IN PARTNERSHIP WITH:
CNRS

Université de Lorraine

Activity Report 2012

Project-Team ALICE

Geometry and Lighting

IN COLLABORATION WITH: Laboratoire lorrain de recherche en informatique et ses applications (LORIA)

RESEARCH CENTER
Nancy - Grand Est

THEME
Interaction and Visualization

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Project-Team ALICE

Keywords: Computer Graphics, Geometry Processing, Visualization

Creation of the Project-Team: January 09, 2006 .

1. Members

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Nicolas Ray [Research scientist (CR)]
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Alejandro Galindo [ANR Physigraphics (since Sept. 10)]
Phuong Ho [ANR Morpho (since Sept. 11) (until Sept. 12)]
Thomas Jost [ERC Goodshape (since Sept. 10)]
Anass Lasram [ANR Similar Cities (since Oct. 09) (until Dec. 12)]
David Lopez [ERC Goodshape (since Sept. 10)]
Kun Liu [ANR Physigraphics (since Sept. 10)]
Romain Merland [ASGA-Gocad (since Oct. 09)]
Vincent Nivoliers [Bourse ENS (since Oct. 08) (until Nov. 12)]
Jeanne Pellerin [ASGA-Gocad (since Sept. 10)]

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2. Overall Objectives

2.1. Introduction

2.1.1. Overall objectives

ALICE is one of the six teams in the Algorithms, Computation, Geometry and Image group in Inria Nancy Grand-Est.

ALICE is a project-team in Computer Graphics. The fundamental aspects of this domain concern the interaction of *light* with the *geometry* of the objects. The lighting problem consists in designing accurate and efficient *numerical simulation* methods for the light transport equation. The geometrical problem consists in developing new solutions to *transform and optimize geometric representations*. Our original approach to both issues is to restate the problems in terms of *numerical optimization*. We try to develop solutions that are *provably correct*, *numerically stable* and *scalable*.

- By provably correct, we mean that some properties/invariants of the initial object need to be preserved by our solutions.
- By numerically stable, we mean that our solutions need to be resistant to the degeneracies often encountered in industrial data sets.
- By scalable, we mean that our solutions need to be applicable to data sets of industrial size.

To reach these goals, our approach consists in transforming the physical or geometric problem into a numerical optimization problem, studying the properties of the objective function and designing efficient minimization algorithms. To properly construct these discretizations, we use the formalism of finite element modeling, geometry and topology. We are also interested in fundamental concepts that were recently introduced into the geometry processing community, such as discrete exterior calculus, spectral geometry processing and theory of sampling.

The main applications of our results concern scientific visualization. We develop cooperations with researchers and people from the industry, who experiment applications of our general solutions to various domains, comprising CAD, industrial design, oil exploration and plasma physics. Our solutions are distributed in both open-source software (Graphite, OpenNL, CGAL) and industrial software (Gocad, DVIZ).

2.2. Highlights of the Year

Sylvain Lefebvre received an ERC Starting grant for his project ShapeForge. The project will start in December 2012, for five years, and is funded for 1.3M euros.

3. Scientific Foundations

3.1. Introduction

Computer Graphics is a quickly evolving domain of research. These last few years, both acquisition techniques (e.g., range laser scanners) and computer graphics hardware (the so-called GPU's, for Graphics Processing Units) have made considerable advances. However, despite these advances, fundamental problems still remain open. For instance, a scanned mesh composed of hundred million triangles cannot be used directly in real-time visualization or complex numerical simulation. To design efficient solutions for these difficult problems, ALICE studies two fundamental issues in Computer Graphics:

- the representation of the objects, i.e., their geometry and physical properties;
- the interaction between these objects and light.

Historically, these two issues have been studied by independent research communities. However, we think that they share a common theoretical basis. For instance, multi-resolution and wavelets were mathematical tools used by both communities [25]. We develop a new approach, which consists in studying the geometry and lighting from the *numerical analysis* point of view. In our approach, geometry processing and light simulation are systematically restated as a (possibly non-linear and/or constrained) functional optimization problem. This type of formulation leads to algorithms that are more efficient. Our long-term research goal is to find a formulation that permits a unified treatment of geometry and illumination over this geometry.

3.2. Geometry Processing for engineering

Participants: Laurent Alonso, Dobrina Boltcheva, Alejandro Galindo, Phuong Ho, Samuel Hornus, Thomas Jost, Bruno Lévy, David Lopez, Romain Merland, Vincent Nivoliers, Jeanne Pellerin, Nicolas Ray, Dmitry Sokolov, Rhaleb Zayer.

Mesh processing, parameterization, splines

Geometry processing recently emerged (in the middle of the 90's) as a promising strategy to solve the geometric modeling problems encountered when manipulating meshes composed of hundred millions of elements. Since a mesh may be considered to be a *sampling* of a surface - in other words a *signal* - the *digital signal processing* formalism was a natural theoretic background for this subdomain (see e.g., [26]). Researchers of this domain then studied different aspects of this formalism applied to geometric modeling.

Although many advances have been made in the geometry processing area, important problems still remain open. Even if shape acquisition and filtering is much easier than 30 years ago, a scanned mesh composed of hundred million triangles cannot be used directly in real-time visualization or complex numerical simulation. For this reason, automatic methods to convert those large meshes into higher level representations are necessary. However, these automatic methods do not exist yet. For instance, the pioneer Henri Gouraud often mentions in his talks that the *data acquisition* problem is still open. Malcolm Sabin, another pioneer of the "Computer Aided Geometric Design" and "Subdivision" approaches, mentioned during several conferences of the domain that constructing the optimum control-mesh of a subdivision surface so as to approximate a given surface is still an open problem. More generally, converting a mesh model into a higher level representation, consisting of a set of equations, is a difficult problem for which no satisfying solutions have been proposed. This is one of the long-term goals of international initiatives, such as the AIMShape European network of excellence.

Motivated by gridding application for finite elements modeling for oil and gas exploration, in the frame of the Gocad project, we started studying geometry processing in the late 90's and contributed to this area at the early stages of its development. We developed the LSCM method (Least Squares Conformal Maps) in cooperation with Alias Wavefront [5]. This method has become the de-facto standard in automatic unwrapping, and was adopted by several 3D modeling packages (including Maya and Blender). We experimented various applications of the method, including normal mapping, mesh completion and light simulation [2].

However, classical mesh parameterization requires to partition the considered object into a set of topological disks. For this reason, we designed a new method (Periodic Global Parameterization) that generates a continuous set of coordinates over the object [6]. We also showed the applicability of this method, by proposing the first algorithm that converts a scanned mesh into a Spline surface automatically [4].

We are still not fully satisfied with these results, since the method remains quite complicated. We think that a deeper understanding of the underlying theory is likely to lead to both efficient and simple methods. For this reason, we studied last year several ways of discretizing partial differential equations on meshes, including Finite Element Modeling and Discrete Exterior Calculus. This year, we also explored Spectral Geometry Processing and Sampling Theory (more on this below).

3.3. Computer Graphics

Participants: Sylvain Lefebvre, Samuel Hornus, Bruno Lévy, Vincent Nivoliers, Nicolas Ray, Dmitry Sokolov, Rhaleb Zayer.

texture synthesis, texture mapping,

Content creation is one of the major challenge in Computer Graphics. Modelling geometries and surface appearances which are visually appealing and at the same time enforce precise design constraints is a task only accessible to highly skilled and trained designers.

In this context the team focuses on methods for by-example content creation. Given an input example and a set of constraints, we design algorithms that can automatically generate a new shape (geometry+texture). We formulate the problem of content synthesis as the joint optimization of several objectives: Preserving the local appearance of the example, enforcing global objectives (size, symmetries, mechanical properties), reaching user defined constraints (locally specified geometry, contacts). This results in a wide range of optimization problems, from statistical approaches (Markov Random fields), to combinatorial and linear optimization techniques.

In addition to the core algorithm we also work on the representation of the content, so as to allow for its efficient manipulation. In this context we develop data-structures and algorithms targeted at massively parallel architectures, such as GPUs. These are critical to reach the interactive rates expected from a content creation technique. We also propose novel ways to store and access content stored along surfaces [7] or in volumes [1].

4. Software

4.1. Graphite

Participants: Dobrina Boltcheva, Phuong Ho, Bruno Lévy, David Lopez, Romain Merland, Vincent Nivoliers, Jeanne Pellerin, Nicolas Ray.

Graphite is a research platform for computer graphics, 3D modeling and numerical geometry. It comprises all the main research results of our “geometry processing” group. Data structures for cellular complexes, parameterization, multi-resolution analysis and numerical optimization are the main features of the software. Graphite is publicly available since October 2003. It is hosted by Inria GForge since September 2008 (1000 downloads in two months). Graphite is one of the common software platforms used in the frame of the European Network of Excellence AIMShape .

4.2. MicroMegas

Participant: Samuel Hornus.

Micromegas is a 3D modeler, developed as a plugin of Graphite, dedicated to molecular biology. It is developed in cooperation with the Fourmentin Guilbert foundation and has recently been renamed "GraphiteLife-Explorer". Biologists need simple spatial modeling tools to help in understanding the role of objects’ relative position in the functioning of the cell. In this context, we develop a tool for easy DNA modeling. The tool generates DNA along any user-given curve, open or closed, allows fine-tuning of atoms’ position and, most importantly, exports to PDB.

In 2012, its development has been actively pursued by Samuel Hornus in the first trimester. The software is freely downloadable. A paper describing will appear in the broad journal PLOS One [9]. A poster was also presented at the European Conference on Computational Biology in september 2012.

4.3. CGAL package for Delaunay triangulations

Participant: Samuel Hornus.

This year was devolved also to finishing touches on the CGAL package for Delaunay triangulations (3rd submission to the CGAL editorial board).

Following the reviews for the second submission, Samuel Hornus has collaborated with Olivier Devillers (Inria Sophia Antipolis) to put the finishing touches to a new CGAL package for Delaunay triangulation in any dimension. It provides exact construction of Delaunay triangulations, supporting both the addition and deletion of vertices. The code takes the form of a collection of C++ template classes to ensures high performance when specializing the code to a given euclidian dimension.

4.4. OpenNL - Open Numerical Library

Participants: Thomas Jost, Bruno Lévy, Nicolas Ray, Rhaleb Zayer.

OpenNL is a standalone library for numerical optimization, especially well-suited to mesh processing. The API is inspired by the graphics API OpenGL, this makes the learning curve easy for computer graphics practitioners. The included demo program implements our LSCM [5] mesh unwrapping method. It was integrated in Blender by Brecht Van Lommel and others to create automatic texture mapping methods. OpenNL is extended with two specialized modules :

- CGAL parameterization package: this software library, developed in cooperation with Pierre Alliez and Laurent Saboret, is a CGALpackage for mesh parameterization.
- Concurrent Number Cruncher: this software library extends OpenNL with parallel computing on the GPU, implemented using the CUDA API.

4.5. Intersurf

Participants: Xavier Cavin, Nicolas Ray.

Intersurf is a plugin of the VMD (Visual Molecular Dynamics) software. VMD is developed by the Theoretical and Computational Biophysics Group at the Beckmann Institute at University of Illinois. The Intersurf plugin is released with the official version of VMD since the 1.8.3 release. It provides surfaces representing the interaction between two groups of atoms, and colors can be added to represent interaction forces between these groups of atoms. We plan to include in this package the new results obtained this year in molecular surface visualization by Matthieu Chavent.

4.6. LibSL

Participants: Anass Lasram, Sylvain Lefebvre.

LibSL is a Simple library for graphics. Sylvain Lefebvre continued development of the LibSL graphics library (under CeCill-C licence, filed at the APP). LibSL is a toolbox for rapid prototyping of computer graphics algorithms, under both OpenGL, DirectX 9/10, Windows and Linux. The library is actively used in both the REVES / Inria Sophia-Antipolis and the Alice / Inria Nancy Grand-Est teams.

5. New Results

5.1. A Runtime Cache for Interactive Procedural Modeling

Participant: Sylvain Lefebvre.

This work further explores hashing techniques that we developed over the past years. In particular, we considered modifying our hashing scheme to create a run-time cache. The cache avoids expensive computations when texturing implicit surfaces with complex procedural functions. This is a result from a collaboration with the Karlsruhe Institute of Technology which was funded by an Inria COLOR grant and has been published this year in the journal "Computers & Graphics" [14].

5.2. Texture Synthesis

Participants: Sylvain Lefebvre, Bruno Jobard.

We continued investigating on Gabor Noise and considered fitting the parameters of our Gabor noise texturing technique from example images. This required a new formulation of our noise, allowing us to solve the problem as a basis pursuit denoising optimization. This is the result of a collaboration with the team REVES / Inria Sophia-Antipolis, the Katholieke Universiteit of Leuven and Université Paris Descartes. This work has been presented at the SIGGRAPH conference this year [8].

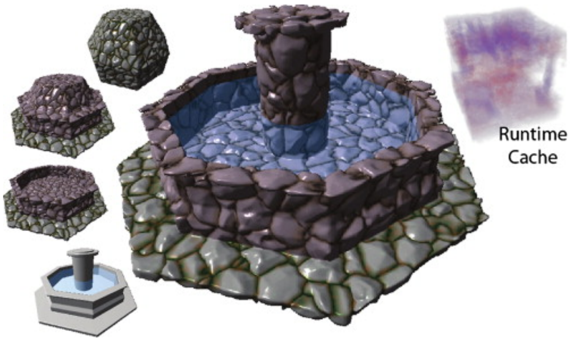

Figure 1. A Runtime Cache for Interactive Procedural Modeling.

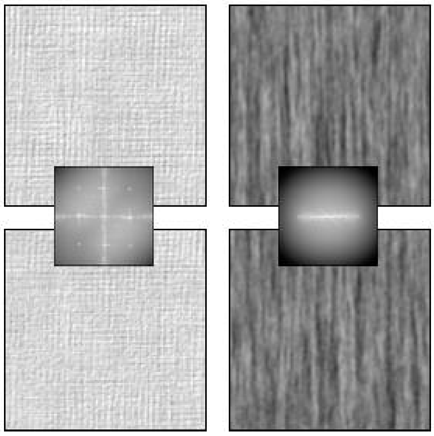

Figure 2. Gabor Noise by Example.

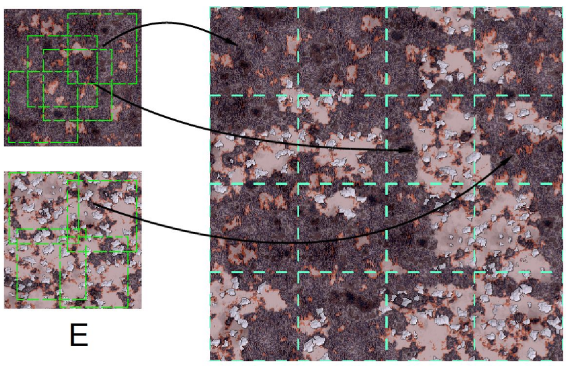

Figure 3. Parallel patch–based texture synthesis.

We also revisited techniques for texture synthesis explicitly copying and assembling large patches of an example image to form a new texture. We accelerate this process through a parallel implementation which both optimizes for the shape of the patches and a deformation along their boundary to better match edges. This work is part of the PhD thesis of Anass Lasram and has been presented this year at the Eurographics/ ACM SIGGRAPH Symposium on High Performance Graphics, [19].

We also studied ways of helping the user to select the parameters of procedural texture generators, by proposing two contributions :

- We studied how to summarize the appearances generated by complex procedural textures in a small preview image. The challenge is to capture the large variety of appearances despite a limited pixel space. We formulate the problem as a layout of high-dimensional samples in a regular grid, and optimize for it through a modified Self Organizing Map algorithm. This work is part of the PhD thesis of Anass Lasram, and is a collaboration with our industrial partner Allegorithmic. This work has been published this year in the journal "Computer Graphics Forum", [10].
- The parameters of complex procedural textures are typically chosen through a slider-based interface. We augment this interface with preview images which predict how the texture will change when manipulating the slider. This greatly simplifies the process of choosing parameters for these textures. This work is part of the PhD thesis of Anass Lasram, and is a collaboration with our industrial partner Allegorithmic. This work has been published this year as EUROGRAPHICS short paper, [18].

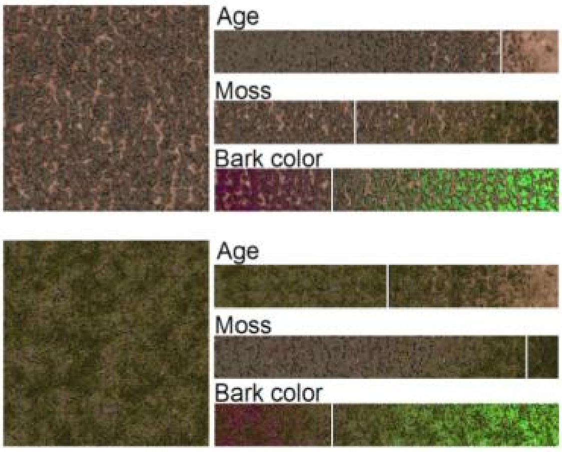

Figure 4. Scented Sliders for Procedural Textures.

5.3. Algorithms and analysis

Participants: Laurent Alonso, Samuel Hornus.

Data structure for fast witness complexes: Samuel Hornus is currently pursuing work started while a post-doc in Sophia Antipolis, on data structure for the fast construction of witness complexes; these are sub complexes of Delaunay triangulations that can be faster to compute for low dimensional data embedded in high dimensional ambiant space.

Analysis of Boyer and Moore's MJRTY Algorithm: Given a set of n elements each of which is either red or blue, Boyer and Moore's algorithm uses pairwise equal/not equal color comparisons to determine the majority color. We analyze the average behavior of their algorithm, proving that if all 2^n possible inputs are equally likely, the average number of color comparisons used is $n - \sqrt{2n/\pi} + O(1)$ and have variance in $\frac{\pi-2}{\pi} n - \frac{\sqrt{2}\, n}{\sqrt{\pi}} + O(1)$. This work has been submitted to SIAM Journal On Computing.

5.4. Visualizing $2D$ Flows with Animated Arrow Plots

Participants: Bruno Jobard, Nicolas Ray, Dmitry Sokolov.

Flow fields are often represented as a set of static arrows in illustration of scientific vulgarization, documentary, meteorology, etc. This simple and schematic representation lets an observer intuitively interpret the main properties of a flow: its orientation and velocity magnitude (Figure 5).

We have investigated how to automatically generate dynamic versions of such representations for $2D$ unsteady flow fields. As a result, we designed an algorithm able to smoothly animate arrows along the flow while controlling their density in the domain over time. Beside keeping an even distribution of arrows over time, we made significant efforts to remove disturbing rendering artefacts such as the apparition of a new arrow, the removing of existing arrows, and the representation of field where the velocity is null. This work has been published as a research report, [24].

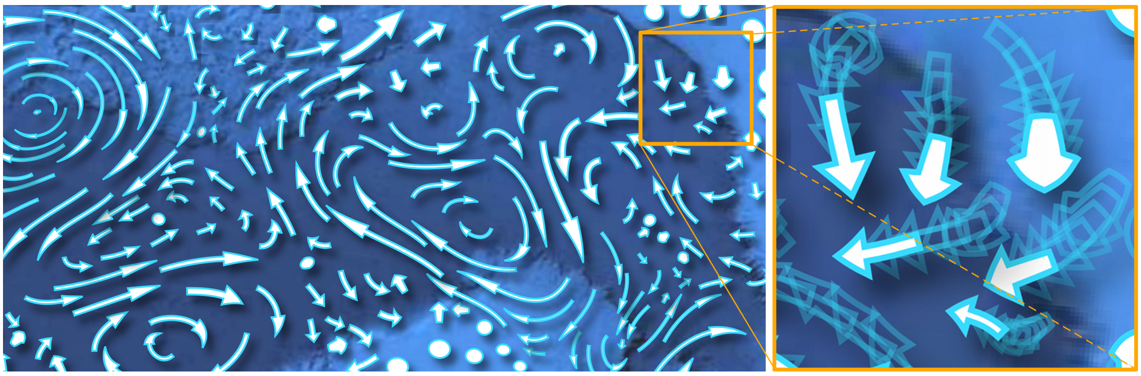

Figure 5. Ocean currents visualized with a set of dynamic arrows. The Close-up shows the arrow trajectories and the morphing of their glyphs.

5.5. Fixing normal constraints for generation of polycubes

Participants: Nicolas Ray, Dmitry Sokolov.

A polycube is a piecewise linearly defined surface where all faces are squares that are perpendicular to an axis of a global basis. Deforming triangulated surfaces to polycubes provides maps (form the original surface to the polycube) that can be used for a number of applications including hex-meshing. To define such a deformation, it is necessary to determine, for each point of the original surface, what will be its orientation (global axis) in the polycube.

This problem is actually tackled by heuristics that basically affect the closest global axis to the surface normal. Coupled with an mesh deformation as pre-processing and some fixing rules as a post-processing, it is able to provide nice results for a number of surfaces. However, nothing ensures that the surface can be deformed to a polycube having these desired face orientation.

We have worked on a method able to determine if there exists a deformation of the surface that respects a given orientation constraint on each point. We have also design an automatic solution that can fix constraints that would prevent the existence of a deformation into a polycube (Figure 6).

This study has highlighted that the constraints on desired orientation are global and requires constrained optimization methods to be solved. Our current solution is able to manage many cases where previous works would fail, but we can still produce some complex cases where interactions between dimension may lead to deadlocks.

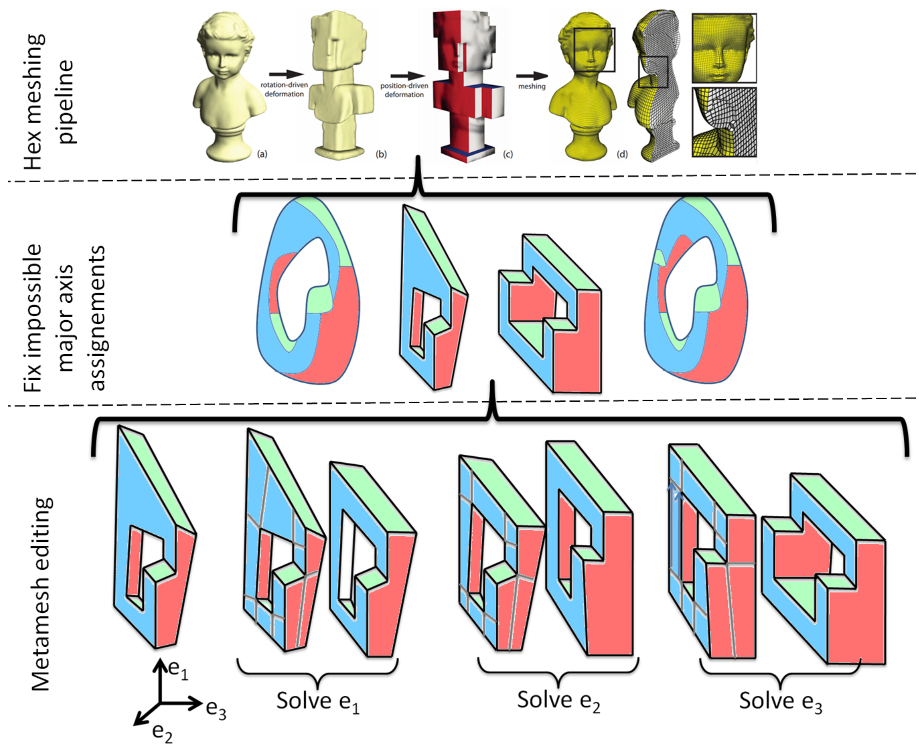

*Figure 6. **Upper row:** the surface is deformed to make its normals closer to major axis, but to reach an equality, we need to have a coherent "wished orientation" of the faces. **Middle row:** we define a valid deformation into a polycube by editing the "wished orientation". **Lower row** the resolution is performed a dimension at a time.*

5.6. Control of the differential behaviour of the joining curve between two fractal curves

Participants: Dmitry Sokolov, S. Podkorytov, C. Gentil, S. Lanquetin.

The general objective of our work is to create a geometric modeller based on iterative processes. Iterative processes can be used to describe a wide array of shapes inaccessible to standard methods such as fractal curves or sets. Our work is based on Boundary Controlled Iterative System (BCIFS). BCIFS upgrades the standard iterative process such as Iterated Function System (IFS) with B-Rep structure. We can describe objects with familiar B-rep structure, where each cell is a fractal object. For instance, if we consider a polyhedron, then each face is a fractal surface, and each edge is a fractal curve. Objects modelled with BCIFS not necessary have the fractal properties, objects such as B-splines curves and surfaces can be modelled as well. So with BCIFS formalism we can operate with both standard and fractal objects.

With this objective in mind, we have to provide tools that work with fractal objects in the same manner as with objects of classical topology. In this project we focus on the constructing of an intermediate curve between two other curves defined by different iterative construction processes. Similar problem often arises with subdivision surfaces, when the goal is to connect two surfaces with different subdivision masks. We start by dealing with curves, willing to later generalize our approach to surfaces. We formalise the problem with Boundary Controlled Iterated Function System model. Then we deduct the conditions that guaranties continuity of the intermediate curve. These conditions determine the structure of subdivision matrices. By studying the eigenvalues of the subdivision operators, we characterise the differential behaviour at the connection points between the curves and the intermediate one. This behaviour depends on the nature of the initial curves and coefficients of the subdivision matrices. We also suggest a method to control the differential behaviour by adding intermediate control points (Figure 7). This work was presented at the Symposium on Solid and Physical Modeling [23].

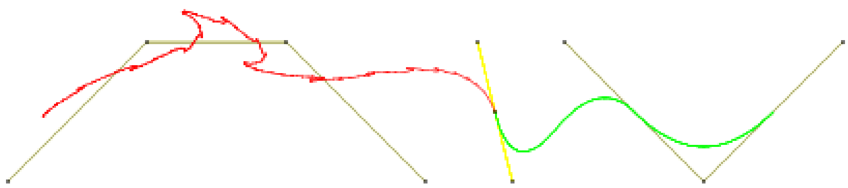

Figure 7. Two intermediate curves between the fractal curve and B-spline. Three control point are used to control the shape of the curve

5.7. Approximate convex hull of affine iterated function system attractors

Participants: Dmitry Sokolov, A. Mishkinis, C. Gentil, S. Lanquetin.

In this paper, we present an algorithm to construct an approximate convex hull of the attractors of an affine iterated function system (IFS). We construct a sequence of convex hull approximations for any required precision using the self-similarity property of the attractor in order to optimize calculations. Due to the affine properties of IFS transformations, the number of points considered in the construction is reduced. The time complexity of our algorithm is a *linear* function of the number of iterations and the number of points in the output convex hull. The number of iterations and the execution time increases logarithmically with increasing accuracy. In addition, we introduce a method to simplify the approximation of the convex hull without loss of accuracy. Figure 8 gives and illustration. This work was published at the Chaos, Solitons & Fractals journal [12].

5.8. Shift-Based Parallel Image Compositing on InfiniBand Fat-Trees

Participant: Xavier Cavin.

In this work, we propose a new parallel image compositing algorithm, called Shift-Based, relying on a well-known communication pattern called shift permutation. Indeed, shift permutation is one of the possible ways to get the maximum cross bisectional bandwidth provided by an InfiniBand fat-tree cluster. We show that our Shift-Based algorithm scales on any number of processing nodes (with peak performance on specific counts), allows overlapping communications with computations and exhibits contention free network communications. This is demonstrated with the image compositing of very high resolution images at interactive frame rates. This work is a collaboration with the SED service of Inria (Olivier Demengeon). It has been presented this year at the Eurographics Symposium on Parallel Graphics and Visualization, [17].

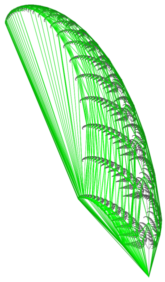

Figure 8. Approximate convex hull for a 3D IFS attractor.

5.9. Multi view data processing

Participants: Rhaleb Zayer, Alejandro Galindo, Kun Liu.

Direct use of denoising and mesh reconstruction algorithms on point clouds originating from multi-view images is often oblivious to the reprojection error. This can be a severe limitation in applications which require accurate point tracking, e.g., metrology. we propose a method for improving the quality of such data without forfeiting the original matches. We formulate the problem as a robust smoothness cost function constrained by a bounded reprojection error. The arising optimization problem is addressed as a sequence of unconstrained optimization problems by virtue of the barrier method. Experimental results on synthetic and acquired data compare our approach to alternative techniques. This work has been presented this year at the 8th International Symposium on Visual Computing, [20].

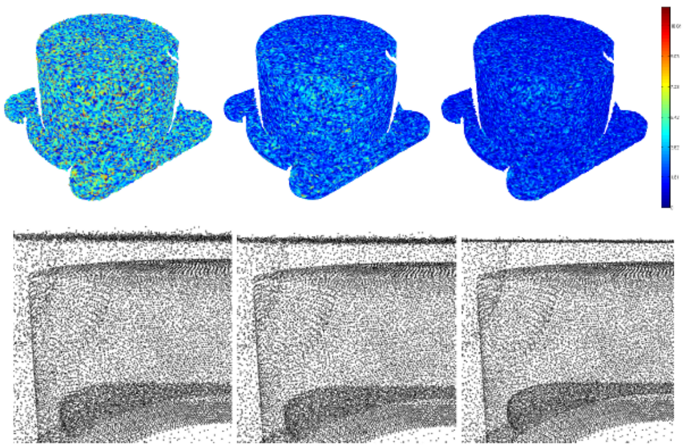

Figure 9. Example of denoising.

5.10. Deformation modeling of slender objects

Participants: Rhaleb Zayer, Alejandro Galindo, Kun Liu.

A desirable property when modeling/editing slender curve-like objects is the ability to emulate the deformation behavior of natural objects (e.g. cables, ropes). Taking such physical considerations into account needs also to abide to editing requirements such as interactivity and full access and control of all degrees of freedom (positional and rotational constraints) during interaction. We regard editing as a static deformation problem but our treatment differs from standard finite element methods in the sense that the interpolation is based on deformation modes rather than the classic shape functions. A careful choice of these modes allows capturing the deformation behavior of the individual curve segments, and devising the underlying mathematical model from simple and tractable physical considerations. In order to correctly handle arbitrary user input (e.g. dragging vertices in a fast and excessive manner), our approach operates in the nonlinear regime. The arising geometric nonlinearities are addressed effectively through the modal representation without requiring complicated fitting strategies. In this way, we circumvent commonly encountered locking and stability issues while conveying a natural sense of flexibility of the shape at hand. Experiments on various editing scenarios including closed and non-smooth curves demonstrate the robustness of the proposed approach. This work has been published this year in the journal "Computers & Graphics", [15].

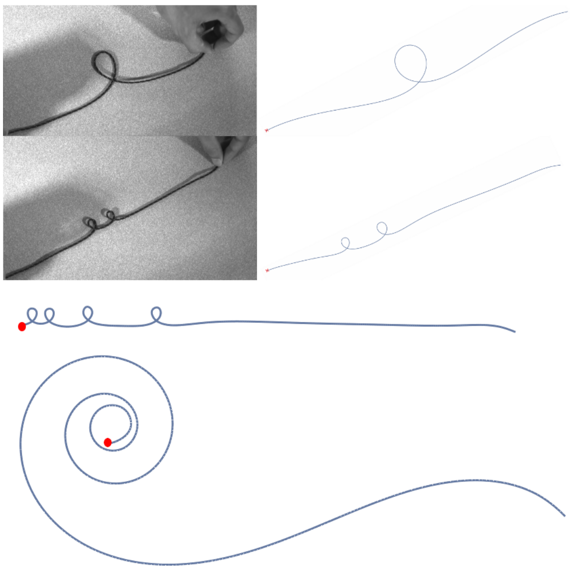

Figure 10. Example of curves.

5.11. Temporally consistent 3D meshing from video data

Participants: Dobrina Boltcheva, Phuong Ho, Bruno Lévy.

This work is a part of the ANR Morpho project (Morpho) which aims at combined analysis of human shapes and motions. In particular, the goal is to study how motions relate to human shapes or how shapes deform in typical motions. During this year, we addressed the first challenge which is building temporally consistent 3D meshes from silhouette images. We have already achieved a very fast meshing algorithm for each frame based on the Centroidal Voronoi Tessellation which has been previously developed in our team. Actually, we are investigating different ways for adding the temporal consistency within our optimisation framework. In particular, we are studding a strategy based on the optimal transport paradigm.

5.12. Re-meshing surfaces

Participants: Nicolas Bonneel, Bruno Lévy, David Lopez, Vincent Nivoliers, DongMing Yan.

In the frame of the ERC GOODSHAPE project, we continued to develop new methods to optimize the sampling of 3D objects. In particular, we studied how to sample a surface with generalized primitives, such as line segments and deformable graphs [11]. We also focused on the problem of remeshing a surface with quads, or fiting a polynomial surface to an input mesh. We proposed a method that minimizes an approximation of the integrated squared distance, based on a restricted Voronoi diagram [22]. Still on the same topic of mesh quadrangulation, we co-published a survey with other international experts of this field [16].

We also worked on anisotropic surface meshing, and developed a technique based on embedding into higher dimensional space and a fast computation of the restricted Voronoi diagram [21].

6. Partnerships and Cooperations

6.1. Regional Initiatives

Our collaborative project “Meshing and PDEs” (cooperation with CORIDA team) aims at developing new techniques for discretizing and solving PDEs, by combining the expertise of the CORIDA team in mathematical modeling with the expertise of the ALICE team in geometry processing.

6.2. National Initiatives

Samuel Hornus has a continued cooperation with the Scientific Foundation Fourmentin-Guilbert on the Graphite-LifeExplorer software.

6.2.1. ANR

Sylvain Lefebvre has a continued collaboration with our industrial partners Allegorithmic and the CSTB through the ANR SIMILAR-CITIES.

Dmitry Sokolov is involved in the ANR COSINUS ModItère (ANR-09-COSI-014) which goal is to design a new geometric modeller based on fractal geometry. The aim of this work is to specify and develop a geometric modeler, based on the formalism of iterated function systems with the following objectives: access to a new universe of original, various, aesthetic shapes, modeling of conventional shapes (smooth surfaces, solids) and unconventional shapes (rough surfaces, porous solids) by defining and controlling the relief (surface state) and lacunarity (size and distribution of holes).

Rhaleb Zayer has continued the investigations on the ANR Physigrafix which aim is to bridge the gap between acquisition and modeling in the context of deformable objects.

6.3. European Initiatives

6.3.1. FP7 Projects

6.3.1.1. GoodShape

Title: Numerical Geometric Abstractions: from bits to equations

Type: IDEAS ()

Instrument: ERC Starting Grant (Starting)

Duration: August 2008 - July 2013

Coordinator: Inria (France)

Abstract: GOODSHAPE involves several fundamental aspects of 3D modelling and computer graphics. GOODSHAPE is taking a new approach to the classic, essential problem of sampling, or the digital representation of objects in a computer. This new approach proposes to simultaneously consider the problem of approximating the solution of a partial differential equation and the optimal sampling problem. The proposed approach, based on the theory of numerical optimization, is likely to lead to new algorithms, more efficient than existing methods. Possible applications are envisioned in inverse engineering and oil exploration.

6.3.1.2. ShapeForge

Title: ShapeForge: By-Example Synthesis for Fabrication

Type: IDEAS ()

Instrument: ERC Starting Grant (Starting)

Duration: December 2012 - November 2017

Coordinator: Inria (France)

Abstract: Despite the advances in fabrication technologies such as 3D printing, we still lack the software allowing for anyone to easily manipulate and create useful objects. Not many people possess the required skills and time to create elegant designs that conform to precise technical specifications. 'By–example' shape synthesis methods are promising to address this problem: New shapes are automatically synthesized by assembling parts cutout of examples. The underlying assumption is that if parts are stitched along similar areas, the result will be similar in terms of its low–level representation: Any small spatial neighbourhood in the output matches a neighbourhood in the input. However, these approaches offer little control over the global organization of the synthesized shapes, which is randomized. The ShapeForge challenge is to automatically produce new objects visually similar to a set of examples, while ensuring that the generated objects can enforce a specific purpose, such as supporting weight distributed in space, affording for seating space or allowing for light to go through. This properties are crucial for someone designing furniture, lamps, containers, stairs and many of the common objects surrounding us. The originality of my approach is to cast a new view on the problem of 'by–example' shape synthesis, formulating it as the joint optimization of 'by–example' objectives, semantic descriptions of the content, as well as structural and fabrication objectives. Throughout the project, we will consider the full creation pipeline, from modelling to the actual fabrication of objects on a 3D printer. We will test our results on printed parts, verifying that they can be fabricated and exhibit the requested structural properties in terms of stability and resistance.

6.4. International Initiatives

6.4.1. Participation In International Programs

Sylvain Lefebvre continues his collaborations with Microsoft Research Asia (Xin Tong), the Hong Kong University (Li-Yi Wei), KIT (Carsten Dachsbacher), and started a new collaboration with ETH Zurik (Olga Sorkine). He was invited for seminars within the teams of Carsten Dachsbacher (KIT) and Rüdiger Westerman (TU Munich).

Bruno Lévy continues his collaborations with Hong-Kong University (Wenping Wang).

6.5. International Research Visitors

6.5.1. Visits of International Scientists

During this last year, our team has been visited by Carsten Dachsbacher, Mathäus Chajdas, Li-Yi Wei and Ivo Ihrke (MPII Sarrbruecken).

6.5.1.1. Internships

Samuel Hornus supervised Pulkit Bansal (Indian master student) as an Inria internship, on the modeling of RNA molecules.

7. Dissemination

7.1. Scientific Animation

Sylvain Lefebvre was in the following program committees in 2012: SIGGRAPH Asia, EGSR, High Performance Graphics, EUROGRAPHICS Short papers and I3D. He joined the editorial board of TOG as an associate editor. He was also an invited speaker at SIBGRAPI 2012 in Ouro Preto, Brazil.

Bruno Lévy was in the following program committees in 2012: ACM SIGGRAPH, Eurographics, SPM, IEEE SMI, ACM/EG SGP, Pacific Graphic, GMP, DGCI. He was an invited speaker in the EIT ICT labs school and gave an invited tutorial at the Internatinal Meshing Roundtable.

Rhaleb Zayer was in the Program committee of EUROGRAPHICS 2012 (Full papers).

7.2. Teaching - Supervision - Juries

7.2.1. Teaching

Sylvain Lefebvre was involved in the following courses:

- Ecole Central Paris - 6h ETD
- Ecole Nationale Supérieure de Géologie - 9h ETD
- Ecole des Mines de Nancy, Introduction à la programmation graphique et de jeux vidéos - 30h ETD
- Université de Lorraine, Mise en place du module d'introduction à la programmation massivement parallèle (OpenCL), M1, 28h ETD en collaboration avec Dmitry Sokolov
- Ecole d'hiver at ENS Lyon - 12h ETD

Samuel Hornus was involved in the following courses:

- "Functional programming with OCaml" at ÉPITECH Nancy (private school training programmers, http://nancy.epitech.eu/). Lecture: 9h. Lab work: 18h. 3 student projects.

Dmitry Sokolov was involved in the following courses:

- Algoritmique avancée, 28h, M2 Math de l'UL, France
- Géométrie et représentation dans l'espace, 35h, L2 Informatique de l'UL, France
- Logiques et Modèles de calcul, 30h, M1 Informatique de l'UL, France
- Infographie 76h, M1 Informatique de l'UL, France
- Modèles de perception et raisonnement, 56h, M1 Informatique de l'UL, France
- Parallelisme de données, 15h, M1 Informatique de l'UL, France

Dobrina Boltcheva was involved in the following courses:

- Synthèse d'images, 15h, Licence ISN, IUT Saint-Dié-des-Vosges
- Traitement d'images, 30h, 2A DUT INFO, IUT Saint-Dié-des-Vosges
- Modélisation des systèmes d'inforamtions I, 26h, 1A DUT INFO, IUT Saint-Dié-des-Vosges
- Modélisation des systèmes d'inforamtions II, 20h, 2A DUT INFO, IUT Saint-Dié-des-Vosges
- Conception de structures de données, 38h, 2A DUT INFO, IUT Saint-Dié-des-Vosges
- Outils de génie logiciel, 48h, 2A DUT INFO, IUT Saint-Dié-des-Vosges

Bruno Lévy teaches "Numerical Geometry" in the Nancy School of Geology, and gave courses at "Ecole de Recherche ENS Lyon" and "Conférences de rentrée de l'ENS Cachan".

7.2.2. Supervision

PhD : Anass Lasram, Exploring and Rendering Synthesized Textures, Université de Lorraine, Finished 10 Dec. 2012, Bruno Lévy and Sylvain Lefebvre

PhD : Vincent Nivoliers, Optimal Sampling of Surfaces, Finished 30 Nov. 2012, Bruno Lévy

PhD in progress : Sergey Podkorytov, Fractal Differential Geometry, Started 1 Sept. 2010, Christian Gentil and Dmitry Sokolov

PhD in progress : Kun LIU, Modèle discret guidé par l'acquisition pour les objets déformables, Started 1 Aug. 2010, Rhaleb Zayer and Bruno Lévy

PhD in progress : Alejandro Patricio GALINDO, Traitment de l'image et video tracking pour l'extraction d'informations pertinentes, Started 15 Sept. 2012, Rhaleb Zayer and Bruno Lévy

PhD in progress : Thomas Joste, Numerical Solvers on the GPU, Bruno Lévy and Sylvain Contassot

PhD in progress : Romain Merland, Voronoi grids for flow simulations in geology, Guillaume Caumon and Bruno Lévy

PhD in progress : David Lopez, Dynamic meshing of free surfaces in fluid simulation, Bruno Lévy

PhD in progress : Jeanne Pellerin, Hybrid meshing for geosciences, Guillaume Caumon and Bruno Lévy

7.2.3. Juries

Sylvain Lefebvre was a jury member for the doctoral committee of Ismael Garcia (U. of Girona).

Bruno Lévy was a jury member for the Habilitation theses of Tamy Boubekeur (Telecom Paristech), Jean-Philippe Vandeborre (Telecom Lille 1), Hyewon Seo (Strasbourg LSIIT), Ivo Ihrke (Bordeaux) and the Ph.D. theses of Alexandre Coninx (Grenoble), Avinash Sharma (Grenoble), Said Jabrane (UCB Lyon), Jean-March Thierry (Telecom Paristech), Simon Boyé (Bordeaux), Yann Savoye (Bordeaux).

7.3. Popularization

Sylvain Lefebvre has continued to animate the "Commission de médiation scientifique" of the Inria Nancy Grand-Est center. He participated in the 2012 science festival, in the "Cordées de la réussite" initiative, presented the software "Mobinet" to high-school teachers, and participated in the prizes ceremony for the Mathematics Olympiads.

Vincent Nivoliers participated to the "Fete de la Science" and "Maths en Jeans" events, by showing demos and giving tutorials.

8. Bibliography

Major publications by the team in recent years

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[2] G. Lecot, B. Lévy, L. Alonso, J.-C. Paul. *Master-Element Vector Irradiance for Large Tessellated Models*, in "Graphite conf. proc.", ACM, 2005, p. 315-322.

[3] S. Lefebvre, S. Hornus, A. Lasram. *By-example synthesis of architectural textures*, in "ACM Trans. Graph.", July 2010, vol. 29, p. 84:1–84:8, http://doi.acm.org/10.1145/1778765.1778821.

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Articles in International Peer-Reviewed Journals

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[10] A. LASRAM, S. LEFEBVRE, C. DAMEZ. *Procedural texture preview*, in "Computer Graphics Forum", May 2012, vol. 31, n^{o} 2pt2, p. 413-420 [*DOI :* 10.1111/J.1467-8659.2012.03020.X], http://hal.inria.fr/hal-00748521.

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[12] A. MISHKINIS, C. GENTIL, S. LANQUETIN, D. SOKOLOV. *Approximate convex hull of affine iterated function system attractors*, in "Chaos, Solitons and Fractals", November 2012, vol. 45, n^{o} 11, p. 1444-1451 [*DOI :* 10.1016/J.CHAOS.2012.07.015], http://hal.inria.fr/hal-00755842.

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