Activity Report 2014

Project-Team ALICE

Geometry and Lighting

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Project-Team ALICE

Keywords: Computer Graphics, Geometry Processing, Visualization

Creation of the Project-Team: 2006 January 09.

1. Members

Research Scientists

Bruno Lévy [Team leader, Inria, Senior Researcher, HdR]
Laurent Alonso [Inria, Researcher]
Samuel Hornus [Inria, Researcher]
Sylvain Lefebvre [Inria, Researcher, HdR]
Jean-Claude Paul [Inria, Senior Researcher, HdR]
Nicolas Ray [Inria, Researcher]
Atsushi Suzuki [Inria]
Rhaleb Zayer [Inria, Researcher]

Faculty Members

Xavier Antoine [Univ. Lorraine, Professor, HdR]
Dobrina Boltcheva [Univ. Lorraine, Associate Professor]
Dmitry Sokolov [Univ. Lorraine, Associate Professor]

Engineers

Frédéric Claux [Inria]
Thierry Valentin [Inria, until May 2014, granted by FP7 VORPALINE project]

PhD Students

An Lu [Inria,from May 2014 until Oct 2014]
Arnaud Botella [Univ. Lorraine]
Jérémie Dumas [ENS Lyon]
Patricio Galindo [Inria]
Kun Liu [Inria]
Jean Hergel [Inria, granted by European Research Council, from Feb 2013]
David Lopez [Inria, granted by FP7 Goodshape project]
Jeanne Pellerin [Univ. Lorraine, until Apr 2014]

Post-Doctoral Fellows

Jonas Martinez-Bayona [Inria, from Apr 2014]
Lionel Untereiner [Univ. Montpellier II, from Sep 2014]

Administrative Assistants

Laurence Félicité [Univ. Lorraine]
Isabelle Herlich [Inria]
Christelle Leveque [CNRS]

Other

Florian Abribat [Inria, from Jun 2014 until Sep 2014]

2. Overall Objectives

2.1. Introduction

ALICE is one of the six teams in the Department 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*.

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. Besides Computer Graphics, our goal is to 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, plasma physics... Our solutions are distributed in both open-source software (Graphite, OpenNL, CGAL) and industrial software (Gocad, DVIZ).

Since 2010, we started to develop techniques to model not only virtual objects, but also real ones. Our Modeling and Rendering research axis evolved, and we generalized our results on by-example texture synthesis to the production of real objects, using 3d printers. As compared to virtual object, this setting defines higher requirements for the Geometry Processing techniques that we develop, that need to be adapted to both numerical simulation and computer-aided fabrication. We study how to include *computational physics* into the loop, and simulation methods for various phenomena (e.g., fluid dynamics).

3. Research Program

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 [28]. 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

Keywords: 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., [29]). 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 [24]. 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 [5]. 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, in 2012 we studied several ways of discretizing partial differential equations on meshes, including Finite Element Modeling and Discrete Exterior Calculus. In 2013, we also explored Spectral Geometry Processing and Sampling Theory (more on this below).

3.3. Computer Graphics

Keywords: texture synthesis, shape synthesis, texture mapping, visibility

Content creation is one of the major challenges in Computer Graphics. Modeling shapes 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.

As as complement to the design of techniques for automatic content creation, 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 [6] or in volumes [1] [23].

The team also continues research in core topics of computer graphics at the heart of realistic rendering and realistic light simulation techniques; for example, mapping textures on surfaces, or devising visibility relationships between 3D objects populating space.

4. Application Domains

4.1. Numerical simulation

flow simulation for oil exploration: we co-advised three Ph.D. theses with the Gocad Consortium, that develops modeling algorithms for oil and gas exploration. We developed specialized meshing algorithms, well suited to represent geological layers at various resolutions [27], [19].

optimal transport: this is an active research topics in the mathematics community. Given two measures μ and ν, optimal transport defines a distance between μ and ν, as the minimum cost of "morphing" μ into ν. This distance (called the *Wasserstein distance*) structures the space of measures and offers new ways of solving some highly non-linear PDEs (Monge-Ampere, Fokker-Plank ...). This requires a numerical way of computing the Wasserstein distance and its gradients. We studied a semi-discrete technique [21] (conditionally accepted to ESAIM J. M2AN) that optimizes power diagrams. This is to our knowledge the first numerical implementation of optimal transport for volumetric densities (computes the Wasserstein distance between a sum of Dirac masses and a piece-wise linear density supported on a tetrahedral mesh).

Bose-Einstein condensates: Xavier Antoine (prof. in mathematics at the Université de Lorraine) joined the team on a "delegation" position (Sept. 2013 - Sept. 2014) to explore some common research topics. We are members of the BECASIM project, funded by the ANR ("French NSF"). In a certain sense, a Bose-Einstein condensate is a "Schroedinger cat" made of a few hundred atoms. By special physical means (low temperature and lasers), the probability waves of these atoms are intermixed, thus forming an alternative state of matter. The BECASIM project aims at developing numerical simulation methods for these complicated phenomena (that intermix fluid dynamics, electromagnetics and quantum physics).

4.2. Fabrication

Our work around fabrication and additive manufacturing finds applications in different fields. Our algorithms for fast geometric computations on solids (boolean operations, morphological operations) are useful to model a variety of shapes, from mechanical engineering parts to prosthetics for medical applications. Our techniques allow for simpler modelling and processing of very intricate geometries and therefore also find applications in art and design, for unusual shapes that would be very difficult to obtain otherwise.

5. New Software and Platforms

5.1. Vorpaline

Participants: Dobrina Boltcheva, Bruno Lévy, Thierry Valentin.

Vorpaline is an automatic surfacic and volumetric mesh generation software, distributed with a commercial license. Vorpaline is based on the main scientific results stemming from projects GoodShape and VORPA-LINE, funded by the European Research Council, about optimal quantization, centroidal Voronoi diagrams and fast/parallel computation of Voronoi diagrams in high-dimension space. The current version provides functionalities such as isotropic/adaptive/anisotropic surface re-meshing, tolerant surface re-meshing, mesh repair and mesh decimation, constrained surface meshing, quad-dominant surface meshing and hex-dominant volume meshing. It is extensively tested on industrial data with a continuous integration platform, and extensively documented. It is now proposed (since 2014) to the sponsors of the Gocad consortium, as an extension package of the Gocad software.

5.2. IceSL

Participants: Jérémie Dumas, Jean Hergel, Sylvain Lefebvre, Frédéric Claux, Jonas Martinez-Bayona, Samuel Hornus.

In the new software IceSL, we propose to exploit recent advances in GPU and Computer Graphics to accelerate the slicing process of objects modelled via a CSG [1] language. Our target are open source low cost *fused deposition modeling* printers such as RepRaps.

Our approach first inputs a CSG description of a scene which can be composed of both meshes and analytic primitives. During display and slicing the CSG model is converted on the fly into an intermediate representation enabling fast processing on the GPU. Slices can be quickly extracted, and the tool path is prepared through image erosion. The interactive preview of the final geometry uses the exact same code path as the slicer, providing an immediate, accurate visual feedback.

IceSL is the recipient software for our ERC research project "ShapeForge", led by Sylvain Lefebvre.

Figure 1. Left. A two-colored vase is modeled in IceSL. Right. An early printed result.

5.3. Graphite

Participants: Dobrina Boltcheva, Samuel Hornus, Bruno Lévy, David Lopez, 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, and is hosted by Inria GForge since September 2008. Graphite is one of the common software platforms used in the frame of the European Network of Excellence AIMShape .

Graphite and its research-plugins are actively developed and extended. The latest version was released on January 2nd, 2014 and has been downloaded 732 times as of Sept 5.

5.4. GraphiteLifeExplorer

Participant: Samuel Hornus.

GLE 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 "GraphiteLifeExplorer". Biologists need simple spatial modeling tools to help in understanding the role of the relative position of objects 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 (the Protein Daba Bank file format).

The development of GLE is currently on hold, but it is still downloaded (freely) about twice a day (1600 downloads to date).

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[1] Constructive Solid Geometry

5.5. OpenNL - Open Numerical Library

Participants: 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 [24] 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 CGAL package for mesh parameterization.
- Concurrent Number Cruncher: this software library extends OpenNL with parallel computing on the GPU, implemented using the CUDA API.

5.6. GEOGRAM

Participant: Bruno Lévy.

GEOGRAM is a software library with geometrical algorithms. The focus is put on the ease of use, minimal memory consumption, minimal size of the code and extensively documented algorithms (whereas in existing libraries such as CGAL, the focus is put on the extensibility). GEOGRAM includes the PCK (Predicate Construction Kit), a system to automatically generate robust predicates from their equation. It provides a standalone exact number type, based on Shewchuk's expansion arithmetics. The library is portable under Linux, Windows, MacOS, Android, and any system that has IEEE floating point arithmetics. The arithmetic kernel may be used by other programming library and proposed as extension packages (e.g. for CGAL).

5.7. LibSL

Participant: 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 Méditerrannée and the ALICE / Inria Nancy Grand-Est teams.

6. New Results

6.1. Highlights of the Year

Fabrication: We proposed a novel technique to automatically generate support structures for additive manufacturing with filament based processes. The deposited filament has to be properly supported at all times, which complicates printing of overhanging shapes: a disposable support has to be generated to temporarily hold the filament deposited above. Existing techniques either generate large structures, wasting material, or generate very thin structures that are hard to print and prone to failure. In contrast, our technique optimizes a scaffolding which is made of vertical pillars and horizontal bridges – such horizontal bridges print properly as long and the filament is deposited in straight line from one pilar to the next. We showed how to formulate scaffolding generation as a minimization problem and proposed a heuristic algorithm based on an efficient plane sweeping approach. The work was published [9] in ACM Transactions on Graphics in 2014 (proceedings of SIGGRAPH 2014). It is integrated within our 3D modeler for additive manufacturing, IceSL.

Optimal transport: this is an active research topics in the mathematics community. Given two measures μ and ν, optimal transport defines a distance between μ and ν, as the minimum cost of "morphing" μ into ν. This distance (called the *Wasserstein distance*) structures the space of measures and offers new ways of solving some highly non-linear PDEs (Monge-Ampere, Fokker-Plank ...). This requires a numerical way of computing the Wasserstein distance and its gradients. We studied a semi-discrete technique [21] submitted to ESAIM J. M2AN), that optimizes power diagrams. This is to our knowledge the first numerical implementation of optimal transport for volumetric densities (computes the Wasserstein distance between a sum of Dirac masses and a piece-wise linear density supported on a tetrahedral mesh).

6.2. New results

This year, we obtained new results in fabrication, in geometry processing and in multi-view reconstruction.

We investigated software solutions for printing with low cost (filament) 3D printers. We proposed a solution to automatically define temporary structures that will supports the object during its creation [9]. We also strongly reduce the artefacts that are produced by multi-material printing [17]. These works allow to better understand the physics of these printers, and to come up with efficient software solutions to common drawbacks of this technology. Other contributions in fabrication are more related to the design of the printable objects, that is developed in our software IceSL. To achieve real-time rendering of CSG models, we developed a new GPU approach for single pass A-Buffer [23]. This technique is also a simple solution to handle complex rendering problems such as transparency. We also proposed [11] an efficient method for performing dilatation and erosion directly on the same representation of volume by sequence of dilatation and erosions on segments.

In geometry processing, we proposed an algorithm to compute the intersection of Voronoi cells and a simplicial complex [25]. This algorithm is fast in dimension up to $10D$ because it doesn't require to explicit the Voronoi diagram. It comes with exact predicates and symbolic perturbation to ensure its robustness. We have also developed an algorithm [13] able to trace streamlines on triangulated surfaces in such a way that two such streamlines cannot cross or merge. This property seems obvious in the continuous case, but was very difficult to enforce with the discrete representations (triangulated surface, and floating points) manipulated by the computer. We did also revisit the Optimal Delaunay triangulation in the case of graded mesh generation [14], and we adapted our remeshing methods to Geologic applications [27].

We obtained some new results in multi-view reconstruction: a new method that expands a limited set of correspondences towards a quasi-dense map across two views [15], and an improvement of variational multi-view reconstruction obtained thanks to a simple characterization of geometric deformations [16].

7. Partnerships and Cooperations

7.1. Regional Initiatives

Meshing and PDEs, Regional Council of Lorraine, 25 KEuros for initiating the cooperation between Xavier Antoine (Prof. in Math., Nancy who joined ALICE for a short-term 1 year period) and Bruno Lévy;

7.2. National Initiatives

7.2.1. *ANR BECASIM (2013 – 2016)*

890 K€. X. Antoine heads the second partner, which includes Bruno Lévy. Budget for Nancy: 170 K€ of which 100 K€ are for IECL (team CORIDA). This project is managed by Inria. Becasim is a thematic "Numerical Models" ANR project granted by the French Agence Nationale de la Recherche for years 2013-2016. The acronym Becasim is related to Bose-Einstein Condensates: Advanced SIMulation Deterministic and Stochastic Computational Models, HPC Implementation, Simulation of Experiments. The members of the ANR Project Becasim belong to 10 different laboratories.

7.2.2. ANR Bond (2013 – 2017)

X. Antoine is a member of the ("projet blanc") ANR BOND (Boundaries, Numerics and Dispersion).

7.2.3. ANR TECSER (2014 – 2017)

X. Antoine is a member of ANR TECSER that stemmed from the ASTRID program (DGA). The consortium gathers Inria (S. Lantéri, Nice-Sophia, ÉPI CORIDA (X. Antoine) and HIEPACS), EADS, and Nuclétudes.

Total budget: 300 K€ of which 54 K€ are for CORIDA.

7.2.4. ANR Morpho (2010 – 2014

Dobrina Boltcheva and Bruno Lévy are involved in the ANR project Morpho. Morpho is aimed at designing new technologies for the measure and for the analysis of dynamic surface evolutions using visual data.

7.3. European Initiatives

7.3.1. FP7 & H2020 Projects

7.3.1.1. SHAPEFORGE

Type: FP7

Defi: NC

Instrument: ERC Starting Grant

Objectif: NC

Duration: December 2012 - November 2017

Coordinator: Sylvain Lefebvre

Inria contact: Sylvain Lefebvre

Abstract: Project Shapeforge aims at developing new methods for creating objects from examples, with 3D printers. The main challenge with this project is combining approaches that are very different in nature: algorithms from computer graphics which are used to build forms and textures using examples are combined with digital optimization methods which make sure that the real object complies with the function it is assigned. Thus, to produce a Louis XV bench, on the basis of a Louis XV chair, you need to not only capture the appearance of the example but also formalize the characteristics of a bench as well as its mechanical properties to ensure that it is solid enough. You then need to find, from among all the shapes that can be produced from a single example, the one that best complies with the various criteria.

7.3.1.2. VORPALINE

Type: FP7

Defi: NC

Instrument: ERC Proof of Concept

Objectif: NC

Duration: July 2013 - June 2014

Coordinator: Bruno Lévy

Inria contact: Bruno Lévy

Abstract: The Vorpaline software takes a new approach to 3D mesh generation, based on the theory of numerical optimization. The optimal mesh generation algorithm developed in the frame of the European Research Council GOODSHAPE project globally and automatically optimizes the mesh elements with respect to geometric constraints (two patents) . The mathematical foundations of this algorithm, i.e. the minimization of a smooth energy function, result in practice in a faster algorithm, and - more importantly - in a higher flexibility. For instance, it will allow automatic generation of the aforementioned "hex-dominant" meshes. It is now proposed (since 2014) to the sponsors of the Gocad consortium, as an extension package of the Gocad software.

7.4. International Initiatives

7.4.1. Inria Associate Teams

7.4.1.1. PREPRINT3D

Title: Model Preparation for 3D Printing

International Partner (Institution - Laboratory - Researcher):

HKU (HONG KONG)

Duration: Delayed for administrative reasons

We seek to develop novel ways to prepare objects for 3D printing which better take into account limitations of the fabrication processes as well as real-world properties such as the mechanical strength of the printed object. This is especially important when targeting an audience which is not familiar with the intricacies of industrial design. We target complex, intricate shapes such as models of vegetation and highly detailed meshes, as well as models with thin walls such as architectural models. Our methods will modify the object geometry and topology while remaining as close as possible to its initial appearance.

7.4.2. Inria International Partners

7.4.2.1. Informal International Partners

- We have a long-term cooperation with the Gocad Consortium (Nancy school of Geology), with co-advised students. This resulted in some applications of our result to oil exploration, listed in the *numerical simulation* item above (Ph.D. theses of Arnaud Botella, Nicolas Cherpeau, Jeanne Pellerin);
- We cooperate since 2008 with Wenping Wang's group (Hong-Kong University), on centroidal Voronoi tesselation. The last results of this cooperation on *Sampling and Remeshing* are published in : [22] Siam J. on Scientific Computing and [30] (SIGGRAPH 2013)
- Cooperation with Pierre Poulin and Gilles-Philippe Paillé on volumetric distance minimization [26] (SGP 2009)
- Cooperation with Tsinghua University (Jean-Claude Paul was Professor there from 2004 to 2013).
- We started a research project with "Ateliers Cini", "Institut Jean Lamour" (IJL) and the "Ecole de Chirurgie de Nancy", to develop new 3D printers using novel types of materials developed by IJL. This project is funded by the "Region Lorraine" under the "Pacte Lorraine" program.

7.5. International Research Visitors

7.5.1. Visits to International Teams

7.5.1.1. Research stays abroad

Jérémie Dumas (PhD student) stayed in Hong Kong for 1 month as a visiting student (12-04-2014 to 10-05-2014). This visit was done in the context of the Equipe Associée PrePrint3D.

8. Dissemination

8.1. Promoting Scientific Activities

8.1.1. Scientific events selection

8.1.1.1. Organizing committee membership

- Bruno Lévy was program co-chair for Eurographics 2014
- Sylvain Lefebvre was STAR co-chair for Eurographics 2014

- Sylvain Lefebvre was PC member of Pacific Graphics 2014
- Nicolas Ray was PC member of Eurographics 2014
- Rhaleb Zayer was PC member of Eurographics 2014

8.1.2. Journal

8.1.2.1. Editorial board membership

- Sylvain Lefebvre is associate editor for ACM Transactions on Graphics
- Bruno Lévy is associate editor for IEEE Transactions on Visualization and Computer Graphics
- Xavier Antoine is associate editor for ISRN Applied Mathematics
- Bruno Lévy is associate editor for Graphical Models (Elsevier)

8.2. Teaching - Supervision - Juries

8.2.1. Teaching

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

License: Samuel Hornus, "Mathématique discrètes", à Télécom Nancy

License: Dmitry Sokolov, Géométrie et représentation dans l'espace, 35h, L2 Informatique de l'UL, France

License: Dobrina Boltcheva, Licence ISN, IUT Saint-Dié-des-Vosges

License: Dobrina Boltcheva, 2A DUT INFO, IUT Saint-Dié-des-Vosges

License: Dobrina Boltcheva, 1A DUT INFO, IUT Saint-Dié-des-Vosges

Master: Sylvain Lefebvre, Ecole de Géologie, introduction to parallelism (3h TP) and introduction to computer graphics (3h cours, 6h TP)

Master: Sylvain Lefebvre, OpenCL, UL, master M2, with Dmitry Sokolov.

Master: Sylvain Lefebvre, Course on Video Game programming at "Ecole des Mines de Nancy". Taught with Guillaume Bonfante.

Master: Dmitry Sokolov, Algorithmique avancée, 28h, M2 Math de l'UL, France

Master: Dmitry Sokolov, Logiques et Modèles de calcul, 30h, M1 Informatique de l'UL, France

Master: Dmitry Sokolov, Infographie 76h, M1 Informatique de l'UL, France

Master: Dmitry Sokolov, Modèles de perception et raisonnement, 56h, M1 Informatique de l'UL, France

Master: Dmitry Sokolov, Parallélisme de données, 15h, M1 Informatique de l'UL, France

Master: Bruno Lévy, "Numerical Geometry" (15 h) in the National School of Geology and in Nancy School of Mines.

8.2.2. Supervision

HdR : Sylvain lefebvre, Synthèse de textures par l'exemple, Université de Lorraine, 30 juin 2014

PhD : Jeanne Pellerin, Prise en compte de la complexité géométrique des modèles structuraux dans des méthodes de maillage fondées sur le diagramme de Voronoï, ENSG, 20 mars 2014, Bruno Lévy and Guillaume Caumon (Université de Lorraine)

8.2.3. Juries

Bruno Lévy was chair of the Inria junior position (CR2) hiring committee for the centre Inria Nancy Grand-Est.

8.3. Popularization

- Bruno Lévy animates "initiation to computer programming", 1h each Friday evening (10 kids, 7 to 12 years old).
- Members of the team participate each year to "science fair" events, scientific demos, conferences for the general audience.
- Sylvain Lefebvre is a member of the scientific mediation committee of the centre Inria Nancy Grand-Est.

9. Bibliography

Major publications by the team in recent years

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

[4] W. C. LI, N. RAY, B. LÉVY. *Automatic and Interactive Mesh to T-Spline Conversion*, in "EG/ACM Symposium on Geometry Processing, 2006-06-26", Italy, 2006, http://hal.inria.fr/inria-00105611/en/

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[6] N. RAY, V. NIVOLIERS, S. LEFEBVRE, B. LÉVY. *Invisible Seams*, in "EUROGRAPHICS Symposium on Rendering Conference Proceedings", J. LAWRENCE, M. STAMMINGER (editors), Eurographics Association, 2010

Publications of the year

Doctoral Dissertations and Habilitation Theses

[7] J. PELLERIN. *Accounting for the geometrical complexity of geological structural modelsin Voronoi-based meshing methods*, Université de Lorraine, March 2014, https://tel.archives-ouvertes.fr/tel-01005722

Articles in International Peer-Reviewed Journals

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