



IN PARTNERSHIP WITH:  
**CNRS**

**Université de Lorraine**

Activity Report 2015

## **Project-Team VEGAS**

# Effective Geometric Algorithms for Surfaces and Visibility

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

RESEARCH CENTER  
**Nancy - Grand Est**

THEME  
**Algorithmics, Computer Algebra and  
Cryptology**



## Table of contents

<b>1. Members</b>	<b>1</b>
<b>2. Overall Objectives</b>	<b>1</b>
<b>3. Application Domains</b>	<b>2</b>
3.1. Computer graphics	2
3.2. Solid modeling	2
<b>4. Highlights of the Year</b>	<b>3</b>
<b>5. New Software and Platforms</b>	<b>3</b>
5.1. ISOTOP	3
5.2. SubdivisionSolver	3
5.3. CGAL Periodic Triangulations and Meshes	4
<b>6. New Results</b>	<b>4</b>
6.1. Robustness issues in computational geometry	4
6.2. Probabilistic analysis of geometric data structures and algorithms	5
6.2.1. The worst visibility walk in a random Delaunay triangulation is $O(\sqrt{n})$	5
6.2.2. Smooth analysis of convex hulls	5
6.3. Non-linear computational geometry	5
6.3.1. Solving bivariate systems and topology of plane algebraic curves	5
6.3.2. Numeric and Certified Isolation of the Singularities of the Projection of a Smooth Space Curve	6
6.3.3. Mechanical design of parallel robots	6
6.3.4. Reflection through quadric mirror surfaces	7
<b>7. Partnerships and Cooperations</b>	<b>7</b>
7.1. National Initiatives	7
7.1.1. ANR PRESAGE	7
7.1.2. ANR SingCAST	7
7.2. International Research Visitors	8
<b>8. Dissemination</b>	<b>8</b>
8.1. Promoting Scientific Activities	8
8.1.1. Scientific events organisation	8
8.1.2. Scientific events selection	8
8.1.2.1. Member of the conference program committees	8
8.1.2.2. Reviewer	8
8.1.3. Journal	9
8.1.3.1. Member of the editorial boards	9
8.1.3.2. Reviewer - Reviewing activities	9
8.1.4. Invited talks	9
8.1.5. Research administration	9
8.1.5.1. Hiring committees	9
8.1.5.2. Steering Committees	9
8.1.5.3. National committees	9
8.1.5.4. Local committees and responsibilities	9
8.1.5.5. Websites	9
8.2. Teaching - Supervision - Juries	10
8.2.1. Teaching	10
8.2.2. Supervision	10
8.2.3. Juries	10
8.3. Popularization	10
<b>9. Bibliography</b>	<b>10</b>



# Project-Team VEGAS

*Creation of the Project-Team: 2005 August 01*

## Keywords:

### Computer Science and Digital Science:

- 5.10.1. - Design
- 6.2.3. - Probabilistic methods
- 7.2. - Discrete mathematics, combinatorics
- 7.5. - Geometry
- 7.6. - Computer Algebra

### Other Research Topics and Application Domains:

- 5. - Industry of the future

## 1. Members

### Research Scientists

Sylvain Lazard [Team leader, Inria, Senior Researcher, HdR]  
Olivier Devillers [Inria, Senior Researcher, HdR]  
Guillaume Moroz [Inria, Researcher]  
Marc Pouget [Inria, Researcher]  
Monique Teillaud [Inria, Senior Researcher, HdR]

### Faculty Member

Laurent Dupont [Univ. Lorraine, Associate Professor]

### Post-Doctoral Fellows

Rémi Imbach [Inria]  
Laurent Veysseire [Inria, until Aug 2015]

### Administrative Assistants

Laurence Benini [Inria]  
Laurence Felicite [Univ. Lorraine]  
Christelle Leveque [Univ. Lorraine]

### Other

Francois Collet [Inria, Master internship, from Mar 2015 until Jul 2015]

## 2. Overall Objectives

### 2.1. Overall Objectives

The main scientific objective of the **VEGAS** research team is to *contribute to the development of an effective geometric computing* dedicated to *non-trivial geometric objects*. Included among its main tasks are the study and development of new algorithms for the manipulation of geometric objects, the experimentation of algorithms, the production of high-quality software, and the application of such algorithms and implementations to research domains that deal with a large amount of geometric data, notably solid modeling and computer graphics.

Computational geometry has traditionally treated linear objects like line segments and polygons in the plane, and point sets and polytopes in three-dimensional space, occasionally (and more recently) venturing into the world of non-linear curves such as circles and ellipses. The methodological experience and the know-how accumulated over the last thirty years have been enormous.

For many applications, particularly in the fields of computer graphics and solid modeling, it is necessary to manipulate more general objects such as curves and surfaces given in either implicit or parametric form. Typically such objects are handled by approximating them by simple objects such as triangles. This approach is extremely important and it has been used in almost all of the usable software existing in industry today. It does, however, have some disadvantages. Using a tessellated form in place of its exact geometry may introduce spurious numerical errors (the famous gap between the wing and the body of the aircraft), not to mention that thousands if not hundreds of thousands of triangles could be needed to adequately represent the object. Moreover, the curved objects that we consider are not necessarily everyday three-dimensional objects, but also abstract mathematical objects that are not linear, that may live in high-dimensional space, and whose geometry we do not control. For example, the set of lines in 3D (at the core of visibility issues) that are tangent to three polyhedra span a piecewise ruled quadratic surface, and the lines tangent to a sphere correspond, in projective five-dimensional space, to the intersection of two quadratic hypersurfaces.

*Effectiveness* is a key word of our research project. By requiring our algorithms to be effective, we imply that the algorithms should be *robust*, *efficient*, and *versatile*. By robust we mean algorithms that do not crash on degenerate inputs and always output topologically consistent data. By efficient we mean algorithms that run reasonably quickly on realistic data where performance is ascertained both experimentally and theoretically. Finally, by versatile we mean algorithms that work for classes of objects that are general enough to cover realistic situations and that account for the *exact geometry* of the objects, in particular when they are curved.

## 3. Application Domains

### 3.1. Computer graphics

We are interested in the application of our work to virtual prototyping, which refers to the many steps required for the creation of a realistic virtual representation from a CAD/CAM model.

When designing an automobile, detailed physical mockups of the interior are built to study the design and evaluate human factors and ergonomic issues. These hand-made prototypes are costly, time consuming, and difficult to modify. To shorten the design cycle and improve interactivity and reliability, realistic rendering and immersive virtual reality provide an effective alternative. A virtual prototype can replace a physical mockup for the analysis of such design aspects as visibility of instruments and mirrors, reachability and accessibility, and aesthetics and appeal.

Virtual prototyping encompasses most of our work on effective geometric computing. In particular, our work on 3D visibility should have fruitful applications in this domain. As already explained, meshing objects of the scene along the main discontinuities of the visibility function can have a dramatic impact on the realism of the simulations.

### 3.2. Solid modeling

Solid modeling, i.e., the computer representation and manipulation of 3D shapes, has historically developed somewhat in parallel to computational geometry. Both communities are concerned with geometric algorithms and deal with many of the same issues. But while the computational geometry community has been mathematically inclined and essentially concerned with linear objects, solid modeling has traditionally had closer ties to industry and has been more concerned with curved surfaces.

Clearly, there is considerable potential for interaction between the two fields. Standing somewhere in the middle, our project has a lot to offer. Among the geometric questions related to solid modeling that are of interest to us, let us mention: the description of geometric shapes, the representation of solids, the conversion between different representations, data structures for graphical rendering of models and robustness of geometric computations.

## 4. Highlights of the Year

### 4.1. Highlights of the Year

In the context of drawing plane algebraic curves with the correct topology, we have obtained and submitted this year major results on the resolution of bivariate algebraic systems. In particular, we presented algorithms whose worst-case and expected (Las Vegas) complexities are not likely to be easily improved as such improvements would essentially require to improve bounds on other fundamental problems (such as computing resultants, checking the squarefreeness of univariate polynomials, and isolating their roots) that have hold for decades. See section 6.3.1 for details.

## 5. New Software and Platforms

### 5.1. ISOTOP

Topology and geometry of planar algebraic curves

KEYWORDS: Topology - Curve plotting - Geometric computing

Isotop is a Maple software for computing the topology of an algebraic plane curve, that is, for computing an arrangement of polylines isotopic to the input curve. This problem is a necessary key step for computing arrangements of algebraic curves and has also applications for curve plotting.

This software, registered at the APP in June 2011, has been developed since 2007 in collaboration with F. Rouillier from Inria Paris - Rocquencourt. The distributed version is based on the method described in [3], which presents several improvements over previous methods. In particular, our approach does not require generic position. This version is competitive with other implementations (such as ALCIX and INSULATE developed at MPII Saarbrücken, Germany and TOP developed at Santander Univ., Spain). It performs similarly for small-degree curves and performs significantly better for higher degrees, in particular when the curves are not in generic position.

We are currently working on an improved version integrating a new bivariate polynomial solver based on several of our recent results published in [11], [22], [27]. This version is not yet distributed.

- Contact: Sylvain Lazard & Marc Pouget
- URL: <http://vegas.loria.fr/isotop/>

### 5.2. SubdivisionSolver

KEYWORDS: Numerical solver - Polynomial or analytical systems

The software SubdivisionSolver solves square systems of analytic equations on a compact subset of a real space of any finite dimension. SubdivisionSolver is a numerical solver and as such it requires that the solutions in the subset are isolated and regular for the input system (i.e. the Jacobian must not vanish). SubdivisionSolver is a subdivision solver using interval arithmetic and multiprecision arithmetic to achieve certified results. If the arithmetic precision required to isolate solutions is known, it can be given as an input parameter of the process, otherwise the precision is increased on-the-fly. In particular, SubdivisionSolver can be interfaced with the Fast\_Polynomial library (<https://bil.inria.fr/en/software/view/2423/tab>) to solve polynomial systems that are large in terms of degree, number of monomials and bit-size of coefficients.

The software is based on a classic branch and bound algorithm using interval arithmetic: an initial box is subdivided until its sub-boxes are certified to contain either no solution or a unique solution of the input system. Evaluation is performed with a centered evaluation at order two, and existence and uniqueness of solutions is verified thanks to the Krawczyk operator.

SubdivisionSolver uses two implementations of interval arithmetic: the C++ boost library that provides a fast arithmetic when double precision is enough, and otherwise the C mpfi library that allows to work in arbitrary precision. Considering the subdivision process as a breadth first search in a tree, the boost interval arithmetic is used as deeply as possible before a new subdivision process using higher precision arithmetic is performed on the remaining forest.

We used SubdivisionSolver for the experiments in [26], [14], see Section 6.3.2.

- Contact: Rémi Imbach
- URL: <https://bil.inria.fr/fr/software/view/2605/tab>

### 5.3. CGAL Periodic Triangulations and Meshes

The **CGAL** library offers a package to compute the 3D periodic Delaunay triangulation of a point set in  $\mathbb{R}^3$ , more precisely the Delaunay triangulation of a point set in the 3-dimensional flat torus with cubic domain [30]. The package has been used in various fields.<sup>1</sup>

We have been extending this package in three directions:

First, a few new small functions have been added to the Delaunay triangulation class and integrated in **CGAL** 4.7.

We have developed and documented some new classes allowing to compute *weighted* periodic Delaunay triangulations. They have been submitted to the **CGAL** editorial board and accepted for inclusion in **CGAL**. The code still needs some polishing, and the testsuite must be completed, before a public distribution in **CGAL**.

We have continued our work to use this package together with the 3D mesh generation package of **CGAL** [29], in order to propose a construction of meshes of periodic volumes. Although last year's preliminary results were already convincing [32], [33], the work is not ready yet for being submitted to **CGAL**: the code requires to be completed, documented, and extensively tested.

- Contact: Monique Teillaud
- In collaboration with Aymeric Pellé (Geometrica project-team)
- This work was done in the framework of the Inria ADT (*Action de Développement Technologique*) OrbiCGAL <http://www.loria.fr/~teillaud/ADT-OrbiCGAL/>

## 6. New Results

### 6.1. Robustness issues in computational geometry

**Participants:** Olivier Devillers, Monique Teillaud.

#### 6.1.1. Qualitative Symbolic Perturbation: a new geometry-based perturbation framework

In a classical Symbolic Perturbation scheme, degeneracies are handled by substituting some polynomials in  $\epsilon$  to the input of a predicate. Instead of a single perturbation, we propose to use a sequence of (simpler) perturbations. Moreover, we look at their effects geometrically instead of algebraically; this allows us to tackle cases that were not tractable with the classical algebraic approach [25].

This work was done in collaboration with Menelaos Karavelas (Univ. of Crete).

<sup>1</sup> see <http://www.cgal.org/projects.html>



## 6.2. Probabilistic analysis of geometric data structures and algorithms

**Participant:** Olivier Devillers.

### 6.2.1. The worst visibility walk in a random Delaunay triangulation is $O(\sqrt{n})$

We show that the memoryless routing algorithms Greedy Walk, Compass Walk, and all variants of visibility walk based on orientation predicates are asymptotically optimal in the average case on the Delaunay triangulation. More specifically, we consider the Delaunay triangulation of an unbounded Poisson point process of unit rate and demonstrate that the worst-case path between any two vertices inside a domain of area  $n$  has a number of steps that is not asymptotically more than the shortest path which exists between those two vertices with probability converging to one (as long as the vertices are sufficiently far apart.) As a corollary, it follows that the worst-case path has  $O(\sqrt{n})$  steps in the limiting case, under the same conditions. Our results have applications in routing in mobile networks and also settle a long-standing conjecture in point location using walking algorithms. Our proofs use techniques from percolation theory and stochastic geometry [24].

This work was done in collaboration with Ross Hemsley (formerly in Inria Geometrica).

### 6.2.2. Smooth analysis of convex hulls

We establish an upper bound on the smoothed complexity of convex hulls in  $\mathbb{R}^d$  under uniform Euclidean ( $\ell^2$ ) noise. Specifically, let  $\{p_1^*, p_2^*, \dots, p_n^*\}$  be an arbitrary set of  $n$  points in the unit ball in  $\mathbb{R}^d$  and let  $p_i = p_i^* + x_i$ , where  $x_1, x_2, \dots, x_n$  are chosen independently from the unit ball of radius  $\delta$ . We show that the expected complexity, measured as the number of faces of all dimensions, of the convex hull of  $\{p_1, p_2, \dots, p_n\}$  is  $O\left(n^{2-\frac{4}{d+1}}(1+1/\delta)^{d-1}\right)$ ; the magnitude  $\delta$  of the noise may vary with  $n$ . For  $d = 2$  this bound improves to  $O\left(n^{\frac{2}{3}}(1+\delta^{-\frac{2}{3}})\right)$ .

We also analyze the expected complexity of the convex hull of  $\ell^2$  and Gaussian perturbations of a nice sample of a sphere, giving a lower-bound for the smoothed complexity. We identify the different regimes in terms of the scale, as a function of  $n$ , and show that as the magnitude of the noise increases, that complexity varies monotonically for Gaussian noise but non-monotonically for  $\ell^2$  noise [13].

This work was done in collaboration with Xavier Goaoc (Univ. Marne la Vallée), Marc Glisse and Remy Thomasse (Inria Geometrica).

## 6.3. Non-linear computational geometry

**Participants:** Guillaume Moroz, Sylvain Lazard, Marc Pouget, Laurent Dupont, Rémi Imbach.

### 6.3.1. Solving bivariate systems and topology of plane algebraic curves

In the context of our algorithm Isotop for computing the topology of plane algebraic curves (see Section 5.1), we work on the problem of solving a system of two bivariate polynomials. We are interested in certified numerical approximations or, more precisely, isolating boxes of the solutions. But we are also interested in computing, as intermediate symbolic objects, a Rational Univariate Representation (RUR) that is, roughly speaking, a univariate polynomial and two rational functions that map the roots of the univariate polynomial to the two coordinates of the solutions of the system. RURs are relevant symbolic objects because they allow to turn many queries on the system into queries on univariate polynomials. However, such representations require the computation of a separating form for the system, that is a linear combination of the variables that takes different values when evaluated at the distinct solutions of the system.

We published this year [11] results showing that, given two polynomials of degree at most  $d$  with integer coefficients of bitsize at most  $\tau$ , (i) a separating form, (ii) the associated RUR, and (iii) isolating boxes of the solutions can be computed in, respectively,  $\tilde{O}_B(d^8 + d^7\tau)$ ,  $\tilde{O}_B(d^7 + d^6\tau)$  and  $\tilde{O}_B(d^8 + d^7\tau)$  bit operations in the worst case, where  $\tilde{O}$  refers to the complexity where polylogarithmic factors are omitted and  $O_B$  refers to the bit complexity.

However, during the publishing process, we have substantially improved these results. We have presented for these three sub-problems new algorithms that have worst-case bit complexity  $\tilde{O}_B(d^6 + d^5\tau)$ . We have also presented probabilistic Las Vegas variants of our two first algorithms, which have expected bit complexity  $\tilde{O}_B(d^5 + d^4\tau)$ . We also show that it is likely difficult to improve these complexities as it would essentially require to improve bounds on other fundamental problems (e.g., computing resultants, checking squarefreeness and root isolation of univariate polynomials) that have hold for decades.

This work was done in collaboration with Yacine Bouzidi (Inria Saclay), Michael Sagraloff (MPII Sarrebrücken, Germany) and Fabrice Rouillier (Inria Rocquencourt). It is published in the research report [22] and submitted to a journal.

A key ingredient of the above work is the classical triangular decomposition algorithm via subresultants [31] on which we obtain two results of independent interest. First, we improved by a factor  $d$  the state-of-the-art worst-case bit complexity of this algorithm [22]. One constraint on this algorithm is that it requires that the curves defined by the input polynomials have no common vertical asymptotes. Our second result is a generalization of this algorithm, which removes that restriction while preserving the same worst-case bit complexity of  $\tilde{O}_B(d^6 + d^5\tau)$ . Furthermore, we actually present a refined bit complexity in  $\tilde{O}_B(d_x^3 d_y^3 + (d_x^2 d_y^3 + d_x d_y^4)\tau)$  where  $d_x$  and  $d_y$  bound the degrees of the input polynomials in  $x$  and  $y$ , respectively. We also prove that the total bitsize of the decomposition is in  $\tilde{O}((d_x^2 d_y^3 + d_x d_y^4)\tau)$ .

This work was done in collaboration with Fabrice Rouillier (Inria Rocquencourt). It is published in the research report [27] and submitted to a journal.

### 6.3.2. *Numeric and Certified Isolation of the Singularities of the Projection of a Smooth Space Curve*

Let a smooth real analytic curve embedded in  $\mathbb{R}^3$  be defined as the solution of real analytic equations of the form  $P(x, y, z) = Q(x, y, z) = 0$  or  $P(x, y, z) = \frac{\partial P}{\partial z} = 0$ . Our main objective is to describe its projection  $\mathcal{C}$  onto the  $(x, y)$ -plane. In general, the curve  $\mathcal{C}$  is not a regular submanifold of  $\mathbb{R}^2$  and describing it requires to isolate the points of its singularity locus  $\Sigma$ . After describing the types of singularities that can arise under some assumptions on  $P$  and  $Q$ , we present a new method to isolate the points of  $\Sigma$ . We experimented our method on pairs of independent random polynomials  $(P, Q)$  and on pairs of random polynomials of the form  $(P, \frac{\partial P}{\partial z})$  and got promising results [14].

On the same topic but with a different approach, we improved our research report [26] by including experimental data using SubdivisionSolver (see Section 5.2) and submitted this work to a journal.

### 6.3.3. *Mechanical design of parallel robots*

In collaboration with F. Rouillier, D. Chablat and our PhD student Ranjan Jha, we analyzed the singularities and the workspace of different families of robots.

The first result is a certified description of the workspace and the singularities of a Delta like family robot [16]. Workspace and joint space analysis are essential steps in describing the task and designing the control loop of the robot, respectively. This paper presents the descriptive analysis of a family of delta-like parallel robots by using algebraic tools to induce an estimation about the complexity in representing the singularities in the workspace and the joint space. A Gröbner based elimination is used to compute the singularities of the manipulator and a Cylindrical Algebraic Decomposition algorithm is used to study the workspace and the joint space. From these algebraic objects, we propose some certified three dimensional plotting describing the shape of workspace and of the joint space which will help the engineers or researchers to decide the most suited configuration of the manipulator they should use for a given task. Also, the different parameters associated with the complexity of the serial and parallel singularities are tabulated, which further enhance the selection of the different configurations of the manipulator by comparing the complexity of the singularity equations.

The second result is an algebraic method to check the singularity-free paths for parallel robots [15]. Trajectory planning is a critical step while programming the parallel manipulators in a robotic cell. The main problem arises when there exists a singular configuration between the two poses of the end-effectors while discretizing the path with a classical approach. This paper presents an algebraic method to check the feasibility of any given trajectories in the workspace. The solutions of the polynomial equations associated with the trajectories are projected in the joint space using Gröbner based elimination methods and the remaining equations are expressed in a parametric form where the articular variables are functions of time  $t$  unlike any numerical or discretization method. These formal computations allow to write the Jacobian of the manipulator as a function of time and to check if its determinant can vanish between two poses. Another benefit of this approach is to use a largest workspace with a more complex shape than a cube, cylinder or sphere. For the Orthoglide, a three degrees of freedom parallel robot, three different trajectories are used to illustrate this method.

#### 6.3.4. Reflection through quadric mirror surfaces

We addressed the problem of finding the reflection point on quadric mirror surfaces, especially ellipsoid, paraboloid or hyperboloid of two sheets, of a light ray emanating from a 3D point source  $P_1$  and going through another 3D point  $P_2$ , the camera center of projection. We previously proposed a new algorithm for this problem, using a characterization of the reflection point as the tangential intersection point between the mirror and an ellipsoid with foci  $P_1$  and  $P_2$ . The computation of this tangential intersection point is based on our algorithm for the computation of the intersection of quadrics [5], [28]. Unfortunately, our new algorithm is not yet efficient in practice. This year, we made several improvements on this algorithm. First, we decreased from 11 to 4 the degree of a critical polynomial that we need to solve and whose solutions induce the coefficients in some other polynomials appearing later in the computations. Second, we implemented Descartes's algorithm for isolating the real roots of univariate polynomials in the case where the coefficients belong to extensions of  $\mathbb{Q}$  generated by at most two square roots. Furthermore, we are currently implementing the generalization of that algorithm when the coefficients belong to extensions of  $\mathbb{Q}$  generated by one root of an arbitrary polynomial. These undergoing improvements should allow us to compute more directly the wanted reflexion point, thus avoiding problematic approximations and making the overall algorithm tractable.

## 7. Partnerships and Cooperations

### 7.1. National Initiatives

#### 7.1.1. ANR PRESAGE

The white ANR grant PRESAGE brings together computational geometers (from the VEGAS and GEOMETRICA projects of Inria) and probabilistic geometers (from Universities of Rouen, Orléans and Poitiers) to tackle new probabilistic geometry problems arising from the design and analysis of geometric algorithms and data structures. We focus on properties of discrete structures induced by random continuous geometric objects.

The project, with a total budget of 400k€, started on Dec. 31st, 2011 and will end in march 2016. It is coordinated by Xavier Goaoc who moved from the Vegas team to Marne-la-Vallée university in 2013.

Project website: <http://webloria.loria.fr/~moroz/ANR-Presage>.

#### 7.1.2. ANR SingCAST

The objective of the young-researcher ANR grant SingCAST is to intertwine further symbolic/numeric approaches to compute efficiently solution sets of polynomial systems with topological and geometrical guarantees in singular cases. We focus on two applications: the visualization of algebraic curves and surfaces and the mechanical design of robots.

After identifying classes of problems with restricted types of singularities, we plan to develop dedicated symbolic-numerical methods that take advantage of the structure of the associated polynomial systems that cannot be handled by purely symbolic or numerical methods. Thus we plan to extend the class of manipulators that can be analyzed, and the class of algebraic curves and surfaces that can be visualized with certification.

This is a 3.5 years project, with a total budget of 100k€, that started on March 1st 2014, coordinated by Guillaume Moroz.

In 2015, the project funded the postdoc position of Rémi Imbach.

Project website: <https://project.inria.fr/singcast/>.

## 7.2. International Research Visitors

### 7.2.1. Visits to International Teams

Monique Teillaud was invited at the Workshop on Computational Geometric and Algebraic Topology, *Mathematisches Forschungsinstitut Oberwolfach*, where she presented **CGAL**, the Computational Geometry Algorithms Library. [https://www.mfo.de/occasion/1542/www\\_view](https://www.mfo.de/occasion/1542/www_view)

## 8. Dissemination

### 8.1. Promoting Scientific Activities

#### 8.1.1. Scientific events organisation

##### 8.1.1.1. Member of the organizing committees

Sylvain Lazard organized with S. Whitesides (Victoria University) the 14th Inria - McGill - Victoria Workshop on Computational Geometry<sup>2</sup> at the Bellairs Research Institute of McGill University in Feb. (1 week workshop on invitation).

Guillaume Moroz co-organized the *Journées Nationales de Calcul Formel 2015 (JNCF)*.

Monique Teillaud co-organized the Dagstuhl Seminar on Computational Geometry, with Otfried Cheong (KAIST, Korea) and Jeff Erickson (University of Illinois at Urbana-Champaign), Leibniz-Zentrum für Informatik, Germany, March 9-13. <http://www.dagstuhl.de/en/program/calendar/semhp/?semnr=15111>

Monique Teillaud co-organized the Workshop on Computational Geometry in non-Euclidean Spaces, with Éric Colin de Verdière (CNRS, ENS Paris) and Jean-Marc Schlenker (Mathematics Research Unit, U. Luxembourg), Inria, Loria, Nancy, August 26-28. The slides of the talks are available on the workshop website <http://neg15.loria.fr/>.

Monique Teillaud and Marc Pouget organized the 39th **CGAL** Developer Meeting, Sept 28 - Oct 2 at Inria Nancy - Grand Est.

#### 8.1.2. Scientific events selection

##### 8.1.2.1. Member of the conference program committees

Monique Teillaud was a member of the program committee of the 2015 *Symposium on Computational Geometry* SoCG'15.

##### 8.1.2.2. Reviewer

All members of the team are regular reviewers for the conferences of our field, namely the *Symposium on Computational Geometry* (SoCG) and the *International Symposium on Symbolic and Algebraic Computation* (ISSAC) and also SODA, CCCG, EuroCG.

---

<sup>2</sup>Workshop on Computational Geometry

### 8.1.3. Journal

#### 8.1.3.1. Member of the editorial boards

Olivier Devillers is a member of the Editorial Board of *Graphical Models*.

Monique Teillaud is a managing editor of JoCG, *Journal of Computational Geometry*. She is also a member of the Editorial Boards of CGTA, *Computational Geometry: Theory and Applications*, and of IJCGA, *International Journal of Computational Geometry and Applications*.

Marc Pouget and Monique Teillaud are members of the **CGAL** editorial board.

#### 8.1.3.2. Reviewer - Reviewing activities

All members of the team are regular reviewers for the journals of our field, namely *Discrete and Computational Geometry* (DCG), *Computational Geometry. Theory and Applications* (CGTA), *Journal of Computational Geometry* (JoCG), *International Journal on Computational Geometry and Applications* (IJCGA), *Journal on Symbolic Computations* (JSC), *SIAM Journal on Computing* (SICOMP), *Mathematics in Computer Science* (MCS), etc.

### 8.1.4. Invited talks

Guillaume Moroz was invited to give a talk at the Fields Institute in Toronto for the workshop on Algebra, Geometry and Proofs in Symbolic Computation. He was also invited to give a talk at the IHP for the seminar on algorithmic and computational geometry and at Supelec.

### 8.1.5. Research administration

#### 8.1.5.1. Hiring committees

S. Lazard was president of the hiring committee for a Professor position (UL/ENSEM/LORIA).

#### 8.1.5.2. Steering Committees

M. Teillaud is a member of the Steering Committee of the European Symposium on Algorithms (ESA).

#### 8.1.5.3. National committees

L. Dupont is a member of “Commission Pédagogique Nationale” (CPN) Information-Communication / Métiers du Multimédia et de l’Internet.

M. Teillaud is a member of the Scientific Board of the *Société Informatique de France* (SIF).

M. Teillaud is a member of the working group for the BIL, *Base d’Information des Logiciels* of Inria.

#### 8.1.5.4. Local committees and responsibilities

S. Lazard: Head of the PhD and Post-doc hiring committee for Inria Nancy-Grand Est (since 2009). Member of the *Bureau de la mention informatique* of the *École Doctorale IAE+M* (since 2009). Head of the *Mission Jeunes Chercheurs* for Inria Nancy-Grand Est (since 2011). Head of the Department Algo at LORIA (since 2014). Member of the *Conseil Scientifique* of LORIA (since 2014).

M. Teillaud is a member of the CDT, *Commission de développement technologique*, of Inria Nancy - Grand Est.

#### 8.1.5.5. Websites

M. Teillaud is maintaining the Computational Geometry Web Pages <http://www.computational-geometry.org/>, hosted by Inria Nancy - Grand Est since December. This site offers general interest information for the computational geometry community, in particular the Web proceedings of the Video Review of Computational Geometry, part of the Annual Symposium on Computational Geometry.

## 8.2. Teaching - Supervision - Juries

### 8.2.1. Teaching

Master : Guillaume Moroz, *Géométrie algébrique et applications en robotique*, 12h, M1, École Mathématique Africaine, Sénégal.<sup>3</sup>

Master: Marc Pouget, *Introduction to computational geometry*, 10.5h, M2, École Nationale Supérieure de Géologie, France.

Licence: Laurent Dupont, *Algorithmique*, 72h, L1, Université de Lorraine, France.

Licence: Laurent Dupont, *Web development*, 75h, L2, Université de Lorraine, France.

Licence: Laurent Dupont, *Traitement Numérique du Signal*, 10h, L2, Université de Lorraine, France.

Licence: Laurent Dupont, *Data structures*, 40h, L1, Université de Lorraine, France.

Licence: Sylvain Lazard, *Algorithms and Complexity*, 25h, L3, Université de Lorraine, France.

### 8.2.2. Supervision

PhD: Rémy Thomasse, Complexity analysis of random convex hulls, defended December 18th 2015. The student is hosted in EPI GEOMETRICA but supervised by O. Devillers [10].

PhD in progress : Ranjan Jha, Étude de l'espace de travail des mécanismes à boucles fermées, started in Oct. 2013, supervised by Damien Chablat, Fabrice Rouillier and Guillaume Moroz.

PhD in progress : Sény Diatta, Complexité du calcul de la topologie d'une courbe dans l'espace et d'une surface, started in Nov. 2014, supervised by Daouda Niang Diatta, Marie-Françoise Roy and Guillaume Moroz.

Postdoc: Rémy Imbach, Topology and geometry of singular surfaces with numerical algorithms, supervised by Guillaume Moroz and Marc Pouget.

Postdoc: Laurent Veysseire, Probabilistic analysis of geometric structures, supervised by Olivier Devillers.

### 8.2.3. Juries

O. Devillers was a member (advisor) of the PhD defense committee of Rémy Thomasse (Univ. Nice - Sophia Antipolis).

S. Lazard was an external examiner (rapporteur) of the Ph.D. of Cuong Tran (Univ. Pierre et Marie Curie).

## 8.3. Popularization

Guillaume Moroz is a member of the organizing committee of the *Olympiades académiques de mathématiques*.

## 9. Bibliography

### Major publications by the team in recent years

- [1] Y. BOUZIDI, S. LAZARD, M. POUGET, F. ROUILLIER. *Separating linear forms and Rational Univariate Representations of bivariate systems*, in "Journal of Symbolic Computation", 2015, pp. 84-119, <https://hal.inria.fr/hal-00977671>

<sup>3</sup><http://nlaga-simons.ucad.sn/index.php/new-international-events>

- [2] H. BRÖNNIMANN, O. DEVILLERS, V. DUJMOVIC, H. EVERETT, M. GLISSE, X. GOAOC, S. LAZARD, H.-S. NA, S. WHITESIDES. *Lines and free line segments Tangent to Arbitrary Three-dimensional Convex Polyhedra*, in "SIAM Journal on Computing", 2007, vol. 37, n<sup>o</sup> 2, pp. 522-551 [DOI : 10.1137/S0097539705447116]
- [3] J. CHENG, S. LAZARD, L. PEÑARANDA, M. POUGET, F. ROUILLIER, E. TSIGARIDAS. *On the topology of real algebraic plane curves*, in "Mathematics in Computer Science", 2010, vol. 4, n<sup>o</sup> 1, pp. 113-137 [DOI : 10.1007/s11786-010-0044-3], <https://hal.inria.fr/inria-00517175>
- [4] O. DEVILLERS, M. GLISSE, X. GOAOC. *Complexity Analysis of Random Geometric Structures Made Simpler*, in "29th Annual Symposium on Computational Geometry", Rio, Brazil, June 2013, pp. 167-175 [DOI : 10.1145/2462356.2462362], <https://hal.inria.fr/hal-00833774>
- [5] L. DUPONT, D. LAZARD, S. LAZARD, S. PETITJEAN. *Near-Optimal Parameterization of the Intersection of Quadrics: I. The Generic Algorithm; II. A Classification of Pencils; III. Parameterizing Singular Intersections*, in "Journal of Symbolic Computation", 2008, vol. 43, pp. 168–191, 192–215, 216–232, <http://hal.inria.fr/inria-00186090/en/>
- [6] H. EVERETT, D. LAZARD, S. LAZARD, M. SAFEY EL DIN. *The Voronoi diagram of three lines*, in "Journal of Discrete and Computational Geometry", 2009, vol. 42, n<sup>o</sup> 1, pp. 94-130 [DOI : 10.1007/s00454-009-9173-3], <http://www.springerlink.com/content/f5601q6324664k2p/?p=6d7bb74bf9df40b0b7756b3a5153809f&pi=5>
- [7] M. GLISSE, S. LAZARD. *An Upper Bound on the Average Size of Silhouettes*, in "Discrete & Computational Geometry", 2008, vol. 40, n<sup>o</sup> 2, pp. 241-257 [DOI : 10.1007/s00454-008-9089-3]
- [8] X. GOAOC, H.-S. KIM, S. LAZARD. *Bounded-Curvature Shortest Paths through a Sequence of Points using Convex Optimization*, in "SIAM Journal on Computing", 2013, vol. 42, n<sup>o</sup> 2, pp. 662-684 [DOI : 10.1137/100816079], <https://hal.inria.fr/hal-00927100>
- [9] M. HEMMER, L. DUPONT, S. PETITJEAN, E. SCHÖMER. *A Complete, Exact and Efficient Implementation for Computing the Edge-Adjacency Graph of an Arrangement of Quadrics*, in "Journal of Symbolic Computation", 2011, vol. 46, n<sup>o</sup> 4, pp. 467-494 [DOI : 10.1016/J.JSC.2010.11.002], <https://hal.inria.fr/inria-00537592>

## Publications of the year

### Doctoral Dissertations and Habilitation Theses

- [10] R. THOMASSE. *Complexity analysis of random convex hulls*, Université Nice Sophia Antipolis, December 2015, <https://hal.inria.fr/tel-01252937>

### Articles in International Peer-Reviewed Journals

- [11] Y. BOUZIDI, S. LAZARD, M. POUGET, F. ROUILLIER. *Separating linear forms and Rational Univariate Representations of bivariate systems*, in "Journal of Symbolic Computation", May 2015, vol. 68, n<sup>o</sup> 0, pp. 84-119 [DOI : 10.1016/J.JSC.2014.08.009], <https://hal.inria.fr/hal-00977671>
- [12] G. MOROZ, B. ARONOV. *Computing the Distance between Piecewise-Linear Bivariate Functions*, in "ACM Transactions on Algorithms", 2015, pp. 1-12, <https://hal.archives-ouvertes.fr/hal-01112394>

### International Conferences with Proceedings

- [13] O. DEVILLERS, M. GLISSE, X. GOAOC, R. THOMASSE. *On the smoothed complexity of convex hulls*, in "31st International Symposium on Computational Geometry", Eindhoven, Netherlands, Lipics, June 2015 [DOI : 10.4230/LIPIcs.SOCG.2015.224], <https://hal.inria.fr/hal-01144473>
- [14] R. IMBACH, G. MOROZ, M. POUGET. *Numeric and Certified Isolation of the Singularities of the Projection of a Smooth Space Curve*, in "Proceedings of the 6th International Conferences on Mathematical Aspects of Computer and Information Sciences", Berlin, Germany, Springer LNCS, October 2015, <https://hal.inria.fr/hal-01239447>
- [15] R. JHA, D. CHABLAT, F. ROUILLIER, G. MOROZ. *An algebraic method to check the singularity-free paths for parallel robots*, in "International Design Engineering Technical Conferences & Computers and Information in Engineering Conference", Boston, United States, ASME, August 2015, <https://hal.archives-ouvertes.fr/hal-01142989>
- [16] R. JHA, D. CHABLAT, F. ROUILLIER, G. MOROZ. *Workspace and Singularity analysis of a Delta like family robot*, in "4th IFTOMM International Symposium on Robotics and Mechatronics", Poitiers, France, June 2015, <https://hal.archives-ouvertes.fr/hal-01142465>

### Conferences without Proceedings

- [17] M. BOGDANOV, M. CAROLI, M. TEILLAUD. *Computing Periodic Triangulations*, in "Shape up - Exercises in Materials Geometry and Topology", Berlin, Germany, September 2015, pp. 60-61, <https://hal.inria.fr/hal-01224549>

### Scientific Books (or Scientific Book chapters)

- [18] L. CASTELLI ALEARDI, O. DEVILLERS, J. ROSSIGNAC. *Compact data structures for triangulations Name: Compact data structures for triangulations*, in "Encyclopedia of Algorithms", Springer, 2015 [DOI : 10.1007/978-3-642-27848-8\_589-1], <https://hal.inria.fr/hal-01168565>

### Books or Proceedings Editing

- [19] O. CHEONG, J. ERICKSON, M. TEILLAUD (editors). *Proceedings of Computational Geometry (Dagstuhl Seminar 15111)*, Schloss Dagstuhl–Leibniz-Zentrum fuer Informatik, France, 2015 [DOI : 10.4230/DAGREP.5.3.41], <https://hal.inria.fr/hal-01177029>
- [20] S. W. CHENG, O. DEVILLERS, S.-W. CHENG, O. DEVILLERS (editors) *Discrete and Computational Geometry; Special Issue: 30th Annual Symposium on Computational Geometry*, Springer, 2015, vol. 53, n<sup>o</sup> 3, <https://hal.inria.fr/hal-01154063>
- [21] S. W. CHENG, O. DEVILLERS, S.-W. CHENG, O. DEVILLERS (editors) *Journal of Computational Geometry; Special issue of Selected Papers from SoCG 2014*, Computational Geometry Lab, Carleton University, 2015, vol. 6, n<sup>o</sup> 2, <https://hal.inria.fr/hal-01154065>

### Research Reports

- [22] Y. BOUZIDI, S. LAZARD, G. MOROZ, M. POUGET, F. ROUILLIER, M. SAGRALOFF. *Improved algorithms for solving bivariate systems via Rational Univariate Representations*, Inria, June 2015, <https://hal.inria.fr/hal-01114767>



- [23] O. DEVILLERS, M. GLISSE, X. GOAOC, R. THOMASSE. *Smoothed complexity of convex hulls by witnesses and collectors*, Inria, October 2015, n<sup>o</sup> 8787, 41 p. , <https://hal.inria.fr/hal-01214021>
- [24] O. DEVILLERS, R. HEMSLEY. *The worst visibility walk in a random Delaunay triangulation is  $O(\sqrt{n})$* , Inria, October 2015, n<sup>o</sup> RR-8792, 25 p. , <https://hal.inria.fr/hal-01216212>
- [25] O. DEVILLERS, M. KARAVELAS, M. TEILLAUD. *Qualitative Symbolic Perturbation: a new geometry-based perturbation framework*, Inria, 2015, n<sup>o</sup> RR-8153, 34 p. , <https://hal.inria.fr/hal-00758631>
- [26] R. IMBACH, G. MOROZ, M. POUGET. *Numeric certified algorithm for the topology of resultant and discriminant curves*, Inria, April 2015, n<sup>o</sup> RR-8653, <https://hal.inria.fr/hal-01093040>
- [27] S. LAZARD, M. POUGET, F. ROUILLIER. *Bivariate Triangular Decompositions in the Presence of Asymptotes*, Inria, September 2015, <https://hal.inria.fr/hal-01200802>

## References in notes

- [28] *QI: a C++ package for parameterizing intersections of quadrics*, 2005, LORIA, Inria Lorraine, VEGAS project, <http://www.loria.fr/equipes/vegas/qi>
- [29] P. ALLIEZ, C. JAMIN, L. RINEAU, S. TAYEB, J. TOURNOIS, M. YVINEC. *3D Mesh Generation*, in "CGAL User and Reference Manual", CGAL Editorial Board, 2009, [http://doc.cgal.org/latest/Manual/packages.html#PkgMesh\\_3Summary](http://doc.cgal.org/latest/Manual/packages.html#PkgMesh_3Summary)
- [30] M. CAROLI, M. TEILLAUD. *3D Periodic Triangulations*, in "CGAL User and Reference Manual", CGAL EDITORIAL BOARD (editor), 2009, <http://doc.cgal.org/latest/Manual/packages.html#PkgPeriodic3Triangulation3Summary>
- [31] L. GONZÁLEZ-VEGA, M. EL KAHOUI. *An Improved Upper Complexity Bound for the Topology Computation of a Real Algebraic Plane Curve*, in "J. of Complexity", 1996, vol. 12, n<sup>o</sup> 4, pp. 527–544
- [32] A. PELLÉ, M. TEILLAUD. *Periodic meshes for the CGAL library*, 2014, International Meshing Roundtable, Research Note, <https://hal.inria.fr/hal-01089967>
- [33] A. PELLÉ, M. TEILLAUD. *CGAL periodic volume mesh generator*, 2014, International Meshing Roundtable, Poster, <https://hal.inria.fr/hal-01089980>