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Project-Team GEOMETRICA

Geometric Computing

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THEME
Algorithms, Certification, and Cryptography

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Project-Team GEOMETRICA

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2. Overall Objectives

2.1. Overall Objectives

Research carried out by the Geometrica project team is dedicated to Computational Geometry and Topology and follows three major directions: (a). mesh generation and geometry processing; (b). topological and geometric inference; (c). data structures and robust geometric computation. The overall objective of the project-team is to give effective computational geometry and topology solid mathematical and algorithmic foundations, to provide solutions to key problems as well as to validate theoretical advances through extensive experimental research and the development of software packages that may serve as steps toward a standard for reliable and effective geometric computing. Most notably, Geometrica, together with several partners in Europe, plays a prominent role in the development of CGAL, a large library of computational geometry algorithms.

2.2. Highlights

We organized the 27th Annual Symposium on Computational Geometry (SoCG 2011) in Paris: http://socg2011.inria.fr/. This is the main conference in the field. We also organised a summer school entitled "Computational Geometric Learning" at the IHP in Paris, to foster connections between Computational Geometry and Machine Learning. About 70 persons attended.

Mariette Yvinec and Pierre Alliez, together with Jane Tournois and Laurent Rineau from the INRIA spin-off Geometry Factory, received the Meshing Maestro Award at the 20th International Meshing Roundtable for their poster "Meshing with CGAL".

Bertrand Pellenard and Pierre Alliez, together with Jean-Marie Morvan from University Lyon1/CNRS and King Abdullah University of Science and Technology, received the Best Technical Poster Award at the 20th International Meshing Roundtable for their poster "Isotropic 2D Quadrangle Meshing with Size and Orientation Control".

3. Scientific Foundations

3.1. Mesh Generation and Geometry Processing

Meshes are becoming commonplace in a number of applications ranging from engineering to multimedia through biomedecine and geology. For rendering, the quality of a mesh refers to its approximation properties. For numerical simulation, a mesh is not only required to faithfully approximate the domain of simulation, but also to satisfy size as well as shape constraints. The elaboration of algorithms for automatic mesh generation is a notoriously difficult task as it involves numerous geometric components: Complex data structures and algorithms, surface approximation, robustness as well as scalability issues. The recent trend to reconstruct domain boundaries from measurements adds even further hurdles. Armed with our experience on triangulations and algorithms, and with components from the CGAL library, we aim at devising robust algorithms for 2D, surface, 3D mesh generation as well as anisotropic meshes. Our research in mesh generation primarily focuses on the generation of simplicial meshes, i.e. triangular and tetrahedral meshes. We investigate both greedy approaches based upon Delaunay refinement and filtering, and variational approaches based upon energy functionals and associated minimizers.

The search for new methods and tools to process digital geometry is motivated by the fact that previous attempts to adapt common signal processing methods have led to limited success: Shapes are not just another signal but a new challenge to face due to distinctive properties of complex shapes such as topology, metric, lack of global parameterization, non-uniform sampling and irregular discretization. Our research in geometry processing ranges from surface reconstruction to surface remeshing through curvature estimation, principal component analysis, surface approximationand surface mesh parameterization. Another focus is on the robustness of the algorithms to defect-laden data. This focus stems from the fact that acquired geometric data obtained through measurements or designs are rarely usable directly by downstream applications. This generates bottlenecks, i.e., parts of the processing pipeline which are too labor-intensive or too brittle for practitioners. Beyond reliability and theoretical foundations, our goal is to design methods which are also robust to raw, unprocessed inputs.

3.2. Topological and Geometric Inference

Due to the fast evolution of data acquisition devices and computational power, scientists in many areas are asking for efficient algorithmic tools for analyzing, manipulating and visualizing more and more complex shapes or complex systems from approximating data. Many of the existing algorithmic solutions which come with little theoretical guarantee provide unsatisfactory and/or unpredictable results. Since these algorithms take as input discrete geometric data, it is mandatory to develop concepts that are rich enough to robustly and correctly approximate continuous shapes and their geometric properties by discrete models. Ensuring the correctness of geometric estimations and approximations on discrete data is a sensitive problem in many applications.

Data sets being often represented as point sets in high dimensional spaces, there is a considerable interest in analyzing and processing data in such spaces. Although these point sets usually live in high dimensional spaces, one often expects them to be located around unknown, possibly non linear, low dimensional shapes. These shapes are usually assumed to be smooth submanifolds or more generally compact subsets of the ambient space. It is then desirable to infer topological (dimension, Betti numbers,...) and geometric characteristics (singularities, volume, curvature,...) of these shapes from the data. The hope is that this information will help to better understand the underlying complex systems from which the data are generated. In spite of recent promising results, many problems still remain open and to be addressed, need a tight collaboration between mathematicians and computer scientists. In this context our goal is to contribute to the development of new mathematically well founded and algorithmically efficient geometric tools for data analysis and processing of complex geometric objects. Our main targeted areas of application include machine learning, data mining, statistical analysis, and sensor networks.

3.3. Data Structures and Robust Geometric Computation

GEOMETRICA has a large expertise of algorithms and data structures for geometric problems.We are pursuing efforts to design efficient algorithms from a theoretical point of view, but we also put efforts in the effective implementation of these results.

In the past years, we made significant contributions to algorithms for computing Delaunay triangulations (which are used by meshes in the above paragraph). We are still working on the practical efficiency of existing algorithms to compute or to exploit classical Euclidean triangulations in 2 and 3 dimensions, but the current focus of our research is more aimed towards extending the triangulation efforts in several new directions of research.

One of these directions is the triangulation of non Euclidean spaces such as periodic or projective spaces, with various potential applications ranging from astronomy to granular material simulation.

Another direction is the triangulation of moving points, with potential applications to fluid dynamics where the points represent some particles of some evolving physical material, and to variational methods devised to optimize point placement for meshing a domain with a high quality elements.

Increasing the dimension of space is also a stimulating direction of research, as triangulating points in medium dimension (say 4 to 15) has potential applications and makes new challenges to trade exponential complexity of the problem in the dimension for the possibility to reach effective and practical results in reasonably small dimensions.

On the complexity analysis side, we pursue efforts to obtain complexity analysis in some practical situations involving randomized or stochastic hypotheses. On the algorithm design side, we are looking for new paradigms to exploit parallelism on modern multicore hardware architectures.

Finally, all this work is done while keeping in mind concerns related to effective implementation of our work, practical efficiency and robustness issues which have become a background task of all different works made by GEOMETRICA.

4. Application Domains

4.1. Geometric Modeling and Shape Reconstruction

Modeling 3D shapes is required for all visualization applications where interactivity is a key feature since the observer can change the viewpoint and get an immediate feedback. This interactivity enhances the descriptive power of the medium significantly. For example, visualization of complex molecules helps drug designers to understand their structure. Multimedia applications also involve interactive visualization and include e-commerce (companies can present their products realistically), 3D games, animation and special effects in motion pictures. The uses of geometric modeling also cover the spectrum of engineering, computer-aided design and manufacture applications (CAD/CAM). More and more stages of the industrial development and production pipeline are now performed by simulation, due to the increased performance of numerical simulation packages. Geometric modeling therefore plays an increasingly important role in this area. Another emerging application of geometric modeling with high impact is medical visualization and simulation.

In a broad sense, shape reconstruction consists of creating digital models of real objects from points. Example application areas where such a process is involved are Computer Aided Geometric Design (making a car model from a clay mockup), medical imaging (reconstructing an organ from medical data), geology (modeling underground strata from seismic data), or cultural heritage projects (making models of ancient and or fragile models or places). The availability of accurate and fast scanning devices has also made the reproduction of real objects more effective such that additional fields of applications are coming into reach. The members of GEOMETRICA have a long experience in shape reconstruction and contributed several original methods based upon the Delaunay and Voronoi diagrams.

4.2. Scientific Computing

Meshes are the basic tools for scientific computing using finite element methods. Unstructured meshes are used to discretize domains bounded by complex shapes while allowing local refinements. GEOMETRICA contributes to mesh generation of 2D and 3D possibly curved domains. Most of our methods are based upon Delaunay triangulations, Voronoi diagrams and their variants. Anisotropic meshes are also investigated. We investigate in parallel both greedy and variational mesh generation techniques. The greedy algorithms consist of inserting vertices in an initial coarse mesh using the Delaunay refinement paradigm, while the variational algorithms consists of minimizing an energy related to the shape and size of the elements. Our goal is to show the complementarity of these two paradigms. Quadrangle surface meshes are also of interest for reverse engineering and geometry processing applications. Our goal is to control the final edge alignment, the mesh sizing and the regularity of the quadrangle tiling.

5. Software

5.1. CGAL, the Computational Geometry Algorithms Library

Participants: Pierre Alliez, Jean-Daniel Boissonnat, Olivier Devillers, Monique Teillaud, Mariette Yvinec.

With the collaboration of Hervé Brönnimann, Manuel Caroli, Pedro Machado Manhães de Castro, Frédéric Cazals, Frank Da, Christophe Delage, Andreas Fabri, Julia Flötotto, Philippe Guigue, Michael Hemmer, Samuel Hornus, Menelaos Karavelas, Sébastien Loriot, Abdelkrim Mebarki, Naceur Meskini, Andreas Meyer, Sylvain Pion, Marc Pouget, François Rebufat, Laurent Rineau, Laurent Saboret, Stéphane Tayeb, Radu Ursu, and Camille Wormser. http://www.cgal.org

CGAL is a C++ library of geometric algorithms and data structures. Its development has been initially funded and further supported by several European projects (CGAL, GALIA, ECG, ACS, AIM@SHAPE) since 1996. The long term partners of the project are research teams from the following institutes: INRIA Sophia Antipolis - Méditerranée, Max-Planck Institut Saarbrücken, ETH Zürich, Tel Aviv University, together with several others. In 2003, CGAL became an Open Source project (under the LGPL and QPL licenses), and it also became commercialized by GEOMETRY FACTORY, a company *Born of INRIA* founded by Andreas Fabri.

The aim of the CGAL project is to create a platform for geometric computing supporting usage in both industry and academia. The main design goals are genericity, numerical robustness, efficiency and ease of use. These goals are enforced by a review of all submissions managed by an editorial board. As the focus is on fundamental geometric algorithms and data structures, the target application domains are numerous: from geological modeling to medical images, from antenna placement to geographic information systems, etc.

The CGAL library consists of a kernel, a list of algorithmic packages, and a support library. The kernel is made of classes that represent elementary geometric objects (points, vectors, lines, segments, planes, simplices, isothetic boxes, circles, spheres, circular arcs...), as well as affine transformations and a number of predicates and geometric constructions over these objects. These classes exist in dimensions 2 and 3 (static dimension) and d (dynamic dimension). Using the template mechanism, each class can be instantiated following several representation modes : one can choose between Cartesian or homogeneous coordinates, use different types to store the coordinates, and use reference counting or not. The kernel also provides some robustness features using some specifically-devised arithmetic (interval arithmetic, multi-precision arithmetic, static filters...).

A number of packages provide geometric data structures as well as algorithms. The data structures are polygons, polyhedra, triangulations, planar maps, arrangements and various search structures (segment trees, d-dimensional trees...). Algorithms are provided to compute convex hulls, Voronoi diagrams, Boolean operations on polygons, solve certain optimization problems (linear, quadratic, generalized of linear type). Through class and function templates, these algorithms can be used either with the kernel objects or with user-defined geometric classes provided they match a documented interface.

Finally, the support library provides random generators, and interfacing code with other libraries, tools, or file formats (ASCII files, QT or LEDA Windows, OpenGL, Open Inventor, Postscript, Geomview...). Partial interfaces with Python, SCILAB and the Ipe drawing editor are now also available.

GEOMETRICA is particularly involved in general maintenance, in the arithmetic issues that arise in the treatment of robustness issues, in the kernel, in triangulation packages and their close applications such as alpha shapes, in meshes... Three researchers of GEOMETRICA are members of the CGAL Editorial Board, whose main responsibilities are the control of the quality of CGAL, making decisions about technical matters, coordinating communication and promotion of CGAL.

CGAL is about 700,000 lines of code and supports various platforms: GCC (Linux, Mac OS X, Cygwin...), Visual C++ (Windows), Intel C++... A new version of CGAL is released twice a year, and it is downloaded about 10000 times a year. Moreover, CGAL is directly available as packages for the Debian, Ubuntu and Fedora Linux distributions.

More numbers about CGAL: there are now 13 editors in the editorial board, with approximately 20 additional developers. The user discussion mailing-list has more than 1000 subscribers with a relatively high traffic of 5-10 mails a day. The announcement mailing-list has more than 3000 subscribers.

6. New Results

6.1. Mesh Generation and Geometry Processing

6.1.1. Isotropic 2D Quadrangle Meshing with Size and Orientation Control

Participants: Pierre Alliez, Bertrand Pellenard.

In collaboration with Jean-Marie Morvan from University of Lyon.

We propose an approach for automatically generating isotropic 2D quadrangle meshes from arbitrary domains with a fine control over sizing and orientation of the elements. At the heart of our algorithm is an optimization procedure that, from a coarse initial tiling of the 2D domain, enforces each of the desirable mesh quality criteria (size, shape, orientation, degree, regularity) one at a time, in an order designed not to undo previous enhancements. Our experiments demonstrate how well our resulting quadrangle meshes conform to a wide range of input sizing and orientation fields. [31].

6.1.2. An Optimal Transport Approach to Robust Reconstruction and Simplification of 2D Shapes

Participants: Pierre Alliez, David Cohen-Steiner.

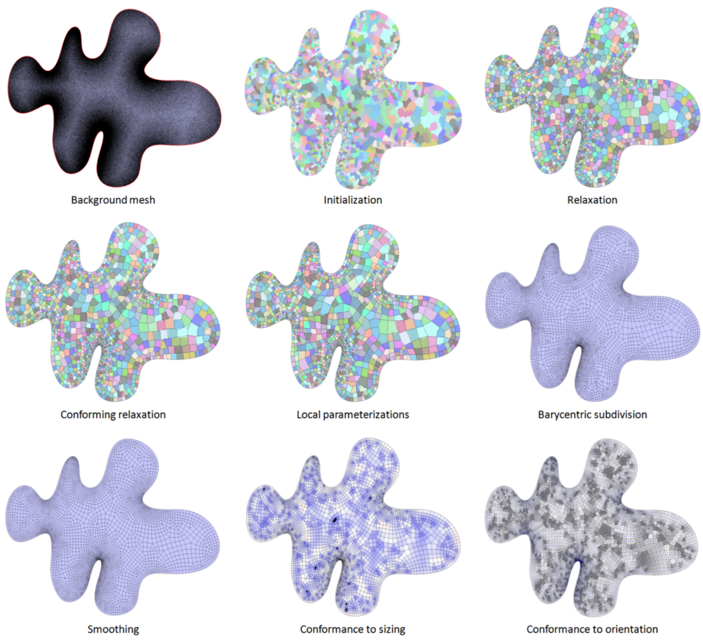

Figure 1. The algorithm takes as input a 2D domain, a sizing field and a cross field (not shown). It then operates on a triangle background mesh: The initialization clusters background mesh triangles so that the tiling roughly meets the size and shape criteria; A relaxation then improves the tiling for shape and orientation while preserving size; A conforming relaxation improves the degree of the tiles and the regularity of the tiling; A series of local parameterizations further improves the degrees and regularity; Barycentric subdivision generates a pure quadrangle mesh; Smoothing finally improves the shape of the quadrangles. We depict the conformance both to the sizing and to the cross field.

In collaboration with Fernando de Goes and Mathieu Desbrun from Caltech.

We propose a robust 2D shape reconstruction and simplification algorithm which takes as input a defect-laden point set with noise and outliers. We introduce an optimal-transport driven approach where the input point set, considered as a sum of Dirac measures, is approximated by a simplicial complex considered as a sum of uniform measures on 0- and 1-simplices. A fine-to-coarse scheme is devised to construct the resulting simplicial complex through greedy decimation of a Delaunay triangulation of the input point set. Our method performs well on a variety of examples ranging from line drawings to grayscale images, with or without noise, features, and boundaries. [25].

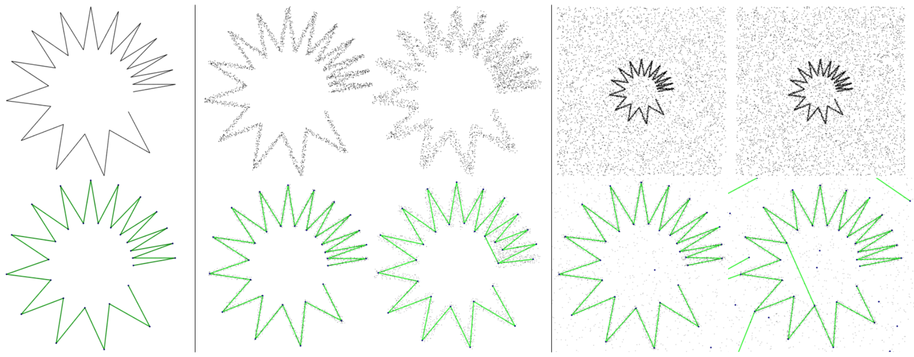

Figure 2. Robustness to noise and outliers. The input shape (3K points) has sharp corners subtending small angles as well as boundaries. Our reconstruction is perfect for a noise-free input (left); as noise is added (middle, 2% and 2.5% of bounding box), the output degrades gracefully, still capturing most of the sharp angles; even after adding 4K or 4.5K outliers and 2% of noise (right), the reconstruction remains of quality, although artifacts start appearing in this regime.

6.1.3. Anisotropic Delaunay Mesh Generation

Participants: Jean-Daniel Boissonnat, Mariette Yvinec.

In collaboration with Camille Wormser from Google.

Anisotropic meshes are triangulations of a given domain in the plane or in higher dimensions, with elements elongated along prescribed directions. Anisotropic triangulations are known to be well suited for interpolation of functions or solving PDEs. Assuming that the anisotropic shape requirements for mesh elements are given through a metric field varying over the domain, we propose a new approach to anisotropic mesh generation, relying on the notion of anisotropic Delaunay meshes. An anisotropic Delaunay mesh is defined as a mesh in which the star of each vertex v consists of simplices that are Delaunay for the metric associated to vertex v. This definition works in any dimension and allows to define a simple refinement algorithm. The algorithm takes as input a domain and a metric field and provides, after completion, an anisotropic mesh whose elements are shaped according to the metric field. [46]

6.1.4. Triangulating Smooth Submanifolds with Light Scaffolding

Participants: Jean-Daniel Boissonnat, Arijit Ghosh.

We propose an algorithm to sample and mesh a k-submanifold $\mathbb{M}$ of positive reach embedded in $\mathbb{R}^d$ [45]. The algorithm first constructs a crude sample of $\mathbb{M}$. It then refines the sample according to a prescribed parameter ϵ, and builds a mesh that approximates $\mathbb{M}$. Differently from most algorithms that have been developed for meshing surfaces of $\mathbb{R}^3$, the refinement phase does not rely on a subdivision of $\mathbb{R}^d$ (such as a grid or a triangulation of the sample points) since the size of such scaffoldings depends exponentially on the ambient

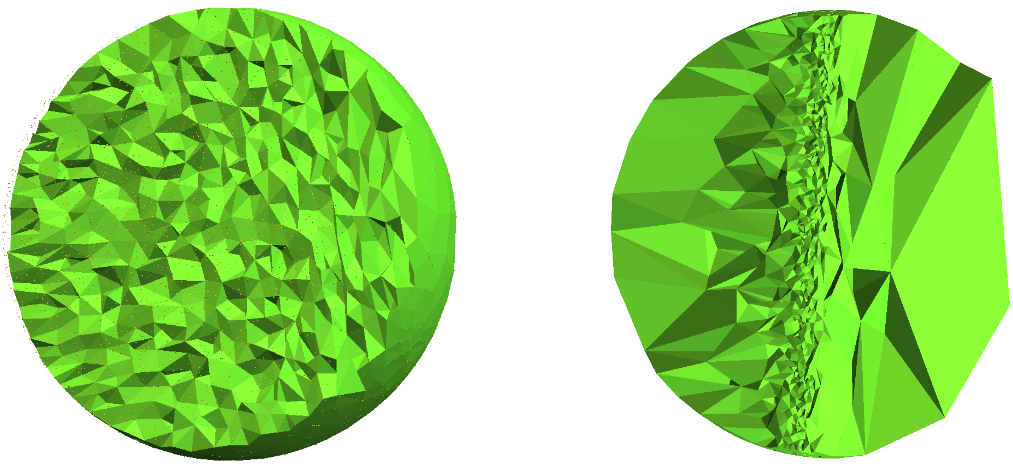

Figure 3. Two examples of anisotropic meshes produced by our algorithm.

dimension d. Instead, we only compute local stars consisting of k-dimensional simplices around each sample point. By refining the sample, we can ensure that all stars become coherent leading to a k-dimensional triangulated manifold $\widehat{\mathbb{M}}$. The algorithm uses only simple numerical operations. We show that the size of the sample is $O(\epsilon^{-k})$ and that $\widehat{\mathbb{M}}$ is a good triangulation of $\mathbb{M}$. More specifically, we show that $\mathbb{M}$ and $\widehat{\mathbb{M}}$ are isotopic, that their Hausdorff distance is $O(\epsilon^2)$ and that the maximum angle between their tangent bundles is $O(\epsilon)$. The asymptotic complexity of the algorithm is $T(\epsilon) = O(\epsilon^{-k^2-k})$ (for fixed $\mathbb{M}$, d and k).

6.2. Topological and Geometric Inference

6.2.1. Metric graph reconstruction from noisy data

Participants: Frédéric Chazal, Marc Glisse.

In collaboration with Mridul Aanjaneya, Daniel Chen, Leonidas J. Guibas and Dmitriy Morozov.

Many real-world data sets can be viewed of as noisy samples of special types of metric spaces called metric graphs. Building on the notions of correspondence and Gromov-Hausdorff distance in metric geometry, we describe a model for such data sets as an approximation of an underlying metric graph. We present a novel algorithm that takes as an input such a data set, and outputs the underlying metric graph with guarantees. We also implement the algorithm, and evaluate its performance on a variety of real world data sets [26].

6.2.2. Persistence-Based Clustering in Riemannian Manifolds

Participants: Frédéric Chazal, Steve Oudot.

In collaboration with Leonidas J. Guibas and Primoz Skraba.

We introduce a clustering scheme that combines a mode-seeking phase with a cluster merging phase in the corresponding density map. While mode detection is done by a standard graph-based hill-climbing scheme, the novelty of our approach resides in its use of *topological persistence* to guide the merging of clusters. Our algorithm provides additional feedback in the form of a set of points in the plane, called a *persistence diagram* (PD), which provably reflects the prominences of the modes of the density. In practice, this feedback enables the user to choose relevant parameter values, so that under mild sampling conditions the algorithm will output the *correct* number of clusters, a notion that can be made formally sound within persistence theory.

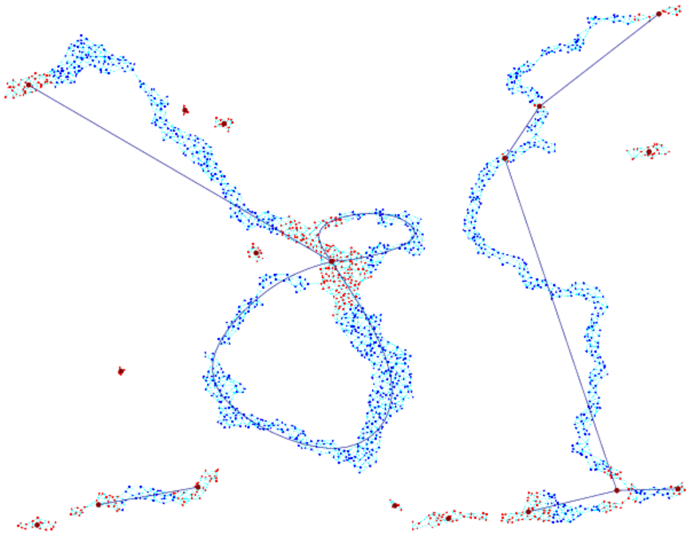

Figure 4. Earthquake data: the input neighborhood graph is shown in cyan, the points marked as belonging to a branch are shown in red, and the points marked as belonging to an edge are shown in blue. The reconstructed graph is shown in dark blue.

The algorithm only requires rough estimates of the density at the data points, and knowledge of (approximate) pairwise distances between them. It is therefore applicable in any metric space. Meanwhile, its complexity remains practical: although the size of the input distance matrix may be up to quadratic in the number of data points, a careful implementation only uses a linear amount of memory and takes barely more time to run than to read through the input. [29].

6.2.3. Data-driven trajectory smoothing

Participant: Frédéric Chazal.

In collaboration with Daniel Chen, Leonidas J. Guibas, Xiaoye Jiang and Christian Sommer

Motivated by the increasing availability of large collections of noisy GPS traces, we present a new data-driven framework for smoothing trajectory data. The framework, which can be viewed of as a generalization of the classical moving average technique, naturally leads to efficient algorithms for various smoothing objectives. We analyze an algorithm based on this framework and provide connections to previous smoothing techniques. We implement a variation of the algorithm to smooth an entire collection of trajectories and show that it performs well on both synthetic data and massive collections of GPS traces. [28].

6.2.4. A Weighted k-Nearest Neighbor Density Estimate for Geometric Inference

Participants: Frédéric Chazal, David Cohen-Steiner.

In collaboration with Gérard Biau, Luc Devroye and Carlos Rodriguez

Motivated by a broad range of potential applications in topological and geometric inference, we introduce a weighted version of the k-nearest neighbor density estimate. Various pointwise consistency results of this estimate are established. We present a general central limit theorem under the lightest possible conditions. In addition, a strong approximation result is obtained and the choice of the optimal set of weights is discussed. In particular, the classical k-nearest neighbor estimate is not optimal in a sense described in the manuscript. The proposed method has been implemented to recover level sets in both simulated and real-life data. [12].

6.2.5. Deconvolution for the Wasserstein metric and geometric inference

Participants: Frédéric Chazal, Claire Caillerie.

In collaboration with Jérôme Dedecker and Bertrand Michel

Recently, [17], [13] have defined a distance function to measures to answer geometric inference problems in a probabilistic setting. According to their result, the topological properties of a shape can be recovered by using the distance to a known measure ν, if ν is close enough to a measure μ concentrated on this shape. Here, close enough means that the Wasserstein distance W_2 between μ and ν is sufficiently small. Given a point cloud, a natural candidate for ν is the empirical measure μ_n. Nevertheless, in many situations the data points are not located on the geometric shape but in the neighborhood of it, and μ_n can be too far from μ. In a deconvolution framework, we consider a slight modification of the classical kernel deconvolution estimator, and we give a consistency result and rates of convergence for this estimator. Some simulated experiments illustrate the deconvolution method and its application to geometric inference on various shapes and with various noise distributions. [14].

6.2.6. Manifold Reconstruction Using Tangential Delaunay Complexes

Participants: Jean-Daniel Boissonnat, Arijit Ghosh.

We give a new provably correct algorithm to reconstruct a k-dimensional manifold embedded in d-dimensional Euclidean space [44]. The input to our algorithm is a point sample coming from an unknown manifold. Our approach is based on two main ideas : the notion of tangential Delaunay complex and the technique of sliver removal by weighting the sample points. Differently from previous methods, we do not construct any subdivision of the d-dimensional ambient space. As a result, the running time of our algorithm depends only linearly on the extrinsic dimension d while it depends quadratically on the size of the input sample, and exponentially on the intrinsic dimension k. This is the first certified algorithm for manifold reconstruction whose complexity depends linearly on the ambient dimension. We also prove that for a dense enough sample the output of our algorithm is ambient isotopic to the manifold and a close geometric approximation of the manifold.

6.2.7. Equating the witness and restricted Delaunay complexes

Participants: Jean-Daniel Boissonnat, Ramsay Dyer, Arijit Ghosh, Steve Oudot.

It is a well-known fact that the restricted Delaunay and witness complexes may differ when the landmark and witness sets are located on submanifolds of Rd of dimension 3 or more. Currently, the only known way of overcoming this issue consists of building some crude superset of the witness complex, and applying a greedy sliver exudation technique on this superset. Unfortunately, the construction time of the superset depends exponentially on the ambient dimension, which makes the witness complex based approach to manifold reconstruction impractical. This work [43] provides an analysis of the reasons why the restricted Delaunay and witness complexes fail to include each other. From this a new set of conditions naturally arises under which the two complexes are equal.

6.2.8. Reconstructing 3D compact sets

Participant: David Cohen-Steiner.

In collaboration with Frédéric Cazals.

Reconstructing a 3D shape from sample points is a central problem faced in medical applications, reverse engineering, natural sciences, cultural heritage projects, etc. While these applications motivated intense research on 3D surface reconstruction, the problem of reconstructing more general shapes hardly received any attention. This paper develops a reconstruction algorithm changing the 3D reconstruction paradigm as follows.

First, the algorithm handles general shapes i.e. compact sets as opposed to surfaces. Under mild assumptions on the sampling of the compact set, the reconstruction is proved to be correct in terms of homotopy type. Second, the algorithm does not output a single reconstruction but a nested sequence of *plausible* reconstructions. Third, the algorithm accommodates topological persistence so as to select the most stable features only. Finally, in case of reconstruction failure, it allows the identification of under-sampled areas, so as to possibly fix the sampling.

These key features are illustrated by experimental results on challenging datasets (see Figure 5), and should prove instrumental in enhancing the processing of such datasets in the aforementioned applications. [16].

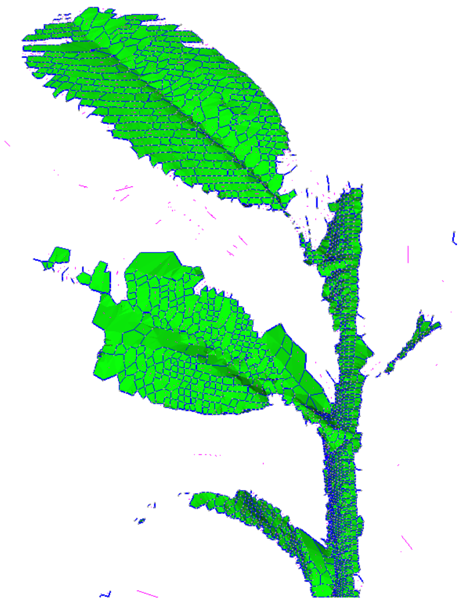

Figure 5. Reconstruction obtained on a data set with heterogeneous dimensions.

6.3. Data Structures and Robust Geometric Computation

6.3.1. Explicit array-based compact data structures for triangulations

Participant: Olivier Devillers.

In collaboration with Luca Castelli Aleardi (LIX, Palaiseau).

We consider the problem of designing space efficient solutions for representing triangle meshes. Our main result is a new explicit data structure for compactly representing planar triangulations: if one is allowed to permute input vertices, then a triangulation with n vertices requires at most $4n$ references ($5n$ references if vertex permutations are not allowed). Our solution combines existing techniques from mesh encoding with a novel use of minimal Schnyder woods. Our approach extends to higher genus triangulations and could be applied to other families of meshes (such as quadrangular or polygonal meshes). As far as we know, our solution provides the most parsimonious data structures for triangulations, allowing constant time navigation in the worst case. Our data structures require linear construction time, and all space bounds hold in the worst case. We have implemented and tested our results, and experiments confirm the practical interest of compact data structures[47], [35]

6.3.2. Hyperbolic Delaunay triangulations and Voronoi diagrams made practical

Participants: Mikhail Bogdanov, Olivier Devillers, Monique Teillaud.

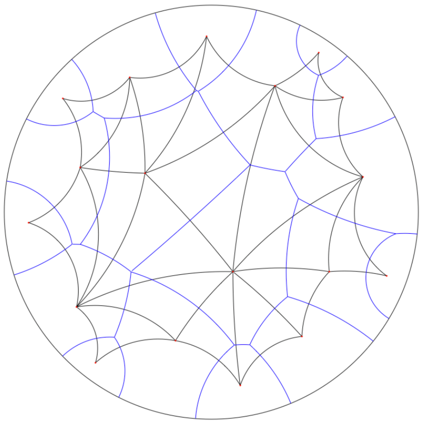

Figure 6. Hyperbolic Delaunay triangulation and Voronoi diagram in the Poicaré plane.

We show how to compute Delaunay triangulations and Voronoi diagrams of a set of points in hyperbolic space in a very simple way. The algorithm is implemented in an exact and efficient way[34] (see Figure 6).

6.4. Applications

6.4.1. Study of the cosmic web

Participant: Monique Teillaud.

In collaboration with many coauthors: members of the OrbiCG Associate Team (Section 8.3.1.3), Herbert Edelsbrunner (IST Austria, Duke University, and Geomagic Inc.), and others

We introduce a new descriptor of the weblike pattern in the distribution of galaxies and matter: the scale dependent Betti numbers which formalize the topological information content of the cosmic mass distribution (see Figure 7. While the Betti numbers do not fully quantify topology, they extend the information beyond conventional cosmological studies of topology in terms of genus and Euler characteristic used in earlier analyses of cosmological models. The richer information content of Betti numbers goes along with the availability of fast algorithms to compute them. When measured as a function of scale they provide a “Betti signature” for a point distribution that is a sensitive yet robust discriminator of structure. The signature is highly effective in revealing differences in structure arising in different cosmological models, and is exploited towards distinguishing between different dark energy models and may likewise be used to trace primordial non-Gaussianities. In this study we demonstrate the potential of Betti numbers by studying their behaviour in simulations of cosmologies differing in the nature of their dark energy [48], [41]. This work uses previous results obtained in GEOMETRICA [49], [50].

6.5. Software

6.5.1. CGAL

Two major new releases of CGAL, versions 3.8 and 3.9, have been been made available in 2011. These releases contain the following new features, involving GEOMETRICA researchers:

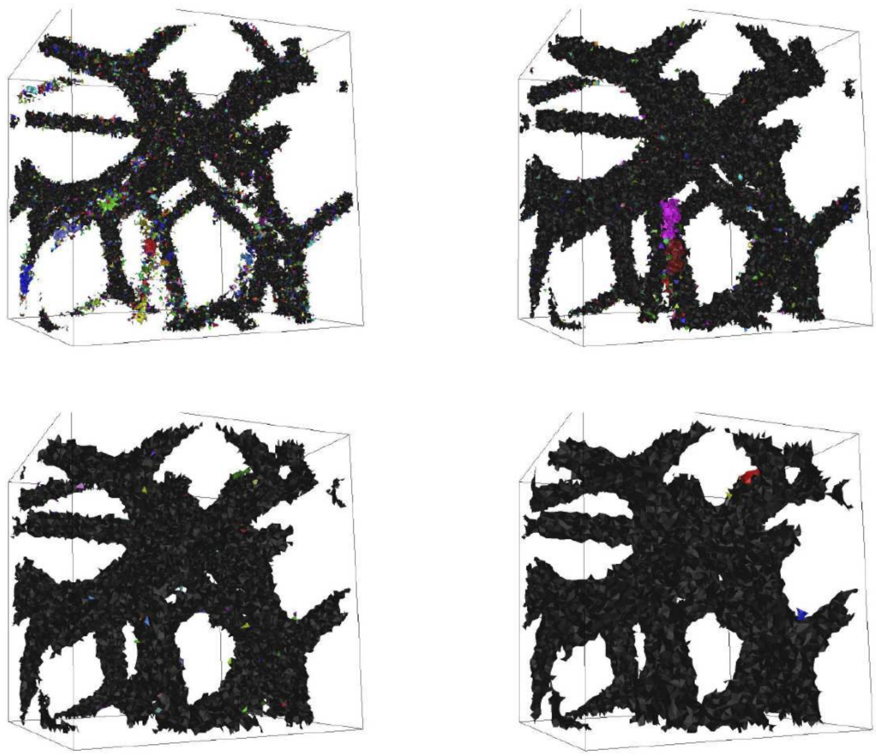

Figure 7. Four α-shapes of a Voronoi filament model realization. It concerns a sample of 200000 particles in a periodic box of 50 h^1Mpc size with 8 Voronoi cells. From top left to bottom right:
$\alpha = 0.5 \times 10^4, 1.0 \times 10^4, 2 \times 10^4 and 4.0 \times 10^4$.

- *Generator*. In release 3.8, the package Generator has been extended to provide various point set generators in dimensions higher than 3. It can generate random point sets in/on a sphere, in a cube, and points on a grid [40].
- *Spatial sorting*. Spatial sorting allows to order a set of points to improve the efficiency of incremental randomized algorithms. The spatial sorting package was existing in previous releases, and has been extended to dimensions higher than 3 in release 3.9 [39].
- *3D Mesh Generation*. The mesh generation package was introduced in CGAL 3.5. From release CGAL 3.6, the package offers, after Delaunay refinement, an optional optimization step to either improve the global mesh quality or get rid of slivers. Release CGAL 3.7 includes an interactive demo based on Qt and the code has been optimized for efficiency. Release 3.8 and further [38] offer the possibility to preserve sharp features such as creases and corners when provided in the description of the input domain.

The new release also contains new packages implemented by our CGAL partners and improvements to some existing packages: a detailed list can be found on the CGAL web site.

Two one-week CGAL developers meetings take place each year. The last one, organized in September at INRIA Sophia Antipolis by Mariette Yvinec, gathered 20 participants.

7. Contracts and Grants with Industry

7.1. Geometry Factory

The initial development phase of the CGAL library has been made by a European consortium. In order to achieve the transfer and diffusion of CGAL in the industry, a company called GEOMETRY FACTORY has been founded in January 2003 by Andreas Fabri (http://www.geometryfactory.com).

The goal of this company is to pursue the development of the library and to offer services in connection with CGAL (maintenance, support, teaching, advice). GEOMETRY FACTORY is a link between the researchers from the computational geometry community and the industrial users.

It offers licenses to interested companies, and provides support. There are contracts in various domains such as CAD/CAM, medical applications, GIS, computer vision...

GEOMETRY FACTORY is keeping close contacts with the original consortium members, and in particular with GEOMETRICA.

In 2011, GEOMETRY FACTORY had the following new customers for CGAL packages developed by GEOMETRICA: Acute3D (3D Delaunay, France), Ansys (2D Circular Kernel, CAD, USA), Autodesk (Poisson Surface reconstruction, CAD, USA), Esri (AABB Tree, GIS, USA), ExxonMobil (3D Delaunay, oil, USA), Halliburton (Poisson Surface reconstruction, oil, USA), Metria (2D Delaunay, GIS, Spain), Petrobras (2D Mesh, Surface mesher, Segment Voronoi diagram, oil, Brasil), Petroglyphgames (2D Constrained Delaunay, games, USA), Zimmer (Poisson Surface reconstruction, medical, Canada).

Moreover, research licenses (in-house research usage for all of CGAL) have been purchased by: Geovariances (petrol, France), Siemens Corporate Research (medical, USA), Spot Image (GIS, France), IGN (GIS, France), Kappa Engineering (oil, Germany), MPI Metal Research (Germany).

8. Partnerships and Cooperations

8.1. National Initiatives

8.1.1. ADT CGAL-Mesh

Participants: Pierre Alliez, Mariette Yvinec, Jean-Daniel Boissonnat.

CGAL-Mesh was a two-year INRIA technological development action started in March 2009. Building upon components from CGAL, we have implemented a generic mesh generation framework for 3D domains. We primarily target applications which involve data acquired from the physical world: geology, medicine, 3D cartography and reverse engineering. We wish to establish for the whole duration of the action a close collaboration with industrial and academic partners so as to maximize the impact of the platform for a number of applications and research experiments.

- Starting date: March 2009

- Duration: 2 years

8.1.2. ANR Triangles

Participants: Olivier Devillers, Monique Teillaud.

Web site: http://www.inria.fr/sophia/geometrica/collaborations/triangles/

We lead the TRIANGLES project funded by the ANR. The project involves:

- the «Laboratoire d'InfoRmatique en Image et Systèmes d'information» (LIRIS), Lyon,
- the «Département d'informatique de l'ENS»
- the GEOMETRICA team.

Triangulations are essential in many applications, in particular for meshing and shape reconstruction. We want to develop and distribute new results for academic and industrial researchers. The goal of the project is the development of robust and effective algorithms for the manipulation of large sets of points, of moving sets of points and points in non Euclidean spaces such as periodic spaces (torus, cylinder), projective, oriented projective or hyperbolic spaces. The results obtained will be implemented in the CGAL library and will be applied to computer vision (visual envelopes, camera calibration), fluid dynamics, astronomy, computer graphics and medical applications.

In the GEOMETRICA team, Triangles is co-funding the scholarship of Pedro de Castro (with «Région PACA») and funding travel expenses and computers. Several meetings have been organized between participants, details can be found on the project's web page.

- Starting date: November 2007

- Duration: 3 years + 6 months prolongation.

8.1.3. ANR GAIA

Participants: Jean-Daniel Boissonnat, Frédéric Chazal, David Cohen-Steiner, Arijit Ghosh.

The aim of this project is to formalize a collaboration between researchers from computational geometry, machine learning and computer vision to study distortions and in particular Bregman divergences, information theory, statistics, Riemannian geometry, and convex analysis.

The other partners of the project are the Université des Antilles et de la Guyane (R. Nock, coordinator), the Ecole Polytechnique (F. Nielsen) and the Lear project-team (C. Schmid).

- Starting date: November 2007

- Duration: 4 years

8.1.4. ANR GIGA

Participants: Pierre Alliez, Jean-Daniel Boissonnat, Frédéric Chazal, David Cohen-Steiner, Mariette Yvinec, Steve Oudot, Marc Glisse.

GIGA stands for Geometric Inference and Geometric Approximation. GIGA aims at designing mathematical models and algorithms for analyzing, representing and manipulating discretized versions of continuous shapes without losing their topological and geometric properties. By shapes, we mean sub-manifolds or compact subsets of, possibly high dimensional, Riemannian manifolds. This research project is divided into tasks which have Geometric Inference and Geometric Approximation as a common thread. Shapes can be represented in three ways: a physical representation (known only through measurements), a mathematical representation (abstract and continuous), and a computerized representation (inherently discrete). The GIGA project aims at studying the transitions from one type to the other, as well as the associated discrete data structures.

Some tasks are motivated by problems coming from data analysis, which can be found when studying data sets in high dimensional spaces. They are dedicated to the development of mathematically well-founded models and tools for the robust estimation of topological and geometric properties of data sets sampled around an unknown compact set in Euclidean spaces or around Riemannian manifolds.

Some tasks are motivated by problems coming from data generation, which can be found when studying data sets in lower dimensional spaces (Euclidean spaces of dimension 2 or 3). The proposed research activities aim at leveraging some concepts from computational geometry and harmonic forms to provide novel algorithms for generating discrete data structures either from mathematical representations (possibly deriving from an inference process) or from raw, unprocessed discrete data. We target both isotropic and anisotropic meshes, and simplicial as well as quadrangle and hexahedron meshes.

This project coordinated by GEOMETRICA also involves researchers from the INRIA team-project ABS, CNRS (Grenoble), and a representative from the industry (Dassault Systèmes).

- Starting date: October 2009.

- Duration: 4 years.

8.1.5. DIGITEO Chair C3TTA: Cell Complexes in Computational Topology: Theory and Applications

Participants: Claire Caillerie, Frédéric Chazal, David Cohen-Steiner, Marc Glisse, Steve Oudot, Amit Patel.

The primary purpose of this project is to bring about a close collaboration between the chair holder Dr Vin de Silva and Digiteo teams working on the development of topological and geometric methods in Computer Science. The research program is motivated by problems coming from the increasing need of studying and analyzing the (often huge) data sets that are now available in many scientific and economic domains. Indeed, due to the improvements of measurement devices and data storage tools, the available data about complex shapes or complex systems are growing very fast. These data being often represented as point clouds in high dimensional (or even infinite dimensional) spaces there is a considerable interest in analyzing and processing data in such spaces. Despite the high dimensionality of the ambient space, one often expects them to be located around an unknown, possibly non linear, low dimensional shape. It is then appealing to infer and analyze topological and geometric characteristics of that shape from the data. The hope is that this information will help to process more efficiently the data and to better understand the underlying complex systems from which the data are generated. In the last few years, topological and geometric approaches to obtain such information have encountered an increasing interest. The goal of this project is to bring together the complementary expertises in computational topology and geometry of the involved Digiteo teams and in applied geometry and algebraic topology of V. de Silva to develop new topological approaches to the previous mentioned domain. The project intends to develop both the theoretical and practical sides of this subject. The other partners of the project are the Ecole Polytechnique (L. Castelli-Aleardi and F. Nielsen) and the CEA (E. Goubault).

- Starting date: January 2009.

- Duration: 3 years.

8.2. European Initiatives

8.2.1. FP7 Projects

8.2.1.1. CG-Learning

Title: Computational Geometric Learning

Type: COOPERATION (ICT)

Defi: FET Open

Instrument: Specific Targeted Research Project (STREP)

Duration: November 2010 - October 2013

Coordinator: Friedrich-Schiller-Universität Jena (Germany)

Others partners: National and Kapodistrian University of Athens (Greece), Technische Universität Dortmund (Germany), Tel Aviv University (Israel), Eidgenössische Technische Hochschule Zürich (Switzerland), Rijksuniversiteit Groningen (Netherlands), Freie Universität Berlin (Germany)

See also: http://cgl.uni-jena.de/

Abstract: The Computational Geometric Learning project aims at extending the success story of geometric algorithms with guarantees to high-dimensions. This is not a straightforward task. For many problems, no efficient algorithms exist that compute the exact solution in high dimensions. This behavior is commonly called the curse of dimensionality. We try to address the curse of dimensionality by focusing on inherent structure in the data like sparsity or low intrinsic dimension, and by resorting to fast approximation algorithms.

8.2.1.2. ERC IRON

Title: Robust Geometry Processing

Type: IDEAS

Instrument: ERC Starting Grant (Starting)

Duration: January 2011 - December 2015

Coordinator: Pierre Alliez, INRIA (France)

See also: http://www-sop.inria.fr/geometrica/collaborations/iron/

Abstract: The purpose of this project is to bring forth the full scientific and technological potential of Digital Geometry Processing by consolidating its most foundational aspects. Our methodology will draw from and bridge the two main communities (computer graphics and computational geometry) involved in discrete geometry to derive algorithmic and theoretical contributions that provide both robustness to noisy, unprocessed inputs, and strong guarantees on the outputs. The intended impact is to make the digital geometry pipeline as generic and ironclad as its Digital Signal Processing counterpart.

8.3. International Initiatives

8.3.1. INRIA Associate Teams

8.3.1.1. COMET

Title: Computational Methods for the analysis of high-dimensional data

INRIA principal investigator: Steve Y. Oudot

International Partner:

Institution: Stanford University (United States)

Laboratory: Computer Science Department

Researcher: Leonidas J. Guibas

International Partner:

Institution: Ohio State University (United States)

Laboratory: Computer Science and Engineering

Researcher: Yusu Wang

Duration: 2011 - 2013

See also: http://geometrica.saclay.inria.fr/collaborations/CoMeT/index.html

CoMeT is an associate team between the Geometrica group at INRIA, the Geometric Computing group at Stanford University, and the Computational Geometry group at the Ohio State University. Its focus is on the design of computational methods for the analysis of high-dimensional data, using tools from metric geometry and algebraic topology. Our goal is to extract enough structure from the data, so we can get a higher-level informative understanding of these data and of the spaces they originate from. The main challenge is to be able to go beyond mere dimensionality reduction and topology inference, without the need for a costly explicit reconstruction. To validate our approach, we intend to set our methods against real-life data sets coming from a variety of applications, including (but not restricted to) clustering, image or shape segmentation, sensor field monitoring, shape classification and matching. The three research groups involved in this project have been active contributors in the field of Computational Topology in the recent years, and some of their members have had long-standing collaborations. We believe this associate team can help create new synergies between these groups.

8.3.1.2. DDGM

Title: Discrete Differential Geometric Modeling

INRIA principal investigator: Pierre Alliez

International Partner:

Institution: California Institute of Technology (United States)

Laboratory: Applied Geometry Lab

Duration: 2009 - 2011

See also: http://www-sop.inria.fr/geometrica/collaborations/ddgm/

Our initial goals were to collaborate on geometry processing and modeling. Our initial focus in 2009 was on the notion of quality of the computational models or discretizations: we carried out research on the generation of quality meshes through variational methods, on the generation of surface mesh parameterizations with low distortion, and on simplifications with guaranteed error bounds. The motivation was to meet the requirements imposed by simulations in computational engineering and computer animation. Amidst the completion of our project, we partially shifted our research goals when we realized that streamlining the geometry processing pipeline could be greatly facilitated if in addition to guaranteeing the output quality, we could provide robustness (i.e., resilience) to defect-laden inputs. This explains our recent focus on methods which are robust to heterogeneous data and to data hampered with a variety of defects. Sampling defects (such as non uniform, widely variable sampling, missing data) and uncertainty (noise, background noise, registration noise, outliers) are indeed increasingly present in datasets coming from cheaper and cheaper sensors. Our quest for ironclad robustness is best illustrated by two shape reconstruction methods we contributed, able to deal with noise and outliers.

8.3.1.3. OrbiCG

Title: Triangulations and meshes in new spaces

INRIA principal investigator: Monique Teillaud

International Partner:

Institution: University of Groningen (Netherlands)

Laboratory: Johann Bernoulli Institute of Mathematics and Computing Science

International Partner:

Institution: University of Groningen (Netherlands)

Laboratory: Kapteyn Astronomical Institute

Duration: 2009 - 2011

See also: http://www-sop.inria.fr/geometrica/collaborations/OrbiCG/

Due to the now established emergence of standardized software libraries, such as the Computational Geometry Algorithms Library CGAL, a result of concerted efforts by groups of researchers in Europe, and whose Geometrica is one of the leaders, the so-far mostly theoretical results developed in computational geometry are being used and extended for practical use like never before for the benefit of researchers in academia and of industry. To fulfill the promise of applicability of computational geometry and to expand the scope of initial efforts, extending the traditional focus on the Euclidean space Rd ("urbi") to encompass various spaces ("orbi") has become important and timely.

8.3.2. Visits of International Scientists

8.3.2.1. Exterior research visitors

Alla Sheffer, *University of British Columbia*, one week in March

David Bommes, *RWTH Aachen*, one week in June

Konstantin Mischaikow *Rutgers University*, 6 weeks in June-July

Vin de Silva *Pomona College*, one month in June

Mathieu Desbrun, *Caltech*, one week in July

Tetsuo Asano, *Japan Advanced Institute of Science and Technology*, one week in September

Jian Sun (Tsinghua University, Pékin), two weeks, September.

Gert Vegter, *Institute of Mathematics and Computing Science, University of Groningen, NL*, three weeks in October

Pratyush Pranav, *Kapteyn Astronomical Institute, University of Groningen, NL*, two weeks in October

Mathijs Wintraecken, *Institute of Mathematics and Computing Science, University of Groningen, NL*, two weeks in October

Rien van de Weijgaert, *Kapteyn Astronomical Institute, University of Groningen, NL*, two weeks in October

8.3.2.2. Visiting Phd students

Kan-Le Shi, *Tsinghua University Beijing*, 4 months.

9. Dissemination

9.1. Animation of the scientific community

9.1.1. Editorial boards of scientific journals

P. Alliez is an associate editor of *ACM Transactions on Graphics* and *Graphical Models*.

J-D. Boissonnat is a member of the editorial board of the *Journal of the ACM*, *Discrete and Computational Geometry*, *Algorithmica*, the *International Journal of Computational Geometry and Applications* and the electronic *Journal of Computational Geometry*. He is also a member of the editorial advisory board of the Springer Verlag book series *Geometry and Computing*.

F. Chazal is an associate editor of *Graphical Models* and *SIAM journal on Imaging Science*.

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

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

M. Yvinec is a member of the editorial board of *Journal of Discrete Algorithms*.

P. Alliez, M. Teillaud (review manager), and M. Yvinec are members of the CGAL editorial board.

9.1.2. Conference program committees

Pierre Alliez was a program committee member of EUROGRAPHICS, EUROGRAPHICS Symposium on Geometry Processing, Shape Modeling International, Sibgrapi and VAST International Symposium on Virtual Reality, Archaeology and Cultural Heritage.

David Cohen-Steiner was a program committee member of EUROGRAPHICS, EUROGRAPHICS Symposium on Geometry Processing, Shape Modelling International.

J-D. Boissonnat was a program committee member of the SIAM/ACM Joint Conference on Geometric and Physical Modeling, the EUROGRAPHICS Symposium on Geometry Processing and Sibgrapi.

Olivier Devillers was a program committee member of the 11th Symposium on Computational Geometry.

Monique Teillaud was a program committee member of WADS, Algorithms and Data Structures Symposium.

9.1.3. Steering committees

Monique Teillaud is a member of the Computational Geometry Steering Committee.

9.1.4. Ph.D. thesis and HDR committees

Pierre Alliez was a referee and member of the Ph.D. defense committee of Sahar Hassan (University of Grenoble), Clément Courbet (École Centrale Paris) and Vincent Vidal (Université de Lyon). He was a referee and member of the habilitation defense committee of Raphaëlle Chaine (Université de Lyon). He was a member of the Ph.D. defense committee of Patrick Mullen (Caltech) and Marcio Cabral (INRIA Sophia).

J-D Boissonnat was a member of the HDR defense committee of Xavier Goaoc (INRIA Lorraine) and Dominique Attali (GIPSA-LAB, Grenoble). He was a member of the PhD defense committee of Tom Dreyfus from the ABS project team, university of Nice Sophia Antipolis.

Olivier Devillers was a referee and a member of the PhD defense committee of Guillaume Batog, «Problèmes classiques en vision par ordinateur et en géométrie algorithmique revisités via la géométrie des droites», Université Nancy 2.

Monique Teillaud was a referee and a member of the PhD defense committee of Maria Saumell Mendiola, "Some problems on proximity graphs", Universitat Politècnica de Catalunya, Barcelone.

9.1.5. INRIA committees

P. Alliez is member of the COST GTAI (conseil d'orientation scientifique et technologique, groupe de travail actions incitatives), of the commission d'animation scientifique (CAS) and of the comité de suivi doctoral (CSD).

F. Chazal is the chair of the “Commission scientifique” at INRIA Saclay - Île de France.

F. Chazal has been a member of the CR2/CR1 recruitment committee at INRIA Saclay.

Monique Teillaud is a member of the INRIA Evaluation Committee, and of the INRIA Sophia CDT (Committee for Technologic Development), and the national INRIA CDT. She was a member of the national INRIA CR2 recruitment committee.

9.1.6. Other committees

J.-D. Boissonnat is a member of the working groups GP1 (Modèles et calcul) and GP2 (Logiciels et systèmes informatiques) de l’Alliance des sciences et technologies du numérique (Allistène).

J.-D. Boissonnat is a member of the AERES Board (Evaluation Agency for Research and Higher Education).

J-D. Boissonnat was a member of the Evaluation Committee in charge of the evaluation of research in Computer Science at the Université Libre de Bruxelles (ULB).

F. Chazal is a member of the Scientific Council of AMIES (Agence pour les Mathématiques en Interaction avec l’Industrie et la Société)

F. Chazal is a member of the “Comité de pilotage” of the MAIRCI and SIGMA (ex-AFA) groups of the SMAI.

O. Devillers was a member of the AERES Committee for the evaluation of the «Laboratoire de Mathématiques, Informatique et Applications de l’Université de Haute Alsace».

M. Glisse is a member of the experts group of AFNOR for the standardization of the C++ language within the ISO/WG21 working group.

9.1.7. Conference organization

F. Chazal, M. Glisse and S. Oudot organized the 27th Annual ACM Symposium on Computational Geometry (SoCG 2011) in Paris: http://socg2011.inria.fr/.

J.-D. Boissonnat and D. Cohen-Steiner (in collaboration with J. Giesen) organized the CG Learning Kick-off Workshop in Paris: http://cgl.uni-jena.de/Workshops/WebHome.

J.-D. Boissonnat chairs the scientific committee of the Jacques Morgenstern Colloquium.

Monique Teillaud organized the Dagstuhl Seminar on Computational Geometry, with Pankaj K. Agarwal (Duke University) and Kurt Mehlhorn (MPII Saarbrücken), Leibniz-Zentrum für Informatik, Germany, March 13-18, 2011. http://www.dagstuhl.de/en/program/calendar/semhp/?semnr=11111

9.1.8. Web site

M. Teillaud is maintaining the Computational Geometry Web Pages http://www.computational-geometry.org/, hosted by INRIA. 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.

9.2. Teaching

We give here the details of courses. Web pages of the graduate courses can be found on the web site :

http://www.inria.fr/sophia/geometrica/

Highschools: «Traitement numérique de la géométrie, Lorsque nos maths s'incarnent dans les ordinateurs», Monique Teillaud, 3h ETD Lycée Jean Cocteau (Miramas), February, 3h ETD Lycée de la montagne (Valdeblore), June, 3h ETD Lycée Henri Matisse, Vence, October.
Master: «Géométrie algorithmique», Olivier Devillers, 13h ETD, M1, Université de Nice.
Master: «Algorithmes géométriques: théorie et pratique», Pierre Alliez, Olivier Devillers, and Monique Teillaud, 28h ETD, M2, Université de Nice.
Master: Computational Geometry Learning, J.-D. Boissonnat, F. Chazal and M. Yvinec, 25h, M2, MPRI (Paris).
Master: Computational Geometry: from Theory to Applications, S. Oudot, 20h, M1, École Polytechnique.
Master: «Maillages 3D et applications», P. Alliez, 21h, Ecole des Ponts ParisTech (Paris).
Doctorat: Geometric Inference, F. Chazal and D. Cohen-Steiner, 20h, Université Paris Sud (Orsay).

9.2.1. Teaching responsibilities

Monique Teillaud is a member of the jury of the Agrégation de Mathématiques.

9.2.2. Ph.D. theses

Phd: Trung Nguyen, *A Disk-Covering Problem with Application in Optical Interferometry)*, Université de Nice-Sophia Antipolis, soutenue le 2 decembre. These encadree par Jean-Daniel Boissonnat, en collaboration avec Thales Alenia Space
PhD in progress: Arijit Ghosh, Approximation of submanifolds, Université de Nice-Sophia Antipolis, started ?, J-D. Boissonnat.
PhD in progress: Clément Maria, Data structures for simplicial complexes, Université de Nice-Sophia Antipolis, started ?, J-D. Boissonnat.
PhD in progress: Mikhail Bogdanov, Triangulations in non-Euclidean spaces, started October 1st 2010, Monique Teillaud.
PhD in progress: Ross Hemsley, Probabilistic methods for the efficiency of geometric structures and algorithms, started October 1st 2011, Olivier Devillers.
PhD in progress: Bertrand Pellenard, Surface and Domain Tiling, Université de Nice-Sophia Antipolis, October 2009, Pierre Alliez.
PhD in progress: Simon Giraudot, Robust Shape Reconstruction, Université de Nice-Sophia Antipolis, November 2011, Pierre Alliez.
PhD in progress: Alexandre Bos, Topological methods for geometric data classification, Université Paris XI, September 2010, Frédéric Chazal and Steve Oudot.
PhD in progress: Claire Caillerie, Sélection de modèles pour l'inférence géométrique, Université Paris XI, September 2008, Frédéric Chazal and Pascal Massart.
PhD in progress: Mickael Buchet, Topological and geometric inference from measures, Université Paris XI, October 2011, Frédéric Chazal and Steve Oudot.

9.2.3. Internships

Internship proposals can be found on the web at http://www.inria.fr/sophia/geometrica/

Paul Seron, Robust 3D reconstruction of urban scenes from LIDAR data, SupAero (France).
Mickael Buchet, Inférence topologique à partir de mesures, Ecole Polytechnique/MPRI, 6 months, March-August.
Vinayak Gagrani, CGAL-implementation of the tangential Delaunay complex, IIT Bombay, 2 months.
Sagar Chordia, Shape approximation with guarantees, IIT Bombay, 2 months.
Clément Maria, Construction du witness complex, Ecole Normale Supérieure de Cachan, MPRI, 6 months.

9.3. Participation to conferences, seminars, invitations

9.3.1. Invited Talks

F. Chazal, 9th International Conference on Sampling Theory and Applications, special session on high-dimensional geometry, Geometric Inference Using Distance-like Functions, Singapore, May 6.

F. Chazal, 4th International Conference on Computational Harmonic Analysis, Surface Segmentation Using Heat Kernel Signature and Topological Persistence, City University of Hong-Kong, May 23.

A. Ghosh, Summer school on Computational Geometric Learning, Reconstructing and meshing submanifolds, Paris, June 9.

F. Chazal, SIAM Conference on Applied Algebraic Geometry, mini-symposium on Persistent Homology, Persistence-based Signatures for Matric spaces, North Carolina State University, October 6.

P. Alliez, Trimester Program on Computational Manifolds and Applications, IMPA, Rio de Janeiro, October 17-21.

F. Chazal, Workshop on Computational Topology, Persistence-based Signatures for Metric spaces, Fields Institute in Toronto, November 11.

Olivier Devillers, "The effect of noise on the number of extreme points" Dagstuhl seminar, March 18th.

S. Oudot, Workshop on Computational Topology, Stable Multi-Scale Signatures for Shapes using Topological Persistence, Fields Institute in Toronto, November 11.

S. Oudot, Journée scientifique SMAI-SIGMA 2011, Unsupervised Learning using Topological Persistence, Université Pierre et Marie Curie, Paris, November 18.

9.3.2. Seminars

Members of the project have presented their published articles at conferences. The reader can refer to the bibliography to obtain the corresponding list. We list below all other talks given in seminars, summer schools and other workshops.

Olivier Devillers, "Delaunay triangulation, theory vs practice", University of Crete, November 16th.

Monique Teillaud, "Delaunay Triangulations of Point Sets in Closed Euclidean d-Manifolds", University of Crete, November 23th.

Jean-Daniel Boissonnat, "Anisotropic Delaunay Meshes of Surfaces", Telecom ParisTech, November 25th.

Mariette Yvinec, "Anisotropic Delaunay meshes ", Weierstrass Institute, Berlin, May 24.

Mariette Yvinec, "CGALmesh", Weierstrass Institute, Berlin, May 26.

9.3.3. The Geometrica seminar

http://www.inria.fr/sophia/geometrica/

The GEOMETRICA seminar featured presentations from the following visiting scientists:

Maks Ovsjanikov (Stanford University / Google): Structure Discovery and Exploration in Unorganized Collections of 3D Models.
Donald Sheehy (Carnegie Mellon University): Mesh Generation and Geometric Persistent Homology.
Quentin Mérigot (LJK, Grenoble): Witnessed k-distance.
Jian Sun (Tsinghua University, Pékin): Fuzzy Geodesics and Consistent Sparse Correspondences For Deformable Shapes.
Tetsuo Asano (JAIST, Japon): Designing Algorithms with Limited Workspace.
Menelaos Karavelas (UOC, Grèce): The maximum number of faces of the Minkowski sum of two convex polytopes.
Mathieu Desbrun (Caltech): HOT: Hodge-Optimized Triangulations.
Meizhu Liu (University of Florida): Total Bregman Divergence and Applications.
Chandrajit Bajaj (University of Texas, Austin): Harmonic Analysis for Molecular Docking.
David Bommes (RWTH, Aachen): Generating and Optimizing Quadrilateral Surface Meshes for Animation and Simulation.
Samuel Hornus (INRIA Nancy): By-example Synthesis of Architectural Textures.
T. Lewiner (PUC, Rio de Janeiro): Topology-Aware Vector Field Visualization by Self-Animating Images.
Julie Digne (CMLA, Cachan): Scale Space for Point Clouds and Applications.
J.E. Deschaud (Mines ParisTech, Paris): Dense Point Cloud Processing and 3D Environment Modelling from LIDAR/Camera Mobile Systems.
Deok-Soo Kim (Hangyang University, Seoul): Beta-complex: Theory and Applications in Computational Molecular Biology.
Alla Sheffer (UBC, Canada): Space-Time Reconstruction - Understanding Motion.
Florent Lafarge (INRIA): Some Contributions to Urban Scene Modeling by Energy Minimization Based Approaches.
Xianhai Meng (Beihang University, Chine): Mesh Generation and 3D Geological Modeling.

9.3.4. Scientific visits

Monique Teillaud, University of Groningen, May 9-21.
Mikhail Bogdanov, University of Groningen, May 9-31.
Frédéric Chazal, City University of Hong-Kong, May 16-29.
Mariette Yvinec, Weierstrass institute in Berlin, May 23-28.
Pierre Alliez, Caltech, October 25 - November 10.
Marc Glisse, Ohio State University, November 13-19.
Steve Oudot, Ohio State University, November 13-17.
Olivier Devillers, University of Crete, November 13-25.
Monique Teillaud, University of Crete, November 13-25.
Monique Teillaud, University of Groningen, December 5-13.
Olivier Devillers, EPI VEGAS, December 7-15.

10. Bibliography

Major publications by the team in recent years

[1] J.-D. BOISSONNAT, M. TEILLAUD (editors). *Effective Computational Geometry for Curves and Surfaces*, Springer-Verlag, 2006, http://www-sop.inria.fr/geometrica/events/book/ECG.html.

[2] P. ALLIEZ, D. COHEN-STEINER, M. YVINEC, M. DESBRUN. *Variational tetrahedral meshing*, in "ACM Transactions on Graphics", 2005, vol. 24, p. 617–625, SIGGRAPH '2005 Conference Proceedings, http://hal.inria.fr/inria-00226418.

[3] N. AMENTA, D. ATTALI, O. DEVILLERS. *Complexity of Delaunay triangulation for points on lower-dimensional polyhedra*, in "Proc. 18th ACM-SIAM Sympos. Discrete Algorithms", 2007, p. 1106–1113, http://hal.inria.fr/inria-00182835/.

[4] J.-D. BOISSONNAT, S. OUDOT. *Provably good sampling and meshing of surfaces*, in "Graphical Models", 2005, vol. 67, p. 405–451, http://hal.archives-ouvertes.fr/hal-00488829/en/.

[5] J.-D. BOISSONNAT, C. WORMSER, M. YVINEC. *Anisotropic diagrams: the Labelle Shewchuk approach revisited*, in "Theoretical Computer Science", 2008, vol. 408, p. 163–173, http://hal.inria.fr/inria-00336798/.

[6] M. BOTSCH, L. KOBBELT, M. PAULY, P. ALLIEZ, B. LÉVY. *Polygon Mesh Processing*, AK Peters, 2010, http://hal.inria.fr/inria-00538098.

[7] L. CASTELLI ALEARDI, O. DEVILLERS, G. SCHAEFFER. *Succinct representations of planar maps*, in "Theoretical Computer Science", 2008, vol. 408, p. 174–187, http://hal.inria.fr/inria-00337821/.

[8] F. CHAZAL, D. COHEN-STEINER, M. GLISSE, L. J. GUIBAS, S. OUDOT. *Proximity of Persistence Modules and Their Diagrams*, in "Proc. 25th Annual Symposium on Computational Geometry", 2009, p. 237–246 [*DOI :* 10.1145/1542362.1542407], http://hal.inria.fr/inria-00292566/.

[9] F. CHAZAL, D. COHEN-STEINER, A. LIEUTIER. *A Sampling Theory for Compact Sets in Euclidean Space*, in "Discrete Comput. Geom.", 2009, vol. 41, n^{o} 3, p. 461–479, http://dx.doi.org/10.1007/s00454-009-9144-8.

[10] Q. MÉRIGOT. *Détection de structures géométriques dans les nuages de points*, Université Nice Sophia Antipolis, Nice, France, 2009, http://tel.archives-ouvertes.fr/tel-00443038/fr/.

[11] Y. TONG, P. ALLIEZ, D. COHEN-STEINER, M. DESBRUN. *Designing Quadrangulations with Discrete Harmonic Forms*, in "Proc. 3rd Annu. Sympos. Geometry Processing", 2006, p. 201–210, ftp://ftp-sop.inria.fr/geometrica/alliez/tacd06.pdf.

Publications of the year

Articles in International Peer-Reviewed Journal

[12] G. BIAU, F. CHAZAL, D. COHEN-STEINER, L. DEVROYE, C. RODRIGUEZ. *A Weighted k-Nearest Neighbor Density Estimate for Geometric Inference*, in "Electronic Journal of Statistics", 2011, vol. 5, p. 204–237, http://dx.doi.org/10.1214/11-EJS606.

[13] J.-D. BOISSONNAT, A. GHOSH. *Triangulating Smooth Submanifolds with Light Scaffolding*, in "Mathematics in Computer Science", 2011, vol. 4, n^{o} 4, p. 431–462, http://hal.inria.fr/inria-00604058/en/.

[14] C. CAILLERIE, F. CHAZAL, J. DEDECKER, B. MICHEL. *Deconvolution for the Wasserstein metric and geometric inference*, in "Electronic Journal of Statistics", 2011, vol. 5, p. 1394–1423, http://dx.doi.org/10.1214/11-EJS646.

[15] L. CASTELLI ALEARDI, O. DEVILLERS, A. MEBARKI. *Catalog Based Representation of 2D triangulations*, in "Internat. J. Comput. Geom. Appl.", 2011, vol. 21, p. 393–402 [*DOI :* 10.1142/S021819591100372X], http://hal.inria.fr/inria-00560400.

[16] F. CAZALS, D. COHEN-STEINER. *Reconstructing 3D compact sets*, in "Computational Geometry Theory and Applications", 2011, vol. 45, n^o 1-2, p. 1–13, http://dx.doi.org/10.1016/j.comgeo.2011.07.005.

[17] F. CHAZAL, D. COHEN-STEINER, Q. MÉRIGOT. *Geometric Inference for Probability Measures*, in "Journal on Foundations of Computational Mathematics", 2011, vol. 11, n^o 6, p. 733–751, http://dx.doi.org/10.1007/s10208-011-9098-0.

[18] F. CHAZAL, L. J. GUIBAS, S. OUDOT, P. SKRABA. *Scalar Field Analysis over Point Cloud Data*, in "Discrete and Computational Geometry", 2011, vol. 46, n^o 4, p. 743–775, http://dx.doi.org/10.1007/s00454-011-9360-x.

[19] O. CHEONG, H. EVERETT, M. GLISSE, J. GUDMUNDSSON, S. HORNUS, S. LAZARD, M. LEE, H.-S. NA. *Farthest-Polygon Voronoi Diagrams*, in "Computational Geometry, Theory and Applications", May 2011, vol. 44, n^o 4, p. 234–247 [*DOI :* 10.1016/J.COMGEO.2010.11.004], http://hal.inria.fr/inria-00442816/.

[20] O. DEVILLERS. *Delaunay Triangulation of Imprecise Points: Preprocess and Actually Get a Fast Query Time*, in "Journal of Computational Geometry", 2011, vol. 2, p. 30–45, http://jocg.org/index.php/jocg/article/view/41.

[21] O. DEVILLERS. *Vertex Removal in Two Dimensional Delaunay Triangulation: Speed-up by Low Degrees Optimization*, in "Computational Geometry: Theory and Applications", 2011, vol. 44, p. 169–177 [*DOI :* 10.1016/J.COMGEO.2010.10.001], http://hal.inria.fr/inria-00560379/.

[22] O. DEVILLERS, M. TEILLAUD. *Perturbations for Delaunay and weighted Delaunay 3D Triangulations*, in "Computational Geometry: Theory and Applications", 2011, vol. 44, p. 160–168 [*DOI :* 10.1016/J.COMGEO.2010.09.010], http://hal.archives-ouvertes.fr/inria-00560388/.

[23] S. PION, A. FABRI. *A Generic Lazy Evaluation Scheme for Exact Geometric Computations*, in "Science of Computer Programming", April 2011, vol. 76, n^o 4, p. 307–323, Special Issue on Library-Centric Software Design (LCSD 2006) [*DOI :* 10.1016/J.SCICO.2010.09.003], http://hal.inria.fr/inria-00562300/.

[24] P. M. M. DE CASTRO, O. DEVILLERS. *On the Size of Some Trees Embedded in* $\mathbb{R}^d$, in "Operations Research Letters", 2011, http://hal.archives-ouvertes.fr/inria-00448335/.

[25] F. DE GOES, D. COHEN-STEINER, P. ALLIEZ, M. DESBRUN. *An Optimal Transport Approach to Robust Reconstruction and Simplification of 2D Shapes*, in "Computer Graphics Forum", 2011, vol. 30, n^o 5, p. 1593–1602, Special issue for EUROGRAPHICS Symposium on Geometry Processing, http://dx.doi.org/10.1111/j.1467-8659.2011.02033.x.

International Conferences with Proceedings

[26] M. AANJANEYA, F. CHAZAL, D. CHEN, M. GLISSE, L. J. GUIBAS, D. MOROZOV. *Metric Graph Reconstruction from Noisy Data*, in "Proc. 27th Annual Symposium on Computational Geometry", 2011, p. 37–46 [*DOI :* 10.1145/1998196.1998203], http://hal.inria.fr/inria-00630774/.

[27] M. CAROLI, M. TEILLAUD. *Delaunay Triangulations of Point Sets in Closed Euclidean d-Manifolds*, in "Proc. 27th Annual Symposium on Computational Geometry", 2011, p. 274–282, http://doi.acm.org/10.1145/1998196.1998236.

[28] F. CHAZAL, D. CHEN, L. J. GUIBAS, X. JIANG, C. SOMMER. *Data-Driven Trajectory Smoothing*, in "Proceedings of the 19th SIGSPATIAL International Conference on Advances in Geographic Information Systems", GIS '11, 2011, http://hal.inria.fr/inria-00636144.

[29] F. CHAZAL, L. J. GUIBAS, S. OUDOT, P. SKRABA. *Persistence-Based Clustering in Riemannian Manifolds*, in "Proc. 27th Annual Symposium on Computational Geometry", 2011, p. 97–106, http://doi.acm.org/10.1145/1998196.1998212.

[30] N. MILOSAVLJEVIC, D. MOROZOV, P. SKRABA. *Zigzag Persistent Homology in Matrix Multiplication Time*, in "Proc. 27th Annual Symposium on Computational Geometry", 2011, p. 216–225, http://doi.acm.org/10.1145/1998196.1998229.

[31] B. PELLENARD, P. ALLIEZ, J.-M. MORVAN. *Isotropic 2D Quadrangle Meshing with Size and Orientation Control*, in "Proceedings of the International Meshing Roundtable", 2011, p. 81–98.

[32] P. M. M. DE CASTRO, O. DEVILLERS. *A Pedagogic JavaScript Program for Point Location Strategies*, in "Video of 27th Annual Symposium on Computational Geometry", 2011, p. 295–296, http://www.computational-geometry.org/SoCG-videos/socg11video/.

[33] P. M. M. DE CASTRO, O. DEVILLERS. *Simple and Efficient Distribution-Sensitive Point Location, in Triangulations*, in "Workshop on Algorithm Engineering and Experiments", 2011, p. 127–138, http://www.siam.org/proceedings/alenex/2011/alenex11.php.

Conferences without Proceedings

[34] M. BOGDANOV, O. DEVILLERS, M. TEILLAUD. *Hyperbolic Delaunay triangulations and Voronoi diagrams made practical*, in "Abstracts XIV Spanish Meeting on Computational Geometry", 2011, p. 113–116, http://www2.uah.es/egc2011/files/ActasEGC2011.pdf.

[35] L. CASTELLI ALEARDI, O. DEVILLERS. *Explicit array-based compact data structures for planar and surface meshes*, in "Abstracts XIV Spanish Meeting on Computational Geometry", 2011, p. 237–240, http://www2.uah.es/egc2011/files/ActasEGC2011.pdf.

[36] O. DEVILLERS. *Delaunay Triangulation of Imprecise Points, Preprocess and Actually Get a Fast Query Time*, in "Abstracts XIV Spanish Meeting on Computational Geometry", 2011, p. 105–108, http://www2.uah.es/egc2011/files/ActasEGC2011.pdf.

[37] A. FABRI, M. TEILLAUD. *CGAL, The Computational Geometry Algorithms Library*, in "10ème Colloque National en Calcul des Structures", 2011.

Scientific Books (or Scientific Book chapters)

[38] P. ALLIEZ, L. RINEAU, S. TAYEB, J. TOURNOIS, M. YVINEC. *3D Mesh Generation*, in "CGAL User and Reference Manual", CGAL Editorial Board, 2011, http://www.cgal.org/Manual/3.8/doc_html/cgal_manual/packages.html#Pkg:Mesh_3.

[39] C. DELAGE, O. DEVILLERS. *Spatial Sorting*, in "CGAL User and Reference Manual", CGAL Editorial Board, 2011, http://www.cgal.org/Manual/3.9/doc_html/cgal_manual/packages.html#Pkg:SpatialSorting.

[40] O. DEVILLERS, S. HERT, M. HOFFMANN, L. KETTNER, S. SCHÖNHERR. *Geometric Object Generators*, in "CGAL User and Reference Manual", CGAL Editorial Board, 2011, http://www.cgal.org/Manual/3.9/doc_html/cgal_manual/packages.html#Pkg:Generators.

[41] R. VAN DE WEYGAERT, G. VEGTER, H. EDELSBRUNNER, B. J. JONES, P. PRANAV, C. PARK, W. A. HELLWING, B. ELDERING, N. KRUITHOF, E. P. BOS, J. HIDDING, J. FELDBRUGGE, E. TEN HAVE, M. VAN ENGELEN, M. CAROLI, M. TEILLAUD. *Alpha, Betti and the Megaparsec Universe: on the Homology and Topology of the Cosmic Web*, in "Transactions on Computational Science XIV", Lecture Notes in Computer Science, Springer-Verlag, 2011, vol. 6970, p. 60–101, http://www.springerlink.com/content/334357373166n902/.

Books or Proceedings Editing

[42] P. K. AGARWAL, K. MEHLHORN, M. TEILLAUD (editors). *Computational Geometry (Dagstuhl Seminar)*, Dagstuhl Reports, Schloss Dagstuhl - Leibniz-Zentrum fuer Informatik, Germany, 2011, n^{o} 11111 [*DOI :* 10.4230/DAGREP.1.3.19], http://drops.dagstuhl.de/opus/volltexte/2011/3199.

Research Reports

[43] J.-D. BOISSONNAT, R. DYER, A. GHOSH, S. OUDOT. *Equating the witness and restricted Delaunay complexes*, European Commission, 2011, n^{o} CGL-TR-24, http://cgl.uni-jena.de/Publications/WebHome.

[44] J.-D. BOISSONNAT, A. GHOSH. *Manifold reconstruction using Tangential Delaunay Complexes*, INRIA, 2011, n^{o} 7142, version 2, http://hal.archives-ouvertes.fr/inria-00440337/.

[45] J.-D. BOISSONNAT, A. GHOSH. *Triangulating Smooth Submanifolds with Light Scaffolding*, INRIA, 2011, n^{o} 7660, version 2, http://hal.inria.fr/inria-00604058/en/.

[46] J.-D. BOISSONNAT, C. WORMSER, M. YVINEC. *Anisotropic Delaunay Mesh Generation*, INRIA, August 2011, n^{o} 7712, http://hal.inria.fr/inria-00615486/en/.

[47] L. CASTELLI ALEARDI, O. DEVILLERS. *Explicit array-based compact data structures for triangulations*, INRIA, 2011, n^{o} 7736, http://hal.archives-ouvertes.fr/inria-00623762/.

[48] R. VAN DE WEYGAERT, P. PRANAV, B. J. JONES, E. P. BOS, G. VEGTER, H. EDELSBRUNNER, M. TEILLAUD, W. A. HELLWING, C. PARK, J. HIDDING, M. WINTRAECKEN. *Probing Dark Energy with Alpha Shapes and Betti Numbers*, arXiv, 2011, http://arxiv.org/abs/1110.5528.

References in notes

[49] M. CAROLI, M. TEILLAUD. *Computing 3D Periodic Triangulations*, in "European Symposium on Algorithms", Lecture Notes in Computer Science, 2009, vol. 5757, p. 37–48, http://www.springerlink.com/content/55415144316j214g/fulltext.pdf.

[50] M. CAROLI, M. TEILLAUD. *3D Periodic Triangulations*, in "CGAL User and Reference Manual", CGAL EDITORIAL BOARD (editor), 2009-2011, http://www.cgal.org/Manual/latest/doc_html/cgal_manual/packages.html#Pkg:Periodic3Triangulation3.