

Preface

GSI 2017 in the Shadow of Blaise Pascal's “Aleae Geometria”



GSI 2017 banner: Euclide, Thales, Clairaut, Legendre, Poncelet, Darboux, Poincaré, Cartan, Fréchet, Libermann, Leray, Koszul, Ferrand, Souriau, Balian, Berger, Choquet-Bruhat, Gromov

On behalf of both the Organizing and the Scientific Committees, it is our pleasure to welcome you to the proceedings of the Third International SEE Conference on Geometric Science of Information (GSI 2017), hosted in Paris, in 2017.

The three-day conference was organized in the framework of the relations set up between [SEE](#) and the following scientific institutions or academic laboratories: Ecole Polytechnique, Ecole des Mines ParisTech, Inria, Supélec, Université Paris-Sud, Institut Mathématique de Bordeaux, Sony Computer Science Laboratories, Institut Mines Télécom. GSI 2017 benefited from scientific and financial sponsors.

We would like to express all our thanks to the local organizers for hosting this second scientific event at the interface between geometry, probability, and information geometry.

The GSI conference cycle was initiated by the [Brillouin Seminar Team](#). The GSI 2017 event has been motivated by the continuity of the first initiatives launched in 2013 (<https://www.see.asso.fr/gsi2013>) and consolidated in 2015 (<https://www.see.asso.fr/gsi2015>). In 2011, we organized an Indo-French workshop on “Matrix Information Geometry” that yielded an [edited book in 2013](#).

The technical program of GSI 2017 covered all the main topics and highlights in the domain of “geometric science of information” including information geometry manifolds of structured data/information and their advanced applications. These proceedings consist solely of original research papers that have been carefully peer-reviewed by two or three experts before, and revised before acceptance.

The GSI 2017 program included a renowned invited speaker and three distinguished keynote speakers.

Historical Background

Like GSI 2013 and 2015, GSI 2017 addressed the inter-relations between different mathematical domains such as shape spaces (geometric statistics on manifolds and Lie groups, deformations in shape space), probability/optimization and algorithms on manifolds (structured matrix manifold, structured data/Information), relational and discrete metric spaces (graph metrics, distance geometry, relational analysis), computational and Hessian information geometry, algebraic/infinite dimensional/Banach information manifolds, divergence geometry, tensor-valued morphology, optimal transport theory, manifold and topology learning, as well as applications such as geometries of audio-processing, inverse problems, and signal processing. The program was enriched by contributions in the area of (stochastic) geometric mechanics and geometric model of quantum physics. GSI 2017 included new topics such as geometric robotics, information structure on neuroscience, stochastic calculus of variations (Malliavin calculus), and geometric deep learning among others.

At the turn of the century, new and fruitful interactions were discovered between several branches of science: information science (information theory, digital communications, statistical signal processing), mathematics (group theory, geometry and topology, probability, statistics, sheaf theory), and physics (geometric mechanics, thermodynamics, statistical physics, quantum mechanics). The GSI conference cycle aims to discover joint mathematical structures to all these disciplines by elaboration of a “general theory of information” embracing physics science, information science, and cognitive science in a global scheme.

The GSI 2017 program comprised 101 papers presented at 19 sessions:

- Session “Statistics on Non-linear Data” chaired by X. Pennec and S. Sommer
- Session “Shape Space” chaired by S. Allasonnière, S. Durrleman, and A. Trouvé
- Session “Optimal Transport and Applications I” chaired by Q. Merigot, J. Bigot, and B. Maury
- Session “Optimal Transport and Applications II” chaired by J.F. Marcotorchino and A. Galichon
- Session “Statistical Manifold & Hessian Information Geometry” chaired by M. Boyom, A. Matsuzoe, and Hassan Shahid
- Session “Monotone Embedding in Information Geometry” chaired by J. Zhang and J. Naudts
- Session “Information Structure in Neuroscience” chaired by P. Baudot, D. Bennequin, and S. Roy
- Session “Geometric Robotics and Tracking” chaired by S. Bonnabel and A. Barrau
- Session “Geometric Mechanics and Robotics” chaired by G. de Saxcé, J. Bensoam, and J. Lerbet
- Session “Stochastic Geometric Mechanics and Lie Group Thermodynamics” chaired by F. Gay-Balmaz and F. Barbaresco
- Session “Probability on Riemannian Manifolds” chaired by M. Arnaudon and A.-B. Cruzeiro
- Session “Divergence Geometry” chaired by M. Broniatowski and I. Csiszar

- Session “Non-parametric Information Geometry” chaired by N. Ay and J. Armstrong
- Session “Optimization on Manifold” chaired by P.A. Absil and R. Sepulchre
- Session “Computational Information Geometry” chaired by F. Nielsen and O. Schwander
- Session “Probability Density Estimation” chaired by S. Said and E. Chevallier
- Session “Geometry of Tensor-Valued Data” chaired by J. Angulo, Y. Berthoumieu, G. Verdoolaege, and A.M. Djafari
- Session “Geodesic Methods with Constraints” chaired by J.-M. Mirebeau and L. Cohen
- Session “Applications of Distance Geometry” chaired by A. Mucherino and D. Gonçalves

Three keynote speakers’ talks opened each day (Prof. A. Trouvé, B. Tumpach, and M. Girolami). An invited honorary speaker (Prof. J.M. Bismut) gave a talk at the end of the first day and a guest Honorary speaker (Prof. D. Bennequin) closed the conference (https://www.see.asso.fr/wiki/18335_invited-keynote-speakers).

Invited Honorary Speaker:

- Jean-Michel Bismut (Paris-Saclay University), “The Hypocoelliptic Laplacian”

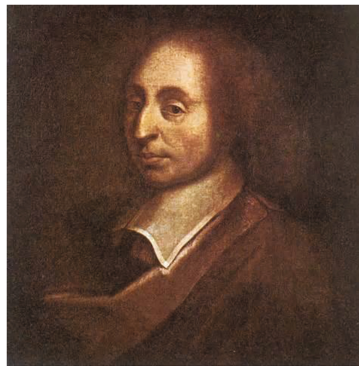
Guest Honorary Speaker:

- Daniel Bennequin (Paris Diderot University), “Geometry and Vestibular Information”

Keynote Speakers:

- Alain Trouvé (ENS Paris-Saclay), “Hamiltonian Modeling for Shape Evolution and Statistical Modeling of Shapes Variability”
- Barbara Tumpach (Lille University), “Riemannian Metrics on Shape Spaces of Curves and Surfaces”
- Mark Girolami (Imperial College London), “Riemann Manifold Langevin and Hamiltonian Monte Carlo Methods”

GSI 2017 Seeding by Blaise Pascal’s Geometry of Chance



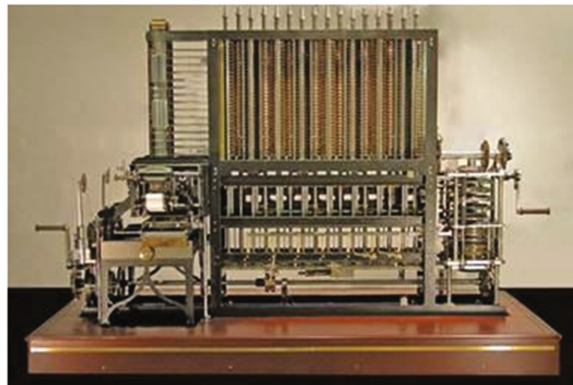
Blaise Pascal's ideas are widely debated in 2017, because Pope François decided to initiate a request for his beatification. Among all the genius ideas of Pascal, one was the invention of probability. The "calculation of probabilities" began four years after the death of René Descartes, in 1654, in a correspondence between Blaise Pascal and Pierre Fermat. They exchanged letters on elementary problems of gambling, in this case a problem of dice and a problem of "parties." Pascal and Fermat were particularly interested in this problem and succeeded in the "party rule" by two different methods. One understands the legitimate pride of Pascal in his address of the same year at the Académie Parisienne created by Mersenne, to which he presented, among "the ripe fruit of our geometry" (*"les fruits mûrs de notre Géométrie"* in French), an entirely new treaty, of an absolutely unexplored matter, the distribution of chance in the games. In the same way, Pascal in his introduction to "Les Pensées" wrote that, "under the influence of Méré, given to the game, he throws the bases of the calculation of probabilities and composes the Treatise of the Arithmetical Triangle." If Pascal appears at first sight as the initiator of the calculation of probabilities, watching a little closer, his role in the emergence of this theory is more complex. However, there is no trace of the word "probabilities" in Pascal's work. To designate what might resemble what we now call calculation of probabilities, one does not even find the word in such a context. The only occurrences of probability are found in "Les Provinciales" where he referred to the doctrine of the Jesuits, or in "Les Pensées." We do not find in Pascal's writings the words of "Doctrine des chances" or "Calcul des chances," but only "Géométrie du hasard" (geometry of chance). In 1654, Blaise Pascal submitted a short paper to "Celeberrimae matheseos Academiae Parisiensi" (ancestor of the French Royal Academy of Sciences founded in 1666), with the title "Aleae Geometria" (Geometry of Chance) or "De compositione aleae in ludis ipsi subjectis," which that was the seminal paper founding Probability as a new discipline in Science. In this paper, Pascal said: "... et sic matheseos demonstrationes cum aleae incertitudine jugendo, et quae contraria videntur conciliando, ab utraque nominationem suam accipiens, stupendum hunc titulum jure sibi arrogat: Aleae Geometria," which we can translate as: "By the union thus realized between the demonstrations of mathematics and the uncertainty of chance, and by the conciliation of apparent contradictions, it can derive its name from both sides and arrogate to itself this astonishing title: Geometry of Chance" (« ... par l'union ainsi réalisée entre les démonstrations des mathématiques et l'incertitude du hasard, et par la conciliation entre les contraires apparents, elle peut tirer son nom de part et d'autre et s'arroger à bon droit ce titre étonnant: Géométrie du Hasard»). We can observe that Blaise Pascal attached a geometrical sense to probabilities in this seminal paper. Like Jacques Bernoulli, we can also give references to another Blaise Pascal document entitled "Art de penser" (the "Logique" of Port-Royal), published the year of his death (1662), with the last chapters containing elements on the calculus of probabilities applied to history, to medicine, to miracles, to literary criticism, and to events of life, etc.

In "De l'esprit géométrique," the use of reason for knowledge is based on a geometric model. In geometry, the first principles are given by the natural common sense to all men, and there is no need to define them. Other principles are clearly explained by definitions of terms such that it is always possible to mentally substitute the explanation for the defined term [23, 24, 25]. These definitions of terms are completely free, the only

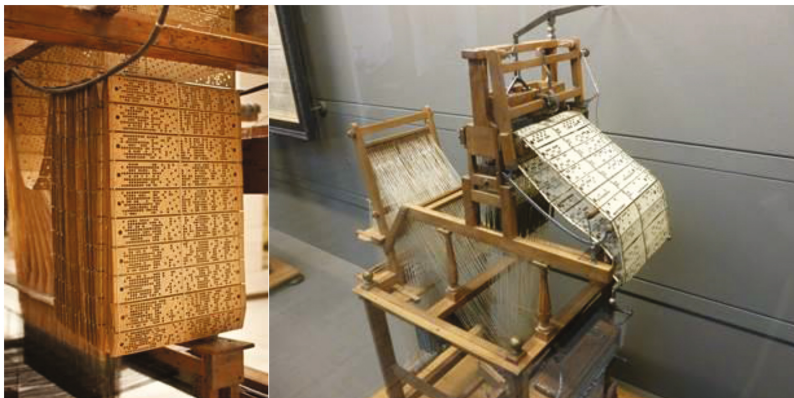
condition to be respected is univocity and invariability. Judging his solution as one of his most important contributions to science, Pascal envisioned the drafting of a small treatise entitled “Géométrie du Hasard” (Geometry of Chance). He never wrote it. Inspired by this, Christian Huygens wrote the first treatise on the calculation of chances, the “De ratiociniis in ludo aleae” (“On Calculation in Games of Chance,” 1657). We can conclude this preamble by observing that seminal work of Blaise Pascal on probability was inspired by geometry. The objective of the GSI conference is to return to this initial idea that we can geometrize statistics in a rigorous way.

We can also make reference to Blaise Pascal for this GSI conference on computing geometrical statistics because he was the inventor of computers with his “Pascaline” machine. The introduction of Pascaline marks the beginning of the development of mechanical calculus in Europe. This development, which passed from calculating machines to the electrical and electronic calculators of the following centuries, culminated in the invention of the microprocessor. Also, Charles Babbage conceived his analytical machine from 1834 to 1837, a programmable calculating machine that was the ancestor of the computers of the 1940s, combining the inventions of Blaise Pascal and Jacquard’s machine, with instructions written on perforated cards, one of the descendants of the Pascaline, the first machine that supplied the intelligence of man. We can observe that these machines were conceived on “mechanical” principles to develop “analytical” computation. GSI could be a source for new HPC machines based on “geometrical” computation. Future machines could be conceived on algorithm (geometrical) structures, with new numerical schemes that will overcome coordinate systems by using an intrinsic approach based on symmetries. We could say that we have to replace René Descartes by Blaise Pascal to build new HPC machines, intrinsically without coordinate systems.

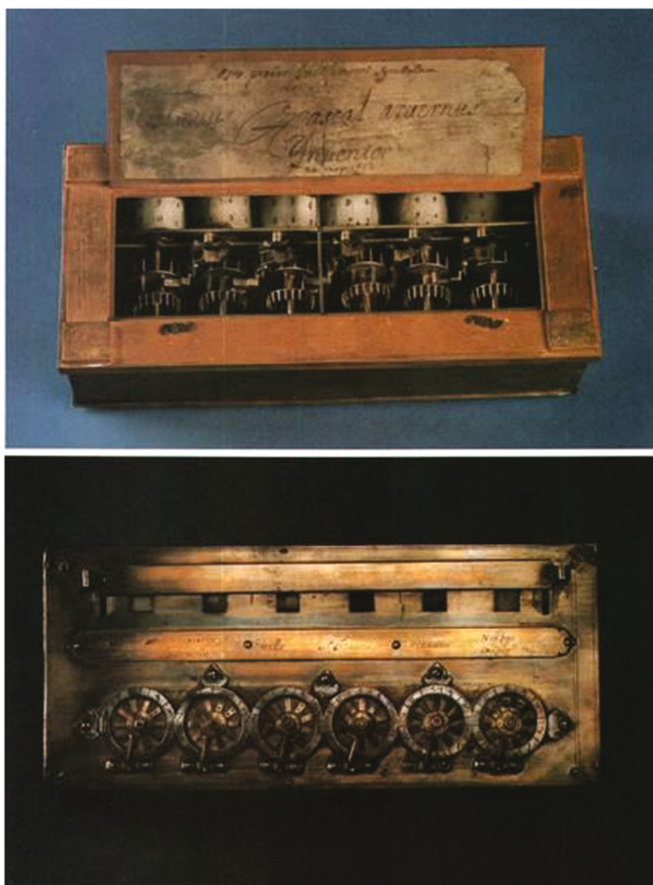
- **Babbage Analytic Machine**



- **Jacquard Loom**



- **Pascaline Machine**



We will conclude with this beautiful citation of Joseph de Maistre comparing geometry and probability:

If we add that the criticism which accustoms the mind, especially in matters of facts, to receive simple probabilities for proofs, is, by this place, less adapted to form it than the geometry which makes it contract the habit of acquiescence only in evidence; We will reply that, strictly speaking, we might conclude from this very difference that criticism gives, on the contrary, more exercise to the mind than geometry: because the evidence, which is one and absolute, first aspect without leaving either the freedom to doubt, or the merit of choosing; Whereas, in order to be in a position to take a decision, it is necessary that they should be compared, discussed, and weighed. A kind of study which, so to speak, breaks the mind to this operation, is certainly of a wider use than that in which everything is subject to the evidence; Because the chances of determining themselves on likelihoods or probabilities are more frequent than those which require that we proceed by demonstrations: why should we not say that they often also hold to much more important objects?

—Joseph de Maistre in *L'Esprit de Finesse*

Si on ajoute que la critique qui accoutume l'esprit, surtout en matière de faits, à recevoir de simples probabilités pour des preuves, est, par cet endroit, moins propre à le former, que ne le doit être la géométrie qui lui fait contracter l'habitude de n'acquiescer qu'à l'évidence; nous répliquerons qu'à la rigueur on pourrait conclure de cette différence même, que la critique donne, au contraire, plus d'exercice à l'esprit que la géométrie: parce que l'évidence, qui est une et absolue, le fixe au premier aspect sans lui laisser ni la liberté de douter, ni le mérite de choisir; au lieu que les probabilités étant susceptibles du plus et du moins, il faut, pour se mettre en état de prendre un parti, les comparer ensemble, les discuter et les peser. Un genre d'étude qui rompt, pour ainsi dire, l'esprit à cette opération, est certainement d'un usage plus étendu que celui où tout est soumis à l'évidence; parce que les occasions de se déterminer sur des vraisemblances ou probabilités, sont plus fréquentes que celles qui exigent qu'on procède par démonstrations: pourquoi ne dirions —nous pas que souvent elles tiennent aussi à des objets beaucoup plus importants?

—Joseph de Maistre dans *L'Esprit de Finesse*

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