6th Conference on the

Geometric Science of Information

GSI'23

FROM CLASSICAL TO QUANTUM INFORMATION GEOMETRY

Saint-Malo, 30th August to 1st September 2023

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6th International Conference on

GEOMETRIC SCIENCE OF INFORMATION

GSI'23

Saint-Malo, France

30th August to 1st September 2023

As for GSI'13, GSI'15, GSI'17, GSI'19 and GSI'21 (https://franknielsen.github.io/GSI/), the objective of this 6th edition of SEE GSI'23 conference, hosted in Saint-Malo, birthplace of Pierre Louis Moreau de Maupertuis, is to bring together pure and applied mathematicians and engineers, with common interest in geometric tools and their applications for information analysis. GSI emphasizes an active participation of young researchers to discuss emerging areas of collaborative research on the topic of "Geometric Science of Information and their Applications". In 2023, GSI main theme is on "FROM CLASSICAL TO QUANTUM INFORMATION GEOMETRY", and the conference will take place at Palais du Grand Large, in Saint-Malo, France.

The GSI conference cycle has been initiated by the Brillouin Seminar Team as soon as 2009 (http://repmus.ircam.fr/brillouin/home). The GSI'21 event has been motivated in the continuity of the first initiative launched in 2013 (https://web2.see.asso.fr/gsi2013) at Mines ParisTech, consolidated in 2015 (https://web2.see.asso.fr/gsi2015) at Ecole Polytechnique, and opened to new communities in 2017 (https://web2.see.asso.fr/gsi2017) at Mines ParisTech, 2019 (https://web2.see.asso.fr/gsi2019) at ENAC Toulouse and 2021 (https://web2.see.asso.fr/gsi2021) at Sorbonne University. We mention that in 2011, we organized an Indo-French workshop on the topic of "Matrix Information Geometry" (https://www.lix.polytechnique.fr/~nielsen/MIG/) that yielded an edited book in 2013, and in 2017, collaborate to CIRM seminar in Luminy with the event TGSI'17 "Topological & Geometrical Structures of Information" (https://fconferences.cirm-math.fr/1680.html).

GSI satellites event have been organized in 2019, and 2020 as FGSI'19 "Foundation of Geometric Science of Information" in Montpellier (https://fgsi2019.sciencesconf.org/) and Les Houches Seminar SPIGL'20 "Joint Structures and Common Foundations of Statistical Physics, Information Geometry and Inference for Learning" (https://franknielsen.github.io/SPIG-LesHouches2020/).

The technical program of GSI'23 covers all the main topics and highlights in the domain of the "Geometric Science of Information" including information geometry manifolds of structured data/information and their advanced applications. These Springer LNCS proceedings consists solely of original research papers that have been carefully peer-reviewed by at least two or three experts. Accepted contributions were revised before acceptance.

As for the GSI'13, GSI'15, GSI'17, GSI'19, and GSI'21, GSI'23 addresses inter-relations between different mathematical domains like 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, geometric structures in thermodynamics and statistical physics, algebraic/infinite dimensional/Banach information manifolds, divergence geometry, tensor-valued morphology, optimal transport theory, manifold and topology learning, ... and applications like geometries of audio-processing, inverse problems and signal/image processing. GSI'23 topics were enriched with contributions from Lie Group Machine Learning, Harmonic Analysis on Lie Groups, Geometric Deep Learning, Geometry of Hamiltonian Monte Carlo, Geometric & (Poly)Symplectic Integrators, Contact Geometry & Hamiltonian Control, Geometric and structure preserving discretizations, Probability Density Estimation & Sampling in High Dimension, Geometry of Graphs and Networks and Geometry in Neuroscience & Cognitive Sciences.

At the turn of the century, new and fruitful interactions were discovered between several branches of science: Information Sciences (information theory, digital communications, statistical signal processing), Mathematics (group theory, geometry and topology, probability, statistics, sheaves theory,...) and Physics (geometric mechanics, thermodynamics, statistical physics, quantum mechanics, ...). GSI biannual international conference cycle is a tentative 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.

More in Frank Nielsen's GSI pages: https://franknielsen.github.io/GSI/

The GSI'23 conference was structured in 25 sessions of 134 papers and 19 posters:

Geometry and Machine Learning

- **Geometric Green Learning,** Alice Barbara TUMPACH, Diarra FALL & Guillaume CHARPIAT
- **Neurogeometry Meets Geometric Deep Learning,** Remco DUITS & Erik BEKKERS, Alessandro SARTI
- **Divergences in Statistics & Machine Learning**, Michel BRONIATOWSKI & Wolfgang STUMMER

Divergences and computational information geometry

- **Computational Information Geometry and Divergences,** Frank NIELSEN & Olivier RIOUL
- **Statistical Manifolds and Hessian information geometry,** Michel NGUIFFO BOYOM

Statistics, Topology and Shape Spaces

- **Statistics, Information and Topology,** Pierre BAUDOT & Grégoire SEARGEANT-PERTHUIS
- **Information Theory and Statistics**, Olivier RIOUL
- **Statistical Shape Analysis and more Non-Euclidean Statistic**s, Stephan HUCKEMANN & Xavier PENNEC
- **Probability and Statistics on manifolds,** Cyrus MOSTAJERAN
- **Computing Geometry & Algebraic Statistics,** Eliana DUARTE & Elias TSIGARIDAS

Geometry & Mechanics

- **Geometric and Analytical Aspects of Quantization and Non-Commutative Harmonic Analysis on Lie Groups,** Pierre BIELIAVSKY & Jean-Pierre GAZEAU
- **Deep learning: Methods, Analysis and Applications to Mechanical Systems,** Elena CELLEDONI, James JACKAMAN, Davide MURARI and Brynjulf OWREN
- **Stochastic Geometric Mechanics,** Ana Bela CRUZEIRO & Jean-Claude ZAMBRINI
- **Geometric Mechanics,** Gery DE SAXCE & Zdravko TERZE
- **New trends in Nonholonomic Systems,** Manuel de LEON & Leonardo COLOMBO

Geometry, Learning Dynamics & Thermodynamics

- **Symplectic Structures of Heat & Information Geometry,** Frédéric BARBARESCO & Pierre BIELIAVSKY
- **Geometric Methods in Mechanics and Thermodynamics,** François GAY-BALMAZ & Hiroaki YOSHIMURA
- **Fluid Mechanics and Symmetry,** François GAY-BALMAZ & Cesare TRONCI
- **Learning of Dynamic Processes,** Lyudmila GRIGORYEVA

Quantum Information Geometry

- **The Geometry of Quantum States,** Florio M. CIAGLIA & Fabio DI COSMO
- **Integrable Systems and Information Geometry (From Classical to Quantum),** Jean-Pierre FRANCOISE, Daisuke TARAMA

Geometry & Biological Structures

- **Neurogeometry,** Alessandro SARTI, Giovanna CITTI & Giovanni PETRI
- **Distance geometry, graph embeddings, and applications,** Antonio MUCHERINO
- **Geometric Features Extraction in Medical Imaging,** Stéphanie JEHAN-BESSON & Patrick CLARYSSE

Geometry & Applications

- **Applied Geometric Learning,** Pierre-Yves LAGRAVE, Santiago VELASCO-FORERO & Teodora PETRISOR

GSI'23 General Chairs

Frederic Barbaresco
(THALES)
www.thalesgroup.com/en/speakers-bureau/frederic-barbaresco

Frank Nielsen
(Sony Computer Science Laboratories Inc.)
www.sonycsl.co.jp/member/tokyo/164

Keynote Speakers

Juan-Pablo ORTEGA
Head, Division of Mathematical Sciences. Associate Chair (Faculty), School of Physical and Mathematical Sciences. Nanyang Technological University, Singapore

LEARNING OF DYNAMIC PROCESSES

Abstract: The last decade has seen the emergence of learning techniques that use the computational power of dynamical systems for information processing. Some of those paradigms are based on architectures that are partially randomly generated and require a relatively cheap training effort, which makes them ideal in many applications. The need for a mathematical understanding of the working principles underlying this approach, collectively known as Reservoir Computing, has led to the construction of new techniques that put together well-known results in systems theory and dynamics with others coming from approximation and statistical learning theory. This combination has allowed in recent times to elevate Reservoir Computing to the realm of provable machine learning paradigms and, as we will see in this talk, it also hints at various connections with kernel maps, structure-preserving algorithms, and physics-inspired learning.

References:

• Gonon, L., Grigoryeva, L., and Ortega, J.-P. [2022] *Approximation bounds for random neural networks and reservoir systems. To appear in The Annals of Applied Probability. Paper*
• Cuchiero, C., Gonon, L., Grigoryeva, L., Ortega, J.-P., and Teichmann, J. [2021] *Expressive power of randomized signature. NeurIPS 2021. Paper*
• Cuchiero, C., Gonon, L., Grigoryeva, L., Ortega, J.-P., and Teichmann, J. [2021] *Discrete-time signatures and randomness in reservoir computing. IEEE Transactions on Neural Networks and Learning Systems, 33(11):6321-6330. Paper*

- Gonon, L. and Ortega, J.-P. [2021] *Fading memory echo state networks are universal. Neural Networks, 138, 10-13. Paper*
- Gonon, L., Grigoryeva, L., and Ortega, J.-P. [2020] *Risk bounds for reservoir computing. Journal of Machine Learning Research, 21(240), 1-61. Paper*
- Gonon, L. and Ortega, J.-P. [2020] *Reservoir computing universality with stochastic inputs. IEEE Transactions on Neural Networks and Learning Systems, 31(1), 100-112 Paper*
- Grigoryeva, L. and Ortega, J.-P. [2019] *Differentiable reservoir computing. Journal of Machine Learning Research, 20(179), 1-62. Paper*
- Grigoryeva, L. and Ortega, J.-P. [2018] *Echo state networks are universal. Neural Networks, 108, 495-508. Paper*
- Grigoryeva, L. and Ortega, J.-P. [2018] *Universal discrete-time reservoir computers with stochastic inputs and linear readouts using non-homogeneous state-affine systems. Journal of Machine Learning Research, 19(24), 1-40. Paper*

Hervé SABOURIN

Director for Strategic projects of the Réseau Figure® (network of 31 universities)
Former Regional Director of the A.U.F (Agence Universitaire de la Francophonie) for the Middle East
Former Vice-President of the University of Poitiers (France)

TRANSVERSE POISSON STRUCTURES TO ADJOINT ORBITS IN A COMPLEX SEMI-SIMPLE LIE ALGEBRA

Abstract: The notion of transverse Poisson structure has been introduced by Arthur Weinstein stating in his famous splitting theorem that any Poisson Manifold M is, in the neighbourhood of each point m, the product of a symplectic manifold, the symplectic leaf S at m, and a submanifold N which can be endowed with a structure of Poisson manifold of rank 0 at m. N is called a transverse slice at M of S. When M is the dual of a complex Lie algebra g equipped with its standard Lie-Poisson structure, we know that the symplectic leaf through x is the coadjoint G. x of the adjoint Lie group G of g. Moreover, there is a natural way to describe the transverse slice to the coadjoint orbit and, using a canonical system of linear coordinates (q1, …., qk), it follows that the coefficients of the transverse Poisson structure are rational in (q1, …., qk). Then, one can wonder for which cases that structure is polynomial. Nice answers have been given when g is semi-simple, taking advantage of the explicit machinery of semi-simple Lie algebras. One shows that a general adjoint orbit can be reduced to the case of a nilpotent orbit where the transverse Poisson structure can be expressed in terms of quasihomogeneous polynomials. In particular, in the case of the subregular nilpotent orbit the Poisson structure is given by a determinantal formula and is entirely determined by the singular variety of nilpotent elements of the slice.

References:

1. Sabourin, H., *Sur la structure transverse à une orbite nilpotente adjointe, Canad.J.Math, 57, (4), 2005, p 750-770.*
2. Sabourin, H., *Orbites nilpotentes sphériques et représentations unipotentes associées : Le cas SL(n), Representation Theory, 9, (2005), p 468-506.*
3. Sabourin, H., *Mémoire d'HDR, Quelques aspects de la méthode des orbites en théorie de Lie, Décembre 2005*
4. Damianou, P., Sabourin, H., Vanhaecke, P., *Transverse Poisson structures to adjoint orbits in semi-simple Lie algebras, Pacific J.*

Math,232, 111-139, 2007.
5. Sabourin, H., Damianou, P., Vanhaecke, P., *Transverse Poisson structures : the subregular and the minimal orbits, Differential Geometry and its Applications Proc. Conf. in Honour of Leonhard Euler, Olomouc, August 2007*
6. Sabourin, H., Damianou, P., Vanhaecke, P., *Nilpotent orbits in simple Lie algebras and their transverse Poisson structures, American Institute of Physics, Conf. Proc. series, Vol. 1023 (2008), pp 148-152.*

Francis BACH
Inria, Ecole Normale Supérieure

INFORMATION THEORY WITH KERNEL METHODS

Abstract: Estimating and computing entropies of probability distributions are key computational tasks throughout data science. In many situations, the underlying distributions are only known through the expectation of some feature vectors, which has led to a series of works within kernel methods. In this talk, I will explore the particular situation where the feature vector is a rank-one positive definite matrix, and show how the associated expectations (a covariance matrix) can be used with information divergences from quantum information theory to draw direct links with the classical notions of Shannon entropies.

References:
Francis Bach. *Information Theory with Kernel Methods. To appear in IEEE Transactions in Information Theory, 2022.* https://arxiv.org/pdf/2202.08545

Eva MIRANDA
Universitat Politècnica de Catalunya and Centre de Recerca Matemàtica

FROM ALAN TURING TO CONTACT GEOMETRY: TOWARDS A «FLUID COMPUTER"

Abstract: Is hydrodynamics capable of performing computations? (Moore 1991). Can a mechanical system (including a fluid flow) simulate a universal Turing machine? (Tao, 2016). Etnyre and Ghrist unveiled a mirror between contact geometry and fluid dynamics reflecting Reeb vector fields as Beltrami vector fields. With the aid of this mirror, we can answer in the positive the questions raised by Moore and Tao. This is a recent result that mixes up techniques from Alan Turing with modern Geometry (contact geometry) to construct a «Fluid computer» in dimension 3. This construction shows, in particular, the existence of undecidable fluid paths. I will also explain applications of this mirror to the detection of escape trajectories in Celestial mechanics (for which I'll need to extend the mirror to a singular set-up). This mirror allows us to construct a tunnel connecting problems in Celestial mechanics and Fluid Dynamics.

References:
Robert Cardona, Eva Miranda, Daniel Peralta-Salas, and Francisco Presas, *Constructing Turing complete Euler flows in dimension 3. Proc. Natl. Acad. Sci. USA 118 (2021), no. 19, Paper No. e2026818118, 9 pp.*
1. Etnyre, R. Ghrist, *Contact topology and hydrodynamics: I. Beltrami fields and the Seifert conjecture. Nonlinearity 13, 441 (2000).*
Eva Miranda, Cédric Oms and Daniel Peralta-Salas, *On the singular Weinstein conjecture and the existence of escape orbits for b-Beltrami fields.*

Commun. Contemp. Math. 24 (2022), no. 7, Paper No. 2150076, 25 pp.
1. *Tao, Finite time blowup for an averaged three-dimensional Navier–Stokes equation. J. Am. Math. Soc. 29, 601–674 (2016).*
Alan Turing, *On Computable Numbers, with an Application to the Entscheidungsproblem. Proceedings of the London Mathematical Society. Wiley. s2-42 (1): 230–265. doi:10.1112/plms/s2-42.1.230. ISSN 0024-6115., (1937).*

Diarra FALL
Institut Denis Poisson, UMR CNRS, Université d'Orléans & Université de Tours, France.

STATISTICS METHODS FOR MEDICAL IMAGE PROCESSING AND RECONSTRUCTION

Abstract: In this talk we will see how statistical methods, from the simplest to the most advanced ones, can be used to address various problems in medical image processing and reconstruction for different imaging modalities. Image reconstruction allows to obtain the images in question, while image processing (on the already reconstructed images) aims at extracting some information of interest. We will review several statistical methods (manely Bayesian) to address various problems of this type.

References:

1. D. Fall, N. Dobigeon, P. Auzou, *«A Bayesian Estimation Formulation to Voxel-Based Lesion Symptom Mapping», Proc. European Signal Processing Conf. (EUSIPCO), Belgrade, Serbia, Sept. 2022.*
2. D. Fall, *«Bayesian Nonparametrics and Biostatistics: the case of PET Imaging», International Journal of Biostatistics, 2019.*
3. D. Fall, E. Lavau and P. Auzou, *«Voxel-Based Lesion-Symptom Mapping: a Nonparametric Bayesian Approach», Proc. IEEE International Conference on Acoustics, Speech and Signl Processing (ICASSP) 2018.*

Bernd STURMFELS
MPI-MiS Leipzig, Germany

ALGEBRAIC STATISTICS AND GIBBS MANIFOLDS

Abstract: Gibbs manifolds are images of affine spaces of symmetric matrices under the exponential map. They arise in applications such as optimization, statistics and quantum physics, where they extend the ubiquitous role of toric geometry. The Gibbs variety is the zero locus of all polynomials that vanish on the Gibbs manifold. This lecture gives an introduction to these objects from the perspective of Algebraic Statistics.

References:

1. Pavlov, B.Sturmfels and S.Telen: *Gibbs manifolds, arXiv:2211.15490*
2. Sturmfels, S.Telen, F-X.Vialard and M.von Renesse: *Toric geometry of entropic regularization, arXiv:2202.01571*
3. Sullivant: *Algebraic statistics. Graduate Studies in Mathematics, 194, American Mathematical Society, Providence, RI, 2018*
4. Huh and B.Sturmfels: *Likelihood geometry, in Combinatorial Algebraic Geometry (eds. Aldo Conca et al.), Lecture Notes in Mathematics 2108, Springer (2014) 63-117.*
5. Geiger, C.Meek and B.Sturmfels: *On the toric algebra of graphical models, Annals of Statistics 34 (2006) 1463-149*

Pierre Louis Moreau de Maupertuis, King's Musketeer Lieutenant of Science and Son of Saint-Malo Corsaire

« *Héros de la physique, Argonautes nouveaux / Qui franchissez les monts, qui traversez les eaux / Dont le travail immense et l'exacte mesure / De la Terre étonnée ont fixé la figure. / Dévoilez ces ressorts, qui font la pesanteur. / Vous connaissez les lois qu'établit son auteur.* »… [Heroes of physics, new Argonauts / Who cross the mountains, who cross the waters / Whose immense work and the exact measure / Of the astonished Earth fixed the figure. / Reveal these springs, which make gravity. / You know the laws established by its author.], Volaire on Pierre Louis Moreau de Maupertuis

Son of René Moreau de Maupertuis (1664-1746) a corsair and shipowner from Saint-Malo, director of the Compagnie des Indes and knighted by Louis XIV, Maupertuis was offered a cavalry regiment at the age of twenty. His father, with whom he has a very close relationship, thus opens the doors of the gray musketeers to him, of which he becomes lieutenant. Between 1718 and 1721, Maupertuis devoted himself to a military career, first joining the company of gray musketeers, then a cavalry regiment in Lille, without abandoning his studies. In 1718, Maupertuis entered the gray musketeers, writes Formey in his Éloge (1760), but he carried there the love of study, and above all the taste for geometry. However, his profession as a soldier was not to last long and at the end of 1721, the learned Malouin finally and permanently went to Paris, as he could not last long in the idleness of the former state of a military officer in time of peace, and soon he took leave of it. This moment marks the official entry of Maupertuis into Parisian intellectual life, halfway between the literary cafés and the benches of the Academy. He nevertheless preferred to abandon this military career to devote himself to the study of mathematics, an orientation crowned in 1723 by his appointment as a member of the Academy of Sciences.

Pierre Louis Moreau de Maupertuis

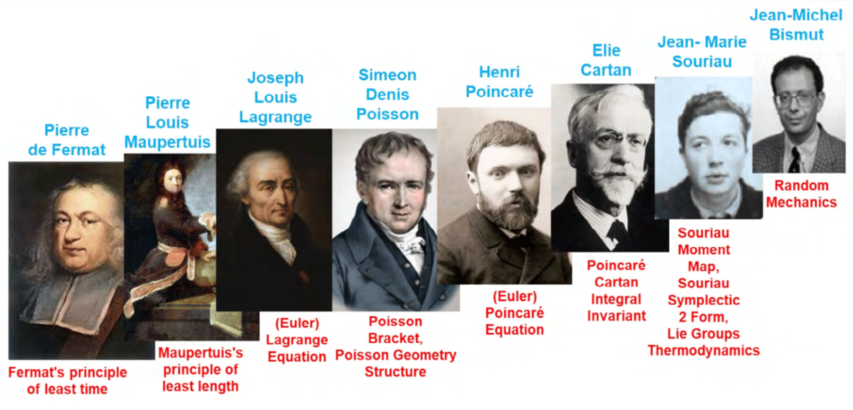
He then published various works of mechanics and astronomy. Pierre Louis Moreau de Maupertuis (1698-1759) became an associate member of the

Pierre Louis Moreau de Maupertuis (1698, 1759), French surveyor and mathematician, working to measure the terrestrial meridian in Lapland.

Royal Society on June 27, 1728. In 1728, Maupertuis visited London, a trip which marked a decisive turning point in his career. Elected associate member of the Royal Society, he discovered Newton's ideas, in particular universal attraction, of which he was to become an ardent propagandist in France, which D'Alembert, in the Discourse preliminary to the Encyclopedia, did not miss. Academician at 25, Pierre-Louis Moreau de Maupertuis led a perilous expedition to Lapland to verify Newton's theory and famous as «the man who flattened the earth». Called by Frederick II to direct the Berlin Academy of Sciences, he was as comfortable in the royal courts as in the Parisian salons.

The rejection of the Newtonian approach, as well as the distrust of the Cartesian approach, lead Maupertuis to the elaboration of a cosmology different from both the finalism of some and the anti-finalism of others. It is a cosmology that cannot be attributed to any particular tradition, and that must rather be read as an independent and creative elaboration. All of Maupertuis' cosmology is based on a physical principle which he was the first to formulate, namely the principle of least action, the novelty of which he underlines on several occasions and generality.

His "principle of least action" constitutes an essential contribution to physics to this day, a fundamental principle in classical mechanics. It states that the motion of a particle between two points in a conservative system is such that the action integral, defined as the integral of the Lagrangian over the time interval of motion, is minimized. Maupertuis's principle was renewed by Cartan-Poincaré Integral Invariant in the field of geometric



History of Calculus of Variations Principles

mechanics. In geometric mechanics, the motion of a mechanical system is described in terms of differential forms on a configuration manifold and the Cartan-Poincaré integral invariant is associated with a particular differential form called the symplectic form, which encodes the dynamics of the system. The integral invariant is defined as the integral of the symplectic form over a closed loop in the configuration manifold. More recently, Maupertuis's principle has been extended by Jean-Marie Souriau through Maxwell's principle with the hypothesis that the exterior derivative of the Lagrange 2-form of a general dynamical system vanishes. For the systems of material points, Maxwell's principle allows, under certain conditions, to define a Lagrangian and to show that the Lagrange form is nothing else than the exterior derivative of the Cartan form, in the study of calculus of variations. Without denying the importance of the principle of least action nor the usefulness of these formalisms, Jean-Marie Souriau declares that Maupertuis'principle and least action principle seem to him less fundamental than Maxwell's principle. His viewpoint seems to him justified because the existence of a Lagrangian is ensured only locally, and because there exist important systems, such as those made of particles with spin, to which Maxwell's principle applies while they have not a globally defined Lagrangian. Jean-Marie Souriau has also geometrized Noether's theorem (algebraic theorem proving that we can associate invariants to symmetries) with "moment map" (components of moment map are Noether's invariants).

« *La lumière ne pouvant aller tout-à-la fois par le chemin le plus court, et par celui du temps le plus prompt … ne suit-elle aucun des deux, elle prend une route qui a un avantage plus réel : le chemin qu'elle tient est celui par lequel la quantité d'action est la moindre.* » [Since light cannot go both by the shortest path and by that of the quickest time… if it does not follow either of the two, it takes a route which has a more real advantage: the path that it holds is that by which the quantity of action is least.], Maupertuis 1744.

ALEAE GEOMETRIA
Blaise Pascal 400th Birthday

*Blaise Pascal had a multi-disciplinary approach of Science, and has developed 4 topics directly related to GSI'23:**

We celebrate in 2023 Blaise Pascal 400th birthday. GSI'23 Moto is "ALEA GEOMETRIA".

In 1654, Blaise Pascal submitted a paper to « Celeberrimae matheseos Academiae Parisiensi » entitled « ALEAE GEOMETRIA : De compositione aleae in ludis ipsi subjectis »

- « *... 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** »

- « *... 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** »

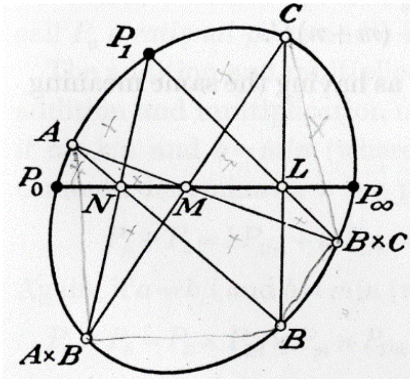
- « *... by the union thus achieved between the demonstrations of mathematics and the uncertainty of chance, and by the conciliation between apparent opposites, it can take its name from both sides and arrogate to right this amazing title:* **Geometry of Chance** »

Blaise Pascal and COMPUTER: Pascaline marks the beginning of the development of mechanical calculus in Europe, followed by Charles Babbage analytical machine from 1834 to 1837, a programmable calculating machine combining the inventions of Blaise Pascal and Jacquard's machine, with instructions written on perforated cards.

Blaise Pascal and PROBABILITY: The «calculation of probabilities» began in a correspondence between Blaise Pascal and Pierre Fermat. In 1654, Blaise Pascal submitted a short paper to «Celeberrimae matheseos Academiae Parisiensi» with the title «Aleae Geometria" (Geometry of Chance), that was the seminal paper founding Probability as a new discipline in Science.

Blaise Pascal and THERMODYNAMICS: Pascal's Experiment in the Puy de Dôme to Test the Relation between Atmospheric Pressure and Altitude. In 1647, Blaise Pascal suggests to raise Torricelli's mercury barometer at the top of the Puy de Dome Mountain (France) in order to test the «weight of air» assumption.

Blaise Pascal and DUALITY: Pascal's Hexagrammum Mysticum Theorem, and its dual Brianchon's Theorem. In 1639 Blaise Pascal discovered, at age sixteen, the famous hexagon theorem, also developed in "Essay pour les Coniques", printed in 1640, declaring his intention of writing a treatise on conics in which he would derive the major theorems of Apollonius from his new theorem.



The GSI'23 conference is dedicated to the memory of Mademoiselle Paulette Libermann, geometer student of Elie Cartan and André Lichnerowicz, PhD student of Charles Ehresmann and familiar with the emerald coast of French Brittany

Paulette Libermann died on July 10, 2007 in Montrouge near Paris. Admitted to the entrance examination to the Ecole Normale Supérieure de Sèvres in 1938, she was a pupil of Elie Cartan and André Lichnerowicz. Paulette Libermann was able to learn about mathematical research under the direction of Elie Cartan, and was a faithful friend of the Cartan family. After her aggregation, she was appointed to Strasbourg and rubbed shoulders with Georges Reeb, René Thom and Jean-Louis Koszul. She prepared a thesis under the direction of Charles Ehresmann, defended in 1953. She was the first ENS Sèvres woman to hold a doctorate in mathematics. She was then appointed professor at the University of Rennes and after at the Faculty of Sciences of the University of Paris in 1966. She began to collaborate with Charles-Michel Marle in 1967. She led a seminar with Charles Ehresmann until his death in 1979, and then alone until 1990. In her thesis, entitled «On the problem of equivalence of regular infinitesimal structures», she studied the Symplectic manifolds provided with two transverse Lagrangian foliations and showed the existence, on the leaves of these foliations, of a canonical flat connection. Later, Dazord and Molino, in the South-Rhodanian geometry seminar, introduced the notion of Libermann foliation, linked to Stefan foliations and Haefliger-structures. Paulette Libermann also deepened the importance of the foliations of a symplectic manifold which she called «simplectically complete», such as the Poisson bracket of two functions, locally defined, constant on each leaf, that is also constant on each leaf. She proved that this property is equivalent to the existence of a Poisson structure on the space of leaves, such that the canonical projection is a Poisson map, and also equivalent to the complete integrability of the sub bundle simplistically orthogonal to the bundle tangent to the leaves. She wrote a famous book with Professor Charles-Michel Marle "Symplectic Geometry and Analytical Mechanics". Professor Charles-Michel Marle told us that Miss Paulette Libermann had bought an apartment in Dinard and spent her summers just in front of Saint-Malo, and so was familiar with the emerald coast of French Brittany.

Mademoiselle Paulette LIBERMANN on Dinard Beach in Front of Saint-Malo

Organization of the Sessions

SESSIONS AUGUST 30TH

	Auditorium Maupertuis	Room Vauban	Room Bouvet
8.00 - 9.00	**Welcome desk (badges) and breakfast**		
09.00 - 09.30	**GSI'23 Opening Session**		
09.30 - 10.30	Eva MIRANDA, (UPC, Spain) From Alan Turing to Contact geometry: towards a "Fluid computer"		
10.30 - 11.00	**Coffee Break**		
11.00 - 12.40	(5) Neurogeometry Meets Geometric Deep Learning, Remco DUITS & Erik BEKKERS, Alessandro SARTI	(5) Statistical Manifolds and Hessian information geometry, Michel NGUIFFO BOYOM	(5) Information Theory and Statistics, Olivier RIOUL
12.40 - 14.00	**Lunch Break**		
14.00 - 15.00	Hervé SABOURIN, (Poitiers Univ., France) Transverse Poisson Structures to adjoint orbits in a complex semi-simple Lie algebra		
15.00 - 16.20	(4/7) Symplectic Structures of Heat & Information Geometry, Frédéric BARBARESCO & Pierre BIELIAVSKY	(4) Applied Geometric Learning, Pierre-Yves LAGRAVE, Santiago VELASCO-FORERO & Teodora PETRISOR	(4) Statistics, Information and Topology, Pierre BAUDOT & Grégoire SEARGEANT-PERTHUIS
16.20 - 16.50	**Coffee Break**		
16.50 - 18.30	(3/7) Symplectic Structures of Heat & Information Geometry, Frédéric BARBARESCO & Pierre BIELIAVSKY	(5) Distance geometry, graph embeddings, and applications, Antonio MUCHERIN •	
18.45 - 19.00	**Group photo 1**		
19.00 - 20.00	**Cocktail**		

SESSIONS AUGUST 31ST

	Auditorium Maupertuis	Room Vauban	Room Bouvet
08.30 - 09.30	Keynote Francis BACH, (ENS PARIS & INRIA, France) Information Theory with Kernel Methods		
09.30 - 10.50	(4) Integrable Systems and Information Geometry (From Classical to Quantum), Jean-Pierre FRANCOISE, Daisuke TARAMA	(4) Divergences in Statistics & Machine Learning, Michel BRONIATOWSKI & Wolfgang STUMMER	(4) Geometric Features Extraction in Medical Imaging, Stéphanie JEHAN-BESSON & Patrick Clarysse
10.50 - 11.20	**Group photo + Coffee Break + GSI'23 Posters Session + CaLIGOLA Posters session, Rita FIORESI**		
11.20 - 13.20	(5) Statistical Shape Analysis and more Non-Euclidean Statistics, Stephan HUCKEMANN & Xavier PENNEC	(6) Fluid Mechanics and Symmetry, François GAY-BALMAZ et Cesare TRONCI	(6) Deep learning: Methods, Analysis and Applications to Mechanical Systems, Elena CELLEDONI, James JACKAMAN, Davide MURARI and Brynjulf OWREN
13.20 - 14.45	**Lunch Break + GSI'23 Posters Session + CaLIGOLA Posters session, Rita FIORESI**		
14.45 - 15. 45	Juan-Pablo Ortega, (NTU, SG) Learning of Dynamic Processes		
15.45 - 16.15	**Coffee Break + GSI'23 Posters Session + CaLIGOLA Posters session, Rita FIORESI**		
16.15 - 18.35	(6) Computational Information Geometry and Divergences, Frank NIELSEN & Olivier RIOUL	(6) Probability and Statistics on manifolds, Cyrus MOSTAJERAN	(7) Geometric Methods in Mechanics and Thermodynamics, François GAY-BALMAZ et Hiroaki YOSHIMURA
18.45 - 19.00	**Group photo 2**		
20.00 - 22.00	**Gala Dinner**		

SESSIONS SEPTEMBER 1ST

	Auditorium Maupertuis	Room Vauban	Room Bouvet
08.30 - 09.30	Diarra FALL, (Orléans Univ., France) Statistics Methods for Medical Image Processing and Reconstruction		
09.30 - 10.30	(4/8)The Geometry of Quantum States, Florio M. CIAGLIA & FABIO DI COSMO	(4/8) Geometric Mechanics, Gery DE SAXCE & Zdravko TERZE	(4/7) Geometric Green Learning, Alice Barbara TUMPACH, Diarra FALL & Guillaume CHARPIAT
10.50 - 11.20	**Coffee Break**		
11.20 - 12.40	(4/8)The Geometry of Quantum States, Florio M. CIAGLIA & FABIO DI COSMO	(4/8) Geometric Mechanics, Gery DE SAXCE & Zdravko TERZE	(3/7) Geometric Green Learning, Alice Barbara TUMPACH, Diarra FALL & Guillaume CHARPIAT
12.40 - 14.00	**Lunch Break**		
14.00 - 15.00	Bernd STURMFELS, (MPI, MiS Leipzig, DE) Algebraic Statistics and Gibbs Manifolds		
15.00 - 16.20	(4) Geometric and Analytical Aspects of Quantization and Non-Commutative Harmonic Analysis on Lie Groups, Pierre BIELIAVSKY & Jean-Pierre GAZEAU	(4) Stochastic Geometric Mechanics, Ana Bela CRUZEIRO & Jean-Claude ZAMBRINI	(4) New trends in Nonholonomic Systems, Manuel de LEON & Leonardo COLOMBO
16.20 - 16.50	**Coffee Break**		
16.50 - 18.30	(5) Learning of Dynamic Processes, Lyudmila GRIGORYEVA	(5) Computing Geometry & Algebraic Statistics, Eliana DUARTE & Elias TSIGARIDAS	(5) Neurogeometry Alessandro SARTI, Giovanna CITTI and Giovanni Petri
18.30 - 18:45	**Closing Session (Papers Awards)**		

Travel Information to GSI'23

Arriving by plane:

1/ Landing at Roissy Charles De Gaulle (CDG) airport, you may either:

- Take a TGV train to Rennes and then a connection to Saint-Malo (around 3,5-hour trip, 3 direct trains per day, 8:48, 12:16, 18:49)

- Take an Air France bus shuttle to Montparnasse railway station and then take a TGV to Saint-Malo • Rent a car in the airport for a 4.5-hour trip by motorways A11/A13 (through Rennes) or A13/A84 (through Caen)

2/ Landing at Orly airport, you may either:

- Take an Air France bus shuttle to Montparnasse railway station and then take a TGV to Saint-Malo (either direct or via Rennes)

- Rent a car at the airport for a 4.5-hour trip by motorways A11/A13 (via Rennes) or A13/A84 (via Caen)

3/ Landing at Rennes –Saint Jacques Airport, you may either:

- Take a bus or a taxi to Rennes railway station. Then take a direct train to Saint-Malo.

- Rent a car or take a taxi (*) Saint-Malo is 75 km away, less than 1-hour trip.

(*) Direct shuttles from Rennes Airport may be organized when there are at least 2 passengers

Arriving by train:

From Paris Montparnasse railway station (town center):

- Direct TGV train to Saint Malo in 2h15 or via Rennes with a connection to Saint Malo (around 2h30 trip)

- To book you ticket on line: https://www.oui.sncf/

Direct TGV trains to Rennes with connection to St Malo (45 à 60 min trip) from:
- Lille (3h30)
- Roissy (2h30)
- Massy Palaiseau (1h35)
- Strasbourg (4h50)
- Lyon (4h)
- Marseille (6h).

Arriving by boat:

From Portsmouth (UK):
Direct and daily cruises with Brittany Ferries

Arriving by car:

1/ From Paris, 3.5 hours by highways:
- A11/A13 (through Rennes)
- A13/A84 (through Caen)

2/ From Rennes: 1 hour by highways

3/ From Nantes: 2 hours by highways

Wednesday, August 30th
GSI'23 Opening Day

DAY 1 OF AUTHOR SESSIONS

8:30-9:30

Opening session, Eva MIRANDA, From Alan Turing to Contact geometry: towards a "Fluid computer"

NEUROGEOMETRY MEETS GEOMETRIC DEEP LEARNING, REMCO DUITS & ERIK BEKKERS, ALESSANDRO SARTI

› Functional Properties of PDE based Group Equivariant Convolutional Neural Networks, Gautam Pai, Gijs Bellaard, Bart M. N. Smets, and Remco Duits

Abstract: We build on the recently introduced PDE-G-CNN framework, which proposed the concept of non-linear morphological convolutions that are motivated by solving HJB-PDEs on lifted homogeneous spaces such as the homogeneous space of 2D positions and orientations isomorphic to G = SE(2). PDE-G-CNNs generalize G-CNNs and are provably equivariant to actions of the roto-translation group SE(2). Moreover, PDE-G-CNNs automate geometric image processing via orientation scores and allow for a meaningful geometric interpretation. In this article, we show various functional properties of these networks:

(1.) PDE-G-CNNs satisfy crucial geometric and algebraic symmetries: they are semiring quasilinear, equivariant, invariant under time scaling, isometric, and are solved by semiring group convolutions.

(2.) PDE-G-CNNs exhibit a high degree of data efficiency: even under limited availability of training data they show a distinct gain in performance and generalize to unseen test cases from different datasets.

(3.) PDE-G-CNNs are extendable to well-known convolutional architectures. We explore a UNet variant of PDE-G-CNNs which has a new equivariant U-Net structure with PDE-based morphological convolutions. We verify the properties and show favorable results on various datasets.

› Continuous Kendall Shape Variational Autoencoders, Sharvaree Vadgama, Jakub M. Tomczak, and Erik Bekkers

Abstract: We present an approach for unsupervised learning of geometrically meaningful representations via equivariant variational autoencoders (VAEs) with hyperspherical latent representations. The equivariant encoder/decoder ensures that these latents are geometrically meaningful and grounded in the input space. Mapping these geometrygrounded latents to hyperspheres allows us to interpret them as points in a Kendall shape space. This paper extends the recent Kendall-shape VAE paradigm by Vadgama et al. by providing a general definition of Kendall shapes in terms of group representations to allow for more flexible modeling of KS-VAEs. We show that learning with generalized Kendall shapes, instead of landmark-based shapes, improves representation capacity.

› A neurogeometric stereo model for individuation of 3D perceptual units, M. V. Bolelli, G. Citti, A. Sarti, and S. W. Zucker

Abstract: We present a neurogeometric model for stereo vision and individuation of 3D perceptual units.We first model the space of position and orientation of 3D curves in the visual scene as a sub-Riemannian structure. Horizontal curves in this setting express good continuation principles in 3D. Starting from the equation of neural activity we apply harmonic analysis techniques in the sub-Riemannian structure to solve the correspondence problem and find 3D percepts.

› Can generalised divergences help for invariant neural networks?, Santiago Velasco-Forero

Abstract: We consider a framework including multiple augmentation regularisation by generalised divergences to induce invariance for nongroup transformations during training of convolutional neural networks. Experiments on supervised classification of images in different scales non considered during training illustrated that our proposition performs better than classical data augmentation.

› Group Equivariant Sparse Coding Christian, Shewmake, Nina Miolane, and Bruno Olshausen

Abstract: We describe a sparse coding model of visual cortex that encodes image transformations in an equivariant and hierarchical manner. The model consists of a group-equivariant convolutional layer with internal recurrent connections that implement sparse coding through neural population attractor dynamics, consistent with the architecture of visual cortex. The layers can be stacked hierarchically by introducing recurrent connections between them. The hierarchical structure enables rich bottom-up and top-down information flows, hypothesized to underlie the visual system's ability for perceptual inference. The model's equivariant representations are demonstrated on time-varying visual scenes.

STATISTICAL MANIFOLDS AND HESSIAN INFORMATION GEOMETRY, MICHEL NGUIFFO BOYOM

› On the tangent bundles of statistical manifolds, Barbara Opozda

Abstract: Curvature properties of the Sasakian metric on the tangent bundle of statistical manifolds are discussed.

› Conformal Submersion with Horizontal Distribution and Geodesics, Mahesh T V and K S Subrahamanian Moosath

Abstract: In this paper, we compare geodesics for conformal submersion with horizontal distribution. Then, proved a condition for the completeness of statistical connection for a conformal submersion with horizontal distribution.

› Geometric properties of beta distributions, Mama Assandje Prosper Rosaire and Dongho Joseph

Abstract: The aim of this work is to prove that the Amari manifold of beta distributions have dual potential, dual coordinate pairs and his corresponding grandient system is linearizable and Hamiltonian

› KV COHOMOLOGY GROUP OF SOME KV STRUCTURES ON R2, Mopeng HERGUEY,and Joseph DONGHO

Abstract: The main concern of this paper is to prove that the vector space R2 have non trivial KV structure and some of them have non trivail KV cohomology. We propose the explicite computation of one of them.

› Alpha-parallel priors on one-sided truncated exponential family, Masaki Yoshioka and FuyuhikoTanaka

Abstract: In conventional information geometry, the deep relationship between differential geometrical structures such as the Fisher metric and alpha-connections and statistical theory has been investigated for statistical models satisfying regularity conditions. However, the study of information geometry on non-regular statistical models has not been fully investigated. A one-sided truncated exponential family (oTEF) is a typical example. In this study, we define the Riemannian metric on the oTEF model not in a formal way but in the way compatible with the asymptotic properties of MLE in statistical theory. Then, we define alpha-parallel

INFORMATION THEORY AND STATISTICS, OLIVIER RIOUL

› A Historical Perspective on Schützenberger-Pinsker Inequalities, Olivier Rioul

Abstract: This paper presents a tutorial overview of so-called Pinsker inequalities which establish a precise relationship between information and statistics, and whose use have become ubiquitous in many information theoretic applications. According to Stigler's law of eponymy, no scientific discovery is named after its original discoverer. Pinsker's inequality is no exception: Years before the publication of Pinsker's book in 1960, the French medical doctor, geneticist, epidemiologist, and mathematician Marcel-Paul (Marco) Schützenberger, in his 1953 doctoral thesis, not only proved what is now called Pinsker's inequality (with the optimal constant that Pinsker himself did not establish) but also the optimal second-order improvement, more than a decade before Kullback's derivation of the same inequality. We review Schûtzenberger and Pinsker contributions as well as those of Volkonskii & Rozanov, Sakaguchi, McKean, Csiszár, Kullback, Kemperman, Vajda, Bretagnolle & Huber, Krafft & Schmitz, Toussaint, Reid & Williamson, Gilardoni, as well as the optimal derivation of Fedotov, Harremoës, & Topsøe

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› Revisiting lattice tiling decomposition and dithered quantisation, Fabio C. C. Meneghetti Henrique K. Miyamoto Sueli I. R. Costa and Max H. M. Costa

Abstract: A lattice tiling decomposition induces dual operations: quantisation and wrapping, which map the Euclidean space to the lattice and to one of its fundamental domains, respectively. Applying such decomposition to random variables over the Euclidean space produces quantized and wrapped random variables. In studying the characteristic function of those, we show a 'frequency domain' characterisation for deterministic quantisation, which is dual to the known 'frequency domain' characterization of uniform wrapping. In a second part, we apply the tiling decomposition to describe dithered quantisation, which consists in adding noise during quantisation to improve its perceived quality. We propose a noncollaborative type of dithering and show that, in this case, a wrapped dither minimises the Kullback-Leibler divergence to the original distribution. Numerical experiments illustrate this result.

› Geometric Reduction for Identity Testing of Reversible Markov Chains, Geoffrey Wolfer and Shun Watanabe

Abstract: We consider the problem of testing the identity of a reversible Markov chain against a reference from a single trajectory of observations. Employing the recently introduced notion of a lumping-congruent Markov embedding, we show that, at least in a mildly restricted setting, testing identity to a reversible chain reduces to testing to a symmetric chain over a larger state space and recover state-of-the-art sample complexity for the problem.

› On Fisher information matrix, array manifold geometry and time delay estimation, Franck Florin

Abstract: The Fisher information matrix is used to evaluate the minimum variance-covariance of unbiased parameter estimation. It is also used, in natural gradient descent algorithms, to improve learning of modern neural networks. We investigate the Fisher information matrix related to the reception of a signal wave on a sensor array. The signal belongs to a parametric family. The objective of the receiver is to estimate the time of arrival, the direction of arrival and the other parameters describing the signal. Based on the parametric model, Fisher information matrix, array manifold and time delay variances are calculated. With an appropriate choice of parameters, the Fisher matrix is block diagonal and easily invertible. It is possible to estimate the direction of arrival on an array of sensors and the time of arrival whatever the signal parameters are. However, some signal characteristics may have an influence on the asymptotic estimation of the time delay. We give examples with a simple parametric family from the literature.

› On the entropy of rectifiable and stratifiedmeasures, Juan Pablo Vigneaux

Abstract: We summarize some results of geometric measure theory concerning rectifiable sets and measures. Combined with the entropic chain rule for disintegrations (Vigneaux, 2021), they account for some properties of the entropy of rectifiable measures with respect to the Hausdorff measure first studied by (Koliander et al., 2016). Then we present some recent work on stratified measures, which are convex combinations of rectifiable measures. These generalize discrete-continuous mixtures and may have a singular continuous part. Their entropy obeys a chain rule, whose “conditional term” is an average of the entropies of the rectifiable measures involved. We state an asymptotic equipartition property (AEP) for stratified measures that shows concentration on strata of a few “typical dimensions” and that links the conditional term of the chain rule to the volume growth of typical sequences in each stratum.

SYMPLECTIC STRUCTURES OF HEAT & INFORMATION GEOMETRY, FRÉDÉRIC BARBARESCO & PIERRE BIELIAVSKY

› The momentum mapping of the affinereal symplectic group, Richard Cushman

Abstract: In this paper we explain how the cocycle of the momentum map of the action of the affine symplectic group on R2n gives rise to a coadjoint orbit of the odd real symplectic group with a modulus.

› Polysymplectic Souriau Lie Group Thermodynamics and The Geometric Structure of Its Coadjoint Orbits, Mohamed El MORSALANI

Abstract: In 1969, Jean-Marie Souriau introduced a ”Lie Groups Thermodynamics” in Statistical Mechanics in the framework of Geometric Mechanics [21]. Frederic Barbaresco and his collaborators have proved in many papers how the Souriau’s model can be applied within information geometry and geometric deep learning. In this paper we will focus on the extension of Souriau’s symplectic

model to the polysymplectic case. We will describe the polysymplectic model and the fact that coadjoint orbits have a polysymplectic and poly-Poisson structure.

› Polysymplectic Souriau Lie Group Thermodynamics and Entropy Geometric Structure as Casimir Invariant Function, Mohamed El MORSALANI

Abstract: In this paper we will continue our work on the extension of Souriau's symplectic model to the polysymplectic case that has been started in.This paper contains a summary of some original results we will publish in a coming paper in preparation. Here we will show that the entropy is still a Casimir Function as in the Souriau standard model. One of the original ideas is the introduction of an extended Lie-Poisson bracket. With its help we could recover many of the properties and results about the entropy as well as dissipative and production dynamics known from the Souriau standard model.

› Poisson geometry of the statistical Frobenius manifold, Noemie Combe, first author1, Philippe Combe1, and Hanna Nencka

Abstract: New insights on parametric families of probability distributions, related to exponential families have been recently given [4,5,6,7]. Throughout the notion of Frobenius manifolds, a deep relation between the class of exponential statistical manifolds, equipped with flat connection and Topological Field theory was possible [8]. The notion of Frobenius manifolds corresponds to a geometrization of the Witten–Dijkraaf–Verlinde–Verlinde PDE equation. In Yu. Manin's classification, this class of statistical manifolds corresponds to the fourth Frobenius manifolds. We refer to it as the statistical Frobenius manifold. In this work, we prove that this source of Frobenius manifolds is a Poisson manifold (i.e.symplectic with Poisson structures). Following the works of Dubrovin–Novikov, one can define Frobenius manifolds by using equations of hydrodynamical type. Such equations of hydrodynamical type imply the existence of Poisson structures. These new statements lead to connecting this new approach to the works that arose from the theory developed by Koszul–Souriau–Vinberg [2,3]. In particular, it allows to highlight the deep connection existing between those two different insights.

› CANONICAL HAMILTONIAN SYSTEMS IN SYMPLECTIC STATISTICAL MANIFOLDS, Michel Nguiffo Boyom

Abstract: What is named Hamiltonian system in a symplectic manifold (M, ω) is an abelian Poisson subalgebra of the Poisson algebra $(C\infty(M), \pi\omega)$ which is defined by (M, ω). If the manifold M is compact then a Hamiltonian system may be regarded as a moment map of an action of an abelian Lie group. We aim to point out some canonical examples of Hamiltonian systems in symplectic statistical manifolds. The examples we are interested in are eigenfunctions of recursions operators of compatible symplectic statistical manifolds. The abstract should briefly rise the contents of the paper in 15–250 words.

› Riemannian geometry of Gibbs cones associated to nilpotent orbits of simple Lie groups, Pierre Bieliavsky, Valentin Dendoncker, Guillaume Neuttiens, and Jérémie Pierard de Maujouy

Abstract: In this short note, we prove that the Gibbs cone of generalized temperatures associated to a minimal coadjoint orbit of a simple Lie group G of Kahler type is not empty. We study the Fisher-Rao metric in the particular case of G = SL2(R). We prove that, in this case, the Gibbs cone equipped with the Fisher-Rao metric is a Riemannian symmetric space.

› Symplectic Foliation Transverse Structure & Libermann Foliation of Heat Theory and Information Geometry, Frédéric BARBARESCO

Abstract: We introduce a symplectic bifoliation model of Information Geometry and Heat Theory based on Jean-Marie Souriau's Lie Groups Thermodynamics to describe transverse Poisson structure of metriplectic flow for dissipative phenomena. This model gives a cohomological characterization of Entropy, as an invariant Casimir function in coadjoint representation. The dual space of the Lie algebra foliates into coadjoint orbits identified with the Entropy level sets. In the framework of thermodynamics, we associate a symplectic bifoliation structure to describe non-dissipative dynamics on symplectic leaves, and transversal dissipative dynamics, given by Poisson transverse structure. The symplectic foliation orthogonal to the level sets of moment map is the foliation determined by hamiltonian vector fields generated by functions on dual Lie algebra. The orbits of a Hamiltonian action and the level sets of its moment map are polar to each other. Souriau's model could be then interpreted by Mademoiselle Paulette Libermann's foliations, clarified as dual to Poisson Gamma-structure of Haefliger, which is the maximum extension of the notion of moment in the sense of J.M. Souriau, as introduced by P. Molino, M. Condevaux and P. Dazord in papers of "Séminaire Sud-Rhodanien de Geometrie ». The symplectic duality to a symplectically complete foliation, in the sense of Libermann, associates an orthogonal foliation. Paulette Libermann proved that a Legendre foliation on a contact manifold is complete if and only if the pseudo-orthogonal distribution is completely integrable, and that the contact form is locally equivalent to the Poincaré-Cartan integral invariant. Paulette Libermann proved a classical theorem relating to co-isotropic foliations, which notably gives a proof of Darboux's theorem. Finally, we explore Edmond Fédida work on the theory of foliation structures in the language of fully integrable Pfaff systems associated with the Cartan's moving frame.

APPLIED GEOMETRIC LEARNING, PIERRE-YVES LAGRAVE, SANTIAGO VELASCO-FORERO & TEODORA PETRISOR

› Generative Ornstein–Uhlenbeck Markets via Geometric Deep Learning, Anastasis Kratsios and Cody Hyndman

Abstract: We consider the problem of simultaneously approximating the conditional distribution of market prices and their log returns with a single machine learning model. We show that an instance of the GDN model of solves this problem without having prior assumptions on the market's "clipped" log returns, other than that they follow a generalized Ornstein-Uhlenbeck process with a priori unknown dynamics.We provide universal approximation guarantees for these conditional distributions and contingent claims with a Lipschitz payoff function.

› SL(2, Z)-Equivariant Machine Learning with Modular Forms Theory and Applications, Pierre-Yves Lagrave

Abstract: This paper introduces an approach for building Machine Learning (ML) algorithms embedding equivariance mechanisms to the Lie group SL (2, Z) by leveraging on modular forms theory. More precisely, we propose using Eisenstein series to build parametric equivariant operators which can then be combined within usual ML architectures to solve both supervised and unsupervised tasks. We substantiate the interest of using SL (2, Z)-equivariance on simulated Toeplitz Hermitian Positive Definite matrices datasets built to reproduce some of the challenges associated with financial time series analysis.

› k-Splines on SPD manifolds, Margarida Camarinha, Luis Machado, and Fatima Silva Leite

Abstract: The generalization of Euclidean splines to Riemannian manifolds was initially motivated by trajectory planning problems for rigid body motion. The increased interest in non-Euclidean splines was essentially due to its relevance in many areas of science and technology. Lie groups and symmetric spaces play an important role in this context. The manifold of symmetric positive definite (SPD) matrices is used, in particular, in computer vision, with emphasis in medical imaging. Different Riemannian structures have been considered in the SPD, in part to reduce the computational effort. In this paper, we first review the theory of high-order geometric splines for general Riemannian manifolds and its specialization to Lie groups. We then solve the variational problem that gives rise to spline curves on the manifold of symmetric positive definite matrices, equipped with the Log-Cholesky metric and having a Lie group group structure introduced in \cite{Lin:2019}. This enables considerable simplifications and, as a consequence, closed form expressions for higher-order polynomial splines are obtained.

› Geometric Deep Learning: a temperature based analysis of graph neural networks, Lapenna M., Faglioni F., and Zanchetta F., Fioresi R.

Abstract: We examine a Geometric Deep Learning model as a thermodynamic system treating the weights as non-quantum and non-relativistic particles. We define the notion of temperature and study it in the various layers for GCN and GAT models. In the end we make some observations regarding potential future applications of our findings.

STATISTICS, INFORMATION AND TOPOLOGY, PIERRE BAUDOT & GRÉGOIRE SEARGEANT-PERTHUIS

› Categorical Information Geometry, Paolo Perrone

Abstract: Information geometry is the study of interactions between random variables by means of metric, divergences, and their geometry. Categorical probability has a similar aim, but uses algebraic structures, primarily monoidal categories, for that purpose. As recent work shows, we can unify the two approaches by means of enriched category theory into a single formalism, and recover important information-theoretic quantities and results, such as entropy and data processing inequalities.

› Higher Information from Families of Measures -Tom Mainiero

Abstract: We define the notion of a measure family: a pre-cosheaf of finite measures over a finite set; every joint measure on a product of finite sets has an associated measure family. To each measure family there is an associated index, or “Euler characteristic”, related to the Tsallis deformation of mutual information. This index is further categorified by a (weighted) simplicial complex whose topology retains information about the correlations between various subsystems.

› Categorical magnitude and entropy, Stephanie Chen and Juan Pablo Vigneaux

Abstract: Given any finite set equipped with a probability measure, one as a categorical generalization of cardinality. This paper aims to connect becomes the logarithm of the cardinality of the set when the uniform

categories endowed with probability, in such a way that the magnitude for certain finite categories, also known as magnitude, that can be see is recovered when a certain choice of "uniform" probability is made. may compute its Shannon entropy or information content. The entropy probability is used. Leinster introduced a notion of Euler characteristic the two ideas by considering the extension of Shannon entropy to finite categories endowed with probability, in such a way that the magnitude is recovered when a certain choice of "uniform" probability is made.

› A categorical approach to Statistical Mechanics, Grégoire Sergeant-Perthuis

Abstract: 'Rigorous' Statistical Mechanics is centered on the mathematical study of statistical systems. In this article, we show that important concepts in this field have a natural expression in terms of category theory. We show that statistical systems are particular representations of partially ordered sets (posets) and express their phases as invariants of these representations. This work opens the way to the use of homological algebra to compute phases of statistical systems. In particular we compute the invariants of projective poset representations. We remark that in this formalism finite-size systems are allowed to have several phases.

DISTANCE GEOMETRY, GRAPH EMBEDDINGS, AND APPLICATIONS-ANTONIO MUCHERINO

› A Linear Program for Points of Interest Relocation in Adaptive Maps, S.B. Hengeveld, F. Plastria, A. Mucherino, D.A. Pelta

Abstract: The Point-Of-Interest (POI) relocation problem is a challenge encountered during the construction of personalized maps for given groups of users. This kind of maps was already studied and is known in the scientific literature under the name of "adaptive maps". In this work, we formulate this problem as a subclass of the widely studied Distance Geometry Problem (DGP), where some extra constraints are included for taking into account the local orientation of the POIs in the map. These very same constraints allow us to linearise the problem, and hence to propose a new linear program for the POI relocation problem. Our initial computational experiments indicate that our new approach is promising for further investigations.

› Exploration of conformations for an intrinsically disordered protein, Shu-Yu Huang, Chi-Fon Chang, Jung-Hsin Lin, and Thérèse E Malliavin

Abstract: Intrinsically disordered proteins (IDP) are at the center of numerous biological processes, and attract consequently extreme interest in structural biology. A systematic enumeration of protein conformations, based on distance geometry, was performed on SERF1a, a 62-residue IDP involved in interactions with amyloid peptides. The results obtained with the interval Branch-and-Prune (iBP) approach haven been compared with those produced by flexible-meccano, using various predictions for backbone torsion angles ϕ and ψ, provided by TALOS and δ2D. The similarity between profiles of local gyration radii provides to a certain extent a converged view of the SERF1a. A better convergence is observed when using the TALOS inputs than using the δ2D inputs. Flexible-meccano provides a less converged view of the protein conformational space than TAiBP.

› Temporal Alignment of Human Motion Data: A Geometric Point of View, Alice Barbara Tumpach and Peter Kán

Abstract: Temporal alignment is an inherent task in most applications dealing with videos:

action recognition, motion transfer, virtual trainers, rehabilitation, etc. In this paper we dive into the understanding of this task from a geometric point: in particular, we show that the basic properties that are expected from a temporal alignment procedure imply that the set of aligned motions to a template form a slice to a principal fiber bundle for the group of temporal reparameterizations. A temporal alignment procedure provides a reparameterization invariant projection onto this particular slice. This geometric presentation allows to elaborate a consistency check for testing the accuracy of any temporal alignment procedure. We give examples of alignment procedures from the literature applied to motions of tennis players. Most of them use dynamic programming to compute the best correspondence between two motions relative to a given cost function. This step is computationally expensive (of complexity O(NM) where N and M are the numbers of frames). Moreover, most methods use features that are invariant by translations and rotations in R3, whereas most actions are only invariant by translation along and rotation around the vertical axis, where the vertical axis is aligned with the gravitational field. The discarded information contained in the vertical direction is crucial for accurate synchronization of motions. We propose to incorporate keyframe correspondences into the dynamic programming algorithm based on coarse information extracted from the vertical variations, in our case from the elevation of the arm holding the racket. The temporal alignment procedures produced are not only more accurate, but also computationally more efficient.

› A study on the covalent geometry of proteins and its impact on distance geometry, Simon B. Hengeveld, Mathieu Merabti, Fabien Pascale, and Thérèse E Malliavin

Abstract: The Distance Geometry Problem (DGP) involves determining the positions of a set of points in space based on the distances between them. Due to the importance of measuring spatial proximity's between atoms in structural biology, Distance Geometry finds a natural application to protein structure determination. When an instance of the DGP is discretizable, the search tree can be explored using the (interval) branch-and-prune algorithm (iBP). A statistical study on a database of protein structures shows that slight variations are observed in the covalent geometry of the molecules, depending on the Ramachandran region of the protein residues. These variations are in agreement with observations made on high resolution X-ray crystallographic structures. These slight variations may cause atomic clashes when using iBP algorithms to calculate a folded protein structure. In this contribution, we compare two software implementations (MDjeep and ib-png) that attempt to address this issue.

› Pseudo-dihedral angles in proteins providing a new description of the Ramachandran map, Wagner Da Rocha, Carlile Lavor3, Leo Liberti, and Thérèse E Malliavin

Abstract: Since the first years of structural biology, the Ramachandran map has provided a simple definition of the curvilinear geometry of the protein backbone. This definition is mainly based on the values of the dihedral angles ϕ and ψ measured between the heavy atoms of the protein backbone. Nevertheless, angle value discontinuities are observed, particularly in the region of the β-strand secondary structure. We introduce new pseudo-dihedral angles involving hydrogen positions instead of some of the positions of the heavy atoms. We determine simple numerical relationships between the old and new dihedral angles. We show that combining the old and new parameters allows us to overcome the discontinuity problem encountered in the Ramachandran map.

Thursday, August 31st

DAY 2 OF AUTHOR SESSIONS

8:30-9:30

Opening session, Francis BACH, Information Theory with Kernel Methods

INTEGRABLE SYSTEMS AND INFORMATION GEOMETRY (FROM CLASSICAL TO QUANTUM), JEAN-PIERRE FRANCOISE, DAISUKE TARAMA

› Complete integrability of gradient systems on a manifold admitting a potential in odd dimension, Mama Assandje Prosper Rosaire, Dongho Joseph, and Bouetou Bouetou Thomas

Abstract: The aim of this paper is to propose a method to study the complete integrability of gradient systems on an odd dimensional statistical manifold with a potential function. We show that these gradient systems are Hamiltonian and completely integrable.

› Geometry-preserving Lie group integrators for differential equations on the manifold of symmetric positive definite matrices, Lucas Drumetz, Alexandre Reiffers-Masson, Naoufal El Bekri, and Franck Vermet

Abstract: In many applications, one encounters time series that lie on manifolds rather than a Euclidean space. In particular, covariance matrices are ubiquitous mathematical objects that have a non Euclidean structure. The application of Euclidean methods to integrate differential equations lying on such objects does not respect the geometry of the manifold, which can cause many numerical issues. In this paper, we propose to use Lie group methods to define geometry-preserving numerical integration schemes on the manifold of symmetric positive definite matrices. These can be applied to a number of differential equations on covariance matrices of practical interest. We show that they are more stable and robust than other classical or naive integration schemes on an example.

› The Phase Space Description of the Geodesics on the Statistical Model on a Finite Set, Trajectory-Confinement and Integrability, Yoshio Uwano

Abstract: The geodesics on the statistical model, Sn−1, on a finite set with n elements are studied as dynamical systems on the phase space, T∗ Sn−1, namely the cotangent bundle of Sn−1. The Riemannian geodesics are described by a Hamiltonian equation on T∗ Sn−1 like in the case [1] of the exponential geodesics. In contrast, the mixture geodesics are described by a non-Hamiltonian first-order differential equation on T*Sn−1. Both of the equations are integrable in the sense that they are solvable by quadrature. Through this study, the symplectic reduction to have the phase space, T∗ Sn−1, works effectively. In particular, a novel clear account is given for confining the mixture geodesics in Sn−1 by the use of the reduction.

› Geodesic flows of α-connections for statistical transformation models on a compact Lie group, Daisuke Tarama and Jean-Pierre Françoise

Abstract: The geodesic flows of the α-connections are studied for a class of statistical transformation models on a compact Lie group. The Fisher-Rao (semi-definite) metric and the Amari-Chentsov cubic tensor, as well as the associated α-connections, are considered for general statistical models. Then, the general framework of statistical transformation models is explained following Barndorff-Nielsen and his coauthors. In Particular, a couple of formulae are given for the Fisher-Rao (semi-definite) metric and the Amari-Chentsov cubic tensor for statistical transformation models, which are used in the latter part of the present paper. The α-connections and the associated geodesic flows are considered for the class of statistical transformation models introduced previously by the authors of the present paper. The ordinary differential equations on the corresponding Lie algebras are explicitly obtained to describe the geodesic flows on the basis of Euler-Poincaré and the Lie-Poisson equations on the Lie algebra.

DIVERGENCES IN STATISTICS & MACHINE LEARNING, MICHEL BRONIATOWSKI & WOLFGANG STUMMER

› On a Cornerstone of Bare-Simulation Distance / Divergence Optimization, Michel Broniatowski and Wolfgang Stummer

Abstract: In information theory, as well as in the adjacent fields of statistics, geometry, machine learning and artificial intelligence, it is important to solve high-dimensional optimization problems on directed distances (divergences), under very non-restrictive (e.g. non-convex) constraints. Such a task can be comfortably achieved by the new dimension- free bare (pure) simulation method of [6],[7]. In the present paper, we give some new insightful details on one cornerstone of this approach.

› Aggregated Tests Based on Supremal Divergence Estimators for non-Regular Statistical Models, Jean-Patrick Baudry, Michel Broniatowski, and Cyril Thommeret.

Abstract: A methodology is proposed to build statistical test procedures pertaining to models with incomplete information; the lack of information corresponds to a nuisance parameter in the description of the model. The supremal approach based on the dual representation of CSAM divergences (or f divergences) is fruitful; it leads to M-estimators with simple and standard limit distribution, and it is versatile with respect to the choice of the divergence. Duality approaches to divergence-based optimisation are widely considered in statistics, data analysis and machine learning: indeed, they avoid any smoothing or grouping technique which would be necessary for a more direct divergence minimisation approach for the same problem. We are interested in a widely considered but still open problem which consists in testing the number of components in a parametric mixture. Although common, this is still a challenging problem since the corresponding model is non-regular particularly because of the true parameter lying on the boundary of the parameter space. This range of problems has been considered by many authors who tried to derive the asymptotic distribution of some statistic under boundary conditions. The present approach based on supremal divergence M-estimators makes the true

parameter an interior point of the parameter space, providing a simple solution for a difficult question. To build a composite test, we aggregate simple tests.

› Extensive Entropy Functionals and Non-Ergodic Random Walks, Valérie Girardin and Philippe Regnault

Abstract: According to Tsallis seminal book on complex systems: «an entropy of a system is extensive if, for a large number n of its elements, the entropy is (asymptotically) proportional to n». According to whether the focus is on the system or on the entropy, an entropy is extensive for a given system or a system is extensive for a given entropy. Yet exhibiting the right classes of random sequences that are extensive for the right entropy is far from being trivial, and is mostly a new area for generalized entropies. This paper aims at giving some examples or classes of random walks that are extensive for Tsallis entropy.

› Empirical Likelihood with Censored Data, M. BOUKELOUA and A. KEZIOU

Abstract: In this paper, we consider semiparametric models defined by moment constraints, with unknown parameter, for right censored data. We derive estimates, confidence regions and tests for the parameter of interest, by means of minimizing empirical divergences between the considered models and the Kaplan-Meier empirical measure. This approach leads to a new natural adaptation of the empirical likelihood method to the present context of right censored data. The asymptotic properties of the proposed estimates and tests are studied, including consistency and asymptotic distributions. Simulation results are given, illustrating the performance of the proposed estimates and confidence regions.

GEOMETRIC FEATURES EXTRACTION IN MEDICAL IMAGING, STÉPHANIE JEHAN-BESSON & PATRICK CLARYSSE

› Diffeomorphic ICP registration for single and multiple point sets, Adrien Wohrer

Abstract: We propose a generalization of the ICP registration algorithm which accommodates diffeomorphic mappings in the LDDMM framework. The algorithm is formulated as a well-posed probabilistic inference, and requires to solve a novel variation of LDDMM landmark registration with an additional term involving the Jacobian of the mapping. The algorithm can easily be generalized to construct a diffeomorphic, statistical atlas of multiple point sets. The method is successfully validated on a first set of synthetic data.

› Chan-Vese Attention U-Net: An attention mechanism for robust segmentation, Nicolas Makaroff and Laurent D. Cohen

Abstract: When studying the results of a segmentation algorithm using convolutional neural networks, one wonders how robust the results are. This leads to questioning the possibility of using such an algorithm in applications where there is little room for doubt. We propose in this paper a new attention gate based on the use of Chan-Vese energy minimization to control more precisely the segmentation masks given by a standard CNN architecture such as the U-Net model. This mechanism allows to obtain a constraint on the segmentation based on the resolution of a PDE. The study of the results allows us to observe the spatial information retained by the neural network on the region of interest and obtains competitive results on the binary segmentation. We illustrate the

efficiency of this approach for medical image segmentation on a database of brain images.

› Using a Riemannian elastic metric for statistical analysis of tumor cell shape heterogeneity, Wanxin Li, Ashok Prasad, Nina Miolane, and Khanh Dao Duc

Abstract: We examine how a specific instance of the elastic metric, the Square Root Velocity (SRV) metric, can be used to study and compare cellular morphologies from the contours they form on planar surfaces. We process a dataset of images from osteocarcoma (bone cancer) cells that includes different treatments known to affect the cell morphology, and perform a comparative statistical analysis between the linear and SRV metrics. Our study indicates superior performance of the SRV at capturing the cell shape heterogeneity, with a better separation between different cell groups when comparing their distance to their mean shape, as well as a better low dimensional representation when comparing stress statistics. Therefore, our study suggests the use of a Riemannian metric, such as the SRV as a potential tool to enhance morphological discrimination for large datasets of cancer cell images.

› Perturbation of Fiedler vector: interest for graph measures and shape analysis, Julien Lefevre, Justine Fraize, and David Germanaud

Abstract: In this paper we investigate some properties of the Fiedler vector, the so-called first non-trivial eigenvector of the Laplacian matrix of a graph. There are important results about the Fiedler vector to identify spectral cuts in graphs but far less is known about its extreme values and points. We propose a few results and conjectures in this direction. We also bring two concrete contributions, i) by defining a new measure for graphs that can be interpreted in terms of extremality (inverse of centrality), ii) by applying a small perturbation to the Fiedler vector of cerebral shapes such as the corpus callosum to robustify their parameterization.

STATISTICAL SHAPE ANALYSIS AND MORE NON-EUCLIDEAN STATISTICS, STEPHAN HUCKEMANN & XAVIER PENNEC

› Exploring Uniform Finite Sample Stickiness, Susanne Ulmer, Do Tran Van and Stephan F. Huckemann

Abstract: It is well known, that Fréchet means on non-Euclidean spaces may exhibit nonstandard asymptotic rates depending on curvature. Even for distributions featuring standard asymptotic rates, there are non-Euclidean effects, altering finite sampling rates up to considerable sample sizes. These effects can be measured by the variance modulation function proposed by Pennec (2019). Among others, in view of statistical inference, it is important to bound this function on intervals of sampling sizes. In a first step into this direction, for the special case of a K-spider we give such an interval based only on folded moments and total probabilities of spider legs and illustrate the method by simulations.

› Characterization of invariant inner products, Yann Thanwerdas and Xavier Pennec

Abstract: In several situations in differential geometry, one can be interested in determining all inner products on a vector space that are invariant under a given group action. For example, bi-invariant Riemannian

metrics on a Lie group G are characterized by Ad(G)-invariant inner products on the Lie algebra g. Analogously, G-invariant Riemannian metrics on a homogeneous spaceM= G/H are characterized by Ad(H)- invariant inner products on the tangent space THM. In addition, given a G-equivariant diffeomorphism between a manifold M and a Euclidean space V , G-invariant log-Euclidean metrics can be defined on M by pullback of G-invariant inner products on V . There exists a general procedure based on representation theory to find all invariant inner products on a completely reducible Euclidean space. It consists in changing the viewpoint from invariant inner products to equivariant automorphisms.

The goal of this work is to diffuse this method to communities of applied mathematics which use differential geometry. Therefore, in this work, we recall this general method that we did not find elsewhere, along with an elementary presentation of the basics of representation theory.

› Types of Stickiness in BHV Phylogenetic Tree Spaces and Their Degree, Lars Lammers, Do Tran Van1, Tom M. W. Nye, and Stephan F. Huckemann

Abstract: It has been observed that the sample mean of certain probability distributions in Billera-Holmes-Vogtmann (BHV) phylogenetic spaces is confined to a lower-dimensional subspace for large enough sample size. This non-standard behavior has been called stickiness and poses difficulties in statistical applications when comparing samples of sticky distributions.We extend previous results on stickiness to show the equivalence of this sampling behavior to topological conditions in the special case of BHV spaces. Furthermore, we propose to alleviate statistical comparision of sticky distributions by including the directional derivatives of the Fréchet function: the degree of stickiness

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› Towards Quotient Barycentric Subspaces, Anna Calissano , Elodie Maignant , and Xavier Pennec

Abstract: Barycentric Subspaces have been defined in the context of manifolds using the notion of exponential barycenters. In this work, we extend the definition to quotient spaces which are not necessary manifolds. We define an alignment map and an horizontal logarithmic map to introduce Quotient Barycentric Subspaces (QBS). Due to the discrete group action and the quotient structure, the characterization of the subspaces and the estimation of the projection of a point onto the subspace is far from trivial.We propose two algorithms towards the estimation of the QBS and we discussed the results, underling the possible next steps for a robust estimation and their application to different data types.

› Rethinking the Riemannian logarithm on flag manifolds as an orthogonal alignment problem, Tom Szwagier and Xavier Pennec

Abstract: Flags are sequences of nested linear subspaces of increasing dimensions. They belong to smooth manifolds generalizing Grassmannians and bring a richer multi-scale point of view to the traditional subspace methods in statistical analysis. Hence, there is an increasing interest in generalizing the formulae and statistical methods already developed for Grassmannians to flag manifolds. In particular, it is critical to compute accurately and efficiently the geodesic distance and the logarithm due to their fundamental importance in geometric statistics. However,

there is no explicit expression known in the case of flags. In this work, we exploit the homogeneous quotient space structure of flag manifolds and rethink the geodesic endpoint problem as an alignment of orthogonal matrices on their equivalence classes. The relaxed problem with the Frobenius metric surprisingly enjoys an explicit solution. This is the key to modify a previously proposed algorithm. We show that our explicit alignment step brings drastic improvements in accuracy, speed and radius of convergence, in addition to overcoming the combinatorial issues raised by the non-connectedness of the equivalence classes.

FLUID MECHANICS AND SYMMETRY, FRANÇOIS GAY-BALMAZ ET CESARE TRONCI

› Casimir-dissipation stabilized stochastic rotating shallow-water equations on the sphere, Werner Bauer and Rüdiger Brecht

Abstract: We introduce a structure preserving discretization of stochastic rotating shallow water equations, stabilized with an energy conserving Casimir (i.e. potential enstrophy) dissipation. A stabilization of a stochastic scheme is usually required as, by modeling subgrid effects via stochastic processes, small scale features are injected which often lead to noise on the grid scale and numerical instability. Such noise is usually dissipated with a standard diffusion via a Laplacian which necessarily also dissipates energy. In this contribution we study the effects of using an energy preserving selective Casimir dissipation method compared to diffusion via a Laplacian. For both, we analyze stability and accuracy of the stochastic scheme. The results for a test case of a barotropically unstable jet show that Casimir dissipation allows for stable simulations that preserve energy and exhibit more dynamics than comparable runs that use a Laplacian.

› High-order structure-preserving algorithms for plasma hybrid models, Stefan Possanner, Florian Holderied1, Yingzhe Li, Byung Kyu Na, Dominik Bell, Said Hadjout, and Yaman Güçlü

Abstract: Wave-particle resonance plays a crucial role for the stability of burning plasma in magnetically confined fusion. We present provably stable algorithms for the accurate simulation of such (nonlinear) processes on long time scales. Our approach combines several recent advances in theoretical and numerical research: on the theoretical side, we rely on Hamiltonian fluid-kinetic hybrid models, largely based on the works of Tronci [35]. To achieve high-order discretization, we use finite element exterior calculus (FEEC) introduced by Arnold et al. [5] based on B-splines coupled with particle-in cell for the resonating particles. Last but not least, structure-preservation (in a sense to be dened more clearly in the text) is achieved by discretization of Poisson brackets, rather than PDEs, following the ideas of Kraus et al. [27]. These efforts culminate in the creation of the open-source software package STRUPHY (STRUcture-Preserving HYbrid codes) [1] which makes available to the scientific community a growing number of plasma hybrid codes, ready for use.

› Hydrodynamics of the probability current in Schrödinger theory, Mauro Spera

Abstract: The present note explores some hydrodynamical aspects of the probability current in Schrödinger's theory based on the observation that the latter shares the same trajectories with the Madelung velocity, whilst exhibiting a regular behaviour. This appears to be useful in analyzing the motion of the zero set of the wave function.

› Variational geometric description for fluids with permeable boundaries, François Gay-Balmaz, Meng Wu, and Chris Eldred

Abstract: Motivated by modelling and numerical applications in geophysical fluid dynamics, such as the outflow of free or forced waves, we present a Lagrangian variational formulation for fluids exchanging energy with its surrounding through the boundary of its spatial domain. We give the variational formulation in the material description and deduce the Eulerian variational formulation by applying reduction by symmetry in the Lagrangian framework. In the material description we use the classical Hamilton principle applied to fluid trajectories, appropriately amended to incorporate boundary forces via a Lagrange-d'Alembert approach, and to take into account only on the fluid particles present in the fluid domain. In particular, our approach extends to the case of permeable domains the well-known geometric description of fluid motion via diffeomorphism groups.

› Lagrangian trajectories and closure models in quantum-classical dynamics, Cesare Tronci and François Gay-Balmaz

Abstract: Mixed quantum-classical models have been proposed in several contexts to overcome the computational challenges of fully quantum approaches. However, current models typically suffer from longstanding consistency issues, and, in some cases, invalidate Heisenberg's uncertainty principle. Here, we present a fully Hamiltonian theory of quantum-classical dynamics that appears to be the first to ensure a series of consistency properties, beyond positivity of quantum and classical densities. Based on Lagrangian phase-space paths, the model possesses a quantum-classical Poincaré integral invariant as well as infinite classes of Casimir functionals.We also exploit Lagrangian trajectories to formulate a finite-dimensional closure scheme for numerical implementations.

› A discrete version for vortex loops in 2D fluids, Cornelia Vizman

Abstract: The manifold of weighted vortex loops in the plane that enclose a fixed area and have a constant total vorticity is known to be a coadjoint orbit of the area preserving diffeomorphism group, obtained by symplectic reduction of the space of parametrized loops. Moreover, it admits a polarization that allows the decomposition into «coordinates», the unparametrized loop, and «momenta», the vorticity density. We give discrete versions of all these results, starting from the configuration space of k-tuples of points in the plane, endowed with an infinitesimal Hamiltonian R-action having the area function as momentum map.

DEEP LEARNING: METHODS, ANALYSIS AND APPLICATIONS TO MECHANICAL SYSTEMS, ELENA CELLEDONI, JAMES JACKAMAN, DAVIDE MURARI AND BRYNJULF OWREN

› DL4TO: A Deep Learning Library for Sample-Efficient Topology Optimization, David Erzmann, S¨oren Dittmer, Henrik Harms, and Peter Maas

Abstract: We present and publish the DL4TO software library, a Python library for three-dimensional topology optimization. The framework is based on PyTorch and allows easy integration with neural networks.
The library fills a critical void in the current research toolkit on the intersection of

deep learning and topology optimization. We present the structure of the library's main components and how the library enabled the incorporation of physics concepts into deep models.

› Learning Hamiltonian Systems with Mono-Implicit Runge–Kutta Methods, Håkon Noren

Abstract: Numerical integrators could be used to form interpolation conditions when training neural networks to approximate the vector field of an ordinary differential equation (ODE) from data. When numerical one-step schemes such as the Runge–Kutta methods are used to approximate the temporal discretization of an ODE with a known vector field, properties such as symmetry and stability are much studied. Here, we show that using mono-implicit Runge–Kutta methods of high order allows for accurate training of Hamiltonian neural networks on small datasets. This is demonstrated by numerical experiments where the Hamiltonian of the chaotic double pendulum in addition to the Fermi– Pasta–Ulam–Tsingou system is learned from data.

› Optimisation via conformal Hamiltonian systems on manifolds with application to deep learning, Marta Ghirardelli

Abstract: The Nesterov and Polyak's heavy ball method are examples of optimisation methods that can be seen as discretizations of a conformal Hamiltonian system in Euclidean spaces. Recently, there has been an interest in considering such type of optimisation methods on manifolds, for instance in training algorithms for neural networks. This is a possible remedy for the problem of vanishing or exploding gradients in recurrent neural networks. We will here present a first approach in combining these two aspects by considering conformal Hamiltonian systems on manifolds together with their discretization. Given a symplectic manifold (M, ω), those diffeomorphisms preserving the symplectic 2-form ω up to a constant are called conformal. We then say that a vector field is conformal if its flow is conformal [2]. Structure-preserving discretizations for a particular class of the latter, namely the dissipative conformal Hamiltonian systems, are well studied in the Euclidean setting e.g. in [1]. There we find Nesterov's accelerated gradient, Polyaks's heavy ball and a relativistic gradient descent method. We aim at seeing how these methods would look like if we choose the setting to be a manifold. Instead of generalizing directly the Euclidean-setting schemes, we start from a study of the general theory of such conformal vector fields on a manifold.We then provide some examples of them which are used (or can be used) in optimisation. From there, we derive discretization schemes which would correspond to the aforementioned methods when going back to the Euclidean setting. Some numerical illustrations conclude the work.

› SE(3)-equivariant hemodynamic field estimation in 3D artery models via graph neural networks, Julian Suk Pim de Haan, Phillip Lippe, Christoph Brune and Jelmer M. Wolterink

Abstract: Coronary hemodynamic fields could be beneficial biomarkers for cardiovascular disease diagnosis, prognosis and treatment planning. Computational fluid dynamics (CFD) can obtain velocity fields from 3D artery models, but its meticulous setup and time-consuming nature hinder clinical acceptance. To address this, we propose using graph neural networks (GNN) as an efficient method to estimate 3D hemodynamic fields mapped to the vertices of artery meshes. Inducing problem-spcific symmetry, we employ SE(3)-equivariant GNNs and train them on synthetic arteries equipped with CFD-generated hemodynamic

fields. Our GNNs achieve considerable speed-up compared to CFD and are robust to misalignment of the input mesh.1.

› A geometric view on the role of nonlinear feature maps in few-shot learning, Oliver J. Sutton, Alexander N. Gorban, and Ivan Y. Tyukin

Abstract: We investigate the problem of successfully learning from just a few examples of data points in a binary classification problem, and present a brief overview of some recent results on the role of nonlinear feature maps in this challenging task. Our main conclusion is that successful learning and generalisation may be expected to occur with high probability, despite the small training sample, when the nonlinear feature map induces certain fundamental geometric properties in the mapped data.

› Learning discrete Lagrangians for variational PDEs from data and detection of travelling waves, Christian Offen and Sina Ober-Blöbaum

Abstract: The article shows how to learn models of dynamical systems from data which are governed by an unknown variational PDE. Rather than employing reduction techniques, we learn a discrete field theory governed by a discrete Lagrangian density Ld that is modelled as a neural network. Careful regularisation of the loss function for training Ld is necessary to obtain a field theory that is suitable for numerical computations: we derive a regularisation term which optimises the solvability of the discrete Euler–Lagrange equations. Secondly, we develop a method to find solutions to machine learned discrete field theories which constitute travelling waves of the underlying continuous PDE.

COMPUTATIONAL INFORMATION GEOMETRY AND DIVERGENCES, FRANK NIELSEN & OLIVIER RIOUL

› Quasi-arithmetic centers, quasi-arithmetic mixtures, and the Jensen-Shannon r-divergences, Frank Nielsen

Abstract: We first explain how the information geometry of Bregman manifolds brings a natural generalization of scalar quasi-arithmetic means that we term quasi-arithmetic centers. We study the invariance and equivariance properties of quasi-arithmetic centers from the viewpoint of the Fenchel-Young canonical divergences. Second, we consider statistical quasi-arithmetic mixtures and define generalizations of the Jensen-Shannon divergence according to geodesics induced by affine connections.

› A numerical approximation method for the Fisher-Rao distance between multivariate normal Distributions, Frank Nielsen

Abstract: We present a method to approximate Rao's distance between multivariate normal distributions based on discretizing curves joining normal distributions and approximating Rao distances between successive nearby normals on the curve by using Jeffrey's divergence. We consider experimentally the linear interpolation curves in the ordinary, natural and expectation parameterizations of the normal distributions. We further consider a curve derived from the Calvo and Oller's isometric embedding of the Fisher-Rao d-variate normal manifold into the cone of (d + 1) x (d + 1) symmetric positive-de_nite matrices [Journal of multivariate analysis 35.2 (1990): 223-242]. Last, we present some informationgeometric properties of the Calvo and Oller's mapping.

› On the f-divergences between hyperboloid and Poincaré distributions, Frank Nielsen and Kazuki Okamura

Abstract: Hyperbolic geometry has become popular in machine learning due to its capacity to embed hierarchical graph structures with low distortions for further downstream processing. It has thus become important to consider statistical models and inference methods for data sets grounded in hyperbolic spaces. In this note, we study f-divergences between the Poincaré distributions and the related hyperboloid distributions.

› Geometry of Parametric Binary Choice Models, Hisatoshi Tanaka

Abstract: In this study, we consider parametric binary choice models from the perspective of information geometry. The set of models is a dually flat manifold with dual connections, which are naturally derived from the Fisher information metric. Under the dual connections, the canonical divergence and the Kullback–Leibler (KL) divergence of the binary choice model coincide if and only if the model is a logit. The results are applied to a logit estimation with linear constraints

› A q-analogue of the family of Poincaré distributions on the upper half plane, Koichi Tojo and Taro Yoshino

Abstract: The authors suggested a family of Poincaré distributions on the upper half plane, which is essentially the same as a family of hyper- boloid distributions on the two-dimensional hyperbolic space. This family has an explicit form of normalizing constant and is SL(2;R)-invariant. In this paper, as a q-analogue of Poincaré distributions, we propose a q-exponential family on the upper half plane with an explicit form of normalizing constant and show that it is also SL(2;R)-invariant.

› λ-Deformed Evidence Lower Bound (λ-ELBO) using Rényi and Tsallis Divergence, Kaiming Cheng and Jun Zhang

Abstract: We investigate evidence lower bound (ELBO) with generalized/ deformed entropy and generalized/deformed relative entropy, in place of Shannon entropy and KL divergence in the standard framework. Two equivalent forms of deformed ELBO have been proposed, suitable for either Tsallis or Rényi deformation, that have been unified in the recent framework of λ-deformation (Wong and Zhang, 2022). Both lead to the corresponding decomposition formula for λ-ELBO, now for any real λ (with λ = 0 reducing to the standard case). The meaning of the deformation factor for variational autoencoder (VAE) is investigated for the λ-deformed ELBO. The results show that the λ values around 0.5 generally achieve better performance in image reconstruction for generative models.

PROBABILITY AND STATISTICS ON MANIFOLDS, CYRUS MOSTAJERAN

› Variational Gaussian approximation of the Kushner optimal filter, Marc Lambert, Silvère Bonnabel, and Francis Bach

Abstract: In estimation theory, the Kushner equation provides the theoretical evolution of the probability density of the state of a stochastic dynamical system given noisy observations, in continuous time. We propose herein a new way to approximate the solution of the Kushner equation through tractable variational Gaussian approximations of two proximal losses associated with the propagation and update steps of the

probability density. The first is a proximal loss based on the Bures-Wasserstein metric and the second is a proximal loss based on the Fisher metric. The solution to this last proximal step is given by implicit updates on the mean and covariance that we proposed earlier. These two variational solutions can be fused and converge to a set of stochastic differential equations on the Gaussian's mean and covariance matrix. These equations are consistent with the Kalman-Bucy and Riccati equations in the linear case and generalize them in the nonlinear one.

› Learning with Symmetric Positive Definite Matrices via Generalized Bures-Wasserstein Geometry, Andi Han, Bamdev Mishra, Pratik Jawanpuria, and Junbin Gao

Abstract: Learning with symmetric positive definite (SPD) matrices has many applications in machine learning. Consequently, understanding the Riemannian geometry of SPD matrices has attracted much attention lately. A particular Riemannian geometry of interest is the recently proposed Bures-Wasserstein (BW) geometry which builds on the Wasserstein distance between the Gaussian densities. In this paper, we propose a novel generalization of the BW geometry, which we call the GBW geometry. The proposed generalization is parameterized by a symmetric positive definite matrix M such that when M = I, we recover the BW geometry. We provide a rigorous treatment to study various differential geometric notions on the proposed novel generalized geometry which makes it amenable to various machine learning applications. We also present experiments that illustrate the efficacy of the proposed GBW geometry over the BW geometry.

› Fisher-Rao Riemannian geometry of equivalent Gaussian measures on Hilbert space, Hà Quang Minh

Abstract: This work presents an explicit description of the Fisher-Rao Riemannian metric on the Hilbert manifold of equivalent centered Gaussian measures on an infinite-dimensional Hilbert space. We show that the corresponding quantities from the finite-dimensional setting of Gaussian densities on Euclidean space, including the Riemannian metric, Levi-Civita connection, curvature, geodesic curve, and Riemannian distance, when properly formulated, directly generalize to this setting. Furthermore, we discuss the connection with the Riemannian geometry of positive definite unitized Hilbert-Schmidt operators on Hilbert space, which can be viewed as a regularized version of the current setting.

› The Gaussian kernel on the circle and spaces that admit isometric embeddings of the circle, Nathael Da Costa, Cyrus Mostajeran, and Juan-Pablo Ortega

Abstract: On Euclidean spaces, the Gaussian kernel is one of the most widely used kernels in applications. It has also been used on non-Euclidean spaces, where it is known that there may be (and often are) scale parameters for which it is not positive definite. Hope remains that this kernel is positive definite for many choices of parameter. However, we show that the Gaussian kernel is not positive definite on the circle for any choice of parameter. This implies that on metric spaces in which the circle can be isometrically embedded, such as spheres, projective spaces and Grassmannians, the Gaussian kernel is not positive definite for any parameter.

› Determinantal expressions of certain Integrals on symmetric spaces, Salem Said and Cyrus Mostajeran

Abstract: The integral of a function f defined on a symmetric space M ‘ G=K may be

expressed in the form of a determinant (or Pfaffian), when f is K-invariant and, in a certain sense, a tensor power of a positive function of a single variable. The paper presents a few examples of this idea and discusses future extensions. Specifically, the examples involve symmetric cones, Grassmann manifolds, and classical domains.

› Projective Wishart distributions, Emmanuel Chevallier

Abstract: We are interested in the distribution of Wishart samples after forgetting their scaling factors. We call such a distribution a projective Wishart distribution. We show that projective Wishart distributions have strong links with the affine-invariant geometry of symmetric positive definite matrices in the real case or Hermitian positive definite matrices in the complex case. First, the Frechet mean of a projective Wishart distribution is the covariance parameter, up to a scaling factor, of the corresponding Wishart distribution. Second, in the case of 2 × 2 matrices, the densities have simple expressions in term of the affine-invariant distance.

GEOMETRIC METHODS IN MECHANICS AND THERMODYNAMICS, FRANÇOIS GAY-BALMAZ ET HIROAKI YOSHIMURA

› A dually flat geometry for spacetime in 5d, Jan Naudts

Abstract: A model of spacetime is presented. It has an extension to five dimensions where the geometry is flat because it is by assumption the dual of the Euclidean geometry w.r.t. an arbitrary positive-denite metric. The 4-d geodesics are characterized by five conserved quantities, one of which is chosen freely. Euler-Lagrange equations of motion are established for the 4-d coordinates. They contain external forces which originate from motion in the fifth dimension. An example is worked out in which the motion of the fifth coordinate is that of a dynamical system with attracting and repelling states.

› Structure-preserving discretization of the Cahn-Hilliard equations recast as a port-Hamiltonian system, Antoine Bendimerad-Hohl, Ghislain Haine, and Denis Matignon

Abstract: The structure-preserving discretization of the Cahn-Hillard equation, a phase field model describing phase separation with diffuse interface, is proposed using the Partitioned Finite Element Method. The discrete counter-part of the power balance is proved and a sufficient condition for the phase preservation is provided.

› Infinite Dimensional Lagrange–Dirac Mechanics with Boundary Conditions, Alvaro Rodriguez Abella, François Gay–Balmaz and Hiroaki Yoshimura

Abstract: The Lagrange–Dirac theory is extended to systems defined on the family of smooth functions on a manifold with boundary, which provides an instance of systems with a Fréchet space as a configuration space. To that end, we introduce the restricted cotangent bundle, a vector subbundle of the topological cotangent bundle which contains the partial derivatives of Lagrangian functions defined through a density. The main achievement of our proposal is that the Lagrange–Dirac equations on the restricted cotangent bundle properly account for the boundary value problem, i.e., the boundary conditions do not need to be imposed ad hoc, but they

arise naturally from the Lagrange–Dirac formulation. After giving the main theoretical results, and showing how boundary forces can be naturally included in the Lagrange–Dirac formulation, we illustrate our framework with the dynamical equations of a vibrating membrane.

› Variational integrators for stochastic Hamiltonian systems on Lie groups, Meng Wu and François Gay-Balmaz

Abstract: Motivated by recent advances in stochastic geometric modelling in fluid dynamics, we derive a variational integrator for stochastic Hamiltonian systems on Lie groups by using a discrete version of the stochastic phase space principle. The structure preserving properties of the resulting scheme, such as its symplecticity and preservation of coadjoint orbits is given, as well as a discrete Noether theorem associated to subgroup symmetries. Preliminary numerical illustrations are provided.

› Hamiltonian variational formulation for non-simple thermodynamic systems, Hiroaki Yoshimura and Françcois Gay-Balmaz

Abstract: A Lagrangian variational formulation for nonequilibrium thermodynamics was proposed in [2,3,4]. In this paper, we develop a Hamiltonian analogue of the Lagrangian variational formulation for non-simple thermodynamic systems. We start with the Lagrangian variational formulation for simple systems, where the Lagrangian is degenerate. Under some assumption, we show how to construct the Hamiltonian variational formulation for nonequilibrium thermodynamics for the simple case. Then, we extend it to the case of adiabatically closed non-simple systems, in which there exists several entropy variables in addition to the mechanical variables. Finally, we illustrate our theory by some examples of the adiabatic piston problem.

› Conservation laws as part of Lagraigna reduction. Application to image evolution, Marco Castrillón López

Abstract: This note collects a series of result into a single formulation. Namely, it is proved that when reduction is performed to a symmetric Lagrangian, the reduced variational equations can be split into two part, one of them is exactly the Noether theorem. Conservation laws enter into reduction as part of the new variaitonal equations. We give a short description of tis situation in the case of evolution of circles in the plane.

› Madelung transform and variational asymptotics in Born-Oppenheimer molecular dynamics, Paul Bergold and Cesare Tronci

Abstract: While Born-Oppenheimer molecular dynamics (BOMD) has been widely studied by resorting to powerful methods in mathematical analysis, this paper presents a geometric formulation in terms of Hamilton's variational principle and Euler-Poincaré reduction by symmetry Upon resorting to the Lagrangian hydrodynamic paths made available by the Madelung transform, we show how BOMD arises by applying asymptotic methods to the variational principles underlying different continuum models and their particle closure schemes. In particular, after focusing on the hydrodynamic form of the fully quantum dynamics, we show how the recently proposed bohmion scheme leads to an alternative implementation of BOMD. In addition, we extend our analysis to models of mixed quantum-classical dynamics.

Friday, September 1st

DAY 3 OF AUTHOR SESSIONS

8:30-9:30

Opening session, Diarra FALL, Statistics Methods for Medical Image Processing and Reconstruction

THE GEOMETRY OF QUANTUM STATES, FLORIO M. CIAGLIA & FABIO DI COSMO

› Monotonicity of the Scalar Curvature of the Quantum Exponential Family for Transverse-Field Ising chains -Takemi Nakamura

Abstract: The monotonicity of the scalar curvature of the state space equipped with the Bogoliubov-Kubo-Mori metric under more mixing a state is an important conjecture called the Petz conjecture. From the standpoint of quantum statistical mechanics, the quantum exponential family, a special submanifold of the state space, is central rather than the full state space. In this contribution, we investigate the monotonicity of the scalar curvature of the submanifold with respect to temperature for transverse-field Ising chains in various sizes and find that the monotonicity breaks down for the chains in finite sizes, whereas the monotonicity seems to hold if the chain is non-interacting or infinite-size. Our results suggest that finite-size effects can appear in the curvature through monotonicity with respect to majorization.

› Can Cencov Meet Petz, F. M. Ciaglia, F. Di Cosmo,, and L.Gonzalez-Bravo

Abstract: We discuss how to exploit the recent formulation of classical and quantum information geometry in terms of normal states on W*-algebras to formulate a problem that unifies Cencov's theorem and Petz's theorem.

› Geometric Quantum States and Lagrangian Polar Duality: Quantum Mechanics without Wavefunctions, Maurice A. de Gosson

Abstract: We propose a geometric formulation of Gaussian (and more general) pure quantum states based on an extended version of polar duality based on the notion of Lagrangian frame (a Lagrangian frame in symplectic space is a pair of transverse Lagrangian planes in that space). Our approach leads to the replacement of the usual interpretation of the uncertainty principle without using the ad hoc notion of spreading, which might lead to a notion of quantum mechanical phase space.

› Souriau's Geometric Principles for Quantum Mechanics, Frederic BARBARESCO

Abstract: As Landau and Lifchitz have pointed out, the relations between quan-tum mechanics and classical mechanics are of a very particular type: they coexist instead of succeeding each other. Any analysis of quantum structure is neces-sarily twofold; especially geometric analysis. We will avoid any ambiguity by putting in the first part, «classic», everything that can be put there. In particular the study of symmetries; and also, as we shall see, the role of Planck's constant. Then two "classically" defined geometric

structures (prequantization, generator group) make it possible to determine what the "quantum states" are: the solutions of a certain system of inequalities. In this sense therefore, the program of geo-metric quantization is carried out. A few examples show that the usual quantum structures are indeed found in all their details. But the choice and the own exist-ence of a generator group possessing quantum states pose to the physicist a new problem for each concrete system; problem which is solved here only in a few cases.

› Generalised Brègman relative entropies: an introduction

Abstract: We present some basic elements of the theory of generalized Brègman relative entropies over nonreflexive Banach spaces. Using nonlinear embeddings of Banach spaces together with the Euler–Legendre functions, this approach unifies two former approaches to Brègman relative entropy: one based on reflexive Banach spaces, another based on differential geometry. This construction allows to extend Brègman relative entropies, and related geometric and operator structures, to arbitrarydimensional state spaces of probability, quantum, and postquantum theory. We give several examples, not considered previously in the literature.

› Unitarity excess in Schwartzschild metric, Philippe Jacquet and Véronique Joly

Abstract: We refer to the black hole information paradox. We look after the existence of eigenvalues with non-zero imaginary part in the Gordon Klein equation with Schwarzschild metric. Such eigenvalues exist because the Schwartzschild metric is singular on the event horizon. The eigenvalues should be proportional to the inverse of black hole radius. The existence has many impacts, among other that black holes should be again eternal. However, the effects of the unitary violation should not be detectable within known black holes with existing technologies.

› Modelling and structure-preserving discretization of the Schrödinger equation as aport-Hamiltonian system, and simulation of a controlled quantum box, Gabriel Verrier, Ghislain Haine, and Denis Matignon

Abstract: The modelling of the Schrödinger Equation as a port-Hamiltonian system is adressed. We suggest two Hamiltonians for the model, one based on the probability of presence and the other on the energy of the quantum system in a time-independent potential. In order to simulate the evolution of the quantum system, we adapt the model to a bounded domain. The model is discretized thanks to the structure preserving Partitioned Finite Element Method (PFEM). Simulations of Rabi oscillations to control the state of a system inside a quantum box are performed. Our numerical experiments include the transition between two levels of energy and the generation of Schrödinger cat states.

› Some remarks on the notion of transition, Florio M. Ciaglia and Fabio Di Cosmo

Abstract: In this paper some rejections on the concept of transition are presented: groupoids are introduced as models for the construction of a "generalized logic" whose basic statements involve pairs of propositions which can be conditioned. In this sense, we could distinguish between classical probability theory where propositions can be conditioned if they have a non-zero intersection, from cases where "non-local" conditioning are allowed. The algebraic and geometrical properties of groupoids can be exploited to construct models of such non-local description.

GEOMETRIC MECHANICS, GERY DE SAXCE & ZDRAVKO TERZE

› A variational principle of minimum for Navier-Stokes equation based on the symplectic formalism, Géry de Saxcé

Abstract: The object of this work is to apply the formalisms of symplectic inclusions and symplectic Brezis-Ekeland-Nayroles principle to dissipative media in spatial representation. In the spirit of Newton-Cartan theory, our approach is covariant in the sense that it includes the gravitation and satisfies Galileo's principle of relativity. This aim is reached in three steps. Firstly, we develop a Lagrangian formalism for the reversible media based on the calculus of variation by jet theory. Next, we propose a corresponding Hamiltonian formalism for such media. Finally, we deduce from it a symplectic minimum principle for dissipative media and we show how to obtain a minimum principle for unstationary compressible and incompressible Navier-Stokes equation. The weak regularity of the potential of dissipation allows to encompass nonsmooth dissipative constitutive laws such as the one of Bingham fluids.

› Singular cotangent models in fluids with dissipation, Baptiste Coquinot, Pau Mir, and Eva Miranda

Abstract: In this article we analyze several mathematical models with singularities where the classical cotangent model is replaced by a b-cotangent model. We provide physical interpretations of the singular symplectic geometry underlying in b-cotangent bundles. The twisted cotangent model includes (for linear potentials) the case of fluids with dissipation. We also discuss more general physical interpretations of the twisted and non-twisted b-symplectic models. These models offer a Hamiltonian formulation for systems which are dissipative, extending the horizons of Hamiltonian dynamics and opening a new approach to study non-conservative systems.

› Continuum mechanics of defective media: an approach using fiber bundles, Mewen Crespo, Guy Casale, and Loïc Le Marrec

Abstract: The kinematics of a micro-structured material is geometrically modeled through the framework of fiber bundle geometry. The material continuum is a fiber bundle M ! B where B is compact and orientable. It is commonly agreed that connections with curvature and torsion can describe defect densities in micro-structured materials. The aim of this work is to introduce a method to derive these objects from the kinematics in an intrinsic way. The material bundle M is therefore placed in the Euclidean fiber bundle E ≡ TE ! E using a placement map φ : M ! E. A first-order transformation F : TM ! TE generalizing Tφ is then introduced. Finally, using F, a metric on B, a connexion on M and a solder form on M are inferred from the Euclidean structure on E. This new objects allow us to describe the current material state via the curvature (disclinations) and torsion (dislocations) tensors. On one hand, we see that the torsion tensor can be non-zero even in the holonomic F = Tφ case. On the other-hand, in order for the material to have a non-zero curvature tensor, we see that one must have a non-holonomic first-order transformation: that is, F/= Tφ.

› Multisymplectic Unscented Kalman Filter for Geometrically Exact Beams, Tianzhi Li and Jinzhi Wang

Abstract: This paper introduces an unscented Kalman filter for the estimation of the dynamics of geometrically exact beams based on multisymplectic geometry

and Hamel's formalism for classical field theories. The presented approach is a field-theoretic analogue of the well-known unscented Kalman filter. The discrete-time propagation equations are derived from the discrete variational principle, rather than a direct discretization of the continuous-time differential equations. As such, the proposed estimation scheme respects intrinsic physical structures of mechanical systems and exhibits excellent numerical properties such as energy conservation and structure preservation. The approach is also applicable to a wide range of models characterized by one-dimensional field theory. Properties of the proposed estimation algorithm are illustrated with numerical simulations.

› Lie group Quaternion Attitude-Reconstruction of Quadrotor UAV, Zdravko Terze, Dario Zlatar, Marko Kasalo and Marijan Andrié

Abstract: The quadrotor unmanned aerial vehicles (UAVs) have already gained enormous popularity, both for commercial and hobby applications. They are utilized for wide range of practical tasks, including fire protection, search and rescue, border surveillance, etc. Therefore, there is an ever-increasing need for better controllers and dynamics simulators. The conventional approach to modeling UAVs is to use rotational quaternions for attitude determination, together with position vector for tracking UAV's center of mass. The attitude is then usually updated by integrating linearized quaternion differential equations and subsequently enforcing unitary norm of the quaternion, through additional algebraic equation. The paper presents utilization of the recently introduced attitude and position update algorithms, based on Lie groups, for modeling UAV dynamics, which exhibit better computational characteristics

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› A variational symplectic scheme based on Simpson's quadrature, François Dubois and Juan Antonio Rojas-Quintero

Abstract: We propose a variational symplectic numerical method for the time integration of dynamical systems issued from the least action principle. We assume a quadratic internal interpolation of the state and we approximate the action in a small-time step by the Simpson's quadrature formula. The resulting scheme is explicited for an elementary harmonic oscillator. It is a stable, explicit, and symplectic scheme satisfying the conservation of an approximate energy. Numerical tests illustrate our theoretical study.

› Generalized Galilean Geometries, Eric Bergshoeff

Abstract: Motivated by non-relativistic string theory, we give a classification of D-dimensional generalized Galilean geometries. They are an extension of the Galilean geometry in the sense that the two nondegenerate metrics of Galilean geometry (one to measure time intervals and another one to measure spatial distances) are replaced by two nondegenerate metrics of rank $p + 1$ and rank $D - p - 1$, respectively, with $p = 0, 1, \cdots, D - 1$. To classify these generalized geometries an important role is played by the so-called intrinsic torsion tensor indicating that this particular torsion is independent of the spin-connection. We show that there is a finite way of setting some of these intrinsic torsion tensors equal to zero and that this leads to a classification of the generalized Galilean geometries. Moreover, we show how some (but not all) of the generalized Galilean geometries that we find can be obtained by taking a special limit of general relativity

› **Towards full 'Galilei general relativity': Bargmann-Minkowski and Bargmann-Galilei spacetimes, Christian Y. Cardall**

Abstract: Galilei-Newton spacetime G with its Galilei group can be understood as a 'degeneration' as $c \to \infty$ of Minkowski spacetime M with its Poincaré group. G does not have a spacetime metric and its Galilei symmetry transformations do not include energy; but Bargmann-Galilei spacetime BG, a 5-dimensional extension that preserves Galilei physics, remedies these infelicities. Here an analogous Bargmann-Minkowski spacetime BM is described. While not necessary for Poincaré physics, it may illuminate a path towards a more extensive 'Galilei general relativity' than is presently known which would be a useful—and conceptually and mathematically sound—approximation in astrophysical scenarios such as core-collapse supernovae.

GEOMETRIC GREEN LEARNING, ALICE BARBARA TUMPACH, DIARRA FALL & GUILLAUME CHARPIAT

› **Stratified Riemannian geometry for frugal learning with brain signals, Sylvain Chevallier and Yann Thanwerdas**

Abstract: Brain states could be explored through the analysis of the electrical activity measured on the surface of the scalp. This method is called electroencephalography (EEG), has high temporal precision but a poor spatial resolution. EEG is usually recorded with many electrodes (between 8 and 64) with a sampling rate between 100 and 500 Hz. While EEG was applied mostly in hospital and in research labs, its low cost allowed the development of EEG devices for various commercial applications like sleep analysis, well-being assistant, music control with connected earbuds, ... Automatic processing and machine learning techniques, at the heart of these applications, face two major challenges; the data are messy and suffer from the curse of dimensionality. Signals collected in clinical and commercial applications are intrinsically uncurated, noisy and messy compared to lab data. Approaches based on covariance matrices yield very good results and several classifiers have been proposed to work directly on the manifold of symmetric positive definite (SPD) matrices. Strong efforts should be made to learn models from few reference data or to integrate large masses of uncurated data. In uncurated data, singular covariance matrices are often encountered, due to disconnected sensors, hardware or muscular artifacts. Those rank-deficient matrices can be equipped with the Bures-Wasserstein distance to provide a metric space structure of different strata~\cite{thanwerdas2023n}. Endowed with this metric, it is possible to address data scarcity by processing all uncurated data, including singular matrices. First results show promising results to overcome artifacts and electrode disconnections.

› **Spotting Expressivity Bottlenecks and Fixing Them Optimally, Manon V Verbockhaven (INRIA); Guillaume Charpiat (INRIA)**

Abstract: Machine learning tasks are generally formulated as optimization problems, where one searches for an optimal function within a certain functional space.
In practice, parameterized functional spaces are considered, in order to be able to perform gradient descent. Typically, a neural network architecture is chosen and fixed, and its parameters (connection weights) are optimized, yielding an architecture-dependent result. This way of proceeding

however forces the evolution of the function during training to lie within the realm of what is expressible with the chosen architecture, and prevents any optimization across possible architectures. Costly architectural hyper-parameter optimization is often performed to compensate for this. Instead, we propose to adapt the architecture on the fly during training.
We show that the information about desirable architectural changes, due to expressivity bottlenecks when attempting to follow the functional gradient, can be extracted from the backpropagation.
To do this, we propose a new mathematically well-grounded method to detect expressivity bottlenecks on the fly and solve them by adding suitable neurons when and where needed.
Thus, while the standard approach requires large networks, in terms of number of neurons per layer, for expressivity and optimization reasons, we are able to start with very small neural networks and let them grow appropriately.
As a proof of concept, we show results~on the MNIST dataset, matching large neural network accuracy, with competitive training time, while removing the need for standard architectural hyper-parameter search.

› On canonical parameterizations of 2D-shapes, Alice Barbara Tumpach

Abstract: This paper is devoted to the study of unparameterized simple curves in the plane. We propose diverse canonical parameterization of a 2D-curve. For instance, the arc-length parameterization is canonical, but we consider other natural parameterizations like the parameterization proportionnal to the curvature of the curve. Both aforementioned parameterizations are very natural and correspond to a natural physical movement: the arc-length parameterization corresponds to travelling along the curve at constant speed, whereas parameterization proportional to curvature corresponds to a constant-speed moving frame. Since the curvature function of a curve is a geometric invariant of the unparameterized curve, a parameterization using the curvature function is a canonical parameterization. The main idea is that to any physically meaningful stricktly increasing function is associated a natural parameterization of 2D-curves, which gives an optimal sampling, and which can be used to compare unparameterized curves in a efficient and pertinent way. An application to point correspondance in medical imaging is given.

› Shape spaces of nonlinear flags, Ioana Ciuclea, Alice Barbara Tumpach and Cornelia Vizman

Abstract: The shape space considered in this article consists of surfaces embedded in R3, that are decorated with curves. It is a special case of the Fréchet manifolds of nonlinear flags, i.e. nested submanifolds of a fixed type. The gauge invariant elastic metric on the shape space of surfaces involves the mean curvature and the normal deformation, i.e. the sum and the difference of the principal curvatures κ1, κ2. The proposed gauge invariant elastic metrics on the space of surfaces decorated with curves involve, in addition, the geodesic and normal curvatures κg, κn of the curve on the surface, as well as the geodesic torsion τg. More precisely, we show that, with the help of the Euclidean metric, the tangent space at (C,Σ) can be identified with C∞(C)×C∞(Σ) and the gauge invariant elastic metrics form a 6-parameter family:

$$\begin{aligned}\mathcal{G}_{(C,\Sigma)}(h_1,h_2) = {} & a_1\int_C (h_1\kappa_g + h_2|_C\kappa_n)^2 d\ell && + a_2\int_\Sigma (h_2)^2(\kappa_1-\kappa_2)^2 dA \\ & + b_1\int_C (D_s h_1 - h_2|_C\tau_g)^2 d\ell && + b_2\int_\Sigma (h_2)^2(\kappa_1+\kappa_2)^2 dA \\ & + c_1\int_C (D_s(h_2|_C) + h_1\tau_g)^2 d\ell && + c_2\int_\Sigma |\nabla h_2|^2 dA,\end{aligned}$$

where $h_1 \in C^\infty(C), h_2 \in C^\infty(\Sigma)$.

› 3 methods to put a Riemannian metric on Shape Space, Alice Barbara Tumpach and Stephen C. Preston

Abstract: In many applications, one is interested in the shape of an object, like the contour of a bone or the trajectory of joints of a tennis player, irrespective of the way these shapes are parameterized. However for analysis of these shape spaces, it is sometimes useful to have a parameterization at hand, in particular if one is interested in deforming shapes. The purpose of the paper is to examine three different methods that one can follow to endow shape spaces with a Riemannian metric that is measuring deformations in a parameterization independent way.

› Riemannian Locally Linear Embedding with Application to Kendall Shape Spaces, Elodie Maignant, Alain Trouvé, and Xavier Pennec

Abstract: Locally Linear Embedding is a dimensionality reduction method which relies on the conservation of barycentric alignments of neighbor points. It has been designed to learn the intrinsic structure of a set of points of a Euclidean space lying close to some submanifold. In this paper, we propose to generalize the method to manifold-valued data. We demonstrate our algorithm on some examples in Kendall shape spaces

› A product shape manifold approach for optimizing piecewise-smooth shapes, Lidiya Pryymak, Tim Suchan, and Kathrin Welker

Abstract: Spaces where each element describes a shape, so-called shape spaces, are of particular interest in shape optimization and its applications. Theory and algorithms in shape optimization are often based on techniques from differential geometry. Challenges arise when an application demands a non-smooth shape, which is commonly-encountered as an optimal shape for fluid-mechanical problems. In order to avoid the restriction to infinitely-smooth shapes of a commonly-used shape space, we construct a space containing shapes in R2 that can be identified with a Riemannian product manifold but at the same time admits piecewise-smooth curves as elements. We combine the new product manifold with an approach for optimizing multiple non-intersecting shapes. For the newly-defined shapes, adjustments are made in the known shape optimization definitions and algorithms to ensure their usability in applications. Numerical results regarding a fluid-mechanical problem constrained by the Navier-Stokes equations, where the viscous energy dissipation is minimized, show its applicability.

GEOMETRIC AND ANALYTICAL ASPECTS OF QUANTIZATION AND NON-COMMUTATIVE HARMONIC ANALYSIS ON LIE GROUPS, PIERRE BIELIAVSKY & JEAN-PIERRE GAZEAU

› Twirled Products and Group-Covariant Symbols, Paolo Aniello

Abstract: A quantum stochastic product is a binary operation on the convex set of states (density operators) of a quantum system preserving the convex structure. We review the notion of twirled product of quantum states, a group-theoretical construction yielding a remarkable class of group-covariant associative stochastic products. In the case where the relevant group is abelian, we then realize the twirled product in terms of the covariant symbols associated with the quantum states involved in the product. Finally, the special case of the twirled product associated with the group of phase-space translations is considered.

› Coherent states and entropy, Tatyana Barron and Alexander Kazachek

Abstract: Let Hk, k ∈ N, be the Hilbert spaces of geometric quantization on a Kähler manifold M. With two points in M we associate a Bell-type state bk ∈ Hk ⊗ Hk. When M is compact or when M is C n, we provide positive lower bounds for the entanglement entropy of bk (asymptotic in k, as k → ∞)

› A non-formal formula for the Rankin-Cohen deformation quantization, Pierre Bieliavsky and Valentin Dendoncker

Abstract: Don Zagier's superposition of Rankin-Cohen brackets on the Lie group SL2(R) defines an associative formal deformation of the algebra of modular forms on the hyperbolic plane [9]. This formal deformation has been used in [6] to establish strong connections between the theory of modular forms and that of regular foliations of co-dimension one. Alain Connes and Henri Moscovici also proved that Rankin-Cohen's deformation gives rise to a formal universal deformation formula (UDF) for actions of the group ax + b. In a joint earlier work [5], the first author, Xiang Tang and Yijun Yao proved that this UDF is realized as a truncated Moyal star-product. In the present work, we use a method to explicitly produce an equivariant intertwiner between the above mentioned, truncated Moyal star-product (i.e. Rankin-Cohen deformation) and a non-formal star-product on ax + b defined by the first author in an earlier work [2]. The specific form of the intertwiner then yields an oscillatory integral formula for Zagier's Rankin-Cohen UDF, answering a question raised by Alain Connes.

› Equivalence of invariant star-products : the "retract" method, Pierre Bieliavsky, Valentin Dendoncker, and Stéphane Korvers

Abstract: In this article, we present a general method for enlarging the group of symmetries (symplectomorphisms) of a given star-product (or deformation quantization) on a symplectic homogeneous space. We call this method the "retract method".

STOCHASTIC GEOMETRIC MECHANICS, ANA BELA CRUZEIRO & JEAN-CLAUDE ZAMBRINI

› Gauge Transformations in Stochastic Geometric Mechanics, Qiao Huang and Jean-Claude Zambrini

Abstract: In the framework of the dynamical solution of Schrödinger's 1931 problem, we compare key aspects of its Lagrangian and Hamiltonian formalisms. This theory is regarded as a stochastic regularization of classical mechanics, in analogy with Feynman's (informal) path integral approach to quantum mechanics. The role of our counterpart of quantum gauge invariance, in the above stochastic framework, will be described. It establishes, in particular, new dynamical relations between classes of diffusion processes, when the theory is restricted to a natural generalization of Schrödinger's original problem, and illustrates differences between the stochastic Lagrangian and Hamiltonian formulations.

› Couplings of Brownian motions on SU(2, C) , Magalie Bénéfice, Marc Arnaudon, and Michel Bonnefont

Abstract: We study couplings of Brownian motions on the subRiemannian manifold SU(2,C), that is diffusion processes having the subLaplacian operator as infinitesimal generator. Using some interesting geometric interpretations of the Brownian motion on this space, we present some basic examples of co-adapted couplings. Inspiring ourselves with works on the Heisenberg group, we also construct two successful couplings on SU(2,C): one co-adapted and one not co-adapted but having a good coupling rate. Finally, using the similar structure of SU(2,C) and SL(2, R) we generalise some of our results for the case of this second subRiemannian manifold.

› A finite volume scheme for fractional conservation laws driven by Lévy noise, Neeraj Bhauryal

Abstract: In this article, we study a semi-discrete finite volume scheme for a fractional conservation law perturbed with Levy noise. With the help of bounded variation estimates and Kruzkov's theory we provide a rate of convergence result.

› The Total Variation-Wasserstein problem: a new derivation of the Euler-Lagrange equations, Antonin Chambolle, Vincent Duval, and João Miguel Machado

Abstract: In this work we analyse the Total Variation-Wasserstein minimization problem.We propose an alternative form of deriving optimality conditions from the approach of [7], and as result obtain further regularity for the quantities involved. In the sequel we propose an algorithm to solve this problem alongside two numerical experiments.

NEW TRENDS IN NONHOLONOMIC SYSTEMS, MANUEL DE LEÓN & LEONARDO COLOMBO

› Existence of global minimizer for elastic variational obstacle a voidance problems on Riemannian manifolds, Leonardo J Colombo and Jacob Goodman

Abstract: This work is devoted to studying existence of global minimizers for optimal control problems with obstacle avoidance. We show the existence of global extrema in the general setting of Riemannian manifolds. This is a problem that consists of minimizing a suitable energy functional among a set of admissible configurations. The given energy functional depends on state variables (trajectory), control variables (velocity, covariant acceleration), and on an artificial potential function used for avoiding obstacles.

› Virtual Affine Nonholonomic Constraints, Efstratios Stratoglou, Alexandre Anahory Simoes, Anthony Bloch, and Leonardo Colombo

Abstract: Virtual constraints are relations imposed in a control system that become invariant via feedback, instead of real physical constraints acting on the system. Nonholonomic systems are mechanical systems with non-integrable constraints on the velocities. In this work, we introduce the notion of virtual affine nonholonomic constraints in a geometric framework. More precisely, it is a controlled invariant affine distribution associated with an affine connection mechanical control system. We show the existence and uniqueness of a control law defining a virtual affine nonholonomic constraint.

› Nonholonomic systems with inequality constraints, Alexandre Anahory Simoes and Leonardo Colombo

Abstract: In this paper we derive the equations of motion for nonholonomic systems subject to inequality constraints, both, in continuous-time and discrete-time. The last is done by discretizing the continuous time variational principle which defined the equations of motion for a nonholonomic system subject to inequality constraints. An example is show to illustrate the theoretical results.

› Nonholonomic brackets: Revisiting Eden, Manuel de León, Manuel Lainz, Asier López-Gordón and Juan Carlos Marrero.

Abstract: The nonholonomic dynamics can be described by the so-called nonholonomic bracket in the constrained submanifold, which is a non-integrable modification of the Poisson bracket of the ambient space, in this case, of the canonical bracket in the cotangent bundle of the configuration manifold. This bracket was defined in [2, 10], although there was already some particular and less direct definition. On the other hand, another bracket, also called no holonomic, was defined using the description of the problem in terms of almost Lie algebroids. Recently, reviewing two older papers by R. J. Eden, we have defined a new bracket which we call Eden bracket. In the present paper, we prove that these three brackets coincide. Moreover, the description of the nonholonomic bracket à la Eden has allowed us to make important advances in the study of Hamilton-Jacobi theory and the quantization of nonholonomic systems.

LEARNING OF DYNAMIC PROCESSES, LYUDMILA GRIGORYEVA

› Signature estimation and signal recovery using Median of Means, Stéphane Chretien and Rémi Vaucher

Abstract: The theory of Signatures is a fast-growing field which has demonstrated wide applicability to a large range of applications, from finance to health monitoring. Computing signatures often relies on the assumptions that the signal under study is not corrupted by noise, which is rarely the case in practice. In the present paper, we study the influence of noise on the computation of signature via the theory of ant concentration. We then propose a median of means approach to the estimation problem and give a bound on the estimation error using Rademacher complexity.

› Forward and Inverse Approximation Theory for Linear Temporal Convolutional Networks, Haotian Jiang and Qianxiao Li

Abstract: We present a theoretical analysis of the approximation properties of convolutional architectures when applied to the modeling of temporal sequences. Specifically, we prove an approximation rate estimate (Jackson-type result) and an inverse approximation theorem (Bernsteintype result), which together provide a comprehensive characterization of the types of sequential relationships that can be efficiently captured by a temporal convolutional architecture. The rate estimate improves upon a previous result via the introduction of a refined complexity measure, whereas the inverse approximation theorem is new.

› Learning Lagrangian Fluid Mechanics with E(3)-Equivariant Graph Neural Networks, Artur P. Toshev, Gianluca Galletti, Johannes Brandstetter, Stefan Adami, and Nikolaus A. Adams

Abstract: We contribute to the vastly growing field of machine learning for engineering systems by demonstrating that equivariant graph neural networks have the potential to learn more accurate dynamic-interaction models than their non-equivariant counterparts. We benchmark two wellstudied ﬂuid-ﬂow systems, namely 3D decaying Taylor-Green vortex and 3D reverse Poiseuille ﬂow, and evaluate the models based on different performance measures, such as kinetic energy or Sinkhorn distance. In addition, we investigate different embedding methods of physical-information histories for equivariant models.We ﬁnd that while currently being ratherslow to train and evaluate, equivariant models with our proposed history embeddings learn more accurate physical interactions.

› Expressiveness and Structure Preservation in Learning Port-Hamiltonian Systems, Juan-Pablo Ortega and Daiying Yin

Abstract: Well-specified parametrization for single-input/single-output (SISO) linear port-Hamiltonian systems amenable to structure-preserving supervised learning is provided. The construction is based on controllable and observable normal form Hamiltonian representations for those systems, which reveal fundamental relationships between classical notions in control theory and crucial properties in the machine learning context, like structure-preservation and expressive power. The results in the paper suggest parametrizations of the estimation problem associated with these systems that amount, at least in the canonical case, to unique identification and prove that the parameter complexity necessary for the replication of the dynamics is only O(n) and not O(n2), as suggested by the standard parametrization of these systems.

› Cold-starting of reservoir systems in the forecasting of dynamical systems, Lyudmila Grigoryeva, Boumediene Hamzi, Felix P. Kemeth, Yannis Kevrekidis, G Manjunath, Juan- Pablo Ortega, and Matthys Jacobus Steynberg

Abstract: We show that under generic hypotheses, a map (called the starting map) can be defined on a short history of observations that maps to a unique initial condition in the reservoir space of an echo state network. The reservoir system's time series from that initial state can be used to run the system in autonomous mode. This map not only saves users from the long "washout» required but also helps forecast from any choice of a short history of the observations

COMPUTING GEOMETRY & ALGEBRAIC STATISTICS, ELIANA DUARTE & ELIAS TSIGARIDAS

› Convex Hulls of Curves: Volumes and Signatures, Carlos Améndola, Darrick Lee, and Chiara Meroni

Abstract: Taking the convex hull of a curve is a natural construction in computational geometry. On the other hand, path signatures, central in stochastic analysis, capture geometric properties of curves, although their exact interpretation for levels larger than two is not well understood.
In this paper, we study the use of path signatures to compute the volume of

the convex hull of a curve. We present sufficient conditions for a curve so that the volume of its convex hull can be computed by such formulae. The canonical example is the classical moment curve, and our class of curves, which we call cyclic, includes other known classes such as d-order curves and curves with totally positive torsion. We also conjecture a necessary and sufficient condition on curves for the signature volume formula to hold. Finally, we give a concrete geometric interpretation of the volume formula in terms of lengths and signed areas.

› Avoiding the general position condition when computing the topology of a real algebraic plane curve defined implicitly, Jorge Caravantes, Gema M. Diaz–Toca, and Laureano Gonzalez–Vega

Abstract: The problem of computing the topology of curves has received special attention from both Computer Aided Geometric Design and Symbolic Computation. It is well known that the general position condition greatly simplifies the computation of the topology of a real algebraic plane curve defined implicitly since, under this assumption, singular points can be presented in a very convenient way for that purpose. In this paper, we will show how the topology of cubic, quartic and quantic plane curves can be computed in the same manner even if the curve is not in general position, avoiding thus coordinate changes. This will be possible by applying new formulae, derived from subresultants, which describe multiple roots of univariate polynomials as rational functions of the considered polynomial. We will also characterize those higher degree curves where this approach can be used and, as an application, we will use this technique to describe the curve which arises when intersecting two ellipsoids.

› Dynamical geometry and a persistence K-theory in noisy point clouds, Sita Gakkhar and Matilde Marcolli

Abstract: The question of whether the underlying geometry of a dynamical point cloud is invariant is considered from the perspective of the algebra of trajectories of the points as opposed to their point-set topology. We sketch two approaches to identifying when the geometry remains invariant, one that accounts for a model of stochastic effects as well, and a second that is based on a persistence K-theory. Additional geometric structure in both approaches is made apparent by viewing them as finite noncommutative spaces (spectral triples) embedded inside the Hodge-de Rham spectral triple. A general reconstruction problem for such spaces is posed. The ideas are illustrated in the setting of understanding the dependence of grid cell population activity on environmental input.

› An Approximate Projection onto the Tangent Cone to the Variety of Third-Order Tensors of Bounded Tensor-Train Rank, Charlotte Vermeylen, Guillaume Olikier, and Marc Van Barel

Abstract: An approximate projection onto the tangent cone to the variety of third-order tensors of bounded tensor-train rank is proposed and proven to satisfy a better angle condition than the one proposed by Kutschan (2019). Such an approximate projection enables, e.g., to compute gradient-related directions in the tangent cone, as required by algorithms aiming at minimizing a continuously differentiable function on the variety, a problem appearing notably in tensor completion. A numerical experiment is presented

which indicates that, in practice, the angle condition satisfied by the proposed approximate projection is better than both the one satisfied by the approximate projection introduced by Kutschan and the proven theoretical bound.

› Toric Fiber Products in Geometric Modeling, Eliana Duarte Benjamin Hollering and Maximilian Wiesmann

Abstract: An important challenge in Geometric Modeling is to classify polytopes with rational linear precision. Equivalently, in Algebraic Statistics one is interested in classifying scaled toric varieties, also known as discrete exponential families, for which the maximum likelihood estimator can be written in closed form as a rational function of the data (rational MLE). The toric fiber product (TFP) of statistical models is an operation to iteratively construct new models with rational MLE from lower dimensional ones. In this paper we introduce TFPs to the Geometric Modeling setting to construct polytopes with rational linear precision and give explicit formulae for their blending functions. A special case of the TFP is taking the Cartesian product of two polytopes and their blending functions.

NEUROGEOMETRY, ALESSANDRO SARTI, GIOVANNA CITTI & GIOVANNI PETRI

› Differential operators heterogenous in orientation and scale in the cortical V1 cortex, Mattia Galeotti, Giovanna Citti, and Alessandro Sarti

Abstract: In the primary visual cortex V1 of the human brain, cortical receptive profiles (RPs) changing from point-to-point act as a differential operator on the visual stimulus, while cortical connectivity inverts the problem and recovers an image called perceived image. We analyze the transform of the visual stimulus performed by the RPs on V1 in order to reconstruct the image perceived by the subject. We consider a differential operator determined by a heterogenous distribution of orientation and scale, whose local representation can be a regular Laplacian, a degenerate Laplacian or a degenerate Laplacian with different scale at different points. We model the associated cortical dynamic via discrete differential operators whose coefficients have a stochastic distribution. We prove a homogenization result, showing that a large class of heterogenous operators H-converges to the classic Laplacian.

› Gabor Frames and Contact structures: Signal encoding and decoding in the primary visual cortex, Vasiliki Liontou

Abstract: This is an overview of an ongoing research project regarding the existence of Gabor frames on manifolds with contact structure, motivated by the need for a mathematical model of V1 which allows the encoding and decoding of a signal by a discrete family of orientation and position dependent receptive profiles. Contact structures and Gabor functions have been used, independently, to model the activity of the mammalian primary visual cortex. Gabor functions are also used in signal analysis and in particular in signal encoding and decoding. A one-dimensional signal, an L2 function of one variable, can be represented in two dimensions, with time and frequency as coordinates. The signal is expanded into a series of Gabor functions (an analog of a Fourier basis), which are constructed from a single seed function by applying time and frequency translations. This article summarizes the construction of a framework of signal analysis on unit

cotangent bundles, determined by their natural contact structure, joint work with prof. M. Marcolli.

› A sub-Riemannian model of the functional architecture of M1 for arm movement direction, Caterina Mazzetti, Alessandro Sarti, and Giovanna Citti.

Abstract: In this paper we propose a neurogeometrical model of the behaviour of cells of the arm area of the primary motor cortex (M1). We mathematically express the hypercolumnar organization of M1 discovered by Georgopoulos, as a fiber bundle, as in classical sub-riemannian models of the visual cortex (Petitot, Citti-Sarti). On this structure, we consider the selective tuning of M1 neurons of kinematic variables of positions and directions of movement. We then extend this model to encode the notion of fragments of movements introduced by Hatsopoulos. In our approach fragments are modelled as integral curves of vector fields in a suitable sub-Riemannian space. These fragments are in good agreements with movement decomposition from neural activity data. Here, we recover these patterns through a spectral clustering algorithm in the subriemannian structure we introduced, and compare our results with the neurophysiological ones of Kadmon-Harpaz et al.

› Geometry of saccades and saccadic cycles, D. V. Alekseevsky and I.M.Shirokov

Abstract: The paper is devoted to the development of the differential geometry of saccades and saccadic cycles. We recall an interpretation of Donders' and Listing's law in terms of the Hopf fibration of the 3-sphere over the 2-sphere. In particular, the configuration space of the eye ball (when the head is fixed) is the 2-dimensional hemisphere S+ L, which is called Listing's hemisphere. We give three characterizations of saccades: as geodesic segment ab in the Listing's hemisphere, as the gaze curve and as a piesewise geodesic curve of the orthogonal group. We study the geometry of saccadic cycle, which is represented by a geodesic polygon in the Listing hemisphere, and give necessary and sufficient conditions, when a system of lines through the center of eye ball is the system of axes of rotation for saccades of the saccadic cycle, described in terms of world coordinates and retinotopic coordinates. This gives an approach to the study the visual stability problem.

› MacKay-type visual illusions via neural fields, Cyprien Tamekue, Dario Prandi and Yacine Chitour

Abstract: To study the interaction between retinal stimulation by redundant geometrical patterns and the cortical response in the primary visual cortex (V1), we focus on the MacKay effect (Nature, 1957) and Billock and Tsou's experiments (PNAS, 2007). Starting from a classical biological model of neural fields equations with a non-linear response function, we use a controllability approach to describe these phenomena. The external input containing a localised control function is interpreted as a cortical representation of the static visual stimuli used in these experiments. We prove that while the MacKay effect is essentially a linear phenomenon (i.e., the nonlinear nature of the activation does not play any role in its reproduction), the phenomena reported by Billock and Tsou are wholly nonlinear and depend strongly on the shape of the nonlinearity used to model the response function.

Poster Session

› Capra-Conjugacies Reveal Convexity in Sparsity, Jean-Philippe CHANCELIER (Ecole des Ponts ParisTech); Michel DE LARA (Ecole des Ponts ParisTech)*

Abstract: The so-called ℓ0 pseudonorm counts the number of nonzero components of a vector. It is a standard notion in sparse optimization. However, as it is a discontinuous and nonconvex function, the ℓ0 pseudonorm cannot be satisfactorily handled with the Fenchel conjugacy. In this talk, we review a series of recent results on a class of Capra (Constant Along Primal Rays) conjugacies that reveal hidden convexity in the ℓ0 pseudonorm.

› Sampling (combinatorially interesting) polytopes, Zafeirakis Zafeirakopoulos (University of Geneva)*

Abstract: Polytopes are fundamental objects in mathematics and appear in a large number of applications. With the recent advances of artificial intelligence, the ability to produce large and diverse datasets is becoming more clear than ever. In this paper we present a method for sampling d-dimensional H-polytopes with prescribed number of facets and bitsize of the H-description. The main characteristic of the proposed method is that the sampling of polytopes of different combinatorial types is guaranteed. We use the notion of the chamber complex in order to sample from all possible combinatorial types given by a (random) set of facet-defining normals. The suggested multi-phase process is described theoretically together with a JuliaLang implementation, as well as experimental data supporting its efficiency and the quality of the results.

› Learning vector bundles for model order reduction in image-based digital twining, David Ryckelynck (MINES Paris PSL)*

Abstract: This work is about the geometrical representation of the solution space for elliptic partial differential equations. The dimension of the input parameter of these equations' scales with the dimension of the finite element model used to forecast numerical predictions. The proposed solution space is the total space of a vector bundle manifold. It is a family of vector subspaces parametrized by points on a base manifold. In the proposed vector bundle, a simple bundle projection holds for practical applications in mechanics of materials. The base manifold is sampled by a train set of finite element predictions. Vector subspaces of the vector bundle aim at generalizing the base manifold by using local reduced order models. The solutions of the elliptic equations are elastic strain fields around a local defect submitted to mechanical loadings. The defect geometry is the input parameter of the elliptic equations. As a train set, we consider defects that have been observed on digital images of mechanical specimens. In this work, the base manifold is equipped with a graph of the mecanical predictions available in the train set. A node of this graph is a series of the strain fluctuation fields around a given defect. Such a graph enable the computation of categories of

points in the total space (i.e. subspace of the total space). Such categories are therefore available on the base manifold. Each category has a representative point on the base manifold. They are extended as categories of local vector subspaces and categories of defects. A piecewize constant bundle projection is proposed over the categories of points in the total space. We propose numerical results to show that the bundle projection can be implemented as a classifier. This classifier is train to recommend a representative point in the base manifold for a given input strain field. A classifier for defects is also train to recommend a vector subspace category for a given input defect image, for latter model order reduction. According to CÃľ a's lemma, the closer the exact solution to the recommended vector subspace the better the mechanical predictions.

› Unsupervised geometric explorations of Autism fMRI brain connectomes, Adriana Haydeé Contreras Peruyero (Centro de Ciencias Matemáticas UNAM); Sebastian Pujalte Ojeda (Instituto de Fisiologia, UNAM); Sophie Achard (CNRS); Pablo Suarez-Serrato (UNAM)

Abstract: We investigate if individuals with Autism Spectrum Disorder can be classified from healthy controls using inferred geometric features from the non-backtracking (NB) distance matrix of fMRI data. For each connectivity matrix we obtained the NB eigenvalues, then clustered distance matrices and used an array of manifold learning techniques (t-SNE, UMAP, Tri-Map, and MDS). These novel unsupervised methods failed to reveal structural geometric differences between the fMRI activity of autism and control subjects.

› Hard Lefschetz Property in symplectic geometry, Robert Wolak (Uniwersytet Jagiellonski); Jose Ignacio Royo Prieto (University of the Basque Country UPV/EHU); Martintxo Saralegi-Aranguren (Université d'Artois)

Abstract: The Hard Lefschetz Property (HLP) is an important property which has been studied in several categories of the symplectic world, both standard and foliated. Both properties (transverse and not) have been recently seen to be equivalent for isometric flows, a category where HLP makes sense, which includes both K-contact and Sasakian manifolds. We also formulate both versions of the HLP for almost-free S3-actions, and prove that they are equivalent for actions satisfying a cohomological condition, which include the important category of 3-Sasakian manifolds, where both conditions are shown to be held

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› Entropy dissipation via Information Gamma calculus: non-reversible SDEs, Qi Feng (University of Michigan, Ann Arbor); Wuchen Li

Abstract: We formulate explicit bounds to guarantee the exponential dissipation for some non-gradient drift stochastic differential equations. We apply Lyapunov methods in the space of probabilities, where the Lyapunov functional is chosen as the relative Fisher information. We derive the Fisher information-induced Gamma calculus to handle non-gradient drift vector fields. We obtain the explicit dissipation bound in L 1 distance between the density function and the invariant distribution.

› SymFlux: a CNN+LSTM approach for symbolic regression of Hamiltonian vector fields, Miguel Evangelista-Alvarado (National Autonomous University of Mexico (UNAM)); Pablo suarez-serrato (UNAM)

Abstract: We present the SymFlux models, which perform symbolic regression on Hamiltonian vector fields. These deep learning models learn to output a symbolic expression of a Hamiltonian function that defines a vector field on the standard symplectic plane. We rely on a combination of CNN and LSTM architectures, in addition to a new vector field dataset we developed for this purpose.

› Linking geometry of the deep brain and clinical outcomes of DBS in Parkinson's disease, Maha BEN SALAH (INSTITUT PASCAL)

Abstract: This paper deals with data from Parkinson's disease patients operated by Deep Brain Stimulation surgery. We describe a full workflow to study the statistical link between the geometry of a patient's deep brain structures, the chosen stimulation point for the electrode, and the clinical outcomes of electrical stimulation at that point. The first stage of the workflow is a joint registration and clustering algorithm whose goal is to build a common parcellisation of all patient's brains into sub-regions with consistent locations across patients. The second stage is to apply classic supervised learning algorithms, based on the sub-regions identified in the first stage, to predict clinical outcomes of stimulation such as symptom improvement and apparition of adverse side effects.

› Wasserstein Barycenter-Based Model Fusion and Linear Mode Connectivity of Neural Networks, Lyudmila Grigoryeva (University of St. Gallen); Boumediene Hamzi (Caltech); Felix P. Keneth (Johns Hopkins University); Yannis Kevrikidis (Johns Hopkins University); G Manjunath (University of Pretoria); Juan-Pablo Ortega (Nanyang Technological University); Matthys Jacobus Steynberg (University of Pretoria)

Abstract: Based on the concepts of Wasserstein barycenter (WB) and Gromov-Wasserstein barycenter (GWB), we propose a unified mathematical framework for neural network (NN) model fusion and utilize it to reveal insights about the linear mode connectivity (LMC) of SGD solutions. In our framework, the fusion occurs in a layer-wise manner and builds on an interpretation of a node in a network as a function of the layer preceding it. The versatility of our mathematical framework allows us to talk about model fusion and LMC for a broad class of NNs. We present extensive numerical experiments to: 1) illustrate the strengths of our approach in relation to other model fusion methodologies and 2) from a certain perspective, provide new empirical evidence for recent conjectures which say that two local minima found by gradient-based methods end up lying on the same basin of the loss landscape after a proper permutation of weights is applied to one of the models.

› Regression on Lie Groups: application to estimation of positions of a drone, Johan Aubray (Enac)*; Florence Nicol (ENAC); stephane puechmorel (ENAC)

Abstract: In this paper, we address the problem of estimating the position

of a mobile such as a drone from noisy position measurements using the framework of Lie groups. To model the motion of a rigid body, the relevant Lie group happens to be the Special Euclidean group SE(n), with n = 2 or 3. Our work takes place in the parametric framework developed by Hinkle et al. (2014), who derived equations for geodesic regression and polynomial regression on Riemannian manifolds. Based on this approach, our goal was to implement this technique to the Lie group SE(3) context. Given a set of noisy points in SE(3) representing measurements on the trajectory of a mobile, one wants to find the geodesic that best fits those points in a Riemannian least squares sense. Finally, applications to simulated data are proposed to illustrate this work. The limitations of such a method and future perspectives are discussed.

› The Riemannian Langevin equation and conic programs, Govind Menon (Brown university); Tianmin Yu (Brown university)

Abstract: Diffusion limits provide a framework for the asymptotic analysis of stochastic gradient descent (SGD) schemes used in machine learning. We consider an alternative framework, the Riemannian Langevin equation (RLE), that generalizes the classical paradigm of equilibration in R n to a Riemannian manifold (Mn, g). The most subtle part of this equation is the description of Brownian motion on (Mn, g). Explicit formulas are presented for some fundamental cones.

› Lipschitz constants between Riemannian metrics on the Stiefel manifold, Simon Mataigne (UCLouvain); P.-A. Absil (UCLouvain); Nina Miolane (UCSB)

Abstract: We give the best Lipschitz constants between the distances induced by any two members of a previously proposed one-parameter family of Riemannian metrics on the Stiefel manifold of orthonormal p-frames in Rn. The one-parameter family contains the well-known canonical and Euclidean metrics. We also provide a lower bound on these distances in terms of the easy-to-compute Frobenius distance. These bounds aim at improving the theoretical guarantees and performances of minimizing-geodesic computation algorithms by reducing the size of the initial velocity search space.

› Quantum Measurement Compression via Likelihood POVMs, Arun Padakandla

Abstract: The problem of quantifying the information content in the outcome of a quantum measurement is a fundamental problem whose investigation began over three decades ago. In 2004, Winter provided an elegant formulation of this quantum measurement compression (QMC) problem and provided a crisp and intuitive solution. The solution of the QMC problem and the associated tools are employed in several other problem scenarios including rate-distortion, purity distillation among others. While Winter's findings \cite{200401CommMathPhy_Win} provide a profound insight on the measurement process, the central tool, the measurement simulation protocol, is very involved and crucially reliant on certain specific tools such as the operator Chernoff bound. This lends his tools difficult to adapt to a broader set of measurement compression scenarios. In this work, we propose a far

more simple measurement simulation protocol based on likelihood POVMs. Developing new techniques to analyze its performance, we prove the proposed protocol is optimal for the MCP. Moreover, we demonstrate that the likelihood POVMs can solve the MCP in several network scenarios including distributed separable measurements and multiple jointly compatible measurements. These findings illustrate the power of the developed analysis techniques and the versatility of the likelihood POVMs.

› Machine learning application in visual field loss for Dominant Optic Atrophy, Rita Fioresi (U. Bologna)

Abstract: Unsupervised Machine Learning algorithms such as Archetypal Analysis (AA) are becoming important in the field of ophthalmology to understand and monitor the progress of many eye diseases such as Glaucoma. We show how AA can be applied to obtain useful information about Dominant Optic Atrophy.

› Thermodynamics Modeling of Deep Learning Systems for a temperature-based filter pruning technique, Michela Lapenna (U. Bologna)

Abstract: We analyse the dynamics of convolutional filters' parameters of a CNN during and after training, via a thermodynamic analogy which allows for a sound definition of temperature. We show that removing high temperature filters has a minor effect on the performance of the model, while removing low temperature filters influences majorly both accuracy and loss decay. This result could be exploited to implement a temperature-based pruning technique for the filters and to determine efficiently the crucial filters for an effective learning. Furthermore, we are also interested in discovering the general characteristics of the dynamics under Stochastic Gradient Descent and we find out the trajectories of weights are characterized by a component of drift and one of oscillation.

› Riemann and Finsler Geometry in Medical Tensor Imaging, Jan Slovák (Masaryk U.)

Abstract: Exploring tools from Differential Geometry and Geometric Analysis with potential applications in Medical Imaging, we focus on Tensor Imaging in brain research, based on MRI data. The poster communicates a few recent enhancements of algorithms for streamline fiber tracking and for 3D segmentation in complex geometry of the fibers and voxels with multiple fiber directions and noise. The discussion will include:

- the observation that considering the reciprocal values of diffusion attenuation signal leads to very simple kind of inversion of the higher order tensors;

- the newly introduced Finsler anisotropy scalar allowing to classify nicely the voxels' number of fiber directions involved;

- the Finsler based modification of streamline and geodesical tractography; and

- the idea to employ the tracked fibers as the input for well-chosen 3D segmentation method.

The results are based on the three defended thesis of the three co-authors.

› Canonical foliations of neural networks: application to robustness, Eliot Tron (U. Toulose). Joint with: N. Couellan, S. Puechmorel

Abstract: Deep learning models are known to be vulnerable to adversarial attacks. Adversarial learning is therefore becoming a crucial task. We propose a new vision on neural network robustness using Riemannian geometry and foliation theory. The idea is illustrated by creating a new adversarial attack that takes into account the curvature of the data space. This new adversarial attack called the two-step spectral attack is a piece-wise linear approximation of a geodesic in the data space. The data space is treated as a (degenerate) Riemannian manifold equipped with the pullback of the Fisher Information Metric (FIM) of the neural network. In most cases, this metric is only semi-definite and its kernel becomes a central object to study. A canonical foliation is derived from this kernel. The curvature of transverse leaves gives the appropriate correction to get a two-step approximation of the geodesic and hence a new efficient adversarial attack.

› GDL approaches to physiological time series analysis, Ferdinando Zanchetta (U. Bologna). Joint with: G. Faglioni, F. Faglioni, R. Fioresi, A. Malagoli, A. Simonetti

Abstract: The analysis of physiological time series, such as the ECG and PPG, has been a very important topic for monitoring the health status of a human being.
We show how Geometric Deep Learning techniques can be useful to design new algorithms useful to tackle applied problems such as the prediction of the Blood Pressure from ECG or PPG signals.

› Geometry of the Entropic Trust Region for Maximally Dense Crystallographic Symmetry Group Packings, Miloslav Torda (University of Liverpool)

Abstract: Stochastic relaxation is a well-known approach used to solve problems in machine learning and artificial intelligence, particularly when dealing with complicated optimization landscapes. Here, our focus is on identifying maximally dense packings of compact sets into n-dimensional Euclidean space, specifically packings restricted to the Crystallographic Symmetry Groups (CSGs). Utilizing stochastic relaxation, we have developed a non-Euclidean trust region algorithm called the Entropic Trust Region Packing Algorithm (ETRPA). The ETRPA is a variant of the natural gradient learning approach, equipped with adaptive selection quantile fitness rewriting. Since CSGs induce a toroidal topology on the configuration space, the ETRPA's search is performed on a statistical manifold of Extended Multivariate von Mises (EMvM) probability distributions, a parametric family of probability measures defined on an n-dimensional torus. To gain insight into the geometric properties of ETRPA, we establish a connection with the generalized proximal method. This connection allows us to examine the algorithm's behavior using local dual geodesic flows that maximize the stochastic dependence among elements of the EMvM distributed random vector. Consequently, ETRPA's theoretical foundation in evolutionary dynamics, statistical physics, and recurrent neural computing can be interpreted in terms of group equivariant geometric learning, providing a deeper understanding of the algorithm and its application in material science.

Program at glance

Day 1:

Time	Auditorium Maupertuis	Room Vauban	Room Bouvet
09.00 - 09.30	Opening Session		
09.30 - 10.30	Eva MIRANDA - (UPC, Spain) From Alan Turing to Contact geometry: towards a "Fluid computer"		
10.30 - 11.00	Coffee Break		
11.00 - 12.40	(5) Neurogeometry Meets Geometric Deep Learning - Remco DUITS & Erik BEKKERS, Alessandro SARTI	(5) Statistical Manifolds and Hessian information geometry - Michel NGUIFFO BOYOM	(5) Information Theory and Statistics - Olivier RIOUL
12.40 - 14.00	Lunch Break		
14.00 - 15.00	Hervé SABOURIN - (Poitiers Univ., France) Transverse Poisson Structures to adjoint orbits in a complex semi-simple Lie algebra		
15.00 - 16.20	(4/8) Symplectic Structures of Heat & Information Geometry - Frédéric BARBARESCO & Pierre BIELIAVSKY	(4) Applied Geometric Learning - Pierre-Yves LAGRAVE, Santiago VALASCO-FORERO & Teodora PETRISOR	(4) Statistics, Information and Topology - Pierre BAUDOT & Grégoire SEARGEANT-PERTHUIS
16.20 - 16.50	Coffee Break		
16.50 - 18.30	(3/8) Symplectic Structures of Heat & Information Geometry - Frédéric BARBARESCO & Pierre BIELIAVSKY	(5) Distance geometry, graph embeddings, and applications - Antonio MUCHERINO	
19.00 - 20.00	Cocktail		

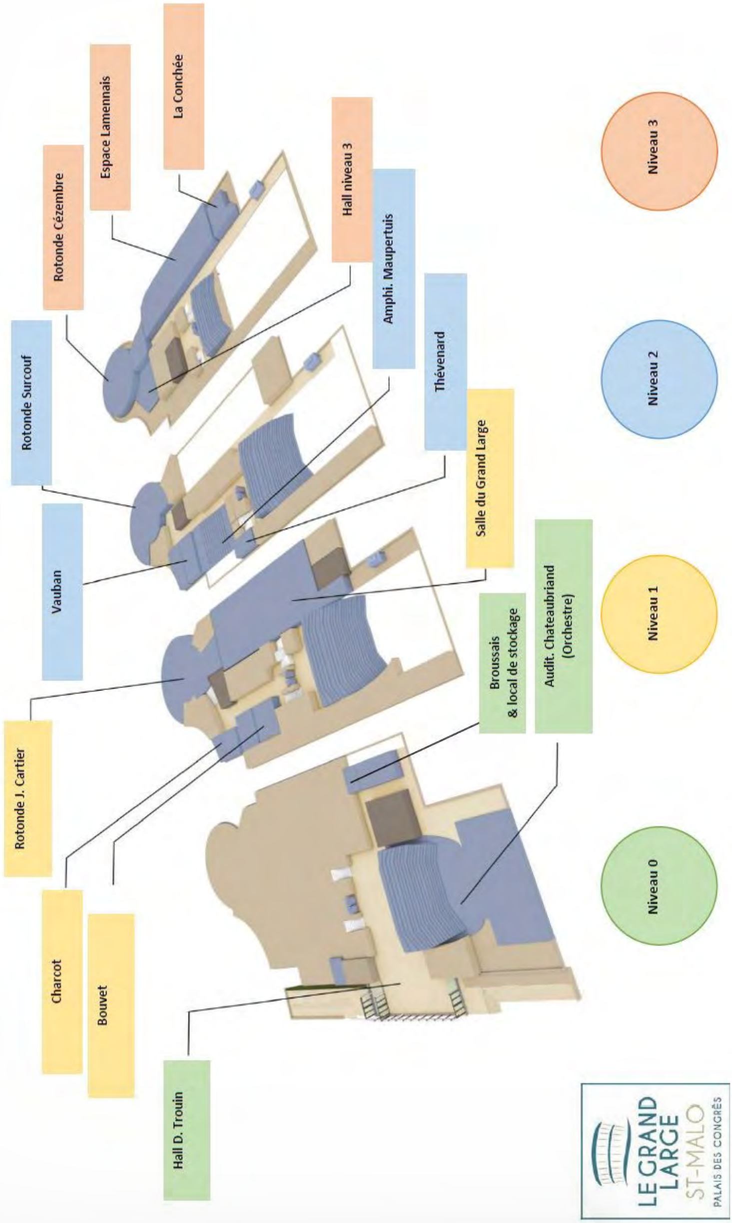
Day 2:

Time	Auditorium Maupertuis	Room Vauban	Room Bouvet
08.30 - 09.30	Keynote Francis BACH - (ENS PARIS & INRIA, France) Information Theory with Kernel Methods		
09.30 - 10.50	(4) Integrable Systems and Information Geometry (From Classical to Quantum) - Jean-Pierre FRANCOISE, Daisuke TARAMA	(4) Divergences in Statistics & Machine Learning - Michel BRONIATOWSKI & Wolfgang STUMMER	(4) Geometric Features Extraction in Medical Imaging - Stéphanie JEHAN-BESSON & Patrick Clarysse
10.50 - 11.20	Coffee Break + GSI'23 Posters Session + CaLIGOLA Posters session - Rita FIORESI		
11.20 - 13.20	(5) Statistical Shape Analysis and more Non-Euclidean Statistics - Stephan HUCKEMANN & Xavier PENNEC	(6) Fluid Mechanics and Symmetry - François GAY-BALMAZ et Cesare TRONCI	(6) Deep learning: Methods, Analysis and Applications to Mechanical Systems - Elena CELLEDONI, James JACKAMAN, Davide MURARI and Brynjulf OWREN
13.20 - 14.45	Lunch Break + GSI'23 Posters Session + CaLIGOLA Posters session - Rita FIORESI		
14.45 - 15. 45	Juan-Pablo Ortega - (NTU, SG) Learning of Dynamic Processes		
15.45 - 18.05	(6) Computational Information Geometry and Divergences - Frank NIELSEN & Olivier RIOUL	(6) Probability and Statistics on manifolds - Cyrus MOSTAJERAN	(7) Geometric Methods in Mechanics and Thermodynamics - François GAY-BALMAZ et Hiroaki YOSHIMURA
18.05 - 19.00	Coffee Break + GSI'23 Posters Session + CaLIGOLA Posters session - Rita FIORESI		
20.00 - 22.00	Gala Dinner		

Day 3:

Time	Auditorium Maupertuis	Room Vauban	Room Bouvet
08.30 - 09.30	Diarra FALL - (Orléans Univ., France) Statistics Methods for Medical Image Processing and Reconstruction		
09.30 - 10.50	(4/8)The Geometry of Quantum States - Florio M. CIAGLIA & FABIO DI COSMO	(4/8) Geometric Mechanics - Gery DE SAXCE & Zdravko TERZE	(4/7) Geometric Green Learning - Alice Barbara TUMPACH, Diarra FALL & Guillaume CHARPIAT
10.50 - 11.20	Coffee Break		
11.20 - 12.40	(4/8)The Geometry of Quantum States - Florio M. CIAGLIA & FABIO DI COSMO	(4/8) Geometric Mechanics - Gery DE SAXCE & Zdravko TERZE	(3/7) Geometric Green Learning - Alice Barbara TUMPACH, Diarra FALL & Guillaume CHARPIAT
12.40 - 14.00	Lunch Break		
14.00 - 15.00	Bernd STURMFELS - (MPI - MiS Leipzig, DE) Algebraic Statistics and Gibbs Manifolds		
15.00 - 16.20	(4) Geometric and Analytical Aspects of Quantization and Non-Commutative Harmonic Analysis on Lie Groups - Pierre BIELIAVSKY & Jean-Pierre GAZEAU	(4) Stochastic Geometric Mechanics - Ana Bela CRUZEIRO & Jean-Claude ZAMBRINI	(4) New trends in Nonholonomic Systems - Manuel de LEON & Leonardo COLOMBO
16.20 - 16.50	Coffee Break		
16.50 -18.30	(5) Learning of Dynamic Processes - Lyudmila GRIGORYEVA	(5) Computing Geometry & Algebraic Statistics - Eliana DUARTE & Elias TSIGARIDAS	(5) Neurogeometry -Alessandro SARTI, Giovanna CITTI and Giovanni Petri
18.30-18.45	Closing Session (Papers Awards)		

Palais du Grand-Large Map



Room Maupertuis (2nd floor)
Plenary Sessions & Parallel Sessions

Room Bouvet (1st floor)
Parallel Sessions

Room Vauban (2nd floor)
Parallel Sessions

Rotonde Surcouf (2nd floor)
Coffee Breaks & Posters Session

Welcome Desk (Ground Floor)
Registration & Badges

Welcome Cocktail

The Welcome Cocktail Reception will take place on August 30th at 19.30pm in La Rotonde Surcouf.
Same floor than Maupertuis Plenary Session Room.

Gala Dinner

The Gala Dinner will take place on August 31st at 20.00 pm in La Rotonde Surcouf.
Same floor than Maupertuis Plenary Session Room.
The gala dinner is included in the full registrations only.

Computational Geometric Science of Information

GEOMSTATS HACKATHON

If you are interested in:

✔ Using and understanding existing implementations of differential geometry,

✔ Implementing ideas, examples, experiments for a/your research paper

✔ Adding hands-on exercises or examples to your differential geometry classes,

✔ Learning how to code differential geometric structures,

✔ Learning how to contribute to an open-source GitHub project.

Come to the hackathon!

When?

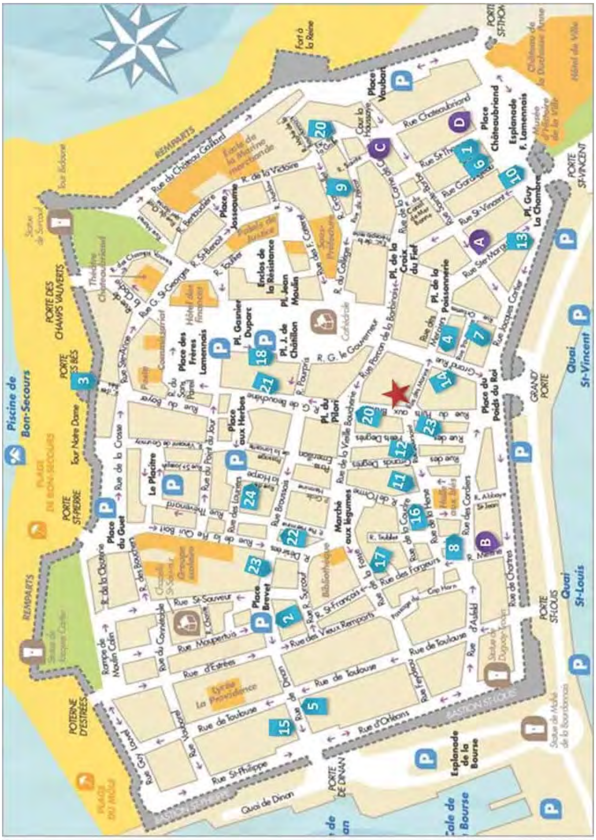
30th August, 31st August and 1st September (lunch break)

Where?

Vauban Room on the 2nd Floor

Nicolas Guigui and **Luis F. Pereira** will be available to answer your questions about computational geometric science of information, guide you through existing implementations, and help you translate your ideas into code. Feel free to join any day, for any duration, with or without a computational project in mind, with or without coding experience!

List of restaurants



CRÊPERIES

1 – La Licorne — 02 99 40 05 18
Service continu
2 – La Brigantine — 02 99 56 82 82
3 – Le Corps de Garde — 02 99 40 91 46
4 – Crêperie Des Lutins — 02 99 40 07 29
5 – Histoire de crêpes — 02 99 40 88 37

POISSONS & FRUITS DE MER

6 – Le Café de l'Ouest — 02 99 56 63 49
Service continu
7 – Ô de Mer — 02 99 40 15 04
8 – Le Cambusier — 02 99 20 18 42
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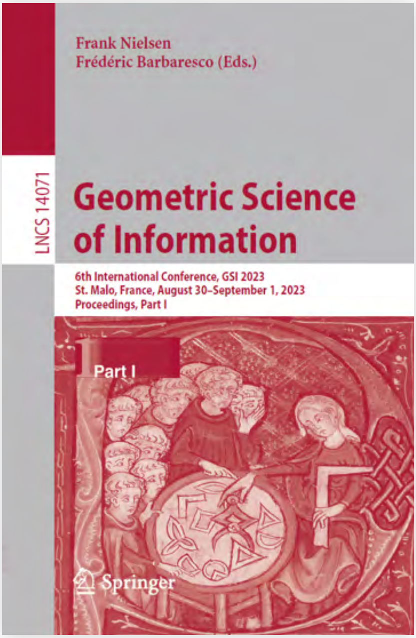

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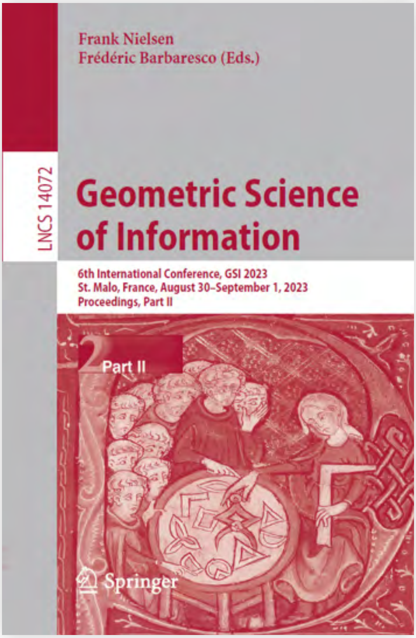

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GSI'23 Special Issue INGE

Dear GSI session Organizer,

We are delighted to announce that in partnership with the Springer Nature Information Geometry (INGE) journal: https://www.springer.com/journal/41884
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The first invited paper just got published with free PDF access:
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Long papers extended contributions accepted to GSI'23 will be submitted via https://www.editorialmanager.com/inge/default2.aspx by selecting GSI23 Special issue
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*Notice that peer-reviewing of the special GSI'23 issue of INGE is ***independent of the peer-reviewing of GSI'23***. When submitting to this special issue, please provide a list of 5 potential reviewers (with emails and affiliations, web pages). Accepted papers will be published online first and a GSI volume with print edition will be issued upon completion of the GSI'23 SI.*

Deadlines for submitting to the special issue:
- *Opening: July 15th 2023*
- *Closing: December 31st 2023*

We kindly ask session Chairs to identify their most novel high-quality papers in their sessions, and to invite the authors of those papers to submit to the GSI'23 SI.


Frederic Barbaresco and Frank Nielsen

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