

Juan Pablo Vigneaux

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Education

Université Paris Diderot, Paris, France.

Doctorate, Mathematics, 2019.

Dissertation: “Topology of Statistical Systems: A Cohomological Approach to Information Theory.”

Supervisor: Daniel Bennequin.

Université Pierre et Marie Curie (UPMC), Paris, France.

Master, Fundamental Mathematics, *mention très bien* (highest honours), 2015.

Pontificia Universidad Católica de Chile (PUC), Santiago, Chile.

Industrial Engineer with specialization in Mathematical Engineering, *distinción máxima* (highest honours), 2014.

BS, Science of Engineering, 2013.

Research experience

Olga Taussky and John Todd Instructor in Mathematics, October 2021–Present

Division of Physics, Mathematics and Astronomy.

California Institute of Technology, Pasadena, California, USA.

Mentor: Matilde Marcolli.

Post-doctoral associate, September 2019—August 2020.

Max Planck Institute for Mathematics in the Sciences, Leipzig, Germany.

Mentor: Nihat Ay. Group: Information Theory of Cognitive Systems.

Doctoral researcher, 2015—August 2019.

Temporary Lecturer (ATER), 2018—2019.

IMJ-PRG: Mathematics Institute of Jussieu–Paris Rive Gauche, France.

Adviser: Daniel Bennequin.

Research assistant, 2012–14.

ANESTOC: Center for Stochastic Analysis and Applications, Santiago, Chile.

Adviser: Rolando Rebolledo.

Research intern, January—March, 2013.

INRIA, Paris, France.

Adviser: Nicolas Broutin. Group: RAP (Networks, Algorithms and Probabilities).

Teaching and mentoring

Department of Mathematics, California Institute of Technology, Pasadena, CA, USA.

Mentored undergrad students:

- Stephanie Chen (then sophomore): guided reading credits in winter and spring terms 2022; undergraduate research project in Summer 2022.
- Eric Paul (then freshman): guided reading credits in winter and spring terms 2022; undergraduate research project in Summer 2022.
- Ryan Leal (then freshman): guided reading credits in spring term 2023; undergraduate research project in Summer 2023.

- Bharathan Sundar (then junior): guided reading in fall term 2023.
- Aman Burman (freshman, co-mentored with Matilde Marcolli): undergraduate research project in Summer 2024.

Lecturer (courses of which I have been the sole instructor):

- *Probability Theory*, Winter 2022 and 2024.
- *Introduction to Mathematical Chaos*, Spring 2022, 2023 and 2024.
- *Algebraic Topology*. Fall 2022.

Organizer:

- Learning seminar on Quantum Optimal Transport, Winter-Spring 2022.

Department of Mathematics, Université Paris Diderot – Paris 7, Paris, France.

Lecturer:

- *Elementary algebra and analysis I*, Fall 2017.

Teaching assistant:

- *Elementary algebra and analysis I*, Fall 2018 and Spring 2016.
- *Elementary algebra and analysis II*, Spring 2019 and Spring 2015.

Faculty of Engineering, Pontificia Universidad Católica de Chile (PUC), Santiago, Chile.

Teaching assistant and course coordinator:

- *Introduction to Mathematical Engineering* (Prof. Rolando Rebolledo), Spring 2014.
- *Stochastic models*, Fall 2011.

Teaching assistant:

- *Numerical Modeling in Engineering*, Fall 2012.
- *Mathematical Modeling in Engineering*, Spring 2012.

Faculty of Mathematics, Pontificia Universidad Católica de Chile (PUC), Santiago, Chile.

Teaching assistant, 2009–12.

- *Calculus I* (single variable calculus), *Calculus III* (vector calculus) and *Probability and Statistics*, several times each.

Service

Department of Mathematics, California Institute of Technology, Pasadena, CA, USA.

- “Information, Geometry, and Physics” seminar co-organizer, Winter 2023–Present.
- Graduate admissions application reviewer, Winter 2022 and Winter 2023.
- PhD candidacy committee member for Sitanshu Gakkhar.

IMJ-PRG: Institut de Mathématiques de Jussieu-Paris Rive Gauche, Paris, France.

- Doctoral students representative at the Institute’s administrative council, 2017-2019.
- Doctoral students’s seminar co-organizer, 2016-2018.

Publications

Peer-reviewed journals

S. Chen and J.P. Vigneaux, “A formula for the categorical magnitude in terms of the Moore-Penrose pseudoinverse.” *Bull. Belg. Math. Soc. Simon Stevin* 30(3): 341-353, 2023.

Introduced a new expression for the magnitude, an invariant of finite enriched categories, and connected its properties with matricial operations.

J. P. Vigneaux, “Typicality for stratified measures,” *IEEE Trans. Inf. Theory* 69(11): 6922-6940,

2023

Described geometrically the typical realizations of stratified measures, which are convex combinations of rectifiable ones. Established a geometric interpretation of Renyi's information dimension for these measures.

J.P. Vigneaux, "A characterization of generalized multinomial coefficients related to the entropic chain rule," *Aequationes Math.*, 97(2): 231-255, 2023.

Introduced frequentist versions of information cohomology and the "fundamental equation of information theory", whose original probabilistic version characterizes entropy. The solutions of the latter are Fontené-Ward multinomial coefficients.

J.P. Vigneaux, "Information structures and their cohomology," in *Theory Appl. Categ.*, 35(38): 1476-1529, 2020.

Defined a general categorical framework for information cohomology, showing among other things that it arises as a derived functor in an abelian category of sheaves. The formalism applies to discrete and continuous observables, as well as quantum ones.

D. Bennequin and J.P. Vigneaux, "A functional equation related to generalized entropies and the modular group," *Aequationes Math.*, 94(6): 1201-1212, 2020.

Solved a new variation of the "fundamental equation of information theory" by applying a novel argument involving an action of $SL_2(\mathbb{Z})$ on probabilities induced by probabilistic conditioning.

J.P. Vigneaux, "Information theory with finite vector spaces," in *IEEE Trans. Inf. Theory*, 65(9): 5674-5687, Sept. 2019.

Determined that the asymptotic rate of growth of certain q -multinomial coefficients is quantified by Tsallis 2-entropy. Developed a version of information theory where words are replaced by finite vector spaces and Tsallis 2-entropy plays the role of Shannon entropy with respect to source coding.

Peer-reviewed conference proceedings

S. Chen and J.P. Vigneaux, "Categorical magnitude and entropy." In: F. Nielsen and F. Barbaresco (eds), *Geom. Sci. Inform. GSI 2023*. Lect. Notes Comput. Sci., vol 14071. Springer, Cham., pp. 278-282, 2023.

Proposed a categorical analogue of entropy, based on the idea that magnitude is a categorical analogue of cardinality and entropy a probabilistic extension of it.

J.P. Vigneaux, "On the entropy of rectifiable and stratified measures." In: F. Nielsen and F. Barbaresco (eds), *Geom. Sci. Inform. GSI 2023*. Lect. Notes Comput. Sci., vol 14071. Springer, Cham., pp. 338-346, 2023.

Reviewed connections between geometric measure theory and the information content of measures with geometric structure.

J.P. Vigneaux, "Entropy under disintegrations." In: F. Nielsen and F. Barbaresco (eds), *Geom. Sci. Inform. GSI 2021*. Lect. Notes Comput. Sci., vol 12829. Springer, Cham., pp. 340-349, 2021.

Showed that every disintegration of measures induces a chain rule for relative entropies. In particular, there is a chain rule for entropies on locally compact topological groups with respect to the Haar measures.

J.P. Vigneaux, "Information cohomology of classical vector-valued observables." In: F. Nielsen and F. Barbaresco (eds), *Geom. Sci. Inform. GSI 2021*. Lect. Notes Comput. Sci., vol 12829. Springer, Cham., pp. 537-546, 2021.

Established that every non-exact 1-cocycle in information cohomology (on a structure that mixes discrete and continuous vector-valued observables) is a linear combination of the differential entropy and the dimension of the underlying support when restricted to the continuous part. This is an algebraic characterization of continuous information measures.

Preprints

J.P. Vigneaux, "A combinatorial approach to categorical Möbius inversion and pseudoinversion,"

arXiv:2407.14647, 2024.

Introduced a new combinatorial interpretation for the Möbius (pseudo)inverse and the magnitude of a category, in terms of paths in the category. This interpretation holds for every category and only involves sums with finitely many terms.

D. Bennequin, O. Peltre, G. Sergeant-Perthuis, and J.P. Vigneaux, “Extra-fine sheaves and interaction decompositions”, arXiv:2009.12646, 2020. Submitted, under review.

Related extra-fine abelian presheaves on posets (a novel analogue of fine sheaves) with a sum-intersection condition that is used in applications to prove the decomposition of the presheaf into a finite direct sum.

Presentations

Invited talk, “A combinatorial approach to categorical Möbius inversion and magnitude” at the Applied Algebraic Topology Research Network’s seminar (online), April 17, 2024.

Invited talk, “Cohomological aspects of information” at the Topos Institute’s Colloquium (online), January 25, 2024.

Contributed talk, “A combinatorial approach to Möbius inversion and pseudoinversion” at Magnitude 2023, Osaka University, Osaka, Japan, December 7, 2023.

Invited talk “New links between information and geometry” at Centre Lagrange, Paris, France, September 11, 2023.

Invited talk “New links between information and geometry” at Max-Planck-Institute for Mathematics in the Sciences, Leipzig, Germany, September 8, 2023.

Invited talk “Typicality for stratified measures” at ETH, Zurich, Switzerland, September 6, 2023.

Contributed talk “On the entropy of rectifiable and stratified measures” at the conference *Geometric Science of Information 2023*, Saint Malo, France, August 30, 2023.

Contributed talk “Categorical Magnitude and Entropy” at the conference *Geometric Science of Information 2023*, Saint Malo, France, August 30, 2023.

Contributed talk “Typicality for stratified measures” at the Information, Geometry and Physics Seminar, Caltech, Pasadena, USA, April 19, 2023.

Invited talk “Quantum optimal transport” at the CMS SIAM Chapter, Caltech, Pasadena, USA, April 7, 2023.

Contributed talk “Categorical magnitude and entropy” at course Ma 20: Frontiers in Mathematics, Caltech, Pasadena, USA, November 1, 2022.

Contributed talk “Optimal transport on certain principal bundles” at the conference *PIMS-IFDS- NSF Summer School on Optimal Transport*, University of Washington, Seattle, USA, June 23, 2022.

Contributed talk “Information cohomology of classical vector-valued observables” at the conference *Geometric Science of Information 2021*, Paris, France, July 23, 2021.

Contributed talk “Entropy under disintegrations” at the conference *Geometric Science of Information 2021*, Paris, France, July 22, 2021.

Visiting researcher, Institute of Mathematics of the Czech Academy of Sciences, Prague Czech Republic, December 10-13, 2019.

Invited talk “Functors on posets, extra-fine sheaves, and interaction decompositions” at the seminar *Algebraic and Combinatorial Perspectives in the Mathematical Sciences* (online), October 30, 2020.

Invited talk “Cohomology of statistical systems” at the Robert Ghrist’s seminar, University of

Pennsylvania, Philadelphia, PA, USA, October 23, 2019.

Invited talk “Cohomology of statistical systems” at the *Category Theory Seminar*, Johns Hopkins University, Baltimore, MD, USA, October 22, 2019.

Invited talk “Information cohomology: an overview” at *OASIS: The Oxford Advanced Seminar on Informatic Structures*, Oxford, England, January 25, 2019.

Invited talk “Une introduction à la topologie de l’information” at the seminar *Higher categories, polygraphs and homotopy*, Université Paris Diderot, Paris, France, September 28, 2018.

Contributed talk “Information theory associated to Tsallis’ 2-entropy” at the conference *Latin American Week on Coding and Information*, Campinas, Brazil, July 26, 2018.

Invited talk, “Entropy and combinatorics” at the colloquium of the Mathematics Institute, Universidad de Talca, Talca, Chile, April 23, 2018.

Contributed talk “Information topology and probabilistic graphical models” at the conference *Applied Algebraic Topology*, Sapporo, Japan, August 8, 2017.

Invited talk “Cohomologie de l’information” at the seminar *Geometry and mathematical physics*, Université Paris Diderot, Paris, France, November 4, 2016.

Awards and scholarships

PGSM Masters Scholarship, Fondation Sciences Mathématiques de Paris, France, 2014.

An international academic scholarship that covered the full cost of studying one year in Paris.

Padre Hurtado award, Pontificia Universidad Católica de Chile, Chile, 2008.

A university-wide academic scholarship that covered the tuition fees of undergraduate education.

Additional research-related experiences

Workshop “Neural Coding and Combinatorics,”
ICERM, Providence, RI, USA, 2023.

International Congress of Mathematicians,
Rio de Janeiro, 2018.

European Talbot Workshop: “Topological aspects of quantum field theories,”
Winterberg, Germany, 2016.

Course “Disruptive technologies and public policies,”
Master 2 École d’Affaires Publiques, Sciences Po, Paris, France, Fall 2015.

Complex Systems Summer School - Chile,
Santa Fe Institute – Universidad del Desarrollo, Zapallar, Chile, 2013.

Skills and competences

First language: Spanish

Other languages: French (level C1), English (level C1), German (level B1)

Programming experience in C#, Java, Python, AMPL, Mathematica, LaTeX.