

Edouard Balzin

Résumé

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Mathematician by training, with multi-disciplinary interests in fundamentals of AI and deep learning algorithms, mathematical physics and algebraic topology. A decade of academic work experience.

Skills in a nutshell

- Track record of publications in international journals, participation in international scientific events to a wide variety of audiences.
- Communication skills: 300 hours of teaching, lead role at two courses in Polytechnique, multiple tutorships and maths popularisation events participation.
- Machine Learning Pipeline experience with skills in Python, PyTorch, Numpy and Scikit-learn, as well as advanced topological tools such as GUDHI and DIPHA.
- Familiarity with Git version control. Advanced Linux user – experience with Debian and Arch-based distributions.
- Administration experience with participation in Polytechnique Bachelor selection committee over multiple years.
- Fluency in English and French, native Russian speaker. Knowledge of Western European, Russian and Central Asian life and culture.

Education

2012-2016 Université Nice Sophia Antipolis/Higher School of Economics Moscow: Mathematics PhD.

- Thesis: “Grothendieck Fibrations and Homotopical Algebra”, co-directors: Dmitry Kaledin (HSE, Moscow) and Carlos Simpson (Nice). Defence date: 20 June 2016 (France), 25 October 2016 (Russia).

2010-2012 National Research University Higher School of Economics: Mathematics Master.

- Thesis: “Factorisation categories, algebras and their generalizations”, advisor: Dmitry Kaledin. Graduated with honours (mention très bien, Russian “red diploma”).

2006-2010 Novosibirsk State University: Physics Bachelor.

- Thesis: “Higher A_∞ -operations and Homological Mirror Symmetry”, advisor: Andrey Losev, ITEP. Graduated with honours (mention très bien, Russian “Red” diploma).

1995-2006 School.

- Graduated with a Gold Medal award, 3rd place in Almaty city mathematical contest.

Employment

2020-2022 Université Côte d’Azur: 3IA postdoctoral researcher. Project lead: 3IA chair Carlos Simpson.

- Two-year postdoc position aimed at developing interactions between pure mathematics and artificial intelligence.
- With Boris Shminke, investigated the problem of generation of semigroups via unsupervised learning of deep neural networks.
- Another project involves studying the changes in deep neural network architectures from a topological viewpoint with aims to understand “shape invariance” of learning and its robustness.
- Research presented over multiple seminars and at 3IA days conference in Sophia-Antipolis.
- Designed from ground-up a differential geometry course for 3rd year Bachelor students at Ecole Polytechnique.

2017-2020 Ecole Polytechnique: Hadamard Lecturer (postdoc).

- Authored two papers devoted to expanding homotopy-theoretic research started in the PhD thesis.
- Participated in scientific events all over Europe and in Australia. Gave around 10 talks on authored research.
- Course instructor for the second year algebra course of Polytechnique's Bachelor. Seminar (petites classes) instructor for the engineer students.
- Administrative duties in Bachelor selection committee.
- Recreational mathematical activities: popularisation of mathematics at "cafe des chercheurs" in Paris, TFJM2 competitions jury.

2012-2017 *Université de Nice Sophia Antipolis/HSE, Moscow*: Doctoral student and ATER.

- Authored a PhD thesis and related research papers.
- Attended over 20 scientific events in Europe, research presented over multiple talks.
- Seminar (travaux dirigés) instructor, 192 hours total.
- Went from basic knowledge to fluent in French.

Preprints, publications and other works

- Edouard Balzin, Boris Shminke, *A Neural network for semigroups*, arXiv:2103.07388, 12 pages, code available at <https://github.com/inpefess/neural-semigroups>.
- Edouard Balzin, *The Formalism of Segal Sections*, arXiv:1811.09601, 59 pages.
- Edouard Balzin, *Reedy Model Structures in Families*, arXiv:1803.00681, 92 pages.
- Eduard Balzin, *Grothendieck Fibrations and Homotopical Algebra*, PhD thesis defended on 20 June 2016.
- Edouard Balzin, *Derived Sections of Grothendieck Fibrations and the Problems of Homotopical Algebra*, Applied Categorical Structures (2017), DOI: 10.1007/s10485-017-9483-1, arXiv: 1410.3387, 50 pages.
- E. R. Balzin, *Derived Sections, Factorisation Algebras and Deligne Conjecture*, 4 pages, Mathematical Notes 100(1), 313-317.
- E. R. Balzin, *Resolutions of categories and derived sections*, Russian Mathematical Surveys 69:5 (2014), pp. 918-920.

Personal information

- Born: 20 February 1989 in Karaganda, USSR (currently Kazakhstan)
- Hobbies and interests: XX century vintage style and formal dress, philosophy, history and fiction writing.
- Personal address:
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91120 Palaiseau, France

References

References available on request.

Detailed academic résumé

Current projects

Machine learning and mathematics (In collaboration with B. Shminke and C. Simpson). The recent explosion of interest in machine learning and data analysis suggests many different research directions.

One of them is to attempt to understand if existing industry-level machine learning methods can be applied to the combinatorics of finite algebraic objects, such as semigroups or n -categories. The number of such mathematical objects explodes quickly with the order of the base set, so perhaps the question of complete classification is a wrong one to ask. As a dataset, the set of all semigroups is hardly known in higher cardinalities, and semigroup symmetries do not allow for a simple application of more efficient convolutional layers.

We thus started to wonder if a neural network could learn to fill multiplication tables of semigroups, especially if there are many ways to do so. What can it then tell us about semigroups of higher order? Our current achievements involve having a neural network architecture that is adapted to the mathematical setting of semigroups and presents, in a “deep learning black box” way, a generation tool for semigroups of certain orders. This network is trained via an unsupervised learning algorithm. We continue study of its properties and what questions can really be tackled: for example, it could be useful to know if for a given partially filled table, a neural network is able to predict the number of all possible semigroup fillings.

Another project goes in a different direction: what can be said about neural networks as mathematical objects? A lot of research comes from the analytical perspective, however a few recent papers make use of category theory and homology to study supervised learning and gradient descent. We believe that the more recent mathematical language of abstract categorical algebra has its place in machine learning, and pursue a deeper understanding of the mentioned constructions.

Our approach is based on a construction in the literature that taking correlations between neurons produces a metric that can then be used to compute the persistent homology of the finite metric space that is the set of all neurons. Our aims are manifold. One of them is to rigorously formulate and prove something that we witness experimentally: that different architectures tend to produce the same “shape”. Besides studying what this shape means abstractly, one hope is that it permits us to understand when and how network learns, and what it means for the learning to be robust, leading, potentially, to a homological approach to supervised learning.

Research and scientific activity

2020-2022 Université Côte d'Azur: 3IA postdoc

- Talk “Neural Networks, categories and homology” at DuaLL seminar, Nice, March 2021 and at the 3IA seminar held online, April 2021
- Talk “Why is AI interesting for a (higher) category theorist”, Nice, October 2021 and Toulouse, December 2021
- *Participant of the following conferences:*
 1. Countless zoom seminars,
 2. Sanya Algebraic Geometry and Machine Learning Online Workshop, January 2021.
 3. 3IA days, Sophia-Antipolis, 30/11–01/12/2021: poster session.
 4. Logic and Higher Structures conference, Marseille and online, February 2022.

2017-2020 Ecole Polytechnique: Hadamard Lecturer

- Talk “Homotopical Algebra and Cartesian Fibrations” at Réseau des Etudiants en Géométrie Algébrique, Institut Henri Poincaré, 6 December 2017.
- Talks entitled “Families of categories in geometry, algebra, and homotopy theory” at
 1. the logic seminar of Marseille University, March 2018,
 2. BYMAT-2018 in Madrid, May 2018, and
 3. Siberian Summer School Current Developments in Geometry in Novosibirsk, August 2018,

- Talk “Segal families over operator categories and their derived sections” at Antwerpen University, October 2018, in Prague, February 2019, in Utrecht, April 2019 and in Sydney, August 2019, and at Nikon Kurnosov’s online COVID seminar, Spring 2020.
- *Participant of the following schools, conferences and scientific activities:*
 1. GAGC-2017 (CIRM, Marseille, December 2017),
 2. BYMAT-2018 (Madrid, May 2018),
 3. Higher Algebra and Mathematical Physics (Max Planck Bonn/Perimeter Institute, August 2018),
 4. Siberian Summer School Current Developments in Geometry (Novosibirsk, August 2018),
 5. CATS-5 (Lisbon, October 2018),
 6. Higher Structures (CIRM, Marseille, January 2019).
 7. Visiting researcher at Macquarie University, August 2019.

2012-2017 Université Nice Sophia Antipolis/Higher School of Economics: ATER/PhD student

- Participant of Kan Extension Seminar organised by Emily Riehl, Harvard. See the link for details: <http://www.math.harvard.edu/~eriehl/kan/>. Talk: “Formal theory of Monads (Following Street)”, web summary available at http://golem.ph.utexas.edu/category/2014/01/formal_theory_of_monads_follow.html
- Short talk “Factorisation categories, algebras and their applications” at the conference GAGC-2013 (January 2013, Marseille); short talk “Categorical resolutions in the context of homotopical algebra” at the conference GAGC-2014, (November 2014, Marseille),
- Talk “Resolutions of categories and derived sections” at the seminar of équipe ATG (Nice, September 2014) and on the same subject at HSE (Moscow, October 2014),
- Talk “Axiomatic infinity-categories” at HSE (Moscow, February 2015), and on the same subject at Workshop “Structures supérieures en Algèbre et Topologie”, CIRM, March 2015,
- Three talks “Topological Quantum Field Theories”, “Boundary Conditions for Field Theories and Related Categories” and “Homological Mirror Symmetry” given on the seminar “Geometry, Topology, and Their Applications” of Sobolev Mathematics Institute, Novosibirsk, May 2015,
- Talk “Segal Sections and Categorical Resolutions” at “Young Topologists Meeting 2015” in Lausanne, July 2015,
- Talk “Reedy model structures for families” at the seminar of équipe ATG (Nice, May 2016),
- Thesis defence talk “Grothendieck Fibrations and Homotopical Algebra”, laboratoire J. A. Dieudonné (Nice, 20 June 2016). Various talks on the work of the thesis in Angers, Bonn, Copenhagen, Freiburg, Moscow, Toulouse and at “Derivators in Prague” and “Young Researchers in Homotopy Theory” (2016-2017).
- *Participant of the following schools and conferences:*
 1. Workshop on Hodge Theory (Paris, December 2012 and November 2013),
 2. GAGC-2013 (CIRM, Marseille, January 2013),
 3. I.M. Gelfand centenary (Moscow, July 2013),
 4. Summer School “Geometry and Algebra” (Yaroslavl, July 2013 and July 2014),
 5. Masterclass “Around Torelli Theorem” (Strasbourg, October 2013),
 6. Carlos Simpson 50th anniversary conference (Paris, December 2013),
 7. Workshop and Conference “Higher Structures in Algebraic Analysis” (Padova, February 2014),
 8. Workshop “Towards The Proof of Geometric Langlands Correspondence” (Jerusalem, March 2014),
 9. “Algebra, Geometry and Physics: a conference in honour of Maxim Kontsevich” (Paris, France, June 2014),
 10. Conference “Young Topologists Meeting 2014” (Copenhagen, July 2014),

11. Conference “Homotopical Algebra, Operads and Grothendieck-Teichmuller groups” (Nice, September 2014),
12. GAGC-2014 (CIRM, Marseille, November 2014),
13. Workshop “Structures supérieures en Algèbre et Topologie” (CIRM, Marseille, March 2015),
14. Conference “Mathematics of the 21st century, the vision of Alexander Grothendieck” (Montpellier, June 2015),
15. Workshop “Munster Functor Calculus Workshop” (Munster, June 2015),
16. Conference “Young Topologists Meeting 2015” (Lausanne, July 2015),
17. Conference “Torsors in Arithmetic and Algebraic Geometry” (Nice, January 2016),
18. Conference “Hochschild Cohomology in Algebra, Geometry, and Topology” (Oberwolfach, February 2016),
19. Conference “String — Math 2016” (Paris, June 2016),
20. Conference “7ECM” (Berlin, July 2016).
21. Conference “Derivators in Prague” (Prague, December 2016).
22. Conference “Young Researchers in Homotopy Theory” (Bonn, February 2017)

2010-2012 National Research University Higher School of Economics: Master of Mathematics

- Talks: “Basics of Grothendieck Derivators”, given on Alexey Gorodentsev and Alexey Rudakov’s “Homological and Homotopical methods in Geometry”, December 1, 2010.
- Laboratory assistant at “Bogomolov Laboratory of Algebraic Geometry and its Applications”.
- Participant of three months (June to August 2012) internship program in mathematics at CMLS, Ecole Polytechnique. Supervisor: Professor Claude Sabbah.
- Participant of 2011 Valery Lunts ‘dachniy’ seminar, July 16-22, of CATS4 conference, 1-6 July 2012, of Vienna Birational Geometry Workshop, August 1-6 2012.
- Assisted in conference organising for “Geometric structures on complex manifolds” (Moscow, October 2011)
- Awards: Moscow Government Scholarship (2011).

2006-2010 Novosibirsk State University: Bachelor of Physics

- Completed master courses (General Relativity, Quantum Physics), math department courses (Algebraic Topology).
- Attended Baikal Summer School on Physics, 2008. Awards: Budker Award 2009, Soloukhin Award 2008.

Teaching Activity

2021

- Instructor for the MAA306 course “Topics in Differential Geometry” (Polytechnique Bachelor program, third year).

2019-2020

- Instructor for the MAA201 course “Euclidean and Hermitian spaces” (Polytechnique Bachelor program, second year).

2018-2019

- Problem sessions instructor for the magistral courses at École Polytechnique. Teaching load: 64 hours per year. Subjects taught: functional analysis.

2015-2017

- Teaching assistant (*responsable des Travaux Dirigés*, problem sessions instructor) for the courses of Algebra, first and second year, and Optional Math, first year, at Université Nice Sophia Antipolis. Teaching load: 96 hours per year.

2010-2012

- Lecturer: 'Lectures on Homotopical Algebra and Model Categories' at Independent University of Moscow, Spring 2012. Notes available at ium.mccme.ru or upon request.
- Teaching assistant:
 - Spring 2012: Mathematical Analysis, 1st year, at Higher School of Economics, Math Department. Algebra-1 course at Independent University of Moscow.
 - Fall 2011: Mathematical Analysis, 1st year, at Higher School of Economics, Math Department. Algebra-1 and Analysis-1 courses at Independent University of Moscow.
 - Spring 2011: Geometry, 1st year, at Higher School of Economics, Math Department.
 - All period: teaching assistance of 1st, 2nd and 3rd year students (discussion and examination of homework problems, a necessary part of the teaching process at HSE Math Department) for additional 2 to 3 hours a week.

Other Activity

- Administrative: participation in the admission for the Bachelor programme at École Polytechnique, 2018-2020 (dossiers grading, selection committee discussions), Referent Instructor for Bachelor Programme 2021 (organisation and monitoring of students' Bachelor theses in mathematics).
- Recreational mathematics: jury member for TFJM² tournament (2019-2020), CGénial school competition (2019). Popularisation of mathematics at "Café des chercheurs", spring 2018.