

Carlo Baldassi

Curriculum vitae

CONTACT INFORMATION Bocconi University
Department of Computational Sciences
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20136 Milano, Italy
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e-mail: carlo.baldassi@unibocconi.it

OVERVIEW **Main research areas:** machine learning and deep learning theory, distributed optimization algorithms, discrete optimization problems, statistical physics of disordered systems, inference problems, computational neuroscience (biologically plausible learning mechanisms), genomics (inference of protein structure from the statistical analysis of large networks).

Programming expertise: I'm an expert in the Julia programming language, having been one of the main contributors to its development since its pre-release days. I'm also an experienced user of several other languages (Python, C, C++, Mathematica, Matlab, Unix scripting tools).

Teaching experience: I've been teaching several computer programming courses, in all cases designing them from scratch. The courses ranged from the undergraduate to the PhD level, from the basics to advanced patterns (numerical analysis, data science, machine learning, deep learning), using C, Python and Julia. I have also briefly taught a mathematics undergraduate course on calculus and probability.

EXTERNAL RESOURCES [Bocconi University](#) [Google Scholar](#) [dblp](#)
[ORCID](#) [GitHub](#)

ACADEMIC AND RESEARCH POSITIONS *Associate Professor* **February, 2023 - Present day**
Bocconi University, DCS, ArtLab and BIDSa, Milan, Italy

Assistant Professor **February, 2017 - January, 2023**
Bocconi University, DCS, ArtLab and BIDSa, Milan, Italy

Scholar **November, 2019 - Present day**
ELLIS Society, Milan ELLIS Unit, Italy

Visiting Researcher **October, 2016 - December, 2016**
Microsoft Research New England, Cambridge, Massachusetts, U.S.A.

Assistant Professor (Italian: RTDa) **March, 2016 - January, 2017**
Politecnico di Torino, DISAT, Torino, Italy
HuGeF - Human Genetics Foundation, Torino, Italy

Visiting Researcher **August, 2015 - December, 2015**
Microsoft Research New England, Cambridge, Massachusetts, U.S.A.

PostDoctoral researcher **May, 2011 - March, 2016**

Politecnico di Torino, DISAT, Torino, Italy
CMP center for multidisciplinary research on optimization and inference, Torino, Italy
HuGeF - Human Genetics Foundation, Torino, Italy

PostDoctoral researcher **Jan, 2009 - May, 2011**
Politecnico di Torino, DIFIS, Torino, Italy
CMP center for multidisciplinary research on optimization and inference, Torino, Italy

PostDoctoral researcher **Jan, 2008 - Dec, 2008**
I.S.I. Foundation, Torino, Italy

EDUCATION

PENS Neuroscience School, Arcachon, France
Advanced Course in Computational Neuroscience August-September 2006

- Dissertation Topic: “Spatio-temporal spiking pattern learning by IF neurons with binary synapses”

Università degli Studi di Torino, Torino, Italy
I.S.I. Foundation, Torino, Italy

Ph.D. Program in “Complex Systems in Post-genomic Biology”, December 2007

- multi-disciplinary Ph.D. Program in Theoretical Physics, Computer Science and Biology
- Dissertation Topic: “A novel algorithm for supervised learning in neuronal models with binary synapses”
- Advisor: prof. Nicolas Brunel

Università degli Studi di Trieste, Trieste, Italy

Master’s degree in Theoretical Physics, September 2004,

- Dissertation Topic: “Estensioni del formalismo SP per problemi di K-soddisfacibilità al caso di variabili multistato” (“*Extensions of the SP formalism for K-satisfiability problems to the case of multi-state variables*”)
- Advisor: prof. Marco Budinich
- Final mark: 110/110 magna cum laude

Liceo Scientifico G. Marinelli, Udine, Italy

Maturità scientifica (B.A.), July 1997

- Experimental course with enhanced program in scientific subjects and foreign languages
- Final mark: 60/60

PUBLICATIONS -
JOURNAL ARTICLES

C. Baldassi, E. M. Malatesta, G. Perugini and R. Zecchina, Typical and atypical solutions in nonconvex neural networks with discrete and continuous weights, *Phys. Rev. E*, Aug 2023, 108 (2), 024310, DOI:10.1103/PhysRevE.108.024310

C. Baldassi, Systematically and efficiently improving existing k-means initialization algorithms by pairwise-nearest-neighbor smoothing, *Transactions on Machine Learning Research*, Dec 2022, openreview:FTtFag3pek

F. Pittorino, A. Ferraro, G. Perugini, C. Feinauer, C. Baldassi and R. Zecchina, Deep networks on toroids: removing symmetries reveals the structure of flat regions in the landscape geometry, *J. Stat. Mech. Theor. Exp.*, Nov 2022, 114007, DOI:10.1088/1742-5468/ac9832

P. Torta, G. B. Mbeng, C. Baldassi, R. Zecchina and G. E. Santoro, Quantum Approximate Optimization Algorithm applied to the binary perceptron, *Phys. Rev. B*, Mar 2023, 107, 094202, DOI:10.1103/PhysRevB.107.094202

C. Baldassi, Recombinator-k-means: An evolutionary algorithm that exploits k-means++ for recombination, *IEEE Trans. Evol. Comput.*, Jan 2022, DOI:10.1109/TEVC.2022.3144134

C. Baldassi, C. Lauditi, E. M. Malatesta, R. Pacelli, G. Perugini and R. Zecchina, Learning through atypical “phase transitions” in overparameterized neural networks, *Phys. Rev. E*, Jul 2022, 106 (1), 014116, DOI:10.1103/PhysRevE.106.014116

F. Pittorino, C. Lucibello, C. Feinauer, E. M. Malatesta, G. Perugini, C. Baldassi, M. Negri, E. Demyanenko and R. Zecchina, Entropic gradient descent algorithms and wide flat minima, *J. Stat. Mech. Theor. Exp.*, Dec 2021, 124015, DOI:10.1088/1742-5468/ac3ae8

C. Baldassi, C. Lauditi, E. M. Malatesta, G. Perugini and R. Zecchina, Unveiling the structure of wide flat minima in neural networks, *Phys. Rev. Lett.*, Dec 2021, 127: 278301, DOI:10.1103/PhysRevLett.127.278301

C. Baldassi, E. M. Malatesta, M. Negri and R. Zecchina, Wide flat minima and optimal generalization in classifying high-dimensional Gaussian mixtures, *J. Stat. Mech. Theor. Exp.*, Dec 2020, 124012, DOI:10.1088/1742-5468/abcd31

C. Baldassi, R. Della Vecchia, C. Lucibello and R. Zecchina, Clustering of solutions in the symmetric binary perceptron, *J. Stat. Mech. Theor. Exp.*, Jul 2020, 073303, DOI:10.1088/1742-5468/ab99be

C. Baldassi, F. Pittorino and R. Zecchina, Shaping the learning landscape in neural networks around wide flat minima, *Proc. Natl. Acad. Sci. U.S.A.*, 2020 117 (1) 161-170, DOI:10.1073/pnas.1908636117

C. Baldassi, S. Cerreia-Vioglio, F. Maccheroni, M. Marinacci and M. Pirazzini, A behavioral characterization of the Drift-Diffusion Model and its multi-alternative extension to choice under time pressure, *Manag. Sci.* 66 (11), 5075-5093, 2020, DOI:10.1287/mnsc.2019.3475

C. Baldassi, E. M. Malatesta and R. Zecchina, Properties of the geometry of solutions and capacity of multi-layer neural networks with rectified linear unit activations, *Phys. Rev. Lett.*, 2019, 123: 170602, DOI:10.1103/PhysRevLett.123.170602

L. Saglietti, F. Gerace, A. Ingrosso, C. Baldassi and R. Zecchina, From statistical inference to a differential learning rule for stochastic neural networks, *Interface focus* 8(6):20180033, DOI:10.1098/rsfs.2018.0033

- C. Baldassi, F. Gerace, H.J. Kappen, C. Lucibello, L. Saglietti, E. Tartaglione and R. Zecchina, Role of synaptic stochasticity in training low-precision neural networks, *Phys. Rev. Lett.*, 2018, 120(26): 268103, DOI:10.1103/PhysRevLett.120.268103
- C. Baldassi and R. Zecchina, Efficiency of quantum vs. classical annealing in nonconvex learning problems, *Proc. Natl. Acad. Sci. U.S.A.*, Feb 2018, 115(7):1457-1462, DOI:10.1073/pnas.1711456115
- C. Baldassi, F. Gerace, L. Saglietti and R. Zecchina, From inverse problems to learning: a statistical mechanics approach, *Journal of Physics: Conference Series*, Jan 2018, 955(1):012001, DOI:10.1088/1742-6596/955/1/012001
- C. Baldassi, A method to reduce the rejection rate in Monte Carlo Markov Chains on Ising spin models, *J. Stat. Mech. Theor. Exp.*, Mar 2017, 033301, DOI:10.1088/1742-5468/aa5335
- C. Bosia, F. Sgrò, L. Conti, C. Baldassi, F. Cavallo, F. Di Cunto, E. Turco, A. Pagnani and R. Zecchina, RNAs competing for microRNAs mutually influence their fluctuations in a highly non-linear microRNA-dependent manner in single cells, *Genome Biol.*, Feb 2017; 18(1):37, DOI:10.1186/s13059-017-1162-x
- C. Baldassi, C. Borgs, J. Chayes, A. Ingrosso, C. Lucibello, L. Saglietti and R. Zecchina, Unreasonable Effectiveness of Learning Neural Nets: Accessible States and Robust Ensembles, *Proc. Natl. Acad. Sci. U.S.A.*, Nov 2016; 113(48):E7655-E7662, DOI:10.1073/pnas.1608103113
- T. Gueudré, C. Baldassi, M. Zamparo, M. Weigt and A. Pagnani, Simultaneous identification of specifically interacting paralogs and interprotein contacts by direct coupling analysis, *Proc. Natl. Acad. Sci. U.S.A.*, Oct 2016; 113(43):12186-12191, DOI:10.1073/pnas.1607570113
- C. Baldassi, F. Gerace, C. Lucibello, L. Saglietti and R. Zecchina, Learning may need only a few bits of synaptic precision, *Phys. Rev. E*, May 2016, 93 (5), 052313, DOI:10.1103/PhysRevE.93.052313
- C. Baldassi, A. Ingrosso, C. Lucibello, L. Saglietti and R. Zecchina, Local entropy as a measure for sampling solutions in Constraint Satisfaction Problems, *J. Stat. Mech. Theor. Exp.*, Feb 2016, 023301, DOI:10.1088/1742-5468/2016/02/023301
- C. Baldassi, A. Ingrosso, C. Lucibello, L. Saglietti and R. Zecchina, Subdominant Dense Clusters Allow for Simple Learning and High Computational Performance in Neural Networks with Discrete Synapses, *Phys. Rev. Lett.*, 2015, 115 (12), DOI:10.1103/PhysRevLett.115.128101
- A. Alemi-Neissi, C. Baldassi, N. Brunel and R. Zecchina, A three-threshold learning rule approaches the maximal capacity of recurrent neural networks, *PLoS Comput. Biol.*, 2015, 11 (8), e1004439, DOI:10.1371/journal.pcbi.1004439
- C. Baldassi and A. Braunstein, A Max-Sum Algorithm for Training Discrete Neural Networks, *J. Stat. Mech. Theor. Exp.*, 2015, P08008, DOI:10.1088/1742-5468/2015/08/P08008
- C. Baldassi, M. Zamparo, C. Feinauer, A. Procaccini, R. Zecchina, M. Weigt and A. Pagnani, Fast and accurate multivariate Gaussian modeling of protein families: Predicting residue contacts and protein-interaction partners, *PLOS ONE*, 2014, 9 (3), e92721,

DOI:10.1371/journal.pone.0092721

C. Baldassi, A. Braunstein and R. Zecchina, Theory and protocols for the material tempotron model, *J. Stat. Mech. Theor. Exp.*, 2013 (12), P12013, DOI:10.1088/1742-5468/2013/12/P12013

C. Baldassi, A. Alemi-Neissi, M. Pagan, J. DiCarlo, R. Zecchina and D. Zoccolan, Shape Similarity, Better than Semantic Membership, Accounts for the Structure of Visual Object Representations in a Population of Monkey Inferotemporal Neurons, *PLoS Comput. Biol.*, 2013, 9(8): e1003167, DOI:10.1371/journal.pcbi.1003167

C. Baldassi, Generalization Learning in a Perceptron with Binary Synapses, *J. Stat. Phys.*, Volume 135, Number 5 / September, 2009, pp. 902-916, DOI:10.1007/s10955-009-9822-1

C. Baldassi, A. Braunstein, N. Brunel and R. Zecchina, Efficient supervised learning in networks with binary synapses, *Proc. Natl. Acad. Sci. U.S.A.*, 2007 Jun 26; 104(26):11079-11084, DOI:10.1073/pnas.0700324104

PUBLICATIONS -
BOOK CHAPTERS

T. Gueudré, C. Baldassi, A. Pagnani and Martin Weigt, Predicting Interacting Protein Pairs by Coevolutionary Paralog Matching, in *Protein-Protein Interaction Networks*, Methods in Molecular Biology, Volume 2074, 2020, pp 57-65, Springer, ISBN:978-1-4939-9873-9, DOI:10.1007/978-1-4939-9873-9_5

C. Baldassi, A. Braunstein, A. Ramezanpour and R. Zecchina, Statistical Physics and Network Optimization Problems, in *Mathematical Foundations of Complex Networked Information Systems*, Lecture Notes in Mathematics, Volume 2141, 2015, pp 27-49, Springer, ISBN:978-3-319-16966-8, DOI:10.1007/978-3-319-16967-5_2

J. Secco, A. Vinassa, V. Pontrandolfo, C. Baldassi and F. Corinto, Binary Synapse Circuitry for High Efficiency Learning Algorithm Using Generalized Boundary Condition Memristor Models, in *Advances in Neural Networks: Computational and Theoretical Issues*, Smart Innovation, Systems and Technologies, Volume 37, 2015, pp 369-374, Springer, ISBN:978-3-319-18163-9, DOI:10.1007/978-3-319-18164-6_36

PUBLICATIONS -
CONFERENCE
PRESENTATIONS
AND PROCEEDINGS

F. Pittorino, A. Ferraro, G. Perugini, C. Feinauer, C. Baldassi and R. Zecchina, Deep networks on toroids: removing symmetries reveals the structure of flat regions in the landscape geometry, *International Conference on Machine Learning (ICML)*, 2022, PMLR:v162/pittorino22a

C. Baldassi, On robust minima in neural networks: theoretical analyses and algorithmic strategies, invited oral presentation at *Artificial Intelligence 2021 - Spring Session*, Gran Sasso Science Institute, Italy, 2021

C. Baldassi, Wide flat minima and entropic algorithms, invited oral presentation at *"Quantum and Physics based machine learning (QPhML) 2020*, ELLIS, Milan-Tübingen-Nijmegen, 2020

F. Pittorino, C. Lucibello, C. Feinauer, E. M. Malatesta, G. Perugini, C. Baldassi, M. Negri, E. Demyanenko and R. Zecchina, Entropic gradient descent algorithms and wide flat minima, *International Conference on Learning Representations (ICLR)*, 2021, arXiv:2006.07897

C. Baldassi, On the existence of wide flat minima in neural network landscapes: analytic and algorithmic approaches, invited oral presentation at *Workshop IV: Using Physical Insights*

for *Machine Learning*, IPAM, University of California, Los Angeles, 2019

C. Baldassi, A large deviations statistical physics approach to finding wide flat minima in neural networks landscapes, invited oral presentation at *Statistical physics and neural computation international workshop*, Guang-zhou, China, 2019

C. Baldassi, Exploiting quantum fluctuations for robust and efficient neural network training, invited oral presentation at *DALI/ELLIS: Quantum ML workshop*, San Sebastian, Spain, 2019

C. Baldassi, A theoretical framework to link local entropy, cross-entropy, wide states and generalization in neural networks, invited oral presentation at *XXIV Convegno Nazionale di Fisica Statistica e dei Sistemi Complessi*, Parma, Italy, 2019

C. Baldassi, Julia: a programming language for data science, invited oral presentation at *4th Open SmartData@PoliTO Workshop*, Torino, Italy, 2019

C. Baldassi, Robust accessible states allow efficient training of neural networks with very low precision stochastic synapses, invited oral presentation at *Computation by natural systems*, The Royal Society at Chicheley Hall, UK, 2018

C. Baldassi, Synaptic [classical and quantum] fluctuations as a recipe for robust and efficient neural network training, invited oral presentation at *2nd Physics Informed Machine Learning conference*, Santa Fe, NM, USA, 2018

P. Chaudhari, C. Baldassi, R. Zecchina, S. Soatto, A. Talwalkar and A. Oberman, Parle: parallelizing stochastic gradient descent, *SysML*, 2018, [arXiv:1707.00424](https://arxiv.org/abs/1707.00424)

P. Chaudhari, A. Choromanska, S. Soatto, Y. LeCun, C. Baldassi, C. Borgs, J. Chayes, L. Sagun, R. Zecchina, Entropy-SGD: Biasing gradient descent into wide valleys, *International Conference on Learning Representations (ICLR)*, Toulon, France, 2017, [arXiv:1611.01838](https://arxiv.org/abs/1611.01838)

C. Baldassi, Neural networks optimization and dense states, invited oral presentation at *XXII Convegno Nazionale di Fisica Statistica e dei Sistemi Complessi*, Parma, Italy, 2017

C. Baldassi, F. Gerace, A. Ingrosso, C. Lucibello, L. Saglietti and R. Zecchina, Robust accessible states allow efficient training of neural networks with very low precision synapses, oral presentation at *StatPhys26*, Lyon, France, 2016.

A. Alemi-Neissi, C. Baldassi, N. Brunel and R. Zecchina A purely local, distributed, simple learning scheme achieves near-optimal capacity in recurrent neural networks without explicit supervision, *Biological Distributed Algorithms (BDA) 2015*, MIT, Boston MA, USA

A. Alemi-Neissi, C. Baldassi, N. Brunel and R. Zecchina, Input-driven unsupervised learning in recurrent neural networks, *Cosyne Abstracts*, Salt Lake City USA. 2014: 191

A. Gitter, A. Braunstein, A. Pagnani, C. Baldassi, C. Borgs, J. Chayes, R. Zecchina and E. Fraenkel, Sharing information to reconstruct patient-specific pathways in heterogeneous diseases, *Pacific Symposium on Biocomputing*, 2014 (19), 39-50, DOI:10.1142/9789814583220_0005

A. Alemi-Neissi, C. Baldassi, A. Braunstein, A. Pagnani, R. Zecchina and D. Zoccolan Information theoretic and machine learning approaches to quantify non-linear visual feature interaction underlying visual object recognition *BMC Neuroscience 2012*, 13(Suppl 1):P2

(16 July 2012), DOI:10.1186/1471-2202-13-S1-P2

M. Pagan, A. Alemi-Neissi, C. Baldassi, R. Zecchina, J. DiCarlo and D. Zoccolan, From luminance to semantics: how natural objects are represented in monkey inferotemporal cortex, *COSYNE 2011 proceedings*, P1 (24 February 2011)

C. Baldassi, A. Braunstein, N. Brunel and R. Zecchina, Adding a weak, stochastic, non-specific reinforcement process to the clipped perceptron algorithm lets it efficiently solve the supervised learning problem in neuronal models with binary synapses, oral presentation at the *Minischool and Workshop on Multiple Time Scales in the Dynamics of the Nervous System*, ICTP Trieste, IT, 2008

C. Baldassi, A. Braunstein, N. Brunel and R. Zecchina, Efficient supervised learning in networks with binary synapses, oral presentation at CNS*2007 Toronto, CA, *BCM Neuroscience 2007*, 8(Suppl 2):S13, DOI:10.1186/1471-2202-8-S2-S13

PROGRAMMING
EXPERIENCE

I've been a major contributor in the development of the Julia programming language for technical and scientific computing (more than 600 commits in the [language repository](#), more than 100k modified lines of code according to [GitHub statistics](#)). I invented and wrote the algorithm that [resolves](#) Julia package versions. I maintain several registered Julia packages, and I'm the creator and maintainer of the [julia-vim plugin](#).

I teach the Julia language in Bocconi's PhD program on Statistics and Computer Science.

I teach or have taught several undergraduate courses on Python and its numerical, scientific, machine learning and deep learning library stack (numpy/scipy/scikit learn/pytorch).

I am very experienced in the use of C and C++ programming languages, Wolfram Research's Mathematica, Mathworks' Matlab and Unix shell scripting languages for scientific applications, and in the use of Linux and Microsoft Server clusters for performing large parallelized computations.

TEACHING
EXPERIENCE

I was part of the first batch of new faculty hires in the field of computer science when Bocconi University opened the BEMACS (BSc in Economics Management and Computer Science) undergraduate course in 2017. As such, I have contributed to the introduction of computer science, and more generally STEM subjects, in the University curriculum (further steps were the creation of the DSBA masters program; the change of the PhD course from 'Statistics' to 'Statistics and Computer Science'; the creation of the BAI undergraduate course). Under these circumstances, I was thus tasked with designing (and am still designing) several new courses or parts of courses entirely from scratch.

Since September 2023 I am the director of the BAI undergraduate course.

I am a member of the PhD in Statistics and Computer Science committee.

Courses taught (in full or in part) at Bocconi University over the years (all in English):

MACHINE LEARNING II **2023 - Present day**
MSc in Data Science and Business Analytics, 2nd year course
Summary: Introduction to statistical machine learning and deep learning

MACHINE LEARNING AND ARTIFICIAL INTELLIGENCE **2022 - Present day**
BSc in Mathematical and Computing Sciences for AI, 3rd year course

Summary: Introduction to neural networks, learning theory, automatic differentiation, deep learning techniques

COMPUTER SCIENCE I (PROGRAMMING) **2020 - Present day**

PhD in Statistics and Computer Science, 1st year course

Summary: Introduction to scientific programming, the Julia programming language, code optimization techniques, numerical issues, parallel computing, GPUs.

COMPUTER SCIENCE - MODULE 1 **2020 - 2023**

BSc in Mathematical and Computing Sciences for AI, 1st year course

Summary: Introduction to computer science and programming, basics of C, basics of Python

COMPUTER PROGRAMMING **2018 - 2022**

BSc in Economics, Management and Computer Science, 2nd year course

Summary: Introduction to numpy/scipy, Monte Carlo, simulated annealing, dynamic programming, first-order continuous optimization methods

FUNDAMENTALS OF COMPUTER SCIENCE **2016 - 2019**

BSc in Economics, Management and Computer Science, 1st year course

Summary: Introduction to computer science and programming, basics of Python

MATHEMATICS MODULE 2 (APPLIED) **2017 - 2019**

BSc in International Economics and Finance, 1st year course

Summary: Integral calculus, introduction to probability theory

TOPICS IN COMPUTER SCIENCE AND OPTIMIZATION **2017 - 2018**

PhD in Statistics, 1st year course

Summary: Maximum entropy principle, approximate maximum likelihood inference (mean field and pseudo-likelihood approximations)

MACHINE LEARNING **2017 - 2017**

BSc in Economics, Management and Computer Science, 2nd year course

Summary: Introduction to basic machine learning techniques, scikit learn

LANGUAGES

Italian (native), English (fluent), French (good)