



# 2021 Ulf Grenander Prize

Michael I. Jordan was awarded the 2021 Ulf Grenander Prize in Stochastic Theory and Modeling at the Annual Meeting of the AMS, held virtually January 6–9, 2021.



Michael I. Jordan

## Citation

The Ulf Grenander Prize in Stochastic Theory and Modeling is awarded to Michael I. Jordan for foundational contributions to machine learning, especially unsupervised learning, probabilistic computation, and core theory for balancing statistical fidelity with computation.

Machine learning (ML) has emerged as one of the highest-impact areas of computer science in the 21st century, and

it has become nearly synonymous with modern artificial intelligence (AI). Michael I. Jordan has played a significant role in bringing ML from infancy to where it is today. Since the 1990s, he has been one of the foremost intellectual leaders of the field, developing numerous important new theories and methods that link AI, statistics, optimization, and computation. His work has provided the foundational building blocks for modern machine learning and has paved the way for both its current successes and its future.

One of Jordan's core contributions to ML is the development of the field of unsupervised learning. In his hands it has moved from a collection of unrelated algorithms to an intellectually coherent field—one largely based on probabilistic inference—that can be used to solve real-world problems. Unsupervised learning dispenses with the labels and reinforcement signals of the other main branches of machine learning, developing algorithms that reason backward from data to the patterns that underlie its generative mechanisms. Working from the general perspective of stochastic modeling and Bayesian inference, Jordan augmented the classical analytical distributions of Bayesian statistics with computational entities having graphical, combinatorial, temporal, and spectral structure.

Furthermore, making use of ideas from convex analysis and statistical physics, he developed new methods for approximate inference that exploited these structures. The resulting algorithms, which are called variational inference, are now a major area of ML and the principal engine behind scalable unsupervised learning. Jordan's general approach to unsupervised learning gave birth to latent Dirichlet allocation, hierarchical Dirichlet processes, kernel independent component analysis, factorial hidden Markov models, multiple kernel learning, DP-means, and distance metric learning—all topics developed by Jordan and his students, and all topics which have become textbook material in unsupervised learning, with thousands of applications in science and technology.

Jordan has also made significant contributions to many of the other important methodologies of ML, such as neural networks, reinforcement learning, and dimensionality reduction. He is known for prescient early work on recurrent neural networks, for the first rigorous theory of convergence of Q-learning (the core dynamic-programming-based framework that underlies reinforcement learning), and for his work on “classification-calibrated loss functions,” which provides a general theory of classification that encompasses boosting and the support vector machine. In more recent years, Jordan has turned his attention to optimization theory and Monte Carlo sampling, focusing on nonconvex optimization and sampling in high-dimensional spaces. Overall, the research accomplishments of Michael I. Jordan have been broader than any specific technique; rather, they go to the core of what it means for a real-world system to learn, and they herald the emergence of machine learning as a science.

Michael I. Jordan has been an intellectual leader in machine learning for more than twenty years. Throughout his career, he has pursued a general agenda of reworking core statistical theory to encompass computational concepts, reworking core computational theory to encompass

statistics, and bringing both these concepts to bear on the study of the foundations of machine learning.

### Biographical Sketch

Michael I. Jordan is the Pehong Chen Distinguished Professor in the Department of Electrical Engineering and Computer Science and the Department of Statistics at the University of California, Berkeley. He received his PhD in cognitive science in 1985 from the University of California, San Diego. His research interests bridge the computational, statistical, cognitive, and biological sciences. He is known for his work on variational inference, topic models, Bayesian nonparametrics, reinforcement learning, convex and nonconvex optimization, distributed computing systems, and game-theoretic learning. He is a member of the National Academy of Sciences and a member of the National Academy of Engineering. He has been named a Neyman Lecturer and a Medallion Lecturer by the Institute of Mathematical Statistics, and he has given a Plenary Lecture at the International Congress of Mathematicians. He received the IEEE John von Neumann Medal in 2020, the IJCAI Research Excellence Award in 2016, the David E. Rumelhart Prize in 2015, and the ACM/AAAI Allen Newell Award in 2009.

### Response from Michael I. Jordan

My career had its origins in the fields of cognitive psychology and philosophy, where, inspired by logicians such as Bertrand Russell, I was drawn to the problem of finding mathematical expression for aspects of human intelligence, including reasoning and learning. Eventually my work began to take mathematical shape in the study of relationships between computation and inference, where again I found myself in debt to pioneers of the past century, including von Neumann, Kolmogorov, Neyman, Wald, Turing, Blackwell, and Wiener. The problems that have fascinated me have revolved around how humans and machines can make good decisions based on uncertain data and do so in a computationally efficient, real-time manner. In studying such problems, I've made use of a wide range of mathematics, including convex analysis, variational analysis, stochastic differential equations, symplectic integration, partial differential equations, graph theory, and random measures. It's been exciting to uncover some of the algorithmic consequences of the mathematical structures studied in these fields, while working within the overall framework of inferential statistics.

My first decade as a professor took place at MIT, and I was well aware of the nearby presence at Brown of Ulf Grenander and his "pattern theory" school, including the friendly and stimulating welcome to be found in that school from mathematicians such as Stuart Geman and David Mumford. In accepting this award, I wish to indicate my delight and honor to be associated with such individuals and with the intellectual tradition of Grenander's pattern theory.

### About the Prize

The Grenander Prize, established in 2017 in honor of Ulf Grenander (1923–2016), recognizes exceptional theoretical and applied contributions in stochastic theory and modeling. It is awarded for seminal work, theoretical or applied, in the areas of probabilistic modeling, statistical inference, or related computational algorithms, especially for the analysis of complex or high-dimensional systems. Grenander was an influential scholar in stochastic processes, abstract inference, and pattern theory. He published landmark works throughout his career, notably his 1950 dissertation, *Stochastic Processes and Statistical Inference*, at Stockholm University, *Abstract Inference*, his seminal *Pattern Theory: From Representation to Inference*, and *General Pattern Theory*. A long-time faculty member of Brown University's Division of Applied Mathematics, Grenander was a Fellow of the American Academy of Arts and Sciences and the National Academy of Sciences and was a member of the Royal Swedish Academy of Sciences.

The members of the 2021 Committee to Select the Winner of the Ulf Grenander Prize were:

- Guillaume Bal
- Paul G. Dupuis
- Gitta Kutyniok

The winner of the inaugural Grenander Prize (2018) was Judea Pearl.

### Credits

Photo of Michael I. Jordan is courtesy of Justin Bettman.