

## MATHEMATICS

# Random Quantization of Hamiltonian Systems

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Presented by Academician of the RAS V.V. Kozlov February 17, 2021

Received February 19, 2021; revised April 5, 2021; accepted April 5, 2021

**Abstract**—A quantization of a Hamiltonian system is an ambiguous procedure. Accordingly, we introduce the notion of random quantization, related random variables with values in the set of self-adjoint operators, and random processes with values in the group of unitary operators. The procedures for the averaging of random unitary groups and averaging of random self-adjoint operators are defined. The generalized weak convergence of a sequence of measures and the corresponding generalized convergence in distribution of a sequence of random variables are introduced. The generalized convergence in distribution for some sequences of compositions of random mappings is obtained. In the case of a sequence of compositions of shifts by independent random vectors of Euclidean space, the obtained convergence coincides with the statement of the central limit theorem for a sum of independent random vectors. The results are applied to the dynamics of quantum systems arising in random quantization of a Hamiltonian system.

**Keywords:** random linear operator, random operator-valued function, operator-valued random process, law of large numbers, central limit theorem, Markovian process, Kolmogorov equation

**DOI:** 10.1134/S1066456242103008X

A quantization of a Hamiltonian system is an ambiguous procedure. For this reason, we introduce the concept of randomized (random) quantization. The random quantization of a Hamiltonian system is a mapping of a linear space of Hamiltonian functions defined on the symplectic phase space such that each Hamiltonian function is taken to a random variable with values in the set of self-adjoint operators acting on the Hilbert space of the quantum system. This scheme covers all known quantization methods, since the value of a random variable at each element of a probability space describes some quantization. Moreover, the random semigroup generated by a random Hamiltonian is a random process with values in the group of unitary operators.

In this paper, we consider the linear quantizations of Hamiltonian systems introduced in [1] and developed in [2]. The linear quantization is a linear mapping of a vector space of Hamiltonian functions defined on the symplectic phase space to a vector space of quantum Hamiltonians representing self-adjoint operators in the Hilbert space of the quantum system.

Interest in the study of random variables with values in the set of unbounded operators in Banach spaces and in the study of random processes with values in the Banach space of bounded linear operators is motivated by some problems of mathematical physics [3–5]. For example, if a Hamiltonian function can be a random variable in functional mechanics [6], then the quantum analogue of functional mechanics is a quantum system with a Hamiltonian representing a random variable with values in the set of self-adjoint operators [7]. The randomness of the Hamiltonian of the quantum system follows from the ambiguity of the quantization procedure for classical Hamiltonian systems [1, 7]. Thus, there are two sources of randomness in the dynamics of quantum systems.

1. The Hamiltonian of a classical system is a random variable with values in the set of continuously differentiable functions on the phase space.

2. Quantization of a classical Hamiltonian system is a random variable with values in the set of linear mappings of the linear manifold of the space of smooth functions on the phase space to a linear man-

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# Random Perturbations Of Hamiltonian Systems

**Gerd Fischer, Ulf Rehmann**



## Random Perturbations Of Hamiltonian Systems:

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*On Random Perturbations of Hamiltonian Systems with Many Degrees of Freedom* Mark I. Freidlin, Matthias Weber, 2000 *Topics in Stochastic Analysis and*

*Nonparametric Estimation* Pao-Liu Chow, Boris S. Mordukhovich, G. George Yin, 2010-07-19 This IMA Volume in Mathematics and its Applications TOPICS IN STOCHASTIC ANALYSIS AND NONPARAMETRIC ESTIMATION contains papers that were presented at the IMA Participating Institution conference on Asymptotic Analysis in Stochastic Processes Nonparametric Estimation and Related Problems held on September 15-17, 2006 at Wayne State University. The conference, which was one of approximately ten selected each year for partial support by the IMA through its affiliates program, was dedicated to Professor Rafail Z. Khasminskii on the occasion of his 75 birthday in recognition of his profound contributions to the field of stochastic processes and nonparametric estimation theory. We are grateful to the participants and especially to the conference organizers for making the event so successful. Pao-Liu Chow, Boris Mordukhovich, and George Yin of the Department of Mathematics at Wayne State University did a superb job organizing this first-rate event and in editing these proceedings. We take this opportunity to thank the National Science Foundation for its support of the IMA. *New Trends in Mathematical Physics* Vidas Sidoravicius, 2009-08-31 This book collects selected papers written by invited and plenary speakers of the 15th International Congress on Mathematical Physics (ICMP) in the aftermath of the conference. In extensive review articles and expository texts as well as advanced research articles, the world's leading experts present the state of the art in modern mathematical physics. New mathematical concepts and ideas are introduced by prominent mathematical physicists and mathematicians covering, among others, the fields of Dynamical Systems, Operator Algebras, Partial Differential Equations, Probability Theory, Random Matrices, Condensed Matter Physics, Statistical Mechanics, General Relativity, Quantum Mechanics, Quantum Field Theory, Quantum Information, and String Theory. All together, the contributions in this book give a panoramic view of the latest developments in mathematical physics. They will help readers with a general interest in mathematical physics to get an update on the most recent developments in their field and give a broad overview on actual and future research directions in this fascinating and rapidly expanding area. **Stochastic Averaging** Wei-Qiu Zhu, Mao-Lin Deng, Guo-Qiang Cai, 2025-06-19 The stochastic averaging methods are among the most effective and widely applied approximate methods for studying nonlinear stochastic dynamics. Upon an overview of global research on the subject, the book highlights a comprehensive summary of research results obtained by the group led by Professor Weiqiu Zhu at Zhejiang University in China and the group led by Professors Y. K. Lin and G. Q. Cai at Florida Atlantic University in the USA over the past three decades. The books are structured to progress logically from foundational principles to simple problems and then to increasingly complex applications. To facilitate understanding and mastery of the methods, the books offer essential preliminary knowledge and a wealth of examples. The book comprises two volumes. Volume 1 introduces the basic principles of stochastic averaging methods and their applications to single-degree-of-freedom systems under various random excitations. It also covers stochastic averaging methods for quasi-Hamiltonian systems subjected to different random excitations, including Gaussian white noise, combined Gaussian and Poisson white noises, and fractional Gaussian noise.

Volume 2 explores stochastic averaging methods for quasi integrable Hamiltonian systems under colored noise excitation quasi integrable Hamiltonian systems with genetic effects under Gaussian white noise and colored noise excitations and quasi generalized Hamiltonian systems under Gaussian white noise excitation Additionally it covers applications of these methods in ecosystems and some other natural science and engineering scenarios These books serve as both introductory texts and valuable reference resources for readers in higher education and research institutions who are interested in or actively engaged in research involving nonlinear stochastic dynamics The fields covered include mechanics physics chemistry biology ecology astronautics and aeronautics oceanography civil engineering mechanical engineering and electrical engineering

**Lyapunov Exponents for Small Random Perturbations of Nilpotent and Hamiltonian Systems** Levon Goukasian, 2001

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**Beyond Peaceful Coexistence; The Emergence Of Space, Time And Quantum** Ignazio

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