

Convergence of Stochastic Interacting Particle Systems in Probability under a Sobolev Norm

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Abstract

In this paper, we consider particle systems with interaction and Brownian motion. We prove that when the initial data is from the sampling of Chorin's method, i.e., the initial vertices are on lattice points $hi \in \mathbb{R}^d$ with mass $\rho_0(hi)h^d$, where ρ_0 is some initial density function, then the regularized empirical measure of the interacting particle system converges in probability to the corresponding mean-field partial differential equation with initial density ρ_0 , under the Sobolev norm of $L^\infty(L^2) \cap L^2(H^1)$. Our result is true for all those systems when the interacting function is bounded, Lipschitz continuous and satisfies certain regular condition. And if we further regularize the interacting particle system, it also holds for some of the most important systems of which the interacting functions are not. For systems with repulsive Coulomb interaction, this convergence holds globally on any interval $[0, t]$. And for systems with attractive Newton force as interacting function, we have convergence within the largest existence time of the regular solution of the corresponding Keller-Segel equation.

1 Introduction

In this paper we consider the N -particle system of many indistinguishable individuals interacting with each other following the same physical laws. To be specific, we consider $\{X_i(t)\}_{i=1}^N \in \mathbb{R}^d$ as the trajectories of the N particles at time t . Suppose all particles have the same "weight", with certain initial data $\{X_i(0)\}_{i=1}^N$, those trajectories following the stochastic differential equations as follows:

$$X_i(t) = X_i(0) + \frac{1}{N} \sum_{j=1}^N \int_0^t F_0(X_i(s) - X_j(s)) ds + \sigma B_i(t) \quad (1)$$

where $\{B_i(t)\}_{i=1}^N$ are independent standard d -dimensional Brownian motions. We show that, as $N \rightarrow \infty$ and under proper assumption of the initial data, the regularized empirical measure of the interacting particle system converges in probability to the solution of the corresponding partial differential equation (PDE) as follows, which is also called the mean-field equation:

$$\begin{cases} \frac{\partial \rho}{\partial t}(x, t) = \frac{1}{2} \Delta \rho - \nabla \cdot (\rho F(x, t)) \\ F(x, t) = \int_{\mathbb{R}^d} F_0(x - y) \rho(y, t) dy. \end{cases} \quad (2)$$

Stochastic Interacting Systems

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Stochastic Interacting Systems in Life and Social Sciences Nicolas Lanchier, 2024-07 This volume provides an overview of two of the most important examples of interacting particle systems the contact process and the voter model as well as their many variants introduced in the past 50 years These stochastic processes are organized by domains of application epidemiology population dynamics ecology genetics sociology econophysics game theory along with a flavor of the mathematical techniques developed for their analysis

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Interactive Systems: Design, Specification, and Verification Chris J. Johnson, 2001-10-24 This book constitutes the thoroughly refereed post proceedings of the 8th International Workshop on the Design Specification and Verification of Interactive Systems DSV IS 2001 held in Glasgow Scotland UK in June 2001 The 12 revised full papers presented have gone through two rounds of reviewing selection and revision The book offers topical sections on mobile interface design context sensitive interfaces supervision and control systems temporal and stochastic issues and new perspectives

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Stochastic Models for Interacting Systems Anthony Kuh, 1987

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