THE UNIVERSITY OF CHICAGO | DEPARTMENT OF STATISTICS

PhD Dissertation Presentation

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"Fast Algorithms via Compressed Moment Representations"

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Abstract

Moment representations arise naturally across many areas of scientific computing, including estimation using statistical moments, discretization of PDEs, and boundary integral formulations. They share a common challenge: the resulting moments are often large, dense, and expensive to form or manipulate directly. This talk discusses recently developed fast algorithms that overcome this challenge by constructing compressed moment representations.

The first part of the talk introduces a fast method of moments for ab initio cryo-electron microscopy reconstruction. By compressing the first three statistical moments of the 2-D projection images of the unknown 3-D molecular structure using low-rank tensor decompositions and randomized numerical linear algebra, the proposed method enables efficient ab initio reconstruction of molecular structures even in extremely low signal-to-noise regimes.

The second part discusses a fast moment-based approach for learning Markov operators that describe high-dimensional stochastic dynamics. By projecting the operator onto structured basis functions and exploiting compressible structures in the resulting moment matrices, we compress the operator and use it to achieve efficient prediction of time-dependent densities and solution of boundary value problems.

The third part of the talk focuses on fast algorithms for boundary value problems arising from wave propagation with infinitely long interfaces, gratings, or obstacles, where classical fast algorithms cannot be applied efficiently. Based on analytic continuation of certain special function identities, a new fast multipole method is developed for efficient evaluation of integral operators defined on complex-coordinate boundaries, allowing us to solve large-scale problems in two and three dimensions.

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