THE UNIVERSITY OF CHICAGO | THE COMMITTEE ON COMPUTATIONAL AND APPLIED MATHEMATICS

JOINT COLLOQUIUM WITH COMPUTATIONAL AND APPLIED MATHEMATICS AND THE DATA SCIENCE INSTITUTE

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Tensor network approximation of Koopman operators

FRIDAY, April 25th, at 12:00 PM
Jones 303, 5747 S. Ellis Ave. Chicago, IL 60637

ABSTRACT

A key structural property of Koopman (composition) operators of dynamical systems is that they are multiplicative on spaces of observables with a product structure. This property implies, for instance, that the point spectrum is an abelian group and that the corresponding eigenfunctions also form a group under pointwise function multiplication. Computational approximation techniques for Koopman operators typically do not preserve multiplicativity in a strict sense, yet one might expect that for approximations that are sufficiently "close" to the original operator products of eigenvalues and eigenfunctions should be useful for building models for the evolution of observables. Using this as a working hypothesis, in this talk we present a scheme for approximating the Koopman evolution of observables that is based on a lift to a Fock space where regularized Koopman operators are multiplicative with respect to the tensor product. This Fock space is generated by a reproducing kernel Hilbert space of observables endowed with the structure of a coalgebra with respect to the tensor product, and the structure of a Banach algebra with respect to the pointwise product of functions. The resulting approximation scheme can be cast in the form of a tree tensor network allowing for efficient computation in high-dimensional spaces generated multiplicatively from a modest collection of approximate Koopman eigenfunctions. We illustrate this approach with applications to measure-preserving ergodic flows on tori.

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