Sparse Identification of Nonlinear Dynamics and Symbolic Regression to Explore Governing Equations in Pattern Formation

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In this talk, we show how data-driven techniques can be used to explore the underlying physical laws governing two-dimensional pattern formation processes. Combining the Sparse Identification of Nonlinear Dynamics (SINDy) framework with symbolic regression, we explored parsimonious partial differential equations that model spatial structures observed in simulations and experimental imagery. Our focus is on steady-state patterns resembling Turing structures, often found in chemical and biological systems, but also emerging in nanomaterials, such as graphene oxide. By treating static patterns as the result of diffusion-reaction dynamics, we adapted SINDy to use spatial derivatives, including Laplacians. Through numerical experiments, including synthetic data from reaction-diffusion models and real data from high-resolution transmission electron microscopy (HR-TEM), we used symbolic regression to refine the structure of the inferred models and proposed interpretable expressions for spatial interactions. This study opens pathways for applying sparse learning to explore governing equations across the physical and biological sciences.

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