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Deep Learning of Conjugate Mappings

Despite many of the most common chaotic dynamical systems being continuous in time, it is through discrete time mappings that much of the understanding of chaos is formed. Henri Poincaré first made this connection by tracking consecutive iterations of the continuous flow with a lower-dimensional, transverse subspace. The mapping that iterates the dynamics through consecutive intersections of the flow with the subspace is now referred to as a Poincaré map, and it is the primary method available for interpreting and classifying chaotic dynamics. Unfortunately, in all but the simplest systems, an explicit form for such a mapping remains outstanding. In this talk I present a method of discovering explicit Poincaré mappings using deep learning to construct an invertible coordinate transformation into a conjugate representation where the dynamics are governed by a relatively simple chaotic mapping. The invertible change of variable is based on an autoencoder, which allows for dimensionality reduction, and has the advantage of classifying chaotic systems using the equivalence relation of topological conjugacies. We illustrate with low-dimensional systems such as the Rössler systems, while also demonstrating the utility of the method on the infinite-dimensional Kuramoto–Sivashinsky equation.