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Bifurcation detection in dynamical systems using deep learning

Developing robust numerical methods for dynamical systems is an important issue across many scientific and industrial applications. In fisheries science, ordinary differential equation (ODE) models are commonly used to study how parameters such as harvesting rates influence population dynamics. Variations in these parameters can lead to qualitative changes in system behaviour, including the appearance or disappearance of equilibrium points or changes in their stability. These phenomena, known as bifurcations, are crucial to fully understand the long-term dynamics of the system but are often difficult to capture using traditional simulation methods.

Continuation methods, such as the Moore-Penrose continuation, provide an effective framework for tracking equilibrium solutions as parameters vary and can successfully handle many types of bifurcations. However, in more extreme cases of bifurcations, these methods may exhibit convergence difficulties. Detecting such problematic regions in advance would therefore significantly improve the reliability of numerical simulations.

In this work, we propose a deep learning approach for the early detection and classification of bifurcation points from time-series data. The model is trained to recognize characteristic patterns associated with different bifurcation types. Once validated, the model will be integrated with the Moore-Penrose continuation to improve the quality of its simulations. The proposed framework will then be tested on a variety of dynamical systems arising in applied mathematics and population dynamics.