Learning Quadratic Embeddings for Nonlinear Dynamical Systems using Deep Learning

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Dynamical modeling of a process is essential to study its dynamical behavior and perform engineering studies such as control and optimization. With the ease of accessibility of data, learning models directly from the data have recently drawn much attention. It is also desirable to construct simple and compact models describing complex nonlinear high-fidelity dynamics for efficient simulations and engineering studies on modest computer hardware. To achieve our goal, we merge two important ingredients. These are–(a) high-fidelity dynamics often evolve in a low-dimensional manifold, and (b) sufficiently smooth nonlinear systems can be rewritten as quadratic models in an appropriate coordinate system, conferring to the McCormick relaxation idea in non-convex optimization. Therefore, we focus on identifying low-dimensional embeddings for high-fidelity dynamical models such that a quadratic model can describe the dynamics of the embeddings. To determine such embeddings, we leverage the powerful expressive capabilities of deep learning, particularly autoencoders. We illustrate the methodologies to learn low-dimensional quadratic embeddings for high-fidelity dynamical models by a couple of examples.

References

[1] P. Goyal and P. Benner. Learning low-dimensional quadratic-embeddings of high-fidelity nonlinear dynamics using deep learning. e-print 2111.12995, arXiv, 2021.