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Koopman operator approximations for PDEs using deep learning

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Koopman operator theory allows for any autonomous nonlinear dynamical system to be transformed into a linear system. Because of the linearity of the Koopman operator, the dynamics can be represented using traditional methods such as eigenfunction expansion. Therefore, the ability to transform a nonlinear dynamical system to a linear system can be a powerful tool for fluid flow problems and other physical systems. However, finding a transformation to linearize a general nonlinear system is difficult. Dynamic mode decomposition (DMD), introduced in the fluid mechanics community, is one approach for approximating the Koopman operator. We present an approach that uses deep learning to approximate the Koopman operator in the context of partial differential equations. Our method is data-driven and therefore does not require knowledge of the governing equations. As a prototypical example, we demonstrate the method on Burgers equation and show the importance of having the right neural network architecture in order to get a good coordinate transformation that linearizes the dynamics.

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