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Paper Review: Machine learning with observers predicts complex spatiotemporal behavior

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Chimeras and branching are two archetypical complex phenomena that appear in many physical systems; because of their different intrinsic dynamics, they delineate opposite non-trivial limits in the complexity of wave motion and present severe challenges in predicting chaotic and singular behavior in extended physical systems. We report on the long-term forecasting capability of Long Short-Term Memory (LSTM) and reservoir computing (RC) recurrent neural networks, when they are applied to the spatiotemporal evolution of turbulent chimeras in simulated arrays of coupled superconducting quantum interference devices (SQUIDs) or lasers, and branching in the electronic flow of two-dimensional graphene with random potential. We propose a new method in which we assign one LSTM network to each system node except for "observer" nodes which provide continual "ground truth" measurements as input; we refer to this method as "Observer LSTM" (OLSTM). We demonstrate that even a small number of observers greatly improves the data-driven (model-free) long-term forecasting capability of the LSTM networks and provide the framework for a consistent comparison between the RC and LSTM methods. We find that RC requires smaller training datasets than OLSTMs, but the latter requires fewer observers. Both methods are benchmarked against Feed-Forward neural networks (FNNs), also trained to make predictions with observers (OFNNs).