Stability analysis and controller synthesis for RNNs using ReLU neural networks

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Abstract: In this presentation, We discuss an automated approach to solve analysis and synthesis of controllers for the piecewise affine dynamical systems modeled as single-hidden-layer rectified unit linear neural networks (ReLU NN). Piecewise affine systems can be derived from the modern machine learning approaches in system identification or as a closed-loop solution of explicit model predictive controllers. We convert the piecewise affine dynamical model of the system into a single-hidden-layer ReLU NN, and then the Lyapunov function and the controller are parametrized as a single-hidden hidden-layer ReLU NN with the same structure as the dynamical system. The benefit of this assumption is the simplification of the controller synthesis and analysis automation. Then, the candidate Lyapunov function and controller are 'learned' using convex optimization methods and network architecture search. Another benefit of this approach is that gradient descent is not used as well as searching for a counterexample. Furthermore, we consider the concept of safety by using a single-hidden-layer ReLU NN to find the control barrier function (CBF). We show that the proposed method is capable of finding a Lyapunov function for a learned dynamics model and a closed-loop explicit MPC. Also, We demonstrate that the proposed method can synthesize a controller with input constraints. Furthermore, we provide simple examples for the control barrier function to show that this method can find safe sets. Finally, the limitations and future directions are discussed.

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