A Control Lyapunov Function Approach to Episodic Learning

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Abstract

We present a novel method for learning Control Lyapunov Functions (CLFs) for uncertain nonlinear affine dynamic systems. With this framework, we can capture a wide class of dynamic uncertainty in the form of parametric error, a class of dynamic uncertainties in the form of unmodeled dynamics.

Figure 1. The episodic learning algorithm. Data D was obtained on a physical inverted pendulum for a total of 10 episodes. The learning algorithm learns a nominal model of the system and improve the projection-to-state stability of the pendulum over time. The learned models 
\[ \hat{a}(x) \] and \[ \hat{b}(x) \] were each represented with 2-layer neural networks trained using an absolute error loss function.

Figure 2. Improvement in the projection-to-state stability of an inverted pendulum system was demonstrated in simulation, showing the ability to stabilize the pendulum up to \( t = 5 \). The box plots indicate the worst case stan deviation bars for all simulated runs, showing the ability to achieve the desired stability.

Figure 3. The episodic learning algorithm. Data D was obtained on a physical inverted pendulum for a total of 10 episodes. The learning algorithm learns a nominal model of the system and improve the projection-to-state stability of the pendulum over time. The learned models 
\[ \hat{a}(x) \] and \[ \hat{b}(x) \] were each represented with 2-layer neural networks trained using an absolute error loss function.

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Future Work

- Explore the application of the proposed method to more complex dynamic systems.
- Investigate the scalability of the proposed method to larger systems.
- Examine the performance of the proposed method in real-world applications.

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