LMI-Based Neural Observer for State and Nonlinear Function Estimation

Rajesh Rajamani[1], Woongsun Jeon[2], Ali Zemouche[3], and Ankush Chakrabarty[4]

[1]University of Minnesota Twin Cities
[2]Chung-Ang University College of Engineering
[3]Universite de Lorraine IUT Henri Poincare-Longwy
[4]Mitsubishi Electric Research Laboratories

September 11, 2023

Abstract

This paper develops a neuro-adaptive observer for state and nonlinear function estimation in systems with partially modeled process dynamics. The developed adaptive observer is shown to provide exponentially stable estimation errors in which both states and neural parameters converge to their true values. When the neural approximator has an approximation error with respect to the true nonlinear function, the observer can be used to provide an H [?] bound on the estimation error. The paper does not require assumptions on the process dynamics or output equation being linear functions of neural network weights and instead assumes a reasonable affine parameter dependence in the process dynamics. A convex problem is formulated and an equivalent polytopic observer design method is developed. Finally, a hybrid estimation system that switches between a neuro-adaptive observer for system identification and a regular nonlinear observer for state estimation is proposed. The switched operation enables parameter estimation updates whenever adequate measurements are available. The performance of the developed adaptive observer is shown through simulations for a Van der Pol oscillator and a single link robot. In the application, no manual tuning of adaptation gains is needed and estimates of both the states and the nonlinear functions converge successfully.

Hosted file

`NAOdraft_20230908.docx` available at https://authorea.com/users/661429/articles/664512-lmi-based-neural-observer-for-state-and-nonlinear-function-estimation