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A Complementary Control Approach of Robust and Adaptive Control for Model based Control of Time-Varying Systems

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***Abstract*— A primary challenge in model-based control is addressing model uncertainties. Methods for handling the uncertainties can be categorized into robust control and adaptive control.**

In robust control, uncertainties in an actual model are observed based on a predefined nominal model and robustly eliminated to make the actual model conform to the nominal model. The Disturbance Observer (DOB) is a widely used technique in robust control due to its simplicity and ability to guarantee robust performance against uncertainties and disturbances. However, DOB is limited in handling time-varying systems because of its reliance on a fixed nominal model. Also, the stability and robustness of DOB are better ensured when discrepancies between the nominal and actual models are minimal, but designing an accurate actual model often demands significant time and effort.

In contrast, adaptive control involves observing and estimating real-time changes in the actual model and directly applying these changes to control gains. The Parameter Adaptation Algorithm (PAA) is a notable method in adaptive control, capable of real-time estimation of changes, including uncertainties and disturbances. However, PAA relies on mathematical parameter estimation, which may not always fit the mechanical system accurately. Also, continuous computation in PAA can lead to transient parameter errors, necessarily.

Robust and adaptive control each present challenges: robust control fails to apply changes in the actual model, while adaptive control is overly sensitive to changes. Notably, their limitations can be complementary. Discrepancies between the actual model and the fixed nominal model in DOB can be minimalized through real-time parameter estimation by PAA, while transient discrepancies in PAA can be robustly eliminated using DOB.

This paper, therefore, proposes a model-based control method for time-varying systems by utilizing the complementary relationship between robust and adaptive control, named Complementary-Adaptive Robust Controller (C-ARC). Recursive Least Squares (RLS), a technique within PAA, and signal filters are used to estimate parameter changes in the actual system on online and to minimize effects of the signal interaction on stability of a control loop, respectively. The estimated model is then evaluated for its suitability before being used as the nominal model for DOB, robustly eliminating discrepancies between the estimated and actual models. Disturbances observed by C-ARC are interpreted as differences between the estimated model and the actual model and thus, the C-ARC provides minimized parameter errors between the estimated and the actual model compared to PAA alone in time domain. The performance of the proposed controller was validated through MATLAB simulations.

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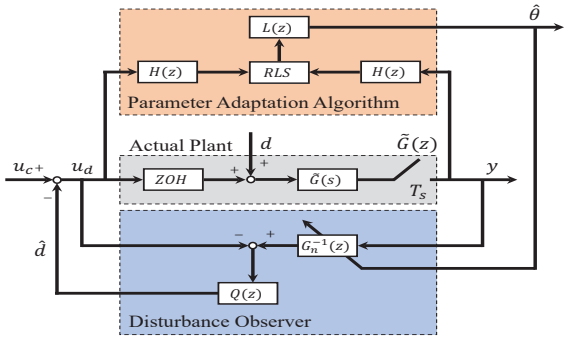

Fig. 1. Block diagram for C-ARC

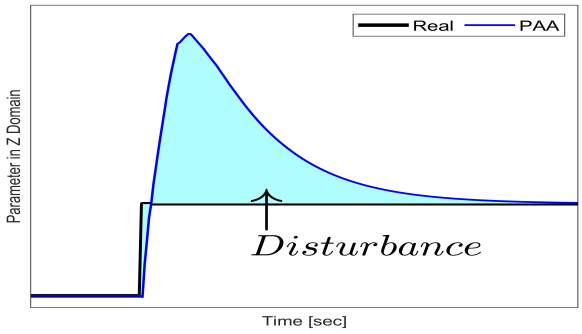

Fig. 2. Meaning of disturbance for C-ARC

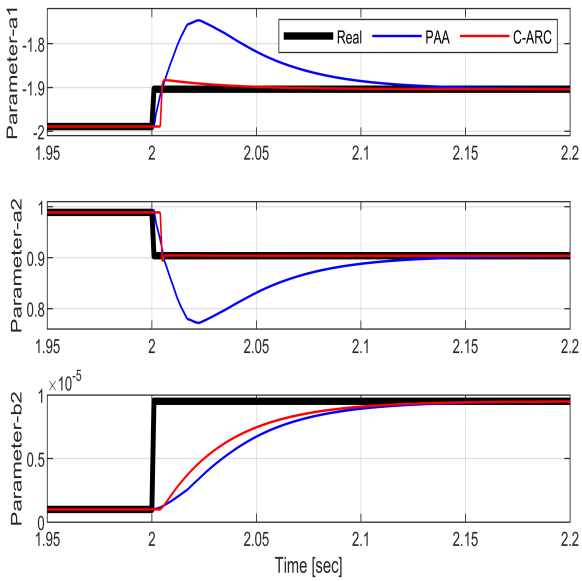

Fig. 3. Comparing estimated parameters; Real, PAA, and C-ARC