Self-tuning Robust Control System for Real-time Hybrid Simulation with Highly Uncertain Nonlinear Physical Substructure

Amin Maghareh*, **Shirley J. Dyke**† **and Christian E. Silva**†

* Lyles School of Civil Engineering
Purdue University
West Lafayette, U.S.A.
e-mail: amaghare@purdue.edu

†School of Mechanical Engineering
Purdue University
West Lafayette, U.S.A.
e-mail: {sdyke and silva15}@purdue.edu

ABSTRACT

In hybrid and real-time hybrid simulations (i.e., cost-effective cyber-physical techniques used to evaluate the dynamic performance of structural system), the reference structure is partitioned into computational and physical substructures. Generally, the computational substructure contains reliable and accurate models of the majority of the reference structure and the physical substructure comprises physical specimens of those parts that are difficult to model numerically. When the physical substructure exhibits rate-dependent characteristics, hybrid simulation must be executed in real-time, usually with time interval of less than or equal to 1 msec.

Coupling between the two substructures is achieved by enforcing equilibrium and compatibility at the interface using a transfer system (e.g. hydraulic actuator). Physical plant refers to the transfer system physically coupled with the physical substructure. A challenging, yet realistic, constraint in real-time hybrid simulation (RTHS) is the lack of/limited understanding about the physical plant prior to implementation (especially in the case of extensive performance variations in the physical substructure due to structural failure, complexity, and nonstationary behavior). However, to design an effective control scheme, a nominal model for the physical plant is required. Thus, for this control problem, any effective control strategy should accommodate for the dynamics of the physical plant and significant parametric and non-parametric uncertainties associated with it.

In this study, we have developed a transfer system control scheme for nonlinear physical plants with high uncertainty to extend the scope of RTHS and accommodate extensive performance variations in the physical substructure. The objective is to rigorously maintain the boundary conditions and enhance the achievable transfer system stability and performance. Adaptive Robust Control System (ARCSys) consists of two complementary control layers. The first one is layer of robustness which includes a nominal model for the physical plant mainly aimed at dealing with non-parametric uncertainties. The second one is layer of adaptation aimed at reducing parametric uncertainties through run-time, slow and controlled learning of the physical plant based on measured performance. This unique integration of two distinct, yet complementary, control approaches is an effective solution to this control problem due to the type of uncertainties associated with the physical plant.