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Data-Driven Multi-Rate Transitioning For Real-Time Hybrid Simulation Tests With Large Nonlinear Numerical Substructures

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Real-time hybrid simulation (RTHS) is an experimental technique based on substructuring, which has been demonstrated to be an efficient and cost-effective alternative to traditional testing methods of structural systems. Complex numerical substructures are needed for greater fidelity and realism, requiring adequate discretization both in space and time for improved resolution. Due to limitations on computational resources, lower-bound constraints on the simulation time step are enforced. Meanwhile, the experimental substructure must be loaded continuously and smoothly to represent the target displacements accurately. Thus, an upper-bound constraint on the control time step is necessary for improved reliability. Different simulation and control rates are used; therefore, a transition between rates is fundamental to coordinate both substructures in real-time. Current approaches rely on an extrapolation-interpolation scheme, where the interface is determined by using a polynomial curve-fitting estimation. Nevertheless, the determination of the polynomial parameters may not be straightforward because it only works for small values of the transition ratio, and it does not work correctly for signals with pulse-like phenomena. This study proposes a novel hybrid coordination approach based on a regularized Wiener statistical FIR filter. The data-driven multi-rate transitioning (DDMRT) filter is applied to the sequence of interface target displacements from the numerical substructure to predict the next point in simulation time. Then, a monomial-based interpolation rule is applied to obtain the next sequence of interface target displacements at the experimental substructure in control time. The filter's accuracy is demonstrated by virtual RTHS simulations of a set of reference systems with linear and nonlinear responses. The proposed scheme achieves good results for all the cases. Consequently, it allows the decoupling of the problem by determining simulation and control rates for numerical and physical substructures, respectively, to satisfy the experimental test's accuracy and stability.