

A State-Space Partitioned Time Integration Algorithm for Real-Time Hybrid Simulation with Nonlinear Numerical Subdomains

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ABSTRACT

Hybrid simulation (HS) merges structural testing and numerical modelling into a unique dynamic simulation paradigm, which has been extensively used to investigate the seismic response of civil structures [1]. In detail, a time stepping analysis algorithm solves for the coupled equation of motion of a prototype structure made of numerical and physical subdomains (NS and PS, respectively), which are assembled in a finite element (FE) fashion. On the PS side, servo-controlled actuators equipped with load cells impose displacement trials to the tested component and measure corresponding restoring forces. The NS is typically instantiated in a structural analysis software. In order to minimize actuator control errors, when the PS restoring force is rate independent, pseudodynamic- (PSD-) HS is performed, which means that the wall-clock duration of HS scales up with respect to the duration of the virtual excitation and velocities scale down of the same amount. If not, real-time- (RT-) HS is performed. In both cases, PS testing is conducted by reproducing boundary and loading conditions as experienced within the prototype structure when subjected to a realistic excitation. Data from experiments is intended support model validation and calibration for tested structural components.

Most of developments related to HS consist on adaptations of existing FE analysis codes to accommodate so-called experimental elements, which incorporate a digital interface to the testing equipment [2]. However, complexity of FE software, which trades off between modularity and computational performance, struggles with the deterministic execution scheduling imposed by RT-HS (i.e., evaluation of the NS response with a constant sampling period of 1÷10 msec). In our opinion, the state-space approach, which is quite popular in the control community, offers a computationally cheaper alternative to FE for modelling nonlinear NS. This presentation describes a state-space partitioned time integration algorithm for RT-HS. The dual-coupling strategy of the modified-PH method [3] allows for assembling state-space equations of PS and NS in a FE fashion. HSs of a two-pier reinforced concrete bridge equipped with three alternative isolation devices are presented as proof-of-concept example [4].

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