Combined Implicit-Explicit Integration Procedure for Real-Time Hybrid Structural Simulation

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In hybrid simulations, the equation of motion of the structure is partitioned into numerical and experimental components. The more accurate implicit integration algorithms to solve for the structural response typically require iterations which are difficult to implement with experimental specimens. This has made explicit integration methods very common in hybrid simulations. However, using explicit procedures imposes stability limits on the time step of the simulations, and restricts the testing of stiff systems. A new procedure that combines the explicit displacement determination and implicit iterative corrections is proposed herein. In this procedure, the displacement and force measurements resulting from experimental data collected in the last few steps are used to estimate the force measurements corresponding to iterative displacements, instead of physically imposing the displacements and measuring the restoring force.

The command displacements are determined using an explicit procedure, thus the states are updated similar to an explicit approach and can include delay compensation. In addition, overcompensation of delay can provide for sufficient experimental data to estimate the corresponding force measurements using interpolation. On the other hand, as the estimation of forces may not be possible in all of the integration steps due to excessive experimental errors, this procedure can automatically detect these situations and switch to an alternate explicit integration procedure, to ensure the completion of the step. Through numerical simulations, it has been demonstrated that the proposed procedure results in better overall energy balance in the system, and reduces the propagation and accumulation of the errors. Experimental simulations are also underway to verify the applicability and reliability of the developed procedure.