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Controlling errors and improving performance of transient simulations using multitime-step integration

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ABSTRACT

A key aspect of simulating the dynamic response of structures is judging how accurate the solution is and how much error it may contain. Errors are primarily introduced into the solution due to the underlying assumptions of the model and due to numerical solution procedures. Inherent problem characteristics, such as geometry, loading, and boundary conditions also affect error and can lead to local regions in the problem domain with high error. In the past, such locations, or problem features, have been dealt with by refining the spatial discretization in these areas. However, location-specific temporal discretization is not possible with methods that use a uniform time-step for the entire problem domain. Thus, one is forced to use a small time-step for the entire problem domain to achieve a low level of error. Multitime-step methods, on the other hand, allow one to choose different time-steps for different regions in the problem domain so that local error can be reduced where needed although still keeping the computational cost low. The aim of this article is to investigate how changing local temporal discretization affects local error, global error, and computational cost for transient problems that contain regions of high error. A method is presented for determining how to best decompose a given problem domain into subdomains, and how to select the time step for each subdomain to minimize the total computational cost and a measure of global error. For a given problem, numerous different combinations of spatial and temporal discretizations were studied to characterize the error in these solutions and their corresponding computational cost. The space of possible multitime-step decompositions was examined to find an optimal spatial decomposition and corresponding time-steps to meet predetermined criteria of cost and error. Recommendations are also made for finding such optimal decompositions for general problems in structural dynamics. Numerical examples for truss and frame structures are presented to show how choosing a finer temporal discretization around local problem features can reduce not only the local error, but also the error throughout the entire problem domain while still minimizing the computational cost of the simulation.