AN EFFICIENT MULTIDOMAIN PSEUDOSPECTRAL METHOD FOR THE STUDY OF WAVE PROPAGATION IN UNBOUNDED MEDIA

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The study of wave propagation phenomena in complex media requires accurate numerical simulations. High order techniques have attracted interest in the latest years, as a means to improve the computational efficiency and reduce the computer time needed for a simulation. The pseudospectral schemes, which are among the most used methods, are based either on the Fourier discrete transform or on high-order orthogonal polynomial interpolation. The main drawbacks of these methods are due to the global character of the discrete operator that corresponds to the wave equation. All nodes of the computational mesh are involved during the evaluation of the wave field, which allows for non-causal noise to be spread on the solution. Efficiency in discretizing complex structures is reduced, since a constant spatial step must be used in the three directions and, last but not least, the parallel implementation of the related computational algorithms shows a drastically reduced performance with the increase of the number of processors. The reason of this behaviour is in the architecture of modern multiprocessor platforms. In fact, the relative inter-processor communication speed is low compared with the higher computational speed of the single CPU, and this precludes the use of global discrete operators on large meshes.

An alternate approach in order to increase flexibility and parallel efficiency, maintaining pseudospectral accuracy, is the method of domain decomposition (DDM). The physical domain is decomposed into subdomains that can overlap (ODDM) or non-overlap each other. Overlapping DDMs could require either iterative or non-iterative solvers, while non-overlapping DDMs often require very complex interface conditions at the (artificial) subdomain boundaries that may limit their applications. We do not consider iterative ODDMs since they are more time consuming than non-iterative ones. Non-iterative ODDMs are based either on local Fourier basis decomposition or on Huygens' principle. In all these methods the solution is computed as a sum of the partial solutions obtained in each subdomain and a particular care must be used in summing up along the overlap regions in order not to introduce spurious effects and to maintain the continuity of the solution. In particular there can be some limitations when regions with different physical properties and strong heterogeneities are considered: overlap zones with non-constant size may need to be used, giving rise to a new computational complexity.

In order to avoid all these problems, we present an overlap domain decomposition method that does not decompose the discrete full wave operator, which requires the continuity of the solution, but on the contrary decomposes the discrete derivative operator that builds the wave operator. The continuity requirement across the subdomain boundaries is simpler and it is assured automatically by the overlap; moreover, the pseudospectral accuracy is maintained. The main advantages of the method are simplicity and efficiency in the parallel implementation. The inter-processor communications are reduced to a minimum, and a high scalability on multiprocessor machines is attainable.