Big Unstructured Mesh Processing on Multiprocessor Computer Systems

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At the present time simulation of physical processes with the help of unstructured meshes and multiprocessing systems with distributed memory occurs widely. The use of unstructured meshes with big number of nodes makes possible to approximate a space near the three-dimensional bodies of irregular shape with sufficient accuracy, but in this case a great computational capability is required. Multiprocessing systems with distributed memory give us required capabilities and make it possible to expand computational capability unrestrictedly for all intents and purposes.

When the number of mesh nodes is increased, some problems that are specific for multiprocessing systems arise. These problems decrease the effectiveness of the computer system use. The time expenditures for processor load balancing, mesh data and mesh functions reading and writing, computing of the parameters that are necessary for numerical simulation of the mesh geometrical parameters and determining of the data for interprocessor exchange while simulation, increase greatly. These expenditures become comparable with the time of the single simulation session. Besides, it is conceivable that mesh data even compressed can not be written in a file because of restriction imposed by file system. As a result the simulation with sufficiently big meshes becomes impossible.

For solving said problems that arise while working with big meshes, some algorithms were developed. These algorithms are algorithms of hierarchical graph division, two-level distributed storage and input-output of the data on mesh and mesh functions. Program libraries for storage and processing of the data on tetrahedron meshes were developed on the basis of said algorithms.

The problem of computational load distribution for unstructured mesh, i.e. mesh division into domains, can not be solved by simple method (as for example for cubic lattice). The reason is that mesh nodes density is mostly variable over the volume and mesh has the irregular structure. To solve this problem it is essential to apply ad hoc algorithm. Here it is proposed to use hierarchical method of graph division. This algorithm aside from its main task, i.e. division of the original mesh into microdomains that are tight mesh domains, enables to get the general description of the mesh as a graph consisted of microdomains and their weighted connections with each other. The latter graph is addressed to as a microdomain graph. The microdomain graph is used for distributing the computational load between the processors.

As the number of mesh nodes increases, essential difficulties arise while storing, writing and reading the data on the mesh. Increasing data amount and the necessity to take into account the peculiarities of the specific computer system causes these difficulties.

With the aim of said expenditures reduction, the algorithm of two-level distributed storage of mesh data is proposed. In keeping with this algorithm, the mesh is divided into some large number of microdomains before using the mesh for simulation. Then in line with the division, the mesh nodes are renumbered, one collects the information that is necessary for

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independent determining the parameters of each microdomain. Hereupon the mesh is written as a description of its general structure and the set of its microdomain descriptions.

The library of parallel programs was developed on the basis of the described method. These programs are designed for dividing the tetrahedral mesh into microdomains. The library contains functions for dividing the original mesh into the specified number of microdomains, for renumbering of the mesh nodes in accordance with the obtained division and functions for determining and collecting the information on microdomains. All working processors as well as some subset of the whole set of processors can call these functions. Also the library includes the uniprocessor function that accomplishes the microdomain graph division into specified number of domains.

The algorithm of distributed storage and input-output of the data on mesh and mesh functions was developed in order to overcome restrictions imposed by file system on file size and to reduce time for data input-output. The subprogram library for storage of the data on tetrahedral meshes was developed on the basis of this algorithm. In keeping with this algorithm the mesh divided into microdomains is stored as a set of files. These files are: file with information on microdomain graph, file with the table of correspondence between the old mesh nodes and the new ones, the set of files with microdomains data, each of them contains data on one or several mesh microdomains. The proposed method enables to read and write information at one time from (in) several files that are stored at different local system disks. Distributed storage of the data on mesh function values of microdomain nodes is performed similarly.

The proposed algorithms enable to perform numerical simulation with meshes whose description size is limited only by the available RAM of the computer system.

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