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COMPUTING WEAKLY PARALLELIZED CALCULATIONS OF OBJECTS MADE OF MATERIALS WITH COMPLEX PHYSICAL-MECHANICAL PROPERTIES

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Abstract. The article demonstrates, by the example of solving a problem of a high degree of static indefinability that the efficiency of parallelizing calculations drops drastically as the number of cores increases. This limits considerably a possibility to design computer systems capable to simulate reliably enough normal and abnormal operation of real technical objects by means of widely used multiprocess hardware. To solve a wide range of problems of deformed solids mechanics, a variant is offered to modernize the method of dividing an object into design units, suggested by the authors earlier, and to divide it into continuums, that provides practically unlimited possibilities for parallelizing a calculation process.

1. Introduction

It is well known that the solution of problems of strength, dynamics and object life should follow the modeling of evolution of force and deformation fields of an object under design subject to mechanical, thermal, radiation and other external influences.

However, at present the problem of developing a computer system that could simulate reliably enough fields in any real technical object may not be considered solved, even on the basis of the modern supercomputer hardware platform. Indeed, it is a well-known fact that the efficiency of cores being used for solving this kind of problems is considerably limited. This may be illustrated by the example of problem solution to determine an object's mode of deformation (6.033 million unknowns, inhomogeneous elastic medium, a static load). The problem was solved by means of the LIRASAPR software verified by the Russian Academy of Architectural and Construction Sciences on a four-core computer based on the Intel Core i7-4771 processor.

Figure 1 presents diagrams of dependence of the time of calculation (*Tp*) and efficiency of parallelization ($Ep=(T1/Tp)/p$) on the number p of cores, where $T1$ is the time of model calculation on one core, Tp is the time of calculation on p cores. The graphs (Fig. 1) show that the efficiency E_p drops drastically as p increases.

At complex physical-mechanical properties of materials, the volume of calculations to simulate an object's mode of deformation increases considerably, forcing to simplify its calculation model, mechanical properties of deformed media and range of external impacts that may result in an impermissibly low level of the computer model informational representativeness.

This is explained by the fact that at present software, where the finite element method with a superelement approach is used [1, 2], cannot ensure a high enough level of parallelization of a calculation process. In this connection a universal method of conventional division of an entire object into design units was offered [3, 4] with organization of a calculation process in a multiprogramming mode in distributed computer networks, that is hardware-software discretization of a calculation process is applied. High possibilities of this method in calculation parallelization were demonstrated by the example of dividing an object into design units having rod connections [5, 6].

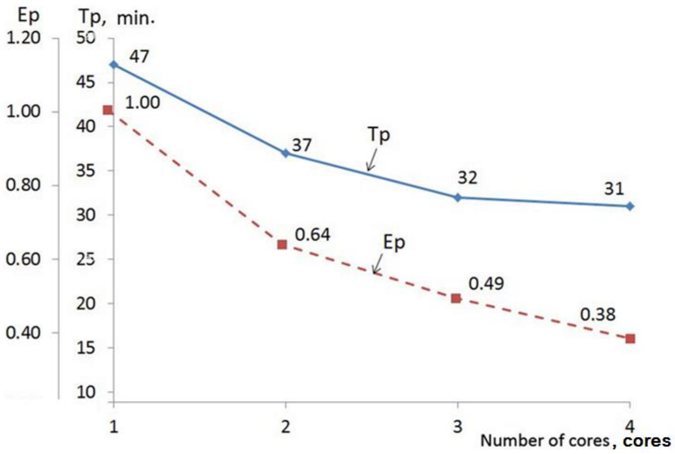

Fig. 1. Graphs of dependence of the time of calculation (*Tp*) and efficiency of parallelization (*Ep*) on the number of cores.

This paper considers a variant of division of continuum medium into design units.

2. Method of continuum medium division into design units

Let us assume that object is conventionally divided into M elements ($1,2,\ldots,M$) and $S_{m,n}$ is the surface (Fig. 2) separating elements e_m and e_n (m,n are numbers of the elements, $m<n$).

Let $\boldsymbol{P}^m(X)$ be the stress vector acting on the surface $S_{m,n}$ of element e_m at point X, and $\boldsymbol{P}^n(X)$ is the same of e_n. Similarly, $\boldsymbol{U}^m(X)$ and $\boldsymbol{U}^n(X)$ are the corresponding displacement vectors. Then, in a quasi-static problem for a continuum, conditions of equilibrium

$$\boldsymbol{P}^m(X) + \boldsymbol{P}^n(X) = 0 \tag{1}$$

and compatibility

$$\boldsymbol{U}^m(X) = \boldsymbol{U}^n(X) \tag{2}$$

must be met for all $X \in S_{m,n}$.

Let us construct a lattice dividing the surface $S_{m,n}$ into elements $F_{m,n,j}$ of a certain shape, where j is the element number. Let us assume that for any $X \in F_{m,n,j}$ $\boldsymbol{P}^m(X) \equiv \boldsymbol{P}_j^m = const$. Suppose that functions $\phi^m_{m,n,j}(X)$, i=1,2,3 of all i-components of vectors $\boldsymbol{P}^m(X)$ are known. Then, components $p^m_{i,j}$ of vector $\boldsymbol{P}_j^m$ may be determined as

$$p^m_{i,j} = \frac{1}{f_{m,n,j}} \iint\limits_{F_{m,n,j}} \phi^m_{m,n,j}(X)\,dF, \tag{3}$$

where $f_{m,n,j}$ is the square of element $F_{m,n,j}$.

Note that if the function $\phi^m_{m,n,j}(X)$ is specified on a set of points, for example, in the result of defining the mode of deformation of element e_m by means of any numerical technique, integral (3) is compute numerically. In an analogous way the discrete presentation $\boldsymbol{P}_j^n(X)$, $\boldsymbol{U}_j^m(X)$, $\boldsymbol{U}_j^n$ is performed.

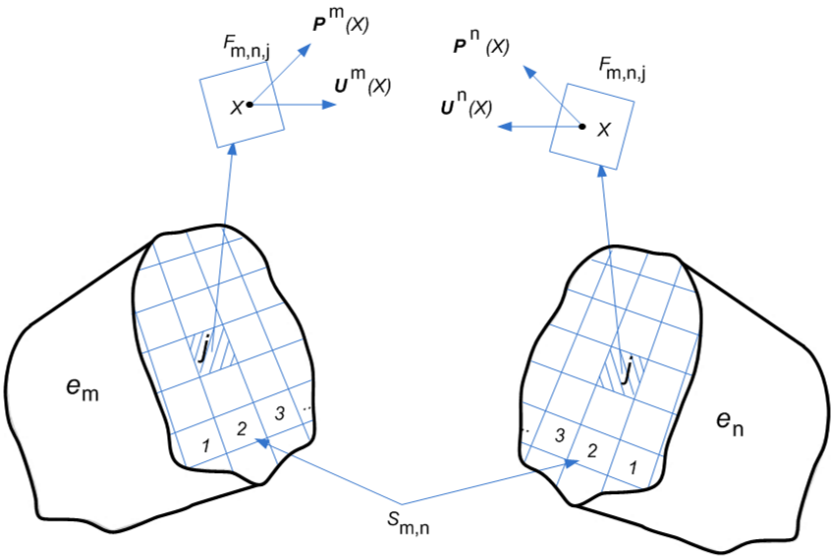

Fig. 2. Division of a continuum into two elements.

In the result of the mentioned discrete presentation of the stress and displacement fields, a problem of modeling evolution of the mode of deformation of materials with complex physical-mechanical properties may be solved by methods described in [6].

3. Computer implementation of the method

Dividing, when possible, project design units into continuums during modeling the evolution of technical objects broadens significantly possibilities of the method of dividing into project design units, that requires in its turn modernization of the "Design Calculation Manager" (DCM) [7], which controls operation of a multiprocessor and multiprogramme system. For this purpose the functional of the used application logic should be enlarged.

In this paper a variant of a system consisting of workstations with web-interface support is considered. This system maintains conventional division of a technical object into project design units and their joint work as an integrated mechanic system. Various software packages of finite element analysis (like ANSYS, NASTRAN, LS-DYNA, Lira, SCAD, etc.) may be used as basic software (BS) for PDU calculation. And one system configuration at the same time may include different basic software. Computers with basic software compute nodes are interconnected in a cluster controlled by a control server (CS) through CS-clients installed on compute nodes (Fig. 3).

As can be seen from the given diagram, the system as a whole incorporates in a local area network both separate compute nodes used by a web-service and local computers of designers, as well as servers of the system. The compute nodes of the web-service contain locally a "Client of a control system" realizing the work logic of a compute node, as well as a "Client of a file distribution server" needed to distribute files of PDU source model between compute nodes and BS.

The server contains several components: a web-server, a files distribution server (FDS) and a control server (CS). The web-server controls the work of a web-interface. This server interacts with the compute nodes specifically allocated only for work with the web-server. The web-server database ensures correct work of the web-interface. The web-interface may be loaded into a user's web browser by means of the Internet from any location in the world. The files distribution server is required for distributing files of the designed PDU model between certain compute nodes. Depending on the compute nodes' occupancy, the server can select an optimum variant of available compute nodes' loading. The control server possesses a certain set of logic, thus, reducing loading of the clients; in addition it makes administration of the system in a whole simpler. The CS works with the database of the MS SQL Server, where all data needed for a database are stored. Data from this database may be loaded either via a local graphic interface or a web-interface by means of interconnection of the “Client CS” with the CS. Evidently, that the given variant of architecture arrangement will allow, on the one hand, to “untie” designers off their working places in the office and, on the other hand, transferring the resource-consuming compute nodes from personal computer to a dedicated server or virtual server or allocate them in the IaaS-cloud.

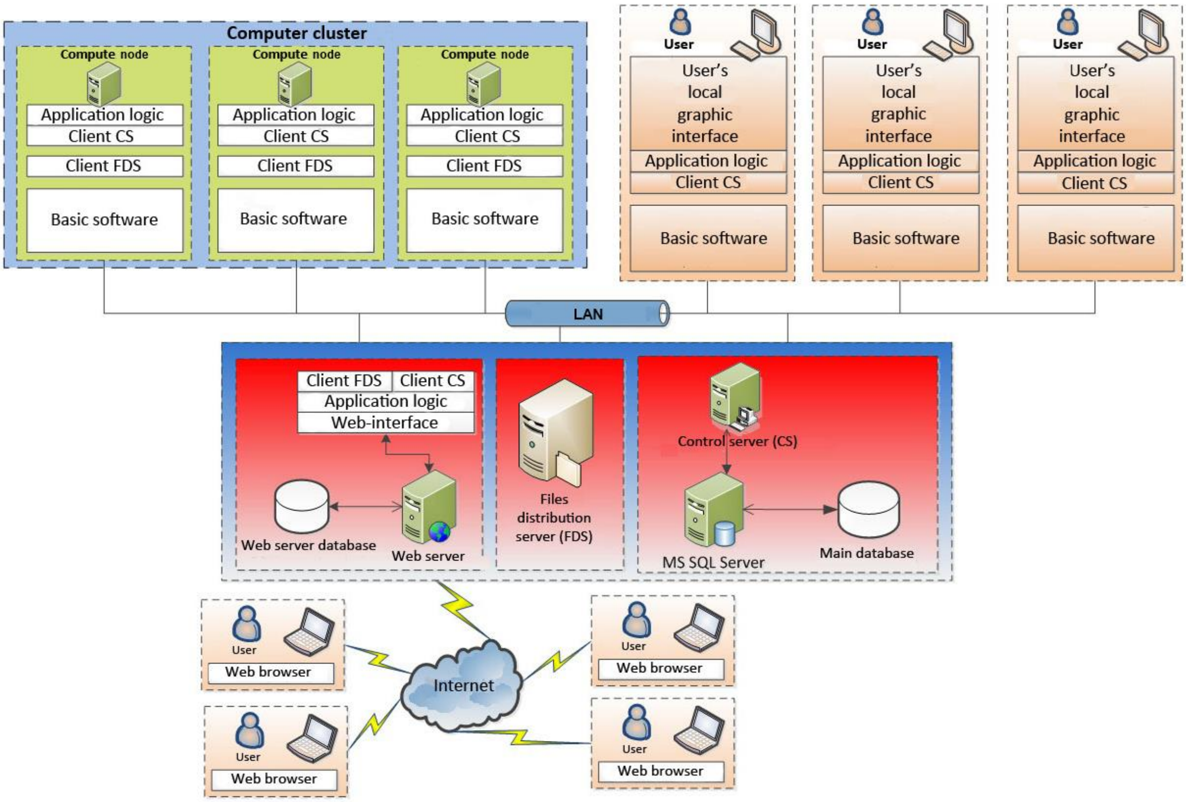

Fig. 3. Cluster architecture on the basis of local area network with web-interface.

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