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Intellegent Computers − the Means for Automatization of Scientific Investigating and Reliable Solving of Scientific and Engineering Problems

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Интеллектуальные компьютеры − средство автоматизации научных исследований и достоверного решения задач инженерии и науки

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Інтелектуальні комп'ютери − засіб автоматизації наукових досліджень і достовірного розв'язування задач інженерії та науки

The intelligent computer investigates characteristics of problem's computer model and on the basis of this information it automatically constructs the solution algorithm, forms a topology from MIMD-computer's processors, creates a parallel program code, solves the problem and, finally, estimates the reliability of the obtained results (the proximity between machine and mathematical solutions as well as estimate of inherited error in the obtained solution).
Key words: intelligent computer, automatization of research, reliability of computer results, intelligent software

Интеллектуальный компьютер исследует свойства компьютерной модели задачи и на основании этой информации автоматически строит алгоритм решения, формирует топологию из процессоров MIMD-компьютера, создает код программы параллельных вычислений, решает задачу и по окончании счета оценивает достоверность полученных результатов (близость машинного решения к математическому и оценку наследственной погрешности в полученном решении).
Ключевые слова: интеллектуальный компьютер, автоматизация научных исследований, достоверность компьютерных результатов, интеллектуальное программное обеспечение.

Інтелектуальний комп'ютер досліджує властивості комп'ютерної моделі задачі і на підставі цієї інформації автоматично будує алгоритм рішення, формує топологію з процесорів MIMD-комп'ютера, створює код програми паралельних обчислень, вирішує завдання і по закінченні рахунки оцінює достовірність отриманих результатів (близькість машинного рішення до математичного та оцінку спадкової похибки в отриманому рішенні).
Ключові слова: інтелектуальний комп'ютер, автоматизація наукових досліджень, достовірність комп'ютерних результатів, інтелектуальне програмне забезпечення

Introduction

Supercomputers [1] have become the tools in engineering and scientific investigations and the means allowing to arrange numerical experiments during the creation of objects of new machinery and buildings. One of problems related to the reliability of computer's results is the proximity between arithmetic and computer arithmetic.

The analysis of the computer's arithmetic showed that:

– continuum of all rational numbers in computer is approximated by set of finite frictions (the rounding-off errors arise already during the input of numerical data)

– phenomenon of «computer zero» generates few difficulties when computational algorithms are implemented (each modern computer possesses the smallest positive number presented in it, but all numbers, being the smallest by the absolute value of this number, are replaced by zero);

– arithmetic operations on computer are different from mathematical ones: the laws of associativity and distributivity play no role in any modern computing as well as the laws of commutativity in floating point operations performed only by the regular procedure. So, the axiomatic of mathematics, including computational mathematics, is not similar to machine mathematics. [2]. The problems of reliability of solutions in linear algebraic problems are dealt with [3-5].

Intelligent software

The intelligent program tools for the investigating and solving of computer models of problem [6-19] have been developed for the solving of above mentioned problems and employment of computers not only for the solving of scientific, engineering and economic problems by debugged programs as well as for the investigating of characteristics of parallel programs intended for the solving of problems under investigation together with estimating of reliability of results obtained on computers/

The scheme of investigating and solving the scientific and engineering problems on traditional computer is depicted in fig. 1, where it is seen that user employs computer only at the final stage of solving the problems.

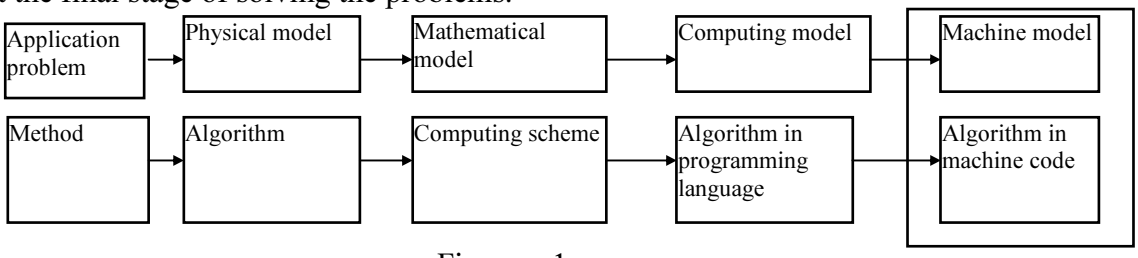

Figure – 1

Application of the intelligent software for the investigating and solving of the scientific and engineering problems is depicted in Fig. 2.

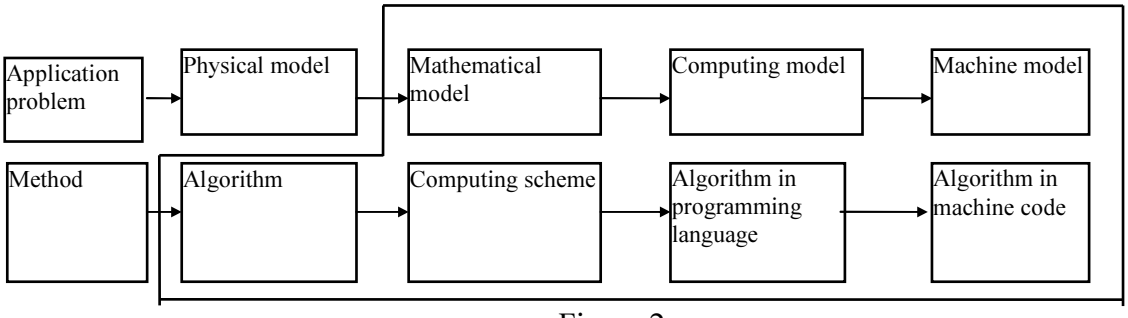

Figure 2

Program's implementation of the intelligent software has been performed on the basis of the knowledge conception. Its development is based on the synthesis of principal achievements in the fields related to: modulus programming, data bases as well as knowledge bases and it relies on the methods designed for work with knowledge: its representation, storage, processing, the obtaining of new knowledge, etc. The intelligent software produces knowledge about characteristics of problem's machine model. With taking into account this information the solution algorithm is chosen automatically, the decision is made as to the optimal number of processors required for the efficient solving of problem, and program implementing this algorithm is synthezited. The solving of problem is carried out together with reliability analysis of the obtained computer results.

Components of the intellectual program software for every class f problems are the following: a dialog system, library of functional modules, planning unit, control unit, block of explanations

With the help of dialog system the interaction with user is carried out, namely statement of problem in the subject area language, problem's solution process, browse-analysis of solution's results, the training of user in work with program tools, the delivering to user the required information, access to the glossary of terms in every class of problems, rendering an assistance to user at every stage of work.

The functional modules implement logically completed parts of problem's solution algorithms as well as procedures for data and information exchanges between processors.

The main aim of the planning/control block is the finding of the most optimal way for the solving of the stated problem with help of information obtained by computer from the corresponding functional modules.

Instead, of the using of traditional libraries and the numerical programming software packages it is reasonable to use libraries of intelligent programs.

By the intelligent program we'll mean a program which in the course of solving the problem examines how the user's algorithm selected for solving of problem is corresponded to the properties of machine's model of problem, forms the configuration from processors cores involved in MIMD-computer according to the amount of processors chosen by computer, then it sends the initial data to the memory of microprocessors, solves the problem and estimates the solution's reliability.

Thus, the difference between intelligent software and the traditional one consists in:

– automatic investigation of characteristics of computer models of problems of the computational mathematics;

– automatic creation both of parallel algorithms and programs based on this investigation;

– choosing the number of processors required for the efficient solving of problems as well as the creation of the required topology of the MIMD-computer's processors;

– the solving of problems with approximately given initial data;

– estimating the reliability of the obtained computer results.

Approbation of the intelligent software was fulfilled in the course of carrying out of two projects for German Center for airspace flights DLR: ISPAR [20] (1996 – 1998) and ISKON [21] (1999 – 2002) and were highly appreciated by German specialists.

Intelligent parallel computer

The intelligent computer intended for the solving of scientific and engineering problems is a computer whose structure and architecture supports the intelligent software.

The hidden parallelism principle is implemented in the intelligent computer. The hidden implementation of parallelism assumes such a mode of user's work on MIMD-

computer under which the solving of problem is carried out in similarly the same manner as on one-processor computer with multiprogram mode.

The implementation of hidden parallelism assumes:

– an automatic determination of the number of processors required for the solving of problem;

– distribution of initial information between processors;

– a determination of optimal configuration of processors involved in MIMD-computer for the solving of real problem;

– creation of the effective algorithms (acceleration Sp sufficiently close to the number p of processors, coefficient Ep, close to unity) and synthesis of programs of parallel computations for the chosen configuration;

– the uniform loading of all processors needed for the solution of problem;

– an organization and synchronization exchanges between processors;

– minimization of exchanges between microprocessors;

– paralleling of not only the arithmetic and logical operations but also the exchanges between processors.

The presented conception of intelligent MIMD-computers has been implemented in a joint project performed by V.M. Glushkov Institute of cybernetics NAS of Ukraine and SSPE «Electronmash». An experimental family of the intelligent workstations Inparcom occupying an intermediate position between super- and personal computers has been created. [22-35].

It is knowledge-oriented computer Inparcom that obtaines and stores knowledge about the properties of computer's model of the problem and according to these characteristics automatically constructs the solution algorithm, forms a topology of processors of MIMD-computers, creates a parallel program code and, finally, after completion of the computational process estimates the reliability of the obtained results.

Inparcom complex consists of: host system, processing unit, communication environment.

Host-system implements the control over multiprocessor (multi-core) computing resource, system-wide monitoring, communication with users' terminal networks, visualization of computational results of the problem and implementation of that part of the computation process and data processing which cannot be parallelized («ill» parallelized). Host-system consists of host-computers (Xeon Quard-Core GHz, 64-bit machine word length, 8 Gbyte of operating memory, 72 Gbyte of disk memory each), peripherals and can be involved in the local or in the global network.

The processing unit supporting the problem's solving with the arrangement of parallel computations is a scalable homogeneous construction consisting of multiple processors (with its own operating and disk memory), integrated by the communicational environment of inter-processor interaction. It can include the computational nodes (Xeon Quard-Core GHz, 64-bit machine word length, 2 Gbyte of operating memory, 36 Gbyte of disk memory each).

The communicational environment consists of Gigabit Ethernet, Infiniband and hypercube. The software supposes three levels:

– operating environment supporting the intelligent software;

– intelligent numerical software for investigation and solution of problems of the computational mathematics with the approximate initial data;

– application software, for example, for investigation and solving of problems on the strength analysis of structures.

The operating environment is based on free GNU/Linux solutions.

However, the user can choose one of three versions of the installed OS: Linux, Windows XP SP2 or Linux +Windows. By desire, the user host automatically switches between Linux and Windows with reloading of nodes. The Linux version based on Scientific Linux 4.2 has been optimized for the instrumental tools of Inparcom.

In the core of parallel computer − a system of data broadcasting − de-facto MPI standard is implemented. MVAPICH optimized for Infiniband, and LAM MPI are implemented in Linux, while for Windows −MPICH. The distributed message passing system PVM is adjusted for the supporting of the maximal number of applications of outer active users.

Free compiler GCC included in Linux supports C++, Fortran and Java. Operating environment includes Internet-server Apach which supportes applications written in PHP, DBCS MySQL languages, standard mathematical libraries (including ScaLAPACK), tests (Linpack, Scali), networks file system.

Operating environment provides:

- the forming of task and run its on the chosen computational nodes;
- the monitoring of the whole computer and problems being performed;
- the storing and visualizing by protocols of parallel computations;
- run of applicaton (parallel program) on host-computer;
- work through a local net and/or Internet with remote access;
- development of parallel programs;
- administrating of parts of network file system accessible to user.

The intelligent numerical software [36] for the investigation and solving of problems of the computational mathematics with approximate input data supports: autometric mode of total investigation and solving of problems by program chosen from library. The classes of problems are implemented:

- system of linear algebraic equations;
- algebraic eigenvalue problem;
- system of non-linear algebraic and transcendental equations;
- system of ordinary differential equations with initial conditions.

The application software, for example, for investigating and solving of problems on the strength analysis of structures may possess tools for:

- the forming of geometric model of structures on the basis of models available in data bank;
- the forming the mathematical problem's model in computer;
- visualization of finite-element covering of element or structure under investigation;
- automatic forming of discrete problem's model and distribution of the data between processors from the chosen topology;
- appeal to the intelligent numerical software for investigating and solving of finite-element problems on MIMD-computer with the visualition of obtained results;
- reliability of analysis of the obtained finite-element or finite-difference solutions.

Application domains of intelligent parallel computers:

- numerical modeling of complicated processes, phenomena, objects and systems for the arrangement of natural experiments on this base;
- creation of trainers for the management of complicated objects of up-to-date machinery including Nuclear Power Station;
- solving of complicated scientific and engineering problems with approximately given initial data;
- preparation of parallel programs for supercomputers.

Conclusions

The advantages of intelligent parallel computers:

– statement of user's problem in computer on subject area language with approximately given initial data;

– freeing the user from work on: the investigating of problem, creation of algorithms, writing and debugging of parallel programs that reduce the times required for the statement and solving scientific and engineering problems not less than 100 times;

– investigating and solving of scientific and engineering problems with approximately given initial data;

– the obtaining of computer solution together with its reliability estimate as well as with (if desired) all propertied of the problem with initial approximate data being solved;

– the significant reduction in the time of computer's investigation and solution of scientific and engineering problems compared with the traditional technology of solving of similar problem on MIMD-computer with the same number of processors and the element base but with traditional parallel architecture.

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RESUME

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Intelligent Computers − the Means for Automatization of Scientific Investigating and Reliable Solving of Scientific and Engineering Problems

The intelligent computer investigates characteristics of problem's computer model and on the basis of this information it automatically constructs the solution algorithm, forms a topology from MIMD-computer's processors, creates a parallel program code, solves the problem and, finally, estimates the reliability of the obtained results (the proximity between machine and mathematical solutions as well as estimate of inherited error in the obtained solution).

Automatization both of investigation of computer models of problems with approximately given initial data and creation of parallel program as well as estimation of reliability of the obtained computer results can be assigned to intelligent computers dealt with in the article being proposed.

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