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INTELLECTUAL PERSONAL SUPERCOMPUTER FOR SOLVING R&D PROBLEMS

New Ukrainian intelligent personal supercomputer of hybrid architecture «Inparcom-pg» has been developed for modeling in defense industry, engineering, construction, etc. Intelligent software for automated analysis and numeric solution of computational problems with approximate data has been developed. It has been used for implementation of simulation applications in construction, welding, and underground filtration.

Keywords: modeling, simulation, intelligent computer, hybrid architecture, computational mathematics, and approximate data.

Mathematical modeling and associated computer experiment is currently among the main tools for studying various natural phenomena and processes in society, economy, science and technology. Simulation significantly reduces the development time and cost of new objects in energy and resource-saving. It increases efficiency of real test planning and makes it possible to consider several variants to select the best.

Nowadays the computer performance growth is achieved due to parallel calculations based on use of multiple processor devices and multi-core processors. In late 2014, Intel announced a processor series with the number of cores varying from 4 to 18, and then in early 2016, from 4 to 22. Note the processors implement MIMD-architecture (the architecture with multiple streams of both commands and data). At the same time, the requirements for high-performance computing are far ahead of the conventional parallel computer capabilities despite the multi-core processors. GPGPU technology (from General-Purpose Graphic Processing Units) meets the demand of accelerating calculations on multi-core computers for big numbers of similar arithmetic operations. It means general purpose computing on video cards.

The approach has bumped the development of specialized graphic processors. They implement the SIMD parallel computing architecture. SIMD means the architecture with single command stream and multiple streams of data. The short-term future of high-performance computing hardware seems to be related to the hybrid systems combining MIMD and SIMD architectures together, such as multi-core computers with GPGPU accelerators.

MOTIVATION FOR THE PERSONAL INTELLIGENT SUPERCOMPUTER DEVELOPMENT

Application of the latest GPGPUs makes it possible to achieve up to 2.62 TFLOPS of double precision calculations in a usual computer system unit. This is a big incentive to implement a «per-

sonal supercomputer» for high performance computing of individual use.

Under conditions of fundamentally new 3D models, transition from the by unit computer modeling to the whole product simulation and complete optimization the significant improvement of the modeling and design quality is possible in defense industry, engineering, construction, etc.

A character feature of application mathematical models is the need to account their input data inaccuracy together with the model equations [1—4]. A numeric simulation key issue which accumulates the impact of all other factors is the computer solution validity. The issue presence and importance is supported even by the fact of NAFEMS (National Agency Finite Element Methods and Standards, UK) groups working over twenty years in 30 countries to ensure reliability and safety of the engineering calculations based on finite element method and related techniques.

For parallel computers, the above mentioned issue is supplemented by the demand for accounting the computer architecture and technical parameters, prediction of the optimal number of processes, planning data distribution among processes, implementation of synchronization of calculations and data exchanges, etc. [5—7]. So the development of parallel algorithms and application programs requires much time, and their successful usage depends on a specific high qualification of users. The issues of obtaining reliable computer solution, of decreasing the time spend for scientific or engineering problem description can be solved by intelligent computers [8—10] through involvement of the computers to studying the model features and generating the parallel programs.

As a part of the innovative R&D project «Development of Hardware-Software System Based on the Personal Intelligent Supercomputer of Hybrid Architecture for Mathematical Modeling in Defense, Engineering, and Construction Industries» Glushkov Institute of Cybernetics of NAS of Ukraine together with *Electronmash* have developed a concept and an experimental model of «Inparcom-pg» personal intelligent supercomputer of hybrid architecture for solving the scientific and engineering problems.

CONCEPT OF PERSONAL INTELLIGENT SUPERCOMPUTER

The innovation of the personal intelligent supercomputer development and use consists in implementation of three major modeling paradigms: computational mathematics, high-performance computing and intelligent software. The paradigm implementation makes it possible to shift the work on formulating and solving problems from the user toward computer in comparison with traditional computer technologies, to reduce the applications development time needed to solve scientific and technological problems, and to improve the quality of computer solutions [10].

Computer models of application problems always contain inaccuracy in input data. However, the vast majority of existing software used in application problem studying implicitly assumes the initial data be precise. The characteristic of computer models with approximate data are a priori unknown mathematical features. Within a given level of inaccuracy one can find both consistent and inconsistent problems, both well-posed and ill-posed ones, both well-conditioned and ill-conditioned ones. In this context a computer problem which is eventually solved is always an approximation of the original problem (because of the inherited input data inaccuracy and/or sampling error and/or numeric representation error) [1, 5, 7].

The situation is strongly complicated by the fact that big mathematical difference between the matrices of complete and incomplete rank exists only in the ideal world of mathematical real numbers. Since computer operations on the matrices are executed with rounding-off, the difference becomes uncertain. Thus, an invertible matrix can become degenerate in a computer. On the

other hand, a degenerate matrix is likely to be turned into a close non-degenerate one due to the rounding errors.

Analysis of computer arithmetic implementation has shown its difference from the conventional arithmetic. It is related both to the rounded representation of real numbers itself and to the simulation of associative low, of distributive low, of commutative low, and so on for the arithmetic operations. I. e., the mathematical axiomatic of computing differs from the computer arithmetic axiomatic.

The issue resolving implies detection of the computer problem features and generation of machine algorithm to obtain an approximate solution of the mathematical problem regardless of its well-posed or ill-posed, well-conditioned or ill-conditioned nature.

Therefore, for each class of mathematical problems with approximate data discussed further a software toolkit to study the computer model mathematical features and to solve the problem has been developed. It selects the best fitted computer algorithm and adjusts its parameters according to the computer parameters and architecture. Finally it estimates the results validity [3, 7].

Thus, the main conceptual principles of the intelligent hybrid supercomputer architecture are the next:

- adaptive automation of the hybrid computer effective topology building on the base of computer algorithms of mathematical feature analysis for the problem computer models;
- guarantee of the solution accuracy requirements according the computational problem model by either software or hardware means based on long number arithmetic and providing the result confidence rating;
- computing density due to the innovative hybrid methods of sparse data processing which are adapted to the latest models of NVIDIA Tesla graphic accelerators based on Kepler architecture with the latest CUDA version, and Inparcom-pg general architecture;
- computing virtualization with generic support of multiple operational systems, system monitoring, connection to grid infrastructure.

High performance of intelligent supercomputer packed in a personal computer case (up to 3—9 *TFLOPS*) is achieved by combining software and hardware dense computing tools, the intelligent computational problem solver and the application software virtualization. Besides, for analysis and solution of basic computational mathematic problems with approximate data including those for sparse data structures performance is increased through use of intelligent and specialized algorithms. Intelligent personal supercomputers occupy a niche between supercomputers and modern personal computers.

The experimental model of «Inparcom-pg» intelligent personal supercomputer implements the above concept.

ARCHITECTURE AND EQUIPMENT OF INTELLIGENT PERSONAL SUPERCOMPUTER

«Inparcom-pg» personal supercomputer is the next step in development of «Inparcom» family of intelligent workstations designed by Glushkov Institute of Cybernetics in cooperation with Electronmash in 2005—2012. The architecture has shifted toward higher calculation density provided by combination of modern GPGPU accelerators, advanced numerical methods, new technologies of processing and storage of big information amounts, application virtualization software [11—13].

«Inparcom-pg» is a knowledge-oriented computer which gains knowledge about the problem computer model features during solving an engineering or scientific problem, automatically builds an algorithm, a program and a topology of the hybrid computer correspondent to the discovered features, and estimates the result reliability after finishing the computing.

The intelligent hybrid personal supercomputer hardware (fig. 1) consists of: *system unit, monitor, keyboard, mouse, and uninterruptible power supply, printer and scanner (or MFP optional)*.

Fig. 1. Components of «Inparcom-pg»

Fig. 2. System unit of «Inparcom-pg»

The system unit (fig. 2) adapted to scientific and engineering problems contains 2 to 4 GPGPUs NVIDIA Tesla K40 with peak performance of 1.43 TFLOPS and 12 GB memory each, at least 64 GB RAM, and highspeed SSD.

As result «Inparcom-pg» personal supercomputer about 100 times outperforms conventional quad-core personal computer in double precision arithmetic. In other words, the time of solving several application problems is reduced from five days to one hour.

SYSTEM SOFTWARE CONFIGURATIONOF INTELLEGENT SUPERCOMPUTER

System software configuration of «Inparcom-pg» personal supercomputer provides support for several modes of use related to the application software features:

- personal computer mode;
- remote desktop mode;
- remote computing service mode.

Figure 3 shows the system software configuration including the operation systems, virtual machines, compilers and libraries.

The system software basic level is presented by Linux operating system. It provides development and runtime environments with highest performance access to physical hardware. Virtual Machines deployed over the Linux basic level create application environments familiar for end-users of each program with graphic user interface. All computational programs are executed in the Linux basic level under the System Monitor control to benefit of the level performance [14].

The fundamental idea of virtual machine technology is abstraction of computer hardware (processor, memory, disk, network, etc.) so to have multiple execution environments with illusion for each of the environments to be is performed on a separate physical hardware. Virtual machines enable complete system fitting to the application specificity and sharing the host machine resources on demand. Virtual machines access the host machine by virtual network and thus can perform calculations on the host machine. Besides, a user can work with application software via the host operational system graphic interface, and if necessary use the virtual machine manager. A user can access applications remotely by VNC (for Linux) or Remote Desktop (for Windows).

INTELLIGENT SOFTWARE FOR SOLVING SCIENTIFIC AND TECHNICAL PROBLEMS

Intelligent numerical software was developed to examine and solve basic problems of computational mathematics with approximate data as a component of the considered system [15].

The intelligent software structure includes a library Inparlib_pg of intelligent programs for analysis and solving problems of the next classes: systems of linear algebraic equations, algebraic eigenvalue problems, systems of nonlinear equations, systems of ordinary differential equations with boundary conditions. It also include Inpartool_pg intelligent software tool that implements the problem description in the subject domain language, automatic execution of the computational mathematics problem analysis and solution processes with the results validity assessments.

Inparlib_pg Intelligent Program Library

Let call intelligent a program which solves a problem by a specified algorithm and during execution checks the user-selected algorithm applicability to the computer model features; automatically generates the efficient configuration of hybrid computer and fits the best number of central processor (CPU) cores and graphics coprocessors (GPU) to minimize the calculation time; distributes the data among processors; solves the problem and makes confidence estimate for the output solution. It provides load balancing, synchronization of data exchange between CPU and GPU, minimization of communication overheads.

In terms of use, the Inparlib_pg library programs are functional components of the Inpartool_pg intelligent tools being it the same time independent reusable components for solving the application problems where computational mathematics is used at intermediate or final stage.

The developed hybrid algorithms and programs are designed so that the algorithm execution is divided into processes run on CPU cores (one process per core). The process here means a program that runs in parallel with others, uses its part of local memory and coordinates with other processes by information exchange implemented in the form of send/receive operations. Parallel processes of such type are implemented by the standard for CPU computing MPI system.

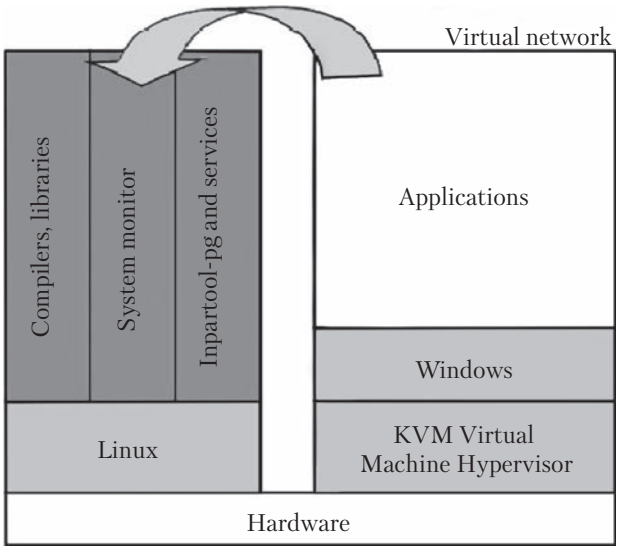


Fig. 3. Configuration of «Inparcom-pg» system software

Each the process, in its turn, is able to parallelize calculations on a number of GPU threads. Usually, a process uses one GPU. Within the development of a parallel algorithm one has to design the task subdivision into subtasks i.e. to determine the subtask priorities; to select better computing resource distribution among the subtasks; to specify which subtasks can be performed in parallel; to coordinate the sequence in which the subtasks should be performed, etc. Thus, the hybrid approach involves two levels of parallelism: parallelism among the process level subtasks and the intra-subtask parallelism by GPU threads.

When implementing the CPU-level subtasks it is necessary to take into account connections between processors and between cores within the processors. Much execution time is spent for exchanges between the processes. Therefore, it is important to select the most efficient topology

for a particular problem, to fit the optimal number of CPUs and to specify interconnection between them. MPI makes it possible to create virtual to-pologies of fixed number of cores (processes). Virtual topology means the software topology of relations between the processes such as ring, grid, torus, hypercube, etc. regardless hardware communication environment. The virtual topology model can be presented by a graph with vertices of processes and edges of communication channels. Thus, a MPI user (programmer) does not need to know the scheme of physical links between the cores which greatly simplifies the process of writing a parallel program. However, the user has to determine the number of cores for solving the task and distribute the data between them ensuring their balanced load. Since the op-erations of data transmission far exceed the dura-tion of arithmetic operations and memory access operations, it is necessary to distribute the data in the processor memory so to provide good balance between the data exchange and arithmetic operations performed concurrently and minimize the whole time of executing the program. When developing algorithms for hybrid architecture it is necessary to take into account the differences in memory models for CPU and GPU. CPU programs can address directly any cell of linear and homogeneous memory. Besides, modern com-puter processors have fairly big internal cache which implicitly improves the performance of algorithms and programs on CPU.

Peak performance of graphics processors greatly exceeds CPU performance. Yet GPU implementation of parallel computing based on NVIDIA CUDA technology contain six types of memory, each with own function and performance. The main issues of parallel computing for hybrid architecture are: need to master different tools for CPU and GPU parallel programming; complexity of resource distribution among the processor cores and graphics coprocessors; limitations of communication between CPU and GPU. In addition, one of the important tasks of algorithm and software developers is prediction which subtasks in each algorithm will be more efficiently implemented on CPUs and which on GPU.

Intelligent Inpartool_pg Software Toolkit

Inpartool_pg is an intelligent software toolkit of the end-user level. It provides user/computer interaction in the problem domain language and executes automatically all stages of computer problem solving (algorithmic, programming with considering approximate initial data and the computer solution validity analysis) [15].

Conceptual principles of process flow chart for problem solving in the intelligent interface include:

- Capability to solve problems with approximate input data;
- Problem specification in the problem domain language;
- User-friendly methods of data input;
- Automatic program synthesis on the base of computer studying of the problem mathematical features, knowledge of the system and the problem to be solved;
- Output of problem solution together with the computer result validity assessment;
- Problem solution supplemented by a protocol of the process of studying the features and evaluation of the results;
- Implicit parallelization. The implicit parallelization assumes [15]:
- Automatic hybrid program subtask distribution among CPUs and GPUs;
- Automatic fitting the numbers of CPUs and GPUs for the program execution, configuration of the computer for the problem efficient solution;
- Automatic distribution of input data among the program processes according the algorithm;
- Load balancing;
- Synchronization of inter-process data exchange;
- Coordination of asynchronous operations;

✦ Minimization of inter-process data exchange.

As result, the user experience of Inparcom-pg personal supercomputer with both multi-core and graphics processors is similar to of a serial personal computer.

Inpartool_pg implements the concept of knowledge driven development. Its design is based on synthesis of the major benefits of modular programming, databases, knowledge bases and the advanced knowledge engineering methods of information presentation, storing, acquisitioning, etc.

The intelligent software architecture was founded on formal models of the subject domain of computational mathematics: the most common problems, methods and algorithms of their solving on hybrid computers. The formal model is closely connected to the principles of automatic analysis of the computer model features in order to automatically generate the algorithm and to synthese hybrid program which accounts the input data approximate nature, mathematics and technical characteristics of the hybrid computer.

Besides, the software design supports use of Inpartool_pg through Internet. The software is of client-server architecture. The client side consists of interactive frontend only. And the server side includes systems that provide the users access to the intelligent software backend as well as analysis and solution of the problems with approximate data on the hybrid computer. Figure 4 schematically depicts the Inpartool_pg client-server architecture.

The remote access, authentication and authorization services provide user with both direct and Internet access to Inpartool_pg.

The Planning and Control System is related to the problem domain specification (in the form of semantic network or graph), the knowledge base and the user interface. Main objective of the computing planning is to find the best method of the problem solving with the least user interaction.

The principles of automated computer problem analysis and solving with assessment of results validity set the next requirements for the planning and control system:

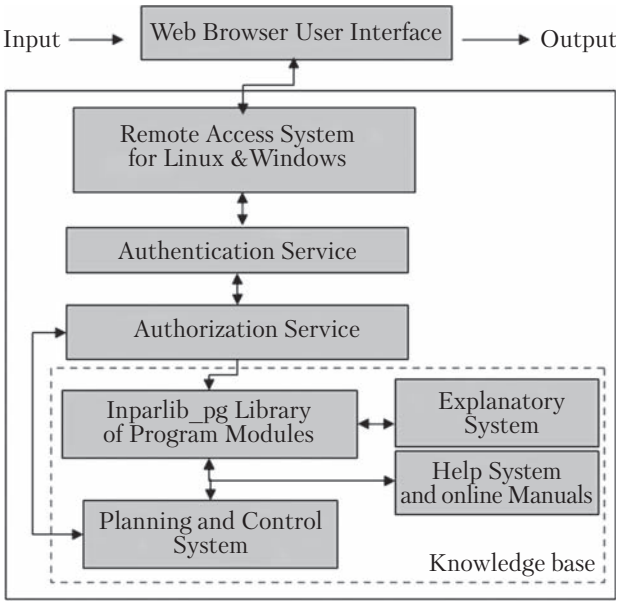


Fig. 4. Client-server architecture of Inpartool_pg

- ✦ information gain from the input data analysis and its transformation to the initial knowledge about the problem features and preferable algorithm;
- ✦ application domain knowledge collection and processing during the computing planning;
- ✦ transformation of the knowledge on the problem features to the algorithm choice and the program synthesis;
- ✦ automatic input data distribution among the processes;
- ✦ output and storing the solution results for further explanation and presentation.

After the semantic graph based formal analysis of the input data features the software modules are selected for further analysis of the problem features. Then the problem features are automatically converted to the algorithm choice, and the program is synthesized. Within the synthesis the computer resources are selected, the virtual interconnection configuration is generated and the computing process is being continued according to the semantic graph. Both control and data ex-

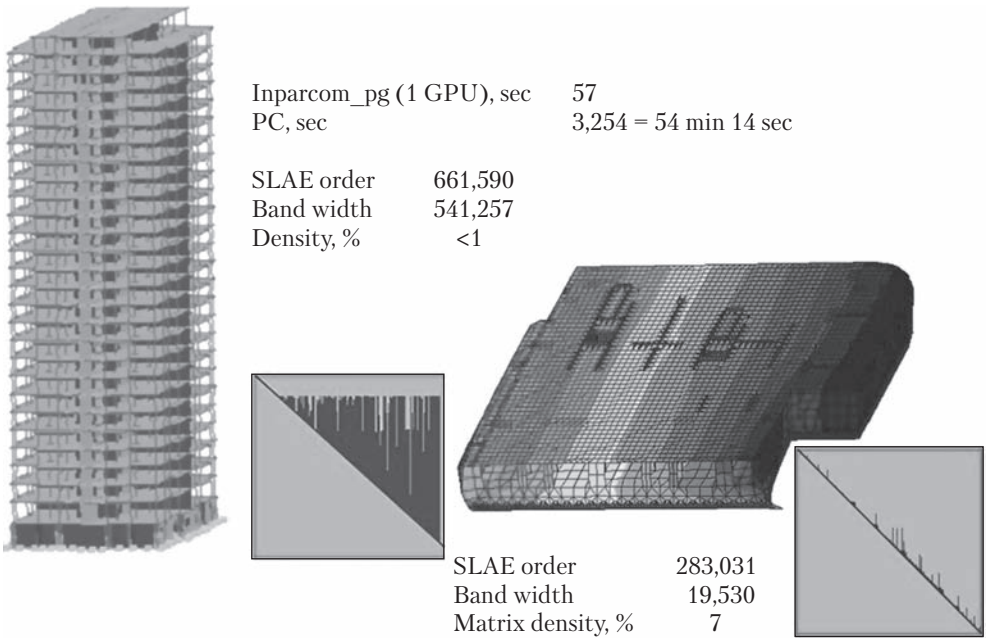


Fig. 5. Results of SLE solutions in LIRA_g

change communication channels between the involved software modules are established.

The Explanatory System explains how the problem solution was obtained and reasons why the particular feature analysis process selected. It presents the problem solution with the confidence estimates or the reasons for inability to obtain it. A user can control the level of detail of the explanations. There are different scenarios of explanations and different level protocols of computing for this purpose.

The Help System provides a user with guides and manuals how to work with Inpartool_pg.

The user interaction with Inpartool_pg is implemented via a system of dialog web forms, namely:

- problem statement and data input;
- computing process control;
- presentation of solution results;
- explanatory;
- help and reference information.

The dialog scenarios have been developed on the base of the application domain model. They account different user goals and different levels of user training in use of the intelligent software: both automatic and interactive automated problem solving modes are supported. Besides, they satisfy the requirements to communicate in the subject domain language and provide convenient intuitive forms for information input/output to make unnecessary the paper documentation.

APPLICATION SOFTWARE

Numerous software tools (from programs to big packages) have been developed over the last decades for solving a wide variety of application problems. In the majority of the cases the tools were designed for computers of traditional serial architecture. Adaptation of the tools for the hybrid architecture computers requires their significant modernization by top level application software developers.

An example of such success story is the program complex ANSYS [16]. It proposes solutions for a wide range of modeling problems in computational aero-hydrodynamics, solid mechanics, electro-magnetic simulation, etc. ANSYS developers implemented (e. g., in ANSYS® v. 16.1)

the aero-hydrodynamics parallel computing tools suitable for both workstations and distributed systems equipped by either multi-core processors or graphics coprocessors.

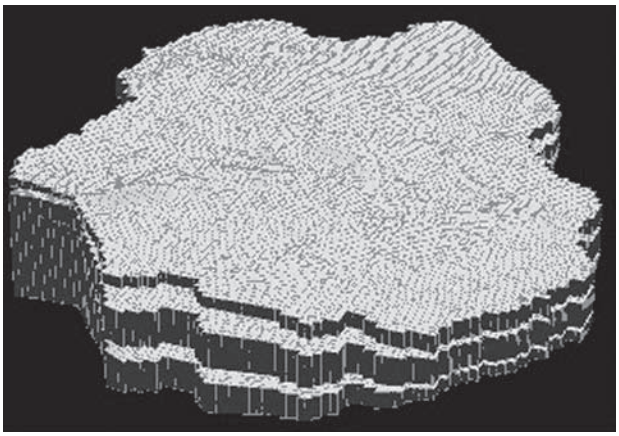
Another approach to parallelization of existing serial software is just replacement of their computational libraries by the new parallel ones at least for the operations especially greedy for computing resources such as processing time, memory, etc. Intelligent software of kind Inparlib_pg library is the best choice for such replacement. It can be used for example to solve systems of linear algebraic equations (SLE). The precondition of this approach is full access to the serial software source code. Inparlib_pg was designed for Linux. However, if the original software runs under Windows the Inparcom-pg technology proposes a solution with the application run on a Windows virtual machine and the Inparlib_pg run in the host Linux environment.

Let's consider three examples of such approach implementation.

Information Technology of Strength Analysis of Building Construction PC Lira_g

The problems of strength analysis arise in different sectors of the economy such as construction and mechanical engineering. Increased design quality demands together with distribution of new construction technologies and materials generate new requirements to numeric modeling. In addition, architecture development stimulates the steady need in calculation of the complex unique objects. So the demand for new solid mechanics methods and computational approaches able to provide the correct and precise computer modeling for real constructions is growing.

The program complex LIRA [17] is developed for building constructions strength calculations on personal computers. Its branch LIRA-cluster [18] developed to use computing clusters for higher performance calculations. Its disadvantage is the need for users to copy big data volumes to and from remote clusters. Besides, LIRA users who aren't IT professionals lack confidence when send proprietary data via Internet to 3rd party hardware.



Geometry of water saturated layers of Chernihiv region with branched network of surface stream flows (the model covered area is 184 × 222 km)

Solution time:	
Inparcom_pg (1 GPU), sec	65
PC (8 cores), sec	1,266 = 21 min 6 sec
SLEA size:	
System order	1,151,112
Band halfwidth	5,367
Memory, Gbyte	20

Fig. 6. Simulation of underground filtering in Nadra-3D_g

The personal supercomputer of hybrid architecture Inparcom-pg makes it possible to use high- performance computing locally. To meet users desires the new information technology of building constructions strength analysis Lira_g was implemented as Inparcom-pg application. It is organized so. The conventional LIRA run in a Windows virtual machine prepares data files for parallel calculations. Then the data files are copied through virtual network in the host Linux en-vironment where the intelligent software is immediately started to distribute the data between the computing units and to execute calculations. The results are converted in the LIRA format and copied back to the virtual machine, and then LIRA catches them and presents. Fig. 5 shows the effect of solving SLE of LIRA by Inparcom-pg.

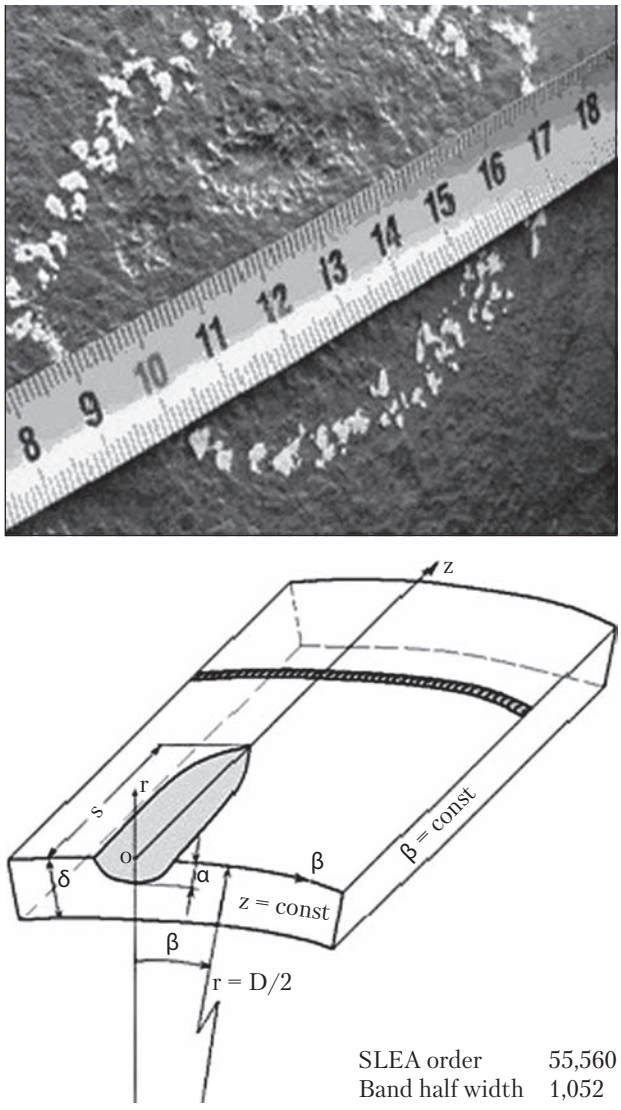


Fig. 7. Simulation of stress-strained state of weld structures in WeldPredictions_g

Information Technology Nadra-3D_g for Spatial Heat and Mass Transfer Modeling

Finite elements method is a popular approach to numerical modeling of physical processes. Glushkov Institute of Cybernetics has developed the finite element solver Nadra-3D [19] for simulation of mass transfer processes such as underground water filtering in large scale multi-component geological environments tested in Chernihiv region. The computational grids of tetrahedral finite elements built for 3D model of the region is highly detailed. It accounts the strata geometry and parameters together with the surface river network. The computational problem is reduced to SLE with wide band matrices. Nadra-3D ported to Inparcom-pg in the form of information technology Nadra-3D_g targets such problems. The system uses Inparlib_pg for reliable and quick solution of big SLE (from 400 thousand to 1.5 million variables, Fig. 6).

The intelligent software use for SLE solving provided significant (tenfold) speedup of the Nadra-3D finite elements modeling. The order of solved SLE: 10^6—10^{12}).

Information Technology for Simulation of Welding Processes and Related Technologies

Technical condition diagnostics of welded structures under significant strains or in aggressive environments is the key to their stability and damage protection. Since welded structures are used in nuclear and thermal power plants, pipelines and other objects of high safety requirements, the most precision evaluation of the structure state from the known operational da-mage such as the surface corrosion metal loss is important to ensure their long-term reliability.

E.O. Paton Electric Welding Institute of NAS of Ukraine has developed the software package WeldPredictions for application research of thermo-mechanical processes of welding and further exploitation of welded structures. It consists of serial personal computer programs. 3D model processing by the programs is computationally hard and requires up to several days of continuous calculations to get result. The WeldPredictions_g information technology [20] has been developed for solving the processing problems on Inparcom-pg intelligent personal supercomputer with Inparlib_pg library SLE program use (fig. 7).

WeldPredictions_g 20-60 times speedups the processing.

CONCLUSIONS AND IMPLEMENTATION PERSPECTIVE

The innovative scientific and technological project «Development of hardware-software system based on intelligent personal supercomputer of hybrid architecture for mathematical modeling in defense industry, mechanical engineering and construction» resulted in implementation of hybrid intelligent personal supercomputer Inparcom-pg including development of several algorithms and programs for hybrid computers to solve problems using the intelligent software which implements the innovative functions of automatic adaptive selection of algorithm, program parameters and hardware configuration on the base of the problem features.

In addition, the approximate nature of input data is accounted, and the solution validity is ensured. The algorithms and software for big sparse dataset processing typical for modeling problems in defense, engineering and construction are developed.

High performance of the personal computer (up to 3 TFLOPS) has been achieved by highly optimized computational libraries, advanced technical means of hybrid architecture and virtualization of application software.

The intelligent parallel supercomputer main advantages are the next:

- release of a user (programmer) from analysis of problem features, development of algorithms and software for hybrid computers reduces the problem statement and solution time for science and engineering;
- use of the subject domain language for computer specification of problems with approximate data;
- the problem computer solution with confidence estimates;
- implicit paralleling provides the comfort of using the parallel computer just like a conventional serial computer.

Inparcom-pg intelligent personal supercomputer of hybrid architecture can be used for a range of modeling problems in the areas such as engineering, nuclear power, aircraft and ship designing, defense industry, civil and industrial construction, electric welding, and economics.

The experimental model of Inparcom-pg is used in *Electronmash* for scientific and engineering calculations including strength analysis of construction projects, underground filtering simulation, modeling of stress-strained states of welded constructions.

Inparcom-pg application for the scientific and engineering problems significantly reduces the time of problem solution and ensures the result quality. Its design reduced the size of parallel computer to the personal computer format and decreased its power consumption through use of modern graphics accelerators.

Inparcom-pg is a high performance computer designed for personal use. It is important for the applications where information protection is of high priority, e. g., for design automation in construction.

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ІНТЕЛЕКТУАЛЬНИЙ ПЕРСОНАЛЬНИЙ СУПЕРКОМП'ЮТЕР ДЛЯ РОЗВ'ЯЗУВАННЯ НАУКОВО-ТЕХНІЧНИХ ЗАДАЧ

Розроблено новий вітчизняний інтелектуальний персональний суперкомп'ютер гібридної архітектури Інпарком_pg, призначений для математичного моделювання процесів в оборонній галузі, галузях машинобудування, будівництва тощо. Створено інтелектуальне програмне забезпечення для автоматичного дослідження та розв'язування задач обчислювальної математики з наближеними даними різної структури. Реалізовано прикладне програмне забезпечення для математичного моделювання задач в будівництві, електрозварюванні та процесів фільтрації.

Ключові слова: математичне моделювання, інтелектуальний комп'ютер, гібридна архітектура, обчислювальна математика, наближені дані.

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ИНТЕЛЛЕКТУАЛЬНЫЙ ПЕРСОНАЛЬНЫЙ СУПЕРКОМПЬЮТЕР ДЛЯ РЕШЕНИЯ НАУЧНО-ТЕХНИЧЕСКИХ ЗАДАЧ

Разработан новый отечественный интеллектуальный персональный суперкомпьютер гибридной архитектуры Інпарком_pg, предназначенный для математического моделирования процессов в оборонной отрасли, отраслях машиностроения, строительства и т. д. Создано интеллектуальное программное обеспечение для автоматического исследования и решения задач вычислительной математики с приближенными данными различной структуры. Реализовано прикладное программное обеспечение для математического моделирования задач в строительстве, электросварке и процессах фильтрации.

Ключевые слова: математическое моделирование, интеллектуальный компьютер, гибридная архитектура, вычислительная математика, приближенные данные.

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