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INTELLIGENT PARALLEL COMPUTER WITH *INTEL XEON PHI* PROCESSORS OF NEW GENERATION

Introduction. *Mathematical simulation with large volumes of data is an actual innovation problem in various spheres of human activity. For their efficient computer research, it is necessary to use powerful computers and high-performance software.*

Problem Statement. *Models of processes studied on modern computers have approximate data, their mathematical properties are a priori unknown. However, the existing software does not take this into consideration. Modern parallel computers require high costs for production and use.*

Purpose. *To develop an intelligent personal computer based on Intel Xeon Phi processors of new generation and intelligent software for automatic research and solution of the main classes of problems of computational mathematics with approximate data.*

Materials and Methods. *The concept and methods for intellectualization of parallel computers of the Inparcom family, which are developed at the Glushkov Institute of Cybernetics of the NAS of Ukraine in cooperation with Electronmash.*

Results. *Intelligent Parallel Computer Inparcom_xp with an Intel Xeon Phi 7210 processor, which makes computations (up to 3.5 TFlops) in the single-locale format (test model, prototype). Intelligent software for automatic research and solution of problems in computational mathematics.*

Conclusions. *The Inparcom_xp guarantees a high reliability of computer solutions of problems, frees users from creating parallel algorithms and programs. The computer is made mainly for individual use, thereby raises the resource of personal computing for R&D calculations.*

Keywords: mathematical simulation, parallel computer, Intel Xeon Phi processor, computational mathematics, and approximate data.

Mathematical simulation with large volumes of data is an actual innovation problem in various spheres of human activity. Very often, due to numerical experiments, researchers can study characteristics of objects and phenomena, which cannot be established theoretically or by field experiments. At present, the quality of mathematical simulation in various fields of science and engineering can be improved only due to the use of fundamentally new 3D models, the transition from computer simulation of individual nodes and aggregates to the calculation and optimization of the product as a whole. Obviously, the consideration of problems stated in such a way leads to the appearance of discrete mathematical models of super-dimensionality, to implement which on the computer the modern personal computers and workstations do not have sufficient computing resources.

During several decades, a significant increase in computer performance was achieved by increasing the number of processors, increasing their clock speed and parallelizing computations. Over the recent 10—12 years, there has been reported a significant increase in the performance

of such several computing systems with parallel computing organization. However, today, raising performance through increasing the clock speed of processors has already reached its limit.

In recent years, multicore computers using coprocessor accelerators of various architectures have become widespread. Among them there are quite powerful hybrid architecture computers that combine *MIMD*- and *SIMD*-architecture. For solving tasks on these computers, the computations are parallelized among multicore central processors using graphic processors that efficiently perform multithreaded similar large volume calculations.

The hybrid architecture supercomputers have long occupied the leading positions in the world ranking of the TOP 500 supercomputers [1]. However, when solving complicated computational tasks using these powerful computers one can face quite significant difficulties caused by specific features of two fundamentally different architectures, communication losses of inter-processor communications, and the use of various software tools *MPI* and *CUDA* for paralleling. Without taking into consideration these features, it is impossible to effectively use the computational capability of hybrid computers.

At the end of 2012, *Intel* offered a new solution for boosting *Intel's* performance — the first-generation *Intel Xeon Phi* processor with *Intel*® MIC (Many Integrated Core) architecture, which was used as a coprocessor, and in the summer of 2016, the release of second-generation *Intel Xeon Phi* multicore processor with *Knights Landing* architecture to be used as a central processing unit was announced. In the latest TOP500 ranking (November 2017), *Intel's* first-generation *Xeon Phi* processor takes the second place, while the second-generation processors are ranked from the seventh to the ninth.

The second generation *Intel Xeon Phi* processors are designed to quickly solve practical problems with huge amount of data. This is ensured by high-speed parallel computing on shared memory of the multicore processor with no communication losses, as well as by the ability to use a large amount of RAM at various levels. However, to effectively use the computing power of computers with Intel Xeon Phi processors it is necessary to use application software that takes into account new architectural capabilities of processors.

Another important factor for the efficient performance of computations is the accuracy of solutions of applications. Mathematical models that describe applied problems always contain errors in the initial data. Consequently, their mathematical properties are not known a priori. Within a given level of error, tasks can be either compatible or incompatible, correctly or incorrectly stated, ill- or well-conditioned. In their turn, the mathematical properties of a computer problem to be solved can significantly differ from the mathematical properties of discrete and mathematical models because of the rounding of computations and data in computer [2—9].

However, most of the available high-performance application software does not take into account the approximate nature of the source data. Therefore, the users have to analyze the reliability of the computation results obtained.

It should also be noted that many users of modern software applications, such as problem-oriented application software packages such as *ANSYS, NASTRAN* [10—12] have indicated their low integration with new computer architectures, closeness, and huge amounts of documentation. They have been noted to ignore the approximate nature of the problem data and not to analyze the reliability of results. An independent solution to these problems requires additional user's efforts and time.

The modern high-performance computer systems, the production of which costs a huge money, require powerful electricity supply and air conditioning systems, have a sufficiently high level of acoustic noise and, therefore, are located in separate special rooms. The necessity of these material investments retards their widespread use.

The authors believe, the promising directions for the development of high-performance computing are the creation and use of intelligent computers based on the latest computing tools (graphic accelerators or the latest models of *Intel Xeon Phi* processors) capable of carrying out computations (up to 3 Tflops) in the format of personal computer as well as the application of modern technologies for storing big amount of information, intellectualizing research processes, and solving problems with approximate data.

In 2015, while implementing the innovative R&D project *The Development of Hardware and Software Complex Based on Intellectual Personal Supercomputer of Hybrid Architecture for Mathematical Simulation in the Defense Industry, Engineering and Construction Sectors* the Glushkov Institute of Cybernetics of the NAS of Ukraine together with *Electronmash* State Corporation developed a concept and created a prototype of single-locale eight-core intelligent personal supercomputer, *Inparcom__pg*, with the latest *NVIDIA Tesla K40* GPUs for solving R&D problems [13].

In 2017, within the framework of the innovative R&D project *The Development of Intelligent Parallel Computer on New Generation Intel Xeon Phi Processors for Science and Engineering*, the Glushkov Institute of Cybernetics of the NAS of Ukraine in cooperation with *Electronmash* developed an architecture and created a prototype single-locale intellectual personal computer *Inparcom_xp* on the second generation *Intel Xeon Phi* multicore processor [14].

These innovative developments are designed to develop the conceptual principles of intellectualization of the *Inparcom* family parallel computers with various architectures [15, 16], which have been developed over the last decade at Glushkov Institute of Cybernetics of the NAS of Ukraine and *Electronmash*.

Conceptually, the intelligent computer for solving R&D problems is a knowledge-oriented parallel computer whose structure, architecture, and operating environment support an intelligent software for automatic studying and solving computational mathematics problems with approximate data.

The main advantages of an intelligent parallel computer are as follows:

- it releases the users from studying the problems and creating parallel algorithms and programs, which reduces the time required for setting and solving problems of science and engineering;
- statement of the problem with approximate data in the language of the subject area;
- it provides requirements for the accuracy of calculations (by means of software or hardware) in accordance with the properties of the computer model of the problem based on multibit arithmetic, enables obtaining results with estimated reliability.

PC BASED ON THE 2ND GENERATION *INTEL XEON PHI* PROCESSOR

According to the conception for designing an intelligent multicore personal computer Inparcom_xp, a prototype single-locale intelligent parallel PC Inparcom_xp with *Intel Xeon Phi* 7210 processor (Fig. 1) has been manufactured [14].

The technical specifications and standard software of Inparcom_xp PC are as follows:

- *Intel Xeon Phi* processor 7210—32 tiles connected by a 2D mesh, 64 cores, 16 Gb "fast" memory (MCDRAM). Each tile contains 2 cores, 2 × 2 VPUs (vector processing units), the first level cache is 32 KB, the second level cache is 1 MB;
- the main operating system is *Linux* or *Windows*;
- RAM — 192 GB, SSD drive — 240 GB, peak (theoretical) performance (DP) — 2.663 TFlops, maximum performance (DP, Linpack test) — 1.793;
- *Intel — C*, *C ++*, *Fortran* compilers;
- MPI parallelization systems, *OpenMP*;
- *Intel* Math Kernel Library (MKL);
- Intelligent software for studying and solving problems of basic classes of computational mathematics.

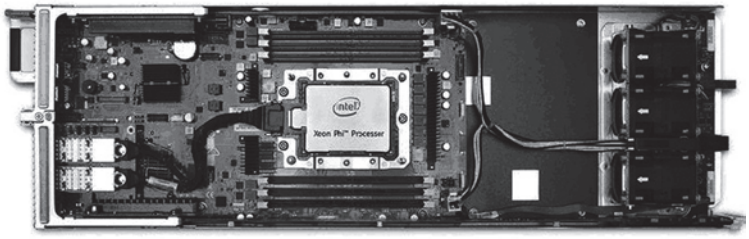

Fig. 1. *Inparcom_xp* intelligent PC prototype

Below, there is more detailed description of the components of *Inparcom_xp* PC.

Architectural Features of the 2nd Generation *Intel Xeon Phi* Processor

The new generation *Intel Xeon Phi*, processor used in the *Inparcom_xp* parallel personal computer is the first Intel boot host processor that supports massive parallelism and the vectorization of large high-performance computing applications. It is the first one where the memory and the switching technologies are integrated. Therefore, unlike the existing processors used as coprocessors and GPU accelerators, its functionality is not limited by communication delays.

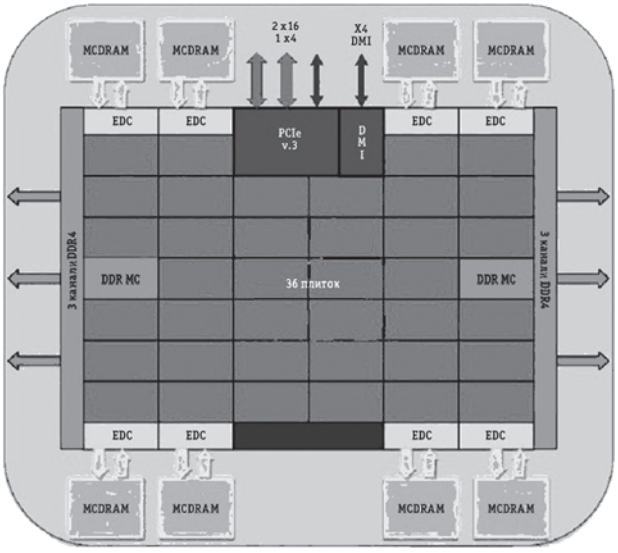

Fig. 2. *Knights Landing* processor architecture

Due to no limitations, the latest *Intel Xeon Phi* processors provide high performance and scalability and can operate in various configurations. This processor belongs to the third generation processors based on the *Intel MIC* architecture and to the second generation of *Xeon Phi* (*Intel Xeon Phi* x200 Family) codenamed *Knights Landing* [17]. Its structure and architecture are shown in Fig. 2.

The *Knights Landing* processor has up to 36 tiles with 2D mesh links topology. Each tile is the two *Intel Atom Airmont* cores (14 HM, version *SilverMont*) with two AVX512 VPUs (vector processing units) to work with numbers in double-precision floating-point format.

Each core has command and data caches, each of 32 Kbytes, with an additional 1 MB cache of the second level, which is shared between the chip cores. The chip provides the coherence of the second level cache for all cores with a total capacity of up to 36 MB. One such core is designed for the simultaneous use of four threads (flows of commands executed simultaneously). The processor also includes eight *MCDRAM* (Multi-Channel DRAM) memory modules with

a total capacity of 16 GB and a bandwidth of over 400 GB/s, which have access to the tile.

In addition, there is still the opportunity to access the distant memory DDR4 2400 having a capacity of up to 384 GB and bandwidth more than 90 GB. The near memory can work in three different modes: as a cache of the distant memory (*Cache Mode*); as part of a single address space with the distant memory (*Flat Mode*); and in *Hybrid Mode*, when one part of the MCDRAM is used as a cache, while the other part is used in a single address space with DDR4 RAM.

Thus, the architectural capabilities of the *Intel Xeon Phi* processor (the use of different levels of RAM) is designed to efficiently perform large-scale tasks.

Specific Features of *Inparcom_xp* PC Software

System software of the single-locale multicore computer *Inparcom_xp* foresees the following several modes:

- the user directly operates the computer;
- remote desktop;
- access to the computer via the Internet.

In order to ensure the efficient use of the specific features of applied software for simulating processes and phenomena in various fields, which mostly function in the Windows operating system, as well as for their interaction with other software operating in the Linux operating system, there are the two system software architectures:

- based on *Windows Server* 2016 and
- based on the *Linux* operating system.

So, the users of this computer have the possibility to independently choose the operating environment, depending on the specific features of applied software used by them.

INTELLIGENT SOFTWARE FOR *INPARSOFT_XP*

In order to solve problems of mathematical simulation of processes and phenomena that arise in scholarly and engineering research, as well as to increase the labor productivity of researchers, intellectual software *Inparsoft_xp* has been created for studying and solving basic classes of problems of computational mathematics (systems of linear algebraic equations, algebraic problem of eigenvalues, nonlinear equations and systems; ordinary differential equations and systems) on parallel computers with the latest *Intel Xeon Phi* processors. This software can be easily adapted to different computer architectures and operating systems (Fig. 3).

Structurally *Inparsoft_xp* consists of *Inpartool_xp* intelligent software (IPS) for the automatic study and solution of computational mathematics problems with approximate data and *Inparlib_xp* library of parallel programs that implement research and solution of certain classes of tasks using specific high-performance methods [15].

From the user's standpoint, *Inpartool_xp* is a software tool for automatically studying and solving problems of computational mathematics with approximate data, which guarantees the reliability of computer results.

Functionally, *Inpartool_xp* provides the following stages [15, 16]:

- setting up a task with approximate data in language of application environment;
- usual forms of initial data input;
- automating the processes of computer research of the mathematical properties of the problem, the choice of algorithm and the synthesis of program for solving based on the knowledge about the subject area and about the problem to be solved;
- solving tasks with increased digit capacity;
- solving tasks with an assessment of the reliability of the computer results obtained with the efficient use of the architecture of the latest *Intel Xeon Phi* processor;
- explaining the process of problem research and solution; and
- realizing the principle of "hidden parallelism".

The realization of "hidden parallelism" involves the automatic formation of an efficient computer configuration (topology) and parallelizing the computations on the optimal number of multicore *Intel Xeon Phi* processors [15].

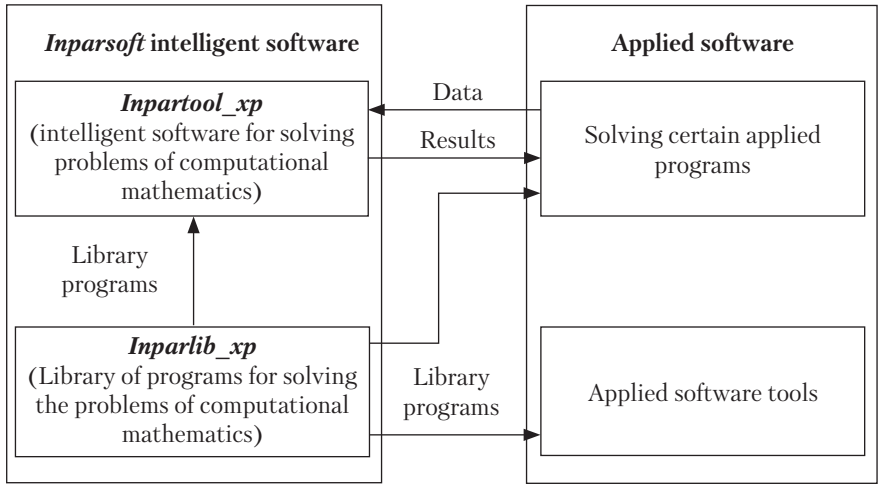

Fig. 3. *Inparsoft_xp* software architecture

Parallel programs in the *Inparlib_xp* library provide solving problems of certain classes by specific algorithms. During the computational process, each program checks whether the chosen algorithm matches the mathematical properties of the computer model of the problem, generates an efficient configuration of the computer from the used processors, performs initial data distribution, solves the problem and evaluates the authenticity of the solution or informs the user of the reason for the refusal to solve the problem by the chosen algorithm [18].

From the end-user standpoint, the library programs are reuse-components for solving applied problems, with computational mathematics tasks as intermediate or final stage.

The *Inparsoft_xp* intelligent software is realized as separate components, which simplifies its adaptation to the user's computing environment. Identical intelligent interfaces have been created for different architecture of parallel computers, remote and local access, and for various operating systems (*Linux*, *Windows*). All necessary applications can be easily connected.

Taking into account the architectural and technological features of the *Intel Xeon Phi* processor, when creating the *Inparsoft_xp* intelligent software, the following methods of raising the computational efficiency were used: parallelization and vectorization of computations; use of cache memory of different levels [16, 19].

The computations in distributed computer memory with several *Intel Xeon Phi* host processors and between CPU cores with shared memory are parallelized using the MPI system [20] and the *OpenMP* system [21], respectively.

One of the important factors in accelerating the computations on the computer with *Intel Xeon Phi* host processor is vectorization. The architecture of this second-generation processor requires the use of the AVX512 command system supporting vector registers. In addition, the *OpenMP* version 4.0 [21] also has the functionality for vectorizing computations on these processors.

To perform matrix-vector operations, one can use the appropriate features of Intel MKL Library (Math Kernel Library) version [22] adapted by *Intel* for the use on the latest *Intel Xeon Phi* processors. Below, there is a brief description of how to perform the computations on the *Intel Xeon Phi* processor using *Intel* MKL programs.

As a library function is called, the computer's hardware capabilities are checked, a code variant that maximizes the efficient use of parallel *SIMD* commands and registers is chosen, and the strategy of work with ultrafast memory *MCDRAM* is determined. It should be noted that the *Intel*

MKL functions work correctly in the case of simultaneous calls from several streams. Thus, appropriate functions from the *Intel* MKL program library used to perform mathematical operations on matrices and vectors provide an efficient use of memory during computations.

APPLIED SOFTWARE ON *INPARCOM_XP* PC

Over the entire period of using computers for solving a wide range of applied problems, a significant amount of software has been created (from individual programs to software systems). Preferably, these software tools are designed for conventional architecture computers (which do not use parallel computing), therefore for their use on the computers with parallel computing they need to be essentially modified, which requires considerable intellectual efforts of developers and time.

Let's consider some of the applied problems that have been solved on *Inparcom_xp* with the latest *Intel Xeon Phi* host processor: 1 locale, *Xeon Phi* 7210 (64 cores, 16 Gb *MCDRAM*), 192 Gb RAM; and on the *Inparcom_pg* PC of the Hybrid Architecture: 1 locale, two *Xeon* 5606 (4 cores), 24 Gb RAM, and 2 *Tesla* K40 *GPU*s.

Mathematical Simulation of Strength of Building Structures

The calculations of strength of buildings and structures are relevant for many industries, including construction, machine-building, etc. Demanding requirements for the quality of design solutions, as well as the use of new advanced construction materials have led to the appearance of absolutely new large-scale problems. For their computer simulation it is necessary to apply new methods for developing and studying correct computer models that adequately represent the real operation of structures.

At its time, LIRA cluster for cluster complexes and hybrid architecture computers [24] was developed based on the existing LIRA software package [23] designed for solving problems related to calculations of strength of building structures using PC. However, the LIRA cluster widely uses network technology, with remote access being the main user's operation mode. This mode foresees copying extra huge amount of data to and from the cluster complex. In addition, this mode does not ensure confidentiality of computations.

New powerful computer *Inparcom_xp* (in the format of PC) enables to use high-performance computations locally. Taking into account the fact that the standard LIRA software package was designed for the use in *Windows*, the *Inparcom_xp* computer has an option of using *Windows* in addition to *Linux*.

Simulation of processes using the LIRA software package is associated with linear algebra problems in which the order of matrices ranges from 100 000 to several dozen millions. Obviously, to solve them, huge computer resources are needed. A high performance of *Intel Xeon Phi* processor and efficient parallel programs from *Inparlib_xp* library have enabled to reduce 20 times and more the time of solution of such problems using the *Inparcom_xp* computer as compared with the time required for their solution on a single-processor computer.

Mathematical Simulation of the Condition and Service Life of Welded Structures

Diagnostics of the technical condition of welded structures operating under significant external loads and in aggressive environments is a key aspect in ensuring the safety of their operation. The application of such structures (nuclear and thermal energy, pipelines) implies high requirements for their long-term reliability. It is important to determine the boundary condition as precisely as possible, based on the known degree of operational damage that, above all, includes local surface corrosion of metal.

For solving tasks related to the thermomechanical processes in welding and operation of welded structures, the Paton Institute of Electric Welding of the NAS of Ukraine has developed *WeldPredictions* software package that realizes a

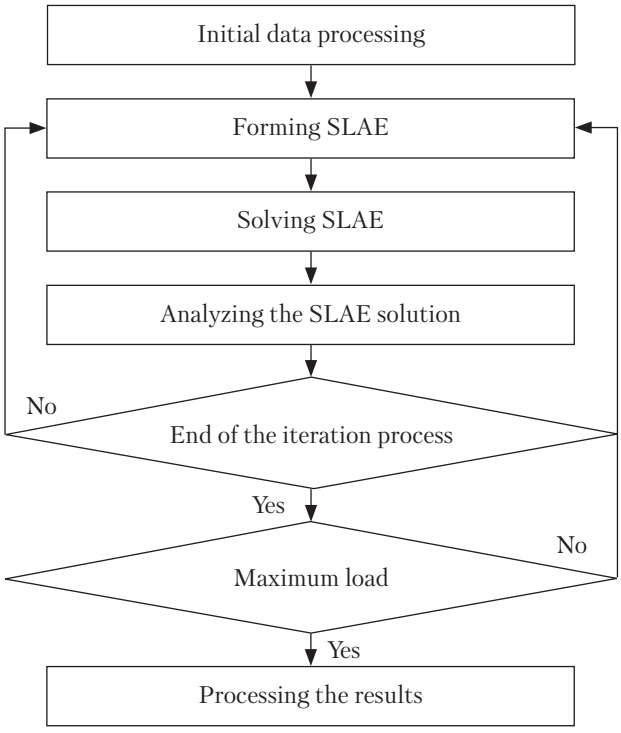

Fig. 4. Flowchart of computer analysis of the stress-strain state of welded structures

sequential model of computations and is used on personal computers. However, for calculations of modern 3D models, large volumes of computing resources and time are required (several days of continuous calculations on a single-processor computer). Therefore, it is expedient to use more powerful computers with parallel computing, in particular, the multicore computer *Inparcom_xp*.

Let's briefly consider one of the typical problems of mathematical simulation of welding processes and related technologies [25], namely, the problem of numerical analysis of the stress-strain state of pipeline elements with the appearance, interaction, and development of viscous fracture pores taken into account. In the general case, the mechanism of viscous fracture has several successive stages: the appearance of the viscous fracture pores in the course of structure production; increase in pores sizes during plastic deformation, interaction and aggregation of viscous fracture pores; the origin of macro-defect and the corresponding decrease in the bearing capacity of both the defective area and the structure as a whole; and development of the macro-defect. Each of these stages has different physical and mechanical nature and is described by the corresponding interrelated model.

Time Characteristics of SLAE Solution with Band Matrix

Matrix order	Semi bandwidth	Sequential algorithm, s	Hybrid algorithm on *Inparcom_pg* (two *GPU*), s	Parallel algorithm on *Inparcom_xp*, s
137 826	4448	1500	45	42.7

Fig. 4 shows the flowchart of solving the problems of numerical analysis of stress-strain and boundary states of welded structures taking into account the appearance, interaction, and development of viscous fracture pores.

It is obvious that in this flowchart, the solution of systems of linear algebraic equations (SLAE) of great order is used on each iteration. It is namely this task that consumes most computer resources and time. In addition, the original software package *WeldPredictions* works in the *Windows* operating system. However, large-scale tasks that arise often require more computing resources (well above 4 GB) than can be used in this operating system.

Therefore, the *WeldPredictions* package has been adapted to the Linux operating system on the *Inparcom_xp*, with an intelligent program for solving the SLAE with an asymmetric band matrix using the parallel algorithm of the Gauss method based on LU-development from the *Inparlib_xp* library applied. The results of solving SLAE (in seconds) by parallel algorithms of the Gaussian method on various computer architectures are given in Table below.

The Table shows that, as compared with the sequential algorithm, the hybrid algorithm realized on a PC with two *GPU*s and the parallel algorithm on a computer with *Intel Xeon Phi* processors (64 cores) enable to speed up the solution 33 and 35 times, respectively.

Problem of Composite Material Stability

The problem of the 3D stability theory of layered composite material under surface compressive loads [26], which reduces to solving a partial generalized algebraic problem of eigenvalues (PGAPE) with a band matrix by the iteration method in a subspace [27] has been simulated in cooperation with the Tymoshenko Institute of Mechanics of the NAS of Ukraine. It is just this problem the solution of which consumes most of computer resources and time. Consequently, the efficiency of solving the whole problem depends, to a large extent, on efficient solution of PGAPE. Therefore, developed intellectual programs that realize parallel algorithms of the iterations method in a subspace, for band matrices, on various computer architectures have been used [28].

The problem has been solved with such initial data: the order of matrices is 12282; the semi bandwidth of the matrix A is 6212 and that of the matrix B is 71; memory is 2 GB.

The time required for solving the PGAPE by different algorithms of the iteration method in a subspace, on various computer architectures is:

- the sequential algorithm: 22 min;
- the hybrid algorithm on *Inparcom_pg*: using one *GPU*: 0 min 18 seconds; using two *GPU*s: 0 min 10 s;
- the parallel algorithm on *Inparcom_xp* with *Intel Xeon Phi* processor (64 cores): 0 min 7 s.

So, the hybrid algorithm for solving the PGAPE on a hybrid personal computer speeds up the solution 18 and 33 times (for the use of one and two *GPU*s, respectively), as compared with the sequential algorithm, while the parallel algorithm on a computer with the latest *Intel Xeon Phi* processor (64 cores) enables accelerating the solution process 45 times.

Based on the calculated eigenvalues, the critical parameters of layered composite material stability under surface compressive load have been determined.

As a result of the implementation of the R&D project *The Development of Intelligent Parallel Computer on New Generation Intel Xeon Phi Processors for Science and Engineering*, the Glushkov Institute of Cybernetics of the NAS of Ukraine has developed *Inparcom_xp* single-locale intellectual parallel computer based on new generation *Intel Xeon Phi* processor for mathematical simulation in science and engineering.

Together with *Electronmash*, a prototype multicore computer with an *Intel Xeon Phi* 7210 processor (64 cores), an additional 192 GB RAM and a SSD drive of 240 GB has been created.

In order to ensure efficient mathematical simulation of processes and phenomena in various subject areas, the *Inparsoft_xp* intelligent algorithmic software has been developed in order to automatically study and to solve basic problems of computational mathematics with the approximate data with reliability of the results estimated. In addition, for the efficient use of *Inparsoft_xp* software and its individual components, the existing application software has been modified for being applied to mathematical simulation in construction, heat transfer, electric welding, stability of structures.

The *Inparcom_xp* intelligent multicore personal computer has enabled high-performance computing (up to 3.5 Tflops) in the single-locale format due to the latest hardware solutions of the *Intel Xeon Phi* processor, compaction of computations, multi-level memory structure, and intellectualization of research and solution of tasks. The experimental solution of practical problems using the *Inparcom _xp* has shown a significant increase in user's labor productivity and guarantees the reliability of the results of mathematical simulation in science and engineering.

The *Inparcom_xp* parallel computer will be used for solving a range of urgent tasks of mathematical simulation, in particular, in such fields as mechanical engineering, nuclear power engineering, aircraft and shipbuilding, defense industry, industrial and civil engineering, electric welding, etc.

The *Inparcom_xp* parallel computer prototype has been already used by *Electronmash* for carrying out researches and engineering calcu-

lations, in particular, for analyzing the strength of buildings and structures, for calculating the filtration in multicomponent environments, and for simulating the stressed-deformed state of welded structures.

Being cheaper, smaller in size and having a lower power consumption, the *Inparcom_xp* personal computer is designed mainly for individual (local) use, which enables to significantly increase the PC resource for scientific and engineering calculations. The option of off-network use is relevant to many users, for example, for automating design in civil engineering, defense industry, etc., insofar as it ensures the confidentiality of calculations. On the other hand, there is an option to use this computer in the remote access mode by several users simultaneously.

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ІНТЕЛЕКТУАЛЬНИЙ ПАРАЛЕЛЬНИЙ КОМП'ЮТЕР НА ПРОЦЕСОРАХ INTEL XEON PHI НОВОГО ПОКОЛІННЯ

Вступ. Математичне моделювання з великими обсягами даних на сьогодні є актуальною інноваційною проблемою в різних сферах людської діяльності. Для їх ефективного комп'ютерного дослідження потрібно використовувати потужні комп'ютери та високопродуктивне програмне забезпечення.

Проблематика. Моделі процесів, які досліджуються на сучасних комп'ютерах, мають наближені дані, їх математичні властивості апріорі невідомі. Проте наявне програмне забезпечення не враховує цього. Сучасні паралельні комп'ютери потребують великих вкладень на виготовлення та використання.

Мета. Розробити інтелектуальний персональний комп'ютер на процесорах нового покоління *Intel Xeon Phi* та інтелектуальне програмне забезпечення для автоматичного дослідження та розв'язування основних класів задач обчислювальної математики з наближеними даними.

Матеріали й методи. Застосовано концепцію та методи інтелектуалізації паралельних комп'ютерів сімейства Інпарком, які розробляються Інститутом кібернетики імені В.М. Глушкова НАН України та Державним підприємством «Електронмаш».

Результати. Експериментальний зразок – інтелектуальний паралельний комп'ютер Інпарком_хр з процесором *Intel Xeon Phi* 7210, який реалізує обчислення (до 3,5 Тфлопс) у форматі одного вузла. Інтелектуальне програмне забезпечення для автоматичного дослідження та розв'язування задач обчислювальної математики.

Висновки. Інпарком_хр гарантує достовірність комп'ютерних розв'язків задач, звільняє користувачів від створення паралельних алгоритмів та програм. Комп'ютер орієнтовано переважно на індивідуальне використання, тим самим піднімаючи ресурс персонального комп'ютінга для науково-технічних розрахунків.

Ключові слова: математичне моделювання, паралельний комп'ютер, процесор *Intel Xeon Phi*, обчислювальна математика, наближені дані.

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ИНТЕЛЛЕКТУАЛЬНЫЙ ПАРАЛЛЕЛЬНЫЙ КОМПЬЮТЕР НА ПРОЦЕССОРЕ *INTEL XEON PHI* НОВОГО ПОКОЛЕНИЯ

Введение. Математическое моделирование с большими объемами данных на сегодня является актуальной инновационной проблемой в различных сферах человеческой деятельности. Для их эффективного компьютерного исследования нужно использовать мощные компьютеры и высокопроизводительное программное обеспечение.

Проблематика. Модели процессов, которые исследуются на современных компьютерах, имеют приближенные данные, их математические свойства априори неизвестны. Однако существующее программное обеспечение не учитывает этого. Современные параллельные компьютеры требуют больших вложений на изготовление и использование.

Цель. Разработать интеллектуальный персональный компьютер на процессорах нового поколения *Intel Xeon Phi* и интеллектуальное программное обеспечение для автоматического исследования и решения основных классов задач вычислительной математики с приближенными данными.

Материалы и методы. Применены концепция и методы интеллектуализации параллельных компьютеров семейства Инпарком, которые разрабатываются Институтом кибернетики имени В.М. Глушкова и ГП «Электронмаш».

Результаты. Экспериментальный образец — интеллектуальный параллельный компьютер Инпарком_хр с процессором *Intel Xeon Phi* 7210, реализующий вычисления (до 3,5 Тфлопс) в формате одного узла. Интеллектуальное программное обеспечение для автоматического исследования и решения задач вычислительной математики.

Выводы. Инпарком_хр гарантирует достоверность компьютерных решений задач, освобождает пользователей от создания параллельных алгоритмов и программ. Компьютер ориентирован преимущественно на индивидуальное использование, тем самым поднимая ресурс персонального компьютинга для научно-технических расчетов.

Ключевые слова: математическое моделирование, параллельный компьютер, процессор *Intel Xeon Phi*, вычислительная математика, приближенные данные.