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PHYSICO-TECHNOLOGICAL PRINCIPLES OF CONSTRUCTION AND OPERATION OF HIGH-PERFORMANCE INFORMATION SYSTEMS

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ФИЗИКО-ТЕХНОЛОГИЧЕСКИЕ ПРИНЦИПЫ ПОСТРОЕНИЯ И ФУНКЦИОНИРОВАНИЯ ВЫСОКОПРОИЗВОДИТЕЛЬНЫХ ИНФОРМАЦИОННЫХ СИСТЕМ

The article defines basic principles of constructing and functioning of high-performance systems using computer technologies, special attention is paid to technologies for creating nano-PC, which constitute one of the most promising fields of innovation: the technology of creating quantum computers using nuclear magnetic resonance, creation of computers based on DNA, i.e., bio molecular computers, neural computers, nano-computers.
Keywords:supercomputer, volatile storage device, reconfigurable systems, ultra-dense recording of information, the carbon nanotubes, the packing density of the elements, quantum computer, bio-computer, neurocomputer, massive parallel circuit, the memory capacity, processing speed.

В статье определены основные принципы построения и функционирования высокопроизводительных систем с помощью компьютерных технологий, которые представляют собой одну из самых перспективных сфер инновационной деятельности: технология создания квантовых компьютеров с использованием ядерного магнитного резонанса, создание компьютеров на базе ДНК, т.е. биомолекулярных компьютеров, нейрокомпьютеров, нано-компьютеров. Большие перспективы обещает сочетание биоинформатики и нанобиотехнологии, что позволит создавать интеллектуальные имплантируемые наносистемы для контроля состояния организма на клеточном уровне.
Ключевые слова: суперкомпьютер, энергозависимое запоминающее устройство, реконфигурируемые системы, сверхплотная запись информации, углеродные нанотрубки, плотность упаковки элементов, квантовый компьютер, биокомпьютер, нейрокомпьютер, массивная параллельная схема, емкость памяти, быстродействие.

Introduction

Problem of creating high-performance information processing systems, in particular information of space-time fields [1-11], is becoming increasingly important. To date, the most effective technical tools of information processing is a computer, computer networks, as well as new interfaces, appearance of which is planned in the period up to 2020 – multi-sensory, multi-modular, multi-linguistic, virtual, creating the effect of telepresence, interfaces«human brain-machine», «brain-brain». Computer technology is one of the most perspective areas of innovation. An important component of these technologies are supercomputers (SC) – the world's most powerful computing systems used in fundamental research in various fields of science, including the modeling of artificial intelligence systems. The main consumer of supercomputers is the USA. Hewlett-Packard and IBM control about 80% of the world supercomputer market, while IBM sends to the market the fastest and most powerful SC in the world (34.8%). Hewlett-Packard's share is estimated at 22.7%. Currently, industrialized countries are actively competing in the creation of the most powerful and most productive SC (the race for the "flops"). Thus, the American company Cray plans in near future to develop and produce SC Granite and Marble with a capacity of up to 10 PF. Currently, the most powerful SC are: SC Milky Way-2 with a peak performance of 2.5 PF at the National University of defense technology of China; Cray XT, known as Jaguar, located in the Oak Ridge National Laboratory, with a peak performance of 1.75 PF; SC IBM Roadrunner with a performance of 1.04 PF at the Los Alamos National Laboratory; SC of National Institute of computer science of the University of Tennessee – 1.03 PF. In Russia, a distributed scientific supercomputer network"SKIF Polygon" – 0.88 PF on the basis of blade-systems "T-platform" was created. However, as practice shows, high power and performance require more space to accommodate the SC, despite the increasing miniaturization through usage of nanocomponents in their design. According to experts, in near future there will be a physical limit to the currently used technological platform based on silicon transistor technologies and completely new computer technologies will be required. These include the technology of creating quantum computers using nuclear magnetic resonance, computers based on DNA, i.e. biomolecular computers, neurocomputers.

Supercomputers

Supercomputers (SC) are the most powerful computing systems in the world in terms of performance and memory. However, it is quite bulky and expensive system. For example, the Chinese supercomputer "Milky Way-2", which occupies one of the leading places in the world among the 500 fastest supercomputers (2.5 PF), weighs more than 150 tons, includes more than a hundred cabinets, has several thousand processors and video chips, costs about 100 million dollars. The efforts of SC developers are aimed at improving the speed, memory capacity, reliability, functionality and manufacturability of production while reducing material consumption, energy consumption, cost, complexity of use and operation. The basis of the improvement strategy is the process of constant miniaturization of the SC element base, which is currently being created with the help of "silicon" technologies.

There are fundamental limitations to further reducing the size of LSI: *thermodynamic* – due to the final temperature of the components, heat exchange conditions, heating, as a result of the flow of current (Joule heat dissipation and heat dissipation conditions), and increasing the clock frequency. All this leads to an increase entropy and loss of information in the system; *electrodynamic* – caused by the inertia of capacitive and inductive components in schemes, which prevents the rapid change of voltages and currents in the transition from one state to another, in particular, when the logical keys in the microprocessor or dynamic memory locations. Additional speed limits are imposed by the finite speed of electromagnetic waves propagation, the motion of charge carriers, the magnetization reversal of ferromagnets, the repolarization of dielectrics; *quantum-mechanical* – are manifested by reducing the characteristic size of the components to atomic scales. In this case, the atomic and electron discreteness in the phenomena of transport and interaction become noticeable. In addition, with a decrease in the thickness of the silicon oxide membrane to 1 nm or less (its usual thickness is several nanometers), which has high dielectric properties and acts as an insulator between individual LSI elements, quantum tunneling effects begin to affect, leading to a sharp increase in the leakage current. In addition, one of the bottlenecks on the path of further integration and miniaturization of LSI is the high-resolution lithography. Using the most convenient and well-developed optical method of lithography predetermines the physical limit of miniaturization to several dozen nanometers when the cutter is exhibited with a short-wave ultraviolet source. To further enhance the resolution, it is necessary to apply either more rigid radiation (X-ray, electronic, ion) or to switch to alternative technologies. There are also problems with long-term memory systems creating that allow information to be stored for a long time without updating and power ingestion. Thus, within the framework of the existing concept, the limit of miniaturization of recording on a magnetic disk has almost been reached – the contribution of one grain of ~10 nm in size to the total magnetization of the area occupied by the bit is measured in fractions of a percent. However, this ratio can only be maintained as the bit sizes decrease to certain limits, as the resistance of magnetization to thermal fluctuations decreases with the decrease in grain size. Nevertheless, the search for ways to improve the "silicon" technology does not stop.

Currently, intensive development is underway to overcome these limitations. Long-term memory systems are being developed based on local changes in the phase state of the carrier with a focused laser beam, maintaining the resulting phase for as long as possible, detecting and reading the recorded bit unlimited number once without destroying the information and, if necessary, erasing it, i.e. returning the material to its original phase state. The most convenient and well-developed phase transition to date is "crystal state-amorphous state" already used in re-recorded DVDs. The increase in the speed of the device is achieved by using binary semiconductor compounds characterized by high electron mobility (In As, In Sb), significantly exceeding (30...50 times) their mobility in silicon. In addition, devices are being developed using tense, elasticly deformed silicon. Intel is already using it in its serial chips to increase the rate of cell switching. The deformation of the silicon lattice by only 1% gives an increase in the switching speed in the field transistor to 20% while increasing the cost of the transistor by only 2%. Achievements in the field of information storage on magnetic media are indicative. Usage of the giant magnetoresistivity effect allowed to significantly increase the amount of non-volatile magnetic memory. American company BeSangInc is developing the world's first silicon nanomemory for 3D architecture. Not only development, but also commercial release of non-volatile storage devices (chips) with ferromagnetic miniature cells (~2,5 nm) is actively conducted. Such devices are an important component in the development of reconfigurable logical elements. In addition, transistor switching schemes are created (in modern microprocessors transistors are as if rigidly "stitched") for rapid reconfiguration of various systems.

A number of promising studies are being carried out in Russia. F.V. Lukin Research Institute of Physical Problems is developing one lithographic technology. This development will stabilize technological operations, ensure good reproducibility of the minimum sizes and minimize the defects. The research into the technology of creating filament-shaped semiconductor nanocrystals is being conducted at the St. Petersburg Physics and Technology Research and Education Center of the Russian Academy of Sciences. The work is aimed at creating new semiconductor nanomaterials and nanosystems with controlled properties that can be used in the production of field transistors. Tekhnomash Scientific Production Association develops nanostructured materials of molecular photonics and layered structures based on them for optical neural network processing of information. Usage of these materials will allow the creation of three-dimensional functional structures, as well as information systems with parallel processing of information, several orders of magnitude superior in speed traditional systems. Research on the magnetic state of composite nanostructures by neutron reflection and scattering methods is carried out by the Joint Institute for Nuclear Research. It has been established that composite nanostructures can be used to create logical elements with four states, which will significantly increase the capacity of storage devices. The Voronezh State University is conducting research on nanostructures for the next generation of electronic engineering, as well as the study of the properties of nanoscale heterogeneous systems, structures and non-linear materials. Nanocrystals, functional materials based on layered and nanogranulated structures, materials with surfaces, modified low-atomic clusters and nanoparticles are studied. Samples of relaxorsegnetoelectrics have been developed, the technology of formation in thin-film segnetoelectrics of nanodomens with sizes that provide the ability to create reprogrammed energy-independent storage devices with a large capacity. V.A. Kotelnikov Institute of radio engineering and electronics of RAS is engaged in fundamental research in the development of one-dimensional structures based on semiconductor GaAs / AlGaA5 heterostructures with two-dimensional electron gas and silicon plates on an insulator. The properties of quasi-aquatic nanomaterials containing conductive metal-chains of atomic size are investigated. The research results serve as a technological basis for ultra-dense recording and storage of information. Technical University "Technological center" is engaged in the creation of electronic devices based on heterostructures, in particular, transistors with high mobility of electrons, tunnel resonance diodes, heterostructure bipolar transistors. «Kurchatov Institute» develops holographic memory of ultra-high capacity. At the same time, many experts believe that the revolutionary transformation of information supercomputer technology will take place outside the "silicon" paradigm. The radical strategy for the development of "non-silicon" electronics abandons the use of silicon as the basis of integrated circuits and involves the development of new nanotechnology. Researchers and technologists are quite obvious huge opportunities for industrial application of carbon nanotubes, which are rolled into a cylinder nanoset consisting of hexagonal modules based on carbon atoms. These tubes have unique electrical and magnetic characteristics. The tubes have an exceptionally small diameter (several nm), their architecture may have a different configuration, depending on the functional features of their application. For example, tunnel carbon nanotubes can be used in transistors, and tubes based on structures with heterogeneous transitions or so-called "neural tree" structures – in the creation of cognitive systems, modeling of neural networks of the brain and artificial intelligence. Nanotubes with semiconductor properties can be used in field-effect transistors like silicon. In this case, the role of an adjustable conductive channel is played by a nanotube, and the role of an isolated gate is a silicon substrate with a thin oxide film on the surface. The change in the gate voltage from +6 to -2 changes the conductivity of the channel by almost 105 times. Over several years of development (for the first time the possibility of creating a transistor on a nanotube was demonstrated in 1998), it was possible to significantly improve the characteristics of nanotubed field-effect transistors and bring them closer to those of the best "silicon" at much smaller sizes. On the same principles it was possible to construct experimental logical devices and memory cells. Thus, a group of American experts as a memory cell was proposed to use a short, closed on both sides of the tube, with a molecule of fullerene C60 placed in it. Van der Waals forces between the molecule and the tube increase near the ends of the nanotube, which leads to the appearance of a two- way potential. One extreme position of the molecule can be attributed to a logical "0", and the other – a logical "1". Switching between these states is provided by the placement of a metal atom in the cavity of the fullerene molecule. As a result of the ionization of the metal, the atom acquires a charge. The application of an electric field along the axis of the tube leads to the movement of the molecule from one extreme position to another. Disabling the field does not change the achieved state, since the molecule is in one of the two potential wells. The result is long-term memory without power consumption. Researchers at Harvard University proposed a construction of a storage matrix in which two rows of nanotubes are located at an angle of 90 ° in parallel planes separated by a gap of 1-2 nm. Such a system has a two-well energy profile, which is created by the elastic forces in the tubes themselves and the van der Waals forces of attraction between them. The application of the potential difference to any pair of tubes belonging to different layers, i.e. to the selected node of the matrix, causes the bending of the upper tube and its attraction to the lower one. When the voltage of the order of volts is touching the tubes and the resistance between them falls by several orders of magnitude, which is easily detected by the corresponding electronics. The van der Waals forces keep the tubes in contact even after the voltage is removed, which ensures non-volatile memory. Erasing the memorized bit of information is carried out by applying the voltage of the same polarity to the tubes of this node, which leads to the uncoupling of the tubes and the return of the memory cell to its original state. The research results show that this technology allows to create dynamic memory matrices with cell sizes 5x5 nm, recording density ~1012 bit/cm2 and speed ~100 GHz. The possibility of creating such a storage matrix on nanotubes, but with an internal insulating layer of silicon nitride containing deep electron traps is shown. It is planned to create devices containing up to 400 billion nanotubes in one mm2, which will significantly affect the quality of the corresponding products of the electronic industry. Such global corporations and scientific organizations as IBM, Intel, NASA, NEC in the USA, Samsung and Shova Denko Com – panels in Japan, M. Planck Institute in Germany, "Kurchatov Institute" in Russia and others are engaged in technological research in the development of nanotubes and their application. So, one of the main advantages of electronics on nanotubes – the packing density of the elements, unattainable in silicon technology, with quite acceptable electrical characteristics. Currently, the transition from laboratory samples to mass technology is being carried out: methods for growing and controlling the growth of nanotubes, their sorting and embedding in the specified configurations have been created. At the same time, the limiting factor of the mass use of nanotubes is the lack of technology for growing them in large quantities and simple ways of connecting them into the necessary electrical circuits. Most of the devices described in the publications on nanotubes created in single copies in the laboratory at the cost of time and labor. In addition, their characteristics are not good reproducibility and reliability. Thus, on the way to mass application without silicon technologies, it seems that many technical obstacles still have to be overcome. It should also be noted that the key to the successful development of nano-supercomputer technology is standardization. The international organization for standardization (ISO) and the international electrotechnical Commission (IEC) have jointly developed, as a precursor to the International standard, voluminous Specifications for nanotechnology terminology (ISO/TS 80 004). This included special terms and definitions of nano-objects and nanostructured materials, carbon nanostructures, and nanometrology, nanopositioning processes.

Quantum computer

A quantum computer is a computer that uses unique quantum mechanical effects, such as interference, parallelism, superposition, entanglement, to perform completely new kinds of calculations that, even in principle, cannot be performed on a single classical computer. So, if a quantum computer consists of *n*qubits (quantum bits), then it can have 2^n different states of qubits at the same time, while a classical computer can have only one of 2^n states at the same time. Qubits in quantum computers can be in the superposition (combination), the combination of on and off at the same time, i.e. it is responding to the laws of quantum mechanics. Switching in the chips of modern computers are in one of the states: either on or off. A quantum computer works by manipulating cubes based on a fixed sequence established by a quantum logic circuit called a quantum algorithm. Photons and individual atoms can be used as qubits. The superposition property allows a quantum computer to perform calculations in an incomparably shorter time than a traditional computer. For example, the fastest modern supercomputer would take hundreds of billions of years to decompose a number hundreds of digits long into two prime factors, and a quantum computer would take several tens of minutes. The main advantage of the quantum computer reveal itself when it is necessary to perform an unlimited number of parallel calculations, when the interest is not their results in themselves, but only some of their combination. The development of quantum computers is currently engaged in specialists of many industrialized countries. Large research of quantum computers creating are conducted in the United States, in particular, the National Institute of standards and technology – NIST. NIST uses ions, neutral atoms and "artificial atoms" created on the basis of the superconductivity effect when processing quantum information. Scientists of the National Academy of Sciences of the United States was prepared for the administration of the President of the United States report "the Second quantum revolution", which notes that the creation of quantum computers will be largely based on the results of the development of nanotechnology. The USA military Agency DARPA is implementing the program "Quantum superpositions in science and technology", which conducts research on the creation of technologies based on the laws of quantum mechanics, including the creation of quantum algorithms and quantum computers. Scientists at Princeton University and Lawrence Berkeley National Laboratory has created an important element of a quantum computer system of the hybrid memory to store the quantum information in qubit 1 on the basis of the electron and the nucleus of an atom of phosphorus, placed in a silicon crystal. The advantage of this system is that it is based on traditional silicone technology and is compatible with traditional computers. Specialists from Florida National High Magnetic Field Laboratory have created a complex compaud material consisting of potassium elements, niobium and oxygen with chromium ions, promising for use in quantum computer technology. In the EU, the project "Use of qubit" is implemented by a Research consortium of 35 academic and industrial groups. One of the main tasks of the consortium is the development and implementation of methods for processing quantum information, the creation of equipment for quantum cryptography systems operating at long distances. In addition, in the EU, within the framework of the program "Science beyond science fiction", there is a subprogram "Quantum information processing and communication in Europe". Currently, the EU is conducting research in such areas as scalability and modular buildup of quantum information systems. This computer architecture will not only create an interface with quantum communications, but also in the near future quantum information networks. In Japan, as well as in the US and the EU, research is underway to develop and create an "element base" of a quantum computer: a system for trapping ions and neutral atoms with appropriate traps; quantum electrodynamic resonators. In 2017, Scientists of the Russian quantum center for the first time in the world developed and tested in practice the technology of "quantum blockchain" – a method of distributed storage and verification of financial, commercial and any other data protected by quantum cryptography. A group of researchers at the Russian quantum center has developed a blockchain platform in which you can use quantum key distribution – that is, quantum cryptography. In certain network configurations, this allows you to discard blockchain elements that are vulnerable to quantum computer attacks. The presence of quantum communications network participants imposes additional requirements when adding a new block to the chain. Thus, the quantum blockchain provides protection against attacks using a quantum computer. On the basis of a combination of quantum communication networks and blockchain technologies, it is planned to develop a whole class of different products for distributed data storage and maintenance of distributed databases.

Biocomputers

The idea of creating a biocomputer belongs to the American Professor L. Aldeman from the University of California (1994). The first model simulating the work of a "molecular machine" in a living cell was created in 1999 by Israeli Professor I. Shapiro from the Weizmann research Institute of natural Sciences. In 2001 I. Shapiro implemented a model in a real biocomputer consisting of DNA molecules, RNA and special enzymes. Enzyme molecules served as hardware, and DNA molecules – software. Specialists at Columbia University have created a DNA computer based on a DNA scheme with an average degree of integration and the highest speed. The computer is designed for scientific research in medicine and biology. American Agency DARPA has developed a project Bio-Comp to create powerful computing systems based on DNA. In addition, a powerful stimulator Bio– SPICE is created for visualization of biomolecular processes by means of machine graphics in order to control the processes of interaction between proteins and genes. Olympus Optical creates a commercial version of the composite DNA computer, which includes molecular and electronic parts, and is designed for genetic analysis. Experts predict in the near future DNA computers as nanofabrics drugs, i.e. in the future, DNA nanocomputers, being placed in a cell, will be able to monitor potential disease-causing changes and synthesize appropriate drugs to combat them. Similar, implantable in a cell computer, created by scientists at Harvard and Princeton universities. The computer is designed to control the activity of genes inside cells, to determine mutated genes, as well as cancer cells. In fact, these kinds of computers are tools for reading cellular signals and can translate complex cellular signatures, the activity of multiple genes, into readable information at the cell output. In addition, they can be programmed to mark diseased cells for which clinical treatment is necessary, or to have an independent therapeutic effect. The ability to direct treatment only to pathological cells without affecting healthy ones is the most important result of the creation of cellular or biomolecular computers. Currently, actively developed direction associated with the creation of biocomputers based on neuron-like elements that will make these computers self-programmable with the ability to make independent decisions.

Currently, specialists from the United States (University of Texas, Massachusetts Institute of Technology, Laboratory in Berkeley) and other industrialized countries are conducting research on the creation of information storage and processing technologies in biological systems, as well as on the creation of biocomputers: genetic (DNA / RNA) and cellular. A DNA or biomolecular computer is a combination of specially selected DNA strands that perform specific computational operations. The main advantages of DNA computers:

– the ability to create massive parallel circuits that are not available for traditional computers running on silicon chips. This ensures the execution of complex mathematical calculations in an extremely short time, measured in minutes. It will take months and years for a traditional computer to perform the same calculations;
– huge storage capacity. Thus, 453 g of DNA molecules have a capacity for data storage exceeding the total capacity of all modern computers, and 10 trillion DNA molecules occupy a volume of 1 cm3, which is enough to store the volume of information in 10 TB;
– use is not binary, but a ternary code, when the information is coded as triplets of nucleotides;
– high performance (~10^{14} operas/s) due to simultaneous reaction of trillions of DNA molecules;
– high storage density, trillions of times higher than today's optical drives;
– low power consumption.

However, there are a number of serious problems that arise in the development of biocomputers: the complexity of reading the results of computing operations, errors in calculations – the accuracy of 1% is clearly insufficient; over time, DNA disintegrates, and the results of calculations disappear.

Neurocomputers

Neurocomputers are trainable intelligent systems based on neural network modeling. The construction of Neurocomputers is based on the following works:

– work by W. McCulloch and W. Pitts , «A logical calculus of the ideas immanent in nervous activity» (1943), which described a model of formal neurons that was the beginning of research in this direction. Thus, in 1945 the Fermi-Clark model was proposed, which gives a formal picture of the process of conditioned-reflex activity, and in 1949 – the Hebb model, which reveals the process of neural networks training;
– F. Rosenblatt's fundamental work «Principles of Neurodynamics» (1956), which provides the theoretical justification and device of PERSEPTRON, the first layered model of the neural network, which could solve the problem of pattern recognition;
– theory of formal neural networks proposed by E. Cagnanelo (1975), as well as his generalized model of the functioning of neural networks in the form of neuro-equalization systems, describing the process of spreading activity over the network, and mnemoequations that reveal the learning process;
– analog model of neural network on D. Hopfield's operational amplifiers (1982) and his new approach to formalization of such models based on the physical and mathematical theory of spin glasses;
– the Boltzmann Machine model, which provides faster learning and eliminates a number of disadvantages of the deterministic prototype;
– neurobiological models of Palm (1983), reflecting the cellular processes of brain functioning;

– complex neural model Fukushima (1985), multilayer, with internal feedbacks, providing training without a teacher, obtaining, storing, using in solving problems of knowledge about the structure of complex images;
– the work of K. Mead "Analog VLSI and neurotransmitters" (1988), which marked the beginning of the theoretical and practical direction for the development and creation of analog neuro – VLSI – neuromicroelectronics;
– a new integrating science – Neuroinformatics (1988), which forms the basis of neural calculations and provides the basis for the creation of Neurocomputers – a new class of massively parallel computers that can solve problems without programming.

The technical base of neural computers neural network are the hardware and software in neuro-VLSI digital and analog types, nano board co – processing part of a conventional computer, specialized and universal neural computers, software for the simulation of neural networks, operating systems, neural computers.

Thus, the theoretical basis for the construction of neurocomputers is connectivist direction, which is based on the use of the idea of linking a large number of elements to build associative networks that allow you to effectively accumulate and use knowledge to solve problems of classification, approximation, pattern recognition, decision-making. This direction has a strong theoretical base, based on biological models of the nervous system, in particular, neural structures of the brain, the theory of formal neurons, dynamic models of neural networks, described by a variety of systems of neural levels, methods of structured representation of knowledge in associative networks with a hierarchical structure, methods of teaching associative networks. The achievement of significant practical results in the creation of neural network hardware and software and the solution of a number of problems with their help became possible thanks to the intensive development of VLSI technology and analog neuromicroelectronic.

Conclusion

Currently, the possibilities of "silicon" technologies are not yet fully exhausted and in the presence of large production capacities, well-established production, specialists, infrastructure, heated markets, this direction will long occupy a dominant position in the market.

The development of the nanometer range will require the creation of fundamentally new physical foundations and technologies for the production of the elemental base of supercomputers, which are seen in general terms now.

The creation of the "element base" of the quantum computer is intensively engaged in a number of research organizations of the leading countries of the world, which creates good conditions for the practical implementation of completely new types of calculations, in principle, impossible for classical computers.

Achievements of bioinformatics in combination with nanobiotechnology will lead in the near future to the creation of intelligent implantable nanosystems that provide control of the body at the cellular level.

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RESUME

S. S. Antsyferov, K. N. Fazilova, K. E. Rusanov
Physico-Technological Principles of Construction and Operation of High-Performance Information Systems

To date, the most effective technical tools of information processing is a computer, computer networks, as well as new interfaces, appearance of which is planned in the period up to 2020 – multi-sensory, multi-modular, multi-linguistic, virtual, creating the effect of telepresence, interfaces "human brain-machine", "brain-brain". Computer technology is one of the most perspective areas of innovation. An important component of these technologies are supercomputers – the world's most powerful computing systems used in fundamental research in various fields of science, including the modeling of artificial intelligence systems**.**

Methods of system analysis of forecasting.

Systematization of modern physico-technological principles of construction and operation of high-performance information systems was carried out.

Currently, the possibilities of "silicon" technologies are not yet fully exhausted and in the presence of large production capacities, well-established production, specialists, infrastructure, heated markets, this direction will long occupy a dominant position in the market.

The development of the nanometer range will require the creation of fundamentally new physical foundations and technologies for the production of the elemental base of supercomputers, which are seen in general terms now.

The creation of the "element base" of the quantum computer is intensively engaged in a number of research organizations of the leading countries of the world, which creates good conditions for the practical implementation of completely new types of calculations, in principle, impossible for classical computers.

Achievements of bioinformatics in combination with nanobiotechnology will lead in the near future to the creation of intelligent implantable nanosystems that provide control of the body at the cellular level.

РЕЗЮМЕ

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Физико-технологические принципы построения и функционирования высокопроизводительных информационных систем

До настоящего времени наиболее эффективным техническим средством обработки информации является компьютер, компьютерные сети, а также новые интерфейсы, появление которых планируется в период до 2020 г., – мультисенсорные, мультимодульные, мультилингвистические, виртуальные, создающие эффект телеприсутствия, интерфейсы «мозг человека – машина», «мозг – мозг». Компьютерные технологии представляют собой одну из самых перспективных сфер инновационной деятельности. Важной новой составляющей этих технологий стали суперкомпьютеры – самые мощные в мире вычислительные системы, используемые при проведении фундаментальных исследований в самых различных областях науки, в том числе при моделировании систем искусственного интеллекта.

Методы системного анализа прогнозирования. Проведена систематизация современных физико-технологических принципов построения и функционирования высокопроизводительных информационных систем.

В настоящее время возможности «кремниевых» технологий до конца еще не исчерпаны и при наличии больших производственных мощностей, отлаженного производства, специалистов, инфраструктуры, разогретых рынков сбыта это направление еще долго будет занимать на рынке доминирующие позиции.

Освоение нанометрового диапазона потребует создания принципиально новых физических основ и технологий производства элементной базы суперкомпьютеров, которые в общих чертах просматриваются уже сейчас.

Созданием «элементной базы» квантового компьютера интенсивно занимается целый ряд научно-исследовательских организаций ведущих стран мира, что создает хорошие предпосылки для практической реализации совершенно новых видов вычислений, в принципе невозможных для классических компьютеров.

Достижения биоинформатики в сочетании с нанобиотехнологией приведут в недалеком будущем к созданию интеллектуальных имплантируемых наносистем, обеспечивающих контроль состояния организма на клеточном уровне.

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