Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

Virtual Streaming Computing Systems with Architecture Based on the Neural Network Information Model

To cite this article: A V Myshev and O A Slavin 2021 *J. Phys.: Conf. Ser.* **1828** 012079

Virtual Streaming Computing Systems with Architecture Based on the Neural Network Information Model

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Abstract: The paper reveals the functional, structural and logical organization of new generation virtual streaming computing systems. Such systems allow realizing a new paradigm of computational intelligence and accessing new intelligent computing capabilities. The paradigm that allows realizing new advantages of virtual streaming computing systems is considered. These capabilities are implemented based on information models of a neural network and non-traditional principles for the development and implementation of various forms of computing. New forms of computing make it possible to control the mechanisms of parallelism, virtualization and intellectualization on the information dynamics of objects in the computing environment.

1. Introduction

Many streaming computing systems (CS) are based on the "pure data flow" model: statistical CS and dynamic CS [1]. The principles of functional organization computing processes in such aircraft are aimed at achieving a high degree of parallelism and ensuring a high utilization factor hardware. They are the main factors that determine the efficiency of computing systems, both in terms of number technical and algorithmic characteristics, and in general.

Multi–pipeline streaming and scalar computing systems for solving streaming problems functionally are systems with high computational efficiency in terms of technical characteristics and algorithmic support. Efficiency is achieved as a result of high degree parallelism of hardware interaction its elements and methodology for the synthesis of parallel circuits and algorithms of computational processes. The capabilities and efficiency of computational intelligence of such computing systems have not been considered. In this case, computational intelligence technologies make it possible to implement new forms of computing, virtual stream computations, simulation modeling, models of processing large data streams and to obtain more accurate and sustainable results. Currently, research on the development of information neural network models streaming computations in conditions of model and algorithmic closure, information exchange, constraints of the computing environment and information uncertainty are open.

The problem of expanding functional, structural and logical capabilities of computational intelligence is not only fundamental and relevant in the designated area but also requires solutions to new scientific and technical problems. These tasks can be defined as follows. First, the implementation of computational intelligence technologies in conditions of isolation,

restrictions, exchange and uncertainty. Secondly, the possibility of building super–complex intelligent virtual neural network streaming computing systems. Third, the possibility of implementing dynamically expandable functional, structural and logical organization of virtual streaming computing systems to increase information reliability of results calculations and data processing.

2. Neural Network Model and Virtual Architecture Flow Computing System

Figure 1 shows a neural network model of functional, structural and logical organization of virtual streaming computing systems. This model [2] is a mathematical, informational and logical prototype of an intelligent streaming computing system. Such systems have important computational and informational properties of mechanisms computational processes. These processes by models that take into account the mathematical, dynamic, informational and metrological aspects of calculations are described. Such models allow realizing a new computing paradigm and implementation of non–traditional forms of computing, taking into account the information dynamics of objects in the computing environment [2,3].

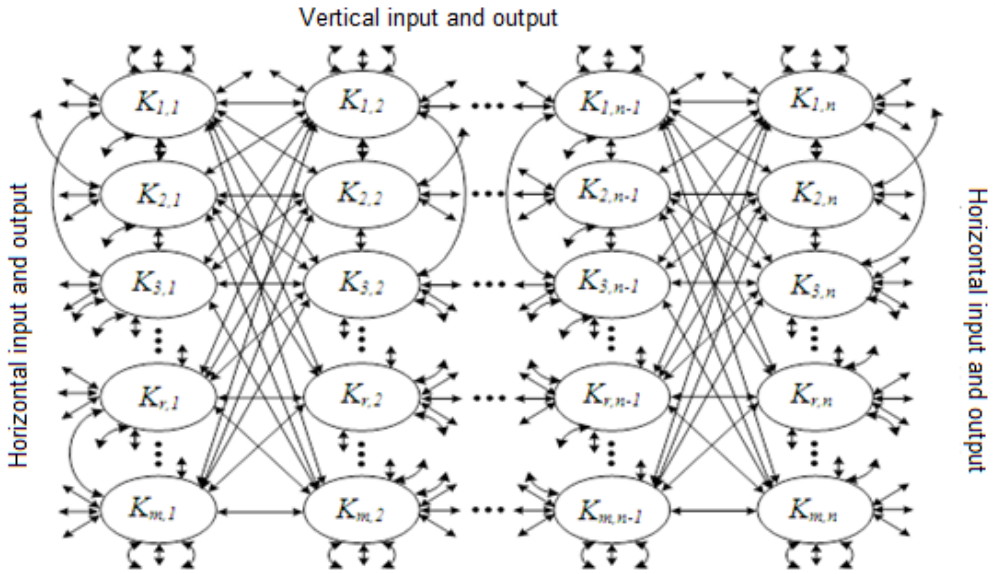

Figure 1. A neural network model of functional, structural and logical organization virtual streaming computing systems.

The neural network paradigm of the functional, structural and logical organization of virtual streaming computing systems has new computational advantages based on non–traditional principles of development and implementation of various forms of computing and streaming parallel computing technologies. Streaming computations in such systems are based on the synthesis of mechanisms for parallelism, virtualization, and intellectualization. The emulation of computational processes is implemented on basis of models information dynamics of the objects computing environment. The mathematical and logical model of the computing environment is based on the theory of chains interacting symbols [3]. The neural network information model of organization virtual streaming computing systems allows realizing a dynamic paradigm of computational intelligence and accessing new intelligent computing capabilities. The designated goals are achieved in the following way.

First, the functional organization and interaction of processor modules and memory modules of such systems are logically, functionally and informationally carried out according to the same principles as neurons in the network information model of the neural network [2]. The structural organization of the virtual streaming computing system is presented in form of

a multilayer modular system for streaming parallel data processing. The paper considers a three-layer model organization and implementation of a multi-modular streaming computing system. The first one is processing elements (PE); the second is a multilevel virtual random access memory of each processor layer module; the third is the total active virtual memory of the entire processor layer. The first layer is split into virtual processor modules. The second layer of shared active virtual memory is divided into virtual memory modules. The structural and logical organization of the first layer is described by the network model of information links and performs the following functions: 1) interface as between elements layers; 2) connections with the external environment; 3) initialization of computing system; 4) routing information in the system; 5) configuration of architecture virtual streaming computing system for the structure of information graph problem being solved; 6) restoration of results computational process in case of failure entire system, individual layers, modules or elements. The modules of the second layer perform functions of storing attributes of memory modules, commands, the local coordinate system of information binding and verifying results (intermediate and final) of computational processes in the computing environment. The modules of the third layer have the following purposes (functional and logical): 1) to store global information coordinate system of checking and verification and reflecting results of computing process on it; 2) perform buffer functions in tiling operations between layer modules, functions of virtual ports and information gateways with the outside world. The modules of the first layer (logically and functionally) are combined and configured into a virtual computational structure by geometry and topology of neuron connections in the information model of the neural network [2]. Each module of the first layer functions in the corresponding area of information space of coordinate system binding and verification of results. The modules of the first layer provide high reliability in the operation of the entire computing system and reliability results obtained. The basic and forming elements of modules first and second layers are virtual cells two types: active and passive virtual cells. Logical and arithmetic operations in modules of the first layer are implemented according to the following principles of computing. The first is the principle of interaction operands of a computing environment with the information virtual environment. The second is the principle of virtual perspective in the design operator. The third is the principle of interconnection results calculations: fractal and informational.

Secondly, the functional, structural and logical organization of the virtual streaming computing system is described on basis of the network information model of neural network. The network model of structural organization computing system describes it in form of global virtual information dynamic neural network with local interaction of elements. A formal neuron of the neural network is defined as a local virtual computing system (network). The logical and physical functions of the local area network are as follows. A local virtual computer network in the physical environment of real streaming aircraft is defined as a virtual computing server–domain. Server–domain defines the scope of informational definition in the virtual address space of its active memory – its domain. General numerical scale for computational process and scale division (numerical precision) – its range is determined in information boundaries of address space of memory domain. The functional and structural organization of active memory is represented by virtual cells of various types. These cells differ in terms of functionality, logical organization and content.

The local area network is a constituent component of the global computing system. The purpose and function of the local area network within the neural network model of the global virtual streaming computing system is as follows. First, the execution of a streamed parallel task is divided into a stream of parallel subtasks in a given range of possible values and a fixed quantum of physical time. Statistical synchronization of computational processes for execution of the streaming task is carried out within allocated real-time quantum. Local area networks are combined into a global virtual computing structure. This neural network structure allows supporting the computational process with a dynamically changing population of active neurons in the fixed and specific quantum of physical time [2]. Active neurons, as mathematical prototypes of local computing systems, can implement various

computational processes within a specific quantum of physical time. The interaction between them is parameterized by the problem algorithm and computing environment.

In the local segment active memory of the local computing system (only in read mode), the coordinate system of information binding and verification for results of calculations (final and intermediate) is stored. Such coordinate systems are designed to control the influence of various kinds of errors and information diffusion in computing technologies. The coordinate grid is a "geometric scene" that reflects the dynamics of information processes in the computing environment. Lattice nodes are a figurative and symbolic reflection of geometric and informational properties of dynamics of processes in the computing environment. The information prototype of the coordinate system is the memory segment of virtual passive cells of fixed length and with information unchanged in them. In the memory segment, the area for determining display results of computing process computing environment is set – their domain and the range values are the range. Virtual streaming computing systems with such functional, structural and logical organization of memory and computing resources are systems with a variable domain–ranges. If the results of the computational process go beyond the range of local computing systems, then there is an interaction with the neighboring one, in the information range of which they fall.

Computational processes in local systems are quantized in physical time. The duration of time slices can be arbitrary and is determined by the conditions of statistical synchronization and computational process. In each quantum of physical time, the number of active local computing systems is determined by the result of calculations in previous quantum and conditions of the problem.

The process of interaction symbol chains in passive and active virtual cells is defined as an information process with local interaction [3]. The logic and algorithms of operations between cells of different types are described in detail in the author's work [4,5].

The functional and structural organization of considered computing systems as a physical platform can have a streaming computing system (for example, transputer, etc.) or a multicore computing system (with a rigid or reconfigurable architecture) [4]. Such virtual streaming computing systems support three phases of virtualization – virtual space, image, and compute.

The practical consequences of using capabilities virtual streaming computing systems for solving streaming problems and processing big data can be summarized as follows. First, there are broad opportunities for the implementation of computational intelligence technologies and the implementation of new forms of computing. Secondly, the cognitive capabilities of intelligent computing systems for processing and analyzing information in conditions of isolation, constraints, exchange and uncertainty become available ready-made. The cognitive capabilities of designated systems include the following: 1) ability, similar to living information systems, to create new forms of intelligent streaming virtual parallel computing; 2) implementation of new forms reliability performance of computing systems new generation in the conditions of isolation, restrictions, exchange and uncertainty.

3. Multi-Layer Modular Scheme

The functional and structural organization of the virtual streaming computing system based on the information model of the neural network allows for practical implementation in form of a multilayer modular system. The topology and geometry multilayer modular computing system includes several layers (see Figure 2). First layer: n1 – processing elements (PE); second layer: n2 – active virtual memory for each PE or PE module; third layer: n3 – total active virtual memory available for all PEs. Such a multi-layer modular computing system can be implemented at the physical, logical and virtual levels. A multilayer scheme can include a large number of layers (but not less than three), depending on the complexity of the problem being solved, the requirements for the reliability of the result, the conditions for organizing the computing process, etc. Such a system contains elements (physical and virtual) according to the functional and logical purpose of the same type for each layer (1, 2, 3). The interaction between elements layers of a complex computing system is carried out at logical and physical levels. The interfaces of interaction between elements layers use the following inputs – outputs: 1st layer – i | o1; 2nd layer – i | o2; 3rd layer – i | o3. Elements of the first

layer perform the following functions: 1) interface between elements of layers and with the external environment; 2) initialization of computing system; 3) routing information in the system; 4) configuration topology of a computing system for structure information graph of the problem being solved; 5) restoration of results computational process in case of failure of the entire system, individual layers or elements. Layer n1 consists of m processing elements (PEs) with an arbitrary topology of connections and a unified logical pool of interaction between them. With this topology and virtual multilayer computing system pooling, the PE is a functional module of the layer. Each PE has a two-level random access memory (RAM). A plurality of RAM blocks for each PE form layer n2.

The n2 layer RAM module is only available to a specific PE or PE module. A variant of the logical division memory module of this level into fields can be described as follows.

1st field – PE attributes, for example, 1) PE logical number is an information attribute; this attribute identifies a number of divisions in quantum scale measurement of values calculated quantity; 2) sign and level of informational activity of PE – to include or not to include new PE, assessment of level their activity; 3) attributes of communication with a memory of lower levels.

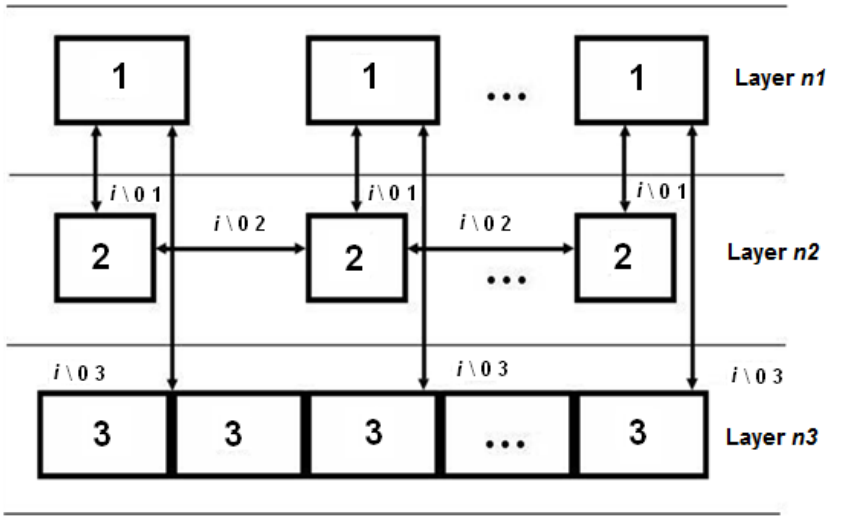

Figure 2. Multilayer modular scheme of a virtual streaming computing system.

Many blocks of random access memory for each processor element form a layer n2.

2nd field – a memory of command segments;

3rd field – active basic virtual memory, elements of which are passive virtual cells of arbitrary fixed length. The cell length is fixed during the computational process and information in them also does not change. The memory (inaccessible for writing) stores a local coordinate system of information binding and verification results (intermediate and final) computational processes in PE computing environment. A coordinate information system is a global information attribute. It defines areas, namely: 1) area of definition mapping states dynamic evolution of objects computational processes in information space of active memory – their domain; 2) area of their values – their range.

The second memory level of layer n2 and its organization (logical, virtual and informational) with the priority of access to fields of this level by different PE has the following features.

First, dynamically active virtual memory is formed at this level. The elements of this memory are cells of two types: 1) active cells, the dimension of which and information in the change; 2) active-passive cells; dimension cells are variable, the information in them does not change.

Secondly, this level of memory has fields available to specific PE and accessible to other PEs of the computing system.

The fields available to specific PE are subsets of virtual addresses for virtual cells of various types in real physical memory. The logical structure and organization of memory fields are dynamically variable. The mechanism for changing logical structure fields is as follows. In the address space of virtual cells various types for a limited area of real physical memory space, virtual cells are not tied to either data types or addressing systems. The content virtual cell is interpreted as a binary field (set). The addresses of virtual cells (logical structure address space) can change after each operation or their combination. These fields form virtual address space for working cells and storing intermediate results of particular PE.

The third layer n3 forms the shared active virtual memory space. The layer is logically divided into memory modules that are used for the following purposes. First, a logical structure of virtual memory is formed on a dedicated subset of modules. This memory structure stores a coordinate grid of information coordinate systems for checking and verifying the results of the computational process. The lattice nodes correspond to passive virtual cells. The results of calculations (intermediate and final) in successive time slices are stored in passive memory cells of the coordinate lattice. They form a logical raster structure of reflecting results in form of character strings for values of a discrete fuzzy random function. The logical structure of results at lattice nodes is an information display of the final topology image solution to a simulated problem or computational process by layers. Secondly, modules of layer n3 perform buffer functions in tiling operations between layer modules, functions of virtual ports and information gateways with the outside world.

4. Organization of Computing Process in the Computing Environment

The functional, structural and logical organization of virtual streaming computing systems based on the information model of neural network and a neuron is a new generation of universal computing systems with new capabilities. This section substantiates this statement and describes the logical scheme configuration of architecture complex system according to the geometry and topology of the neural network for the structure of the information graph problem being solved.

The main block of a considered computing system with neural network architecture is the formal neuron (see Figure 1). The physical prototype of neuron in layer n1 is the union of a certain number PEs in this layer. For layer n2, this is a union of corresponding memory modules layer 2. The number of PEs in the formal neuron is determined by the functional purpose and logical organization of the computing process according to the structure of the information graph problem being solved. Information input and output connections for various types of buses between modules of layers n1, n2, n3 within boundaries of information space neural network and the neuron are carried out through the inputs–outputs i | o1, i | o2, i | o3. PEs perform arithmetic and logical operations on variable and fixed-length character strings. Operation codes are stored in command segments of active virtual memory of module layer 2. Computational processes in a computing environment are implemented and proceed under conditions of model isolation, constraints, exchange and uncertainty. Models of algorithms and procedures computational technologies are constructed according to stochastic schemes Monte Carlo type. Algorithms of such computational technologies belong to a class of algorithms on fuzzy subsets. Calculation results are fuzzy stochastic values. The values of these quantities (symbolic chains of fixed length) are determined at lattice nodes of the information coordinate system. The physical prototype of the lattice is a set of passive virtual active virtual memory cells.

The logical scheme for constructing algorithms for iterative processes in a computing environment is described on basis of fuzzy algorithms operations and procedures. The efficiency and accuracy of such processes cannot be verified by direct substitution. The accuracy of informational representation initial data, operands operations and results obtained in the computing environment is set by the number of significant characters. The required accuracy of results operations between operands of different lengths in the computing environment is ensured by the implementation of technologies for interacting with the

information environment [3,5]. In the computing environment of complex computing systems, the difference between the following concepts is strictly defined and indicated: a calculated value and calculated value. The calculated quantity is a deterministic quantity, and the calculated quantity is blurred. An information image fuzzy value (a symbolic chain of a fixed length) is set at lattice nodes of the information coordinate system. Interactions between operands in a computing environment are completed with the operation of projecting the result previous operation into the lattice node of the information coordinate system. The initial conditions of operands iterative process are determined and set in an informational neighborhood of one or more lattice nodes of information coordinate system. The lattice of the information coordinate system is logically divided into layers of possible values (the domain of definition) of the calculation result. They are related to each other by time or by parametric variables. The time interval (physical or informational) of implementation computational process is multiple of physical time slices fixed duration. In the allocated quantum of physical time, only information objects of neighboring layers interact. The grid of the information coordinate system has a geometry similar to the neural network (see Figure 1). In each quantum of physical time in the computing environment, the number of active neurons is fixed and determined. After completion of computations in specific fixed time quantum, their number at the next step – quantum can change quantitatively and qualitatively – new neurons can be connected to calculations. If the results fall into the informational zone of inactive neurons, then such neuron is activated at the next step – quantum.

The coordinate grid of the information system for binding and verifying calculation results is logically and informationally divided into parts. Each neuron corresponds to an area of information space of the coordinate grid.

The computational process ends with the formation of blurred image computation result in form of a topological complex onset of active nodes information coordinate system. The calculated values are reflected in the set passive virtual cells of virtual active memory.

The last step in the execution of the procedure in the computing environment is to extract calculation results from the blurred image in the form deterministic image. This procedure is carried out by operating topological incarnation blurred image calculation results. The procedure takes into account the criteria for connectivity of calculation results: fractal connectivity and information connectivity. The adequacy and validity of the result are determined by the degree of closeness estimates result from values obtained according to the specified criteria.

The unique and stable nature of the information model neural network and its elements are analogous to topology and architecture of class considered stream computing systems. Computing systems of this class open up ample opportunities for the development of artificial and computational intelligence systems, a wide range of logical and software designers. They relate to the implementation of solutions in the field of artificial intelligence and pattern recognition. Such systems also open up opportunities for the implementation of new principles of computing.

An additional advantage of the virtual streaming computing system is a unique form of parallel information processing and organization of parallel computing processes. Neurons of neural networks (Figure 1) are logical prototypes of local dynamic computing networks. Within the quantum–step computations, such networks are autonomous, even for processes united by one algorithm. They make it possible to use a neural network with its geometry and topology of connections, as a template for the computing environment. In this environment, neurons in parallel can take part in solving various problems and implementing a wide range of logic circuits.

5. Conclusion

The functional, structural and logical organization of virtual streaming computing systems based on the information model of neural network and neuron is a paradigm for the implementation of reconfigurable virtual streaming computing systems. In such systems, the synergy of software engineering technologies, streaming computing under conditions multifactor uncertainty, parallelism, big data virtualization, artificial and computational

intelligence, reconfigurable streaming computing systems, streaming tasks, and many others are realized.

This paradigm is interdisciplinary. It introduces a new entity–objects into a methodology for developing new generation computing systems architectures. The virtual streaming computing systems discussed in this paper belong to this generation and are the subject of current and future research.

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