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RESEARCH OF COMPUTING EFFICIENCY IN MODULAR MULTIPROCESSOR SYSTEMS

Abstract. The article is devoted to the research of efficiency of a multiprocessor computing system in solving problems aimed at expanding the computing area. The basic regularities concerning the time of solving the problem are revealed, depending on the change in the multiprocessor system calculations area. The research is aimed at determining the deceleration factor associated with the increase of the computing area of a multiprocessor system when compared with the computer version with an unlimited computing area. The analytical ratios are derived for determining the calculations deceleration coefficient. A stage of simulation for calculations of the deceleration factor was carried out to determine the regularities of its change, depending on the application of a particular computing platform. The revealed tendencies of such a change point to the need to reconcile the components of the network interface and computing capabilities of the chosen computing platform. The derived analytical relations were aimed at determining the optimal number of nodes of a multiprocessor system which allow the minimum delay of calculations.
Keywords: multiprocessor system, efficiency, computing deceleration, computing area, network interface.

Introduction. Recently, a number of publications appeared, aimed at studying the efficiency of solving applied problems with the help of multiprocessor systems. Thus, publication [1] proves that efficiency estimation of a multiprocessor system in organizing the one-way and two-way modes of boundary data exchange is determined. It is shown here that, in a two-way operation mode of the network interface, under otherwise equal conditions, in the optimal version of the multiprocessor system operation, it is possible to reduce the number of nodes of multiprocessor system and improve the efficiency of calculations. The publication [2] estimates the effectiveness of multiprocessor system when organizing of half-duplex and duplex modes of the network interface. It has been proved here that the "duplex" mode essentially reduced computing time and, in addition, the accelerationed increased significantly. Publication [3] estimates efficiency of a multiprocessor system at organization of

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multichannel modes of a cluster network functioning are established. Such operating modes allow not only to improve the efficiency of parallelization, but also essentially reduce the time of calculations, as well as significantly accelerate them. The results were achieved by reducing the time boundary exchange between the computing nodes of the cluster system. The publication [4] showed the studies that were conducted to determine the load capacity of the cluster system communication lines. This allowed to set the optimal number of nodes of multiprocessor system for different modes of its operation. The publication [5] is devoted to the research of the features when using the InfiniBand network interface in a multiprocessor computing system in solving problems aimed at expanding the computing area. This research reveals the basic regularities regarding the time of solving the problem depending on the change of the computing area.

This research studies the problem of computations deceleration in multiprocessor computing systems, aimed at expanding the computing area.

The purpose of the research is to further develop the approach associated with definition of methodology for effectiveness evaluation of the multiprocessor modular computing system and the impact on this indicator of the calculations deceleration. At the same time, the main attention is paid to the impact peculiarities on this indicator of network interface of multiprocessor system.

At the same time it is necessary to solve the following problems:

1. To perform research aimed at determining the deceleration factor associated with an increase in the computing area in multiprocessor systems distributed over its nodes in comparison with a computer with an unlimited computing area. To output analytic ratios for deceleration calculations.

2. To run the simulation phase of the deceleration computation and set the patterns for its modification depending on the computing platforms in use.

3. To solve the problem of determining the optimal number of nodes in a multiprocessor system with minimal system deceleration.

We should note that the research of these problems is important and relevant. This is not only due to the fundamental limitation of the maximum possible performance of ordinary serial computers, but also to the almost constant existence of computational problems which solution requires additional capabilities of existing computer facilities.

The unresolved parts of the problem. The working methods of analyzing the multiprocessor systems efficiency do not allow to determine the optimal number of its nodes for solving a certain class of problems taking into account the calculations deceleration. At the same time, to solution of such problems is short of proper research development on the analysis of the network interface impact on the efficiency of modular multiprocessor computer systems. In addition, to estimate the efficiency of a computing multiprocessor system, the basic analytical relationships are usually not provided through the parameters of the system being studied.

The research results. The presented researches tend to determine the deceleration factor (K) associated with the increase in computing area, distributed over its nodes of multiprocessor system, compared with the computer version with an unlimited computing area. It is obvious that such a deceleration value will be determined by the following ratio:

$$K = \frac{T_C^N}{T_C^1}. \quad (1)$$

where T_c^N is the computing time of a single iteration when applying the N computing nodes, sec; and T_c^1 is the computing time of a single iteration for a single-processor computing system. The ratio (1) shows that such a coefficient is determined taking into account the increase of the computing area, distributed over the nodes of the multiprocessor system. Then, in a multiprocessor application, the total time of a single iteration will be determined on the basis of the following relationship:

$$T_{it} = T_c^N + T_{ex}. \quad (2)$$

Under these conditions, T_{ex} is the time of boundary data interchange between the nodes of a cluster, sec. We should note that if the iteration computing time depends only on the processor power, the time of the boundary data interchange is determined by the size of a difference grid, the number of nodes of the cluster system and the bandwidth of the computing network. Consequently, the value T_{ex} can be determined as follows:

$$T_{ex} = \frac{m \cdot N \cdot \sqrt{\frac{S}{\pi}}}{k \cdot d \cdot V_p}. \quad (3)$$

The *m* value can be equal to the one for unilateral mode of the boundary data interchange or two for two-way mode, V_p is the throughput of the network interface port (Gigabits per second (Gbps)), *N* is the number of nodes of the multiprocessor system, *S* is the total computing area of the multiprocessor system, *k* is the number of channels of communication computer networks working simultaneously (number

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of computing networks), d - half-duplex (d = 1) or duplex (d = 2) mode of the computing system cluster's network.

Taking into account the relation (2), we obtain:

$$K = \frac{T_c^N + T_{ex}}{T_c^1(S)} \quad . \tag{4}$$

Taking into account the ratio (3.4), the deceleration factor (K) value can be given in an analytic-friendly form:

$$K = \frac{1}{N}\left(1 + \frac{T_{ex}}{T_c^N}\right). \tag{5}$$

For the analyzing convenience of obtained results, the expression (5) is represented as follows:

$$K = \frac{1}{N}(1 + K_1). \tag{6}$$

In the ratio (6), K_1 is defined as:

$$K_1 = \frac{T_{ex}}{T_c^N}. \tag{7}$$

Such a coefficient can be interpreted as the factor of active calculations deceleration. This is due to the fact that this value, in the main, affects the deceleration rate as a whole. Finally, based on the formulas (5 – 7) allow to determine the number of nodes in the multiprocessor system (N_{id}), which corresponds to the minimum calculations deceleration. So, we obtain:

$$N_{id} = \sqrt[3]{\left(\frac{k \cdot d \cdot V_p \cdot \sqrt{\pi \cdot R}}{m \cdot V_c}\right)^2} \quad . \tag{8}$$

In the ratio (8) R represents the available RAM of the node of the multiprocessor system R (Gbps). In accordance with the above ratios, computing experiments were carried out for a computer platform equipped with an Intel E8400 3 GHz processor. Here, for the initials there were adopted corresponding characteristics of the class of problems that are solved by the cluster system. These parameters are given in table .

Table 1

The data for calculating system performance using a computer platform equipped with an Intel E8400 3 GHz processor

V_p	8 Gbps
T_C^1	100 c
V_c	$14 . 10^{9}$ bps
R	24 Gbps
m	2
d	2
k	2

The simulation results are presented as graphical dependencies (Figure 1).

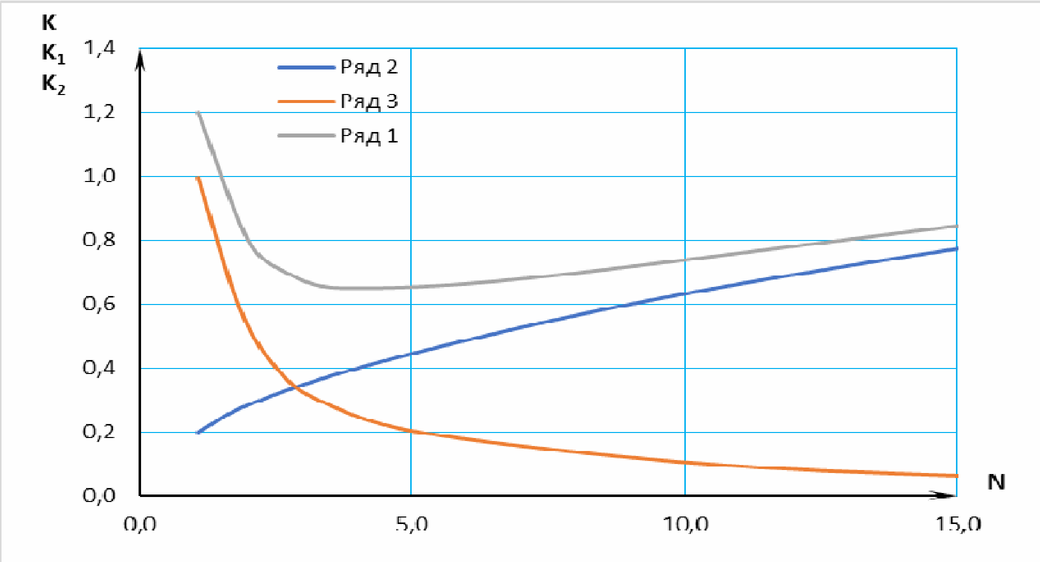

Figure 1 – Dependence curves of the deceleration rate, depending on the number of nodes of the multiprocessor system

Figure 1 line 1 shows a general tendency to change the calculations deceleration rate. Line 2 shows the effect of the time boundary data interchange by deceleration factor value. At the same time, line 3 shows the effect of the number of nodes on the multiprocessor system by the deceleration factor value. Against the background of the marked dependencies, we can note the significant effect of the time boundary data interchange by the deceleration factor value. This circumstance emphasizes the need to implement the procedure for reconciling the network interface and computing capabilities of the selected computer platform.

In addition, it becomes apparent that, under otherwise equal conditions, there is a problem of optimal choice of the number of nodes of a multiprocessor system in order to minimize the deceleration factor. On the basis of the relation (8), we get in

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this case N_{id} = 3, while the smallest amount of calculations deceleration corresponds to K = 0.65. Under these conditions, the question arises: at what expense and how can we reduce the amount of decelerations in the multiprocessor computing system? The highlight of the peculiarities of such work mode of the multiprocessor system is devoted to authors' further research.

Conclusions. The researches have been conducted to determine the deceleration factor associated with an increase in the computing area of a multiprocessor system, distributed over its nodes, compared with a computer version with an unlimited computing area. The analytical ratios for the computation deceleration coefficient are derived. The decisive role of time boundary data interchange by the deceleration factor value is shown.

The stage of simulation of the calculations deceleration value and the regularities of its change are determined, depending on the application of various computing platforms. The revealed tendencies of such a change point to the need to reconcile the components of the network interface and computing capabilities of the chosen computing platform.

The analytical relations are derived that tend to determine the optimal number of nodes of a multiprocessor that allow minimum calculations delay.

In the further researches, the authors intend to highlight the features of reconciling the components of the network interface and computing capabilities of selected computer platforms in order to minimize the computing deceleration in multiprocessor systems.

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Дослідження ефективності обчислень в модульних багатопроцесорних системах

Статтю присвячено дослідженню ефективності багатопроцесорної обчислювальної системи при розв'язуванні задач, спрямованих на розширення області обчислень. Мета дослідження полягає в подальшому розвитку підходу, пов'язаного з визначенням методики оцінювання ефективності багатопроцесорної модульної обчислювальної системи і впливу на цей показник уповільнення обчислень. При цьому основна увага приділяється особливостям впливу на даний показник мережевого інтерфейсу багатопроцесорної системи. Діючи методи аналізу ефективності багатопроцесорних систем не дозволяють визначити оптимальне число її вузлів для розв'язування певного класу задач з урахуванням показників уповільнення обчислень. У той же час, для розв'язування заданого класу задач, не набули належного розвитку дослідження, присвячені аналізу впливу мережевого інтерфейсу на ефективність модульних багатопроцесорних обчислювальних систем. Крім того, для оцінювання ефективності обчислювальної багатопроцесорної системи зазвичай не подаються основні аналітичні співвідношення через параметри досліджуваної системи.

Виявлено основні закономірності щодо часу розв'язування задачі в залежності від зміни області обчислень багатопроцесорної системи. Проведені дослідження спрямовано на визначення коефіцієнта уповільнення обчислень, пов'язаного зі збільшенням області обчислень багатопроцесорної системи в порівнянні з варіантом комп'ютера з необмеженою областю обчислень. Виведені аналітичні співвідношення для визначення коефіцієнта уповільнення обчислень. проведено етап моделювання коефіцієнта уповільнення обчислень з метою встановлено закономірності його зміни в залежності від застосування певної обчислювальної платформи. Виявлені тенденції зміни такого коефіцієнта вказують на необхідність узгодження компонентів мережевого інтерфейсу й обчислювальних можливостей обраної обчислювальної платформи. Виведено аналітичні співвідношення, які спрямовано на визначення оптимального числа вузлів багатопроцесорної системи у відповідності з якими досягається мінімальне уповільнення розрахунків.

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