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Cubic Basic Splines and Parallel Algorithms

H.N. Zaynidinov[1], O.U. Mallayev[2], I. Yusupov[3],
[1]Tashkent university of Information technologies named after Muhammad al-Khwarizmi, Uzbekistan,
tet2001@rambler.ru
[2]Tashkent university of Information technologies named after Muhammad al-Khwarizmi, Uzbekistan,
info-oybek@rambler.ru
[3]Tashkent university of Information technologies named after Muhammad al-Khwarizmi, Uzbekistan,
ibrohimbek.211_10@mail.ru

ABSTRACT

The relevance of using parallel computing systems is reflected, the main approaches to parallelizing processes and data processing methods are reflected, the principles of parallel programming technologies are described, the main parameters of parallel algorithms are studied using cubic splines calculation example, a comparative analysis of the effectiveness of using parallelism technologies is given.

Key words: Parallel computing, parallelism, data parallelization, task parallelization, data processing, OpenMP, MPI.

1. INTRODUCTION

Computing equipment throughout the entire period of existence was created to facilitate and accelerate mathematical calculations. Today, when engineering, medical, biological, physical and chemical sciences, electronic commerce are rapidly developing, more and more demands are placed on computer technologies, as the technology has to perform complex functions, process more and more operations, and more and more tasks appear, for the solution of which the capabilities of existing computer technology is not enough.

The development of scientific and technological progress, due to practical need at the present stage, has expanded the list of applied problems that require high-power computers capable of performing a huge number of computational operations per unit of time, which reduces the calculation time [3]–[5].

The actual way to speed up the computation process today is to use computer technology that implements parallel data processing tools. Parallel computing not only reduces the calculation time, but also provides the ability to solve complex and time-consuming tasks.

The scope of parallel computing systems (VS) is currently so wide that their importance is acquiring the strategic status of the development of computer technology. Among them, we can distinguish strategic and scientific research, industry, management, etc. [6]–[9].

These areas are constantly evolving, which requires an increase in the volume of settlements from year to year. In this case, the use of high-performance technology with parallel data processing is the most effective means of calculation, and each specialist in this field is forced to study parallel programming [12].

Computing technique is “a combination of technical and mathematical tools, methods and techniques used for mechanization and automation of computing and information processing” [1].

The performance of computing systems is characterized by the concept of power, that is, the number of operations per unit of time. The greater the power, the faster the calculations. To increase power, it is necessary to use several computing devices that perform several operations in parallel. In this case, the algorithm for solving the problem is divided into several sub-tasks that could be performed separately on these computing devices. Therefore, a parallel computing process is the simultaneous execution of several data processing operations using several functional devices.

The main programming patterns of a parallel process contain two basic approaches to parallelization: parallelization over data (data parallel) and parallelization over tasks (message passing). Depending on how the data is processed in the computing device, 4 architecture classes are distinguished: SISD, SIMD, MISD and MIMD [3], [15].

The main technologies of parallel programming are divided into two types: for systems with shared memory and for systems with shared memory.

In systems with distributed memory, each computing node is independent of the other. They are characterized by a certain mechanism of interposes communication, such as transmission over a network of messages. For these purposes, the Message Passing Interface - MPI standard was developed. This technology works only with processes, 2 mechanisms are used for interaction between them: pairwise interaction between 2 processes and collective interaction between all processes of the communicator [2], [14].

In systems with shared memory, it is more efficient to use not a multiprocessor program, but a multithreaded one. For these purposes, the generally accepted world standard is the technology OpenMP (Open Multi-Processing). Programming consists of 3 parts: the use of environment variables, the use of OpenMP functions and the OpenMP directive. This technology uses “forked” parallelism [4], [6].

2. PARALLELING PROCESSES FOR CALCULATING THE PARAMETERS OF CUBIC BASIC SPLINES

Designing parallel programs is a rather complicated process in the scientific and technical field. It requires the following phased actions, such as dividing common tasks into subtasks, identifying information dependencies among subtasks, scaling subtasks, and distributing them to computing elements.

The main efficiency parameters of parallel computing systems are: runtime, acceleration, and scalability (efficiency). The maximum acceleration (S) of the parallel algorithm is determined by formula 1, and the efficiency of the parallel algorithm (E) is determined by formula 2 [11], [13]:

$$S=\frac{T_1}{T_p}=\frac{T_1}{\alpha T_1+\frac{(1-\alpha)T_1}{p}}\le\frac{1}{\alpha}, \qquad (1)$$

$$E=\frac{S}{p} \qquad (2)$$

where T_1 is the execution time of the sequential algorithm; T_p is the execution time of the parallel part of the algorithm; α is the proportion of sequential operations in the algorithm; p is the number of identical processors.

We will analyze the effectiveness of using one or another parallel programming technology using the example of calculating the minimum polynomial splines or spline functions. The choice of a cubic spline for studying the efficiency of parallel computing is based on its wide application [7].

A spline function is a piecewise polynomial function whose parameters are located on a certain segment, which is divided into a finite number of i-th pieces. This function with all derivatives on the whole segment is continuous, and on each piece it is an m-th polynomial [10]. If the degree of the polynomial m is 1 or 2, then the polynomial spline is minimal.

Any spline Sm (x) of degree m of defect 1 that interpolates a given function f (x) can be uniquely represented by B-splines in the form of a sum [8], [10]:

$$f(x)\cong S_m(x)=\sum_{i=-1}^{m-1} b_i\cdot B_i(x), \quad a\le x\le b\,, \qquad (3)$$

where b_i – are the coefficients, $B_i(x)$ - is the basic spline

According to formula (3), the value of the interpolated function at an arbitrary point in a given interval is determined by the values of only m-1 terms - pair products of basis functions by constant coefficients. For example, cubic B-splines require four basis terms. The value of the function is calculated by the formula:

$$\begin{aligned} f(x)\cong S_3(x)=b_{-1}B_{-1}(x)+\\ +b_0B_0(x)+b_1B_1(x)+b_2B_2(x)\end{aligned} \quad \text{for } x\in[0,1] \qquad (4)$$

The remaining basic splines on this sub interval are equal to zero and, therefore, do not participate in the formation of the sum.

If you use one main base spline and use the variable j to set the addresses of different sections of the main spline, then equation (4) takes the form:

$$\begin{aligned} &S_3[i]=(b[i-1]\,B[j+30])+b[i]\,B[j+20]\\ &+b[i+1]\,B[j+10])+b[i+2]\,B[j]) \end{aligned}$$

The problem statement is such that it is required to calculate cubic spline of degree m = 3 using various parallel programming technologies and analyze the results of calculations by the main efficiency parameters by comparison. To implement the parallel algorithm for computing the cubic spline, we chose the integrated development environment MS Visual Studio 2012 and the C ++ programming language, and the TUIT training cluster, including 4 physical cores Intel (R) Core (TM) i7, was used as the technological platform for conducting computational experiments -7700 CPU 3.60 GHz (8 threads).

Table 1. Performance parameters of OpenMP and MPI.

Number of calculations	Number of OpenMP Threads						
	1	4			8		
	T_1, мс	T_4, мс	S	E	T_8, мс	S	E
80000	2,00	1	2	1.00	0.72	2.78	0.69
800000	30,00	14.6	2.05	1.03	4.6	6.52	1.63
8000000	220,00	89.2	2.47	1.23	33	6.67	1.67
80000000	1710,00	526.8	3.25	1.62	239.1	7.15	1.79
800000000	16800,00	4845.5	3.47	1.73	2200	7.64	1.91
Number of calculations	**Number of MPI Processes**						
	1	4			8		
	T_1, мс	T_4, мс	S	E	T_8, мс	S	E

80000	2,00	1.2	1.667	0.83	1	2.00	0.50
800000	30,00	15.7	1.91	0.96	5.6	5.36	1.34
8000000	220,00	90.8	2.42	1.21	36.2	6.08	1.52
80000000	1710,00	546.6	3.13	1.56	279.5	6.12	1.53
800000000	16800,00	4995.5	3.36	1.68	2378	7.06	1.77

In the process of computing, parallelism based on data was applied to the parallel algorithm, that is, each process calculated a certain part of the spline function.

3. COMPARATIVE ANALYSIS OF ALGORITHM EFFICIENCY

To analyze the effectiveness of parallel OpenMP and MPI algorithms, their main parameters were determined with a different number of calculations performed for 4 and 8 threads (Table 1).

From table 1 it can be seen that with an increase in flows from 4 to 8: the execution time of parallel algorithms was reduced by almost 2 times, but in OpenMP threads ran faster than processes in MPI (Figure 1);

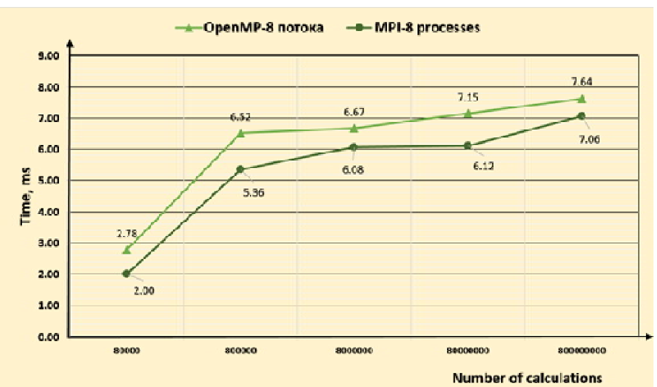

Figure 1: The execution time of processes (threads)

the acceleration of parallel OpenMP and MPI algorithms increased, and the first accelerated faster than the second (Figure 2);

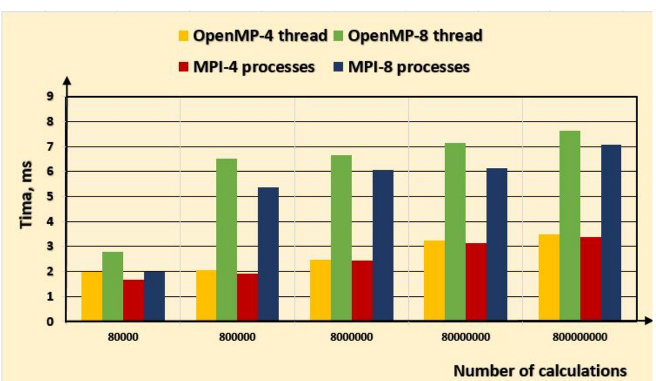

Figure 2: Acceleration dynamics of parallel algorithms

The efficiency of parallel algorithms has decreased, but the efficiency of OpenMP is much higher than that of MPI. (Figure 3).

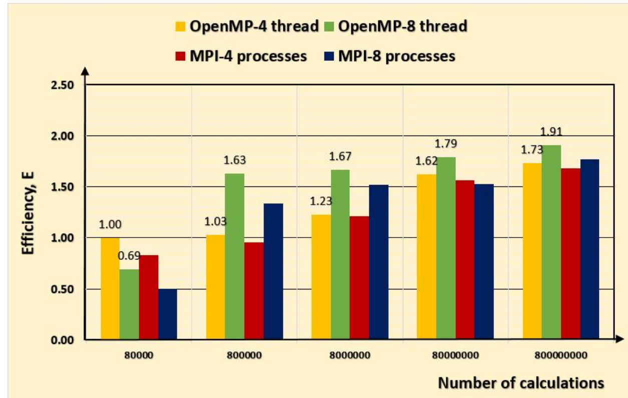

Figure 3: Analysis of the effectiveness of parallel algorithms

4. CONCLUSION

So, the use of parallel computing systems today is relevant. The development of various fields of science and technology expands the range of applied tasks more laborious than the previous ones, for the solution of which it is necessary to use powerful computers with the ability to perform parallel computing. Determining the main parameters of parallel computing systems allows you to determine the degree of its effectiveness. The calculation of the cubic spline using various parallel programming technologies has shown that OpenMP technology is the most effective. It is the most relevant in modern times, but it requires significant costs.

REFERENCES

1. A.R. Aydinya. ***Apparatnyye sredstva vychislitel'noy tekhniki***, Direct-media, 2016, PP. 125-145.
2. A.C. Antonov. ***Parallelnoye programmirovaniye s ispolzovaniyem tekhnologii MPI***, textbook, MGU, 2004. p. 71.
3. V.A. Billing. ***Parallel'nyye vychisleniya i mnogopotochnoye programmirovaniye***, Textbook, NOU TUIT, volume 2, 2016, p. 311.
4. I.G. Burova and Yu.K. Demyanovich. ***Minimal'nyye splayny i ikh prilozheniya***, Textbook, SPbGU, 2010, p. 364.
5. V.P. Gergel. ***Vysokoproizvoditel'nyye vychisleniya dlya mnogoyadernykh mnogoprotsessornykh system***, Textbook, NNGU, 2010, p. 364.
6. O.U. Mallaev **Algorithm and software for speeding up computer memory using OpenMP technology**, Descendants of Mohammed al-Khwarizmi TUIT, pp. 71–75.
7. H. Zayniddinov, S. Madhusudan and S. Dhananjay. **Polynomial Splines for Digital Signal and Systems**,

Monograph, LAMBERT Academic Press, Germany, 2016, p. 208.

8. H.N. Zaynidinov, G.O. Tojiboev and O.U. Mallaev, **Parallel algorithms for processing seismic signals on multicore processors**, Automation and software engineering, 2018, volume 1, pp. 89–95.
9. H.N. Zaynidinov and O.U. Mallayev. **Paralleling of calculations and vectorization of processes in digital treatment of seismic signals by cubic spline**, IOP Conf. Series: Materials Science and Engineering 537, 2019, doi:10.1088/1757-899X/537/3/032002, 68-69.
10. S. Dhananjay, S. Madhusudan and H. Zaynidinov. **Parabolic Splines based One-Dimensional Polynomial**. Applied Sciences and Technology, 2019, volume 1, pp. 1–10.
11. H.N. Zaynidinov and O.U. Mallayev. **Vectorization of parallel processing of seismic signals using technology of Parallel Studio,** Descendants of Mohammed al-Khwarizmi TUIT, 2018, volume 2, pp. 14–25.
12. H.N. Zaynidinov and O.U. Mallayev **Definition of synchronization processes during parallel signal processing in multicore processors**, 2019 International Conference on Information Science and Communications Technologies (ICISCT), 2019, 4-6 Nov, Publisher: IEEE, DOI: 10.1109/ICISCT47635.2019.9012006
13. S.F. Sadikan, A.A. Ramli and U.N. **Wisesty. An Initial Framework of Fuzzy Neural Network Approach for Online Learner Verification Process,** International Journal of Advanced Trends in Computer Science and Engineering, Volume 8, No.1.3, 2019. https://doi.org/10.30534/ijatcse/2019/3781.32019
14. M. A. Arasi and S. Babu, **Survey of Machine Learning Techniques in Medical Imaging**, International Journal of Advanced Trends in Computer Science and Engineering, vol. 8, no. 5, pp. 2107-2116, 2019. https://doi.org/10.30534/ijatcse/2019/39852019
15. S. K. Trisal and A. Kaul, **Dynamic Behavior Extraction from Social Interactions Using Machine Learning and Study of Over Fitting Problem**, International Journal of Advanced Trends in Computer Science and Engineering, vol. 8, no. 5, pp. 2205-2214, 2019. https://doi.org/10.30534/ijatcse/2019/54852019