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EFFICIENCY OF PARALLEL PROGRAMMING IN THE OPEN MP STANDARD

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Abstract. The purpose of the study is to identify the features of performing computing in a parallel computing environment. In accordance with the goal, the task was set: to identify the features of performing computing in the OpenMP environment (a standard for parallel computing); to study the effectiveness of actions performed in OpenMP; and to experimentally describe the practical implementation of didactic principles. The article presents, from the author's point of view, a brief description of the methods of obtaining knowledge and achieving success based on parallel programming and parallel data processing using computer tools. Solving simple problems of the numerical method by parallel computing can include many methods and techniques. The fact that various libraries and structures can be used in the OpenMP standardization environment to solve specific tasks is demonstrated using the experiment tasks [1]. Thus, it is argued that the rapid development of the modern information technology industry is inextricably linked with the training of experienced, modern specialists in the field of high-performance computing. As a result of the study, it was found that parallel computing of simple tasks for any users gives them a significant opportunity to perform efficient computing.

Keywords: *parallel computing, digital resources, OpenMP, digital methods, information and communication technology, simple computing.*

Introduction

Currently, the technologies of computer architecture and industry have become much more widely used. This indicates an increase in demand for solving applied tasks. The OpenMP standard provides the usual library and models for the efficiency of parallel programming, that is, it provides a parallelization system, a processing mechanism and equipment that can be used. The OpenMP standard, specifies an efficiency mechanism for parallel calculations between processing processes. This is done by solving calculations using multiple processes, using Biblioteca and models that perform kindling. The efficiency of OpenMP depends on the condition of the parallel system, the processing mechanism, and the use of equipment. It transforms the system into a parallelization model, using processing mechanisms that produce managers, and support ready-made processing. Assistants of the OpenMP standard, allowing the use of a parallel system on joint machines. They provide assistance in improving processing, operations, data, and other (Kopyl'cov et al., 2014).[2,3]

Parallel computing is a computing architecture in which multiple processors work together to perform or transform a task at the same time. Many supercomputers use the principle of parallel computing (Serik & Erlanova, 2020).

Parallel computing in education

The capabilities of computer cores in order to reduce the calculation time of problems of numerical methods that cannot be solved by analytical methods, problems of numerical methods that take a long time to solve or require reducing the error. Digital methods are intensively taught in universities of the Republic of Kazakhstan in educational programs related to mathematics and information technologies. L. N. Gumilyov Eurasian National University, Al-Farabi Kazakh National University, International University of Information Technologies, K. I. Satpayev Kazakh National Research Technical University. On parallel computing, the works of the following authors are published: Akzhalov A. Zh. "parallel computing", E. Duissenbiev" parallel computing high-performance technologies " Serik M., Bakiyev M. N.,

Zulpykhar Zh. E., Shyndaliev N. T. "parallel computing in Matlab", Karelkhan N. "cluster of parallel computing" (Kropachev et al., 2020).[4]

Subsequently, high-performance computing developed rapidly, became more and more popular, and became an indispensable tool in efficient computing in all industries. It is known that all important scientific and technical calculations are implemented using high-performance calculations. In addition, foreign scientists who studied parallel calculations: Aktulga H. M., Fogarty J. C., Pandit S. A., Grama A. Y., Pekurovsky Dmitry, Yokota Rio, Barba L. A., Knepley Matthew G., Gao X., Owen L. D. Guzik S. M. J. As evidence, we can cite large-scale calculations carried out on the Russian supercomputer "Lomonosov" to develop a cure for coronavirus infection. These calculations are expected to last several days, and the experimental result will be ready in a few months.

Establishing and justifying the relevance of the problem. Materials and methods of research the process of integrating children with special educational needs into a full-fledged life on an equal basis with normal children is closely linked to the development of inclusive education in the Republic of Kazakhstan, which involves meeting educational needs by providing full-fledged activities to ensure equality of rights, creating equal opportunities for quality education. Implementation of the values and principles of inclusive education in the professional training of students requires experimental testing, which should be organized in accordance with the methodological requirements and conditions of research work (Antyukhov, 2010).

Subsequently, high-performance computing is developing rapidly, the need for it is increasing, and the entire industry is becoming profitable. It has become an indispensable tool in calculations. All important scientific and technical calculations are known that it is implemented using high-performance computing. As one of the proofs of "Lomonosov" for Russia to develop a cure for coronavirus infection, it would not be superfluous to cite large-scale calculations carried out on a supercomputer. He claims that the calculations last several days, and the experimental result is ready in a few months (Serik & Erlanova, 2020).

In accordance with the purpose of the article, the following tasks were defined: adaptation of the components of the methodological system for teaching students how to solve parallel computing in the conditions of open – source computing; determination of the effectiveness of simple calculations using experimental tests, i.e. theoretical and empirical methods were used in scientific and pedagogical (Sycheva & Arzumanova, 2019).

Parallel computing plays an important role in education, improving the learning process and providing students with practical skills in solving computational problems. Here are some ways to use parallel computing in education: High-Performance Computing (HPC) Education: Parallel computing is taught as a special subject or module in computer science and engineering programs. Students will learn about models, algorithms and methods of parallel programming used in high-performance computing systems. They gain hands-on experience working with parallel programming languages and tools.[5]

OpenMP is a common standard used in parallel programming in the world. For the use of orepmr in Kazakhstan, it is possible through parallel programming projects and increasing the productivity of information technology workers. The state of the parallelization system in Kazakhstan, the OpenMP standard, allows you to create sufficient, high-quality, effective projects.

An important aspect is the fact that the effectiveness of parallel programming in the OpenMP standard is taken into account when developing parallel applications. OpenMP is a widely used programming model for parallel programming with shared memory that allows developers to write code that can be executed simultaneously in multiple threads. Efficiency in parallel programming refers to how well parallel code uses available computing resources, such as processors or cores, to achieve acceleration and performance gains.

OpenMP (Open Multi-Processing) is a set of compiler directives, library procedures and environment variables that allow developers to create parallel programs for multiprocessor systems. Several key factors that can affect the efficiency of parallel programming in OpenMP are:

1. Load Balancing. Effective load balancing is very important to achieve high efficiency of parallel programs. It involves a uniform distribution of computational load on available threads or processors to ensure optimal use of all resources. Load imbalance can lead to inactivity of some flows and overload of others, which leads to a decrease in efficiency.

2. Application of standard libraries (usually performing parallel calculations using the OpenMP standard).

OpenMP contains several hardware components that support multiple structures and may have other features (Kryuchin and Khabirova, 2014).

The OpenMP standard covers several aspects of computing projects:

Parallel execution of loops: OpenMP provides directives, such as *# pragma omp parallel for*, that allow parallelizing the execution of loops across multiple threads. This is particularly useful for operations that can be performed independently of each other, such as processing array elements or iterating over a large range of values.

The C++ Standard Library provides several data containers and algorithms that can be effectively used for parallel computations with OpenMP. For example, the *std:vector* container can be parallelized using the *#pragma omp parallel for* directive, allowing loops to be executed across multiple threads. STL algorithms, such as std::transform, can also be parallelized with OpenMP.

Let's consider solving the simplest problems of the numerical method using parallel calculations in C++. This is an extensive topic that includes many techniques and techniques. First of all, you can get acquainted with the general principles of parallel programming in C++. You can use various libraries and frameworks, such as OpenMP, to solve specific problems.

MobaXterm is a Unix terminal with many interesting features. You can run it in Windows by double-tapping the executable file – it doesn't require installation. It is one of the most powerful programs for performing administrative tasks on computers and servers running on Windows operating systems. MobaXterm offers advanced Unix-like command line features for Windows.[6]

Solving simple numerical problems using parallel computing-this can include many methods and techniques. You can use various libraries and frameworks, such as OpenMP, to solve specific problems.

A simple example of a program that calculates the value of the function sin (x) in the range from 0 to pi using the rectangle method:

```
#include <iostream>
#include <cmath>
#include <chrono>

double f(double x) {
    return sin(x);
}

double integrate(double a, double b, int n) {
    double h = (b - a) / n;
```

```
    double sum = 0.0;
    for (int i = 0; i < n; i++) {
        sum += f(a + (i + 0.5) * h) * h;
    }
    return sum;
}

int main() {
    double a = 0.0;
    double b = M_PI;
    int n = 100000000;

    auto start_time_seq = std::chrono::high_resolution_clock::now();
    double sum_seq = integrate(a, b, n);
    auto end_time_seq = std::chrono::high_resolution_clock::now();

    auto start_time_par = std::chrono::high_resolution_clock::now();
#pragma omp parallel
    {
#pragma omp single
        {
            double sum_par = integrate(a, b, n);
            std::cout << "Parallel result: " << sum_par << std::endl;
        }
    }
    auto end_time_par = std::chrono::high_resolution_clock::now();

    std::cout << "Sequential time: " << std::chrono::duration_cast<std::chrono::milliseconds>(end_time_seq - start_time_seq).count() << " ms" << std::endl;
    std::cout << "Parallel time: " << std::chrono::duration_cast<std::chrono::milliseconds>(end_time_par - start_time_par).count() << " ms" << std::endl;
    std::cout << "Sequential result: " << sum_seq << std::endl;

    return 0;
}
```

We compare the execution time of the sequential and parallel versions of the program and display the results. To run this program, you need to copy the code to a text file with the extension .CPR and save it on your computer. Then we compile the code using the OpenMP C++ compiler. From the console, we can see the execution time of the serial and parallel versions of the program, as well as the results of calculations.

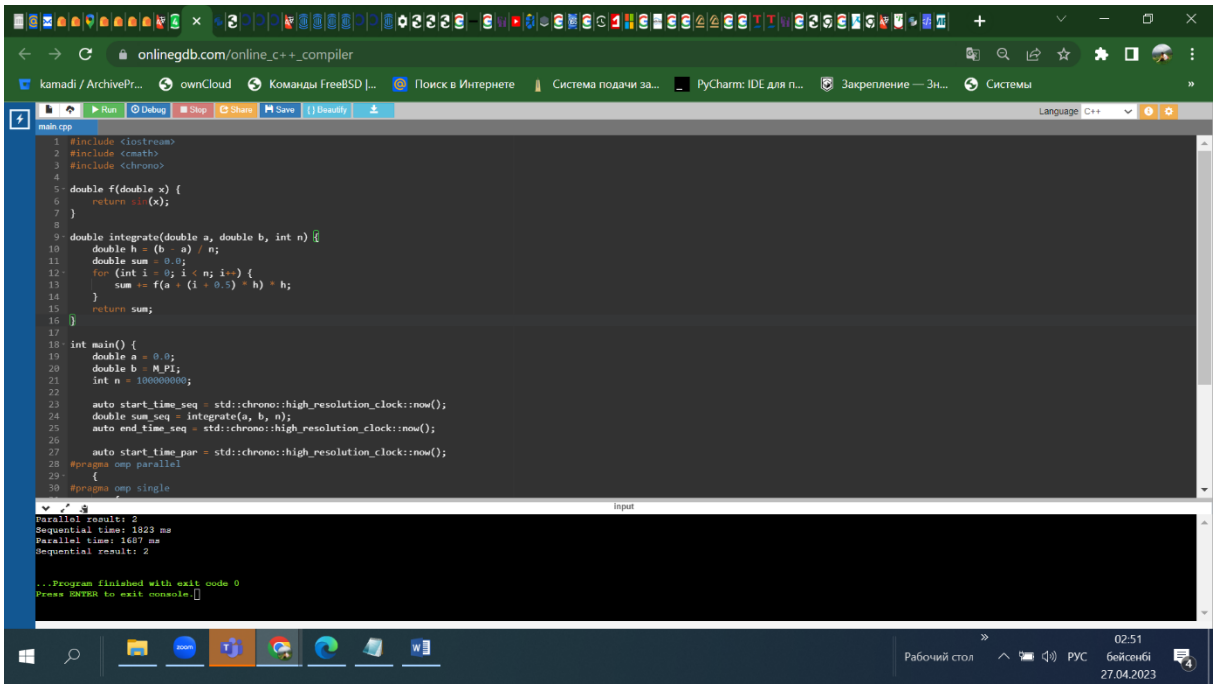

Fig 1. The first attempt to compile code using the OpenMP C++ compiler. From the console, we can see the execution time of the serial and parallel versions of the program.

Source: own research

Sequential time: 2176 ms

Parallel time: 2142 ms

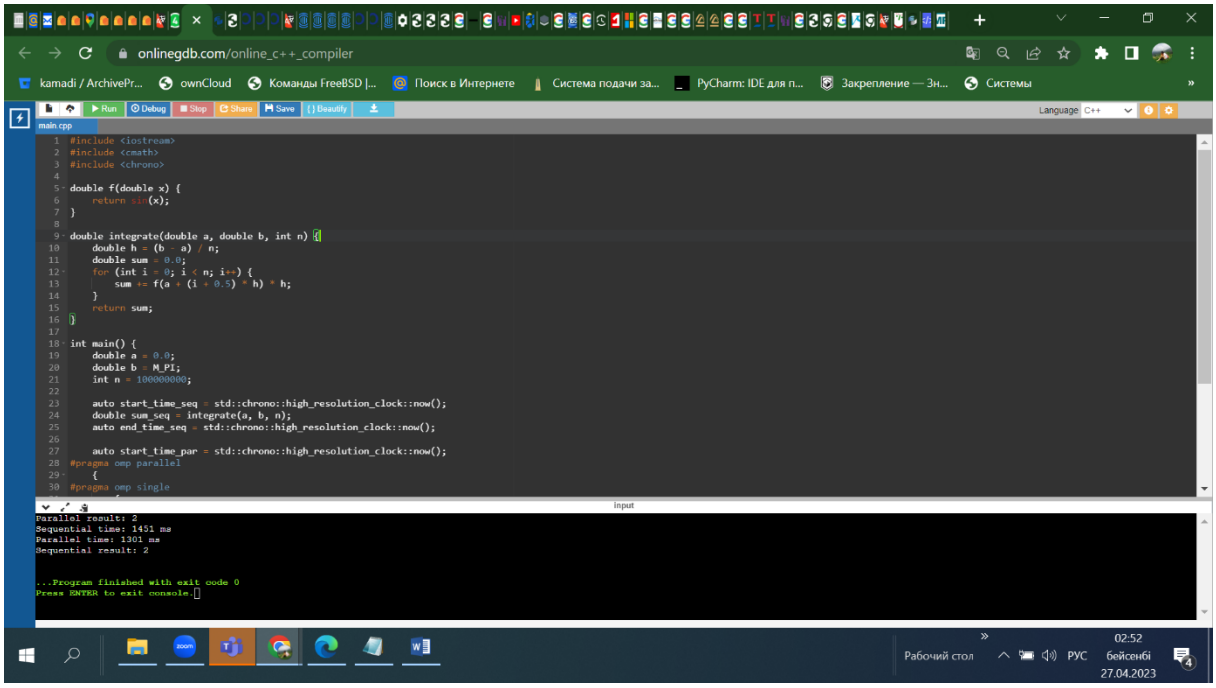

Fig 2. The second attempt to compile the code using the OpenMP C++ compiler. From the console, we can see the execution time of the serial and parallel versions of the program.

Source: own research

Sequential time: 1451 ms

Parallel time: 1301 ms

Conclusion

In conclusion, methods for incorporating computations and their execution in the OpenMP environment were examined, enabling students to adapt to life and solve simple tasks they encounter daily quickly and efficiently. OpenMP is a simple example of a program that calculates the value of the sin(x) function in the range from 0 to pi using the rectangle method in the middle programmatically executed and its effectiveness is determined. In practice, these exercises (program that calculates the value of the function sin (x) in the range from 0 to pi using the rectangle method) have been identified as an effective way to introduce users to the classic method of programming that efficiently and quickly solves simple tasks, such as determining the value of a function or solving daily encountered routine assignments.

By utilizing the OpenMP standard through the selected examples discussed in the article, it is possible to observe the efficiency of solving complex and parallel problems in the process of equation solving.

With the help of the examples considered in the article, it is possible to determine that in the process of solving problems using a parallel program, simple problems themselves do not exist. Summing up the considered works, we come to the conclusion that the speed of execution of the problems generated using MPI technology will increase, but it, in turn, will also depend on the number of cores. The use of the OpenMP environment for such calculations is of great importance in the development of thinking and cognitive abilities of children who need special knowledge and are normal.

The studies conducted show that utilizing the MPI technology improves the speed of executing assignments, but it is dependent on the number of cores available. In such cases, using the OpenMP framework becomes essential to enhance the knowledge development and cognitive abilities of students by nurturing their thinking and conceptual skills.

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