Learning Parallel Computations with ParaLab

Victor Gergel and Anton Shtanyuk

Institute of IT, Mathematics and Mechanics, Lobachevsky State University of Nizhni Novgorod, Russia

Abstract

In this work, we present the ParaLab teachware system, which can be used for learning the parallel computation methods. ParaLab provides the tools for simulating the multiprocessor computational systems with various network topologies, for carrying out the computational experiments in the simulation mode, and for evaluating the efficiency of the parallel computation methods. The visual presentation of the parallel computations taking place in the computational experiments is the key feature of the system. ParaLab can be used for the laboratory training within various teaching courses in the field of parallel, distributed, and supercomputer computations.

Keywords

Parallel computations, Education, Numerical experiments, Curriculum.

Introduction

In the paper, we are going to focus on the issues of providing a necessary laboratory training along with the wide spectrum of the problems, arising in the education in the PDSC field. Thus, in order to conduct the laboratory training, it is necessary to provide access to a real supercomputer system (preferably, even to several various supercomputers with different hardware and architectures). Computational experiments may take quite a long time and, therefore, may require large computational resources (including the financial ones). Finally, the conducted parallel computations are not observable visually: the developers of the parallel algorithms and programs cannot see, which processors execute distributed computations, what data are transferred, and which processors are involved in such transfer, etc.

We present the Parallel Laboratory (ParaLab) teachware system, which provides the capabilities to carry out the computational experiments for the purpose of learning and investigation of the parallel algorithms for solving complex computational problems. The system can be applied in the laboratory training within various educational courses in the PDSC field, giving the learners an opportunity:

- to simulate the multiprocessor computational systems with various processor number and network topologies,
- to visualize the computation processes and the data transfer operations taking place in the parallel solving of various computational problems,
- to evaluate the efficiency of the studied parallel computation methods.

ParaLab Overview

1. The capabilities

ParaLab provides the following capabilities for studying parallel computations.

- *Simulating the computational system*. To simulate a computational system, one can define the topology of a parallel computational system for carrying out the computational experiments, select the number of processors in this topology, set the performance of the processors, select the communication network parameters and the communication method. ParaLab allows to simulate high-performance computational systems that can consist of a set of computational nodes. Each computational node can contain one or several processors, and each processors can have one or several cores.
- *Selecting the problem statement and the method for its solving*. Within the framework of the ParaLab system, the student can perform the computational experiments for the following set of problems: matrix-vector multiplication, matrix multiplication, solving the systems of linear equations, sorting, graph processing, solving the differential equations in partial derivatives, and multidimensional global optimization.
- *Performing a computational experiment*. ParaLab provides a wide choice of tools for carrying out the computational experiments. The experiments can be performed either in the automatic mode or in the step-by-step mode, when calculations are suspended after each iteration of the algorithm is completed
- *Analyzing the results of the computational experiments*. The ParaLab system accumulates the results of the computational experiments automatically. The system provides the tools for plotting the dependencies featuring the parallel computations (execution time, speedup, efficiency) vs the parameters of the problem or the computational system. The dependencies are plotted according to the theoretical models for the computational complexity of the parallel algorithms

2. Parallel Methods for Studying with ParaLab

- *Matrix computations.*
- *Data sorting*
- *Graph processing*
- *Solving the differential equations in partial derivatives*
- *Multiextremal optimization*

Laboratory Training with ParaLab for Learning Parallel Methods

ParaLab can be used by the university students and teachers within the framework of the laboratory training in various educational courses in the PDSC field. ParaLab system can be applied also in research for evaluating the efficiency of the parallel computations as well. In practical application of the ParaLab system for teaching parallel computations, the following scheme of the laboratory training could be recommended.

- **Lab 1.** Simulating a computational system. This lab is aimed at studying the architecture of the multiprocessor systems. Using ParaLab, standard topologies of the computational systems can be considered with the possibility of the visualization of them at various number of the computational nodes, processors, and cores. Within the framework of the lab, the communication network performance (latency and bandwidth) as well as the basic methods of data transfer (message and packet modes) can also be studied.
- **Lab 2**. Studying the parallel methods of the matrix computations. Within the framework of this lab, the basic methods of matrix distribution between the processors (the horizontal and vertical block-striped schemes, the checkerboard block decomposition of the matrices) can be considered.
- **Lab 3.** Studying the parallel data sorting methods. This lab continues the topic of studying the parallel methods for solving the complex computational problems. Within the framework of this lab, the parallel bubble sorting algorithm, the Shell sorting method, and the quick sorting algorithm can be considered
- **Lab 4.** Studying the parallel methods of graph processing. Within the framework of this lab, the Prim's parallel algorithm for finding the minimum spanning tree and the Dijkstra's parallel method for finding the shortest paths are studied. The graphs for performing the experiments are generated by a random graph generator or can be set by a graphic editor by uploading from a file.
- **Lab 5.** Studying the methods for analyzing the experimental results. The lab is assigned for studying the basic principles of carrying out the computational experiments and the methods of accumulation and analysis of the obtained experimental data.

Conclusion

In this paper, we present the ParaLab teachware system, which can be applied for studying the methods of parallel computations. ParaLab provides the tools for modeling the multiprocessor computational systems with various topologies of the data transfer network, for performing the computational experiments in the simulation mode, and for evaluating the efficiency of the parallel computation methods being studied. The visual demonstration of the parallel computation processes executed during the performed computational experiments is the key feature of ParaLab system.

The system can be applied for the laboratory training within various educational courses in the PDPS field. ParaLab is applied intensively in the educational activities at University of Nizhny Novgorod as well as in other Russian universities. More than 90% of the students have noted the usefulness of ParaLab in studying the parallel programming during the surveys.

ParaLab system