Learning Parallel Computations with ParaLab

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***Abstract* – In this paper, 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

I. INTRODUCTION

The importance of the problem of education in the field of the parallel, distributed, and supercomputing computations (PDSC) is widely recognized by the international educational community.

In this paper, we present the Parallel Laboratory (ParaLab) teachware system [1], 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.

II. PARALAB OVERVIEW

In general, ParaLab is an integrated software environment for learning and research of the parallel algorithms for solving complex computational problems. A wide range of the tools for visualizing the parallel computations and for analyzing the experimental results allows studying the efficiency of various algorithms for different computational systems, making the conclusions on the scalability of the parallel algorithms, and evaluating the possible speedup of the parallel computations [2,3].

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.
- **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**. Prior to execution of a computational experiment, one can set up the necessary visualization parameters, select the desired demonstration rate, the visualization mode of the data transfer between the processors, and the granularity degree of the visualization of the parallel computations performed.
- **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.

III. PARALLEL METHODS FOR STUDYING WITH PARALAB

A wide choice of the parallel methods for solving a number of the problems of computational mathematics can be studied with ParaLab [1-5].

1) ***Matrix computations***. The following algorithms are provided by ParaLab:

- parallel algorithms of the matrix-vector multiplication with the block-striped and checkerboard block matrix decomposition,
- a parallel algorithm of the matrix multiplication for the block-striped data decomposition scheme and two parallel methods (the Fox and Cannon algorithms) for the checkerboard block matrix decomposition,
- the parallel Gauss method for solving the systems of linear equations.

2) ***Data sorting.*** A parallel variant of the bubble sorting method and the parallel Shell and quick sorting algorithms are implemented in ParaLab.

3) ***Graph processing***. For the graph processing problems, ParaLab uses the Prim's parallel method for finding the minimum spanning tree and the Dijkstra's and Floyd's algorithms for finding the shortest paths.

4) ***Solving the differential equations in partial derivatives.*** In the ParaLab system, the parallel Gauss-Seidel method is implemented for this class of problems.

5) ***Multiextremal optimization***. The parallel index method [6] is implemented for solving the multiextremal optimization problems in ParaLab.

IV. Laboratory Training with ParaLab for Learning Parallel Methods

The laboratory training with ParaLab system can be implemented in accordance with the following successive scheme:

- Simulating the multiprocessor computational systems (the topology selection, setting the number and performance of processors, selection of the data transfer method, and setting up the communication network parameters);
- Choosing the class of the problems to be solved and setting the problem parameters;
- Setting up the graphical indicators for visualizing the parallel computation process (the status of data on the system processors, the data transfer via the network, the current computational results);
- The execution of the experiment in the computations simulation mode; choosing the experiment mode: automatic or step-by-step, single or a series of executions, single or multiple experiments in the time-sharing mode for different variants of the computational system topologies, number of processors, the problem parameters, etc.;
- Analyzing the experimental results accumulating in the experiment log file; evaluating the execution time subject against the complexity of the problem and the number of processors; plotting the dependencies of the speedup and the efficiency of the parallel computations;
- Implementing the experiments with the real parallel computations; execution of the parallel programs on a single processor and on a multiprocessor computational system using the remote access; comparing the theoretical estimates with the results of real computational experiments.

The laboratory training with ParaLab can be conducted, for example, according to the following set of assignments:

- A student solves a complex computational problem using several parallel methods and a computational system, compares the results to each other, and interprets them within the theory of the parallel algorithms;
- A student constructs several computational systems in such a way that allows to demonstrate the basic theoretical concepts of parallel computations;
- A student constructs one or several computational systems and solves the problems with various values of the computational system parameters, thus studying the effect of the parameters on the time of the algorithm execution;
- A student performs real computation experiments using a cluster in the remote access mode and compares the results of real and simulated experiments.

V. Conclusion

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.

The new users will find ParaLab to be useful for learning the parallel computation methods, the advanced users can apply the system for evaluating the efficiency of novel parallel algorithms to be developed.

References

[1] Gergel, V., Labutina, A. The ParaLab system for investigating the parallel algorithms // Lecture Notes in Computer Science, 2010, 6083 LNCS, pp. 95-104

[2] Kumar V., Grama A., Gupta A., Karypis G. Introduction to Parallel Computing. - The Benjamin/Cummings Publishing Company, Inc., 1994

[3] Quinn, M.J. Parallel Programming C with MPI and OpenMP. - Mccraw-Hill, New York, 2004

[4] Gergel, V.P. Theory and Practice of Parallel Computations. – BINOM, Moscow, 2007. (In Russian)

[5] V. Gergel, A. Liniov, I. Meyerov, A. Sysoyev, NSF/IEEE-TCPP Curriculum Implementation at the State University of Nizhni Novgorod // IPDPSW '14 Proceedings of the 2014 IEEE International Parallel & Distributed Processing Symposium Workshops. – IEEE Computer Society Washington, DC, USA, 2014, pp. 1079-1084.

[6] Gergel, V.P., Strongin, R.G. Parallel computing for globally optimal decision making // Lecture Notes in Computer Science, 2763, 2003, pp. 76-88.