Unified Assessment of Skills in Parallel and Distributed Computing

Victor Gergel, Iosif Meyerov, Alexander Sysoyev
Faculty of Computational Mathematics and Cybernetics
Lobachevsky State University of Nizhni Novgorod
Nizhni Novgorod, Russia
e-mail: gergel@unn.ru

Abstract – The problem of training specialists in the field of Parallel and Distributed Computing is discussed. We propose an integrated approach to curriculum contents and knowledge assessment unification. The core idea is to develop unified Professional Certification Program on Parallel and Distributed Computing based on the international practices and NSF/IEEE-TCPP project recommendations. Potential use of the approach is demonstrated by the example of Intel Parallel Programming Professional Certification Program developed in Russian universities under Intel support.

Keywords – Parallel and distributed computing, NSF/IEEE-TCPP project, knowledge assessment system, professional certification, supercomputing education

I. INTRODUCTION

The first exaflop computing systems are expected to be developed in 2018-2020. The importance of development and practical use of multicore computer potential offers an extremely important challenge to the higher education system – effective and large-scale students training in PDC field. The lack of skilled staff in this field is a serious problem for the modern world. One of the problems to ensure the high level of training in high performance computing is the diversity of existing curricula in PDC field.

To solve the problem of curriculum diversity it is necessary to define the PDC domain area and thereafter to develop the requirements for the curriculum contents. The development of the unified assessment system for professional knowledge and skills gained by the students in PDC field is also a matter of principle.

II. PARALLEL AND DISTRIBUTED COMPUTING.
INTERNATIONAL EXPERIENCE AND DOMAIN DEFINITION

At the moment the following basic activities to define the HPC domain can be outlined in the international education community:

- A set of knowledge and skills developed within Russian program of supercomputing education initiated by the Supercomputer University Consortium of Russia and supported by the Russian President and Government [1].
- Recommendations on the contents of the PDC domain prepared by ACM and IEEE-CS international communities within the development of Computing curricula [2].
- Recommendations on the contents of the domain of Parallel and Distributed Computing developed within the project realized under support of NSF (USA) and IEEE-TCPP (Technical Committee on Parallel Programming) [3,4].

III. THE PROJECT OF UNIFIED KNOWLEDGE ASSESSMENT SYSTEM

A. The assessment system

Curricula in PDC field ensure as a rule step-by-step mastering of the studied domain. Thus, the knowledge assessment shall provide several check-up levels. The higher the level, the higher the requirements for the set of students’ knowledge and skills shall be. The assessment system can include the following levels:

1) Introduction Level. This level incorporates initial themes within the general courses and implies basic knowledge in the field of system architectures (first of all – systems with shared memory), in developing basic parallel programs and examples of the practical use of parallel and distributed computing to solve various applied problems.

2) Basic level. This level supposes rather substantial knowledge and skills in applying the technology of parallel program development to the systems with shared and distributed memory (such as OpenMP and MPI), as well as the knowledge of basic parallel algorithms.

3) Main level. This level includes the knowledge and skills practically in all PDC issues. Such knowledge is derived from the advanced training courses. To reach this level the students shall also complete the self-training tasks of an increased difficulty level.

4) Advanced level. This level supposes the students’ concentration in PDC field. To reach this level the students shall be trained under supervision of experienced lecturers and specialists and participate in solving actual scientific and applied problems.

Tutorial materials in PDC domain area consist of textbooks and manuals used to study the basic and advanced courses. Very useful materials will be presented in the textbook [5] developed within the NSF/IEEE-TCPP project. Various visualization tools of parallel computing (such as ParaLab [6]) can also contribute to more successful mastering of the subject.
B. The basic courses

1. CS101 Introduction to Computer Programming. The training course ensures the systematic description of key issues in program development. The following issues can be studied in PDC subject:

2. CS102 Object Oriented Programming. The training course is intended to master the object-oriented approach to the development of intricate software. The following issues can be studied within PDC subject:

3. CS103 Data Structures and Algorithms. The training course implies the general types of data structures and discusses their effective realization. The following issues can be studied within PDC subject:

4-6. CS220 Computer Architecture, CS225 Operating Systems, CS230 Computer Networks. These courses are major disciplines for students in computer sciences. To assess knowledge in these courses the set shall include test questions directly related to PDC subject.

7. CS338 Parallel Computing. The target of the training course is to master the set of knowledge and skills required to successfully start the professional activities in the field of parallel programming. The distinguishing feature of the course is its integral character. The course contains both necessary theoretical knowledge in the field of parallel computing and practical skills in the development of parallel programs.

IV. Practical Application of the Approach by the Example of Professional Certification System

The certification program includes several levels: Introduction, Basic, Expert and Master.

The curriculum for the initial levels (Introduction, Basic) consists of the following educational modules:

- **Module 1. “Introduction into the fundamentals of parallelism”.** The main object of this module is to prepare the students to further study of methods and technologies of parallel computing, to teach them fundamental knowledge in mathematical basis of parallel computing, architectural aspects of parallelism and knowledge in operation systems.

- **Module 2. “Introduction into technology of parallel programming (OpenMP, MPI, TBB, Cilk Plus)”.** Once the initial knowledge is acquired, the students study particular technologies of parallel programming. OpenMP and MPI technologies are taught in the certification program for the Introduction and Basic levels, TBB and Cilk Plus are included in the Basic level.

- **Module 3. “Introduction into application of tools for parallel programming by the example of Intel Parallel Studio software”.** This module focuses on possible practical application of tools for parallel programming (including the special compiler, debugger, profiler, mathematical libraries) to solve the parallel software development problems. The module includes the examples of problems originated from practical programming and explains the methods of their solution. The tutorial materials illustrate the application of program tools followed by the compulsory fulfillment of self-training tasks.

- **Module 4. “Introduction into parallel algorithms by the examples of classical sections of numerical methods”.** This module implies the study of parallel algorithms developed to solve classical mathematical problems.

The developed set of test questions includes about 300 questions. The questions for each test session are selected randomly. With a great probability we can say that each student sitting in the classroom will take an individual test. At the Introduction level the student shall pass a test containing 28 questions. A test for the Basic level includes 40 questions.

After the test is completed, we can review the statistics of different type – for a group of users, for an individual user, for a test or even for a question from a certain test. The results of different groups can be compared which allows to evaluate the general level of training for the groups and relative complexity of the questions for each of the groups.

The UNN Competence Center for Educational Programs and the Competence Center for High-Performance Computing of Moscow State University supported by Intel experts coordinate the Certification Program.

The certification has been performed on the basis of the certification centers. More than 12500 students have been certified. More than 45 000 students have been informed about the Certification Program.

V. Conclusion

According to the main idea of the approach not only curricula of the training courses shall be unified but also the system of knowledge assessment for the trained specialists. To do this an international work group shall be assembled and recommendations for further discussion and introduction shall be developed. The article presents the pilot variant of the available recommendations based on the previous experience in the development of the certification program for Intel technologies of parallel programming.

REFERENCES


