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Strategic initiative “Achieving leading positions in the field
of supercomputer technology and high-performance computing”

Parallel Programming
for Multiprocessor Distributed Memory Systems

08 Practice
Parallel Algorithms of Graph Processing

Brief description

Nizhni Novgorod
2014

08_PRACTICE. PARALLEL ALGORITHMS OF GRAPH PROCESSING

OBJECTIVES

An objective of the practice is to demonstrate a practical application of the parallel algorithms of graph processing by example of solving the shortest path problem.

ABSTRACT

The work is organized in the following way. The shortest path problem is stated. Implementation of serial solving method (Floyd algorithm) is discussed and demonstrated. Possible parallel algorithm and scheme of data distribution are considered. Implementation of parallel algorithm (Floyd method) using MPI is described.

BRIEF OVERVIEW

Mathematical models in the form of graphs are widely used for modeling various phenomena, processes and systems. As a result, many theoretical and applied problems may be solved by means of various procedures of graph model analysis. It is possible to select a set of typical algorithms of graph processing among all those procedures. The problems of graph theory, modeling algorithms, analyzing and solving problems based on graphs are discussed in a number of publications.

The practice discusses the Floyd algorithm for solving the problem of search for the shortest paths among all the pairs of graph vertices. To develop the parallel variant of the Floyd method a complete design cycle is carried out. The sequential computational scheme is described, the possible ways for algorithm parallelizing are discussed, the efficiency of the obtained parallel computations is evaluated, the software implementation is suggested and the results of the computational experiments are given. The approach, which is used for parallelizing the Floyd algorithm, consists in distributing the vertices of the graph among the processors. In this case the information communications consist in broadcasting an adjacency matrix row from a processor to all the processors at each method iteration.

The first section of the practice contains necessary term definitions from graph theory, the problem of search for the shortest paths among all the pairs of graph vertices statement and pseudocode of the Floyd algorithm.

In the second section the project for Microsoft Visual Studio is developed step-by-step. The developed application implements the serial algorithm as well as the necessary steps to input initial data (number of vertices, the adjacency matrix), finish the execution correctly, and carry out the computational experiments.

In the third section the data distribution scheme is considered, the computation organization is presented, so parallel algorithm is formulated. Partitioning the adjacency matrix into horizontal stripes is chosen.

The last section is devoted to implementation of previously described parallel algorithm as an MPI parallel program. Serial implementation is used as the basis. Parallel program is developed step-by-step like serial one. Necessary steps include parallel program initialization, data input (the adjacency matrix), data distribution, parallel Floyd algorithm implementation, gathering the results.

FOR STUDENTS

Additional information on the Floyd method and the Prim algorithm may be obtained, for instance, in Cormen, et al. (2009). More detailed information on the problem of graph partition may be found in Schloegel, et al. (2000). We may also recommend the work by Quinn (2004), which described a number of typical problems of parallel programming for the purpose of studying MPI.

REFERENCES

1. Cormen, T.H., Leiserson, C.E., Rivest, R.L., Stein C. (2009). Introduction to Algorithms, 3rd Edition. – The MIT Press.
2. Schloegel, K., Karypis, G., Kumar, V. (2000). Graph Partitioning for High Performance Scientific Simulations.
3. Quinn, M.J. (2004). Parallel Programming in C with MPI and OpenMP. – New York, NY: McGraw-Hill.
4. Foster, I. (1995). Designing and Building Parallel Programs: Concepts and Tools for Software Engineering. Reading, MA: Addison-Wesley.

EXERCISES

1. Study the Prim algorithm for finding the minimum spanning tree. Develop the program, which implements this algorithm.

2. Study the Dejkstra method for solving the problem of finding the shortest path from one of the graph vertices to the other. Develop the program, which implements this algorithm.

TEST QUESTIONS

1. What data structure may be used to present dense weighted graph?
 - a. (+) Adjacency matrix
 - b. Stack
 - c. Queue
2. What is the complexity order for Floyd algorithm for solving the problem of search for the shortest paths?
 - a. $O(n)$
 - b. $O(n^2)$
 - c. (+) $O(n^3)$
3. What are the main methods of distributing the adjacency matrix elements among processors?
 - a. (+) Partitioning data into stripes (vertically and horizontally).
 - b. Partitioning data using LU decomposition.
 - c. (+) Partitioning data into rectangular fragments (blocks).
4. What number of processes may be used during the execution of parallel implementation of Floyd algorithm for solving the problem of search for the shortest paths?
 - a. (+) Any possible number of processes may be used.
 - b. The number of processes should be a perfect square.
 - c. The number of processes should be equal the number of matrix rows.
5. What function should be used to distribute between processes the adjacency matrix size in parallel implementation of Floyd algorithm for solving the problem of search for the shortest paths?
 - a. MPI_Send
 - b. (+) MPI_Bcast
 - c. MPI_Scatter
 - d. MPI_Gather
6. What function should be used to distribute between processes the adjacency matrix in parallel implementation of Floyd algorithm for solving the problem of search for the shortest paths?
 - a. MPI_Send
 - b. MPI_Bcast
 - c. (+) MPI_Scatter
 - d. MPI_Gather

7. What function should be used to get the result vector in parallel implementation of Floyd algorithm for solving the problem of search for the shortest paths?
 - a. MPI_Reduce
 - b. MPI_Bcast
 - c. MPI_Scatter
 - d. (+) MPI_Gather
8. What virtual topology should be used to implement parallel implementation of Floyd algorithm for solving the problem of search for the shortest paths?
 - a. (+) MPI_COMM_WORLD is enough.
 - b. Cartesian topology
 - c. Special graph topology
9. What method may be used to check the correctness of the parallel implementation of Floyd algorithm for solving the problem of search for the shortest paths?
 - a. (+) Compare the results of the parallel program with the results of the serial one.
 - b. (+) Implement algorithm that calculate the path weight for every possible path in the graph and compare the results.
 - c. The implementation of the parallel program guarantees the correctness.