University of Management and Technology Lahore
School of Science and Technology
Department of Computer Science

Complex Computing Problem (CCP)

Temperature Evolution Simulation of a Rod

Semester: Fall 2024

Course: Parallel and Distributed Computing (CS 4172)

Maximum Marks: 20/100

Shared with Students: Week 5

Submission Date: Monday, Week 13

TABLE I
COURSE LEARNING OUTCOMES (CLOs).

CLO	Description
CLO 1	**Describe** parallel hardware and software and distributed computing architectures and programming models. (Level: C2)
CLO 2	**Apply** knowledge of shared memory programming with OpenMP to write efficient parallel programs for a given problem. (Level: C3)
CLO 3	**Apply** knowledge of distributed memory programming using message passing interface (MPI) to write efficient parallel programs for a given problem. (Level: C3)
CLO 4	**Analyze** the performance of a parallel program written with OpenMP or MPI or CUDA libraries. (Level: C4)
CLO 5	Propose a solution to a given design problem while adhering to professional ethics and norms of computing practices. There must be a **debate** among team members before every design decision and student must appreciate ethical problems related to teamwork and plagiarism (A3)
CLO 6	**Develop** a report on the entire process of designing the solution of given CCP such that every step is communicated effectively. The students should mention in the report the argument through which they **compared** the design choices to get to the final decision. The student will also present orally the results and process of the design at the end of the entire activity. (A4)

TABLE II
PROGRAM LEARNING OUTCOMES (PLOs) FOR CCP.

PLO	Description
2	**Knowledge for Solving Computing Problems**: Apply knowledge of computing fundamentals, knowledge of a computing specialization, and mathematics, science, and domain knowledge appropriate for the computing specialization to the abstraction and conceptualization of computing models from defined problems and requirements
3	**Problem Analysis**: Identify and solve complex computing problems reaching substantiated conclusions using fundamental principles of mathematics, computing sciences, and relevant domain disciplines.
7	**Communication**: Communicate effectively with the computing community about complex computing activities by being able to comprehend and write effective reports, design documentation, make effective presentations, and give and understand clear instructions.
9	**Ethics**: Understand and commit to professional ethics, responsibilities, and norms of professional computing practice

TABLE III
Range of Complex Problem Solving

CCP Attribute	Attribute	A Complex Computing Problem
1	Range of conflicting requirements	Involves wide-ranging or conflicting technical, computing, and other issues.
2	Depth of analysis required	Has no obvious solution, and requires conceptual thinking and innovative analysis to formulate suitable abstract models.
3	Depth of knowledge required	A solution requires the use of in-depth computing or domain knowledge and an analytical approach that is based on well-founded principles.
8	Interdependence	Is a high-level problem possibly including many component parts or sub-problems.

+

TABLE IV

Blooms Taxonomy Domain Levels

CCP Attribute.	Domain	Description	Bloom's Taxonomy Level
1	Cognitive	**Understanding**: Grasp meaning of materials	C2
2	Cognitive	**Applying**: Use information in a new situation.	C3
3	Cognitive	**Analyzing**: Identify schemas or relationships.	C4
3	Affective	**Valuing:** Attach values and express personal opinion	A3
8	Affective	**Organization or conceptualizing Values:** Reconcile internal conflicts, develop value system	A4

TABLE IV

ASSESSMENT RUBRIC AND DELIVERABLES (MAX. MARKS:15).

Assessment Criteria	CCP Attribute	CLO / PLO	Outstanding	Effective	Inadequate
Problem analysis resulting in constraints to be imposed on solution.	Range of conflicting requirements	4/3	3	2	1
Design including Flow chart / Block diagrams, comparison if alternative solutions.	Depth of knowledge required	5/7	3	2	1
Show interdependence of submodules and their communication	Interdependence	5/7	2	1	1
Report originality		6/9	2	1	0.5
Report flow, and clarity	Depth of knowledge required	6/9	2	1	0.5
Viva.	Depth of knowledge required, Interdependence	6/7	3	2	1

Complex Computing Problem Statement

We aim to model the temperature $T(x,\ t)$ of a rod of length **N** meter, with both ends maintained at $T_0{}^{o}\,C$, while the initial temperature distribution along the rod is given by T(x , 0) = 100 sin(πx). The rod is insulated except at the ends, and we need to simulate the temperature changes over time due to heat conduction.

The solution provided must satisfy the following constraints:

- **Rod Length:** N meter. (Start from N=1 m)
- **Boundary Conditions:** Both ends at $T_0{}^{o}\,C$. (Start from $T_0 = 0^{o}\,C$)
- **Initial Temperature:** T(x,0)=100 sin(πx).
- **Material:** Uniform.
- **Insulation:** Heavy insulation except at the ends.(ideal insulation)

NOTE: You should use only C or C++ for the implementation of the solution.

Depth of knowledge required

As a first step domain knowledge should be acquired by the student. A mathematical model should be finalized for the problem at hand.

Then the student should research the various programming techniques, algorithms, hardware configurations, and configurations of the system they will be using to develop and deploy their algorithm.

Students should formulate a suitable abstract model. They should consider factors such as workload balance, data dependencies, and communication overhead to devise an effective abstract model for solving the mathematical model finalized earlier. Students must explore and analyze various techniques to optimize the performance of the parallel algorithm solution. They should creatively analyze and fine-tune their implementation to ensure efficient resource utilization and minimize idle time.

Range of conflicting requirements

This problem involves several trade-offs, where improving one aspect may lead to challenges in others. Students should identify these variables and seek an optimal balance. They should be prepared to report on some of the conflicting aspects of the problem, such as:

Resource Utilization: While maximizing resource utilization is important, it can lead to increased overhead due to communication and synchronization among parallel processes. This overhead may counteract potential performance gains, making it essential to find a balance between efficient resource use and maintaining system performance.

Report submission tasks: LaTeX generated PDF- No other format will be accepted.

1) Report must be written in double column, 10-point font, Times New Romans, with 10 pages providing related references at the end of the report in IEEE format.

2) Report must contain details of implementation and algorithms/techniques used, with proper captions for algorithm, figures and tables, graphs for results. Make your own figures in MS VISIO 2019/ Adobe Photoshop or any other software

3) Write report using LaTeX template.

4) Use Overleaf.com for write-up.

The following should be added in the technical report.

1. Title
2. Authors with their affiliation/ Dept/School/University Name/ Email ID.
3. Abstract/ Summary not more than 250 words with Keywords
4. Sequential code Implementation detail
5. Strategy for Parallelization/Methodology
6. Parallel Algorithm(s) implementation detail
7. Implementation code files for Multithreading/OpenMP/MPI and CUDA based solution
8. Discussion on results and Performance analysis (Amdahl's speed up with no of processors, time complexity of the algorithm)
9. References
10. Photos of Co-Authors with brief biographic sketch—3-4 lines max.
11. Include in report an Editable Link of overleaf.com (shared link) of your writ-up for instructor to see your work.
12. Make a video (.mp4) file with your group member explaining how you have attempted to solve the given problem using parallel techniques and upload video on YouTube. Include in the report the YouTube link.
13. Plagiarism must be less than 15%. Your report will be uploaded on Turnitin.com for plagiarism check. Write in your own words.