

Assignment 1

ECSE 420: Parallel Computing

Due: October 1, 2025

Submission instructions: Students are to work in groups of two on the assignment. Each group should submit a pdf file that contains the following information: students' names, students' IDs, instructions on how to run each file and the associated question solved. Students are also expected to submit a .zip file containing their source code. This code must compile and run without error. Sample codes are provided for Questions 1&3; students just need to modify these sample codes. The code must be well formatted, commented, and follow the [Google Java Style Guide](#). For more information, see the ECSE420AssignmentSubmissionInstructions.pdf in the Assignment section on [myCourses](#).

Questions

1. **(24 marks)** Matrix multiplication is a common operation in linear algebra. Suppose you have multiple processors, so you can speed up a given matrix multiplication. Answer the following:
 - 1.1. Modify the following method in the sample code to Implement a matrix multiplication sequentially:

```
public static double[][] sequentialMultiplyMatrix(double[][] a, double[][] b)
```

Explain how you validate the method produces the correct results.
 - 1.2. Modify the following method in the sample code to Implement a matrix multiplication in parallel:

```
public static double[][] parallelMultiplyMatrix(double[][] a, double[][] b)
```

Explain how the parallel tasks are defined in your code (e.g., how the matrices are divided between threads), and how their results are combined to produce the correct results. Explain how you validate the method works correctly.
 - 1.3. Add a method to the source code that measures the execution time for both sequential and parallel matrix multiplication. Explain how you can test the method returns plausible results.
 - 1.4. Vary the number of threads being used by the parallel method for matrix sizes of 4000 by 4000 and plot the execution time as a function of the number of threads. Discuss the speed-up obtained vs. the number of threads used.
 - 1.5. Vary the size of the matrices being multiplied as (100 by 100, 200 by 200, 500 by 500, 1000 by 1000, 2000 by 2000, 3000 by 3000, 4000 by 4000) and plot the execution time as a function of matrix size for both parallel and sequential methods in one figure. Use the number of threads for which the parallel execution time in 1.4 above was minimum.
 - 1.6. For the generated graphs in 1.4 and 1.5 comment on their shape and possible reasons for the observed behavior.



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2. **(8 marks)** Write a program that demonstrates deadlock.
- 2.1. Explain under what conditions (in general) deadlock could occur and comment on its possible consequences (in general). Explain how your program demonstrates this.
 - 2.2. Discuss possible design solutions to avoid deadlock (in general). Could this solution be used in your example program to avoid deadlock?
3. **(16 marks)** The original *dining philosophers problem* was invented by E. W. Dijkstra, a concurrency pioneer, to clarify the notions of deadlock- and starvation-freedom. Imagine five philosophers who spend their days just thinking and feasting on rice. They sit around a circular table with five chairs. The table has a big plate of rice in the center; however, due to current supply chain shortages, there are only five chopsticks available, as shown in Fig. 1. Each philosopher thinks. When they get hungry, they pick up the two chopsticks closest to them. If a philosopher can pick up both chopsticks, they can eat for a while. When philosopher finishes eating, they put down the chopsticks and start to think again.

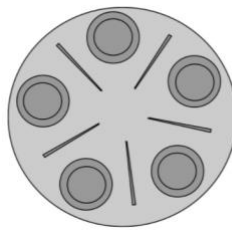


Figure 1

- 3.1. Modify the class `public class DiningPhilosophers` in the sample code to simulate the behavior of the philosophers for any number n of them, where each philosopher is a thread, and the chopsticks are shared objects. Notice that you must prevent a situation where two philosophers hold the same chopstick at the same time. Notice that in this program philosophers should be eventually deadlocked. Explain how you ensure that two philosophers cannot hold the same chopstick simultaneously. Why is possible that, eventually, the philosophers will be deadlocked?
- 3.2. Amend your program so that it never reaches a state where philosophers are deadlocked, that is, it is never the case that each philosopher holds one chopstick and is stuck waiting for another to get the second chopstick. Explain your solution to avoid deadlock. Is starvation possible even if no deadlock occurs in your program? Explain why/why not?

Amend your program so that no philosopher ever starves. Explain your solution to avoid starvation. How can you test that your solution is starvation free?



4. (12 marks) Use Amdahl's law to answer the following questions:

- 4.1. Suppose the sequential part of a program accounts for 40% of the program's execution time on a single processor. Find an expression for the overall speedup that can be achieved by running the program on an n -processor machine. (The expression should be a formula for speedup as a function of n .) Show all intermediate steps. What is the limit of the speed-up if there is no bound to how many processors your system can have?
- 4.2. Now suppose the sequential part accounts for 30% of the program's computation time. Let s_n be the program's speedup on n processors, assuming the rest of the program is perfectly parallelizable. Your supervisor tells you to double this speedup: the revised program should have speedup $s'_n \geq 2s_n$. You advertise for a programmer to replace the sequential part with an improved version that decreases the sequential time percentage by a factor of k . Find an expression for the value of k you should advertise for. Show all intermediate steps.
- 4.3. Suppose the sequential time percentage could be decreased 3-fold, and when we do so, the modified program takes half the time of the original on n processors. What fraction of the overall execution time did the sequential part account for? Express your answer as a function of n . Show all intermediate steps.

You may assume that the program, when executed sequentially, takes unit time.

Total for assignment: 60 marks



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