Lecture 1: Welcome to COMP 322!

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http://comp322.rice.edu
Acknowledgments

Vivek Sarkar
Dan Wallach
Shams Imam
Your Teaching Staff!

- TAs
  - Adrienne Li, Austin Hushower, Claire Xu, Diep Hoang, Hunena Badat, Maki Yu, Mantej Singh, Rose Zhang, Victor Song, Yidi Wang

- Instructors
  - Zoran Budimlić (zoran@rice.edu)
  - Mack Joyner (mjoyner@rice.edu)
Office Hours

• Regular office hour schedule can be found at Office Hours link on course web site
• Send email to instructors (zoran@rice.edu, mjoyner@rice.edu) or TAs if you need to meet some other time
• Use Piazza to post and answer questions
Course Syllabus

• Fundamentals of Parallel and Concurrent Programming taught in six topics
  1. Functional Programming Fundamentals (2 weeks)
  2. Creating Parallel and Concurrent Programs using Functional Concepts (4 weeks)
  3. Fundamentals of Shared-Memory Concurrent Programming (3 weeks)
  4. Data Parallel Programming Model and Loop Parallelism and Concurrency (2 \(\frac{2}{3}\) weeks)
  5. Message-Passing Programming Model (1 \(\frac{1}{3}\) week)
  6. Miscellaneous Topics (1 week)
• Labs and programming assignments will be in Java 11
• Habanero-Java (HJ) library developed at Rice as a pedagogic parallel programming model
  • Only used as a uniform way to illustrate the concepts
  • We will relate concepts to other languages and frameworks
Grade Policies

Course Rubric

- Homework (5) 40% (written + programming components)
  - Weightage proportional to # weeks for homework
- Exams (2) 40% (scheduled midterm + scheduled final)
- Weekly Labs 10% (labs need to be submitted by the following Monday)
- Quizzes 5% (on-line quizzes on Canvas)
- Class Participation 5% (in-class worksheets)
Parallelism and Concurrency are Everywhere
What is Parallel Computing

- **Parallel computing**: using multiple processors in parallel to solve problems quicker than with a single processor and/or with less energy.

- Example of a parallel computer: Apple M1 MAX
  - 10-core Multi-Processor
    - 8 performance cores
    - 2 high-efficiency cores
  - 32 GPU cores
  - 16 neural engine cores
  - Unified memory on-chip (up to 64GB)
  - 57 billion transistors
Gordon Moore (co-founder of Intel) predicted in 1965 that the transistor density of semiconductor chips would double roughly every 1-2 years (Moore's Law)

- area of a transistor halves every 1-2 years
- feature size reduces by \( \sqrt{2} \) every 1-2 years
Parallelism Saves Power (Simplified Analysis)

Maximum Frequency is capped by Voltage
→ Power is proportional to \((\text{Frequency})^3\)

**Baseline example:** single 1GHz core with power P

**Option A:** Increase clock frequency to 2GHz → Power = 8P

**Option B:** Use 2 cores at 1 GHz each → Power = 2P

• Option B could deliver the same performance as Option A with 4x less power ... provided your software runs in parallel!
What is Parallel Programming

- Specification of operations that can be executed in parallel
- A parallel program is decomposed into sequential subcomputations
- Threads, Jobs, Processes, *Tasks*
- Parallel programming constructs define the semantics of task creation, termination, location and interaction
What is Concurrent Programming

• Programming technique
• An application making progress on two or more tasks at the same time
• Execute and complete in an overlapping time period
• Manage access to shared resources
Concurrent vs. Parallel Programming

• “Things happening at the same time”
• Parallel Programming: Improve performance
• Concurrent Programming: Solve a problem by using concurrently executing tasks and managing shared resources
• Example: 200 COMP 322 students, one final exam with 10 questions
• Parallelism without Concurrency
  • 10 TAs, each TA grades 20 complete exams
• Concurrency without Parallelism
  • 1 TA, the TA grades question 1 first for all exams, then question 2, and so on ...
• Concurrency and Parallelism
  • 10 TAs, each TA grades a separate question
Another Example: Playing a Piano

Eine Kleine Nachtmusik
1st movement simplified

Moderately, with a little rubato (~c. 60)

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Parallelism vs Concurrency

Parallelism:
“How do I get my app to run about twice as fast on my new 8-core Mac vs. my old 4-core Mac?”
- Chris Jermaine

Concurrency:
“My application has simultaneous events happening that are instigated from a variety of sources and I cannot control the timing, how do I efficiently and correctly handle this concurrency in a principled and structured way?”
- Scott Rixner
Example Problem: Computing the sum of array elements

Algorithm 1: Sequential ArraySum

Input: Array of numbers, X.
Output: \( sum = \text{sum of elements in array } X \).

\[
\begin{align*}
\text{sum} & \leftarrow 0; \\
\text{for } i & \leftarrow 0 \text{ to } X.\text{length} - 1 \text{ do} \\
& \quad \sum \leftarrow \sum + X[i]; \\
\text{return } \sum;
\end{align*}
\]

Observations:
- The decision to sum up the elements from left to right was arbitrary
- The computation graph shows that all operations must be executed sequentially
Basic idea:

- Decompose problem into two tasks for partial sums (parallelism)
- Combine results to obtain final answer after partial sums are done (concurrency)
- This is a parallel divide-and-conquer pattern