COMP 322 / ELEC 323: Fundamentals of Parallel Programming

Lecture 1: Task Creation & Termination (async, finish)

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Special thanks to Vivek Sarkar!

Your Teaching Staff!

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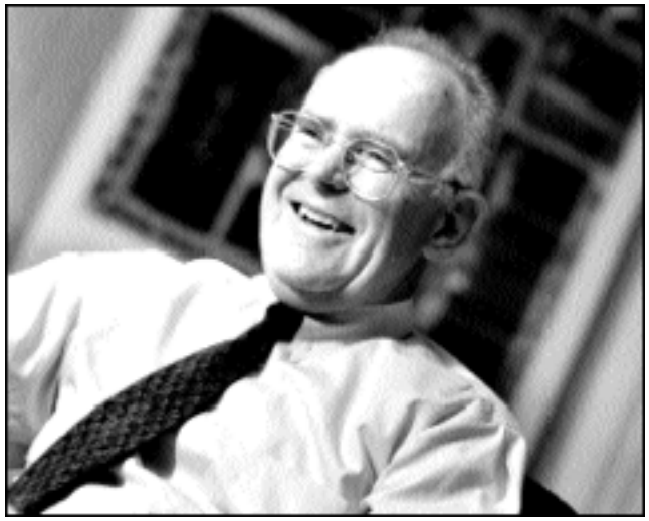
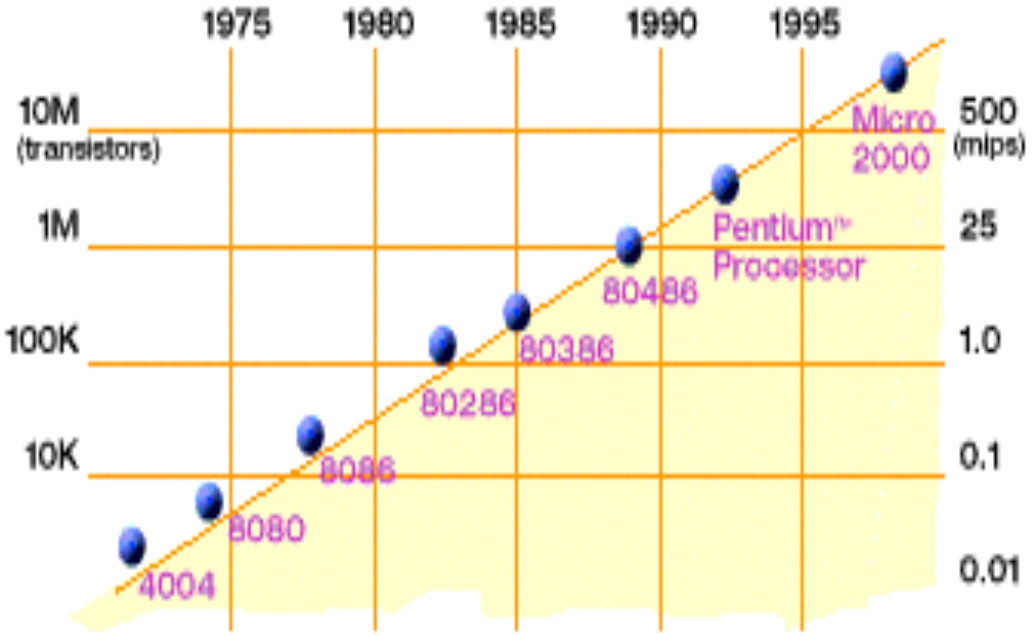
- **Instructors**
  - — Mack Joyner, Zoran Budimlić

Moore's Law and Dennard Scaling





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 transistor halves every 1-2 years

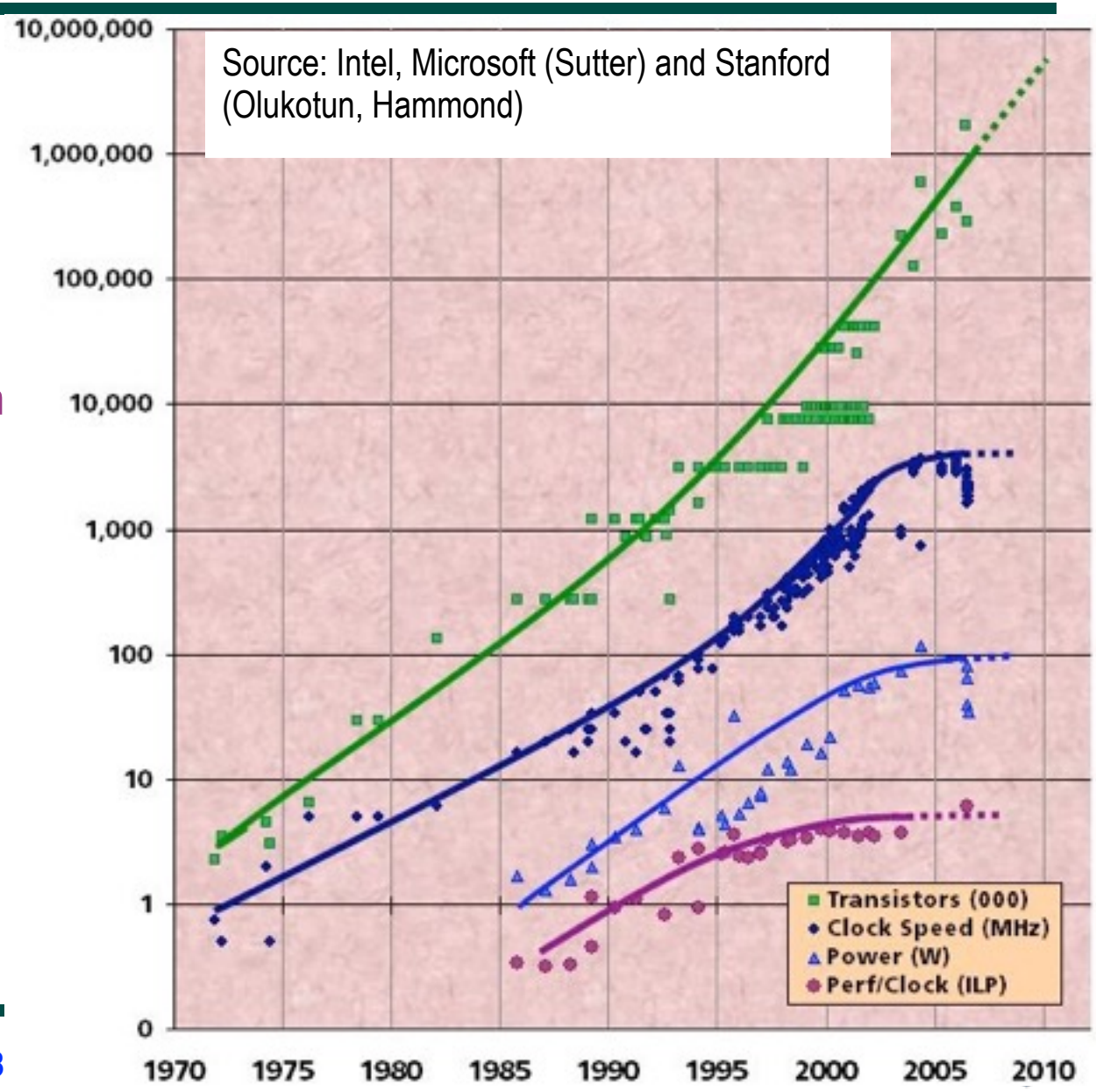
⇒ feature size reduces by √2 every 1-2 years

Dennard Scaling states that power for a fixed chip area remains constant as transistors grow smaller

Slide source: Jack Dongarra

Recent Technology Trends

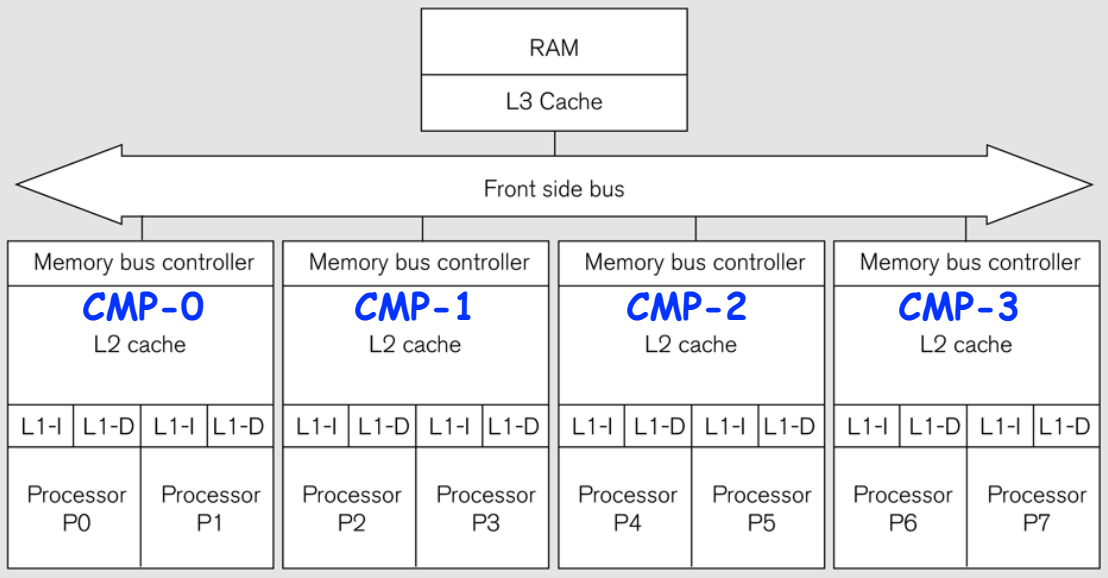
- **Chip density (transistors)** is increasing ~2x every 2 years
- **Clock speed** is plateauing below 10 GHz so that **chip power** stays below 100W
- **Instruction-level parallelism (ILP)** in hardware has also plateaued below 10 instructions/cycle
- ⇒ ***Parallelism must be managed by software!***



What is Parallel Computing?

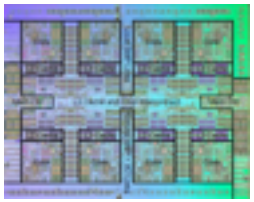
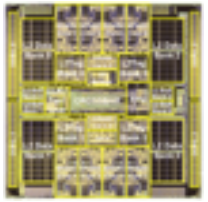
- **Parallel computing:** using multiple processors in parallel to solve problems more quickly than with a single processor and/or with less energy

- Example of a parallel computer
  - —An 8-core Symmetric Multi-Processor (SMP) consisting of four dual-core chip microprocessors (CMPs)

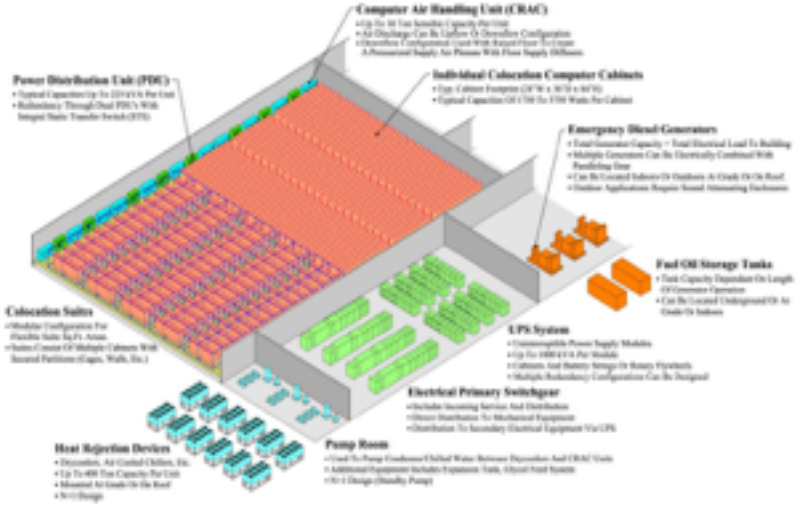


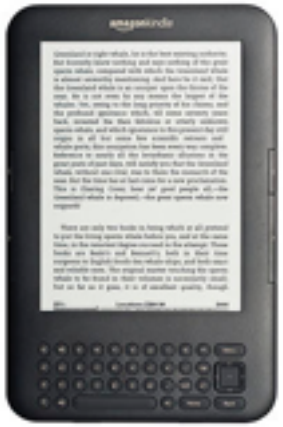
Source: Figure 1.5 of Lin & Snyder book, Addison-Wesley, 2009

All Computers are Parallel Computers --- Why?






Parallelism Saves Power (Simplified Analysis)

Nowadays (post Dennard Scaling), Power ~ (Capacitance) * (Voltage)^2 * (Frequency)

and maximum Frequency is capped by Voltage

➔ Power is proportional to (Frequency)^3

Baseline example: single 1GHz core with power P

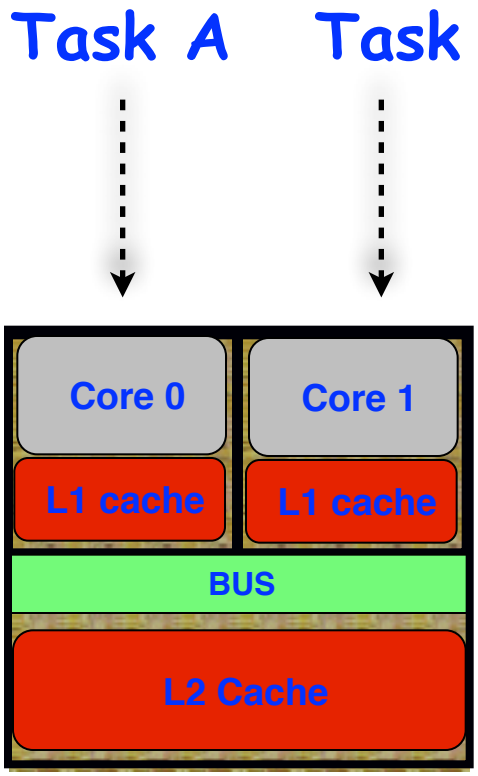
Option A: Increase clock frequency to 2GHz ➔ Power = 8P

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

- Option B delivers same performance as Option A with 4x less power … provided software can be decomposed to run in parallel!

What is Parallel Programming?

- Specification of operations that can be executed in parallel
- A parallel program is decomposed into sequential subcomputations called ***tasks***
- Parallel programming constructs define task creation, termination, and interaction



Schematic of a dual-core Processor

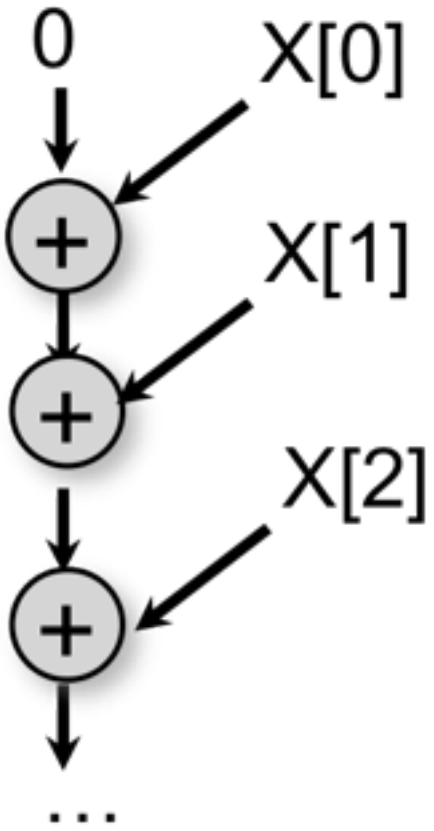
Example of a Sequential Program: Computing the sum of array elements

Algorithm 1: Sequential ArraySum

Input: Array of numbers, X.
Output: sum = sum of elements in array X.

```
sum ← 0;
for i ← 0 to X.length − 1 do
    sum ← sum + X[i];
return sum;
```

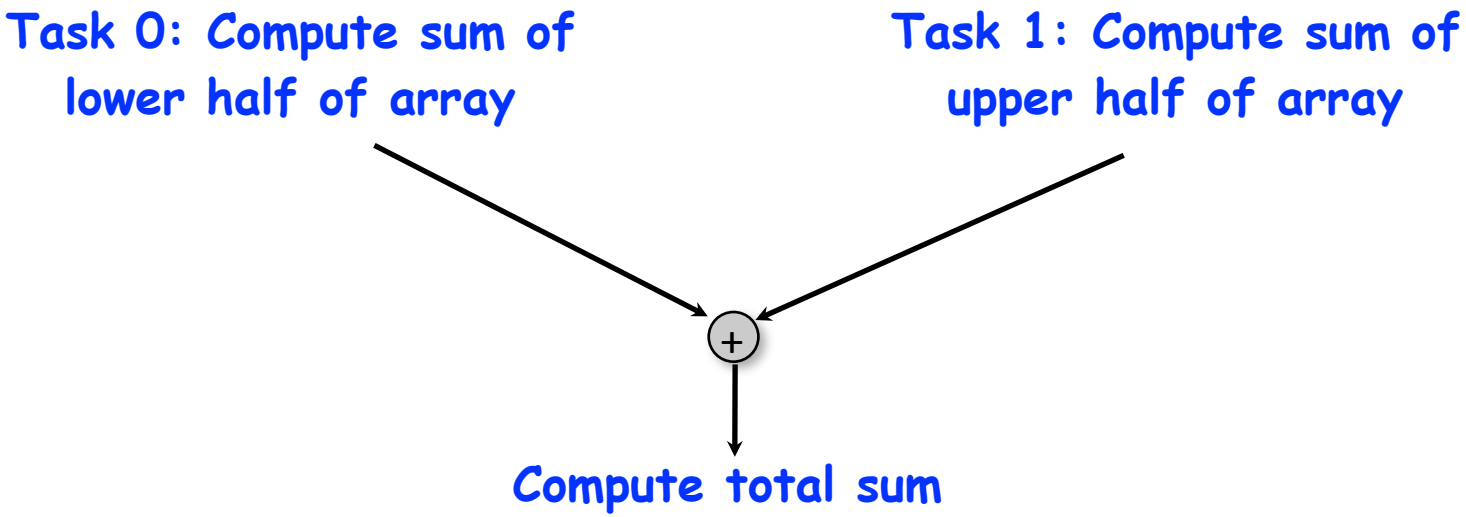
Computation Graph



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

Parallelization Strategy for two cores (Two-way Parallel Array Sum)



Basic idea:

- Decompose problem into two tasks for partial sums
- Combine results to obtain final answer
- Parallel divide-and-conquer pattern

Async and Finish Statements for Task Creation and Termination (Pseudocode)

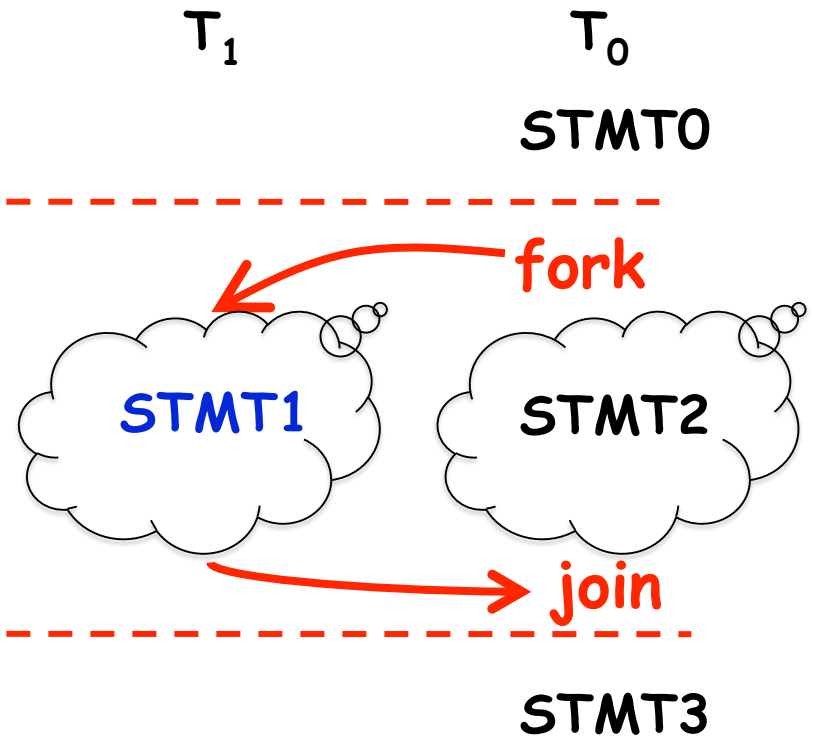
async S

- Creates a new child task that executes statement S

finish S

- Execute S, but wait until *all* asyncs in S's scope have terminated.

```
// T0 (Parent task)
STMT0;
finish {    //Begin finish
  async {
    STMT1; //T1 (Child task)
  }
  STMT2;    //Continue in T0
            //Wait for T1
}           //End finish
STMT3;      //Continue in T0
```



Two-way Parallel Array Sum using async & finish constructs

Algorithm 2: Two-way Parallel ArraySum

Input: Array of numbers, X.
Output: sum = sum of elements in array X.

```
// Start of Task T1 (main program)
sum1 ← 0; sum2 ← 0;
// Compute sum1 (lower half) and sum2 (upper half) in parallel.
finish{
    async{
        // Task T2
        for i ← 0 to X.length/2 − 1 do
            sum1 ← sum1 + X[i];
    };
    async{
        // Task T3
        for i ← X.length/2 to X.length − 1 do
            sum2 ← sum2 + X[i];
    };
};
// Task T1 waits for Tasks T2 and T3 to complete
// Continuation of Task T1
sum ← sum1 + sum2;
return sum;
```


Course Syllabus

- Fundamentals of Parallel Programming taught in three modules
  1. Parallelism
  2. Concurrency
  3. Locality & Distribution
- Each module is subdivided into units, and each unit into topics
- Lecture and lecture handouts will introduce concepts using pseudocode notations
- Labs and programming assignments will be in Java 8
  - —Initially, we will use the Habanero-Java (HJ) library developed at Rice as a pedagogic parallel programming model
    - HJ-lib is a Java 8 library (no special compiler support needed)
    - HJ-lib contains many features that are easier to use than standard Java threads/ tasks, and are also being added to future parallel programming models
  - —Later, we will learn parallel programming using standard Java libraries, and combinations of Java libs + HJ-lib

Grade Policies

Course Rubric

- Homework (5) 40% (written + programming components)
  - Weightage proportional to # weeks for homework
- Exams (2) 40% (scheduled midterm + scheduled final)
- Labs 10% (labs need to be checked off by Monday)
- Quizzes 5% (on-line quizzes on Canvas)
- Class Participation 5% (in-class worksheets)

Next Steps

- **IMPORTANT:**
  - —Bring your laptop to this week's lab at 4pm on Thursday (HH 100)
  - —Watch videos for topics 1.2 & 1.3 for next lecture on Wednesday
- **HW1 will be assigned on Jan 9th and be due on Jan 23rd. (Homework is normally due on Wednesdays.)**
- **Each quiz (to be taken online on Canvas) will be due on the Friday after the unit is covered in class. The first quiz for Unit 1 (topics 1.1 - 1.5) is due by Jan 25.**
- **See course web site for syllabus, work assignments, due dates, …**
  - **http://comp322.rice.edu**

OFFICE HOURS

- Regular office hour schedule can be found at Office Hours link on course web site
- Send email to instructors (mjoyner@rice.edu, zoran@rice.edu) if you need to meet some other time this week
- And remember to post questions on Piazza!