INFORMATION and REMINDERS

- Deadline extension for HW6: Tuesday, April 11, 11:59pm.
- HW7 has been posted. Deadline: Tuesday, April 18, 11:59pm.
- Project 2 Use \texttt{plt-r5rs} - racket version v6.5
- Midterm
  1. returned in recitation; left-over exams are with me after this week
  2. April 21 is deadline to “challenge” your grade.
- FINAL EXAM
  1. Monday, May 8, 4:00-7:00pm, College Ave. Campus
  2. cumulative, more than 60\% new material; closed book, closed notes
  3. CONFLICTS? Need to know as soon as possible; there are fixed rules to resolve conflicts
Programming with Concurrency

Why do we care about concurrency?

• Today, concurrency is nearly everywhere (peta-flops supercomputers to high-end smart phones).

• Necessary to keep “Moore’s Law” alive due to power/heat dissipation limits.

• Some form of parallel programming will be required, i.e., automatic tools have not been able to hide all aspects of concurrency.

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Need to understand the basics of parallel programming
Programming with Concurrency

Two ways of thinking about concurrency?

**data-centric view:** partition the data that can be worked on in parallel (data-level parallelism);
⇒ your work is determined by the data that you are assigned to work on.

**task-centric view:** partition the work that can be done concurrently (task-level parallelism);
⇒ your data is determined by the work that you have to do

What tasks have “to travel” to what data (data-centric) or what data has “to travel” to what tasks (task-centric) are symmetric problems.
Programming with Concurrency

Task-level parallelism can be performed at different levels:

1. **Instruction-level** parallelism (ILP) – typically exploited by hardware or compiler

2. **Loop-level parallelism** – single loop iterations are considered individual tasks

3. **Procedure-level** parallelism – different procedures may be executed concurrently

4. **Process-level** parallelism – different programs may be executed concurrently

Will concentrate on loop-level parallelism
Loop-level Parallelism

We will concentrate on compilation issues for compiling scientific codes. Some of the basic ideas can be applied to other application domains as well. Typically, scientific codes

- Use arrays as their main data structures.
- Have loops that contain most of the computation in the program.

As a result, advanced optimizing transformations concentrate on loop level optimizations. Most loop level optimizations are source-to-source, i.e., reshape loops at the source level.

We will talk about briefly about

- Dependence analysis
- Vectorization
- Parallelization
OpenMP

- Allows expression of parallelism at different levels: task and loop level
- Parallelization is done through **pragmas**.
- Look at the OpenMP documentation on our class web site.

**Shared-Memory programming model programming**
Parallel Threads Execution Model

Distributed Memory
Project and OpenMP

Two important issues while specifying the parallel execution of a `for` loops:

- **safety** – parallel execution has to preserve all dependences
- **profitability** – benefits of parallel execution have to compensate for the overhead penalty
dependence relation: Describes all statement-to-statement execution orderings for a sequential program that must be preserved if the meaning of the program is to remain the same.

There are two sources of dependences:

**data dependence**

\[ S_1 \quad \text{pi} = 3.14 \]
\[ S_2 \quad r = 5.0 \]
\[ S_3 \quad \text{area} = \text{pi} \times r^{**2} \]

**control dependence**

\[ S_1 \quad \text{if (t .ne. 0.0) then} \]
\[ S_2 \quad a = a/t \]
\[ \text{endif} \]

How to preserve the meaning of these programs?
Execute the statements in an order that preserves the original load/store order.
Dependence — Basics

Theorem

Any reordering transformation that preserves every dependence (i.e., visits first the source, and then the sink of the dependence) in a program preserves the meaning of that program.

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Note: Dependence starts with the notion of a sequential execution, i.e., starts with a sequential program.
Next Lecture

Things to do:

• Dependence analysis

• More on automatic vectorization / parallelization