Lecture 01—Introduction

ECE 459: Programming for Performance

Patrick Lam

University of Waterloo

January 7, 2014

[Thanks to Jon Eyolfson for slides!]

Course Website

`http://patricklam.ca/p4p/`

I also added everyone enrolled as of Sunday to Piazza.

Staff

Instructor

Patrick Lam p.lam@ece.uwaterloo.ca DC 2597D/DC2534

Teaching Assistants

Xavier Noumbissi	xnoumbis@uwaterloo.ca	DC 2553
Morteza Nabavi	mnabavi@uwaterloo.ca	E5-4131
Saeed Nejati	snejati@uwaterloo.ca	E5-4132

Schedule

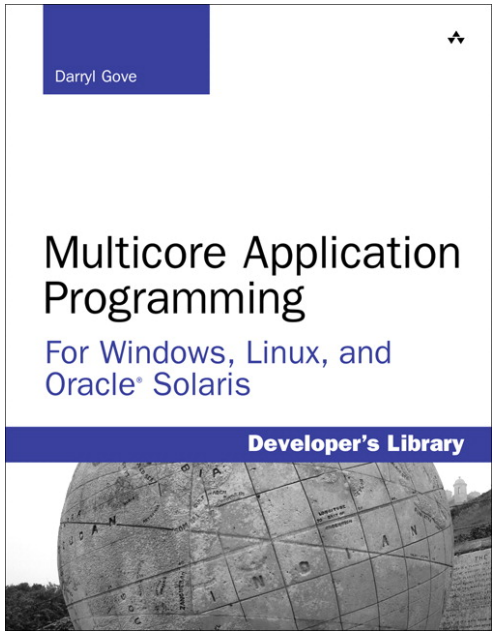
Lectures:	January 7—April 4 Tuesday 2:30 PM, RCH 302 Thursday 2:30PM QNC 2502
Tutorials:	not used
Midterm:	Wednesday February 26 19:00–20:20, DC 1530

Office Hours

Let's have them. When?

[Academic, and other, advice also available!]

Recommended Textbook



Multicore Application Programming For Windows, Linux, and Oracle Solaris. Darryl Gove. Addison-Wesley, 2010.

Goal

Make programs run faster!

Making Programs Faster

Two main ways:

Making Programs Faster

- Increase bandwidth (tasks per unit time); or
- Decrease latency (time per task).

Examples of bandwidth/latency:
Network (connection speed/ping), traffic (lanes/speed)

Our Focus

Primarily on increasing bandwidth (more tasks/unit time).

- Do tasks in parallel

Decreasing time/task usually harder, with fewer gains.

CPUs have been going towards more cores rather than raw speed.

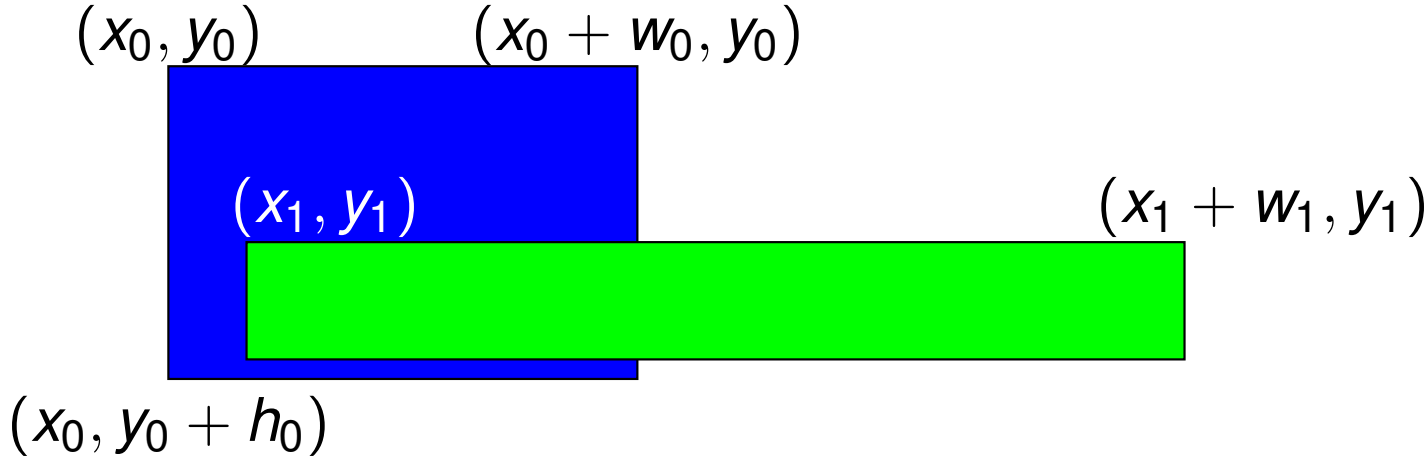
A Bit on Improving Latency

We won't return to these topics, but we'll touch on them now.

- Profile the code;
- Do less work;
- Be smarter; or
- Improve the hardware.

Intermission

While working on Assignment 1, I ran into this puzzle:



When do these rectangles intersect?

Increasing Bandwidth: Parallelism

Some tasks are easy to run in parallel.

Examples: web server requests, computer graphics, brute-force searches, genetic algorithms

Others are more difficult.

Example: linked list traversal (why?)

Hardware

- Use pipelining (all modern CPU do this):
  - Implement this in software by spliting a task into subtasks and running the subtasks in parallel
- Increase the number of cores/CPUs.
- Use multiple connected machines.
- Use specialized hardware, such as a GPU which contains hundreds of simple cores.

Barriers to parallelization

- Independent tasks (“embarrassingly parallel problems”) are trivial to parallelize, but dependencies cause problems.
- Unable to start task until previous task finishes.
- May require synchronization and combination of results.
- More difficult to reason about, since execution may happen in any order.

Limitations

- Sequential tasks in the problem will always dominate maximum performance
- Some sequential problems may be parallelizable by reformulating the implementation
- However, no matter how many processors you have, you won't be able to speed up the program as a whole (known as **Amdahl's Law**)

Data Race

- Two processors accessing the same data.

- For example, consider the following code:

```
x = 1
print x
```

You run it and see it prints 5

- **Why?** Before the print, another thread wrote a new value for `x`. This is an example of a data race.

Deadlock

Two processors trying to access a shared resource.

- Consider two processors trying to get two resources:

Processor 1	**Processor 2**
`Get Resource 1`	`Get Resource 2`
`Get Resource 2`	`Get Resource 1`
`Release Resource 2`	`Release Resource 1`
`Release Resource 1`	`Release Resource 2`

- Processor 1 gets Resource 1, then Processor 2 gets Resource 2, now they both wait for each other **(deadlock)**.

Objectives

- Implement parallel programs which use 1) synchronization primitives and 2) asynchronous I/O
- Describe and use parallel computing frameworks
- Be able to investigate software and improve its performance
- Use and understand specialized GPU programming/programming languages

Assignments

1. Manual parallelization using Pthreads/async I/O
2. Automatic parallelization and OpenMP
3. Application profiling and improvement
4. GPU programming

Breakdown

- 40% Assignments (10% each)
- 10% Midterm
- 50% Final

Grace Days

- 4 grace days to use over the semester for late assignments
- **No mark penalty** for using grace days
- Try not to use them just because they're there

Homework for Thursday

We'll be doing exercises based on this presentation:

`http://www.infoq.com/presentations/click-crash-course-modern-hardware`

I'll post the exercises on Wednesday.

Suggestions?

- Just let me know