Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Systems@ETH Zürich

Supporting Parallelism in Operating Systems & Programming Languages

Course Introduction

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What is the course about?

How the system stack supports and manages parallelism

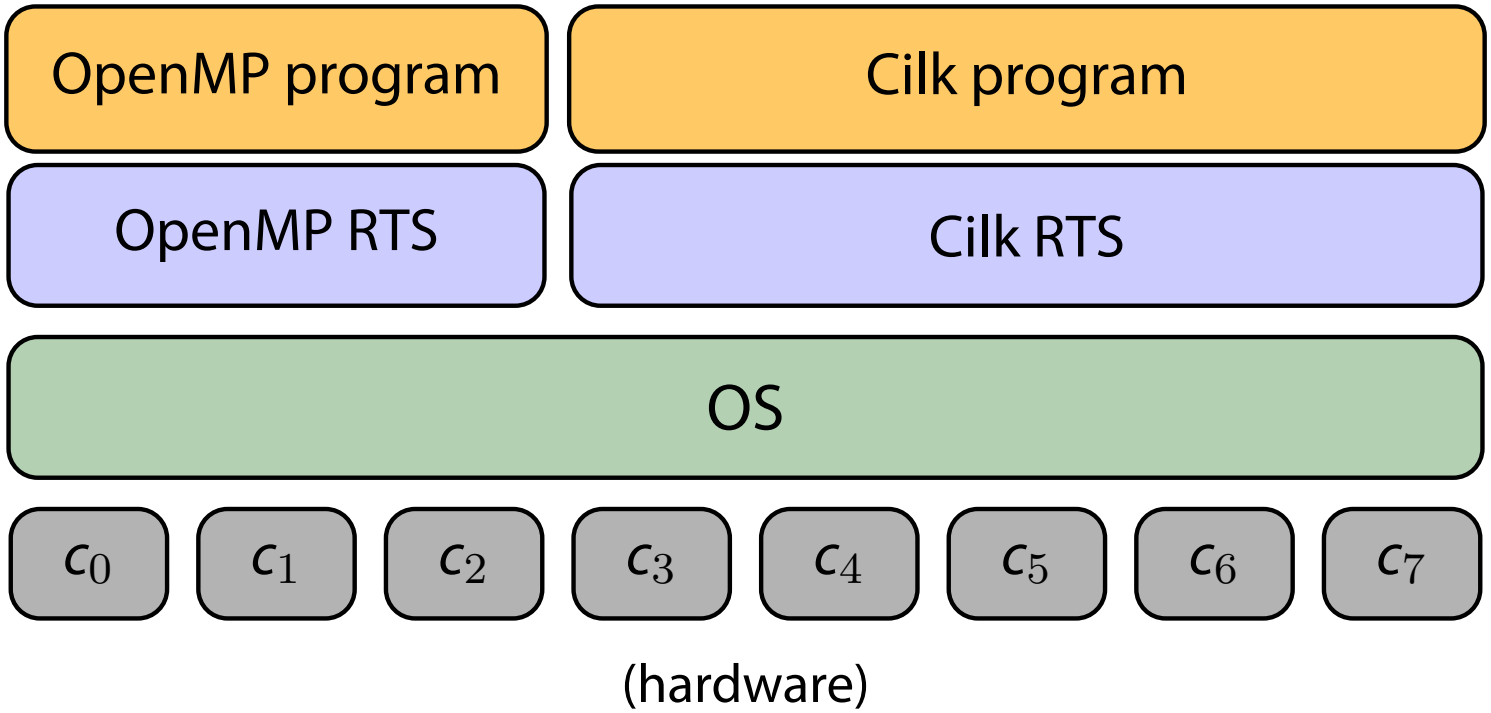
Two layers:

- Operating System (OS)
- Parallel Programming Languages (PPLs)

We will examine:

- each layer individually
- their synergy (or lack thereof)

Context: the system stack



Motivation

- Parallel machines dominate
  - parallel programming is difficult
  - system performance is critical
    (can't just wait for the next-generation faster processor)
- Cooperation of OS+PLes
  - Usually, they are designed separately
  - OSes evolved from uni-processors designs
    - e.g., typical OS designs manage processes/threads, not parallel programs
  - Parallel programming was not used in general-purpose machines
    - e.g., parallel programs assume they run alone on the machine

Course Organization

- **Lectures** (13^{00}-15^{00})[1]
  - arranged by topics (scheduling, synchronization, etc)
  - design and implementation (this is not a theory course)
- **Exercises** (15^{00}-16^{00})
  - apply (some of) the lectures' content in practice
- **Performance assessment**
  - exercises ($\sim 60\%$)
  - 15' oral examination ($\sim 30\%$)
  - class participation ($\sim 10\%$)
- **Course webpage:**
  `http://www.systems.ethz.ch/courses/fall2012/SPOSPL`

[1] time can (and will) be dynamically managed as needed

Prerequisites

Familiarity with:

- basic OS designs
- systems programming
- computer architecture

Relevant Courses by SG

- Systems Programming and Computer Architecture
  (`http://www.systems.ethz.ch/courses/fall2012/SPCA`)
- Operating Systems and Networks
  (`https://www-old.systems.ethz.ch/education/spring-2012/os_networks`)

- Let me know if I should move slower (or faster!)

Contact info

- mailing list
  - `https://lists.inf.ethz.ch/mailman/listinfo/sospl-course`
  - please subscribe
  - please don't answer questions (even if you know the answer)
  - don't post spoilers
  - try google first
    - it will probably answer faster!
- `akourtis@inf.ethz.ch`

Lectures

- about:
  - challenges posed by parallel hardware
  - design & implementation choices
  - interfaces (OS $\leftrightarrow$ RTS)

- let's make the course highly interactive
  - Please interrupt me to ask questions
  - It will help me determine the best pace

Lecture Topics Overview

- Parallelism
- Scheduling
- Synchronization
- Memory Management
- I/O
- Advanced Topics

Lecture topics: Parallelism

- Hardware
  - current (and future) parallel hardware
- OS issues
  - parallelism inside the OS
  - OS interfaces
- Parallel programming languages
  - parallel programming constructs
  - run-time support

Lecture topics: Scheduling

i.e., mapping of work units to execution units

- work units:
  - processes
  - kernel-level threads
  - user-level tasks
  - loop iterations
- load-balancing
- OS scheduling and interfaces
- Language RTS scheduling

Lecture topics: Synchronization

- Primitives
  - low-level
    - spinlocks, mutexes, semaphores
    - barriers
    - RCU
  - high-level
    - Transactional Memory
    - Message Passing
- Scaling issues in OS and RTSes
- scheduling-synchronization issues

Lecture topics: Memory Management

- Stack:
  - non-linear stacks
- Heap:
  - Allocation/management
    - e.g., `malloc()`, `free()`
  - Garbage Collection
  - Sharing Memory
  - NUMA (e.g., page migration OS policies)

Exercises: Overview

- teams of 2
- design and implementation (in C)
- 2-3 week projects
- related to lecture material

Exercise Format

- Initial exercise presentation
- First attempt to solve the problem
  - first implementation
  - intermediate report
  - check progress
- Discussion
  - first attempt discussion
  - questions/issues/problems
- Final implementation / report
  - performance measurements (?)
- <<for bonus points...>>
  - feel free to improvise!

Programming environment for exercises

Linux

- gcc
- GNU libc
- GNU/Linux-specific extensions are OK! (e.g., `-D_GNU_SOURCE`)
- pthreads
- use `-O2`
- please use `-Wall -Werror` gcc flags
- assume `x86_64` if needed
  (but: make sure to keep the arch-dependent parts separate)

libraries/OS facilities

- man pages
- documentation (e.g., glibc)
- google
- source code
  - `find`, `grep`, `ack`
  - `cscope`
- ask (mailing list)

Coding: Keep it Simple

- Debugging takes up most of the time
  - in parallel programming doubly so
- Break up your program to small, testable, units/versions
- Make sure that each of these units/versions work before proceeding
  - It will save you time in the long-run!

Coding: Optimizations

- don't try optimizations
- really, **don't do it!**
- If you have to do it:
  - make sure that it works correctly first
  - where is the bottleneck?
  - keep original (simple) version
  - try optimization and compare
  - is it worth it?
- but, **don't do it!**

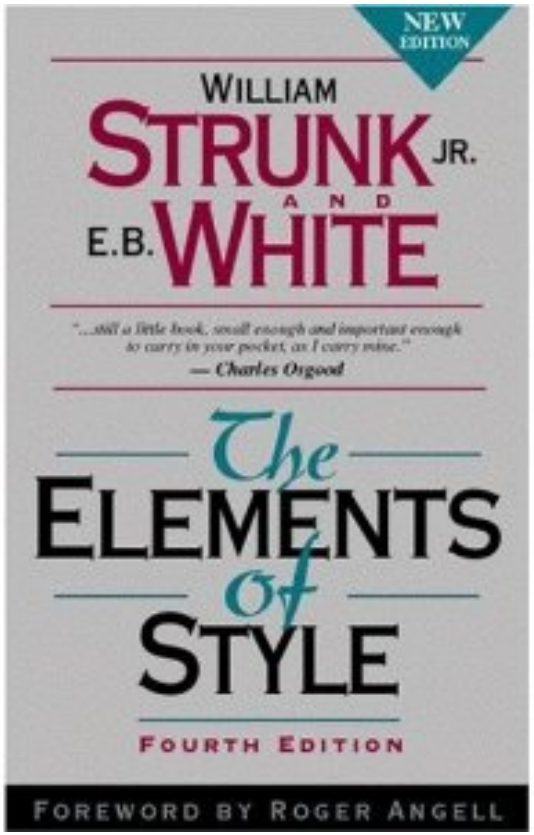
Exercise Deliverables: Overview

- Deliverables
  - code
  - reports
- by email:
  - Subject prefix: << [SPOSPL.ExerXX] >>
- you are allowed (but NOT encouraged!) to delay the deliverables of **one** exercise for a week.
  - Please use that option only if you really need it

Exercise Deliverables: Reports

- be concise
- pdf files (please do not send me .doc* files)
- answer to questions
- brief discussion of design if asked
- things you found interesting
- selecting a way to present your data using graphs is part of the exercise
- be concise

(book suggestion)



Exercise Deliverables: Code

- a tarball with the code
- or even better: setup a code repository and sent me the url

I might need to take a closer look, so please include:

- a `Makefile` for building it
  - typing `make` should build everything
  - ...cleanly
- readable source code
  - please read `Documentation/CodingStyle` of linux kernel
  - `indent` utility
- command line help
- scripts can also be helpful

Poll
(1/2)

- Do you have access to a multicore linux machine for development?
  - laptop?
  - how many cores?
- Have you ever written a parallel program?
  if yes,
  - in what language/environment
  - have you ever written code that uses locking?
  - for more than one objects?
  - deal with deadlocks?
  - deal with scalability problems?

Poll
(2/2)

- How comfortable are you with the linux programming environment?
  - do you know what the `(2)` stands for in `read(2)`?
  - experience with typical development tool-chain?
    - `make`, `gcc`, `glibc`, ...
  - experience with typical UNIX tools?
    - `find`, `grep`, ...
  - system calls? (e.g., `mmap()`)
  - pthreads
  - can you find your way around the linux kernel/gcc/glibc code?
- Have you ever written assembly code?
  - Would you like to?

Hardware for experiments

- MBS@SG ?
  - you need to send me your nethz names
- Development
  - general purpose machines: not exclusive access
    - ikqxx, incrediblesxx, shrekxx
    - use `uptime(1)`, `w(1)`, etc
  - your machine
- exclusive access machines
  - Thursdays ($06^{00} - 06^{00}$ UTC)
- please respect other users:
  - **don't** login to machines you are not supposed to
  - be nice; use common sense

https://mbs.ethz.ch/

Things to do ASAP

- Subscribe to the mailing list
- Send me an e-mail with:
  - your nethz name
- Find a partner for the exercises
  - Should I do it randomly?

Questions?