A language-oriented approach to teaching concurrency

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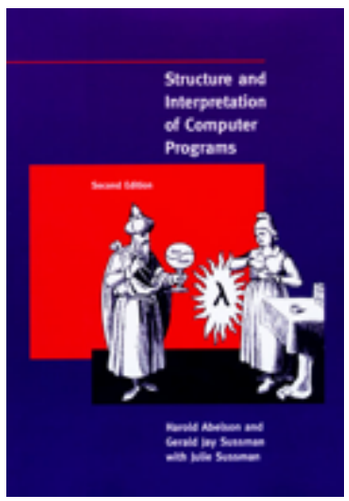
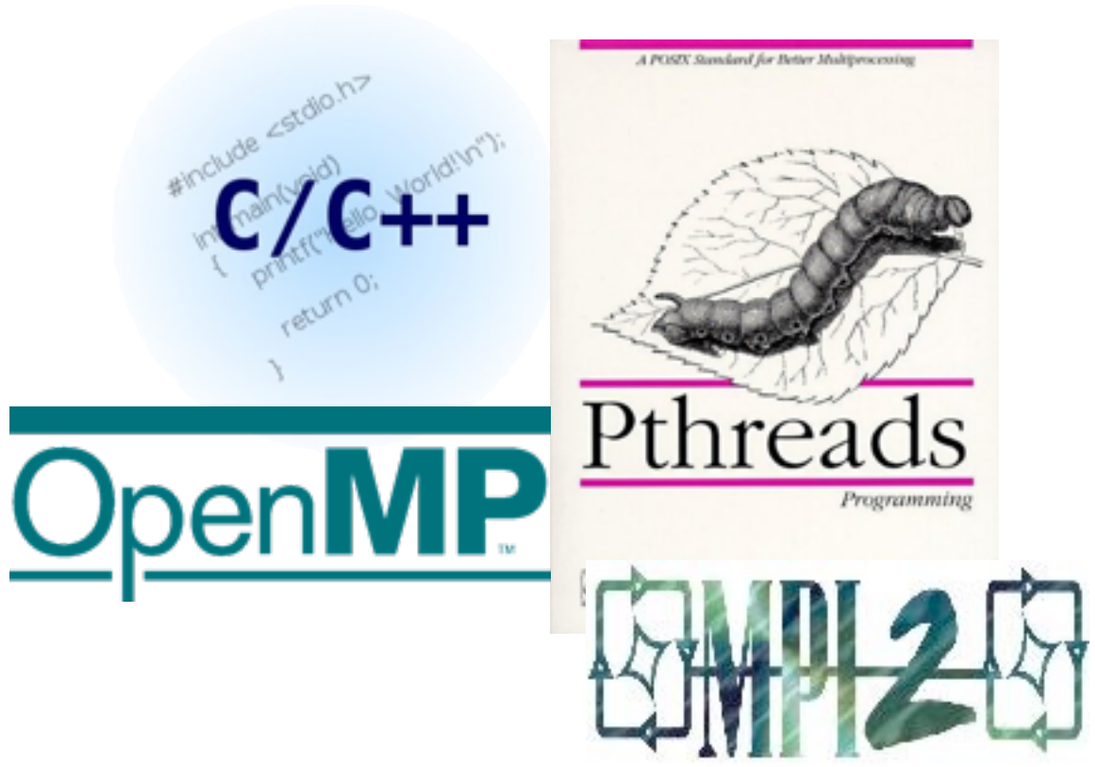
Context

- Organizing new graduate-level course on Concurrency at University of Brussels, Belgium
  - Existing course focuses on high-performance computing
- Background:



State of the art

- Pthreads, OpenMP & MPI
    - All are based on a C/C++ substrate
- Low-level models: explicit shared-state or low-level send/receive
- Low-level environments: fighting the compiler
- Primary goal = HPC



Concurrency vs HPC

- It’s not because we have multicore machines that every programmer suddenly needs to be skilled in high-performance computing

- From an article in ACM Queue (Oct. 2008): “Real-World Concurrency” by Bryan Cantrill and Jeff Bonwick:

  - *“[T]he proliferation of concurrent hardware has awakened an anxiety that all software must use all available physical resources. Just as no programmer felt a moral obligation to eliminate pipeline stalls on a superscalar microprocessor, no software engineer should feel responsible for using concurrency simply because the hardware supports it.”*

Why use a concurrent language?

- Concurrent programming is difficult. Until mastered, don’t make it harder than strictly necessary
  - Use a language designed for the task
  - Changes the “path of least resistance”
    - Language should encourage use of good patterns, inhibit use of bad practices
    - Easier to unlearn/avoid existing habits that conflict with concurrency goals

- Synergy between functional and concurrent programming

Functional programming

- Overloaded term:
  - referential transparency
  - deterministic functions
  - higher-order abstractions
  - parametric type systems
  - lazy computation
  - **immutable data**

Immutability

- Because side-effects are at the root of most problems in concurrent programming
  - *“Side effects prevent concurrency”*
    [Joe Armstrong, Programming Erlang]

  - *“By emphasizing pure functions that take and return immutable values, [functional programming] makes side effects the exception rather than the norm. This is only going to become more important as we face increasing concurrency in multicore architectures”*
    [Rich Hickey, from foreword of Programming Clojure]

- Key message to students: “embrace immutability”

What functional language to choose?

- Loose criteria:
  - Promulgate functional programming style (w/ focus on immutable data)
  - Sufficiently practical (reliable implementation, sufficient documentation)
  - *“A language that doesn't affect the way you think about programming, is not worth knowing.”* [Alan Perlis, Epigrams in Programming]

Many choices

Haskell

A Purely Functional Language

featuring static typing, higher-order functions, polymorphism, type classes and monadic effects

F#

Jo&Caml

Clojure

Many choices

Clojure

We chose Erlang + Clojure. Why?

- Cultural bias: SICP, dynamic typing, experience with actor-based languages => YMMV

- Choices encompass complementary hardware architectures, concurrency models:

  - Erlang: distributed memory architectures, message passing model

  - Clojure: shared memory architectures, shared state model

Conclusion

- Concurrency control is essential to any software engineer, not just HPC programmers. It's not { just | all } about performance.
- C + library is not the most efficient medium to teach concurrency
- Get at the core of the problem: side effects => embrace immutability
  - Choose a language that makes this the natural thing to do
- We settled on Erlang + Clojure.
- Feedback / Thoughts?