Overview

Concurrency Models

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Course Design

• Objectives: Concurrency programming *theories* and *practices*
• Lecturer: Yanqiao ZHU
  • Research interests:
    • Data Mining and Data Analysis
    • Machine Learning
    • Concurrency and Distributed Systems
• Teaching language: Chinese lectures, with English presentation slides
• No homework, but necessary preparation needed.
• Code examples will be drawn from a number of programming languages.
  • Java, C++, Clojure (Haskell), Elixir (Erlang), Python, Go, possibly more...
  • To make use of a specific concurrency framework, it requires a specific language.
• Refer to tutorials of different programming languages in advance.
Concurrent or Parallel?

• When we execute a program, we create a process.
  • A sequential program has a single thread of control.
  • A concurrent program has multiple threads of control.

• A single computer can have multiple processes running at once.
  • If that machine has a single processor, then the illusion of multiple processes running at once is just that: an illusion.
  • That illusion is maintained by the operating system; it coordinates access to the single processor by the various processes; only one process runs at a time.

• If a machine has more than a single processor, then true parallelism can occur.
  • You can have $N$ processes running simultaneously on a machine that has $N$ processors.
• A *concurrent* program has multiple logical threads of control. These threads may or may not run in parallel.

• A *parallel* program potentially runs more quickly than a sequential program by executing different parts of the computation *simultaneously* (in parallel). It may or may not have more than one logical thread of control.

• *Concurrency* is a property of the code; *parallelism* is a property of the running program.
• Alternative way of thinking about it:
  • Concurrency is part of the problem domain.
    • Multiple events can happen at the same time.
  • Parallelism is an aspect of the solution domain.
    • Design a program such that computations occur simultaneously.
Concurrency: Beyond Multiple Cores

- Responsiveness
- Fault Tolerance
- Efficiency
- Simplicity
Why Worry about Concurrency?

• “Concurrency is hard and I’ve only ever needed single-threaded programs. Why should I care about it?”

• The days of waiting for faster hardware is (long) gone.
• To make software systems that perform efficiently, you need to incorporate concurrency into your system designs.
“Concurrency is hard and I’ve only ever needed single-threaded programs. Why should I care about it?”

Changing environment
- multicore computers (including handheld devices)
- use of computing clusters to solve problems on the rise

Performance
- Growth rates for chip speed are flat; You can’t wait 18 months for a 2x speed-up anymore.
- Instead, chips are becoming “wider”: more cores, wider bus (more data at a time), more memory.
Why Worry about Concurrency? (cont.)

• Chips are not getting faster (in the same way they used to).
  • A single-threaded, single-process application is not going to see any significant performance gains from new hardware.

• Instead, software will only see performance gains from new hardware.
  • If it is designed to do more work in parallel.
  • As the number of processors available to it increases.

• The application’s computations must be amenable to parallelization.
  • It must be possible to break its work into tasks that can run at the same time with no need to coordinate with each other.

• Concurrent programming is becoming hard to ignore.
  • Lots of application domains in which concurrency is the norm.
• While concurrency is widespread, it is error prone.

• Programmers trained for single-threaded programming face unfamiliar problems.
  • Synchronization
  • Race conditions
  • Deadlocks
  • “Memory barriers”
Parallel Architecture

Bit-Level
• The history of computing moves from 8- to 16-, 32-, and now 64-bit architectures.

Instruction-Level
• Modern CPUs are highly parallel, using techniques like pipelining, out-of-order execution, and speculative execution.

Data-Level
• *Data-parallel* (SIMD, for “single instruction, multiple data”) architectures are capable of performing the same operations on a large quantity of data in parallel.

Task-Level
• *Distributed-memory system*: each processor has its own local memory and where interprocessor communication is primarily via the network.
When designing a modern application, we now have to ask

- How many machines are involved?
- What software components will be deployed on each machine?
- For each component
  - Does it need concurrency?
  - If so, how will we achieve that concurrency?
    - multiple threads?
    - multiple processes?
    - both?
Google made a splash in 2008 by announcing the creation of a new web browser that was

- multi-process (one process per tab) and
- multi-threaded (multiple threads handle loading of content within each tab)

They documented their engineering choices via a comic book.

Advantages: stability, speed and security.
Course Topics

1. Intro. to Parallel Computing
2. Multithreaded Programming
3. Intro. to Asynchronous Programming
4. Functional Programming
5. The Actor Model
6. The CSP Model
7. The Lambda Architecture
Bibliographies

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Seven Databases in Seven Weeks
Seven Languages in Seven Weeks
Seven More Languages in Seven Weeks
Java Concurrency in Practice
C++ Concurrency In Action
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Programming Elixir 1.3
Parallel and Concurrent Programming in Haskell

Operating System Concepts (9th Edition)

The Art of Multiprocessor Programming (Revised 1st Edition)

Big Data: Principles and Best Practices of Scalable Real-time Data Systems

Big Data SMACK

Concepts, Techniques, and Models of Computer Programming

Concurrency in Go

The Little Elixir & OTP Guidebook
Thank You