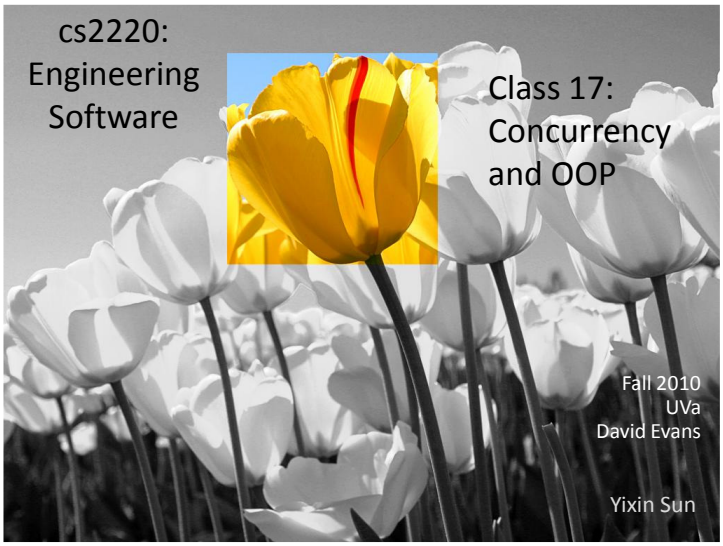

PS5 Designs [Throughout the Day]

1. Blanton, James — Kalish, Michael
2. Borja, Joseph — Oh, Uyn — Noh, Brian
3. Brown, Jeremy — Hearn, Charles
4. Chen, Jiamin — Sparkman, Elisabeth — Sun, Yixin
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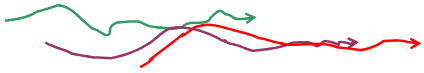
8. Herder, Samuel — Wallace, Alexander

Partial Ordering of Events

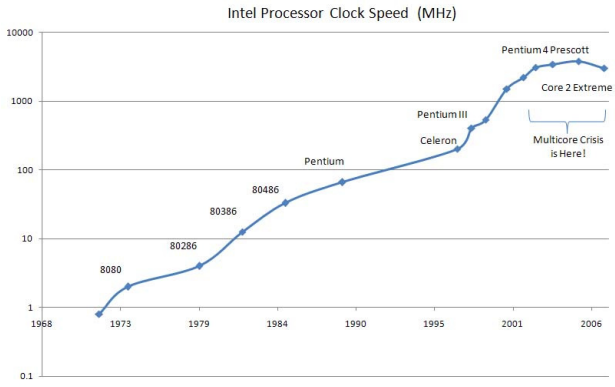
- Sequential programs give use a *total ordering* of events: everything happens in a determined order
- Concurrency gives us a *partial ordering* of events: we know some things happen before other things, but not total order



How is concurrency a kind of abstraction?

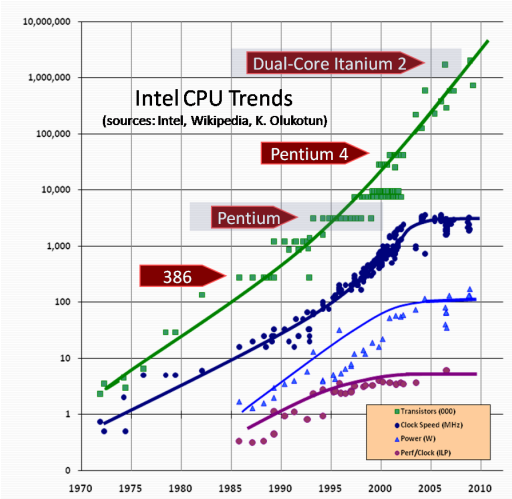
Value of Concurrency

- As an **abstraction**: hides the details of exactly when things happen
  - Program thinking about objects
  - Interleaving of events
- Opportunity for **implementations**:
  - Execute faster by using multiple cores



A Picture of the Multicore Crisis

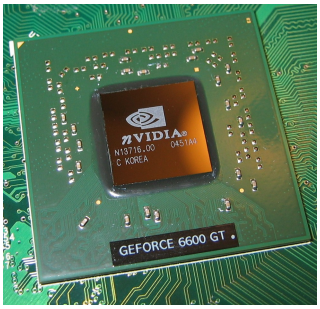
http://smoothspan.wordpress.com/2007/09/06/a-picture-of-the-multicore-crisis/



The Free Lunch Is Over: A Fundamental Turn Toward Concurrency in Software, Herb Sutter

http://www.gotw.ca/publications/concurrency-ddj.htm

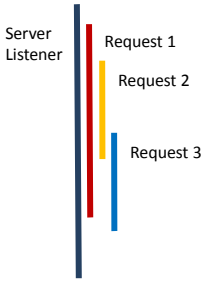
Where is most of the processing power on your PC?



nVIDIA GeForce GTX 470
448 Cores

nVIDIA QuadroPlex 7000 DHIC
1792 cores

Challenge of Concurrency

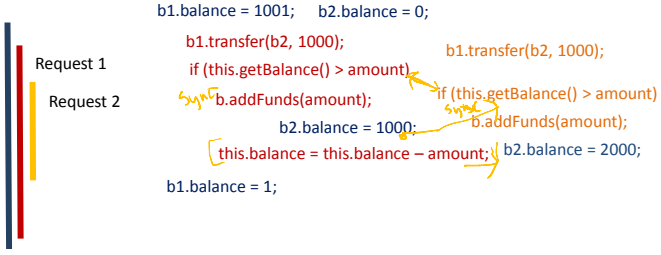


Instruction Streams

Store

Shared Data

```
public class BankAccount {
  private int balance;
  ..
  public void transfer(BankAccount b, int amount) throws InsufficientFundsException {
    // MODIFIES: this, b
    // EFFECTS: If this account has more than amount value, transfers amount from
    // this account to b. Otherwise, throws InsufficientFundsException.
    if (this.getBalance() > amount) {
      synchronized(b) {
      b.addFunds(amount);
      this.balance = this.balance – amount;
    } else { throw new InsufficientFundsException(); }
  }
```



Why are threads hard?

Too few ordering constraints: **race conditions**

Too many ordering constraints: **deadlocks**

poor performance, livelocks, starvation

Hard/impossible to reason modularly

- If an object is accessible to multiple threads, need to think about what any of those threads could do at any time!

Testing is **even more impossible** than it is for sequential code

- Even if you test all the inputs, don't know it will work if threads run in different order

Solutions

No shared store

Functional programming

Scheme without **set!**, **set-car!**, **set-cdr!**

Use analysis tools and locking discipline

http://findbugs.sourceforge.net/

Force **determinism**

Require thread interleavings to happen in a predictable way

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from Class 2...

Buzzword Description

"A ~~simple~~, **object-oriented**, distributed, interpreted, **robust**, **secure**, architecture neutral, portable, high-performance, **multithreaded**, and dynamic language." [Sun95]

As the course proceeds, we will discuss how well it satisfies these "buzzwords". You should especially be able to answer how well it satisfies each of the blue ones in your final interview.

What does is mean for a language to be "Object-Oriented"?

What is an Object?

- Packaging state and procedures
  - state: the rep
    - What a thing is
  - procedures: methods and constructors
    - What you can do with it

Bjarne Stroustrup (C++)'s Answer

"Object-oriented programming is programming with inheritance. Data abstraction is programming using user-defined types. With few exceptions, object-oriented programming can and ought to be a superset of data abstraction. These techniques need proper support to be effective. Data abstraction primarily needs support in the form of language features and object-oriented programming needs further support from a programming environment. To be general purpose, a language supporting data abstraction or object-oriented programming must enable effective use of traditional hardware."

"I invented the term *Object-Oriented* and I can tell you I did not have C++ in mind."

Alan Kay

Programming Language History

- Before 1954: twidling knobs, machine code, assembly code
- FORTRAN (John Backus, UVa dropout, 1954) – Formula Translation
- Algol (Peter Naur, Alan Perlis, et. al., 1958-1960)
  - Most influential programming language
  - Many of the things Algol did first (types, while, blocks) are in Java

BNF Grammar

Programming Language History

Simula (Dahl and Nygaard, 1962-7)
- First language with subtyping and inheritance

CLU (Liskov et. al., 1970s)
- First language with good support for **data abstraction** (but no subtyping or inheritance)

Smalltalk (Kay et. al., 1970s)
- First successful language and programming system to support subtyping and inheritance

2002 Turing Award

2008 Turing Award

2003 Turing Award

Simula

- Considered the first "object-oriented" programming language
- Language designed for *simula*tion by Kristen Nygaard and Ole-Johan Dahl (Norway, 1962)
- Had special syntax for defining classes that packages state and procedures together

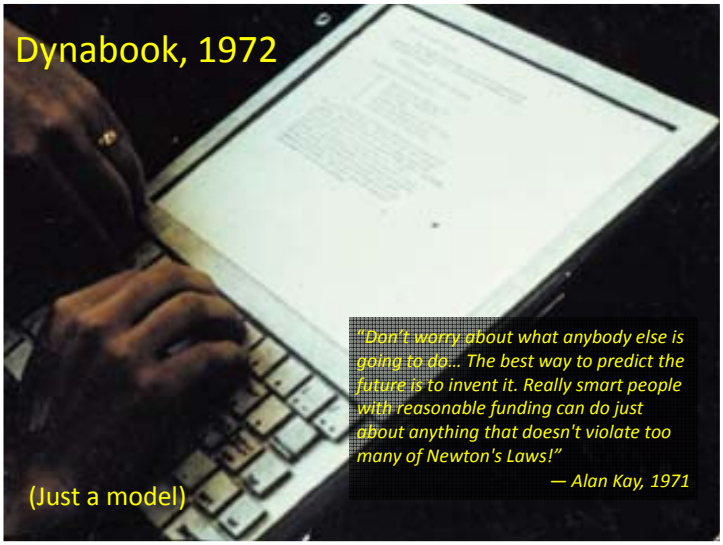
Counter in Simula

```
class counter;
  integer count;
  begin
    procedure reset(); count := 0; end;
    procedure next();
        count := count + 1; end;
    integer procedure current();
        current := count; end;
  end
```

Does this have everything we need for "object-oriented programming"?

XEROX Palo Alto Research Center (PARC)

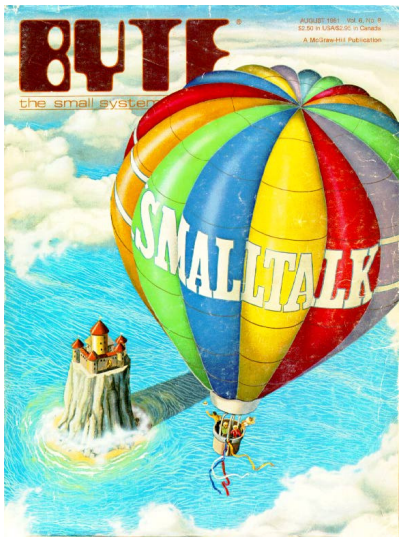
1970s:
- Bitmapped display
- Graphical User Interface
  - Steve Jobs paid $1M to visit and PARC, and returned to make Apple Lisa/Mac
- Ethernet
- First personal computer (Alto)
- PostScript Printers
- **Object-Oriented Programming**



Dynabook 1972

- Tablet computer intended as tool for learning
- Alan Kay wanted children to program it also
- Hallway argument, Kay claims you could define "the most powerful language in the world in a page of code"

Proof: **Smalltalk**
Scheme is as powerful, but takes two pages
Simple Java compiler and VM requires thousands of pages



BYTE Magazine, August 1981

Smalltalk

- Everything is an *object*
- Objects communicate by sending and receiving *messages*
- Objects have their own state (which may contain other objects)
- How do you do 3 + 4?

  send the object **3** the message **"+ 4"**

Counter in Smalltalk

```
class name counter
  instance variable names count
  new count <- 0
  next count <- count + 1
  current ^ count
```

CLU

- Developed by Barbara Liskov and colleagues at MIT (1973-1978)
- First language to provide real support for data abstraction
  - Encapsulation
  - Abstract data types: hide representation outside data type implementation
  - Parameterized types (generics), iteration abstraction, exceptions

Problems in Simula that motivated CLU

1. "Simula did not support encapsulation, so its classes could be used as a data abstraction mechanism only if programmers obeyed rules not enforced by the language."
2. Simula did not provide support for user-defined type "generators." These are modules that define groups of related types, e.g., a user-defined set module that defines set[int], set[real], etc.
3. It associated operations with objects, not with types.
4. "It treated built-in and user-defined types non-uniformly. Objects of user-defined types had to reside in the heap, but objects of built-in type could be in either the stack or the heap."

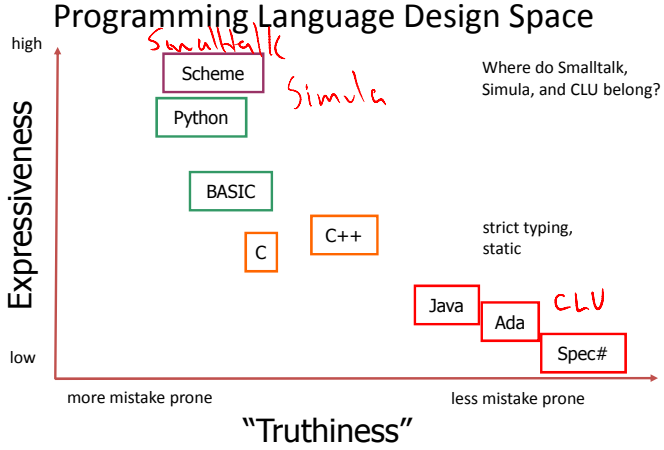
Barbara Liskov, *A History of CLU*, 1992

CLU "solved" all of these…how many do Java solve?

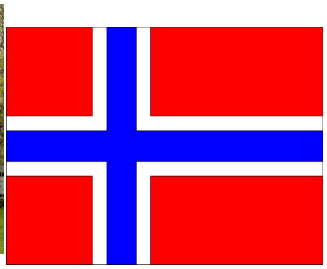
counter in CLU

```
counter = cluster is create, next, current
  rep = record [count: int];
  create = proc () returns (counter);
     return up(rep${count: 0});
     end create;
  next = proc (c: counter);
     val : rep := down(c);
     val.count := val.count + 1;
     end next;
  current = proc (c: counter) returns (int);
     return (down(c).count);
     end current;
  end counter;
```

Programming Language Design Space



So, who really was the first object-oriented programmer?



Edsger Dijkstra (1930-2002)
1972 Turing Award Winner

Object-oriented programming is an exceptionally bad idea which could only have originated in California.

Object-Oriented Programming

Object-Oriented Programming is a *state of mind* where you program by *thinking about objects*

It is difficult to reach that state of mind if your language doesn't have:

Mechanisms for packaging state and procedures

Subtyping Java has **extends** and **implements**

Java has **class**

Other things can help: **dynamic dispatch**, **inheritance**, **automatic memory management**, **everything is an object**, **mixins**, **good donuts**, etc.

Who was the first object-oriented programmer?

By the word operation, we mean any process which alters the mutual relation of two or more things, be this relation of what kind it may. This is the most general definition, and would include all subjects in the universe. **Again, it might act upon other things besides number, were objects found whose mutual fundamental relations could be expressed by those of the abstract science of operations...** Supposing, for instance, that the fundamental relations of pitched sounds in the science of harmony and of musical composition were susceptible of such expression and adaptations, the engine might compose elaborate and scientific pieces of music of any degree of complexity or extent.

Ada, Countess of Lovelace, around 1843