# CS 312 Lecture 1
# Course overview

Dan Huttenlocher
Cornell University Computer Science
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# Course staff

- Prof. Dan Huttenlocher
- Grad TAs:
  - Jean-Baptiste Jeannin
  - Ed McTigue
- UG Consultants:
  - Andrew Owens
  - Tanya Gupta
  - Rick Ducott
  - Dane Wallinga
  - David Kupiec
  - Matt Pokryzwa
  - Jerzy Hausknecht
  - Jacob Bank
  - Nyk Lotocky

- Office, consulting hours posted on web
- Consulting Sun, Tue, Wed, Thu evenings
- Use TA, instructor office hours!

# What this course is about

Helping you become expert designers and developers of valuable software systems.

**1) Programming paradigms**

New programming language concepts and constructs

**2) Reasoning about programs**

- Correctness
- Performance
- Designing for change and reuse

**3) Tools**

Data structures and algorithms

# Course meetings

- Lectures Tues, Thurs: Phillips 219
- Recitations Monday, Wednesday
  - Upson 109, at 2:30pm
  - Upson 109, at 3:35pm
  - Possible third section – early evening?

- New material is presented in lecture **and** recitation
- Attendance is expected at lecture **and** recitation
- Participation counts

# Course web site

http://www.cs.cornell.edu/courses/cs3110

- Announcements
- Lecture notes
- Assignments
- Course software
- OCaml documentation
- Other resources

# Course newsgroup

cornell.class.cs312

- A great place to ask questions!
- A great place to see if your question has already been asked
- A place to discuss course ideas
  - But don’t solve assignments for other people

# Readings

- Course material in lecture notes on website
  - But you are also responsible for in-class material…
- Some other useful texts:
  - *The Objective Caml System*, Leroy et al. (online)
  - *Introduction to Objective Caml*, Hickey. (online)

# Assignments

- 6 problem sets – generally due Thursdays
  - PS1 released Thursday, due Jan. 29: “OCaml Warmup”
- Mix of programming, written problems
- Submitted electronically via CMS
  - 24 hours late 10% penalty, 48 hours late 20% penalty
- Four single-person assignments (1–4)
  - Two weeks each
- Two two-person assignments (5–6)
  - Three weeks each

# Exams

- Exams test material from lectures, problem sets, assume you have done assignments

- Prelim 1: March 5, 7:30PM
- Prelim 2: April 14, 7:30PM

- Final exam May 8, 2:00PM

- Any makeup exams must be scheduled within the first two weeks of class
  - Check your schedule and let me know!

# Academic integrity

- Strictly and carefully enforced
  - Please don't make us waste time on this
  - Automated tools readily reveal code similarity even if you try to hide it by changing names, spacing, etc.
  - Written problems also often surprisingly easy to see
- Start assignments early and get help from course staff!
  - Use the generous late policy if you can't make the deadline

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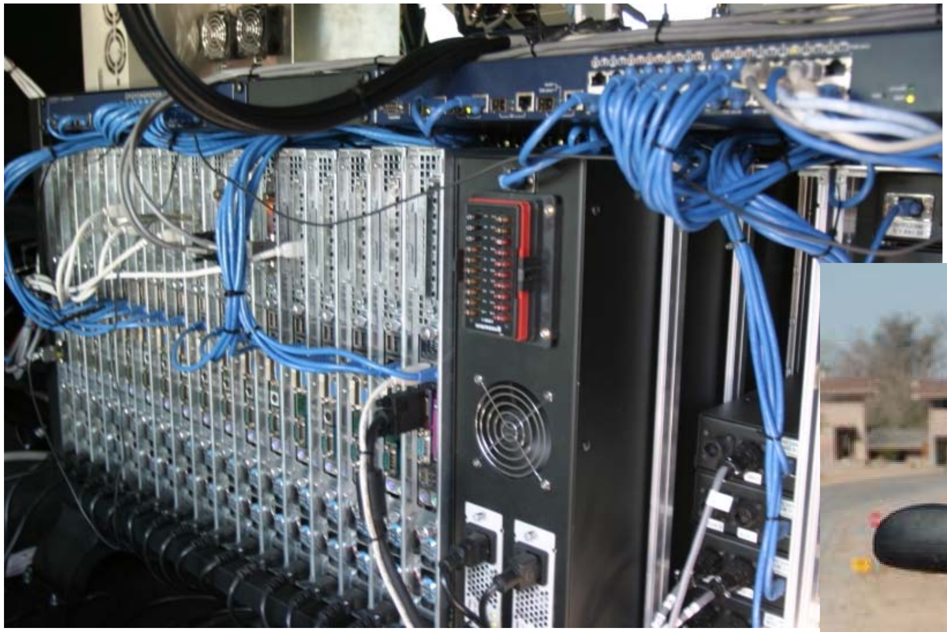
# Why do you need this class?

- Skills and ideas that will help you become better software designers and implementers
  - 10x difference in productivity, fun, …

- A course about creating good software – just because you write it doesn't make it good
  - Correct
  - Fast
  - Maintainable
  - Reusable

- Needed in many upper level courses
- Needed for serious programming tasks
- Needed for managing programming projects

# Programming any big system



# 1) Programming Paradigms

- Functional programming
- Polymorphism
- Pattern matching
- Modular programming – beyond OO/classes
- Concurrent programming – multi-core and UI
- Types and type inference
- Managed memory (garbage collection)

- We'll use ML to convey these concepts
  - The important part are the concepts, not the ML syntax!

# 2) Programming Techniques

- *Design and reasoning: critical to robust, trustworthy software systems*.
- Design and planning:
  - Modular programming
  - Data abstraction
  - Specifications, interfaces, data structures (the curse of bad ones)
    - Interfaces as treaties
- Reasoning about programs
  - Program execution models
  - Reasoning about program correctness
  - Reasoning about performance via asymptotic complexity
  - Using induction to reason about program behavior
- Testing

# 3) Data Structures & Algorithms

- Standard structures: lists, trees, stacks, graphs, etc.
  - Functional versions of these structures

- More advanced structures:
  - Balanced trees: AVL, Red-Black, B-trees, splay trees
  - Disjoint sets
  - Hash tables
  - Binary heaps

- Algorithms on these data structures
  - Analysis of correctness and performance

# Imperative style

- Program uses **commands** (a.k.a **statements**) that *do* things to the **state** of the system:
  - x = x + 1;
  - p.next = p.next.next;

- Functions/methods can have **side effects**
  - int wheels(Vehicle v) { v.size++; return v.numw; }

# Functional style

- **Idea:** program without side effects
  - Effect of a function is *only* to return a result value

- Program is an **expression** that **evaluates** to produce a **value** (e.g., 4)
  - E.g., 2+2
  - Works like mathematical expressions

- Enables **equational reasoning** about programs:
  - if x = y, replacing y with x has no effect:

**`let x = f(0) in x+x`** same as **`f(0)+f(0)`**

# Functional style

- Binding variables to values, not changing values of existing variables

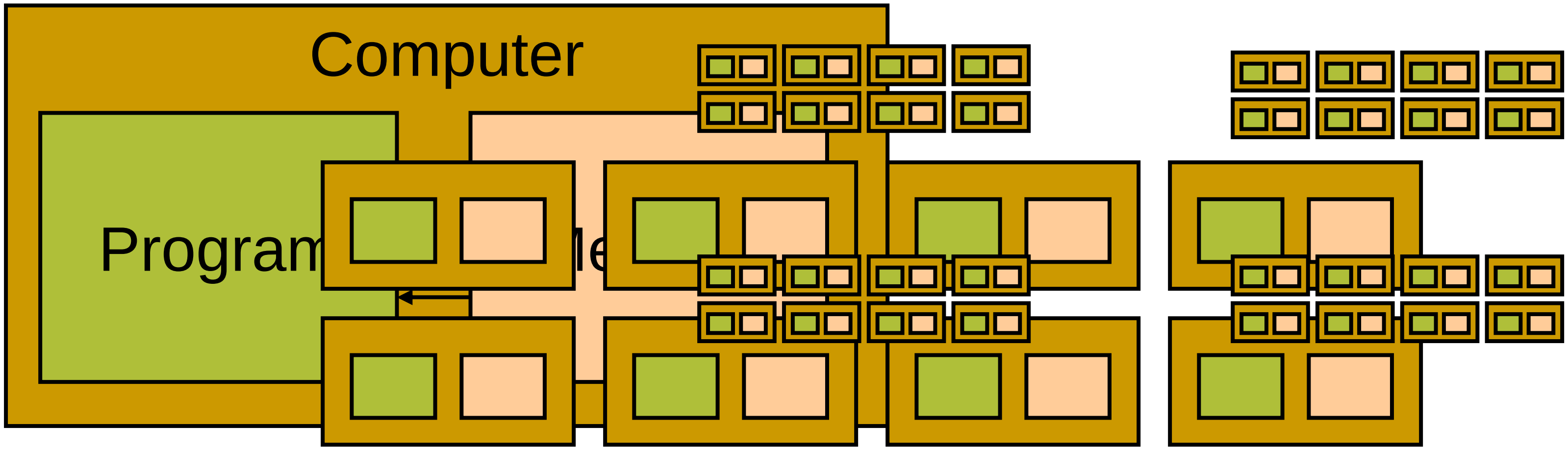
- No concept of **`x=x+1`** or **`x++`**

- Neither of these does anything remotely like **`x++`**

```
let x = x+1 in x
let rec x = x+1 in x
```

- Former assumes an existing binding for **`x`** and creates a new one (no modification of **`x`**), latter is invalid expression

# Trends against imperative style



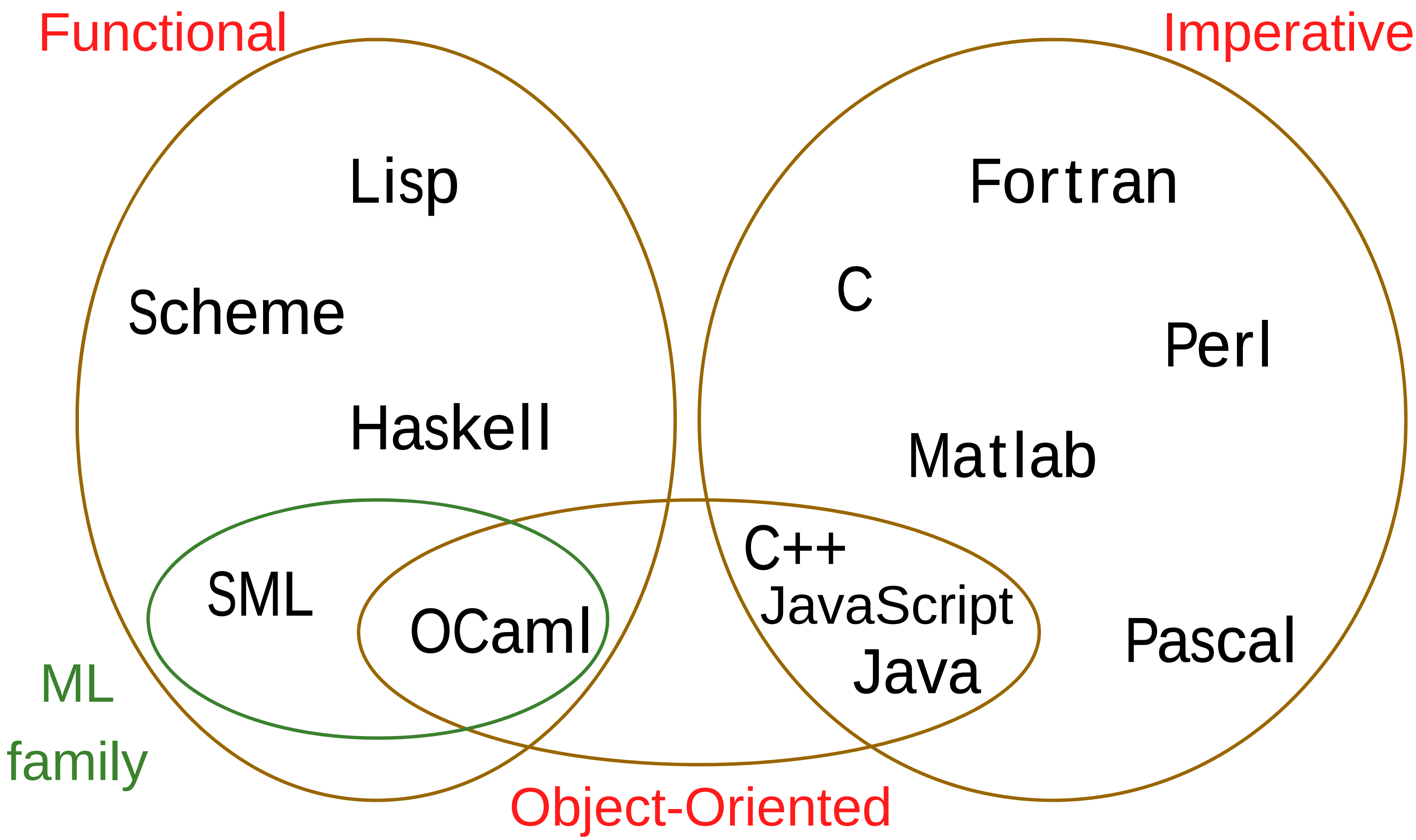

- **Fantasy:** program interacts with a single system state
  - Interactions are reads from and writes to variables or fields.
  - Reads and writes are very fast
  - Side effects are instantly seen by all parts of a program
- **Reality today:** there is no single state
  - Multicores have own caches with inconsistent copies of state
  - Programs are spread across different cores and computers (PS5 & PS6)
  - Side effects in one thread may not be immediately visible in another
  - **Imperative languages are a bad match to modern hardware and it's only getting worse**

# Imperative vs. functional

- ML: a *functional* programming language
  - Encourages building code out of functions
  - Like mathematical functions; f(x) always gives the same result
  - No side effects: easier to reason about what happens
  - Equational reasoning is easier
  - A better fit to hardware, distributed and concurrent programming

- Functional style usable in Java, C, …
  - Becoming more important with fancy interactive UI’s and with multiple cores
  - A form of encapsulation – hide the state and side effects inside a functional abstraction

# Programming Languages Map



# Imperative “vs.” functional

- Functional languages:
  - Higher level of abstraction
  - Closer to specification
  - Easier to develop robust software

- Imperative languages:
  - Lower level of abstraction
  - Often more efficient
  - More difficult to maintain, debug
  - More error-prone

# Example 1: Sum Squares

```
y = 0;
for (x = 1; x <= n; x++) {
  y = y + x*x;
}
```

# Example 1: Sum Squares

```
int sumsq(int n) {
    y = 0;
    for (x = 1; x <= n; x++) {
        y += x*x;
    }
    return n;
}
```

```
let rec sumsq (n:int):int =
  if n=0 then 0
  else n*n + sumsq(n-1)
```

# Example 1: Sum Squares Revisited

Types can be left implicit and are then inferred: **n** an integer, returns an integer

```
let rec sumsq n =
  if n=0 then 0
  else n*n + sumsq(n-1)
```

# Example 1a: Sum f's

Functions are first-class objects, used as arguments returned as values

```
let rec sumop f n =
  if n=0 then 0
  else f n + sumop f (n-1)

sumop (function x -> x*x*x) 5
```

# Example 2: Reverse List

```
List reverse(List x) {
   List y = null;
   while (x != null) {
      List t = x.next;
      x.next = y;
      y = x;
      x = t;
  }
  return y;
}
```

# Example 2: Reverse List

```
let rec reverse lst =
  match lst with
      [] -> []
    | h :: t -> reverse t  @ [h]
```

Pattern matching simplifies working with data structures, being sure to handle all cases

# Example 3: Pythagoras

```
let pythagoras x y z =
  let square n = n*n in
    square z = square x + square y
```

Every expression returns a value, when this function is applied it returns a Boolean value

# Why ML?

- ML (esp. Objective Caml) is the most robust and general functional language available
  - Used in financial industry: good for rapid prototyping.
- ML embodies important ideas much better than Java, C++
  - Many of these ideas still work in Java, C++, and you should use them…
- Learning a different language paradigms will make you more flexible down the road
  - Likely that Java and C++ will be replaced by other languages
  - Principles and concepts beat syntax
  - Ideas in ML will probably be in next gen languages

# Rough schedule

- Introduction to functional programming (6)
- Modular programming and functional data structures (4)
- Reasoning about correctness (4)
- ***Prelim 1***
- Imperative programming and concurrency (4)
- ***Spring break***
- Data structures and analysis of algorithms (5)
- ***Prelim 2***
- Topics: memoization, streams, managed memory (5)
- ***Final exam***

# Announcements

- Problem set 1 released Thursday
  - Due January 29 at 11:59pm
  - Look on the course web site and CMS

- Consulting starts on Sunday
- **Help sessions:** getting started with OCaml+Emacs
  - This Thursday 22 &Sunday 25, 7pm, Upson B7 lab
- CMS access will be set up today. Send mail to cs312-l@cs.cornell.edu if not.