CS 312 Lecture 1
Course overview

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Spring 2007

What this course is about

Helping you become expert software system designers and programmers

1) Programming paradigms

Programming language concepts and constructs

2) Reasoning about programs

- Correctness
- Performance
- Designing for reasoning

3) Tools

Data structures and algorithms

Course staff

- Prof. Andrew Myers
- Two TAs:
  - Xin Zheng
  - Olga Belomestnykh
- Consultants:
  - Tyler Steele
  - Ben Weber
  - Edward McTighe
  - Kareem Amin
  - Bob Albright
  - Paul Lewellen
  - Andrew Owens
- Office, consulting hours posted on web
- One hour of consulting Sun-Wed evening
- TAs, instructor have office hours: use them!

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Course meetings

- Lectures Tues, Thurs: Thurston 203
- Recitations Monday, Wednesday
  - Olin Hall 245, at 2:30pm
  - Olin Hall 245, at 3:35pm
  - Possible third section
- New material is presented in lecture **and** recitation
- Attendance is expected at lecture **and** recitation
- Participation counts

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Course web site

http://www.cs.cornell.edu/courses/cs312

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

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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

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Readings

- Course material in lecture notes on website
  - But also responsible for in-class material…
- Some other useful texts:
  - *Elements of ML Programming*, Ullman
  - *ML for the working programmer*, Paulson
  - *Programming in Standard ML*, Harper (on-line)
  - *Notes on Programming in SML*, Pucella (on-line)
  - *Program Development in Java: Abstraction, Specification, and Object-Oriented Design*. Liskov, Guttag.
    - Material on abstraction and specification, but in Java

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Assignments

- 6 problem sets
  - PS1 assigned today: “SML Warmup”
- Mix of programming, written problems
- Submitted electronically via CMS
- Three single-person assignments (1-3)
- Three two-person assignments (4-6)

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Exams

- Exams test material from lectures, written problems, assume you have done assignments
- Prelim 1: March 8
- Prelim 2: April 17
- Final exam May 14, 9-11:30AM
- Makeup exams must be scheduled within the first two weeks of class
  - Check your schedule and let the instructor know

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Academic integrity

- Strictly and carefully enforced
- Please don't make us waste time on this
- Start assignments early and get help from course staff!

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What this course is about

Goal: help you develop as expert programmers and system designers

1) Programming paradigms

Programming language concepts and constructs

2) Reasoning about programs

- Correctness
- Performance
- Designing for reasoning

3) Tools

Data structures and algorithms

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Why do you need to know this?

- Science and craft of programming
- You'll acquire skills that will help you become better programmers
  - 10x difference in productivity, fun, …
- Needed in many upper level courses
- Needed for any serious programming task
- Needed for managing programming projects

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1) Programming Paradigms

- Functional programming
- Polymorphism
- Pattern matching
- Modular programming
- Concurrent programming
- Type inference
- Garbage collection

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

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2) Programming Techniques

- *Design and reasoning: critical to robust, trustworthy software systems*.
- Design and planning:
  - Modular programming
  - Data abstraction
  - Specifications, interfaces
- Reasoning about programs
  - Program execution models
  - Reasoning about program correctness
  - Reasoning about performance via asymptotic complexity
  - Using induction to reason about program behavior
- Testing

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3) Data Structures & Algorithms

- Standard structures: lists, trees, stacks, graphs, etc.
  - Functional versions of these structures
- Advanced structures:
  - Balanced trees: AVL, Red-Black, B-trees, splay trees
  - Hash tables
  - Binary heaps
- Algorithms on these data structures

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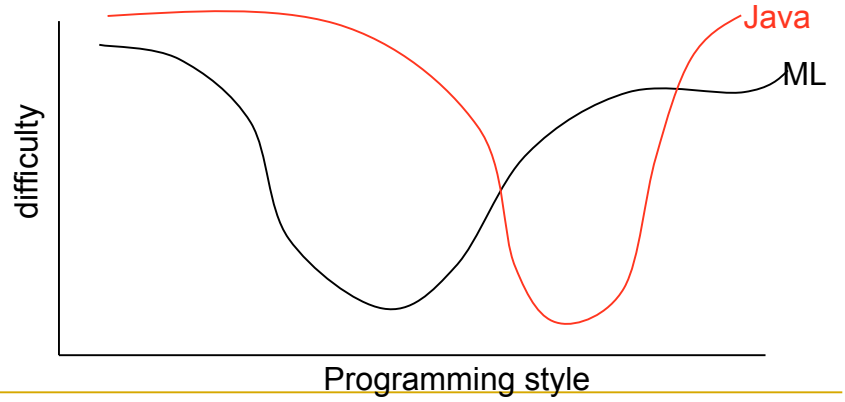
Language and programming style

- Sapir-Whorf hypothesis: language influences how we think
  - In CS: language influences how we design software



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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; }
- **Problem:** Difficult to reason about how state changes during program execution
  - Intertwined state across module boundaries
  - Complex object graphs

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Functional style

- **Idea:** program without side effects
  - Effect of a function abstraction 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
- Allows **equational reasoning** to show programs work:
  - if x = y, replacing y with x has no effect:
  - let val x = f(0) in x+x vs. f(0) + f(0)
- A good match to staged computation
- Information has tree-like structure (no cycles)

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Imperative vs. functional

- ML: a *functional* programming language
  - Encourages building code out of functions
  - Like mathematical functions; f(x) always gives the same result
- Functional style usable in ML, Java, C, …
  - No side effects: easier to reason about what happens
  - Equational reasoning

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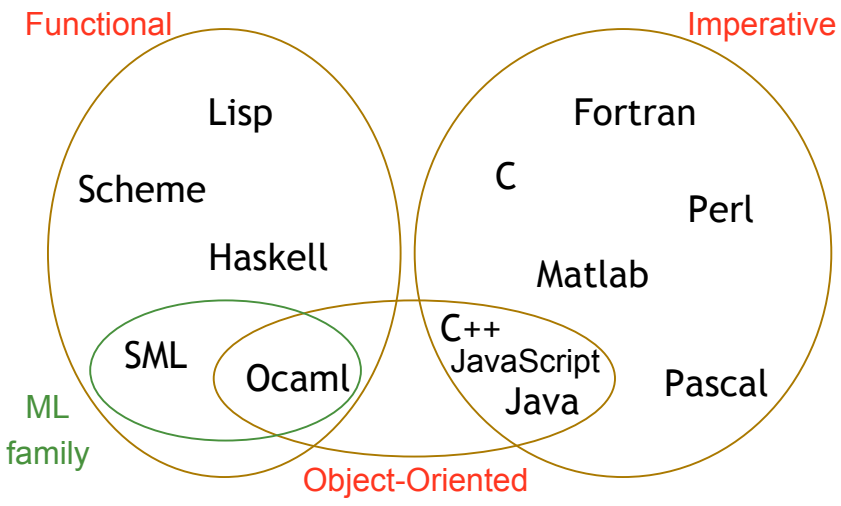
Programming Languages Map



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Imperative vs. functional

- Functional languages:
  - Higher level of abstraction
  - Closer to specification
  - Easier to develop robust software
- Imperative languages:
  - Lower level of abstraction
  - Sometimes more efficient
  - More difficult to maintain, debug
  - More error-prone

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Example 1: Sum

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

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Example 1: Sum

```
int sum(int n) {
    y = 0;
    for (x = 1; x <= n; x++) {
        y += x*x;
    }
    return n;
}
fun sum(n: int): int =
    if n=0 then 0
        else n*n + sum(n-1)
```

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Example 2: Reverse

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

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Example 2: Reverse

```
fun reverse(l : int list) : int list =
  case l of
     [] => []
   | h :: t => reverse(t) @ [h]
```


Why ML?

- ML is not used much in industry. But:
- ML embodies important ideas much better than Java, C++
  - These ideas have Java, C++ manifestations
- Learning a very different language will give you more flexibility down the road
  - New languages are constantly emerging: Java and C++ will be obsolete soon
  - Principles and concepts beat syntax
  - Ideas in ML will probably be in next gen languages
- Cred among the right people!

Rough schedule

- Introduction to functional programming (5)
- Specs and modular programming (4)
- Reasoning about programs (4)
- ***Prelim 1***
- Data structure case studies (2)
- ***Spring break***
- Language semantics and implementation (4)
- ***Prelim 2***
- Advanced data structures (4)
- Concurrency and event-driven programming (3)
- ***Final exam***

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Announcements

- Problem set 1 released today
  - Due January 31, at 11:59pm
  - Posted on the course web site and CMS
- Consulting starts today
- **Help session:** getting started with SML + Emacs: Thursday, Upson B7, 7pm
- Send mail to Xin (xz83) if you do not have CMS access for 312

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