Course Motivation
(Did you think I forgot? 😊)

• Why learn the fundamental concepts that appear in all (most?) languages?
• Why use languages quite different from C, C++, Java, Python?
• Why focus on functional programming?
• Why use ML, Racket, and Ruby in particular?
• Not: Language X is better than Language Y

[You won’t be tested on this stuff]

Summary

• No such thing as a “best” PL
• Fundamental concepts easier to teach in some (multiple) PLs
• A good PL is a relevant, elegant interface for writing software
  – There is no substitute for precise understanding of PL semantics
• Functional languages have been on the leading edge for decades
  – Ideas have been absorbed by the mainstream, but very slowly
  – First-class functions and avoiding mutation increasingly essential
  – Meanwhile, use the ideas to be a better C/Java/PHP hacker
• Many great alternatives to ML, Racket, and Ruby, but each was chosen for a reason and for how they complement each other

What is the best kind of car?

What is the best kind of shoes?

Cars / Shoes

Cars are used for rather different things:
– Winning a Formula 1 race
– Taking kids to soccer practice
– Off-roading
– Hauling a mattress
– Getting the wind in your hair
– Staying dry in the rain

Shoes:
– Playing basketball
– Going to a formal
– Going to the beach

More on cars

• A good mechanic might have a specialty, but also understands how “cars” (not a particular make/model) work
  – The upholstery color isn’t essential (syntax)
• A good mechanical engineer really knows how cars work, how to get the most out of them, and how to design better ones
  – I don’t have a favorite kind of car or a favorite PL
• To learn how car pieces interact, it may make sense to start with a classic design rather than the latest model
  – A popular car may not be best
  – May especially not be best for learning how cars work
Why semantics and idioms

This course focuses as much as it can on semantics and idioms

- Correct reasoning about programs, interfaces, and compilers requires a precise knowledge of semantics
  - Not “I feel that conditional expressions might work like this”
  - Not “I like curly braces more than parentheses”
  - Much of software development is designing precise interfaces; what a PL means is a really good example

- Idioms make you a better programmer
  - Best to see in multiple settings, including where they shine
  - See Java in a clearer light even if I never show you Java

Hamlet

The play Hamlet:
- Is a beautiful work of art
- Teaches deep, eternal truths
- Is the source of some well-known sayings
- Makes you a better person

Continues to be studied centuries later even though:
- The syntax is really annoying to many (yet rhythmic)
- There are more popular movies with some of the same lessons
- Reading Hamlet will not get you a summer internship

All cars are the same

- To make it easier to rent cars, it is great that they all have steering wheels, brakes, windows, headlights, etc.
  - Yet it is still uncomfortable to learn a new one
  - Can you be a great driver if you only ever drive one car?

- And maybe PLs are more like cars, trucks, boats, and bikes

- So are all PLs really the same…

Are all languages the same?

Yes:
- Any input-output behavior implementable in language X is implementable in language Y [Church-Turing thesis]
- Java, ML, and a language with one loop and three infinitely-large integers are “the same”

Yes:
- Same fundamentals reappear: variables, abstraction, one-of types, recursive definitions, …

No:
- The human condition vs. different cultures (travel to learn more about home)
- The primitive/default in one language is awkward in another
- Beware “the Turing tarpit”

Functional Programming

Why spend 60-80% of course using functional languages:
- Mutation is discouraged
- Higher-order functions are very convenient
- One-of types via constructs like datatypes

Because:
1. These features are invaluable for correct, elegant, efficient software (great way to think about computation)
2. Functional languages have always been ahead of their time
3. Functional languages well-suited to where computing is going

Most of course is on (1), so a few minutes on (2) and (3) …

Ahead of their time

All these were dismissed as “beautiful, worthless, slow things PL professors make you learn”

- Garbage collection (Java didn’t exist in 1995, PL courses did)
- Generics (List<T> in Java, C#), much more like SML than C++
- XML for universal data representation (like Racket/Scheme/LISP/…)
- Higher-order functions (Ruby, Javascript, C#, …)
- Type inference (C#, Scala, …)
- Recursion (a big fight in 1960 about this – I’m told 😊)
- …
The future may resemble the past

Somehow nobody notices we are right... 20 years later

- “To conquer” versus “to assimilate”
- Societal progress takes time and muddles “taking credit”
- Maybe pattern-matching, currying, hygienic macros, etc. will be next

Recent-ish Surge, Part 1

Other popular functional PLs (alphabetized, pardon omissions)

- Clojure http://clojure.org
- Erlang http://www.erlang.org
- F# http://tryfsharp.org
- Haskell http://www.haskell.org
- OCaml http://ocaml.org
- Scala http://www.scala-lang.org

Some “industry users” lists (surely more exist):

- http://www.haskell.org/haskellwiki/Haskell_in_industry
- http://ocaml.org/companies.html
- In general, see http://cufp.org

Recent-ish Surge, Part 2

Popular adoption of concepts:

- C#, LINQ (closures, type inference, …)
- Java 8 (closures)
- MapReduce / Hadoop
  - Avoiding side-effects essential for fault-tolerance here
- …

Why a surge?

My best guesses:

- Concise, elegant, productive programming
- JavaScript, Python, Ruby helped break the Java/C/C++ hegemony
- Avoiding mutation is the easiest way to make concurrent and parallel programming easier
  - In general, to handle sharing in complex systems
- Sure, functional programming is still a small niche, but there is so much software in the world today even niches have room

The languages together

SML, Racket, and Ruby are a useful combination for us

<table>
<thead>
<tr>
<th></th>
<th>dynamically typed</th>
<th>statically typed</th>
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</thead>
<tbody>
<tr>
<td>functional</td>
<td>Racket</td>
<td>SML</td>
</tr>
<tr>
<td>object-oriented</td>
<td>Ruby</td>
<td>Java</td>
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ML: polymorphic types, pattern-matching, abstract types & modules
Racket: dynamic typing, “good” macros, minimalist syntax, eval
Ruby: classes but not types, very OOP, mixins

Really wish we had more time:

Haskell: laziness, purity, type classes, monads
Prolog: unification and backtracking

But why not…

Instead of SML, could use similar languages easy to learn after:

- OCaml: yes indeed but would have to port all my materials ☹️
  - And a few small things (e.g., second-class constructors)
- F#: yes and very cool, but needs a .Net platform
  - And a few more small things (e.g., second-class constructors, less elegant signature-matching)
- Haskell: more popular, cooler types, but lazy semantics and type classes from day 1

Admittedly, SML and its implementations are showing their age (e.g., andalso and less tool support), but it still makes for a fine foundation in statically typed, eager functional programming
But why not…

Instead of Racket, could use similar languages easy to learn after:

– Scheme, Lisp, Clojure, …

Racket has a combination of:
– A modern feel and active evolution
– "Better" macros, modules, structs, contracts, …
– A large user base and community (not just for education)
– An IDE tailored to education

Could easily define our own language in the Racket system
– Would rather use a good and vetted design

But why not…

Instead of Ruby, could use another language:

• Python, Perl, JavaScript are also dynamically typed, but are not as "fully" OOP, which is what I want to focus on
  – Python also does not have (full) closures
  – JavaScript also does not have classes but is OOP

• Smalltalk serves my OOP needs
  – But implementations merge language/environment
  – Less modern syntax, user base, etc.

Is this real programming?

• The way we use ML/Racket/Ruby can make them seem almost "silly" precisely because lecture and homework focus on interesting language constructs

• "Real" programming needs file I/O, string operations, floating-point, graphics, project managers, testing frameworks, threads, build systems, …
  – Many elegant languages have all that and more
    • Including Racket and Ruby
  – If we used Java the same way, Java would seem "silly" too

A note on reality

Reasonable questions when deciding to use/learn a language:

• What libraries are available for reuse?
• What tools are available?
• What can get me a job?
• What does my boss tell me to do?
• What is the de facto industry standard?
• What do I already know?

Our course by design does not deal with these questions
– You have the rest of your life for that
– And technology leaders affect the answers