CS 3110

Introduction to 3110

Prof. Clarkson
Fall 2016

Today's music: Prelude from Final Fantasy VII
by Nobuo Uematsu (remastered by Sean Schafianski)

Welcome!

- Programming isn’t hard
- Programming well is very hard
  - High variance among professionals’ productivity: 10x or more
  - Studying functional programming will make you a better programmer, but it requires an open mind

What is a functional language?

A functional language:

- defines computations as mathematical functions
- avoids mutable state

State: the information maintained by a computation

Mutable: can be changed (antonym: *immutable*)

Functional vs. imperative

Functional languages:

- Higher level of abstraction
- Easier to develop robust software
- Immutable state: easier to reason about software

Imperative languages:

- Lower level of abstraction
- Harder to develop robust software
- Mutable state: harder to reason about software

You don't have to believe me now.
If you master a functional language, you will. ☺

Imperative programming

Commands specify how to compute by destructively changing state:

```
x = x+1;
a[i] = 42;
p.next = p.next.next;
```

Functions/methods have **side effects**:

```
int wheels(Vehicle v) {
  v.size++;
  return v.numWheels;
}
```

Mutability

The fantasy of mutability:

- It's easy to reason about: the machine does this, then this...

The reality of mutability:

- Machines are good at complicated manipulation of state
- Humans are not good at understanding it!
  - mutability breaks *referential transparency*: ability to replace expression with its value without affecting result of computation
  - In math, if f(x)=y, then you can substitute y anywhere you see f(x)
  - In imperative languages, you cannot: f might have side effects, so computing f(x) at time t might result in different value than at time t'

...mutable programming is not well-suited to building correct code!

Mutability

More fantasy about mutability:

- There is a single state
- The computer does one thing at a time

The reality of mutability:

- There is no single state
  - Programs have many threads, spread across many cores, spread across many processors, spread across many computers… each with its own view of memory
- There is no single program
  - Most applications do many things at one time

…mutable programming is not well-suited to modern computing!

Functional programming

Expressions specify what to compute

- Variables never change value
- Functions never have side effects

The reality of immutability:

- No need to think about state
- Powerful ways to build correct programs and concurrent programs

Why study functional programming?

1. Functional languages teach you that programming transcends programming in a language (assuming you you have only programmed in imperative languages)
2. Functional languages predict the future
3. (Functional languages are *sometimes* used in industry)
4. Functional languages are elegant

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Analogy: studying a foreign language

- Learn about another culture; incorporate aspects into your own life
- Shed preconceptions and prejudices about others
- Understand your native language better

Alan J. Perlis

1922-1990

"A language that doesn't affect the way you think about programming is not worth knowing."

First recipient of the Turing Award
for his "influence in the area of advanced programming techniques and compiler construction"

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Functional languages predict the future

- Garbage collection
  Java [1995], LISP [1958]
- Generics
  Java 5 [2004], ML [1990]
- Higher-order functions
  C#3.0 [2007], Java 8 [2014], LISP [1958]
- Type inference
  C++11 [2011], Java 7 [2011] and 8, ML [1990]
- **What's next?**

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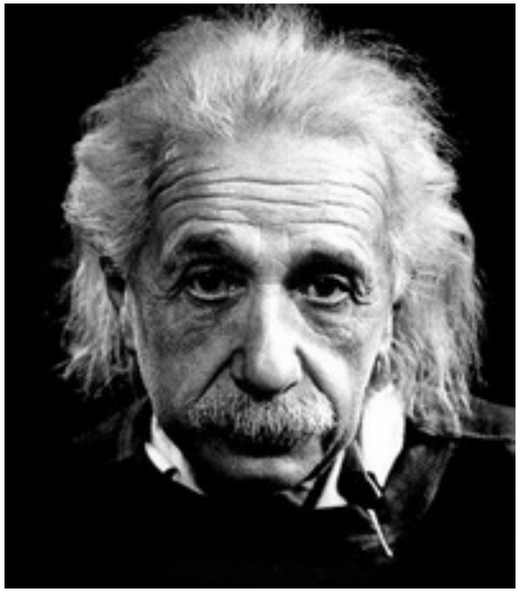
Functional languages in the real world

- Java 8
- F#, C# 3.0, LINQ
- Scala
- Haskell
- Erlang
- OCaml

https://ocaml.org/learn/companies.html

...but Cornell CS (et al.) require functional programming for your *education*, not to get you a job

Albert Einstein


1879-1955

"Education is what remains
after one has forgotten
everything one learned
in school."

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Elegant

Neat Stylish

Dignified Refined

Simple

Effective Graceful

Precise Consistent

Tasteful

Elegant

Neat Stylish

Beautiful

Precise Consistent

Tasteful

Do aesthetics matter?

YES!

Who reads code?

- Machines
- Humans

- Elegant code is easier to read and maintain
- Elegant code might (not) be easier to write

OCaml

A pretty good language for writing beautiful programs

O = Objective, Caml=not important
ML is a family of languages; originally the “meta-language” for a tool

OCaml is awesome because of…

- Immutable programming
  - Variable's values cannot destructively be changed; makes reasoning about program easier!
- Algebraic datatypes and pattern matching
  - Makes definition and manipulation of complex data structures easy to express
- First-class functions
  - Functions can be passed around like ordinary values
- Static type-checking
  - Reduce number of run-time errors
- Automatic type inference
  - No burden to write down types of every single variable
- Parametric polymorphism
  - Enables construction of abstractions that work across many data types
- Garbage collection
  - Automated memory management eliminates many run-time errors
- Modules
  - Advanced system for structuring large systems

A GLIMPSE OF OCAML…

Languages are tools

Languages are tools

- There's no universally perfect tool
- There's no universally perfect language
- **OCaml is good for this course** because:
  - good mix of functional & imperative features
  - relatively easy to reason about meaning of programs
- **But OCaml isn't perfect** (see above)
  - there will be features you miss from language X
  - there will be annoyances based on your expectations
  - keep an open mind, try to have fun

LOGISTICS

Course website

http://www.cs.cornell.edu/Courses/cs3110/2016fa/

- Full syllabus (required reading)
- Lecture slides & notes
  - Typically available within 24 hours after lecture
  - Supplement, do not replace, attendance
- Labs for recitation

Course staff

Instructor: Michael Clarkson

- PhD 2010 Cornell University
- Research areas: security and programming languages
- I go by "Prof. Clarkson" in this course

TAs and consultants: 51 at last count

- Head TA for Consulting: Chirag Bharadwaj
- Head TA for Grading: Julia Proft
- Head TA for Recitations: Dan Sainati

Course meetings

- **Lectures:** TR 10:10-11:00 am
  - attendance is semi-mandatory, measured by i>clicker
  - go buy an i>clicker and bring it on Thursday
- **Recitations:** mostly MW
  - Attendance is semi-mandatory, measured by TAs
  - TR sections are effectively MW delayed one day
  - You need to attend your registered section
  - bring your laptop with OCaml installed
- **Consulting:** coverage nearly every day

Communication

- If it's about content, post a message on Piazza
  - Messages restricted only to me probably will get lost

- If it's about your own personal logistics, come see me in person...most emergencies really can wait

- Or if you have to, send email to cs3110-instructors-L@cornell.edu (= me + a couple select senior staff)

Academic integrity

- You are bound by the Cornell Code of Academic Integrity, the CS Department Code of Academic Integrity, and the CS 1110 Explanation of Academic Integrity
  - All linked from course website
  - You are responsible for understanding them
- I use MOSS to detect plagiarism; it works
- If you have a question about what is or is not allowed, please ask
- If you fear you have committed a violation, tell me before grading commences

Enrollment

- The course is at fire-code capacity
  - I cannot add any students; there is no waitlist
  - You will have to wait until someone drops
  - Please, no auditors this semester
- CS 3110 will be taught in the spring and historically is never full then

Your TODO list for tonight

1. read the syllabus
2. buy an i>clicker
3. login to CMS

   trouble?

   - IF YOU ARE ENROLLED IN 3110: contact Head TA for Grading with your full name and NetID
   - Otherwise, WAIT: you will be semi-automatically added after you enroll with the Registrar; we won't add you before then
4. login to Piazza
5. install OCaml
   - we provide a virtual machine on course website; must use this semester's
   - will be used in recitation tomorrow: download tonight
   - trouble? post on Piazza or see a consultant in person

Upcoming events

- [Tue-Thur pm] Drop by my office in the afternoon if you need something immediately
- [Wednesday] Recitations begin (none today); bring laptop
- [Wednesday pm] Consulting hours start; check calendar on course website for times and places
- [Thursday am] bring i>clicker

…why are you still here? Get to work! ☺

THIS IS 3110