CMSC 330: Organization of Programming Languages

Functional Programming with OCaml

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

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

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 an expression with its value without affecting the result
  - 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 one time might result in different value at another

Mutability

The fantasy of 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

Functional programming

Expressions specify what to compute

- Variables never change value
- Functions (almost) never have side effects

The reality of immutability:

- No need to think about state
- Easier (and more powerful) ways to build correct programs and concurrent programs

Why study functional programming?

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]
- Pattern matching
  - ML [1990], Scala [2002]

Why study functional programming?

Functional languages in the real world

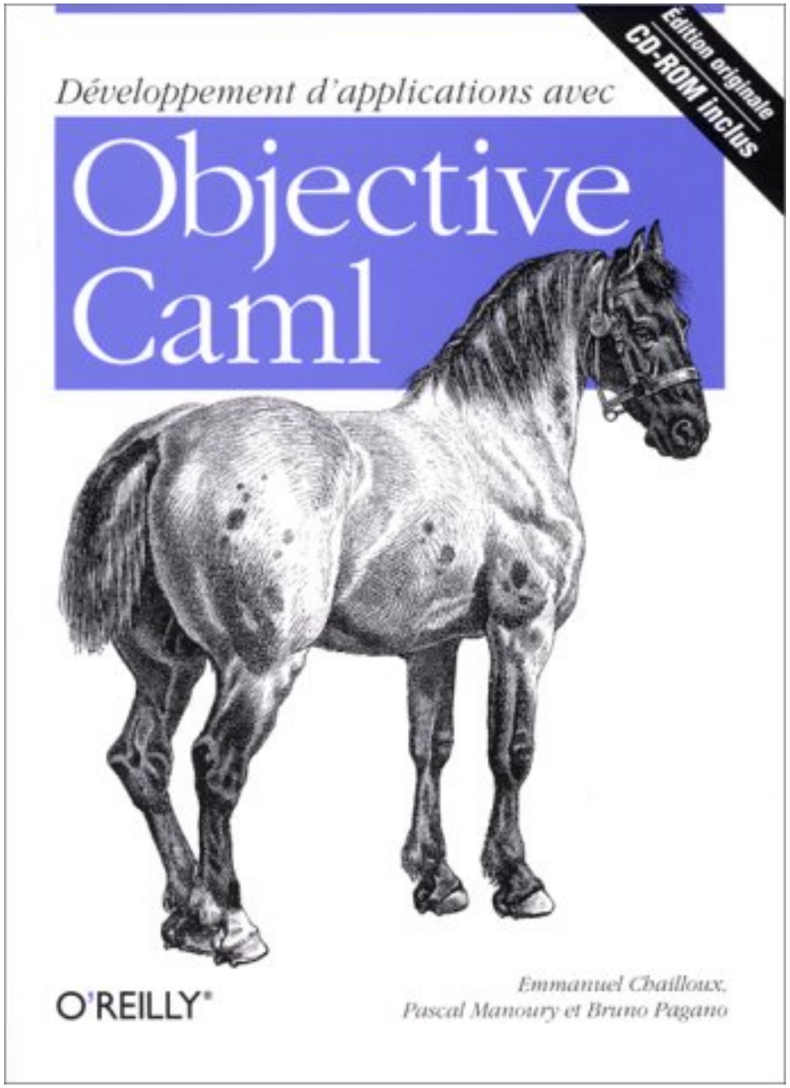
- Java 8 ORACLE
- F#, C# 3.0, LINQ Microsoft
- Scala twitter foursquare LinkedIn
- Haskell facebook BARCLAYS at&t
- Erlang facebook amazon T-Mobile
- OCaml facebook Bloomberg CITRIX

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

ML-style (Functional) Languages

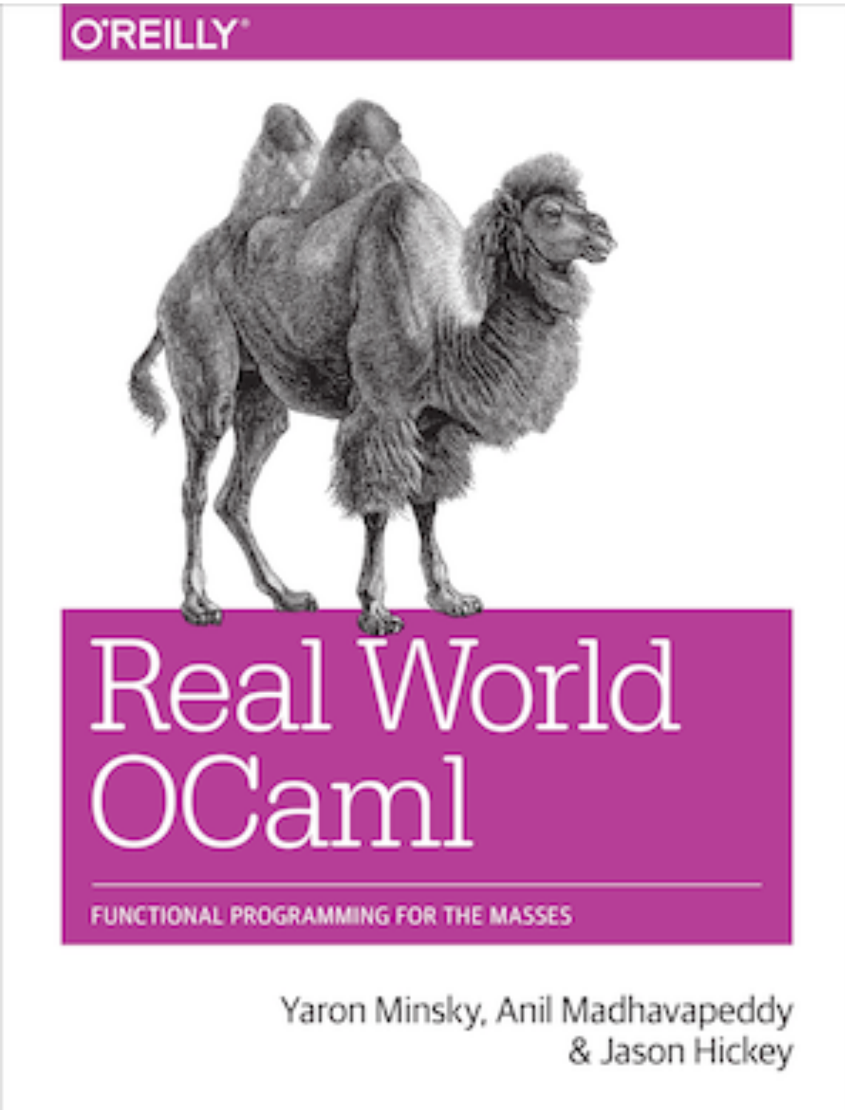
- ML (Meta Language)
  - Univ. of Edinburgh, 1973
  - Part of a theorem proving system LCF
- Standard ML
  - Bell Labs and Princeton, 1990; Yale, AT&T, U. Chicago
- OCaml (Objective CAML)
  - INRIA, 1996
    - French Nat'l Institute for Research in Computer Science
  - O is for "objective", meaning objects, which we'll ignore
- Haskell (1998): *lazy* functional programming
- Scala (2004): functional and OO programming

Useful Information on OCaml language



- Translation available on the class webpage
  - *Developing Applications with Objective Caml*
- Webpage also has link to another book
  - *Introduction to the Objective Caml Programming Language*

More Information on OCaml



- Book designed to introduce and advance understanding of Ocaml
  - Authors use OCaml in the real world
  - Introduces new libraries, tools
- Free HTML on-line
  - realworldocaml.org

Features of ML

- First-class functions
  - Functions can be data, too: parameters and return values
- Favor immutability ("assign once")
- Data types and pattern matching
  - Convenient for certain kinds of data structures
- Type inference
  - No need to write types in the source language
    - But the language is statically typed
  - Supports parametric polymorphism
    - *Generics* in Java, *templates* in C++
- Exceptions
- Garbage collection