

CMSC 330: Organization of Programming Languages

Functional Programming with OCaml

What is a functional language?

A functional language:

- defines computations as **mathematical functions**
- discourages use of 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
 - Like mathematical variables
- 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

Key Features of ML

- First-class functions
 - Functions can be parameters to other functions (“higher order”) and return values, and stored as data
- 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++
- Like Ruby, Java, ...: exceptions and garbage collection

Why study functional programming?

Functional languages predict the future:

- Garbage collection
 - Java [1995], LISP [1958]
- Parametric polymorphism (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], Java X [201?]
 - <http://cr.openjdk.java.net/~briangoetz/amber/pattern-match.html>

Why study functional programming?

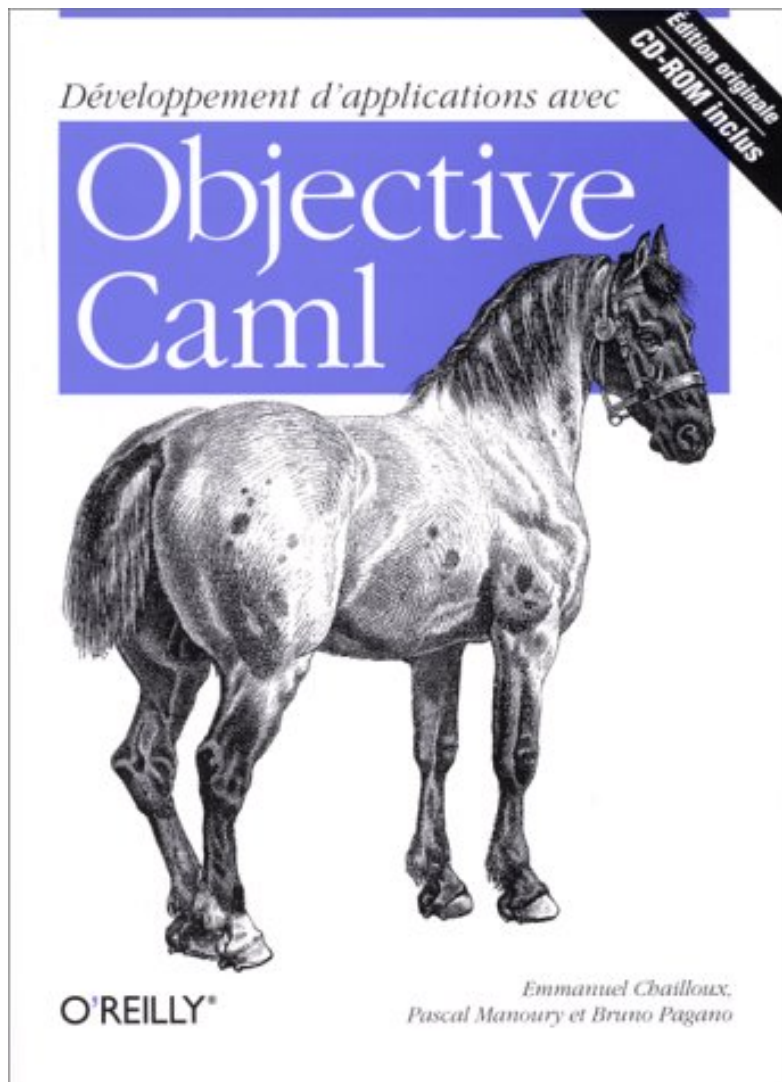
Functional languages in the real world

- **Java 8** 
- **F#, C# 3.0, LINQ**  Microsoft
- **Scala**   **Linked in** 
- **Haskell**    at&t
- **Erlang**    **T-Mobile**
- **OCaml**  **Bloomberg** 
<https://ocaml.org/learn/companies.html>  **Jane Street**

ML-style (Functional) Languages

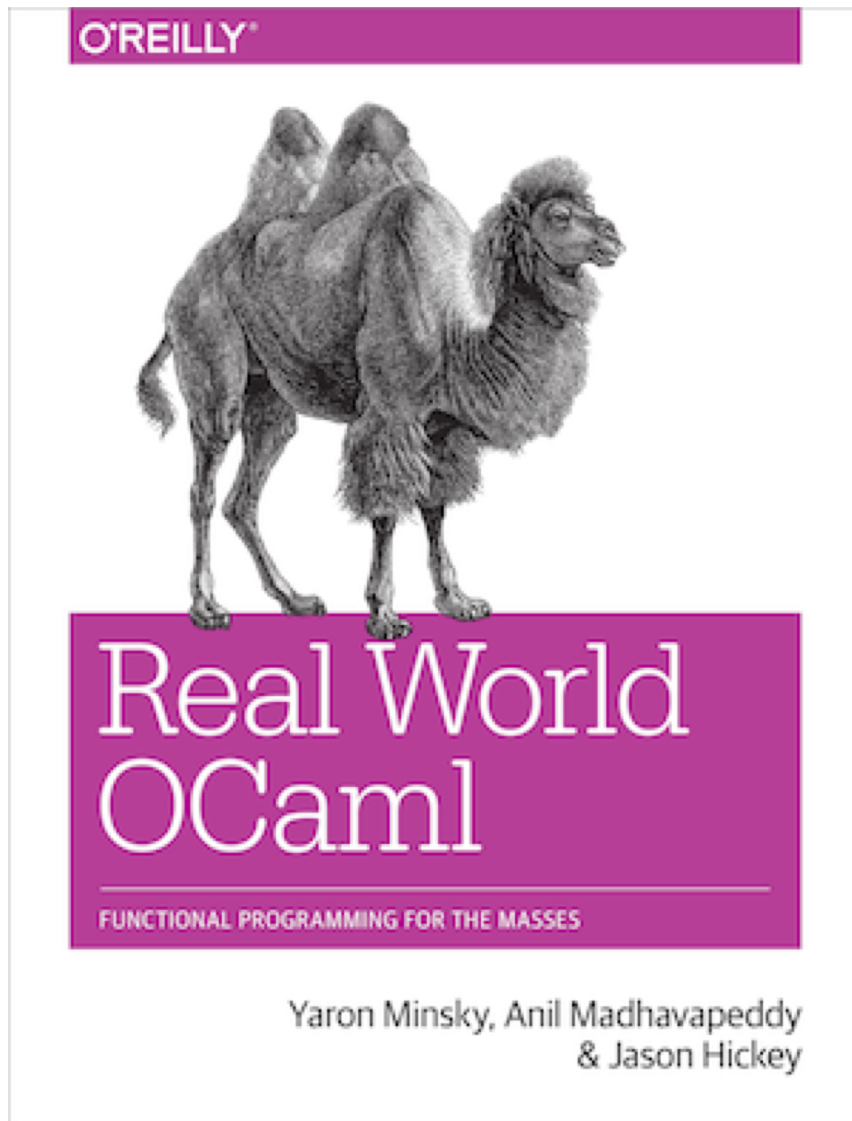
- ML (Meta Language)
 - Univ. of Edinburgh, 1973
 - Part of a theorem proving system LCF
- Standard ML
 - Bell Labs and Princeton, 1990; Yale, AT&T, U. Chicago
- OCaml (Objective CAML)
 - INRIA, 1996
 - French Nat'l Institute for Research in Computer Science
 - O is for “objective”, meaning objects (which 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 online
 - realworldocaml.org

Coding Guidelines

- We will not grade on style, but style is important
- Recommended coding guidelines:
- <https://ocaml.org/learn/tutorials/guidelines.html>