# Presentation

# MPRI 2.4

François Pottier

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# Why follow this course?

Computers are wonderful machines...

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Computers are wonderful machines...

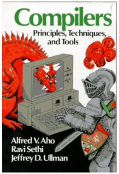
... but they don't always do what was intended.

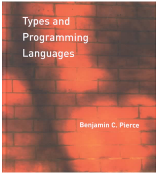
# Why follow this course?

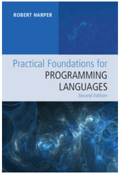
The theory of programming languages aims to describe

how programs are structured,
what they mean,
how they are interpreted or compiled,

and how one can prove properties of programs and properties of tools, such as type-checkers or compilers.



# What is functional programming?

Programming in Scheme, OCaml, Haskell, Scala, Agda, Coq, F*, ...

Key features:

- Immutable variables and values. Mutable state discouraged.
- Functions as values. Higher-order functions.
- Algebraic data structures (lists, trees, ...) as values.
- Recursion. Tail recursion preferred to loops.
- Close to mathematical language and to the $\lambda$-calculus.
- A taste for expressive, safe, static type systems. Polymorphism.
- Automatic memory management preferred.
- Equational reasoning.

— *A program does not "do" something; it "is" something.*

# What is functional programming?

```
(* Do not think of data as memory blocks and pointers --
   think in terms of sums, products, and recursion. *)
type 'a list =
| []
| (::) of 'a * 'a list
```

# What is functional programming?

```
(* Parameterize [map] with the transformation [f]
   that should be applied to every list element. *)
let rec map f xs =
  (* Let the structure of the data
     guide the structure of the code. *)
  match xs with
  | [] -> []
  | x :: xs -> f x :: map f xs
            (* Do not modify the input list
                     -- allocate a new list. *)

let add x ys =
  map (fun y -> x + y) ys
   (* ^^^^^^^^^^^^^^^ This closure refers to [x]. *)
```

# What is functional programming?

```
(* Do not write a loop -- write a tail-recursive function. *)
(* [rev_append xs ys] is equivalent to [rev xs @ ys]. *)
let rec rev_append xs ys =
  match xs with
  | [] -> ys
  | x :: xs -> rev_append xs (x :: ys)

(* Do not be afraid to write many small functions. *)
let rev xs =
  rev_append xs []
```

Steele, Lambda: the ultimate GOTO, 1977.

# Why learn functional programming?

Functional programming is a culture — a school of thought.

It differs from “mainstream” programming in pedagogical ways:

- A belief that mutable data, jumps and loops are not fundamental,
- A belief that functions are simpler and often as powerful as objects,
- A taste for declarative thinking.

Furthermore, it has a tradition of solid (meta)theory:

- formal definitions of semantics, type systems, code transformations...
- proofs of type soundness, proofs of semantic preservation, ...
- moving towards machine-checked definitions and proofs.

## Why follow this course?

An introduction to programming languages (PL),
a subfield of computer science (CS).

Our conferences are POPL, ICFP, PLDI, OOPSLA, ESOP, LICS, etc.

In this course, we wish to teach at the same time:

- several key programming techniques;
- the (meta)theory of programming languages.

# What topics are hot these days?

The 270 papers submitted to POPL 2023 discuss, among other topics:

- quantum programs;
- program synthesis;
- probabilistic programs;
- automatic differentiation;
- proofs of (concurrent / distributed) programs
  (with relaxed / persistent memory);
- information flow (differential privacy, ...);
- static analysis (via CFL reachability, abstract interpretation...);
- type theory (with linear types, modal types, ...);
- industrial languages (WebAssembly, SPIR-V, Hack, ...);
- features of industrial hardware (ARM, ...).

We aim to offer the basic culture needed to approach these topics.

# What is in this course?

Four main segments:

- Semantics, Type Systems, and Program Transformations (Pottier)
- Semantic Proofs of Type Soundness and Logical Relations (Scherer)
- Typed Programming (Dagand)
- Programming with Resources in Rust (Jourdan)

A detailed syllabus apepars online.

New this year: semantic proofs of type soundness; logical relations in Iris; ML type inference and bidirectional type inference.