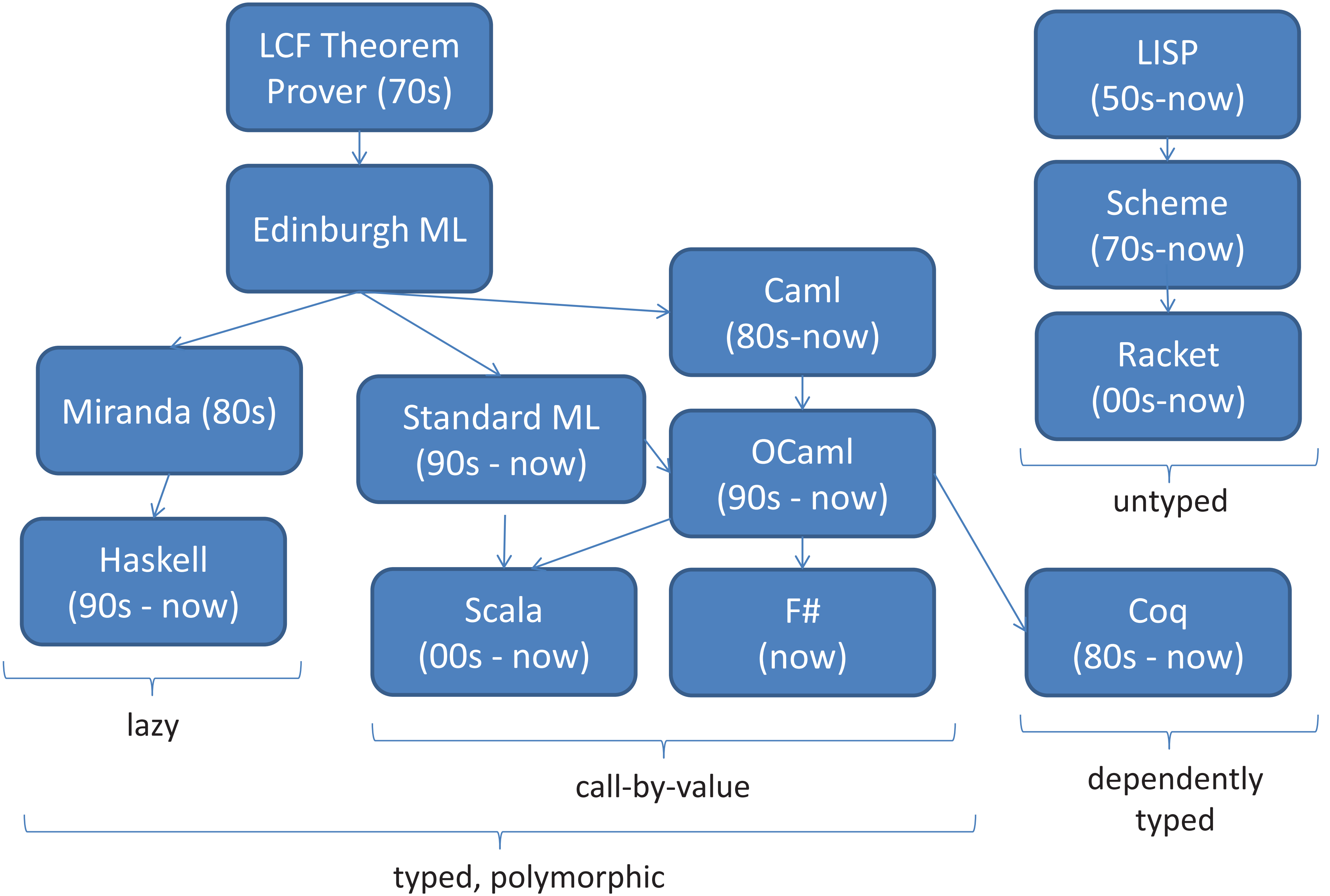
Introduction to OCaml

Vastly Abbreviated FP Geneology



But Why Functional Programming *Now*?

- Functional programming will introduce you to new ways to *think about* and *structure* your programs:
  - new reasoning principles
  - new abstractions
  - new design patterns
  - new algorithms
  - elegant code

- Technology trends point to increasing parallelism:
  - multicore, gpu, data center
  - functional programming techniques such as map-reduce provide a plausible way forward for many applications

Functional Languages: Who's using them?

map-reduce in their data centers

Scala for
correctness, maintainability, flexibility

Erlang for
concurrency,
Haskell for
managing PHP

F# in Visual Studio

Haskell to
synthesize hardware

O'Caml
for reliability

Haskell
for specifying
equity derivatives

mathematicians

Coq proof of
4-color theorem

www.artima.com/scalazine/articles/twitter_on_scala.html
http://gregosuri.com/how-facebook-uses-erlang-for-real-time-chat
http://www.janestcapital.com/technology/ocaml.php
http://msdn.microsoft.com/en-us/fsharp/cc742182
http://labs.google.com/papers/mapreduce.html
http://www.haskell.org/haskellwiki/Haskell_in_industry

Functional Languages: Join the crowd

- Elements of functional programming are showing up all over
  - F# in Microsoft Visual Studio
  - Scala combines ML (a functional language) with Objects
    - runs on the JVM
  - C# includes "delegates"
    - delegates == functions
  - Python includes "lambdas"
    - lambdas == more functions
  - Javascript
    - find tutorials online about using functional programming techniques to write more elegant code
  - C++ libraries for map-reduce
    - enabled functional parallelism at Google
  - Java has generics and GC
  - ...

Thinking Functionally

In Java or C, you get (most) work done by *changing* something

```
temp = pair.x;
pair.x = pair.y;
pair.y = temp;
```

commands *modify* or *change* an existing data structure (like pair)

In ML, you get (most) work done by *producing something new*

```
let (x,y) = pair in
(y,x)
```

you *analyze* existing data (like pair) and you *produce* new data (y,x)

This simple switch in perspective can change the way you

think

about programming and problem solving.

Thinking Functionally

pure, functional code:

```
let (x,y) = pair in
(y,x)
```

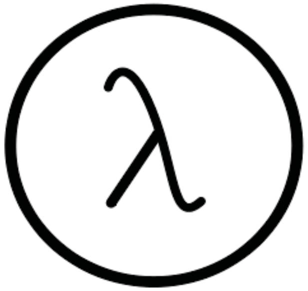
- *outputs are everything!*
- *output is <u>function</u> of input*
- *data properties are stable*
- *repeatable*
- *parallelism apparent*
- *easier to test*
- *easier to compose*

imperative code:

```
temp = pair.x;
pair.x = pair.y;
pair.y = temp;
```

- *outputs are irrelevant!*
- *output is not function of input*
- *data properties change*
- *unrepeatable*
- *parallelism hidden*
- *harder to test*
- *harder to compose*

Why OCaml?



Small, orthogonal core based on the *lambda calculus*.

- Control is based on (recursive) functions.
- Instead of for-loops, while-loops, do-loops, iterators, etc.
  - can be defined as library functions.
- Makes it easy to define semantics

Supports *first-class, lexically scoped, higher-order* procedures

- a.k.a. first-class functions or closures or lambdas.
- first-class: functions are data values like any other data value
  - like numbers, they can be stored, defined anonymously, ...
- lexically scoped: meaning of variables determined statically.
- higher-order: functions as arguments and results
  - programs passed to programs; generated from programs

These features also found in Scheme, Haskell, Scala, F#, Clojure, ...

Why OCaml?

Statically typed: debugging and testing aid

- compiler catches many silly errors before you can run the code.
  - A type is worth a thousand tests
- Java is also strongly, statically typed.
- Scheme, Python, Javascript, etc. are all strongly, *dynamically typed* – type errors are discovered while the code is running.

Strongly typed: compiler enforces type abstraction.

- cannot cast an integer to a record, function, string, etc.
  - so we can utilize *types as capabilities*; crucial for local reasoning
- C/C++ are *weakly typed* (statically typed) languages. The compiler will happily let you do something smart (*more often stupid*).

Type inference: compiler fills in types for you

OCaml Resources

- Home: https://ocaml.org/
- Tutorial: https://ocaml.org/learn/tutorials/
- User Manual: https://caml.inria.fr/pub/docs/manual-ocaml-4.09/
- Cheat Sheets: https://ocaml.org/docs/cheat_sheets.html
- 99 Problems (solved) in OCaml: https://ocaml.org/learn/tutorials/99problems.html

OCaml Installation

- https://ocaml.org/docs/install.html
- Linux/macOS:
  - Compiler: follow the online instructions
  - Editor: any text editor you like, e.g. Emacs, Vim
- Windows:
  - Compiler:
    - recommend OCPWin (https://www.typerex.org/ocpwin.html)
    - easy installation: EXE file
  - Editor:
    - recommend OCaml-Top (https://www.typerex.org/ocaml-top.html)
    - recommend Version 1.1.1 (https://github.com/OCamlPro/ocaml-top/releases): easy installation with MSI file

Install Successfully?

```
Chunhui Guo@ChunhuiGuo-PC ~
$ ocaml -version
The OCaml toplevel, version 4.02.1+ocp1

Chunhui Guo@ChunhuiGuo-PC ~
$ ocamlc -version
4.02.1+ocp1
```

OCaml Online Compiler

- Try OCaml by OCamlPRO:
  https://try.ocamlpro.com/

- IOCamlJS notebook:
  - https://andrewray.github.io/iocamljs/
  - similar to Jupyter Notebook for Python

A First OCaml Program

- https://caml.inria.fr/pub/docs/u3-ocaml/ocaml-steps.html
- “Hello world” program
  - file: hello.ml

```
print_string “Hello world!\n”;;
```

a function

;; end of code block

- string argument enclosed in "..."
- no parens
- normally call a function f like this: `f arg1 arg2 …`
- parens are used for grouping, precedence only when necessary

How to execute OCaml program?

- (1) compile and execute

```
Chunhui Guo@ChunhuiGuo-PC /cygdrive/d/OCaml_Code
$ ocamlc -o hello hello.ml

Chunhui Guo@ChunhuiGuo-PC /cygdrive/d/OCaml_Code
$ ./hello
Hello world!
```

```
D:\OCaml_Code>ocamlc -o hello.o hello.ml

D:\OCaml_Code>hello.o
Hello world!
```

How to execute OCaml program?

- (2) type interactively, using the interpreter `ocaml` as a big desk calculator

```
Chunhui Guo@ChunhuiGuo-PC /cygdrive/d/OCaml_Code
$ ocaml hello.ml
Hello world!

Chunhui Guo@ChunhuiGuo-PC /cygdrive/d/OCaml_Code
$ ocaml < hello.ml
        OCaml version 4.02.1+ocp1

# Hello world!
- : unit = ()
#
```

How to execute OCaml program?

- (3) use the interpreter `ocaml` in batch mode for running scripts

```
Chunhui Guo@ChunhuiGuo-PC ~
$ ocaml
        OCaml version 4.02.1+ocp1

# print_string "Hello world!\n";;
Hello world!
- : unit = ()
# exit 0;;
```

A Second OCaml Program

a comment
(* … *)

sumTo8.ml:

```
(* sum the numbers from 0 to n
   precondition: n must be a natural number
*)
let rec sumTo (n:int) : int =
  match n with
    0 -> 0
  | n -> n + sumTo (n-1)

let _ =
  print_int (sumTo 8);
  print_newline()
```

A Second OCaml Program

the name of the function being defined

sumTo8.ml:

```
(* sum the numbers from 0 to n
   precondition: n must be a natural number
*)
let rec sumTo (n:int) : int =
  match n with
    0 -> 0
  | n -> n + sumTo (n-1)

let _ =
  print_int (sumTo 8);
  print_newline()
```

the keyword “let” begins a definition; keyword “rec” indicates recursion

A Second OCaml Program

sumTo8.ml:

```
(* sum the numbers from 0 to n
   precondition: n must be a natural number
*)
let rec sumTo (n:int) : int =
  match n with
    0 -> 0
  | n -> n + sumTo (n-1)

let _ =
  print_int (sumTo 8);
  print_newline()
```

result type int

argument named n with type int

A Second OCaml Program

deconstruct the value n using pattern matching

sumTo8.ml:

```
(* sum the numbers from 0 to n
   precondition: n must be a natural number
*)
let rec sumTo (n:int) : int =
  match n with
    0 -> 0
  | n -> n + sumTo (n-1)

let _ =
  print_int (sumTo 8);
  print_newline()
```

data to be deconstructed appears between key words “match” and “with”

A Second OCaml Program

vertical bar "|" separates the alternative patterns

sumTo8.ml:

```
(* sum the numbers from 0 to n
   precondition: n must be a natural number
*)
let rec sumTo (n:int) : int =
  match n with
    0 -> 0
  | n -> n + sumTo (n-1)

let _ =
  print_int (sumTo 8);
  print_newline()
```

deconstructed data matches one of 2 cases:
(i) the data matches the pattern 0, or (ii) the data matches the variable pattern n

A Second OCaml Program

Each branch of the match statement constructs a result

sumTo8.ml:

```
(* sum the numbers from 0 to n
   precondition: n must be a natural number
*)
let rec sumTo (n:int) : int =
  match n with
    0 -> 0
  | n -> n + sumTo (n-1)

let _ =
  print_int (sumTo 8);
  print_newline()
```

construct
the result 0

construct
a result
using a
recursive
call to sumTo

A Second OCaml Program

sumTo8.ml:

```
(* sum the numbers from 0 to n
   precondition: n must be a natural number
*)
let rec sumTo (n:int) : int =
  match n with
    0 -> 0
  | n -> n + sumTo (n-1)

let _ =
  print_int (sumTo 8);
  print_newline()
```

print the result of calling sumTo on 8

print a new line