Introduction to OCaml

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Minor tweaks to Jed Liu’s tutorial
which was
based on CS 3110 course notes
and an SML tutorial by Mike George
Installing OCaml

- **Linux:**
  - `yum install ocaml`
  - `apt-get install ocaml`
  - `emerge dev-lang/ocaml`

- **Windows:**
  - [http://caml.inria.fr/ocaml/release.en.html](http://caml.inria.fr/ocaml/release.en.html)
  - Get the **Microsoft-based native Win32 port**

- OCaml toplevel system demo
let sixEleven = 6110

(* A local variable declaration *)
let fortyTwo =
    let six = 6
    and nine = 7
in six * nine
Base Types

```ocaml
let x : int = -7
let y : char = 'a'
let z : string = "moo"
let w : float = 3.14159
let v : bool = true
```

- OCaml has type inference
- Type declarations are optional in many places
- But having them makes it much easier to debug type errors!
Tuples and Datatypes

(* Tuples (a.k.a. product types) *)
let t1 : int * int = (3, 5)
let t2 : string * bool * char = ("moo", true, 'q')
let t3 : unit = () (* The empty tuple *)

(* A simple datatype (like enum or union) *)
type suit = Spades | Diamonds | Hearts | Clubs
let c : suit = Clubs
More Datatypes

(* Datatype constructors can carry values *)
(* and be recursive (and look like CFGs) *)

```ocaml
type var = string

type exp = Var of var
  | Lam of var * exp
  | App of exp * exp

let id : exp = Lam ("x", Var "x")

let w : exp =
  App (Lam ("x", App (Var "x", Var "x"))),
  Lam ("x", App (Var "x", Var "x")))
```

- Can build up tuples and datatypes...
- How to break them down and actually use them?
let t1 : int * int = ...

(* Binds two variables at once *)
let (a, b) = t1

(* Use _ for "don’t care" *)
let (_, b) = t1

(* Can match constants too *)
let (a, 5) = t1

- OCaml warns about non-exhaustive patterns
let suitname : string =
  match c with
  Spades -> "spades" | Diamonds -> "diamonds"
  | Hearts -> "hearts" | Clubs -> "clubs"

(* Base types are just special datatypes *)
(* and can also be pattern-matched *)

let b : bool = ...
let x : int =
  match b with
    true -> 1
  | false -> 0
let suitname : string =
    match c with
    Spades -> "spades" | Diamonds -> "diamonds"
    | Hearts -> "hearts" | Clubs -> "clubs"

(* Base types are just special datatypes *)
(* and can also be pattern-matched *)

let b : bool = ...

let x : int =
    match b with
    true -> 1
    | false -> 0

(* Says the same thing and is better style: *)
let x : int = if b then 1 else 0
A Warning about Pattern Matching

(*) What does this evaluate to? *)

```ocaml
let pair = (42, 611)
let x = 611
match pair with
  (x, 611) -> 0
| (42, x) -> 1
| _ -> 2
```
A Warning about Pattern Matching

(* What does this evaluate to? *)

```ocaml
let pair = (42, 611)
let x = 611
match pair with
  (x, 611) -> 0
| (42, x) -> 1
| _ -> 2
```

- Patterns can refer to datatype constructors and constants
- But cannot refer to pre-existing variables
- They can only *declare* new variables
Functions

(* A variable with a function value *)

let square : int -> int =
    fun (x:int) -> x * x (* anonymous fun! *)

(* Same thing, more succinct *)

let square (x:int) : int = x * x
let rec fact (x:int) : int = 
  if x = 0 then 1 
  else x * (fact (x-1))

(* Mutually recursive functions *)
let rec isOdd (x:int) : bool = 
  x != 0 && isEven (x-1)
and isEven (x:int) : bool = 
  x = 0 || isOdd (x-1)
(* How many arguments does this take? *)

let rec gcd (a, b) : int =
  if b = 0 then a
  else gcd (b, a mod b)
(* How many arguments does this take? *)
let rec gcd (a, b) : int =
  if b = 0 then a
  else gcd (b, a mod b)

(* More explicitly: *)
let rec gcd (p : int * int) : int =
  match p with (a, b) ->
    if b = 0 then a
    else gcd (b, a mod b)
Curried Functions

let rec gcd (a, b) : int =  
  if b = 0 then a  
  else gcd (b, a mod b)

(* Preferred style: *)  
let rec gcd’ (a:int) (b:int) : int =  
  if b = 0 then a  
  else gcd’ b (a mod b)

(* Has type int -> int -> int *)

(* More explicitly: *)  
let rec gcd’ (a:int) : int -> int =  
  fun (b:int) ->  
      if b = 0 then a  
      else gcd’ b (a mod b)
We have

\[
gcd : \text{int} \times \text{int} \rightarrow \text{int}
\]
\[
gcd' : \text{int} \rightarrow (\text{int} \rightarrow \text{int})
\]

Through currying and uncurrying, these types are somehow “equivalent”

Squint hard and you might see logical propositions...

\[
A \land B \implies C
\]
\[
A \implies (B \implies C)
\]

...which are logically equivalent!
(* Newton’s method of approximation *)
let rec newton f guess : float =
    let goodEnough = abs_float (f guess) < 0.0001
    in
    if goodEnough then guess
    else
        let
            f' x = (f x -. f (x -. 0.0001)) /. 0.0001
        in
            let newGuess =
                guess -. (f guess) /. (f' guess)
            in newton f newGuess
(* What is this function’s type? *)

let id x = x
Polymorphism

(* What is this function’s type? *)
let id x = x

(* More explicitly *)
let id (x : 'a) : 'a = x

(* A polymorphic datatype *)
type 'a lst =
  Empty
| Cons of ('a * 'a lst)

let rec map (f:'a -> 'b) (l:'a lst) : 'b lst =
  match l with
  | Empty -> Empty
  | Cons (hd, tl) -> Cons (f hd, map f tl)
OCaml has lists built-in

- `[]` is the empty list
- `::` is the cons operator
- `@` is the append operator
- `[1; 2; 3]` is a three-element list
  (note the semicolons)

```ocaml
let rec reverse (l : 'a list) : 'a list =
    match l with
    | [] -> []
    | hd :: tl -> (reverse tl) @ [hd]
```

- A fancy list pattern:
  
  ```list
  [a; (42, [611]); (b, c:::d)]
  ```
Putting It All Together

- Demo: #use "fv.ml"
Summary

- Types, tuples, datatypes
- Pattern matching
- Higher-order functions, anonymous functions, currying
- Polymorphism
Resources

- CS 3110 notes
  http://www.cs.cornell.edu/courses/cs3110/2008fa/

- Objective CAML Tutorial
  http://www.ocaml-tutorial.org/

- SML vs. OCaml

- OCaml manual
  http://caml.inria.fr/pub/docs/manual-ocaml/