CMSC 330: Organization of Programming Languages

OCaml Data Types

Review: Fold

tail recursive

```
let rec fold_left f a l =
  match l with
  [ ] -> a
  | h::t -> fold_left f (f a h) t
```

Processes list from head to tail

becomes new a in each iteration

```
let rec fold_right f l a =
  match l with
  [ ] -> a
  | h::t -> f h (fold_right f t a)
```

Processes list from tail to head.

not tail recursive, creates too many stack frames over large lists and DS's.

Review: Fold

```
fold_left (+) 0 [1;2;3]
fold_left (+) 1 [2;3]
fold_left (+) 3 [3]
fold_left (+) 6 []
6
```

```
fold_right (+) [1;2;3] 0
1 + (fold_right (+) [2;3] 0)
1 + (2 + (fold_right (+) [3] 0))
1 + (2 + (3 (fold_right (+) [] 0)))
1 + (2 + ( 3 + 0)) 1 + (2 + 3)
1 + 5
6
```

OCaml Data

- So far, we've seen the following kinds of data
  - Basic types (int, float, char, string)
  - Lists
    - One kind of data structure
    - A list is either [ ] or h::t, deconstructed with pattern matching
  - Tuples and Records
    - Let you collect data together in fixed-size pieces
  - Functions

- How can we build other data structures?
  - Building everything from lists and tuples is awkward

(User-Defined) Variants

```
type gen =
    |Int of int
    |Str of string;;
```

enum types

allows for polymorphic lists & data structures

```
let ls = [Int 10; Str "alice"]
```

gen list = [~~~]

type gen

```
let print_gen lst =
  match lst with
    |Int i->Printf.printf "%d\n" i
    |Str s-> Printf.printf "%d\n" s

List.iter print_gen ls
```

prints type of each elt of the gen list by using pattern matching on each gen type.

Variants (full definition)

- Syntax
  - `type t = C1 [of t1] | ... | Cn [of tn]`
  - the `Ci` are called constructors
- Evaluation
  - A constructor `Ci` is a value if it has no assoc. data
    - `Ci vi` is a value if it does
  - Destructing a value of type `t` is by pattern matching
    - patterns are constructors `Ci` with data components, if any
- Type Checking
  - `Ci [vi]` : `t` [if `vi` has type `ti`]

Data Types: Variants with Data

```
type shape =
   Rect of float * float
 | Circle of float
```

```
let area s =
  match s with
      Rect (w, l) -> w *. l
    | Circle r -> r  *. r *. 3.14
;;
area (Rect (3.0, 4.0));; (* 12.0  *)
area (Circle 3.0);;      (* 28.26 *)
```

`[Rect (3.0, 4.0) ; Circle 3.0]. (* shape list*)`

Quiz 1

```
type foo = ((string list) * int) list
```

Which one of the following could match type **foo**?

```
A. [("foo", "bar", 5)]
B. [(["foo", "bar"],6)]
C. [([("foo", "bar")],8)]
D. [(["foo"; "bar"],7)]
```

Quiz 1

```
type foo = ((string list) * int) list
```

Which one of the following could match type **`foo`**?

A. `[("foo", "bar”, 5)]` string * string * int) list
B. `[(["foo", "bar"],6)]` ((string*string) list*int) list
C. `[([("foo", "bar")],8)]` same as B
D. `[(["foo"; "bar"],7)]` (string list * int) list

Quiz 2: What does this evaluate to?

```
type num = Int of int | Float of float;;

let aux a =
  match a with
  | Int i -> i
  | Float j -> int_of_float j
;;

aux (Float 5.0);;
```

A. 5

B. 2

C. 5.0

D. Type Error

Quiz 2: What does this evaluate to?

```
type num = Int of int | Float of float;;

let aux a =
  match a with
  | Int i -> i
  | Float j -> int_of_float j
;;

aux (Float 5.0);;
```

A. 5

B. 2

C. 5.0

D. Type Error

Option Type

```
let divide x y =
  if y != 0 then Some (x/y)
  else None


let string_of_opt o =
  match o with
    Some i -> string_of_int i
  | None -> "nothing"
```

```
type optional_int =
    None == NULL
  | Some of int
```

let hd lst =
match lst with ??
[] -> ?? (-1)
| h::_ -> h
;;

what if the first item is -1? There's no NULL value to return. Using option types, you do not have to return the head item as a list, just as the item itself. → hd

Must return head as 1-item list. [hd]

- Comparing to Java: **None** is like **null**, while **Some** *i* is like an **Integer(*i*)** object

Polymorphic Option Type

```
type 'a option =
  Some of 'a
| None
```

```
let opthd l =
  match l with
    [] -> None
  | x::_ -> Some x
```

```
let p = opthd [];;     (* p = None *)
let q = opthd [1;2];;  (* q = Some 1 *)
let r = opthd [“a”];;  (* r = Some “a” *)
```

Quiz 3: What does this evaluate to?

```
let foo f = match f with
      None -> 42.0
    | Some n -> n +. 42.0
;;
foo 3.5;;
```

A. `45.5`

B. `42.0`

C. `Some 45.5`

D. Error

Quiz 3: What does this evaluate to?

```
let foo f = match f with
     None -> 42.0
   | Some n -> n +. 42.0
;;
~~foo 3.5~~;;   foo (Some 3.5)
```

A. **45.5**

B. **42.0**

C. **Some 45.5**

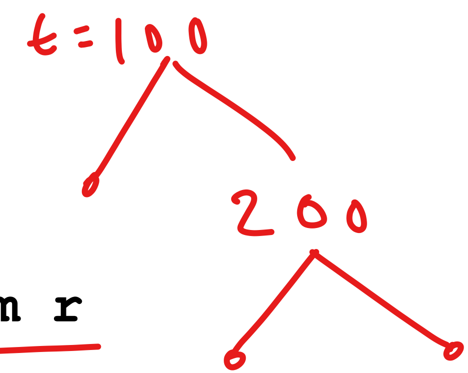
D. **Error**

Recursive Data Types: List

```
type 'a mylist =
    Nil
  | Cons of 'a * 'a mylist


let l = Cons (10, Cons (20, Cons (30, Nil)))

let rec len = function
    Nil -> 0
  | Cons (_, t) -> 1 + (len t)
```

Recursive Data Types: Binary Tree

```
type 'a tree =
    Leaf
  | Node 'a tree * 'a * 'a tree

let empty = Leaf
let t = Node(Leaf, 100, Node(Leaf,200,Leaf))


let rec sum t =
  match t with
     Leaf -> 0
    | Node(l,v,r)-> sum l + v + sum r
```



sum left tree.

sum right tree.

OCaml Exceptions

```
exception My_exception of int
let f n =
  if n > 0 then
    raise (My_exception n)
  else
    raise (Failure "foo")
let bar n =
  try
    f n
  with My_exception n ->
      Printf.printf "Caught %d\n" n
    | Failure s ->
      Printf.printf "Caught %s\n" s
```

OCaml Exceptions: Useful Examples

- **`failwith s`**: Raises exception Failure s (s is a string).
- **`Not_found`**: Exception raised by library functions if the object does not exist
- **`invalid_arg s`**: Raises exception Invalid_argument s

```
let div x y =
  if y = 0 then failwith "div by 0" else x/y;;

let lst =[(1,"alice");(2,"bob");(3,"cat")];;
let lookup key lst =
  try
    List.assoc key lst
  with
    Not_found -> "key does not exist"
```