

CMSC 330: Organization of Programming Languages

OCaml Data Types

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 Types

type can be used to create new names for types

- Like **typedef** in C – a name might be more useful for communicating intent than just the type structure

Example

```
# type mylist = int*(int list);;
type mylist = int * int list
# let empty:mylist = (0, []);;
val empty : mylist = (0, [])
# let add x ((n,xs):mylist) mylist = (n+1,x::xs);;
val add : int -> mylist -> mylist = <fun>
# let length ((n,_):mylist) = n;;
val length : mylist -> int = <fun>
# let x = add 1 (add 2 empty);;
val x : mylist = (2, [1; 2])
```

Annotation required
to tell type inference
you want **mylist**,
not **int*int list**

(User-Defined) Variants

```
type coin = Heads | Tails
```

```
let flip x =
```

```
  match x with
```

```
    Heads -> Tails
```

```
  | Tails -> Heads
```

```
let rec count_heads x =
```

```
  match x with
```

```
    [] -> 0
```

```
  | (Heads::x') -> 1 + count_heads x'
```

```
  | (_::x') -> count_heads x'
```

In simplest form:
Like a C `enum`

Basic pattern
matching
resembles C
`switch`

Combined list
and variant
patterns possible

Constructing and Destructing Variants

- Syntax

- **type** $t = C1 \mid \dots \mid Cn$
- the Ci are called **constructors**
 - Must begin with a capital letter

- Evaluation

- A constructor Ci is already a value
- Destructing a value v of type t is done by pattern matching on v ; the patterns are the constructors Ci

- Type Checking

- $Ci : t$ (for each Ci in t 's definition)

Data Types: Variants with Data

- We can define variants that “carry data” too
 - Not just a constructor, but a constructor *plus values*

```
type shape =  
  Rect of float * float (* width*length *)  
  | Circle of float      (* radius *)
```

- **Rect** and **Circle** are constructors
 - where a **shape** is either a **Rect** (***w***, ***l***)
 - for any floats ***w*** and ***l***
 - or a **Circle** ***r***
 - for any float ***r***

Data Types (cont.)

```
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 *)
```

- Use pattern matching to **deconstruct** values
 - Can bind pattern values to data parts
- Data types are *aka* **algebraic data types** and **tagged unions**

Data Types (cont.)

```
type shape =  
    Rect of float * float (* width*length *)  
    | Circle of float      (* radius *)  
  
let lst = [Rect (3.0, 4.0) ; Circle 3.0]
```

- What's the type of `lst`?
 - `shape list`
- What's the type of `lst`'s first element?
 - `shape`

Variation: Shapes in Java Compare this to OCaml

```
public interface Shape {  
    public double area();  
}
```

```
class Rect implements Shape {  
    private double width, length;  
  
    Rect (double w, double l) {  
        this.width = w;  
        this.length = l;  
    }  
  
    double area() {  
        return width * length;  
    }  
}
```

```
class Circle implements Shape {  
    private double rad;  
  
    Circle (double r) {  
        this.rad = r;  
    }  
  
    double area() {  
        return rad * rad * 3.14159;  
    }  
}
```

Option Type

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

```
let p = divide 1 0;;  
print_string  
  (string_of_opt p);;  
(* prints "nothing" *)  
  
let q = divide 1 1;;  
print_string  
  (string_of_opt q);;  
(* prints "1" *)
```

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

Polymorphic Option Type

- A **Polymorphic** version of `option` type can work with *any kind of data*
 - As `int option`, `char option`, etc...

*Polymorphic parameter:
like `Option<T>` in Java*

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

In fact, this **option** type
is built into OCaml

```
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 1

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

Which one of the following could match foo?

- A. `[(3, "foo", "bar")]`
- B. `[(7, ["foo"; "bar"])]`
- C. `[(5, ["foo", "bar"])]`
- D. `[(9, [("foo", "bar")])]`

Quiz 1

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type foo = (int * (string list)) list
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Which one of the following could match foo?

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- D. `[(9, [("foo", "bar")])]`

Quiz 2: What does this evaluate to?

```
type num = Int of int | Float of float;;  
let plus a b =  
  match a, b with  
  | Int i, Int j -> Int (i+j)  
  | Float i, Float j -> Float (i +. j)  
  | Float i, Int j -> Float (i +. float_of_int j)  
;;  
plus (Float 2.0) (Int 2);;
```

- A. 4.0
- B. Int 4
- C. Float 4.0
- D. Type Error

Quiz 2: What does this evaluate to?

```
type num = Int of int | Float of float;;
let plus a b =
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  | Int i, Int j -> Int (i+j)
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  | Float i, Int j -> Float (i +. float_of_int j)
;;
plus (Float 2.0) (Int 2);;
```

- A. 4.0
- B. Int 4
- C. Float 4.0**
- D. Type Error

Quiz 3: What does this evaluate to?

```
let foo f = match f with
  None -> 42.0
  | Some n -> n +. 42.0
;;
foo 3.3;;
```

- A. 45.3
- B. 42.0
- C. Some 45.3
- D. Error

Quiz 3: What does this evaluate to?

```
let foo f = match f with
  None -> 42.0
  | Some n -> n +. 42.0
;;
foo 3.3;;  foo (Some 3.3)
```

- A. 45.3
- B. 42.0
- C. Some 45.3
- D. Error**

Recursive Data Types

- We can build up lists with **recursive** variant types

```
type 'a mylist =  
  Nil  
  | Cons of 'a * 'a mylist  
  
let rec len = function  
  Nil -> 0  
  | Cons (_, t) -> 1 + (len t)  
  
len (Cons (10, Cons (20, Cons (30, Nil))))  
(* evaluates to 3 *)
```

- Won't have nice **[1; 2; 3]** syntax for this kind of list

Variants (full definition)

• Syntax

- type $t = C1 \text{ [of } t1] \mid \dots \mid Cn \text{ [of } tn]$
- the Ci are called constructors
 - Must begin with a capital letter; may include associated data - notated with brackets $[]$ to indicate it's optional

• Evaluation

- A constructor Ci is a value if it has no assoc. data
 - $Ci \text{ } vi$ 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

- $Ci \text{ } [vi] : t$ [if vi has type ti]

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
```

Exceptions (cont.)

- Exceptions are declared with **exception**
 - They may appear in the signature as well
- Exceptions may take arguments
 - Just like type constructors
 - May also have no arguments
- Catch exceptions with **try...with...**
 - Pattern-matching can be used in **with**
 - If an exception is uncaught
 - Current function exits immediately
 - Control transfers up the call chain
 - Until the exception is caught, or until it reaches the top level

OCaml Exceptions (cont.)

- **failwith**: Raise exception **Failure** with the given string.
- **invalid_arg**: Raise exception **Invalid_argument** with the given string
- **Not_found**: Raised if the object does not exist

```
let div x y =  
  if y = 0 failwith "divide by zero" 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"
```