CMSC 330: Organization of Programming Languages

Basic OCaml Modules

Modules

- So far, most everything we've defined has been at the "top-level" of OCaml
  - This is not good software engineering practice
- A better idea: Use modules to group associated types, functions, and data together
  - Avoid polluting the top-level with unnecessary stuff
- For lots of sample modules, see the OCaml standard library, e.g., List, Str, etc.

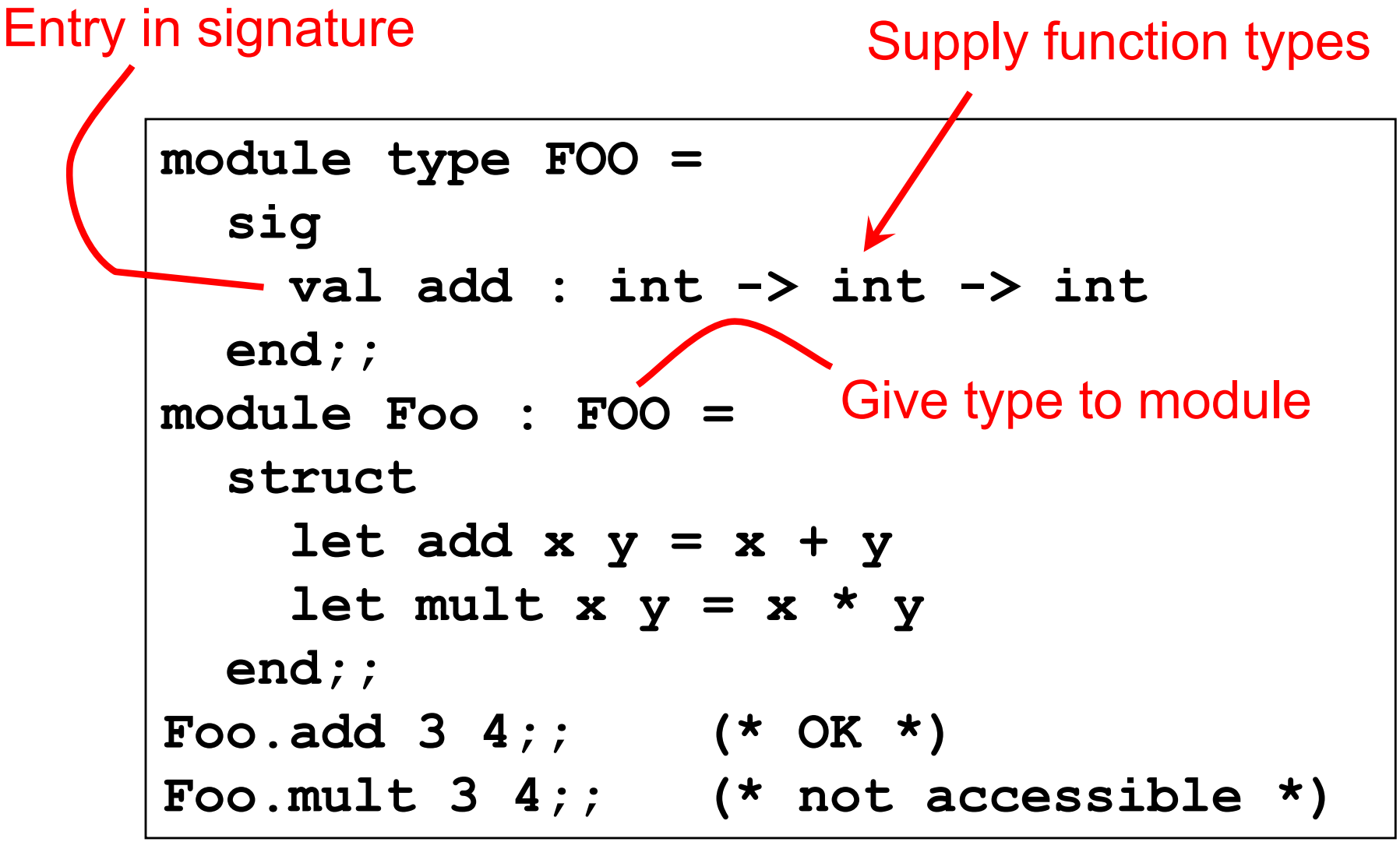
Creating A Module In OCaml

```
module ISet =
  struct
    type set = EMPTY | INS of int * set

    let empty = EMPTY

    let isEmpty(s) = s = EMPTY

    let insert(s, i) = INS(i,s)

    let rec contains(s, i) =
      match s with
        | EMPTY -> false
        | INS(j,r) -> if i = j then true
                      else contains(r,i)
  end;;
```

Creating A Module In OCaml (cont.)

```
module ISet =
  struct
    type set = …
    let empty = …
    let isEmpty = …
    let insert = …
    let contains = …
  end;;

# empty;;
ERROR: unbound value empty
# ISet.empty;;
- : ISet.set = ISet.EMPTY
# ISet.contains (Set.empty, 1);;
- bool = false
# open ISet;; (* add ISet names to curr scope *)
# empty;;
- : ISet.EMPTY (* now defined *)
```

Module Signatures



Module Signatures (cont.)

- Convention: Signature names in all-caps
  - This isn't a strict requirement, though
- Items can be omitted from a module signature
  - This provides the ability to hide values
- The default signature for a module hides nothing
  - This is what OCaml gives you if you just type in a module with no signature at the top-level

Abstraction = Hiding

- Signatures hide module implementation details
  - Why do that? Doesn't that reduce flexibility?

- This is good software engineering practice
  - Ensures data structure invariants maintained
    - clients can't construct arbitrary data structures, only ones our module's functions create
  - Facilitates code collaboration
    - Write code to the interface as implementation worked out
  - Clients do not rely details that may change
    - Changing set representation later won't affect clients

Abstract Data Types

Idea: Hide data value's internal representation from its clients

Invented by Barbara Liskov in the CLU programming language

- Professor at MIT since 1971

Won Turing Award for ADTs and other contributions in 2008

http://amturing.acm.org/award_winners/liskov_1108679.cfm

Abstract Data Types In OCaml Sigs

```
module type ISET =
  sig
    type set
    val empty : set
    val isEmpty : set -> bool
    val insert :  set * int -> set
    val contains : set * int -> bool
end;;

module ISet : ISET =
  struct
    type set = EMPTY | INS of int * set
    ...
    let insert (s,i) = INS(i,s)
  end
```

- The definition of **`set`** is hidden from ISet clients

Quiz 1: Evaluation on ADTs

```
# ISet.empty
- : ISet.set = <abstr>  (* OCaml won't show impl *)
# ISet.EMPTY
Unbound Constructor ISet.EMPTY
# ISet.isEmpty (ISet.insert(ISet.empty, 0))
- : bool = false
# open ISet;;
(* doesn't make anything abstract accessible *)
```

```
# ISet.insert (ISet.empty, 0)
A.- : ISet.set = <abstr>
B.Type Error
C.- : ISet.INS (0, ISet.EMPTY)
```

Quiz 1: Evaluation on ADTs

```
# ISet.empty
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# ISet.EMPTY
Unbound Constructor ISet.EMPTY
# ISet.isEmpty (ISet.insert(ISet.empty, 0))
- : bool = false
# open ISet;;
(* doesn't make anything abstract accessible *)
```

```
# ISet.insert (ISet.empty, 0)
```

A. `- : ISet.set = <abstr>`

B. `Type Error`

C. `- : ISet.INS (0, ISet.EMPTY)`

Multiple representations

```
module ISetBST : ISET =
  struct
    type set = TIP | BIN of int * set * set
    ...
    let rec insert (s,i) =
     match s with
        TIP -> BIN(i,TIP, TIP)
      | BIN(j,l,r) ->
        if i = j then s
        else if i < j then BIN(j,insert(l,i),r)
        else BIN(j,l,insert(r,i))
  end
```

- Now **`set`** is a binary search tree (why?)

Quiz 2: Mixing ADTs?

```
# ISetBST.empty
- : ISetBST.set = <abstr>  (* OCaml won't show impl *)
# ISetBST.insert (ISetBST.empty, 0)
- : ISetBST.set = <abstr>
# ISetBST.contains (ISetBST.empty, 0)
- : bool = false
```

```
# ISet.insert (ISetBST.empty, 0)
```

A. `- : ISet.set = <abstr>`

B. `- : ISetBST.set = <abstr>`

C. `Type Error`

D. `- : ISetBST.INS (0, ISet.EMPTY)`

Quiz 2: Mixing ADTs?

```
# ISetBST.empty
- : ISetBST.set = <abstr>  (* OCaml won't show impl *)
# ISetBST.insert (ISetBST.empty, 0)
- : ISetBST.set = <abstr>
# ISetBST.contains (ISetBST.empty, 0)
- : bool = false
```

```
# ISet.insert (ISetBST.empty, 0)
A.- : ISet.set = <abstr>
B.- : ISetBST.set = <abstr>
C.Type Error
D.- : ISetBST.INS (0, ISet.EMPTY)
```

Different ADTs are … different

- The **`set`** type of ISet and ISetBST look the same, but are not
  - Both modules are an instance of the ISET signature
  - But because the type's definition is hidden, it is not safe to mix them
- This distinction is enforced by the type system
  - set type is an abstract type
  - the instances of modules having the ISET signature (which has an abstract type) are called abstract data types (ADTs)

Other Module Systems

- How OCaml's approach compare to modularity in...
  - Java?
  - C?
  - Ruby?

Modules In Java

- Java classes are like modules
  - Provide implementations for a group of functions
  - But classes can also
    - ➢ Instantiate objects
    - ➢ Inherit attributes from other classes

- Java interfaces are like module signatures
  - Defines a group of functions that may be used
  - Implementation is hidden
  - But: Objects and modules/ADT not the same
    - ➢Next lecture topic!

Modules In C

- .c files are like modules
  - Provides implementations for a group of functions
- .h files are like module signatures
  - Defines a group of functions that may be used
  - Implementation is hidden
- Usage is not enforced by C language
  - Can put C code in .h file

Modules In Ruby

- Ruby explicitly supports modules
  - Modules defined by module … end
  - Modules cannot
    - ➢ Instantiate objects
    - ➢ Derive subclasses

```
puts Math.sqrt(4)     # 2
puts Math::PI         # 3.1416

include Math          # open Math
puts sqrt(4)          # 2
puts PI               # 3.1416
```