~ Lecture VI ~

Keywords:

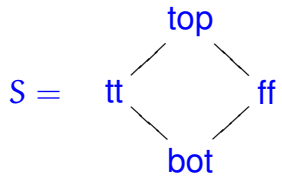
enumerated types; polymorphic `datatype`s: `option` type, disjoint-union type; abstract types; error handling; exceptions.

References:

- [MLWP]
  - Section 2.9, § Records
  - Chapter 4, § The `datatype` declaration
  - Section 7.6, § The `abstype` declaration
  - Chapter 4, § Exceptions

Enumerated types

Example:
The lattice



may be implemented as

```
datatype S = bot | tt | ff | top ;
fun lt (bot,_) = true
  | lt (_,top) = true
  | lt _ = false ;
~
"p04"
```


The `datatype` declaration defines the set of *constructors* of the datatype:

```
> New type names: =S
  datatype S
  = (S,{con bot : S, con ff : S,
        con top : S, con tt : S})
  con bot = bot : S
  con ff = ff : S
  con top = top : S
  con tt = tt : S
> val lt = fn : S * S -> bool
```


Polymorphic datatypes

1. The standard library declares the datatype `option`:

   ```
   datatype 'a option = NONE | SOME of 'a ;
   ```

   Note the polymorphism

   ```
   > New type names: =option
     datatype 'a option =
     ('a option,{con 'a NONE : 'a option,
                 con 'a SOME : 'a -> 'a option})
     con 'a NONE = NONE : 'a option
     con 'a SOME = fn : 'a -> 'a option
   ```

   Type τ `option` contains a copy of type τ, augmented with the extra value `NONE`.

The `option` type can be used to supply optional data to a function, but its most obvious use is to indicate errors.

Example:

```
fun find P l
  = case dropwhile ( fn x => not(P x) ) l of
      [] => NONE
    | (h::_) => SOME h ;
> val 'a find
    = fn : ('a -> bool) -> 'a list -> 'a option
```


2. Disjoint-union type.

```
datatype ('a,'b)sum
  = In1 of 'a | In2 of 'b ;
~
"p05"
> New type names: =sum
  datatype ('a, 'b) sum =
  (('a, 'b) sum,
   {con ('a, 'b) In1 : 'a -> ('a, 'b) sum,
    con ('a, 'b) In2 : 'b -> ('a, 'b) sum})
  con ('a, 'b) In1 = fn : 'a -> ('a, 'b) sum
  con ('a, 'b) In2 = fn : 'b -> ('a, 'b) sum
```

Examples:

```
type intORreal = (int,real)sum ;
type 'a myoption = (unit,'a)sum ;
```


Abstract types

Examples:

1. Complex numbers.

```
abstype complex = C of real * real
with
  fun ComplexRep( x , y ) = C(x,y) ;
  val origin = C( 0.0 , 0.0 ) ;
  fun X( C(x,y) ) = x ;
  fun Y( C(x,y) ) = y ;
  fun norm v = Math.sqrt( X(v)*X(v) + Y(v)*Y(v) ) ;
  fun scalevec( r, v ) = C( r*X(v) , r*Y(v) ) ;
  fun normal v = scalevec( 1.0/(norm v) , v ) ;
  fun CartRep v = ( X v , Y v ) ;
end ;
```



```
> New type names: complex
  type complex = complex
  val ComplexRep = fn : real * real -> complex
  val origin = <complex> : complex
  val X = fn : complex -> real
  val Y = fn : complex -> real
  val norm = fn : complex -> real
  val scalevec = fn : real * complex -> complex
  val normal = fn : complex -> complex
  val CartRep = fn : complex -> real * real
```

```
val v1 = normal( ComplexRep(2.0,2.0) ) ;
CartRep v1 ;
norm v1 ;
> val v1 = <complex> : complex
> val it
  = (0.707106781187, 0.707106781187) : real * real
> val it = 1.0 : real
```


2. Queues.

```
abstype 'a Queue = Q of 'a list * 'a list
  with
    val empty = Q([],[]) ;
    fun null( Q([],[]) ) = true
      | null _ = false ;
    fun enq x ( Q([],_) ) = Q( [x] , [] )
      | enq x ( Q(front,back) ) = Q( front , x::back ) ;
    fun deq( Q(_::[],back) ) = Q( rev back , [] )
      | deq( Q(_::rest,back) ) = Q( rest , back )
      | deq( _ ) = empty ;
    fun hd( Q(head::rest,_) ) = SOME head
      | hd( Q([],_) ) = NONE ;
  end ;
```



```
type 'a Queue
val empty = - : 'a Queue
val null = fn : 'a Queue -> bool
val enq = fn : 'a -> 'a Queue -> 'a Queue
val deq = fn : 'a Queue -> 'a Queue
val hd = fn : 'a Queue -> 'a option
```



```
enq 0 empty; enq 1 it; deq it ; hd it ;
val it = - : int Queue
val it = - : int Queue
val it = - : int Queue
val it = SOME 1 : int option

enq 0 empty; enq 1 it; deq it ; deq it ; hd it ;
val it = - : int Queue
val it = - : int Queue
val it = - : int Queue
val it = - : int Queue
val it = NONE : int option
```

Exceptions

Exceptions are raised on various runtime failures including failed pattern match, overflow, *etc.* One can also define custom exceptions and raise them explicitly.

Examples:

1.
```
exception Error of string ;
fun f b
  = ( if b
      then raise Error "It's true\n"
      else raise Error "It's false\n"
        ) handle Error m => print m ;
val f = fn : bool -> unit
- f true ;
It's true
```


2. Queues.
```
abstype 'a Queue = Q of 'a list * 'a list
  with
    exception E ;
    val empty = Q([],[]) ;
    fun null( Q([],[]) ) = true
      | null _ = false ;
    fun enq x ( Q([],_) ) = Q( [x] , [] )
      | enq x ( Q(front,back) ) = Q( front , x::back ) ;
    fun deq( Q(_::[],back) ) = Q( rev back , [] )
      | deq( Q(_::rest,back) ) = Q( rest , back )
      | deq( _ ) = empty ;
    fun hd( Q(head::rest,_) ) = head
      | hd( Q([],_) ) = raise E ;
  end ;
```



```
datatype 'a instruction
  = create of 'a Queue -> 'a Queue
  | observe of 'a Queue -> 'a ;

fun process obs []  q  = obs
  | process obs ( (create f)::ins ) q
      = process obs ins ( f q )
  | process obs ( (observe f)::ins ) q
      = process (  (f q)::obs handle E => []  ) ins q ;
val process = fn :
'a list -> 'a instruction list -> 'a Queue -> 'a list
```