ML Lectures (continued)
Winter 2007

Polymorphism

Greek: *poly = many , morph = form*

Definitions:

Polymorphism:

- dictionary.com: the capability of assuming different forms; the capability of widely varying in form. The occurrence of different forms, stages, or types
- Software: a value/variable can belong to multiple types

Monomorphism:

Dictionary.com: having only one form, same genotype…

Software: every value/variable belongs to exactly one type

Without polymorphism, a typed language would be very rigid.

We would have to define many different kinds of *length* functions:

int-length : int list → int

real-length: real list → int

string-length: string list → int ……..

And the code for each of these functions would be virtually identical!

Polymorphism adds flexibility & convenience.

Polymorphism

There are 3 kinds of polymorphism:

1. Ad-hoc polymorphism: also known as *overloading*. Different operations known by same name that the compiler/interpreter resolves.

2. Inheritance-based polymorphism: subclasses define new version of methods possessed by super class. OO languages use this a lot!!

3. Parametric Polymorphism: types/type variables explicitly used as parameters.

Polymorphism

1. Ad-hoc polymorphism:

Different operations on different types known by the same name *(also called overloading)*

E.g. 3.0 + 4

compiler/interpreter must change 4 to 4.0 first

2. Inheritance polymorphism:

- Use sub-classing to define new versions of existing functions *(OO)*

E.g.:

```
public class Employee{
        public int salary;
        public void income() = {return
    salary;}
    }
    public class Waitress extends Employee{
        public int tips;
        public void income() = {return
    (salary + tips);}
    public class Professor extends Employee;
```

Polymorphism

3. Parametric Polymorphism:

- Allows types to be parameters to functions and other types.
- Basic idea is to have a type variable…
- Type of function depend on type of parameter
- Implementation:

  Homogenous implementations (ML)
  - One one copy of code is generated
  - Polymorphic parameters must internally be implemented as pointers

  Heterogeneous implementation (C++)
  - One copy of function code per instantiation
  - Access to polymorphic parameters can be more efficient

Polymorphic Functions

Function Polymorphism:
values (including variables or functions) that can have more than one type

Examples:

```
fun length L = if (null L) then 0 else 1 + length (tl L);

fun reverse [] = []
  | reverse (h::t) = reverse(t) @ [h];

fun listify x = [x];

fun apply (f,x) = (f x);
apply(real,5);
```

Without polymorphism, we would need many functions:
int-length, int-reverse, real-length, real-reverse, etc.

Polymorphic Functions

Polymorphic functions are common in ML:

```
- fun id X = X;
val id = fn : 'a -> 'a
```

```
- id 7;
val it = 7 : int
- id "abc";
val it = "abc" : string
```

```
- fun listify X = [X];
val listify = fn : 'a -> 'a list
```

```
- listify 3;
val it = [3] : int list
- listify 7.3;
val it = [7.3] : real list
```

```
- fun double X = (X,X);
val double = fn : 'a -> 'a * 'a
```

```
- double "xy";
val it = ("xy","xy") : string * string
- double [1,2,3];
val it = ([1,2,3],[1,2,3]) : int list * int list
```


Polymorphic Functions

```
- fun inc(N,X) = (N+1,X);
val inc = fn : int * 'a -> int * 'a
```

```
- inc (2,5);
val it = (3,5) : int * int
- inc (4,(34,5));
val it = (5,(34,5)) : int * (int * int)
```

```
- fun swap(X,Y) = (Y,X);
val swap = fn : 'a * 'b -> 'b * 'a
```

```
- swap ("abc",7);
val it = (7,"abc") : int * string
- swap (13.4,[12,3,3]);
val it = ([12,3,3],13.4) : int list * real
```

```
- fun pair2list(X,Y) = [X,Y];
val pair2list = fn : 'a * 'a -> 'a list
```

```
- pair2list(1,2);
 val it = [1,2] : int list
- pair2list(1,"cd");
?
```

Polymorphic Functions

- fun apply(Func,X) = Func X;
*val apply = fn : ('a -> 'b) * 'a -> 'b*

```
- apply (hd, [1,2,3]);
val it = 1 : int
- apply (length, [23,100]);
val it = 2 : integer
```

- fun applytwice(Func,X) = Func(Func X);
*val applytwice = fn : ('a -> 'a) * 'a -> 'a*

```
- applytwice (square,3);
val it = 81 : int
- applytwice (tl, [1,2,3,4]);
?
- applytwice (hd, [1,2,3,4]);
?
```

ML

Polymorphism

Operators that restrict polymorphism

- Arithmetic operators: **+ , -, * , –**
- Division-related operations e.g. */* **, div, mod**
- Inequality comparison operators: **< , <=, >=, >**,etc.
- Boolean connectives: **andalso, orelse, not**
- String concatenation operator: **^**
- Type conversion operators
  - E.g. **ord, chr, real, str, floor, ceiling, round, truncate,…**

Operators that allow polymorphism

- Tuple operators
- List operators
- Equality operators **=, <>**