Lecture 20

- Louden Chapters 6,9
- Data Types and Abstract Data Types

Arrays as functions

- f: U -> V (if U is ordinal type) f(i) array
- C arrays types can be without sizes array variables must have fixed size

```
int array_max(int a[], int size)   // parameters are essentially pointers
{
    int temp, i;
    assert(size > 0);
    temp = a[0];
    for (i=1; i < size; i++)
      { if (a[i] > temp) temp = a[i]; }
    return temp;
}
```


Java arrays

Java arrays are heap allocated and the size can be specified completely dynamically (but once specified can not change unless reallocated)

```
class ArrayTest
{  static int array_max(int[] a)
   {  int temp;
      temp = a[0];
      for (int i = 1; i < a.length; i++)
      { if (a[i] > temp) temp = a[i]; }
      return temp;
   }
}
```

```
u = Integer.parseInt(in.readLine());
int[] x = new int[u];
```


Multidimensional Arrays (row major, column major form)

```
int x[10][20];     /* c code */
int array_max(int a[][20], int size);


int [] [] x = new int [10][20];    /* Java code */
```

Pointers and Arrays in C

```
int a[] = {1,2,3,4,5};
int* p = a;
printf("%d\n", *p);
printf("%d\n", *(p+2));
printf("%d\n", *(a+2));
printf("%d\n", 2[a]);

/* all of the above print 3 :-) */
```

a[2] is shorthand for *(a+2);

Recursive Datatypes in C

in ML:

```
datatype CharList = EmptyCharList
                  | CharListNode of char * CharList;
```

C requires that each data type has a fixed maximum size determined at translation time

Each node has a fixed size and they can be strung together to form a list of arbitrary size

```
struct CharListNode
{  char data;
   struct CharListNode* next;
};
typedef struct CharListNode* CharList;
```


Using recursive – pointer types

```
CharList cl = (CharList) malloc(sizeof(struct CharListNode));
(*cl).data = 'a';
(*cl).next = 0;

/* this is so common that there is a short-hand notation */
cl->data = 'a';
cl->next = 0;

(*cl).next = (CharList) malloc(sizeof(struct CharListNode));
(*(*cl).next).data = 'b';   /* cl->next->data='b'; */
(*(*cl).next).next = 0;     /* cl->next->next=0; */
```


Type equivalence

- Structural equivalence
  - two datatypes are the same if they have the same structure (trickier than it sounds)
- Name equivalence
  - two types are the same only if they have the same name

Type equivalence in C, ML

- C
  - name equivalence for structs
  - structure equivalence for everything else
- ML
  - type Age int; (structural equivalence)
  - datatype NewAge = NewAge int; (name equivalence)

Type checking

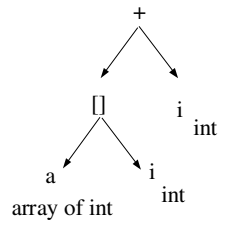
- C, C++ : weak type checking
- Scheme : strong dynamic type checking
- Ada : strong type checking – no type inference (very verbose)
- ML : strong type checking + type inference
  - flexibility + protection from errors

Polymorphic Type Checking

- Hindley-Milner type checking (1969,1978)
- Major feature of ML and Haskell
- The machinery for automatically determining the types of arguments and results of functions without the programmer having to specify them

An example

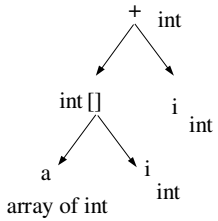
a[i] + i



Type checker fills in the types of each node and check if everything is ok

An example

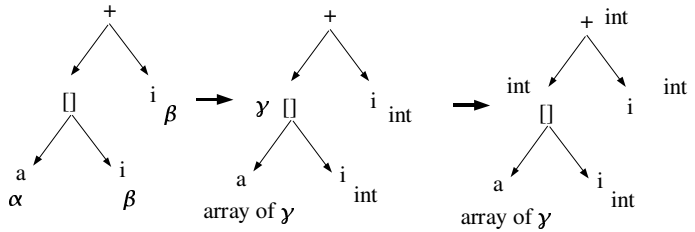
a[i] + i



Type checker fills in the types of each node and check if everything is ok

Can we do without type declarations ?

type variables: α,β,γ (only int subscripts)



Hindley-Milner type checking

- Instantiation: once a type variable is replaced by an actual type, the ALL instances of that variable must be updated
- Unification:
  - any type variable unifies with any type expression
  - type constants unify if they are the same
  - two type constructions unify if they are the same all components also (recursively) unify

Unification examples

- 'a unifies to b' array
- int unifies to int
- 'a list unifies with 'b list
- 2 can not unify with array of a
- array of int cannot unify with array of char

Polymorphic type checking

- 'b array must be the same as 'a array therefore 'b and 'a are the “same” but we don't know what they are
- REALLY COOL
- Implicit Parametric Polymorphism (compiler does it for you)
- Explicit Parametric Polymorphism
- Ad-hoc polymorphism (overloading)

There is more to it

- Read pages 240-244 of your book and using your experience with the ML compiler you should have no problem understanding them

Code translation for polymorphic types

- Without knowing the types translator cannot determine the size of values
- Two solutions
  - Expansion = examine all uses generate seperate code for each use
  - Boxing and tagging = Fix size for scalar types + size field for the rest (flag bit to disambiguate) (also used for garbage collection)

Explicit Polymorphism

In ML (explicit works nicely with HM type checking):

```
datatype 'a Stack = EmptyStack
                  | Stack of 'a * ('a Stack);
```

In C++ (templates are explicit polymorphism)

```
Stack<int> s;
```

The most recent addition to Java are are Generics which are similar.

```
template <typename T>
struct StackNode
{   T data;
    StackNode<T> *next;
};
template <typename T>
struct Stack
{ StackNode<T>* theStack;
};
```