Symbol Tables

ASU Textbook Chapter 7.6, 6.5 and 6.3

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Definitions

- **Symbol table: A data structure used by a compiler to keep track of semantics of variables.**
  - **Data type.**
  - **When is used: scope.**
    - *The effective context where a name is valid.*
  - **Where it is stored: storage address.**
- **Possible implementations:**
  - **Unordered list: for a very small set of variables.**
  - **Ordered linear list: insertion is expensive, but implementation is relatively easy.**
  - **Binary search tree: $O(\log n)$ time per operation for n variables.**
  - **Hash table: most commonly used, and very efficient provided the memory space is adequately larger than the number of variables.**

Hash Table

- **Hash function $h(n)$: returns a value from $0, \ldots, m-1$, where n is the input name and m is the hash table size.**
  - **Uniform and randomized.**
- **Many design for $h(n)$.**
  - **Add up the integer values of characters in a name and then take the remainder of it divided by m.**
  - **Add up a linear combination of integer values of characters in a name, and then $\cdots$**
- **Resolving collisions:**
  - **Linear resolution: try $(h(n)+1) \bmod m$ for m being a prime number.**
  - **Chaining.**
    - *Open hashing.*
    - *Keep a chain on the items with the same hash value.*
    - *Most popular.*
  - **Quadratic-rehashing: try $(h(n)+1^2) \bmod m$, and then try $(h(n)+2^2) \bmod m$, $\ldots$, try $(h(n)+i^2) \bmod m$.**

Performance of Hash Table

- **Performance issues on using different collision resolution schemes.**
- **Hash table size must be adequately larger than the maximum number of possible entries.**
- **Frequently used variables should be distinct.**
  - **Keywords or reserved words.**
  - **Short names, e.g.,** i, j **and** k.
  - **Frequently used identifiers, e.g.,** $main$.
- **Uniformly distributed.**

Contents in symbol tables

- **Possible entries in a symbol table:**
  - **Name: a string.**
  - **Attribute:**
    - ▷ ***Reserved word***
    - ▷ ***Variable name***
    - ▷ ***Type name***
    - ▷ ***Procedure name***
    - ▷ ***Constant name***
    - ▷ ...
  - **Data type.**
  - **Scope information: where it can be used.**
  - **Storage allocation, size, ...**
  - ...

How to store names

- **Fixed-length name: allocate a fixed space for each name allocated.**
  - **Too little: names must be short.**
  - **Too much: waste a lot of spaces.**

NAME										ATTRIBUTES
s	o	r	t							
a										
r	e	a	d	a	r	r	a	y		
i	2									

- **Variable-length name:**
  - **A string of space is used to store all names.**
  - **For each name, store the length and starting index of each name.**

NAME		ATTRIBUTES
index	length	
0	5	
5	2	
7	10	
17	3	

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
s	o	r	t	$	a	$	r	e	a	d	a	r	r	a	y	$	i	2	$

Handling block-structures

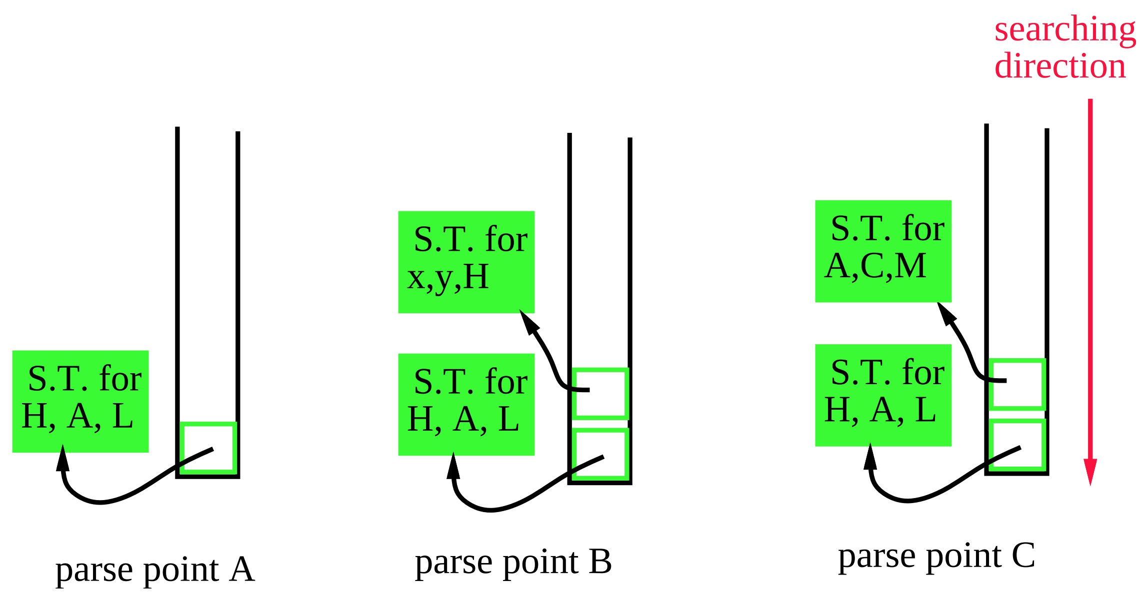
- **Nested block means nested scope.**
- **Example (C language code)**

```
main()
{    /* open a new scope */
     int H,A,L;  /* parse point A */
     ...
     { /* open another new scope */
       float x,y,H; /* parse point B */
       ...
       /* x and y can only be used here */
       /* H used here is float */
       ...
     } /* close an old scope */
     ...
     /* H used here is integer */
     ...
     { char A,C,M; /* parse point C */
     ...
     }
}
```

Two common approaches (1/3)

- **An individual symbol table for each scope.**
  - **Use a stack to maintain the current scope.**
  - **Search top of stack first.**
  - **If not found, search the next one in the stack.**
  - **Use the first match.**
  - **Note: a popped scope can be destroyed in a one pass compiler, but it must be saved in a multi-pass compiler.**

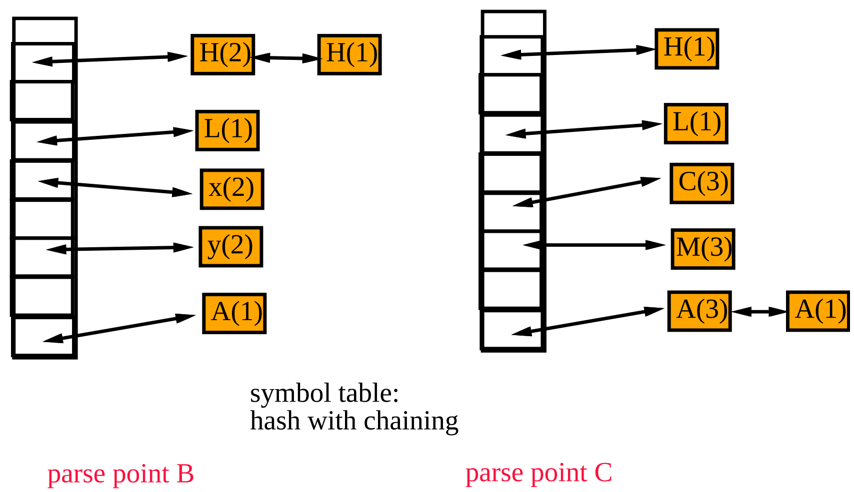
```
main()
{    /* open a new scope */
     int H,A,L;  /* parse point A */
     ...
     { /* open another new scope */
       float x,y,H; /* parse point B
       ...
       /* x and y can only be used he
       /* H used here is float */
       ...
     } /* close an old scope */
     ...
     /* H used here is integer */
     ...
     { char A,C,M; /* parse point C *
     ...
     }
}
```



Two common approaches (2/3)

- **A single global table marked with the scope information.**
  - ▷ *Each scope is given a unique scope number.*
  - ▷ *Incorporate the scope number into the symbol table.*
- **Two possible codings (among others):**
  - **Hash table with chaining.**
    - ▷ *Same names hash into the same location by adding at the front.*
    - ▷ *When a scope is closed, all entries of that scope are removed.*

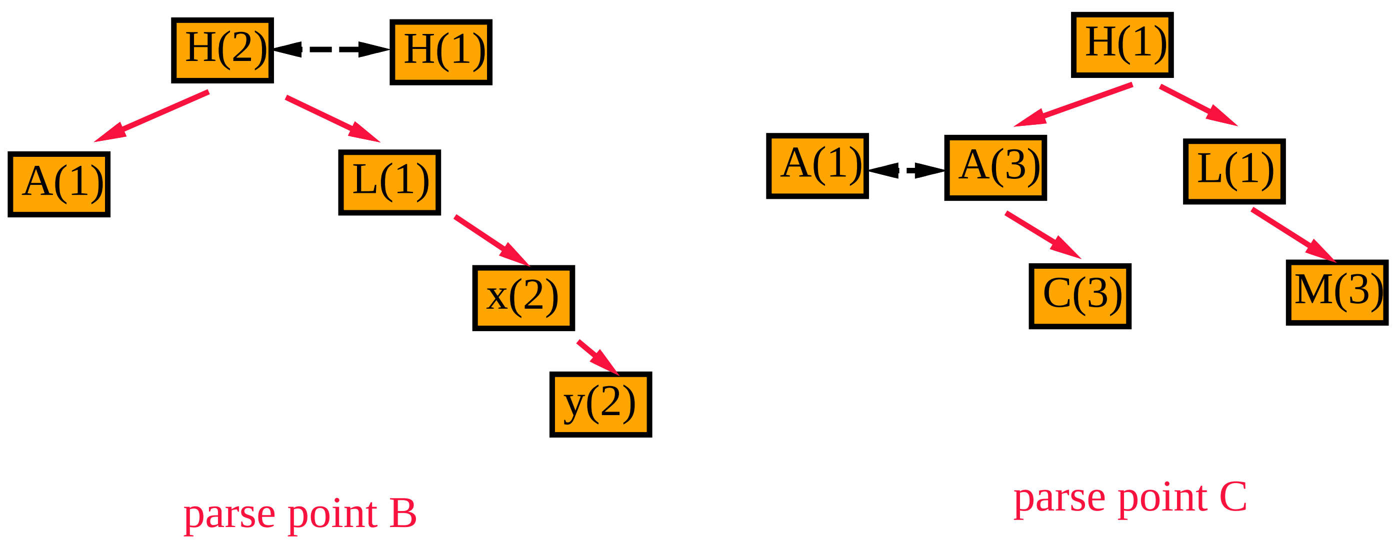
```
main()
{    /* open a new scope */
     int H,A,L;  /* parse point A */
     ...
     { /* open another new scope */
       float x,y,H; /* parse point B */
       ...
       /* x and y can only be used here */
       /* H used here is float */
       ...
     } /* close an old scope */
     ...
     /* H used here is integer */
     ...
     { char A,C,M; /* parse point C */
     ...
     }
}
```



Two common approaches (3/3)

- **A second coding choice:**
  - **Binary search tree:**

```
main()
{    /* open a new scope */
     int H,A,L;  /* parse poin
     ...
     { /* open another new sco
       float x,y,H; /* parse p
       ...
       /* x and y can only be
       /* H used here is float
       ...
     } /* close an old scope *
     ...
     /* H used here is integer
     ...
     { char A,C,M; /* parse po
     ...
     }
}
```



- **It is difficult to close a scope.**
  - **Need to maintain a list of entries in the same scope.**
  - **Using this list to close a scope and to reactive it for the second pass.**

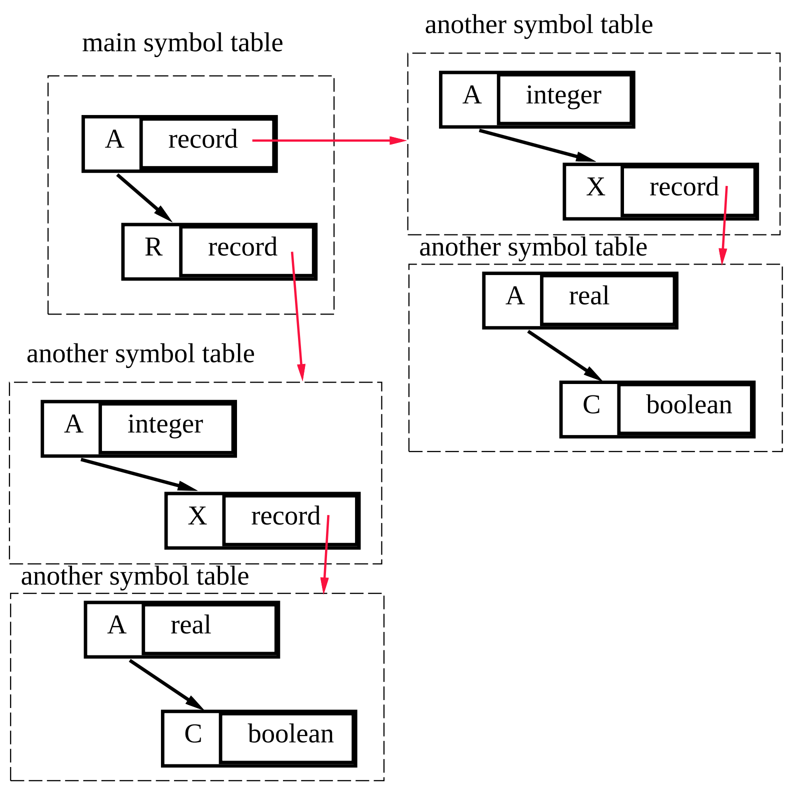
Records and fields

- The “with” construct in PASCAL can be considered an additional scope rule.
  - Field names are visible in the scope that surrounds the record declaration.
  - Field names need only to be unique within the record.
- Example (PASCAL code):

```
A, R: record
        A: integer
        X: record
             A: real;
             C: boolean;
           end
      end
...
R.A := 3;        /* means R.A := 3; */
with R do
  A := 4;        /* means R.A := 4; */
```

Implementation of field names

- **Two choices for handling field names:**
  - **Allocate a symbol table for each record type used.**



  - **Associate a record number within the field names.**
    - ▷ *Assign record number #0 to names that are not in records.*
    - ▷ *A bit time consuming in searching the symbol table.*
    - ▷ *Similar to the scope numbering technique.*

Implementation of PASCAL "with" construct

- **Example:**

```
with R do
begin
    A := 3;
    with X do
      A := 3.3
end
```

- **If each record (each scope) has its own symbol table,**
  - **then push the symbol table for the record onto the STACK.**
- **If the record number technique is used,**
  - **then keep a stack containing the current record number**
  - **during searching, success only if it matches the current number.**
  - **If fail, then use next record number in the stack as the current record number and continue to search.**
  - **If everything fails, search the normal main symbol table.**

Overloading (1/3)

- **A symbol may, depending on context, mean more than one thing.**
- **Example:**
  - **operators:**
    - $I := I + 3;$
    - $X := Y + 1.2;$
  - **function call return value and recursive function call:**
    - $f := f + 1;$

Overloading (2/3)

- **Implementation:**
  - **Link together all possible definitions of an overloading name.**
  - **Call this an overloading chain.**
  - **Whenever a name that can be overloaded is defined**
    - ▷ *if the name is already in the current scope, then add the new definition in the overloading chain;*
    - ▷ *if it is not already there, then enter the name in the current scope, and link the new entry to any existing definitions;*
    - ▷ *search the chain for an appropriate one, depending on the context.*
  - **Whenever a scope is closed, delete the overloading definitions from the head of the chain.**

Overloading (3/3)

- **Example: PASCAL function name and return variable.**
  - **Within the function body, the two definitions are chained.**
    - *i.e., function call and return variable.*
  - **When the function body is closed, the return variable definition disappears.**

```
[PASCAL]
function f: integer;
begin
    if global > 1 then f := f +1;
    return
end
```

Forward reference (1/2)

- **Definition:**
  - **A name that is used before its definition is given.**
  - **To allow mutually referenced and linked data types, names can sometimes be used before it is declared.**
- **GOTO labels:**
  - **If labels must be defined before its usage, then one-pass compiler suffices.**
  - **Otherwise, we need either multi-pass compiler or one with "back-patching".**
    - ▷ ***Avoid resolving a symbol until all its possible definitions have been seen.***
    - ▷ ***In C, ADA and languages commonly used today, the scope of a declaration extends only from the point of declaration to the end of the containing scope.***

Forward reference (2/2)

- **Pointer types:**
  - **determine the element type if possible;**
  - **chaining together all references to a pointer to type T until the end of the type declaration;**
  - **all type names can then be looked up and resolved.**

```
[PASCAL]
type link = ^ cell;
cell = record
         info: integer;
         next: link;
       end;
```

Type equivalent and others

- **How to determine whether two types are equivalent?**
  - **Structural equivalence:**
    - *Express a type definitions using a directed graph using nodes as entries.*
    - *Two types are equivalent if and only if their structures (graphs) are the same.*
    - *A difficult job for compilers.*
  - **Name equivalence:**
    - *Two types are equivalent if and only if their names are the same.*
    - *An easy job for compilers, but the coding takes more time.*
- **Symbol table is needed during compilation, might also be needed during debugging.**

How to use?

- **Define symbol tbale routines:**
  - **Find_in_symbol_table($name$,$scope$): check whether a name within a particular scope is currently in the symbol table or not.**
    - ▷ ***return not found or***
    - ▷ ***an entry in the symbol table***
  - **Insert_into_sumbol_table($name$,$scope$)**
    - ▷ ***Return the newly created entry.***
  - **Delete_from_sumbol_table($name$,$scope$)**
- **Grammar productions:**
  - **Declaration:**
    - ▷ $D \rightarrow TL$ ***{ insert each name in $2.namelist into symbol table, allocate*** $sizeof(\$1.type)$ ***bytes, error for duplicated names}***
    - ▷ $T \rightarrow int\{\$\$.type = int\}$
    - ▷ $L \rightarrow id, L$ ***{insert the new name into $3.namelist and put it in $$.namelist}*** $\mid id$ ***{create a list of one name $$.namelist}***
  - **Allocate global and temperatory data space at the end of code.**
    - ▷ $P \rightarrow program \cdots end$ ***{printf("GDATA:\n");***
      printf("nbytes %d\n",total_Gsize);
      printf("TDATA:\n");
      printf("nbytes %d\n",total_Tsize); }

More issues on usage

- **Expressions:**
  - $S \rightarrow E + E$ **{ generate code for adding data at $1.taddr and $3.taddr}**
    - ▷ ***printf("load*** R_1***,TDATA+%d\n",$1.taddr);***
    - ▷ ***printf("load*** R_2***,TDATA+%d\n",$3.taddr);***
    - ▷ ***free $1.taddr and $3.taddr from temp space;***
    - ▷ ***printf("add*** R_1***,***R_2***\n");***
    - ▷ $current\_t$ ***=allocate temp space;***
    - ▷ ***printf("store TDATA+%d,*** R_1***\n",***$current\_t$***);***
    - ▷ $\$\$.taddr = current\_t$
  - $E \rightarrow id$ **{find symbol table entry, allocate at global adta space** $gadd$**}**
    - ▷ ***printf("load*** R_1***, GDATA+%d\n",***$gaddr$***);***
    - ▷ $current\_t$ ***=allocate temp space;***
    - ▷ ***printf("store TDATA+%d,*** R_1***\n",***$current\_t$***);***
    - ▷ $\$\$.taddr = current\_t$