CS 461

Programming Language Concepts

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Ch3 Names, Scopes, and Bindings

*Some slides adapted from the ones by Michael Scott

Naming plays a fundamental role in PLs

◆Use names for
- variables
- functions
- types
- Modules (packages)

Syntactic Issues for Naming

◆Lexical rules for names
- most languages: a letter followed by a series of letters or digits
- some languages allow special characters
  - Cobol: allow the hyphen character
  - C-like language: allow the underscore character
- some early languages has length restrictions
  - Fortran 77: 6 chars

Syntactic Issues for Naming

◆Collection of reserved words or keywords.
- Cannot be used as identifiers (e.g., if, while, do, …)
- Predefined identifiers: e.g., library routines

◆Case sensitivity
- C-like languages: yes
- Early languages (Pascal, Ada): no

Variable Names

Language	Name limits	Connectors	Case Sensitivity	Notes
Fortran 77	6 chars.	none	No	only letters and digits
COBOL	30 chars.	hyphen	No	
Ada	no limit	underscore	No	
C89	none, 31 chars. significant	underscore	Yes	
C99	none, 63 chars significant	underscore	Yes	
C++	implementation specific[1]	underscore	Yes	
Java	no limit	underscore	Yes	also allows Unicode currency symbols

[1] C++ has no limit on name length; the number of significant characters is implementation specific

Variable Naming Convention

- ◆Hungarian notation
  - Each variable name begins with one or more lowercase characters identifying the data type

Prefix	Data Type	Examples
b	Bool	// bCondition
c	Char	
l	LONG	
n	int	// nCount
p	pointer	// pNextNode
w	WORD	

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Binding

- ◆Binding is an association between a program entity (such as a variable) and a property (such as its value, scope, type, …)
  - The scope of a binding is the part of the program in which the binding is active
- ◆A binding is **static** if the association occurs at compile time.
- ◆A binding is **dynamic** if the association occurs at run-time.
  - AKA late binding

Static vs. Dynamic Binding

- ◆In general, early binding times are associated with greater efficiency
  - Compiled languages tend to have early binding times
  - E.g., static type checking
- ◆Later binding times are associated with greater flexibility
  - Interpreted languages tend to have later binding times
  - E.g., dynamic type checking

Variables' Bindings

- ◆Storage location (e.g., memory address)
- ◆Value
- ◆Type
- ◆Scope
- ◆Lifetime

L-values and R-values

- ◆In C-like languages, "x = x + 1"
  - The same x refers to different bindings depending on whether it appears on the left of or the right of the assignment
- ◆L-value - use of a variable name to denote its storage location.
  - Ex: x = …
- ◆R-value - use of a variable name to denotes its value.
  - Ex: … = … x …
- ◆Some languages support/require explicit dereferencing (e.g., ML)
  - Ex: x := !x + 1

Scope

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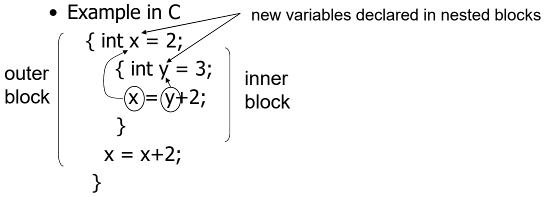
Block-Structured Languages

◆Nested blocks, local variables

- Example in C



```
{ int x = 2;
   { int y = 3;
     x = y+2;
   }
  x = x+2;
}
```

- Storage management
  - Enter block: allocate space for variables
  - Exits block: some or all space may be deallocated

Examples

◆Blocks in common languages

- C/C++/Java { … }
- Algol begin … end
- ML let … in … end
  - let x = 3 in let y =3 in x + y

Forms of Scope

◆Inlined blocks

◆Scope associated with functions or procedures

◆A for-loop in Java/C++ can introduce a scope

Java/C++ for-loop: can introduce a scope

```
for (int i = 0; i < 10; i++) {
   System.out.println(i);
   ...
}

... i ... // invalid reference to i
```

◆Not for C though

Scoping in typical languages

	Algol	C	Java	Ada
Block	nested	nested	nested	nested
For Loop	no	no	yes	yes
Function	nested	yes	yes	nested
Class	n/a	n/a	nested	yes
Package	n/a	n/a	yes	yes

Scope Vs. Lifetime

◆Scope

- Region of program text where a variable is visible

◆Lifetime

- Period of time when the storage for the variable is allocated

```
|{ int x = … ;
|   |{  int y = … ;
|   |   |{  int x = … ;
|   |   |    ….
|   |   |   };
|   |};
|};
```

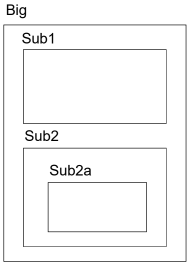
- Nested scopes
- Inner declaration of x hides outer one.
  - outer one not visible
  - Note: Java does not support redeclaration of variables
- Called "hole in scope"
- Lifetime of outer x includes time when inner block is executed
- Lifetime ≠ scope
- Lines indicate "contour model" of scope.

Static Scoping

- ◆In static scoping, a name is visible to a collection of statements according to its lexical position in the source program.
- ◆Most modern languages use static scoping
  - Java, C, Scheme, Ada

Example of static scoping (Ada)

```
procedure Big is
    X : Integer;
    procedure Sub1 is
    begin -- of Sub1
    ... X ...
    end; -- of Sub1
    procedure Sub2 is
      X : Integer;
      procedure Sub2a is
      begin -- of Sub2a
         ... X ...
      end -- of Sub2a
    begin -- of Sub2
    ... X ...; ... Sub2a ...
    end; -- of Sub2
begin -- of Big
... X ...
end; -- of Big
```



Implementing the scope: Symbol Tables

- ◆A *symbol table* is a data structure kept by a translator that allows it to track declared names and their bindings.
- ◆Assume for now that each name is unique within its local scope.
- ◆The data structure is usually a stack of dictionaries
  - Which are maps from keys to values; keys: names; values: bindings for names

Pseudo-algorithm for scoping

1. For each scope, build a dictionary, which records name-binding pairs for all names declared in the scope
2. Build the stack of dictionaries
   a) The rules are different between static scoping and dynamic scoping
3. Given a name reference, to find its binding
   a) Search the dictionary on top of the stack; if found, return the binding.
   b) Otherwise, repeat the process on the next dictionary down the stack.
   c) If the name is not found in any dictionary, report an error.

Static scoping

- ◆The stack of dictionaries is built based on the lexical position of where a name appears

Dynamic Scoping

- ◆In dynamic scoping, a name is bound to its most recent declaration based on the program’s call stack
  - Used by Lisp, APL, Snobol, Perl.
- ◆Stack of dictionaries corresponds to the call stack
- ◆Dictionary for each scope built at compile time, but managed at run time.