UNIT-III

SUBPROGRAMS

Basic Definitions:

- A subprogram definition is a description of the actions of the subprogram abstraction
- A subprogram call is an explicit request that the subprogram be executed
- A subprogram header is the first line of the definition, including the name, the kind of
- subprogram, and the formal parameters
- The parameter profile of a subprogram is the number, order, and types of its parameters
- The protocol of a subprogram is its parameter profile plus, if it is a function, its return type
- A subprogram declaration provides the protocol, but not the body, of the subprogram
- A formal parameter is a dummy variable listed in the subprogram header and used in the subprogram
- An actual parameter represents a value or address used in the subprogram call Statement

Actual/Formal Param Correspondence Two basic choices:

- Positional

– Keyword

– Sort (List => A, Length => N);

– For named association:

– **Advantage**: order is irrelevant

Disadvantage: user must know the formal

– parameter‘s names

Sort (List => A, Length => N);

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Default Parameter Values Example, in Ada:

procedure sort (list : List_Type; length : Integer := 100);

---

sort (list => A);

Two Types of Subprograms

- Procedures provide user-defined statements, Functions provide user-defined operators

Design Issues for Subprograms

- What parameter passing methods are provided?
- Are parameter types checked?
- Are local variables static or dynamic?
- What is the referencing environment of a passed subprogram?
- Are parameter types in passed subprograms checked?
- Can subprogram definitions be nested?
- Can subprograms be overloaded?
- Are subprograms allowed to be generic?
- Is separate/independent compilation supported?
- Referencing Environments

– If local variables are stack-dynamic:

Advantages:

– Support for recursion

– Storage for locals is shared among some subprograms

Disadvantages:

– Allocation/deallocation time

– Indirect addressing

– Subprograms cannot be history sensitive

– Static locals are the opposite

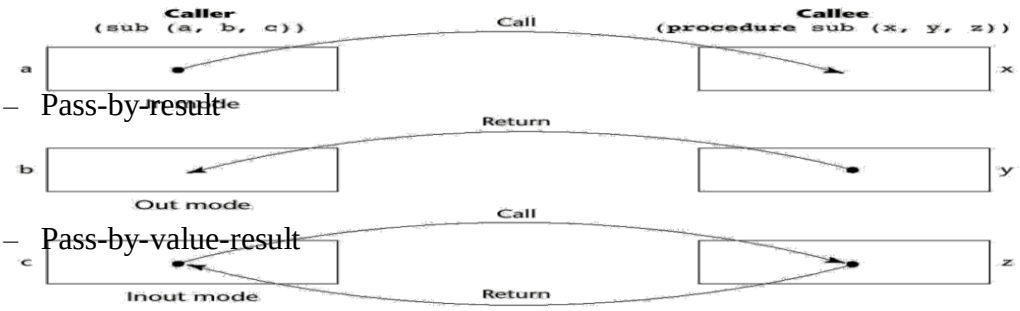
Parameters and Parameter Passing: Semantic Models: in mode, out mode, inout mode

Conceptual Models of Transfer:

Physically move a value ○
Move an access path

Implementation Models:

– Pass-by-value



– Pass-by-result

– Pass-by-value-result

– Pass-by-reference

– Pass-by-name

Models of Parameter Passing

Pass-By-Value

– in mode

– Either by physical move or access path

Disadvantages of access path method: Must write-protect in the called subprogram, Accesses cost more (indirect addressing)

Disadvantages of physical move:

Requires more storage Cost of the moves **Pass-By-Result**

– out mode

Disadvantages:

– If value is moved, time and space

– In both cases, order dependence may be a problem procedure sub1(y: int, z: int);

...

sub1(x, x);

Value of x in the caller depends on order of assignments at the return

Pass-By-Value-Result:

sub1(i, a[i]);

Pass-By-Name Example 2

inout mode

Physical move, both ways Also called pass-by-copy

Disadvantages: Those of pass-by-result Those of pass-by-value **Pass-By-Reference** inout mode Pass an access path Also called pass-by-sharing **Advantage**: passing process is efficient

Disadvantages:

Slower accesses can allow aliasing: Actual parameter collisions: sub1(x, x); Array element
collisions: sub1(a[i], a[j]); /* if i = j */ Collision between formals and globals Root cause of all of
these is: The called subprogram is provided wider access to non locals than is necessary

Pass-by-value-result does not allow these aliases (but has other problems!)

Pass-By-Name multiple modes By textual substitution ,Formals are bound to an access method at the time of the call, but actual binding to a value or address takes place at the time of a reference or assignment

Purpose: flexibility of late binding

Resulting semantics:

If actual is a scalar variable, it is pass-by-reference If actual is a constant expression, it is pass-by-value If actual is an array element, it is like nothing else

If actual is an expression with a reference to a variable that is also accessible in the program, it is also like nothing else

Pass-By-Name Example 1 procedure sub1(x: int; y: int); begin x:= 1;

y := 2;
x := 2;

y := 3;
end;

Assume k is a global variable procedure sub1(x: int; y: int; z: int); begin k := 1;

y := x;

k := 5;

z :=x; end;

sub1(k+1, j, i);

Disadvantages of Pass-By-Name

- Very inefficient references
- Too tricky; hard to read and understand

Param Passing: Language Examples

FORTRAN, Before 77, pass-by-reference 77—scalar variables are often passed by value result ALGOL 60 Pass-by-name is default; pass-by-value is optional

ALGOL W: Pass-by-value-result ,C: Pass-by-value Pascal and Modula-2: Default is pass-by value;,pass-by-reference is optional

Param Passing: PL Example

C++: Like C, but also allows reference type parameters, which provide the efficiency of pass-by- reference with in-mode semantics

Ada

All three semantic modes are available If out, it cannot be referenced If in, it cannot be assigned Java Like C++, except only references

Type Checking Parameters

Now considered very important for reliability

FORTRAN 77 and original C: none

Pascal, Modula-2, FORTRAN 90, Java, and Ada: it is always required

ANSI C and C++: choice is made by the user

Implementing Parameter Passing

ALGOL 60 and most of its descendants use the runtime stack Value—copy it to the stack; references are indirect to the stack Result—sum, Reference—regardless of form, put the address in the stack

Name:

Run-time resident code segments or subprograms evaluate the address of the parameter Called for each reference to the formal, these are called thunks Very expensive, compared to reference or value-result

Ada Param Passing Implementations

Simple variables are passed by copy (valueresult) Structured types can be either by copy or reference This can be a problem, because Aliasing differences (reference allows aliases, but value-result does not) Procedure termination by error can produce different actual parameter results Programs with such errors are ―erroneous‖

Multidimensional Arrays as Params

If a multidimensional array is passed to a subprogram and the subprogram is separately compiled, the compiler needs to know the declared size of that array to build the storage mapping function

C and C++

Programmer is required to include the declared sizes of all but the first subscript in the actual parameter , This disallows writing flexible subprograms Solution: pass a pointer to the array and the sizes of the dimensions as other parameters; the user must include the storage mapping function, which is in terms of the size

More Array Passing Designs

Pascal Not a problem (declared size is part of the array‘s type)

Ada

Constrained arrays—like Pascal

Unconstrained arrays—declared size is part of the object declaration Pre-90 FORTRAN , Formal parameter declarations for arrays can include passed parameters

SUBPROGRAM SUB(MATRIX, ROWS, COLS, RESULT) INTEGER ROWS, COLS

REAL MATRIX (ROWS, COLS), RESULT

... END

Design Considerations for Parameter Passing

–Efficiency

–One-way or two-way

–These two are in conflict with one another!

–Good programming => limited access to

–variables, which means one-way whenever possible

– Efficiency => pass by reference is fastest way to pass structures of significant size Also, functions should not allow reference Parameters

Subprograms As Parameters: Issues

Are parameter types checked?

Early Pascal and FORTRAN 77 do not Later versions of Pascal, Modula-2, and FORTRAN 90 do Ada does not allow subprogram parameters C and C++ - pass pointers to functions; parameters can be type checked

What is the correct referencing?

environment for a subprogram that was sent as a parameter?

Possibilities:

It is that of the subprogram that called it (shallow binding) It is that of the subprogram that declared it (deep binding)

It is that of the subprogram that passed it (ad hocbinding, never been used)

For static-scoped languages, deep binding is most natural

For dynamic-scoped languages, shallow binding is most natural

Overloading

An overloaded subprogram is one that has the same name as another subprogram in the same referencing environment C++ and Ada have overloaded subprograms built-in, and users can write their own overloaded subprograms

Generic Subprograms

– A generic or polymorphic subprogram is one that takes parameters of different types on different activations Overloaded subprograms provide ad hoc polymorphism

– A subprogram that takes a generic parameter that is used in a type expression that describes the type of the parameters of the subprogram provides parametric polymorphism

– See Ada generic and C++ template examples in text

– Independent compilation is compilation of some of the units of a program separately from the rest of the program, without the benefit of interface information

– Separate compilation is compilation of some of the units of a program separately from the rest of the program, using interface information to check the correctness of the interface between the two parts

Language Examples:

- FORTRAN II to FORTRAN 77: independent
- FORTRAN 90, Ada, Modula-2, C++: separate
- Pascal: allows neither

Functions Design Issues:

- Are side effects allowed?
- Two-way parameters (Ada does not allow)
- Nonlocal reference (all allow)
- What types of return values are allowed?

– FORTRAN, Pascal, Modula-2: only simple types

– **C**: any type except functions and arrays

– **Ada:** any type (but subprograms are not types)

– **C++ and Java**: like C, but also allow classes to be r**eturned Accessing Nonlocal**

Environments

The nonlocal variables of a subprogram are those that are visible but not declared in the subprogram Global variables are those that may be visible in all of the subprograms of a program

Methods for Accessing Non locals

FORTRAN COMMON

The only way in pre-90 FORTRANs to access nonlocal variables Can be used to share data or share storage Static scoping

External declarations: C

– Subprograms are not nested

– Globals are created by external declarations (they are simply defined outside any function)

– Access is by either implicit or explicit declaration

– Declarations (not definitions) give types to externally defined variables (and say they are defined elsewhere)

– External modules: Ada and Modula-2:

– Dynamic Scope:

User-Defined Overloaded Operators

Nearly all programming languages have overloaded operators

Users can further overload operators in C++ and Ada not carried over into Java)

Ada Example (where Vector_Type is an array of Integers):

```
function "*"(a, b : inVector_Type) return Integer is
   sum : Integer := 0; begin
   for index in a _range loop
   sum := sum + a(index) * b(index); end loop;
   return sum; end "*";
```

Are user-defined overloaded operators good or bad?

Coroutines:

Coroutine is a subprogram that has multiple entries and controls them itself Also called symmetric control A coroutine call is named a resume. The first resume of a coroutine is to its beginning, but subsequent calls enter at the point just after the last executed statement in the coroutine. Typically, coroutines repeatedly resume each other, possibly forever. Coroutines provide quasiconcurrent execution of program units (the coroutines) Their execution is interleaved, but not overlapped