CSB4404 – PROGRAMMING PARADIGMS

B.Tech – VII Semester

Unit 3

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IMPLEMENTING SUB PROGRAMS

The General Semantics of Calls and Returns

• The subprogram call and return operations of a language are together called its subprogram linkage

• A subprogram call has numerous actions associated with it

– Parameter passing methods

– Static local variables

– Execution status of calling program

– Transfer of control

– Subprogram nesting

Implementing “Simple” Subprograms:

- Subprograms cannot be nested
- All local variables are static
- e.g. Subprograms in early versions of Fortran

Implementing “Simple” Subprograms: Call Semantics

- Save the execution status of the caller
- Carry out the parameter-passing process
- Pass the return address to the callee
- Transfer control to the callee

Implementing "Simple" Subprograms: Return Semantics

- If pass-by-value-result parameters are used, move the current values of those parameters to their corresponding actual parameters
- If it is a function, move the functional value to a place the caller can get it
- Restore the execution status of the caller
- Transfer control back to the caller

Storage required for call/return actions

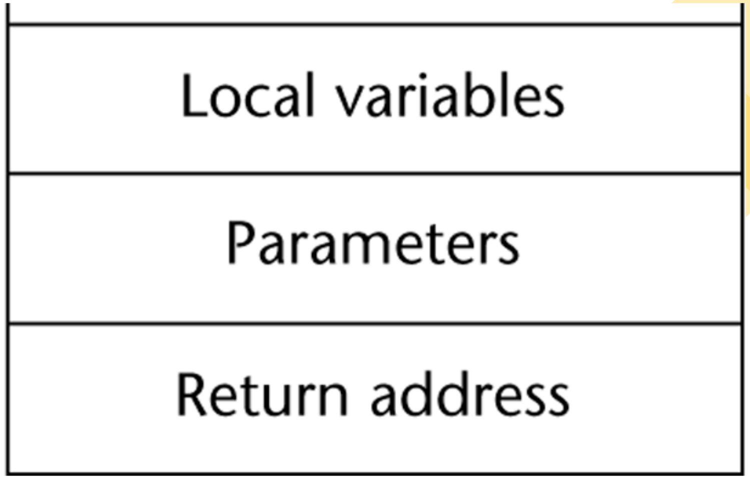
- Status information about the caller
- Parameters
- Return address
- Functional value for function subprograms
- These along with local variables and the subprogram code, form the complete collection of information a subprogram needs to execute and then return to the caller

Implementing "Simple" Subprograms: Parts

- Two separate parts: the actual code and the noncode part (local variables and data that can change)
- The format, or layout, of the noncode part of an executing subprogram is called an activation record
- An activation record instance (ARI) is a concrete example of an activation record (the collection of data for a particular subprogram activation)

An Activation Record for “Simple” Subprograms

Because languages with simple subprograms do not support recursion, there can be only one active version of a given subprogram at a time
Therefore, there can be only a single instance of the activation record for a subprogram
Since activation record instance of a simple subprogram has fixed size it can be statically allocated
It could be also attached to the code part



Note: In the rest of the slides the saved execution status of the caller will be omitted

Implementing Subprograms with Stack-Dynamic Local Variables

• More complex activation record

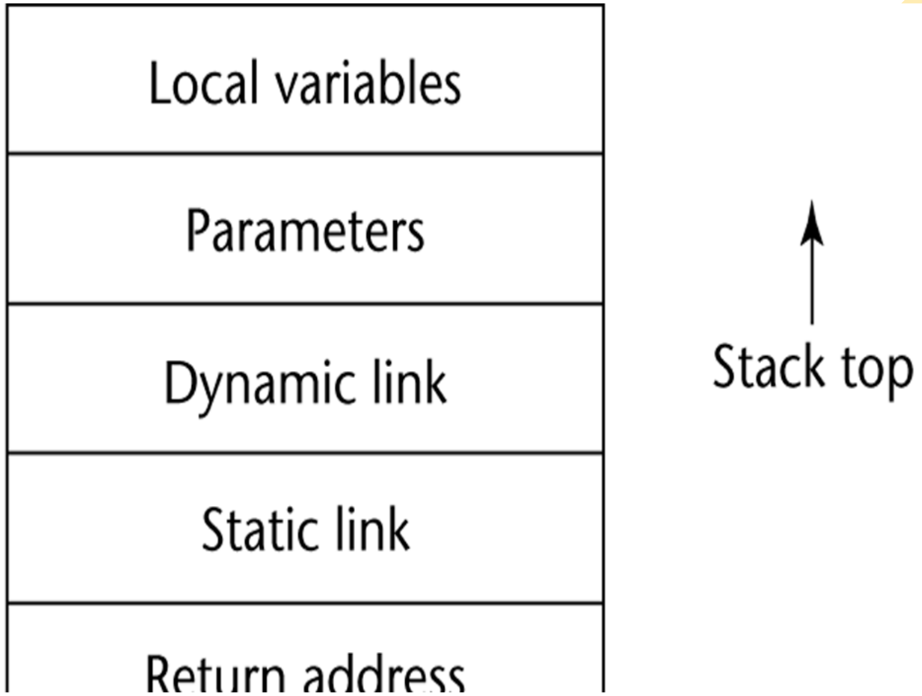
– The compiler must generate code to cause implicit allocation and de-allocation of local variables

– Recursion must be supported (adds the possibility of multiple simultaneous activations of a subprogram)

Typical Activation Record for a Language with Stack-Dynamic Local Variables

Return address: pointer to the code segment of the caller and an offset address in that code segment of the instruction following the call

Dynamic link: pointer to the top of the activation record instance of the caller In static scoped languages this link is used in destruction The stack top set to the value of old dynamic link



Implementing Subprograms with Stack-Dynamic Local Variables: Activation Record

- The activation record format is static, but its size may be dynamic
- An activation record instance is dynamically created when a subprogram is called
- Run-time stack

An Example: C Function

```
void sub(float total, int part)
{
int list[4];
float sum;
…
}
```

Local	sum
Local	list [5]
Local	list [4]
Local	list [3]
Local	list [2]
Local	list [1]
Parameter	part
Parameter	total
Dynamic link	
Static link	
Return address	

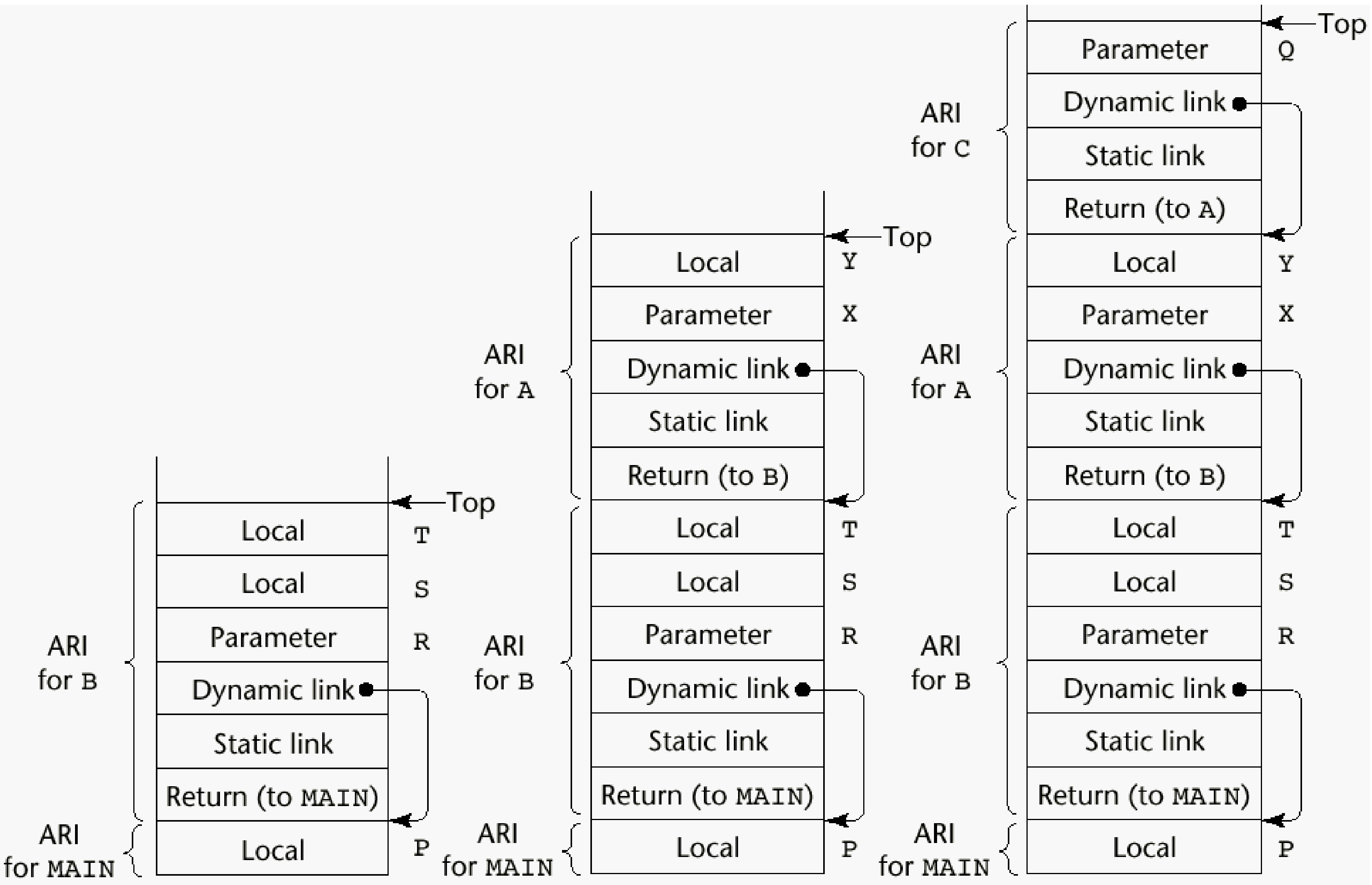
An Example Without Recursion

```
void A(int x) {
int y;
...
C(y);
...
}
void B(float r) {
int s, t;
...
A(s);
...
}
void C(int q) {
...
}
void main() {
float p;
...
B(p);
...
}
```

main calls B

B calls A

A calls C



ARI = activation record instance

Dynamic Chain and Local Offset

- The collection of dynamic links in the stack at a given time is called the dynamic chain, or call chain
- Local variables can be accessed by their offset from the beginning of the activation record. This offset is called the local_offset
- The local_offset of a local variable can be determined by the compiler at compile time
- The first local variable declared in a subprogram would be allocated in the activation record two positions (return address and dynamic link) plus the number of parameters from the bottom
- Local offset for

– y in fun1 is 3

– s in fun2 is 3

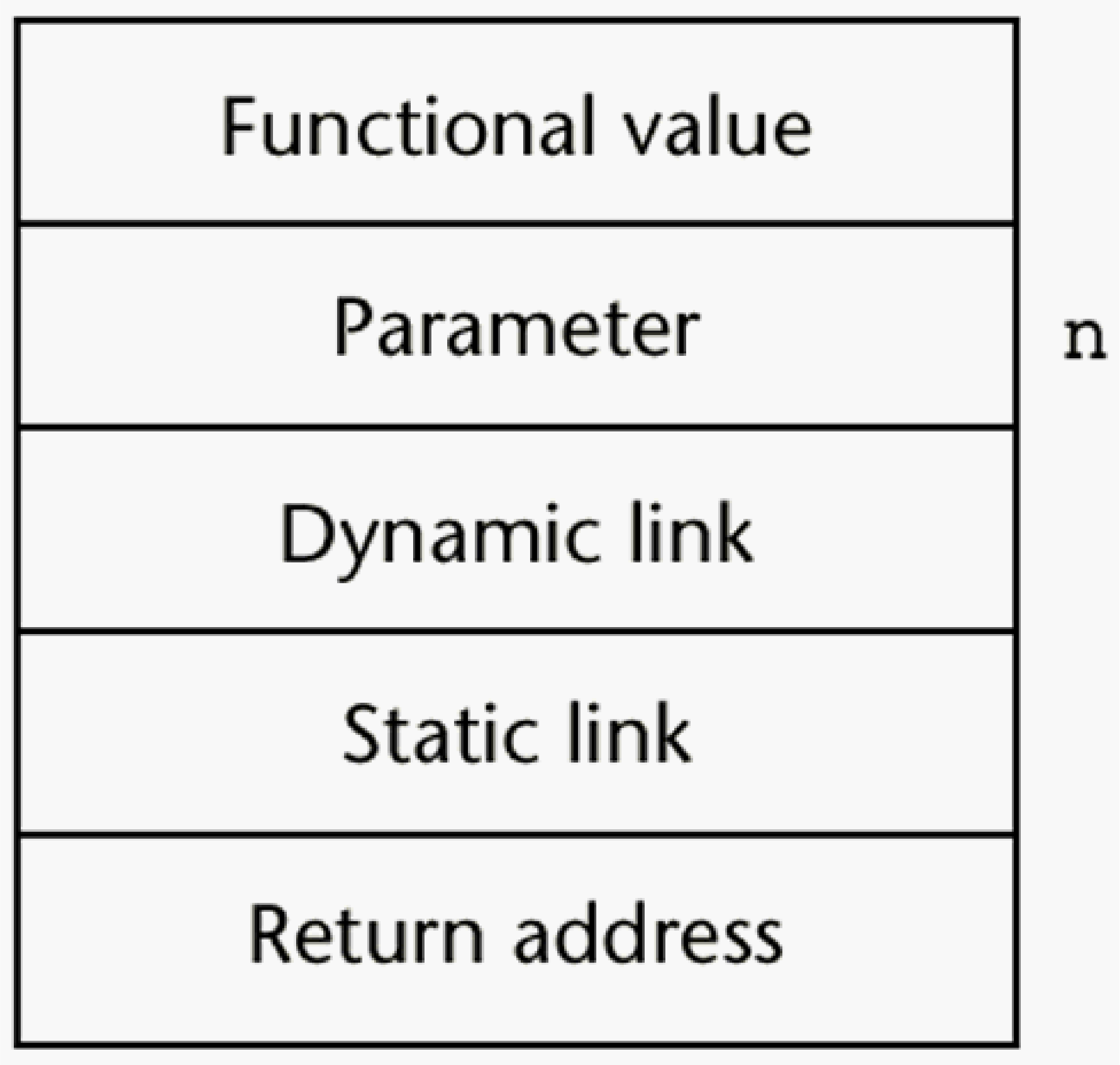
– t in fun2 is 4

An Example With Recursion

- The activation record used in the previous example supports recursion, e.g.

```
int factorial (int n) {
<-----------------------------1
if (n <= 1) return 1;
else return (n * factorial(n - 1));
<-----------------------------2
}
void main() {
int value;
value = factorial(3);
<-----------------------------3
}
```

Activation Record for factorial



Nested Subprograms

• Some non-C-based static-scoped languages (e.g., Fortran 95, Ada, JavaScript) use stack-dynamic local variables and allow subprograms to be nested

• All variables that can be non-locally accessed reside in some activation record instance in the stack

• The process of locating a non-local reference:

1. Find the correct activation record instance

2. Determine the correct offset within that activation record instance

Locating a Non-local Reference

- Finding the offset is easy
- Finding the correct activation record instance

– Static semantic rules guarantee that all non-local variables that can be referenced have been allocated in some activation record instance that is on the stack when the reference is made (a subprogram is callable only when all of its static ancestors are active)

Static Scoping

- A static chain is a chain of static links that connects certain activation record instances
- The static link in an activation record instance for subprogram A points to one of the activation record instances of A's static parent
- The static chain from an activation record instance connects it to all of its static ancestors

Example Pascal Program

```
program MAIN_2;
var X : integer;
procedure BIGSUB;
var A, B, C : integer;
procedure SUB1;
var A, D : integer;
begin { SUB1 }
A := B + C; <-----------------------1
end; { SUB1 }
procedure SUB2(X : integer);
var B, E : integer;
procedure SUB3;
var C, E : integer;
begin { SUB3 }
SUB1;
E := B + A: <--------------------2
end; { SUB3 }
begin { SUB2 }
SUB3;
A := D + E; <-----------------------3
end; { SUB2 }
begin { BIGSUB }
SUB2(7);
end; { BIGSUB }
begin
BIGSUB;
end; { MAIN_2 }
```

Blocks

- Blocks are user-specified local scopes for variables
- An example in C

```
{int temp;
temp = list [upper];
list [upper] = list [lower];
list [lower] = temp
}
```

- The lifetime of temp in the above example begins when control enters the block
- An advantage of using a local variable like temp is that it cannot interfere with any other variable with the same name

Implementing Blocks

- Two Methods:

1. Treat blocks as parameter-less subprograms that are always called from – the same location Every block has an activation record; an instance is created every time the block is executed

2. Since the maximum storage required for a block can be statically determined, this amount of space can be allocated after the local variables in the activation record

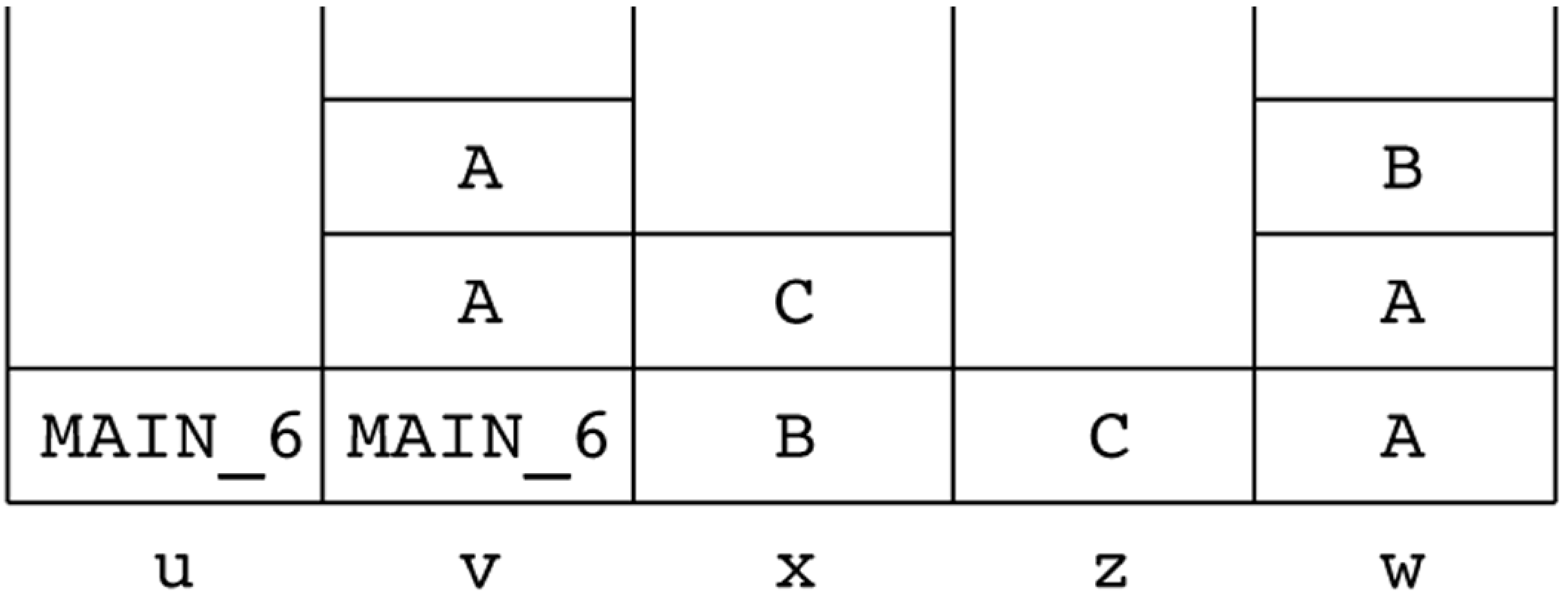
Implementing Dynamic Scoping

• Deep Access: non-local references are found by searching the activation record instances on the dynamic chain • Shallow Access: put locals in a central place

– One stack for each variable name

– Central table with an entry for each variable name

Using Shallow Access to Implement Dynamic Scoping



(The names in the stack cells indicate the program units of the variable declaration.)