Local Variable Allocation

- Local scalar variables are bound to storage within an activation record instance
- Local variables that are structures are sometimes allocated elsewhere, and only leave their descriptors and a pointer to the storage as part of the activation record

An Example

```
void sub(float total, int part) {
     int list[5];
     float sum;
     …
}
```

Local	sum
Local	list[4]
Local	list[3]
Local	list[2]
Local	list[1]
Local	list[0]
Parameter	part
Parameter	total
Dynamic link	
Return address	

Recursion

- Function recursion means that a function can eventually call itself
- Recursion adds the possibility of multiple simultaneous activations of a subroutine at a given time, with at least one call from outside the subroutine, and one or more recursive calls
- Each activation requires its own activation record instance

An Example

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

How does the stack change?

Implementing nested subroutines

- Some static-scoped languages use stack-dynamic local variables and allow subroutines to be nested
  - FORTRAN 95, Ada, Python, and JavaScript
- Challenge
  - How to access nonlocal variables?

Two-step access process

- Find the activation record instance on the stack where the variable was allocated
  - more challenging and more difficult
- Use the **local_offset** of the variable to access it
  - local_offset describes the offset from the beginning/bottom of an activation record

Key Observations

- In a given subroutine, only variables that are declared in static ancestor scopes are visible and can be accessed
- Activation record instances of all static ancestors are always on the stack when variables in them are referenced by a nested subroutine: A subroutine is callable only when all its static ancestors are active

Finding Activation Record Instance

- Static chaining
  - A new pointer, **static link (static scope pointer or access link)**, is used to point to the bottom of an activation record instance of the static parent
  - The pointer is used for access to nonlocal variables
  - Typically, the static link appears below parameters in an activation record

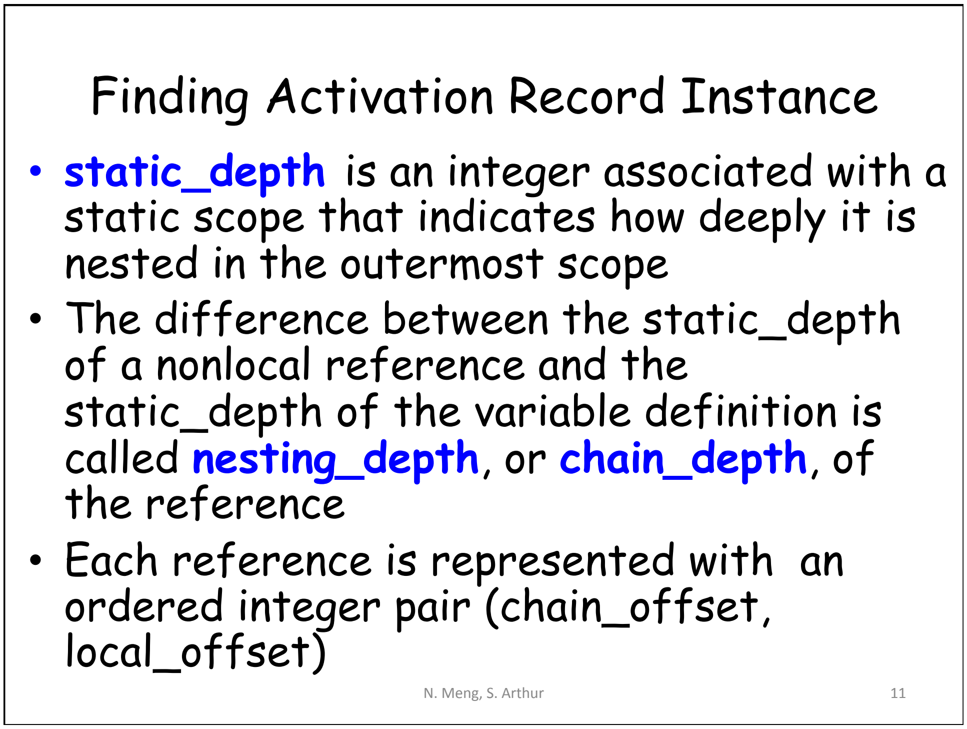
Finding Activation Record Instance

- A static chain is a chain of static links that connect the activation record instances of all static ancestors for an executing subroutine
- This chain can be used to implement nonlocal variable access

Local variables
Parameters
Dynamic link
Static link
Return address

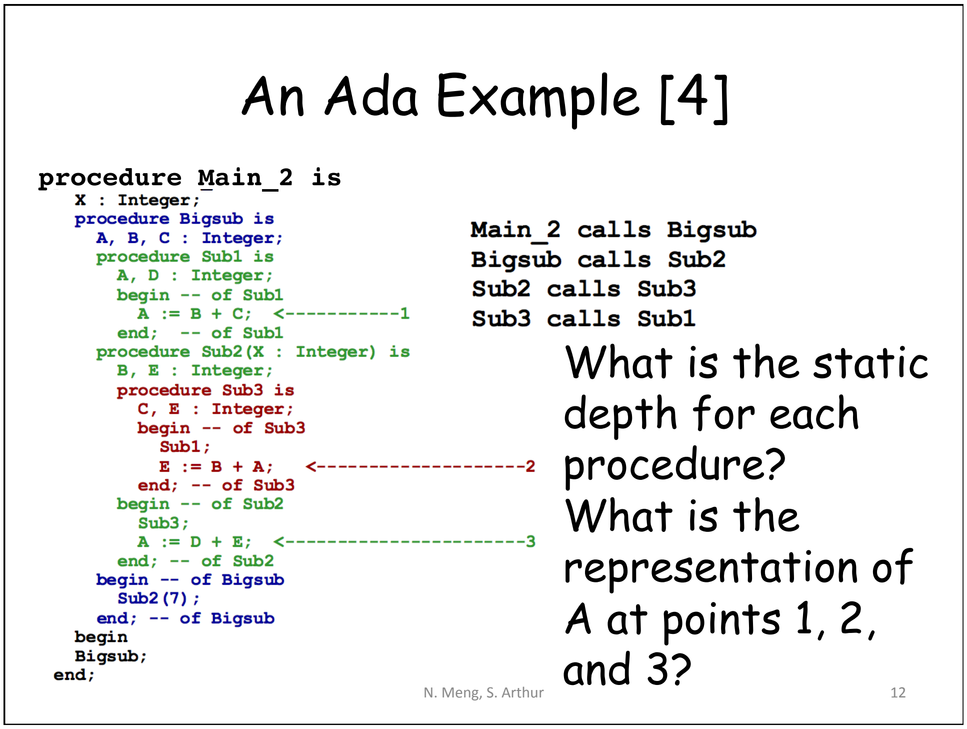
Finding Activation Record Instance

- With static links, finding the correct activation record instance is simple
  - Search the static chain until a static ancestor is found to contain the variable
- However, the implementation can be even simpler
  - Compiler identifies both nonlocal references, and the length of static chain to follow to reach the correct record



Finding Activation Record Instance

- **static_depth** is an integer associated with a static scope that indicates how deeply it is nested in the outermost scope
- The difference between the static_depth of a nonlocal reference and the static_depth of the variable definition is called **nesting_depth**, or **chain_depth**, of the reference
- Each reference is represented with an ordered integer pair (chain_offset, local_offset)

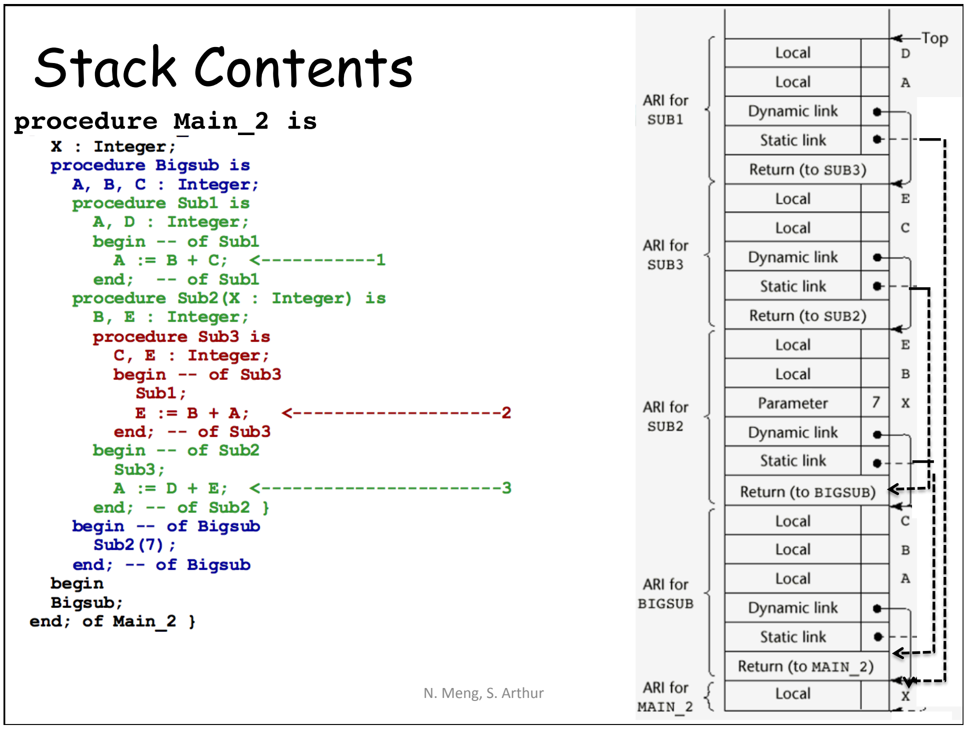


An Ada Example [4]

```
procedure Main_2 is
   X : Integer;
   procedure Bigsub is
     A, B, C : Integer;
     procedure Sub1 is
       A, D : Integer;
       begin -- of Sub1
         A := B + C;  <-----------1
       end;  -- of Sub1
     procedure Sub2(X : Integer) is
       B, E : Integer;
       procedure Sub3 is
         C, E : Integer;
         begin -- of Sub3
           Sub1;
           E := B + A;   <--------------------2
         end; -- of Sub3
       begin -- of Sub2
         Sub3;
         A := D + E;  <-----------------------3
       end; -- of Sub2
     begin -- of Bigsub
       Sub2(7);
     end; -- of Bigsub
   begin
   Bigsub;
 end;
```

```
Main_2 calls Bigsub
Bigsub calls Sub2
Sub2 calls Sub3
Sub3 calls Sub1
```

What is the static depth for each procedure?
What is the representation of A at points 1, 2, and 3?



Stack Contents

```
procedure Main_2 is
  X : Integer;
  procedure Bigsub is
    A, B, C : Integer;
    procedure Sub1 is
      A, D : Integer;
      begin -- of Sub1
        A := B + C;  <-----------1
      end;  -- of Sub1
    procedure Sub2(X : Integer) is
      B, E : Integer;
      procedure Sub3 is
        C, E : Integer;
        begin -- of Sub3
          Sub1;
          E := B + A;   <--------------------2
        end; -- of Sub3
      begin -- of Sub2
        Sub3;
        A := D + E;  <----------------------3
      end; -- of Sub2 }
    begin -- of Bigsub
      Sub2(7);
    end; -- of Bigsub
  begin
  Bigsub;
 end; of Main_2 }
```

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