COMPILERS
Activation Records

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Subprogram Invocation Mechanics

- Save status of caller.
- Process parameters.
- Save return address.
- Jump to called subprogram.
- … do stuff ...
- Process value-result/result parameters and function return value(s).
- Restore status of caller.
- Jump back to caller's saved position.

Frames / Activation Records

- An activation record is the layout of data needed to support a call to a subprogram.
- For languages that do not allow recursion, each subprogram has a single fixed activation record instance stored in memory (and no links).

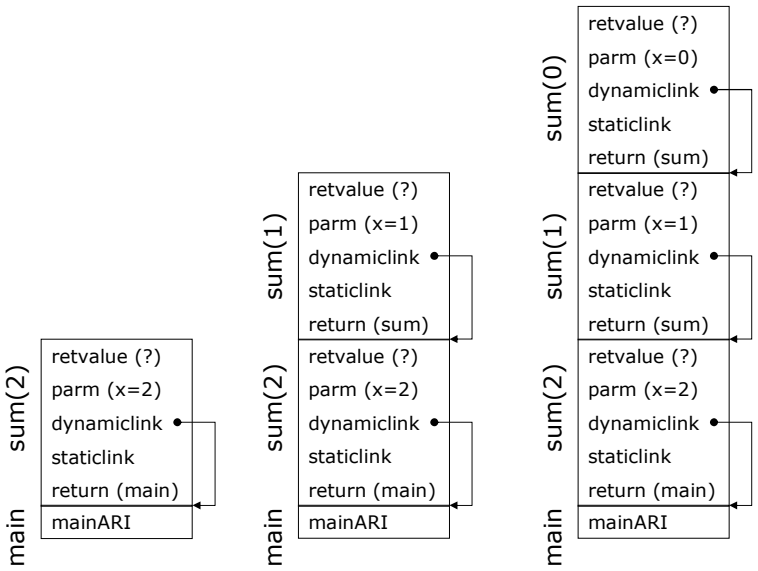
Function return value
Local variables
Parameters
Dynamic link
Static link
Return address

Stack-based Recursion

- When recursion is implemented using a stack, activation records are pushed onto the stack at invocation and popped upon return.
- Example:

```
int sum ( int x )
{
   if (x==0) return 0;
   else return (x + sum (x-1));
}
void main ()
{ sum (2); }
```

Recursion Activation Records



Non-local References

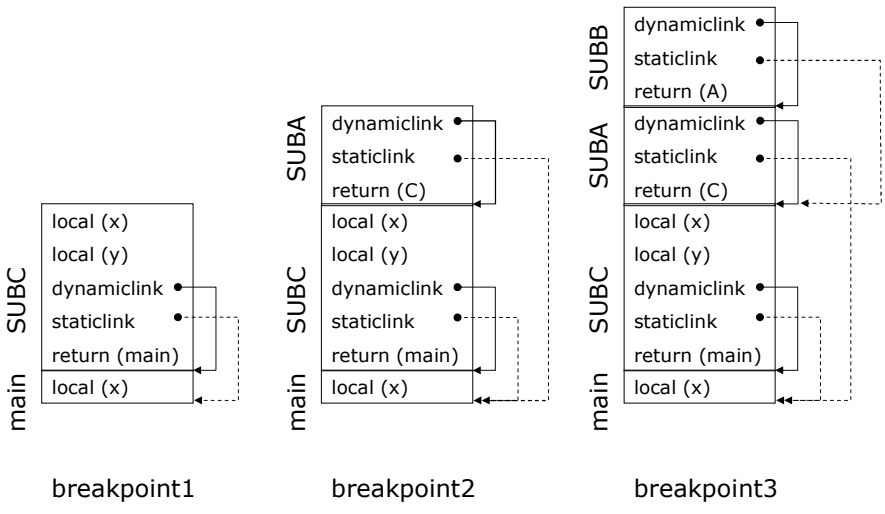
- To access non-local names in statically-scoped languages, a program must keep track of the current referencing environment.
- Static chains
  - Link a subprogram's activation record to its static parent.
- Displays
  - Keep a list of active activation records.

Non-local Reference Example

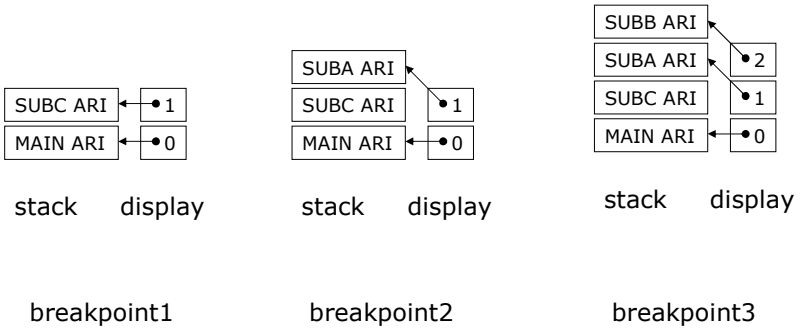
- Example:

```
main {
   int x;
   sub SUBA {
      sub SUBB {
         x = 1;          <-- breakpoint3
      }
      SUBB;              <-- breakpoint2
   }
   sub SUBC {
      int x;
      int y;
      SUBA;              <-- breakpoint1
   }
   SUBC;                 <-- breakpoint0
}
```

Static Chains



Displays



breakpoint1 breakpoint2 breakpoint3

Static Chains vs. Displays

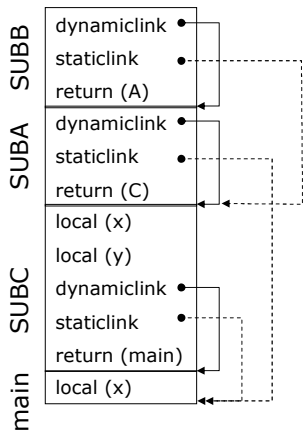
- Static chains require more indirect addressing – displays require a fixed amount of work.
- Displays require pointer maintenance on return – static chains do not.
- Displays require "backing up" of display pointer – static chains require static links in each activation record.

Dynamic Scoping

- Dynamically scoped languages can be implemented using:
- Deep Access
  - Follow the dynamic chains to find most recent non-local name definition.
- Shallow Access
  - Maintain a separate stack for each name.

Deep Access

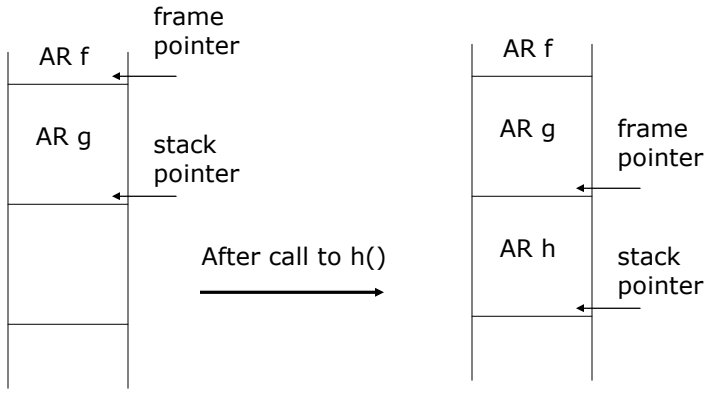
- At breakpoint3, by following dynamic links from SUBB, the closest definition of x is in SUBC.
- (Remember that for static scoping, by following static links, the closest definition is in main.)



breakpoint3

Frame Pointers

- Stack frames are usually supported by:
  - stack pointer - points to top of stack
  - frame pointer - points to top of previous frame



View Shifts

- On a Pentium machine,
  - M[SP + 0] <-- FP
    - save old frame pointer
  - FP <-- SP
    - move frame pointer to top of stack
  - SP <-- SP - K
    - move stack pointer to end of new frame
- On machines which use registers for frame optimisation, remember to save registers in temporary variables.

Register Handling

- One set of registers are typically used by many subprograms, so a value expected by one may be overwritten by another.
- Solution:
  - Make it the responsibility of the caller to save registers first (caller-save)
  - Make it the responsibility of the callee to save registers first (callee-save)
- Optimise which registers need to be saved as some values can be thrown away.

Parameter Passing

- Registers are more efficient than copying every parameter to the stack frame.
  - Registers are limited so pass first k parameters in registers and rest in frame.
- Nested subprogram calls require saving and restoring so there is dubious cost savings!
  - leaf procedures, different registers, done with variables, register windows
- How does C support varargs ?

Return Addresses

- Traditionally a stack frame entry.
- More efficient to simply use a register.
  - Same saving procedure necessary as before for non-leaf subprograms.

Temporaries and Labels

- Each time a local variable is encountered, a unique *temporary* name is generated – this temporary will eventually map to either a register or a memory location (usually on the stack).
- Each time a subprogram is encountered, a unique *label* is generated.
- These must be unique to prevent naming conflicts - the optimiser will deal with efficiency.

Frame Implementation 1/2

- A Frame class corresponds to the frame for each subprogram.
  - During translation, frames are created to track variables and generate prologue/epilogue code.
- Frame can be an abstract class with instantiations for different machine architectures.
  - Each instantiation must know how to implement a "view shift" from one frame to another.

Frame Implementation 2/2

- Each time a local variable is defined, a method of Frame can be called to allocate space appropriately (on stack frame or in registers).
  - f.allocLocal (false)
  - Parameter indicates if variable requires memory (escapes) or not - should we allocate stack space or temporary?
- Allocating a temporary for each variable can be slow - future stages will optimise by reusing both registers and space.

Stack vs. Registers

- Why use registers?
  - Faster and smaller code
- If registers are so great, why use stack?
  - variables used/passed by reference
  - nested subprograms
  - variable is not simple or just too big
  - arrays
  - registers are needed for other purposes
  - too many variables