Concepts Introduced in Chapter 7

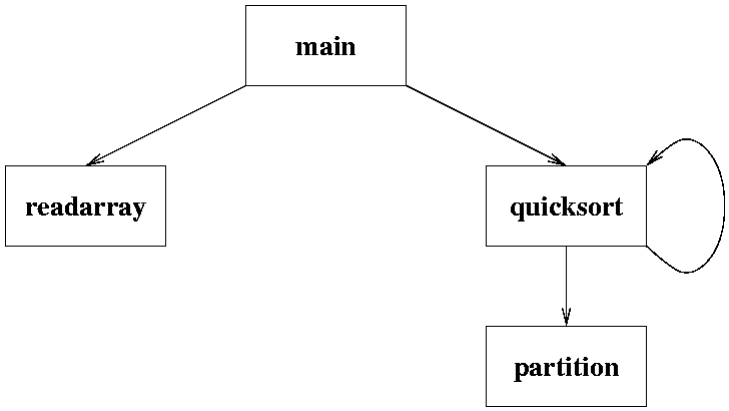
- Storage Allocation Strategies
  - Static
  - Stack
  - Heap
- Activation Records
- Access to Nonlocal Names
  - Access links
  - Displays

Activation Records

- An activation record is usually a contiguous block of storage that holds information relevant to one activation (execution) of a routine.
- Activation records can be placed in different storage areas depending on the run-time environment of the programming language.
  - Static data: FORTRAN
  - Stack: ALGOL, C, Pascal, Ada, C++
  - Heap: Functional Languages
    - LISP, ML, Haskell, Erlang

Call Graphs

- Call graphs represent the possible sequence of function calls in a program.



Typical Actions During Call and Return

- Calling sequence actions
  - Caller assigns the actual arguments.
  - Caller stores return address.
  - Caller jumps to callee.
  - Callee adjusts stack pointer for the activation record.
  - Callee saves nonscratch register values it will use.
- Return sequence actions
  - Callee assigns the return value.
  - Callee restores nonscratch register values and stack pointer address.
  - Callee jumps to the return address.
  - Caller accesses the return value.

Storage Allocation Strategies

- Static Allocation - lays out storage for all data objects at compile time
  - Restrictions
    - size of object must be known and alignment requirements must be known at compile-time
    - no recursion
    - no dynamic data structures

Storage Allocation Strategies (cont.)

- Stack allocation - manages run-time storage as a stack (LIFO model)
  - Activation record is pushed on as function is entered.
  - Activation record is popped off as function is exited.
  - Restrictions
    - Values of locals cannot be retained when an activation ends.
    - A called activation cannot outlive a caller.

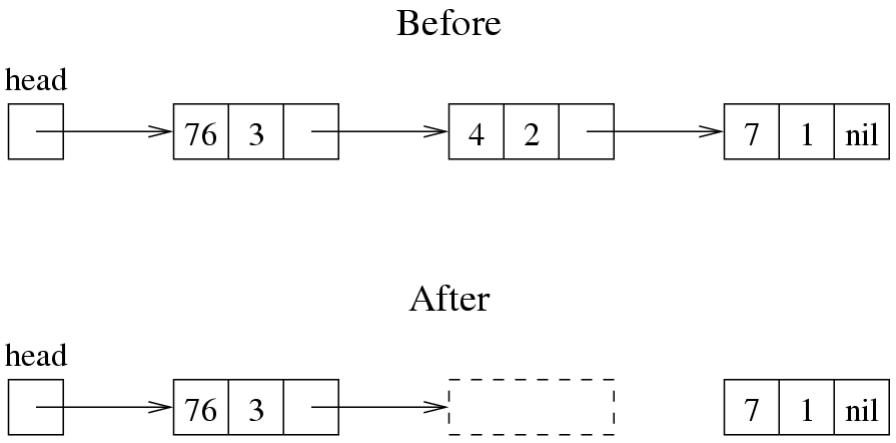
Issues to Address in Calling Conventions

- Responsibility of the caller versus the callee.
- Identifying registers for special purposes.
  - stack pointer, frame pointer, return address
- Preserving the value of registers across calls.
  - callee save, caller save
- Passing arguments.
  - through registers, on the stack

Storage Allocation Strategies (cont.)

- Heap Allocation - allocates and deallocates storage as needed at run-time from a data area known as a heap
  - Most flexible
  - Most inefficient

Creation of Dangling References and Garbage



Heap Storage Reclamation Strategies

- explicit reclamation
  - used in Pascal, Ada, C, C++
  - complicates programming
- implicit reclamation
  - used in Lisp and Java
  - reference counts
  - mark and sweep (garbage collection)

Access to Nonlocal Names

- The scope of a declaration in a block-structured language is given by the most closely nested rule:
  - The scope of a declaration in a block *B* includes *B*.
  - If a name *X* is not declared in a block *B*, then an occurrence of *X* in *B* is in the scope of a declaration of X in an enclosing block *B´* such that
    - *B´* has a declaration of *X*, and
    - *B´* is more closely nested around *B* than any other block with a declaration of *X*.

Lexical Scope without Nested Procedures

- The lexical-scope rules for a language without nested procedures, such as C, are simpler than those of a block-structured language, such as Pascal.
- The scope of a declaration outside a function consists of the function bodies that follow the declaration.

Lexical Scope without Nested Procedures (cont.)

- C functions accesing a nonlocal variable `a`.

```
int a[11];
readarray() { ... a ... }
int partition(int y, int z) { ... a ... }
quicksort(int m, int n) { ... a ... }
main() { ... a ... }
```

- Note that all functions access the same `a`.
- Functions in C can be easily passed as parameters and can be returned as a function result.

Lexical Scope with Nested Procedures

- In a block structured language, a procedure can access nonlocal names that are local variables in other procedures.
- Since such variables are local variables in other procedures, they are placed in activation records on the run-time stack.
- How can they be accessed at run-time?

Referencing Variables with Access Links

- An access link points to the most recent activation of the procedure that contains the current procedure.
- Suppose
  - *Np* is the nesting depth of procedure *p* that refers to a nonlocal variable *a*.
  - *Na* is the nesting depth of the procedure that contains *a*.
- *Np* - *Na* access links would have to be traversed when in procedure *p* to get to the activation record that contains *a*.

Establishing Access Links

- Suppose *p* calls *x*.
- Two cases for setting up the access link.
  - If $Np < Nx$
    - Procedure *x* is nested more deeply than procedure *p*. *x* must be declared within *p*. The access link should point to the caller.
  - If $Np \geq Nx$
    - Follow $Np - Nx + 1$ access links from the caller to reach the activation record of the procedure that encloses the called procedure *x* most closely.

Displays

- An alternative to access links is a display, which is an array of pointers to activation records indexed by the nesting depth.
- Advantage is that referencing nonlocal variables always requires only two memory references.
  - Accessing the activation record through d[i].
  - Accessing variable within the activation record.

Displays (cont.)

- When a new activation record for a procedure at nesting depth i is set up:
  - save the value of d[i] in the new activation record
  - Set d[i] to point to the new activation record
- Just before an activation ends, d[i] is reset to the saved value.