Name, Scope, and Binding

In Text: Chapter 3

Outline [1]

- Variable
- Binding
  - Storage bindings and lifetime
  - Type bindings
- Type Checking
- Scope
- Lifetime vs. Scope
- Referencing Environments

Variable

- A **program variable** is an abstraction of a memory cell or a collection of cells
- It has several attributes
  - Name: A mnemonic character string
  - Address
    - Points to location memory
    - May vary dynamically
  - Type
    - Range of values + legal operations
    - E.g., int type in Java specifies a value range of -2147483648 to 21473647, and arithmetic operations for +, -, *, /, %

Variable

- Scope
  - Range over which the variable is visible
  - Static/dynamic
- Lifetime
  - Time during which the variable is bound to a specific location

Binding

- A **binding** is an association between two things, such as a name and the thing it names
- **Binding time** is the time at which a binding takes place

Possible Binding Time

- Language design time
  - Bind operator symbols to operations
- Language implementation time
  - Bind floating point type to a representation
- Compile time
  - Bind a variable to a type in C or Java
- Load time
  - Bind a variable to a memory cell (C static variable)
- Runtime
  - Bind a nonstatic local variable to a memory cell (method variables)

An Example

```
count = count + 5
```

- `count` is a local variable
  - When is the type of `count` bound?
  - When is + bound to addition?
  - When the value of `count` is bound?

Static and Dynamic Binding

- A binding is **static** if it occurs before run time and remains unchanged throughout program execution
- A binding is **dynamic** if it occurs during execution or can change during execution of the program

An Example of Dynamic Binding

- In JavaScript and PHP,

```
list = [10.2, 3.5];
… …
list = 47;
```


Static and Dynamic Binding

- As binding time gets earlier:
  - execution efficiency goes up
  - safety goes up
  - flexibility goes down
- Compiled languages tend to have early binding times
- Interpreted languages tend to have later bindings

ONE CANNOT OVERSTATE THE IMPORTANCE OF BINDING TIMES IN PROGRAMMING LANGUAGES

Storage Bindings and Lifetime

- Allocation
  - Getting a memory cell from a pool of available memory to bind to a variable
- Deallocation
  - Putting a memory cell that has been unbound from a variable back into the pool
- Lifetime
  - The lifetime of a variable is the time during which it is bound to a particular memory cell

Lifetime

- If an object's memory binding outlives its access binding, we get **garbage**
- If an object's access binding outlives its memory binding, we get a **dangling reference**

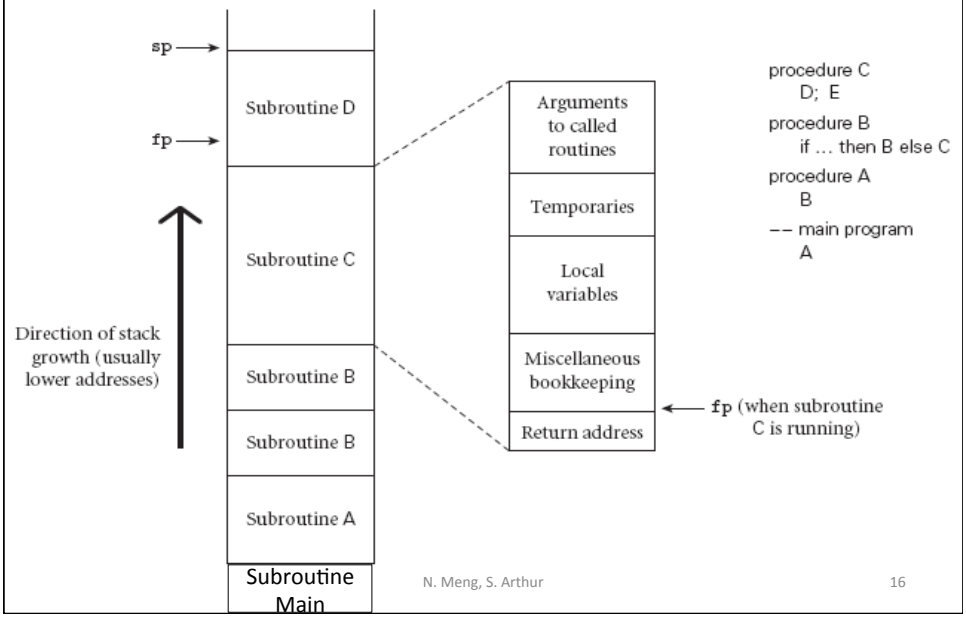
Storage Allocation Mechanism

- Static allocation
- Stack-based allocation
- Heap allocation
- Variable lifetime begins at allocation, and ends at deallocation either by the program or garbage collector

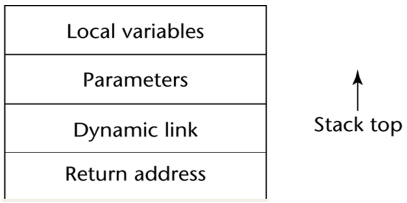
Static Allocation

- Static memory allocation is the allocation of memory at compile time before the associated program is executed
- When the program is loaded into memory, static variables are stored in the data segment of the program's address space
- The lifetime of static variables exists throughout program execution
  - E.g., static int a;

Stack-based Allocation



A More General Representation



Stack-based Allocation

- The location of local variables and parameters can be defined as negative offsets relative to the base of the frame (fp), or positive offsets relative to sp
- The **displacement addressing** mechanism allows such addition to be specified implicitly as part of an ordinary `load` or `store` instruction
- Variable lifetime exists through the declared method

Heap-based Allocation

- Heap
  - A region of storage in which subblocks can be allocated and deallocated at arbitrary time
- Heap space management
  - Different strategies achieve different trade-offs between speed and space

Garbage Collection Algorithms

- Reference Counting
  - Keep a count of how many times you are referencing a resource (e.g., an object in memory), and reclaim the space when the count is zero
  - It cannot handle cyclic structures
  - It causes very high overhead to maintain counters

Garbage Collection Algorithms

- Mark-Sweep
  - Periodically marks all live objects transitively, and sweeps over all memory and disposes of garbage
  - Entire heap has to be iterated over
  - Many long-lived objects are iterated over and over again, which is time-consuming

Garbage Collection Algorithms

- Mark-Compact
  - Mark live objects, and move all live objects into free space to make live space compact
  - It takes even longer time than mark-sweep due to object movement

Garbage Collection Algorithms

- Copying
  - It uses two memory spaces, and each time only uses one space to allocate memory, when the space is used up, copy all live objects to the other space
  - Each time only half space is used

Garbage Collection Algorithms

- Generational Garbage Collection
  - Studies show that
    - most objects live for very short time
    - the older an object is, the more likely it is to live quite long
- Concentrate on collections of young objects, and move surviving objects to older generations, which are collected less frequently

Space Concern

- Fragmentation
  - The phenomenon in which storage space is used inefficiently
  - E.g., although in total 6K memory is available, there is not a 4K contiguous block available, which can cause allocation to fail

Space Concern

- Internal fragmentation
  - Allocates a block that is larger than required to hold a given object
  - E.g., Since memory can be provided in chunks divisible by 4, 8, or 16, when a program requests 23 bytes, it will actually gets 32 bytes
- External fragmentation
  - Free memory is separated into small blocks, and the ability to meet allocation requests degrades over time