CSE 307: Principles of Programming Languages

Variables and Constants

R. Sekar

Topics

Variables and Constants

- Variables are stored in memory, whereas constants need not be.
  - Value of variables can change at runtime.
- Variables have a location (*l*-value) and value (*r*-value).
- Constants have a value, but no location.

Constants

- Constants may some times be stored in memory
- If so, they have r-values but not l-values
- Since values stored in constants cannot be changed, there is no use in accessing l-values
- Thus constants have a “Value semantics”

Values and Constants

- **Values** are quantities manipulated by a program (e.g. integers, strings, data structures, etc.)
- **Constants** have a fixed value for the duration of its existence in a program.
- Constants in a program may be
  - **Literals:** unnamed values specified using a particular representation. e.g.:
    - `42`
    - `"Markov"`
    - `0x2eff`
  - **Symbolic:** names associated with fixed values. e.g.
    - `const int n = 100;`
    - `static final int limit = 1024`

Binding Time of Constants

- **Compile-time**

  `const int n = 100;`

  Binding of `n` (to value `100`) is known at compile time.
- **Load-time**

  `static final Date d = new Date();`

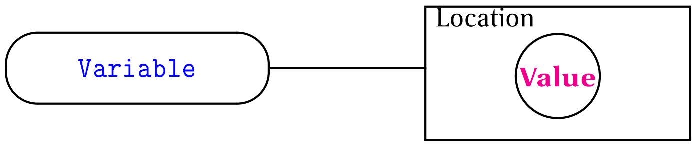
  Constant `d` is bound to the value of today’s date *at load time*.
- **Execution-time**

  `int f(int x) { const int y = x+1; ...}`

  Constant `y` is bound to its value at execution time!
  - Note that `y` is *local* to `f` and refers to different entities for each invocation of `f`. The above declaration says that `y` will be constant for any particular invocation.

Variables

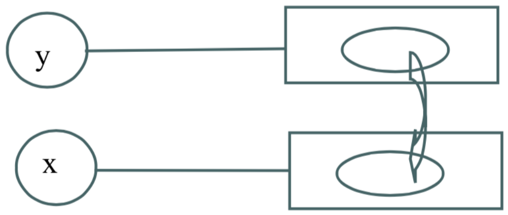
- **Variables** are associated with **locations** in **Store** (memory)
- Representation of variables (for explanations only):



- The stored values are changed through **assignments**: e.g. `x = y;`
  - The value stored at the location associated with `y` is copied to the location associated with `x`

L-value, R-value and Assignment

- In an assignment x = y
  - we refer to l-value of x on the lhs ("l" for location or lhs of assignments)
  - r-value of y on the rhs ("r" for right-hand-side of assignments)
  - **Storage semantics:** update *location* of x with the *value* of y



- Accessing a value stored at a location is called "dereferencing".
  - C/C++/Java: l-values of variables on rhs are implicitly dereferenced to get their r-values.
  - In ML, dereferencing should be explicit, as in `x := !y`

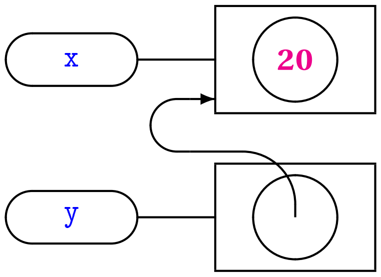
Pointers

- C/C++ "address-of" operation to explicitly turn a reference into a *pointer*.

  e.g. `&x` evaluates to the location of `x`.

  Example:

```
int x;
// x's location stores int
int *y;
// y's location stores
// pointers to int
x = 20;
y = &x;
```

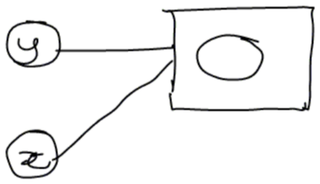


- The "*" operator is used to dereference a pointer

  e.g. in the above example, the value stored at `*y` is **20**

L-value and R-value (Continued)

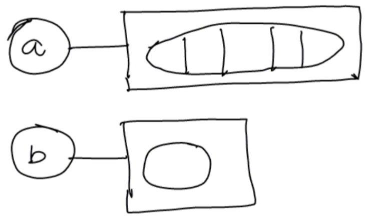
- **Pointer semantics**
  - x simply “points” to y
  - more efficient if the size of y is large
  - but causes confusion in languages with assignment



- Java uses storage semantics for basic types, and pointer semantics for objects
- C/C++ use value semantics for all types
- In a language free of side-effects (i.e., memory updates), both semantics are equivalent.

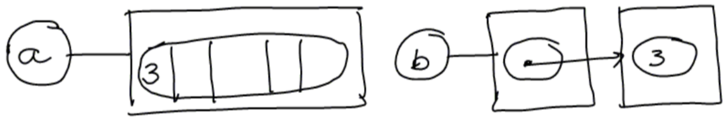
Arrays Vs Pointers in C

- In C, arrays are similar to pointers
  - int a[5];
  - int *b
- a and b have the same type, but semantically, they differ
- b = a is allowed, but a = b is not!
  - the l-value of a cannot be changed (it is a const)



Arrays vs. Pointers in C

- *a=3 and *b=3 have very different effects



- For this to work correctly, b should have been previously initialized to hold a valid pointer value

Garbage

- Location that has been allocated, but no longer accessible
  - int *x = new int; *x = 5;
  - int y = 3; x = &y;

Garbage (Continued)

- Accumulation of garbage can lead to programs running out of memory eventually
- But no immediate adverse impact on program
  - correctness of program is unaffected by garbage
- A program that produces garbage is said to have memory leaks

Dangling Pointer

- A pointer that points to memory that has been deallocated
- Consider:

```
int *x, *y, *z;
x = new int;
*x = 3;
y= x
delete x;
x = NULL;
z = new int;
*z = 5;
*y = 2;
```

Dangling Pointer (Continued)

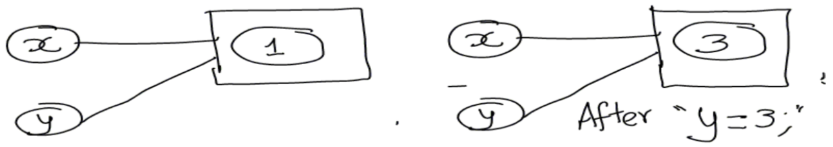
- Dangling pointers have an immediate impact on correctness
  - they cause program to fail
- Failure may be immediate
  - access through NULL pointer
- or be delayed
  - corruption of data structures reached through dangling pointers

Dangling Pointer Vs. Garbage

- As compared to garbage, dangling pointers cause much more serious errors
- So, it is safer to never free memory
  - But programs will run out of memory after a period of time
    - Not an issue for programs that run for short times
  - To avoid this, can use garbage collection
    - automatically release unreachable memory
    - used in OCAML, Java
    - garbage collection is much harder for languages with weak type systems (e.g., C and C++).

Aliases

- Alias: Two variables have the same l-value
- C does not support references, but C++ does
  - Use the syntax <typename>&:
    - int& y
  - References have to be initialized with their l-value
    - int x = 1; int& y = x;

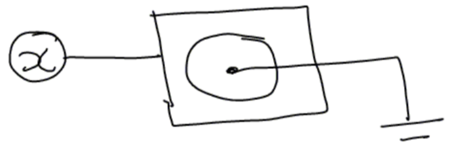


Aliases

- x and y are aliased
  - they both have same l-value
- when two variables are aliased, assignments to one variable have the side-effect of changing the r-value of the other variable
- side-effects cause confusion
  - They should be used sparingly
  - Aliasing should be used very carefully

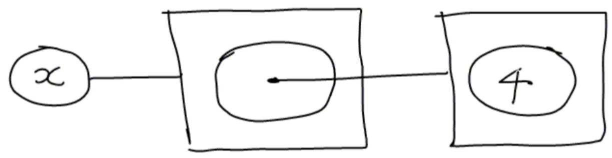
Aliases (Continued)

- Aliases may be created using pointer variables as well
- int *x = NULL;



Aliases (Continued)

- x = new int;
- *x = 4;



Aliases (Continued)

- int *y;
- y = x;