
CSE 374

Programming Concepts & Tools

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(Thanks to Hal Perkins)

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Lecture 9 – C: Locals, lvalues and rvalues, more pointers

The story so far...

- The low-level execution model of a process (one address space)
- Basics of C:
 - Language features: functions, pointers, arrays
 - Idioms: Array-lengths, strings with '\0' terminators
 - Control constructs and int guards
- Today, more features:
 - Local declarations
 - Storage duration and scope
 - Left vs. right expressions; more pointers
 - Dangling pointers
 - Stack arrays and implicit pointers (confusing)
- Later: structs; the heap and manual memory management

Storage, lifetime, and scope

- At run-time, every variable needs space
 - When is the space allocated and deallocated?
- Every variable has scope
 - Where can the variable be used (unless another variable shadows it)?
- C has several answers (with inconsistent reuse of the word static)
- Some answers rarely used but **understanding storage, lifetime, and scope is important**
- **Related: Allocating space is separate from initializing that space**
 - Use uninitialized bits? Hopefully crash but who knows?
 - Unlike Java, which zeros out objects and complains about uninitialized locals

Storage, lifetime, and scope

- *Global variables* allocated before main, deallocated after main. Scope is entire program
 - Usually bad style, kind of like public static Java fields
 - But can be OK for truly global data like conversion tables, physical constants, etc.
- *Static global variables* like global variables but scope is just that source file, kind of like private static Java fields
 - Related: static functions cannot be called from other files
- *Static local variables* lifetime like global variables (!) but scope is just that function, rarely used (We *won't* use them)
- *Local variables* (often called *automatic*) allocated “when reached” deallocated “after that block”, scope is that block
 - With recursion, multiple copies of same variable (one per stack frame/function activation)
 - Like local variables in Java

lvalues vs rvalues

- In intro courses we are usually fairly sloppy about the **difference between the left side of an assignment and the right**. To “really get” C, it helps to get this straight:
 - Law #1: Left-expressions get evaluated to locations (addresses)
 - Law #2: Right-expressions get evaluated to values
 - Law #3: Values include numbers and pointers (addresses)
- The key difference is the “rule” for variables:
 - As a **left-expression**, a **variable is a location** and *we are done*
 - As a **right-expression**, a **variable gets evaluated to its location’s contents**, and *then* we are done
 - Most things do not make sense as left expressions
- Note: This is true in Java too

Function arguments

- Storage and scope of arguments is like for local variables
- But initialized by the caller (“copying” the value)
- So assigning to an argument has no affect on the caller
- But assigning to the space *pointed-to* by an argument might

```
void f() {  
    int i=17;  
    int j=g(i);  
    printf("%d %d",i,j);  
}  
  
int g(int x) {  
    x = x+1;  
    return x+1;  
}
```

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```
void f() {  
    int i=17;  
    int j=g(&i);  
    printf("%d %d",i,j);  
}  
  
int g(int* p) {  
    *p = (*p) + 1;  
    return (*p) + 1;  
}
```

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void f() {  
    int i=17;  
    int j=g(&i);  
    printf("%d %d",i,j);  
}
```

```
int g(int* p) {  
    int k = *p;  
    int *q = &k;  
    *p = *q;  
    (*p) = (*q) + 1;  
    return (*q) + 1;  
}
```


Pointers to pointers to ...

- Any level of pointer makes sense:
 - Example: `argv`, `*argv`, `**argv`
 - Same example: `argv`, `argv[0]`, `argv[0][0]`
- But `&(&p)` makes no sense (`&p` is not a left-expression, the value is an address but the value is in no-particular-place)
- This makes sense (well, at least it's legal C):

```
void f(int x) {  
    int*p = &x;  
    int**q = &p;  
    ... can use x, p, *p, q, *q, **q, ...  
}
```
- Note: When playing, you can print pointers (i.e., addresses) with `%p` (just numbers in hexadecimal)

Dangling pointers

```
int* f(int x) {
    int *p;
    if(x) {
        int y = 3; /* scope of y only between these { } */
        p = &y; /* ok */
    } /* ok, but p now dangling */
    /* y = 4 does not compile */
    *p = 7; /* could CRASH but probably not */
    return p; /* uh-oh, but no crash yet */
}

void g(int *p) { *p = 123; }
void h() {
    g(f(7)); /* HOPEFULLY YOU CRASH (but maybe not) */
}
```

Arrays and Pointers

- If p has type T^* or type $T[]$:
 - $*p$ has type T
 - If i is an int, $p+i$ refers to the location of an item of type T that is i items past p (*not* $+i$ storage locations unless each item of type T takes up exactly 1 unit of storage)
 - $p[i]$ is defined to mean $*(p+i)$
 - if p is used in an expression (including as a function argument) it has type T^*
 - Even if it is declared as having type $T[]$
 - One consequence: array arguments are always “passed by reference” (as a pointer), not “by value” (which would mean copying the entire array value)

Arrays revisited

- “Implicit array promotion”: a variable of type `T[]` becomes a variable of type `T*` in an expression

```
void f1(int* p) { *p = 5; }
```

```
int* f2() {  
    int x[3];    /* x on stack */  
    x[0] = 5;  
    /* (&x)[0] = 5; wrong */  
    *x = 5;  
    *(x+0) = 5;  
    f1(x);  
    /* f1(&x); wrong – watch types! */  
    /* x = &x[2]; wrong – x isn't really a pointer! */  
    int *p = &x[2];  
    return x;    /* wrong – dangling pointer – but type correct */  
}
```