CS 61C
Fall 2019

C Basics

Discussion 2: September 9, 2019

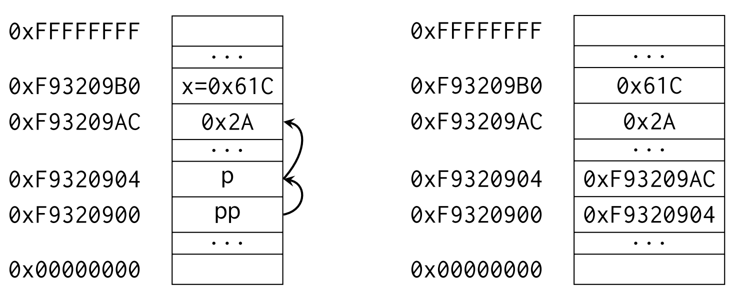
1 C

C is syntactically similar to Java, but there are a few key differences:

1. C is function-oriented, not object-oriented; there are no objects.
2. C does not automatically handle memory for you.
   - Stack memory, or *things that are not manually allocated*: data is garbage immediately after the *function in which it was defined* returns.
   - Heap memory, or *things allocated with* `malloc`, `calloc`, *or* `realloc`: data is freed only when the programmer explicitly frees it!
   - There are two other sections of memory that we learn about in this course, *static* and *code*, but we'll get to those later.
   - In any case, allocated memory always holds garbage until it is initialized!
3. C uses pointers explicitly. If `p` is a pointer, then `*p` tells us to use the value that `p` points to, rather than the value of `p`, and `&x` gives the address of `x` rather than the value of `x`.

   On the left is the memory represented as a box-and-pointer diagram.

   On the right, we see how the memory is really represented in the computer.



   Let's assume that **`int`**`* p` is located at `0xF9320904` and **`int`** `x` is located at `0xF93209B0`. As we can observe:

   - `*p` evaluates to `0x2A` (42_{10}).
   - `p` evaluates to `0xF93209AC`.
   - `x` evaluates to `0x61C`.
   - `&x` evaluates to `0xF93209B0`.

   Let's say we have an **`int`** `**pp` that is located at `0xF9320900`.

1.1 What does `pp` evaluate to? How about `*pp`? What about `**pp`?

`pp` evaluates to `0xF9320904`. `*pp` evaluates to `0xF93209AC`. `**pp` evaluates to `0x2A`.

1.2 The following functions are syntactically-correct C, but written in an incomprehensible style. Describe the behavior of each function in plain English.

(a) Recall that the ternary operator evaluates the condition before the `?` and returns the value before the colon (`:`) if true, or the value after it if false.

```c
int foo(int *arr, size_t n) {
    return n ? arr[0] + foo(arr + 1, n - 1) : 0;
}
```

Returns the sum of the first N elements in `arr`.

(b) Recall that the negation operator, `!`, returns 0 if the value is non-zero, and 1 if the value is 0. The `~` operator performs a *bitwise not* (NOT) operation.

```c
int bar(int *arr, size_t n) {
    int sum = 0, i;
    for (i = n; i > 0; i--)
        sum += !arr[i - 1];
    return ~sum + 1;
}
```

Returns -1 times the number of zeroes in the first N elements of `arr`.

(c) Recall that `^` is the *bitwise exclusive-or* (XOR) operator.

```c
void baz(int x, int y) {
    x = x ^ y;
    y = x ^ y;
    x = x ^ y;
}
```

Ultimately does not change the value of either `x` or `y`.

2 Programming with Pointers

2.1 Implement the following functions so that they work as described.

(a) Swap the value of two **`int`**s. *Remain swapped after returning from this function.*

```c
void swap(int *x, int *y) {
    int temp = *x;
    *x = *y;
    *y = temp;
}
```

(b) Return the number of bytes in a string. *Do not use* `strlen`.

```c
int mystrlen(char* str) {
    int count = 0;
    while (*str++) {
        count++;
    }
    return count;
}
```

2.2 The following functions may contain logic or syntax errors. Find and correct them.

(a) Returns the sum of all the elements in `summands`.

It is necessary to pass a size alongside the pointer.

```c
int sum(int* summands, size_t n) {
    int sum = 0;
    for (int i = 0; i < n; i++)
        sum += *(summands + i);
    return sum;
}
```

(b) Increments all of the letters in the `string` which is stored at the front of an array of arbitrary length, `n >= strlen(string)`. Does not modify any other parts of the array's memory.

The ends of strings are denoted by the null terminator rather than n. Simply having space for n characters in the array does not mean the string stored inside is also of length n.

```c
void increment(char* string) {
    for (i = 0; string[i] != 0; i++)
        string[i]++; // or (*(string + i))++;
}
```

Another common bug to watch out for is the corner case that occurs when incrementing the character with the value 0xFF. Adding 1 to 0xFF will overflow back to 0, producing a null terminator and unintentionally shortening the string.

(c) Copies the string `src` to `dst`.

```c
void copy(char* src, char* dst) {
    while (*dst++ = *src++);
}
```

No errors.

(d) Overwrites an input string `src` with “61C is awesome!” if there's room. Does nothing if there is not. Assume that `length` correctly represents the length of `src`.

```c
void cs61c(char* src, size_t length) {
    char *srcptr, replaceptr;
```

```
    char replacement[16] = "61C is awesome!";
    srcptr = src;
    replaceptr = replacement;
    if (length >= 16) {
        for (int i = 0; i < 16; i++)
            *srcptr++ = *replaceptr++;
    }
}
```

`char *srcptr, replaceptr` initializes a `char` pointer, and a `char`—not two `char` pointers.

The correct initialization should be, `char *srcptr, *replaceptr`.

3 Memory Management

3.1 For each part, choose one or more of the following memory segments where the data could be located: **code, static, heap, stack**.

(a) Static variables

Static

(b) Local variables

Stack

(c) Global variables

Static

(d) Constants

Code, static, or stack

Constants can be compiled directly into the code. `x = x + 1` can compile with the number 1 stored directly in the machine instruction in the code. That instruction will always increment the value of the variable `x` by 1, so it can be stored directly in the machine instruction without reference to other memory. This can also occur with pre-processor macros.

```
#define y 5

int plus_y(int x) {
    x = x + y;
    return x;
}
```

Constants can also be found in the stack or static storage depending on if it's declared in a function or not.

```
const int x = 1;

int sum(int* arr) {
```

```
    int total = 0;
    ...
}
```

In this example, `x` is a variable whose value will be stored in the static storage, while `total` is a local variable whose value will be stored on the stack. Variables declared **`const`** are not allowed to change, but the usage of **`const`** can get more tricky when combined with pointers.

(e) Machine Instructions

Code

(f) Result of `malloc`

Heap

(g) String Literals

Static or stack.

When declared in a function, string literals can be stored in different places. `char* s = "string"` is stored in the static memory segment while `char[7] s = "string"` will be stored in the stack.

3.2 Write the code necessary to allocate memory on the heap in the following scenarios

(a) An array `arr` of k integers

`arr = (int *) malloc(sizeof(int) * k);`

(b) A string `str` containing p characters

`str = (char *) malloc(sizeof(char) * (p + 1));` Don't forget the null terminator!

(c) An $n \times m$ matrix `mat` of integers initialized to zero.

`mat = (int *) calloc(n * m, sizeof(int));`

Alternative solution. This might be needed if you wanted to efficiently permute the rows of the matrix.

```
mat = (int **) calloc(n, sizeof(int *));
for (int i = 0; i < n; i++)
    mat[i] = (int *) calloc(m, sizeof(int));
```

Suppose we've defined a linked list **`struct`** as follows. Assume `*lst` points to the first element of the list, or is `NULL` if the list is empty.

```
struct ll_node {
    int first;
    struct ll_node* rest;
}
```

3.3 Implement `prepend`, which adds one new `value` to the front of the linked list. Hint: why use ll_node $**lst$ instead of ll_node$*lst$?

```c
void prepend(struct ll_node** lst, int value) {
    struct ll_node* item = (struct ll_node*) malloc(sizeof(struct ll_node));
    item->first = value;
    item->rest = *lst;
    *lst = item;
}
```

3.4 Implement `free_ll`, which frees all the memory consumed by the linked list.

```c
void free_ll(struct ll_node** lst) {
    if (*lst) {
        free_ll(&((*lst)->rest));
        free(*lst);
    }
    *lst = NULL; // Make writes to **lst fail instead of writing to unusable memory.
}
```