CS 61C Fall 2018

C Basics

Discussion 2: September 3, 2018

1 C

strings end with null terminator ('\0'), this is equivalent to zero.

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

Array's size is not kept so you must keep it. sizeof gets size of type not length of array

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 allocated the way you're accustomed to*: data is garbage immediately after the *function in which it was defined* returns.
    - Heap memory, or *things allocated with* `malloc`, `calloc`, *or* `realloc` *commands*: data is freed only when the programmer explicitly frees it!
    - In any case, allocated memory always holds garbage until it is initialized!
3. C uses pointers explicitly. `*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.

0xFFFFFFFF		0xFFFFFFFF	
	...		...
0xF93209B0	x=0x61C	0xF93209B0	0x61C
0xF93209AC	0x2A	0xF93209AC	0x2A
	...		...
0xF9320904	p	0xF9320904	0xF93209AC
0xF9320900	pp	0xF9320900	0xF9320904
	...		...
0x00000000		0x00000000	

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

- `*p` should return `0x2A` (42_{10}).
- `p` should return `0xF93209AC`.
- `x` should return `0x61C`.
- `&x` should return `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`.

&pp = 0xF9320900
pp = 0xF9320904
*pp = 0xF93209AC
↑ This is data from pp dereferenced.

Dereference the address 0xF93209AC which is 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++;
```

```c
    }
    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.

```c
#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.

```c
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.

and where it points to is the same but the data there can change depending on where it is stored / what pointers it was stored with.

(e) Machine Instructions

Code (TEXT)

(f) Result of `malloc`

Heap

other things which allocate heap = calloc + realloc; Free can free any of these. Note: they ALL return a pointer to the location on the heap where the data is stored. If it returns NULL, then it could not allocate any more memory. DON'T FORGET NULL CHECK for any alloc. Also realloc may or may not use the same location in memory!

(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);
```

To make it compatable with ALL systems, If you put just 4, it would be only compatable with systems where sizeof(int) == 4 which is not generally true.

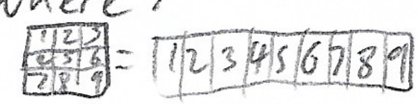
(b) A string `str` containing p characters

`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));
```

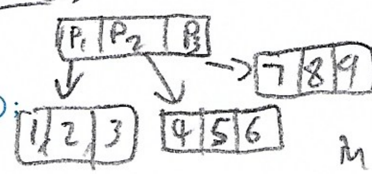
← linear array where:



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));
```

where:



could do same but store rows. Different methods useful in different types of accesses.

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.

```
void prepend(struct ll_node** lst, int value) {
    struct ll_node* item = (struct ll_node*) malloc(sizeof(struct ll_node));
```

2 makes new struct ll_node in the heap

```
    item->first = value; ← puts value to newly created structure -
    item->rest = *lst; ← sets rest to current start.
    *lst = item; ← sets start to newly created + now setup structure.
}
```

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

```
void free_ll(struct ll_node** lst) {
    if (*lst) { ← checks to see if has actual node + not null.
        free_ll(&((*lst)->rest)); ← recursively frees the rest structure.
        free(*lst); ← frees current structure
    }
    *lst = NULL; // Make writes to **lst fail instead of writing to unusable memory.
}
```

Remember since this is a recursive call, it will free ALL structs in the linked list.