C Introduction

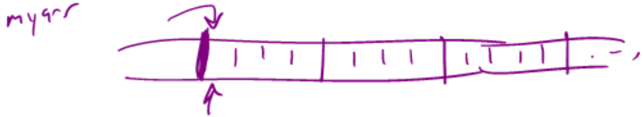
CS 2130: Computer Systems and Organization 1

March 31, 2023

Announcements

- Homework 7 (writing C functions) due Monday at 11pm
    - Note: test on your own! Limited Gradescope submissions
- Quiz 7 opens today, submit by Sunday night
- If you are having `git` issues, please come to office hours!
- Exam 2 next Friday

Arrays



Array: 0 or more values of same type stored contiguously in memory

- Declare as you would use: `int myarr[100];`
- `sizeof(myarr)` = 400 — 100 4-byte integers
- Can declare array literals:

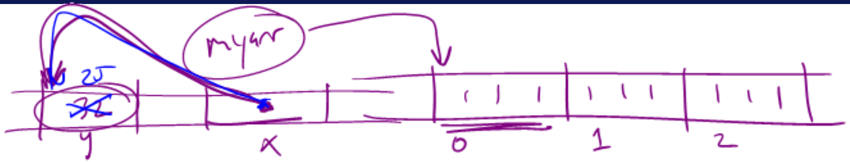
  `int y[5] = {1, 1, 2, 3, 5}`
- `myarr` treated as pointer to first element

Pointers and Arrays

int y = 32;

int *x = &y;

*x = 25;



`*myarr` and `myarr[0]` are equivalent

- Pointer to single value and pointer to first value in array
- Treat array as pointer to the first value (lowest address)
- Indexing into array: `myarr[n]` and `*(myarr+n)`
  - If `myarr` is an `int *`, then `myarr+1` points to **next int** in memory
  - Adding 1 to pointer adds `sizeof()` the type we're pointing to

*(myarr + 5)

ptr

+5 sizeof(int)

name

int *x = &y

type

Pointers and Arrays

int a[10][10]

Consider: `int **a`

↓*

int *

**a => 1

a[0][0] => 1

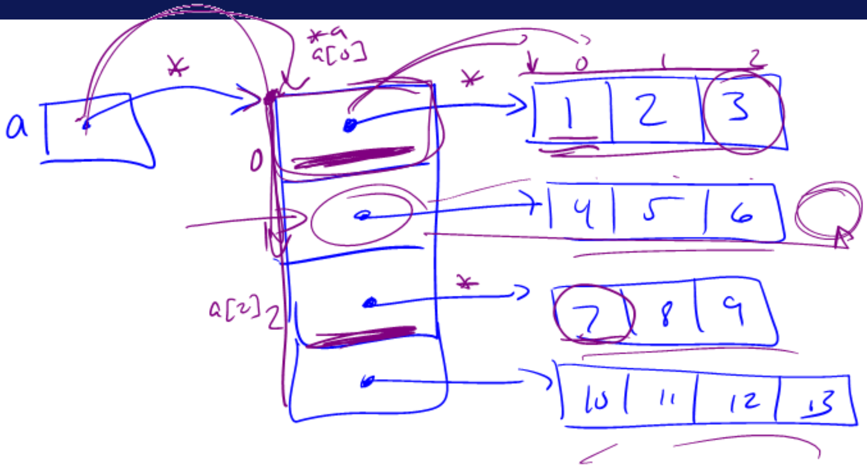
*(a[2]) => 7

(*a)[2] => 3

a[1][3] => ?

a[1][0] =>

a[0][1] =>



* a[1] =>

Pointers

- All pointers are the same size: address size in underlying ISA
- Two special int types (defined using typedef)
  - `size_t` - integer the size of a pointer (unsigned)
  - `ssize_t` - integer the size of a pointer (signed)
  - With our compiler and ISA, these are both variants of `long`

Pointers

Consider the following code:

+2int

```
int x = 10;
int *y = &x;
int *z = y + 2;
long w = ((long)z) - ((long)y);
```

Why is `w` = 8?

Other Types and Values

- Literal values - integer literals are implicitly cast
  - `unsigned long very_big = 9223372036854775808uL`
  - `u` for unsigned, `L` for long
- `enum` - named integer constants (in ascending order)

  -
    ```
           0  1  2        101
    enum { a, b, c, d=100, e };
    int foo = e;
    ```
- `void` - a byte with no meaning or ”nothing”
  - Pointers: `void *p`
  - Return values: `void myfunction();`
- Casting - changing type, converting
  - Integer: zero- or sign-extend or truncate to space
  - Int to float: convert to nearby representable value
  - Float to int: truncate remainder (no rounding)

Structures

`struct` - Structures in C

- Act like Java classes, but no methods and all public fields
- Stores fields adjacently in memory (but may have padding)
- Compiler determines padding, use `sizeof()` to get size
- Name of the resulting type includes word `struct`

```
struct foo {
    long a;
    int b;
    short c;
    char d;
};

struct foo x;
x.b = 123;
x.c = 4;
```

Structure Literals

```c
struct a {
    int b;
    double c;
};

/* Both of the following initialize b to 0 and c to 1.0 */
struct a x = { 0, 1.0 };
struct a y = { .b = 0, .c = 1.0 };
```

typedef

`typedef` - give new names to any type!

- Fairly common to see several names for same data type to convey intent
- Ex: `unsigned long` may be `size_t` when used in sizes
- Examples:

  ```
  typedef int Integer;
  Integer x = 4;
  typedef double ** dpp;
  ```
- Used with *anonymous structs*:

  ```
  typedef struct { int x; double y; } foo;
  foo z = { 42, 17.4 };
  ```

Struct Example

```
typedef struct {
    long x;
    long y;
    long *array;
    long length;
} foo;
```

Struct Example

```
long sum2(foo *arg) {
    long ans = arg->x;
    for(long i = 0; i < arg->length; i += 1)
        ans += arg->y * arg->array[i];
    return ans;
}
```

```
sum2:
    movq    (%rdi), %rax
    movq    24(%rdi), %r8
    testq   %r8, %r8
    jle     .LBB1_3
    movq    8(%rdi), %rdx
    movq    16(%rdi), %rsi
    xorl    %edi, %edi
.LBB1_2:
    movq    (%rsi,%rdi,8), %rcx
    imulq   %rdx, %rcx
    addq    %rcx, %rax
    incq    %rdi
    cmpq    %rdi, %r8
    jne     .LBB1_2
.LBB1_3:
    retq
```

Struct Example

```
long sum1(foo arg) {
    long ans = arg.x;
    for(long i = 0; i < arg.length; i += 1)
        ans += arg.y * arg.array[i];
    return ans;
}
```

```
sum1:
    movq    8(%rsp), %rax
    movq    32(%rsp), %r8
    testq   %r8, %r8
    jle     LBB0_3
    movq    16(%rsp), %rdx
    movq    24(%rsp), %rsi
    xorl    %edi, %edi
.LBB0_2:
    movq    (%rsi,%rdi,8), %rcx
    imulq   %rdx, %rcx
    addq    %rcx, %rax
    incq    %rdi
    cmpq    %rdi, %r8
    jne     .LBB0_2
.LBB0_3:
    retq
```