

C Introduction

CS 2130: Computer Systems and Organization 1

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Announcements

- Homework 6 due tonight at 11:59pm
- Homework 7 available soon, due next Monday on Gradescope
- Midterm 2 is on April 3
 - Similar format to midterm 1
 - Schedule with SDAC early if needed

Data Types in C

Integer data types

Data type	Size
char	
short	
int	
long	
long long	

Each has 2 versions: *signed* and *unsigned*

Data Types in C

Helpful Resources

- Wikipedia
- Our Reference and Summary

`sizeof()` - returns size in bytes

- `sizeof(int)` returns 4

Data Types in C

Floating point

- float
- double

Data Types in C

Data Types in C

Pointers - how C uses addresses!

Data Types in C

Pointers - how C uses addresses!

- Hold the address of a position in memory
- Need to know the kind of information stored at that location

Example

```
int main() {
    int x = 3;
    long y = 4;
    int *a = &x;
    long *b = &y;
    long z = *a;
    int w = *b;
    return 0;
}
```

Example

```
int main() {
    int x = 3;
    long y = 4;
    int *a = &x;
    long *b = &y;
    long z = *a;
    int w = *b;
    return 0;
}
```

```
0000000000000000 <main>:
 0: 55                                push   %rbp
 1: 48 89 e5                          mov    %rsp,%rbp
 4: 31 c0                              xor    %eax,%eax
 6: c7 45 fc 00 00 00 00             movl   $0x0,-0x4(%rbp)
 d: c7 45 f8 03 00 00 00             movl   $0x3,-0x8(%rbp)
14: 48 c7 45 f0 04 00 00             movq   $0x4,-0x10(%rbp)
1b: 00
1c: 48 8d 4d f8                        lea   -0x8(%rbp),%rcx
20: 48 89 4d e8                        mov   %rcx,-0x18(%rbp)
24: 48 8d 4d f0                        lea   -0x10(%rbp),%rcx
28: 48 89 4d e0                        mov   %rcx,-0x20(%rbp)
2c: 48 8b 4d e8                        mov   -0x18(%rbp),%rcx
30: 48 63 09                          movslq(%rcx),%rcx
33: 48 89 4d d8                        mov   %rcx,-0x28(%rbp)
37: 48 8b 4d e0                        mov   -0x20(%rbp),%rcx
3b: 48 8b 09                          mov   (%rcx),%rcx
3e: 89 4d d4                          mov   %ecx,-0x2c(%rbp)
41: 5d                                pop   %rbp
42: c3                                retq
```

Example

Swap Example

```
void swap(int *a, int *b) {  
    int tmp = *a;  
    *a = *b;  
    *b = tmp;  
}
```

Using Compilers

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

Pointers and Arrays

`*x` and `x[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: `x[n]` and `*(x+n)`
 - If `x` is an `int *`, then `x+1` points to **next int** in memory
 - Adding 1 to pointer adds `sizeof()` the type we're pointing to

Pointers and Arrays

Consider: `int **a`

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:

```
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)
 - `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

```
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
```