C Introduction

CS 2130: Computer Systems and Organization 1

April 3, 2023

Announcements

- Homework 7 (C functions) due tonight at 11pm
- Bring questions to our review session on Wednesday
- Exam 2 on Friday

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 };` (a=0, b=1, c=2, e=101)
    `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)

```
float a = 12.34;
void *p = &a;
float b = *(float*)p
```

Structures

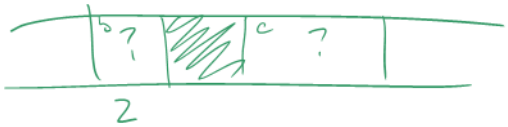
`struct` - Structures in C

- 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 };
```

struct a 2;

typedef

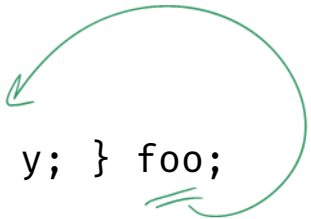
`typedef` - give new names to any type!

- 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*:

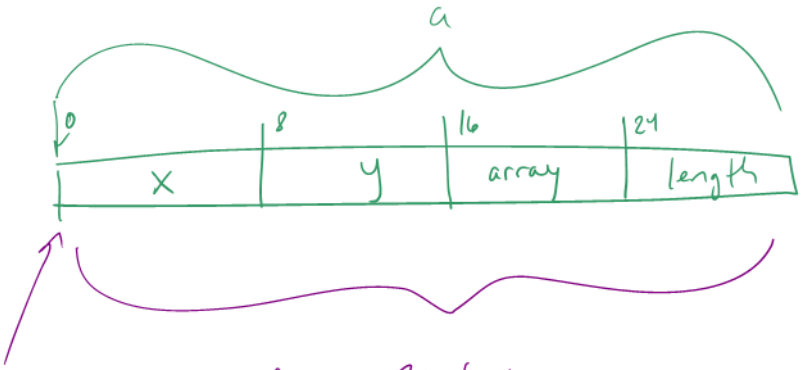
```
typedef struct { int x; double y; } foo;
foo z = { 42, 17.4 };
```



Struct Example

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

foo a;



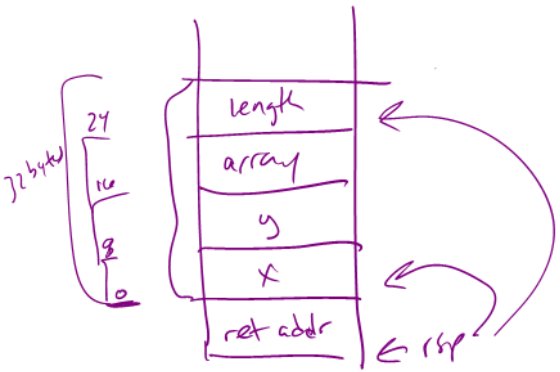
Struct Example

```
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
```

C Reference Guide

Calling Functions

The C code

```
long a = f(23, "yes", 34uL);
```

compiles to

```
movl $23, %edi
leaq label_of_yes_string, %rsi
movq $34, %rdx
callq f
# %rax is "long a" here
```

without respect to how f was defined. It is the calling convention, not the type declaration of f, that controls this.

Calling Functions

But, if the C code has access to the type declaration of f, then it might perform some implicit casting first; for example, if we declared

```
long f(double a, const char *b, double c);
```

```
long a = f(23, "yes", 34uL);
```

then the call would be interpreted by C as having implicit casts in it:

```
long a = f((double)23, "yes", (double)34uL);
```

Calling Functions

and the arguments would be passed in floating-point registers, like so:

```
movl $23, %eax
cvtsi2sd %eax, %xmm0           # first floating-point argument

leaq label_of_yes_string, %rdi # first integer/pointer argument

movl $34, %eax
cvtsi2sd %eax, %xmm1           # second floating-point argument

callq f
# %rax is "long a" here
```

Function Declaration

```
int f(int x);
```

- Declaration of the function
- Function header
- Function signature
- Function prototype

We want this in every file that invokes `f()`

Function Definition

```
int f(int x) {
    return 2130 * x;
}
```

- Definition of the function

We only want this in **one `.c` file**

- Do not want 2 definitions
- Which one should the linker choose?

Header Files

C header files: `.h` files

- Written in C, so look like C
- Only put header information in them
  - Function headers
  - Macros
  - `typedef`s
  - `struct` definitions
- Essentially: information for the **type checker** that does not produce any actual binary
- `#include` the header files in our `.c` files

Big Picture

Header files

- Things that tell the type checker how to work
- Do not generate any actual binary

C files

- Function definitions and implementation
- Include the header files

Including Headers

```
#include "myfile.h"
```

- Quotes: look for a file where I'm writing code
- Our header files

```
#include <string.h>
```

- Angle brackets: look in the standard place for includes
- Code that came with the compiler
- Likely in `/usr/include`

string.h