

# **CS 241: Systems Programming**

## **Lecture 16. Enums and Structs**

Spring 2020

Prof. Stephen Checkoway

# Course project

Work in groups of 4 (one group of 3)

A written proposal (750 words) is due in one week (Monday)

I'll give feedback on the proposal by spring break

A written status update (750 words) is due on April 12

The completed project and report (2000 words) is due on May 3

7 minute presentations will be the last day of class, May 8

# Requirements

Must involve a significant amount of effort (more than one or two people could do alone)

- ▶ all partners are expected to contribute to the implementation, the write ups, and the presentation
- ▶ division of labor within each part is expected and good!

Involve a significant new programming technology you haven't used before

- ▶ a new language (C, C++, C#, Rust, Go, Ruby, Haskell, JavaScript, etc.), or
- ▶ significant use of a framework or library (e.g., Django for Python or some graphical framework for Java)

# Requirements

Collaboration must happen on GitHub

- ▶ This means regular commits
- ▶ I *strongly* recommend you learn about pull requests and use them along with code review of each commit before it gets pushed to master
- ▶ Using GitHub issues to track bugs that need to be fixed or features that need to be implemented is a great idea

Your code must contain tests similar to what we've done with the homework

- ▶ Find and use the appropriate tests for your language/framework
- ▶ You must use Travis CI to perform automated testing

# What you do is up to you!

## Suggestions

- ▶ Program a microcontroller (like an Arduino) to use some sensors and lights/actuators to do something (you can test with a simulator)
- ▶ Implement a game (e.g., Mancala, checkers) using some game building framework (SDL, PyGame, etc.)
- ▶ Use OpenCV to do something with computer vision
- ▶ Implement some machine learning algorithms (like k-means or k-nearest neighbors) and run them on some interesting datasets <http://archive.ics.uci.edu/ml/index.php> and do some visualization
- ▶ Build an interactive website
- ▶ Make some interactive art (audio and video)

# Proposals

Due next Monday (2020-03-16) by the end of the day

Tell me

- ▶ what you are doing
- ▶ how are you doing it
- ▶ what you need to learn to do it
- ▶ a proposed schedule with milestones (the status report will discuss the milestones, you might want to track these on GitHub)

Be ambitious but **realistic!**

- ▶ Be explicit about which features are essential, which are nice-to-have that you plan to do, and which are stretch goals

# Report

A 2000 word (maximum!) write up

- ▶ standalone description of your project
- ▶ what you accomplished
- ▶ what you weren't able to get to
- ▶ what you found most challenging
- ▶ anything else you think I should know

Due the Sunday before presentations (2020-05-03)

# Demo and presentation

Last week of class (there will be a sign up for the day later in the semester)

Spend 7 minutes showing off and talking about your project

- ▶ 5 minutes of talking; 2 minutes of answering questions
- ▶ I know public speaking is *awful* (unless you enjoy it), but this is a super low-stakes way to get practice at it in a supportive environment
- ▶ Everybody must speak
- ▶ (Attendance at both days of presentations is mandatory, I will check with clickers)
- ▶ Tell us who you are, what you did, and how you did it (tell us what didn't work if you like)
- ▶ Show off some features
- ▶ 🙌🙌🙌 Get some applause 🙌🙌🙌

# Enumerations: named constants

Anonymous, implicit values

- ▶ **enum** {  
    FOO, // has value 0  
    BAR, // has value 1  
    QUX, // has value 2  
};
- ▶ These are integers  
**int** x = FOO;

# Named enums

You can name the enum

- ▶ `enum` Color {  
    RED,  
    YELLOW,  
    GREEN,  
    /\* etc. \*/  
};
- ▶ This defines a new integer type  
`enum` Color c = YELLOW;

Useful in switch statements

- ```
switch(c) {  
case RED:  
    return "red";  
case YELLOW:  
    return "yellow";  
case GREEN:  
    return "green";  
/* etc. */  
}
```
- ▶ Compiler can check you covered all cases

# Explicit values

```
enum Permission {  
    READ_PERM = 1 << 2,  
    WRITE_PERM = 1 << 1,  
    EXEC_PERM = 1 << 0,  
    RWX_PERM = READ_PERM | WRITE_PERM | EXEC_PERM,  
};
```

```
/* We can use them as normal integers */
```

```
enum Permission no_exec(enum Permission perm) {  
    return perm & ~EXEC_PERM;  
}
```

```
enum Permission {  
    READ_PERM = 1 << 2,  
    WRITE_PERM = 1 << 1,  
    EXEC_PERM = 1 << 0,  
    RWX_PERM = READ_PERM | WRITE_PERM | EXEC_PERM,  
};
```

What value does `EXEC_PERM + 4` have?

A. `READ_PERM`

D. 5

B. `RWX_PERM`

E. Undefined behavior

C. 4

# Structures

Group related data together by creating a new type

```
struct Point {  
    float x;  
    float y;  
};
```

Create and initialize a new Point named p

```
struct Point p = {  
    .x = -33.8f,  
    .y = 20.0f,  
};
```

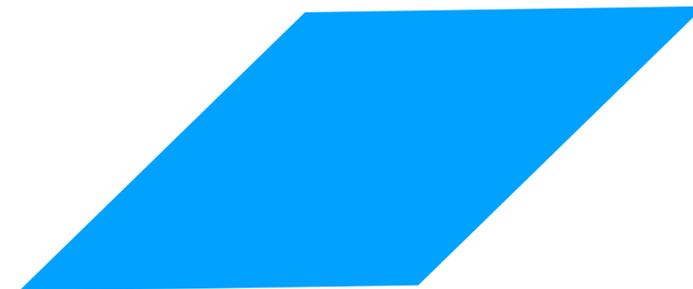
# Nested structs

Structs can contain other structs (or arrays or arrays of structs or...)

```
struct Quadrilateral {  
    struct Point vertex[4];  
};
```

We can initialize a Quadrilateral

```
struct Quadrilateral rhombus = {  
    .vertex = {  
        [0] = { .x = 0.0f, .y = 0.0f },  
        [1] = { .x = 1.0f, .y = 0.0f },  
        [2] = { .x = 0.5f, .y = 1.0f },  
        [3] = { .x = 1.5f, .y = 1.0f },  
    },  
};
```



# Accessing a struct's members

**struct** Point has two members, x and y

- ▶ `p.x = 100.4f;`
- ▶ `printf("%f\n", p.y);`

**struct** Quadrilateral has one member vertex which is an array

- ▶ `rhombus.vertex //` gives a pointer to the first vertex
- ▶ `rhombus.vertex[3].x = 0.0f;`

# C has structure values

We can pass a structure (by value) to a function or return one

```
struct Quadrilateral embiggen(struct Quadrilateral q) {  
    for (int i = 0; i < 4; ++i) {  
        q.vertex[i].x *= 2.0f;  
        q.vertex[i].y *= 2.0f;  
    }  
    return q;  
}
```

```
struct Foo {  
    int y;  
};  
struct Bar {  
    int z;  
    struct Foo f;  
};
```

Given a **struct** Bar named b, how do you modify b's f's y member?

A. **struct** Foo f = b.f;  
f.y = 35;

B. b.f.y = 35;

C. b.Foo.y = 35;

D. Both A and B

E. All of A, B, and C

# Pointers to structs

```
// Use a pointer to a struct to update in place.
void embiggen2(struct Quadrilateral *q) {
    for (int i = 0; i < 4; ++i) {
        (*q).vertex[i].x *= 2.f; // Dereference q, then access vertex
        (*q).vertex[i].y *= 2.f; // Dereference q, then access vertex
    }
}
```

```
// Same as embiggen2, but using ->
void embiggen3(struct Quadrilateral *q) {
    for (int i = 0; i < 4; ++i) {
        q->vertex[i].x *= 2.f;
        q->vertex[i].y *= 2.f;
    }
}
```

```
struct Foo {  
    int y;  
};  
struct Bar {  
    int z;  
    struct Foo *f;  
};
```

Given a **struct** Bar named b, how do you modify b's f's y member?

A. **struct** Foo \*f = b.f;  
f->y = 35;

B. b.f->y = 35;

C. b->f.y = 35;

D. Both A and B

E. All of A, B, and C

# Anonymous structs

Like enums, structs can be anonymous

```
struct {  
    char *const name;  
    enum { STUDENT, GRADER, PROFESSOR } role;  
} people[] = {  
    [0] = { .role = PROFESSOR, .name = "Stephen" },  
    [1] = { .role = GRADER, .name = "Max" },  
    /* ... */  
};
```

- ▶ people is an array of this anonymous struct
- ▶ the role member is an anonymous enum
- ▶ note that the initializer need not list members in order
- ▶ we could make this whole thing const by writing **const struct**

# Compound literals

Compound literal: (type) { initializer }

- ▶ `(struct Point) { .x = 5.f, .y = 80.3f }`

This has pretty limited use since you can just declare and initialize an instance of the struct

Macros are about the only time it's useful

```
#define MAKE_POINT(x_coord, y_coord) \  
    (struct Point) { .x = (x_coord), .y = (y_coord) }
```

# Type definitions

It's pretty clunky referring to things as **enum** Foo or **struct** Bar

Use a typedef!

- ▶ Generic form: **typedef** From To;
- ▶ Examples

```
typedef struct Point Point;  
typedef enum Color Color;
```

You can typedef an anonymous struct

```
typedef struct {  
    float x;  
    float y;  
} Point;
```

# In-class exercise

<https://checkoway.net/teaching/cs241/2020-spring/exercises/Lecture-16.html>

Grab a laptop and a partner and try to get as much of that done as you can!