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 week of class, May 6 and 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`

B. `RWX_PERM`

C. `4`

D. `5`

E. Undefined behavior

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,
};
```

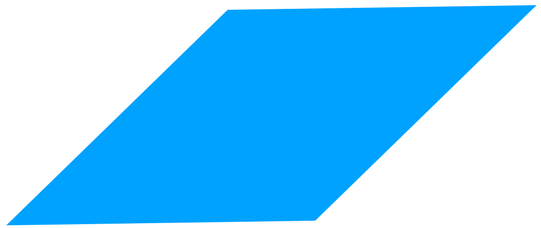
Nested structs

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!