

601.220 Intermediate Programming

Struct types

Outline

- Structs

Structures

- A collection of related variables, bundled together into one variable

```
struct card {  
    int rank;  
    char suit;  
};
```

Structures

Variables in a struct are *fields*

```
struct cc_receipt {  
    float amount;  
    char cc_number[16];  
};
```

Two fields: float named amount, and char[16] named cc_number

Structures

We're programming a checkers game.

We want a struct describing everything about a game piece

```
struct checkers_piece {  
    // ???  
};
```



Structures

```
struct checkers_piece {  
    int x; // horizontal offset  
    int y; // vertical offset  
    int black; // 0 = white, non-0 = black  
};
```

Structures

```
// struct_eg1.c:
#include <stdio.h>

struct date {
    int year;
    int month;
    int day;
};

int main() {
    struct date today; // like 3 variables in 1!
    today.year = 2020; // use . to refer to fields
    today.month = 2;
    today.day = 21;
    printf("Today's date: %d/%d/%d\n",
           today.month, today.day, today.year);
    return 0;
}
```

```
$ gcc -c struct_eg1.c -std=c99 -pedantic -Wall -Wextra
```

```
$ gcc -o struct_eg1 struct_eg1.o
```

```
$ ./struct_eg1
```

```
Today's date: 2/21/2020
```

Structures

The `struct name { ... };` syntax defines a new struct data type

```
struct date {  
    int year;  
    int month;  
    int day;  
};
```

This syntax declares a *variable* that *has* that type

```
struct date today;
```


Structures

struct variable can be initialized in similar way to an array:

```
struct date {  
    int year;  
    int month;  
    int day;  
};
```

...

```
struct date today = {2020, 2, 21};
```

Structures

struct fields can be other structs

```
struct date {  
    int year;  
    int month;  
    int day;  
};  
  
struct cc_transaction {  
    // struct within a struct is fine!  
    struct date purchase_date;  
    float amount;  
    char cc_number[16];  
};
```

Structures

struct fields can be pointers

```
struct player {  
    int home_runs;  
    int strikeouts;  
    int walks;  
};  
  
struct team {  
    struct player *catcher;  
    struct player *first_baseman;  
    struct player *second_baseman;  
    ...  
};
```

Structures

`sizeof(struct player)` returns total size of all fields

```
struct date {  
    int year;  
    int month;  
    int day;  
};
```

What is `sizeof(struct date)`?

Structures

```
// struct_sizeof.c:
```

```
#include <stdio.h>
```

```
struct date {
```

```
    int year;    // 4 bytes
```

```
    int month;   // 4 bytes
```

```
    int day;     // 4 bytes
```

```
};
```

```
int main() {
```

```
    printf("%d\n", (int)sizeof(struct date));
```

```
}
```

```
$ gcc -c struct_sizeof.c -std=c99 -pedantic -Wall -Wextra
```

```
$ gcc -o struct_sizeof struct_sizeof.o
```

```
$ ./struct_sizeof
```

```
12
```

Structures

A struct can be a function parameter and/or return type

```
struct date next_day(struct date d) {  
    if ((++d.day) > 30) { // assume 30-day months  
        d.day = 1;  
        if ((++d.month) > 12) {  
            d.month = 1;  
            d.year++;  
        }  
    }  
    return d;  
}
```

Structures

What if it were a void function, without return d at the end?

```
void next_day(struct date d) {  
    if ((++d.day) > 30) { // assume 30-day months  
        d.day = 1;  
        if ((++d.month) > 12) {  
            d.month = 1;  
            d.year++;  
        }  
    }  
}
```

Structures

structs are passed by value. So `next_day` on previous slide has no effect. We need to return a new struct, or take a pointer to a struct and dereference/modify it

Structures

```
void next_day_in_place(struct date *d) {  
    if ((++(*d).day) > 30) {  
        (*d).day = 1;  
        if ((++(*d).month) > 12) {  
            (*d).month = 1;  
            (*d).year++;  
        }  
    }  
}
```

Structures

`d->day` is a synonym for `(*d).day`

```
void next_day_in_place(struct date *d) {  
    if ((++d->day) > 30) {  
        d->day = 1;  
        if ((++d->month) > 12) {  
            d->month = 1;  
            d->year++;  
        }  
    }  
}
```

Structures

```
// date.h:
#ifndef DATE_H
#define DATE_H

struct date {
    int year;    // 4 bytes
    int month;   // 4 bytes
    int day;     // 4 bytes
};

#endif
```

Structures

```
// struct_next_day_1.c:
#include <stdio.h>
#include "date.h" // "struct date" defined here

struct date next_day(struct date d) {
    if (++d.day > 30) {
        d.day = 1;
        if (++d.month > 12) {
            d.month = 1;
            d.year++;
        }
    }
    return d;
}

int main() {
    struct date today = {2020, 2, 21};
    struct date tomorrow = next_day(today);
    printf("Tomorrow's date: %d/%d/%d\n",
           tomorrow.month, tomorrow.day, tomorrow.year);
}
```

```
$ gcc -c struct_next_day_1.c -std=c99 -pedantic -Wall -Wextra
$ gcc -o struct_next_day_1 struct_next_day_1.o
$ ./struct_next_day_1
Tomorrow's date: 2/22/2020
```

Structures

```
// struct_next_day_2.c:
#include <stdio.h>
#include "date.h" // "struct date" defined here

void next_day_in_place(struct date *d) {
    if ((++d->day) > 30) {
        d->day = 1;
        if ((++d->month) > 12) {
            d->month = 1;
            d->year++;
        }
    }
}

int main() {
    struct date today = {2020, 12, 30};
    next_day_in_place(&today);
    printf("Tomorrow's date: %d/%d/%d\n",
           today.month, today.day, today.year);
    return 0;
}
```

```
$ gcc -c struct_next_day_2.c -std=c99 -pedantic -Wall -Wextra
$ gcc -o struct_next_day_2 struct_next_day_2.o
$ ./struct_next_day_2
Tomorrow's date: 1/1/2021
```

Structures

You can have an array of structs

```
struct album {  
    const char *name;  
    const char *artist;  
    double length;  
};  
  
struct album music_collection[99999];  
music_collection[0].name = "The Next Day";  
music_collection[0].artist = "David Bowie";  
music_collection[0].length = 41.9;  
music_collection[1].name = "Hunky Dory";  
...
```

Structures

```
// struct_array.c:
#include <stdio.h>

struct album {
    const char *name;
    const char *artist;
    double length;
};

int main() {
    struct album music_collection[99999];
    music_collection[0].name = "The Next Day";
    music_collection[0].artist = "David Bowie";
    music_collection[0].length = 41.9;
    music_collection[1].name = "Hunky Dory";
    return 0;
}
```

Structures

What is `sizeof(struct album)`?

```
struct album {  
    const char *name;  
    const char *artist;  
    double length; // 8 bytes  
};
```


Structures

```
// struct_sizeof_album.c:
#include <stdio.h>

struct album {
    const char *name;
    const char *artist;
    double length; // 8 bytes
};

int main() {
    printf("sizeof(struct album) = %d\n", (int)sizeof(struct album));
    return 0;
}
```

Structures

```
$ gcc -c struct_sizeof_album.c -std=c99 -pedantic -Wall -Wextra
$ gcc -o struct_sizeof_album struct_sizeof_album.o
$ ./struct_sizeof_album
sizeof(struct album) = 24
```

24 bytes

- `const char *s` are just (8-byte) pointers
- Strings themselves not stored in the struct

Structures

You can have a struct with an array in it:

```
struct cc_receipt {  
    float amount;  
    char cc_number[16];  
};
```

What is sizeof(struct cc_receipt)?

```
struct cc_receipt {  
    float amount; // 4 bytes  
    char cc_number[16];  
};
```

Structures

```
// sizeof_receipt.c:
#include <stdio.h>

struct cc_receipt {
    float amount; // 4 bytes
    char cc_number[16];
};

int main() {
    printf("sizeof(struct cc_receipt) = %d\n",
        (int)sizeof(struct cc_receipt));
    return 0;
}
```

Structures

```
$ gcc -c sizeof_receipt.c -std=c99 -pedantic -Wall -Wextra  
$ gcc -o sizeof_receipt sizeof_receipt.o  
$ ./sizeof_receipt  
sizeof(struct cc_receipt) = 20
```

Answer: 20 bytes. `char cc_number[16]` is inside the struct, taking up 16 bytes.

Structures

```
// struct_sizeof_receipt.c:
#include <stdio.h>

struct ten_ints {
    int ints[10];
};

void func1(struct ten_ints ints) {
    printf("func1 sizeof(ints)=%d\n", (int)sizeof(ints));
}

void func2(int *ints) {
    printf("func2 sizeof(ints)=%d\n", (int)sizeof(ints));
}

int main() {
    struct ten_ints ints;
    func1(ints);
    func2(ints.ints);
    return 0;
}

$ gcc -c struct_sizeof_receipt.c -std=c99 -pedantic -Wall -Wextra
$ gcc -o struct_sizeof_receipt struct_sizeof_receipt.o
$ ./struct_sizeof_receipt
func1 sizeof(ints)=40
func2 sizeof(ints)=8
```

Structures

When a `struct` is passed to a function, everything inside is copied, including arrays

This means an array wrapped in a `struct` is actually pass-by-value

Zoom poll!

What is the output of the following program?

```
#include <stdio.h>
struct Pokemon {
    char type;
    char name[12];
};
struct Pokemon makeElectric(struct Pokemon p) {
    p.type = 'E';
    return p;
}
int main(void) {
    struct Pokemon charmander = {
        'F', "Charmander"
    };
    makeElectric(charmander);
    printf("%s (%c)\n",
        charmander.name,
        charmander.type);
    return 0;
}
```

- A. Charmander (F)
- B. Charmander (E)
- C. Pikachu (E)
- D. Some other output
- E. Code does not compile

Structures

Sometimes we get tired of writing struct over and over:

```
struct cc_receipt {  
    float amount;  
    char cc_number[16];  
};  
  
struct cc_receipt lunch_receipt;  
struct cc_receipt dinner_receipt;
```

Structures

So we use this shorthand:

```
typedef struct {  
    float amount;  
    char cc_number[16];  
} cc_receipt;  
  
cc_receipt lunch_receipt;  
cc_receipt dinner_receipt;
```

Now we can refer to the type simply as `cc_receipt` instead of `struct cc_receipt`

Structures

Say we have these definitions in `tennis.h`:

```
// tennis.h:
#ifndef TENNIS_H
#define TENNIS_H

typedef struct { // career statistics
    const char *name;
    int winners;
    int aces;
    int double_faults;
} player;

typedef struct {
    player *male;
    player *female;
} mixed_doubles_team;

#endif
```

Structures

Why might we do this:

```
typedef struct {  
    player *male;  
    player *female;  
} mixed_doubles_team;
```

Instead of this?

```
typedef struct {  
    player male;  
    player female;  
} mixed_doubles_team;
```

Take first case (using pointers)...

Structures

```
// tennis.h:
#ifndef TENNIS_H
#define TENNIS_H

typedef struct { // career statistics
    const char *name;
    int winners;
    int aces;
    int double_faults;
} player;

typedef struct {
    player *male;
    player *female;
} mixed_doubles_team;

#endif
```

Structures

```
// tennis.c:
#include <stdio.h>
#include "tennis.h"

int main() {
    player bob_bryan;
    player victoria_azarenka;
    player samantha_stosur;

    mixed_doubles_team french_open_2008 =
        {&bob_bryan, &victoria_azarenka};

    mixed_doubles_team wimbledon_2008 =
        {&bob_bryan, &samantha_stosur};

    // updates "propagate" to team structs!
    bob_bryan.double_faults++;
    samantha_stosur.winners++;
    // ...
}
```

Structures

Size of struct is *at least* the sum of the sizes of its fields
It can be bigger if the compiler decides to add “padding”

```
struct plane {  
    int passengers;  
    double cargo_weight;  
};
```

Structures

```
// sizeof_plane.c:
#include <stdio.h>

struct plane {
    int passengers;      // int: 4 bytes
    double cargo_weight; // double: 8 bytes
};

int main() {
    printf("sizeof(struct plane) = %d\n", (int)sizeof(struct plane));
    return 0;
}
```


Structures

```
$ gcc -c sizeof_plane.c -std=c99 -pedantic -Wall -Wextra  
$ gcc -o sizeof_plane sizeof_plane.o  
$ ./sizeof_plane  
sizeof(struct plane) = 16
```

For obscure efficiency reasons, the compiler preferred to put 4 bytes of “spacer” between the int & double, driving total size to 16

Structures

Structures can be defined in a nested way:

```
typedef struct {  
    struct {      // this struct type doesn't have a name;  
        int r;    // it's just used once to declare a  
        int b;    // field named color  
        int g;  
    } color;  
    struct {      // again, no name  
        int x;  
        int y;  
    } position;  
} pixel;  
  
pixel p;  
p.color.r = 255;  
p.position.x = 40;  
p.position.y = 50;
```

Structures

```
// nested_struct.c:
#include <stdio.h>

typedef struct {
    struct {      // this struct type doesn't have a name;
        int r;    // it's just used once to declare a
        int b;    // field named color
        int g;
    } color;
    struct {      // again, no name
        int x;
        int y;
    } position;
} pixel;

int main() {
    pixel p;
    p.color.r = p.color.g = p.color.b = 255;
    p.position.x = 40;
    p.position.y = 50;
    printf("[%d, %d, %d] at (%d, %d)\n",
           p.color.r, p.color.g, p.color.b,
           p.position.x, p.position.y);
    return 0;
}
```

Structures

```
$ gcc -c nested_struct.c -std=c99 -pedantic -Wall -Wextra  
$ gcc -o nested_struct nested_struct.o  
$ ./nested_struct  
[255, 255, 255] at (40, 50)
```