CMSC 216
Introduction to Computer Systems
Lecture 6
Strings, cont. &
Structures and Unions

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Administrivia

- Project 1 questions?
  - due Wed., 6PM
- Read Reek, Chapter 10: Structures and Unions

Parts of Chapters 8 and 9, Reek

ARRAYS AND STRINGS

String library functions, cont.

- Comparing strings:

```
int strcmp(char s1[], char s2[]);
```

  - works just the same as **`s1.compareTo(s2)`** did in Java:
    - returns negative number if **`s1`** is less than **`s2`**
    - returns positive number if **`s1`** is greater than **`s2`**
    - returns 0 if **`s1`** and **`s2`** match character for character
  - Example:

```
if (strcmp(str1, "hello") == 0)
  printf("str1 is \"hello\"\n");
```

A possible `strcmp()` implementation

```
int strcmp(char s1[], char s2[]) {
  int i;
  for (i = 0; s1[i] && s2[i]; i++)
    if (s1[i] != s2[i])
      break;
  return s1[i] - s2[i];
}
```

- Notice the return statement subtracts characters; remember that **`char`** is an integer type

String library functions, cont.

- Copying strings:

  `strcpy(char dest[], char src[]);`

  – copies the string in **`src`** to **`dest`**

  – it is up to the programmer to ensure that dest is an array with enough characters to hold the string
    - being lazy with this function can result in buffer overflows

  – Example:

```
char str[] = "cherry";
char str2[10] = "milkshake";
strcpy(str2, str);
```

A possible `strcpy()` implementation

```
void strcpy(char dst[], char src[]) {
  int i = 0;
  while (src[i]) {
    dst[i] = src[i];
    i++;
  }
  dst[i] = '\0';
}
```

- What expression gives the minimum size of the array **`dst`** (to ensure safe execution)?

Chapter 10, Reek

STRUCTURES AND UNIONS

Structures

- Like arrays, hold multiple items
- Items need not be of the same type
- Items referred to by field names, not numerical indices
- You can assign the value of another structure to a structure
- You cannot use **==** or **!=**
- Similar to a Java class with all public fields and no methods

Creating structures

- Example:

```
struct employee {
  int id_number;
  char last_name[10];
  char first_name[10];
  double salary;
} emp1, emp2;
```

- Declares two variables (**emp1** and **emp2**) of type **struct employee**
- **employee** is called the tag of these two structs
  - used to differentiate between different kinds of structs

Structure declarations

- More formally, this is the syntax for declaring structures (or structure types):

  struct ***tag*** **{** ***member-list*** **}** ***variable-list*****;**
- Omitting *variable-list* creates a new type
- Omitting *member-list* (and **{}**) declares variables of an existing **struct** type
- Omitting *tag* means you create a unique type for the variables listed
  - even if *member-list*s are the same
  - prevents use of those **struct**s as function arguments

Accessing fields of a structure

- Dot operator:

```
struct point {
  int x, y;
};

struct point p1, p2, points[5];
p1.x = 17;
p2.y = 22;
points[0].x = 13;
points[0].x++;
```

The **typedef** keyword

- You can give types new names
  - eases readability and maintainability
- **typedef** ***existing-type new-name*;**
  - the type may be created along with the **typedef** usage, as we'll see with structures
- **typedef double Dollars;**
  Dollars x, y = 1.25;
  - now you know that **x** and **y** shouldn't be assigned values like **sqrt(15)**
- Using caps to start **typedef**'d names helps set them apart from other types

Combining **typedef** and **struct**

- Combining the two keywords:

```
typedef struct {
  int i;
  char ch;
} Ex_struct;
...
Ex_struct a[10], b;
```

- Structure definitions (either form) should be placed in header files if the structures are used across multiple files

Structure storage

- How much space does a structure use in memory?

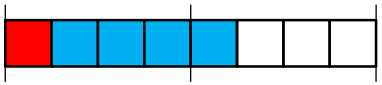
```
struct one {
  double b;
  int a;
} s1;

printf("%d\n", sizeof(s1));
```

- Assuming **int**s use 4 bytes and **double**s 8 bytes each, prints "**12**"

Structure storage, cont.

- But due to alignment issues, things aren't always that simple:

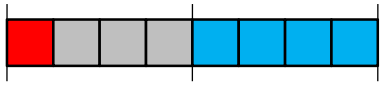
```
struct two {
  char a;
  int b;
} s2;
```



Wrong - blue **int** isn't properly aligned (and whatever comes after this won't be, either)

- **int**s must begin at 4-byte boundaries, so s2 must be 8 bytes, not 5.

Right - blue **int** is properly aligned, and gray bytes in memory are left unused



- To minimize unused space, order fields from longest to shortest

Assigning and comparing structures

- Each field is copied for an assignment

```
struct ex_struct a, b;
...
a = b;
```

- Is **a == b** true now? Two issues:
  - **a** and **b** are still separate objects in memory
  - can't just compare bits - what if there's unused space?
- Because it doesn't make sense to do these types of comparisons, the **==** won't compile

Structure initialization

- Much like array initialization
- The items listed in the initializer are assigned to the fields in order
- Zeroes used to fill uninitialized fields when an initializer is used
- Example:

```
typedef struct {
  int i;
  char ch;
  double d;
} Ex_struct;
Ex_struct a = {4, 's', 3.5};
Ex_struct b = {5, 'g'};
```


Nested structure example

```
/* a Section contains a number like 0101, and
 * how many students are enrolled */
typedef struct {
  int number;
  int num_students;
  int start_time;
} Section;

/* a Course contains a number like 313,
 * and two Sections */
typedef struct {
  int course_number;
  Section section1, section2;
} Course;

Section s = {101, 30, 1300};
Course c = {213, {}, {201, 30, 1200}};
...
c.section1 = s;                 /* referring to a whole Section */
c.section2.num_students = 29;   /* referring to one field of a
                                   Section in the Course */
```


Structures and functions

- Structure arguments are passed by value
- We can return structures from functions

```
Section add_students(Section sec, int students_to_add) {
  Section new_section = sec;
  new_section.num_students += students_to_add;
  return new_section;
}
Section s = { 0101, 10, 1400 }, t;
...
t = add_students(s, 26);
```

Aside: parameters are variables, too!

- Because arguments are passed and returned by value, you can use the parameters as variables:

```
Section add_students(Section sec, int students_to_add) {
  sec.num_students += students_to_add;
  return sec;
}
Section s = { 0101, 10, 1400 }, t;
...
t = add_students(s, 26);
```


Unions

- Look much like structures
- But all fields share the same memory space, so are only as large as largest field
- Only one field valid at a time

```
typedef union {
  int i;
  double d;
} Number;
...
Number a, b;
a.i = 2;
b.d = 3.14159;
printf("%d\n", b.i);
```

blue bytes are used when accessed as an int, red bytes used when accessed as a double