CMSC 216
Introduction to Computer Systems
Lecture 5
Intro. to C, completed,
Arrays and Strings &
Structures and Unions

Administrivia

- Read Reek, Chapter 10: Structures and Unions

Parts of Chapters 8 and 9, Reek

Arrays and Strings

Chapter 10, Reek

Structures and Unions

Basic string library functions

- C has many different functions for working with strings; to use these, you must **`#include <string.h>`**
- We're only covering a small subset here; if you ever want to see all of them, more information can be found in the string.h man page
  - Note: the prototypes there are slightly different than what we'll be covering here, because we haven't covered pointers yet, but functionality is the same

String library functions, cont.

- String length:

  `size_t strlen(char str[]);`

  – returns the length of the string pointed to by the string passed in as a parameter

  – string length is the number of characters in the string, **not counting** the null byte

  – Example:

```
char str[] = "ice cream";
printf("\"%s\": %d chars\n", str, strlen(str));
```

Output:

```
"ice cream": 9 chars
```

A possible `strlen()` implementation

```
size_t strlen(char str[]) {
  size_t i;
  for (i = 0; str[i]; i++)
    ;
  return i;
}
```

- The integer type **`size_t`** is discussed in the project #1 handout
- What would happen if you passed an uninitialized character array into this function?

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:

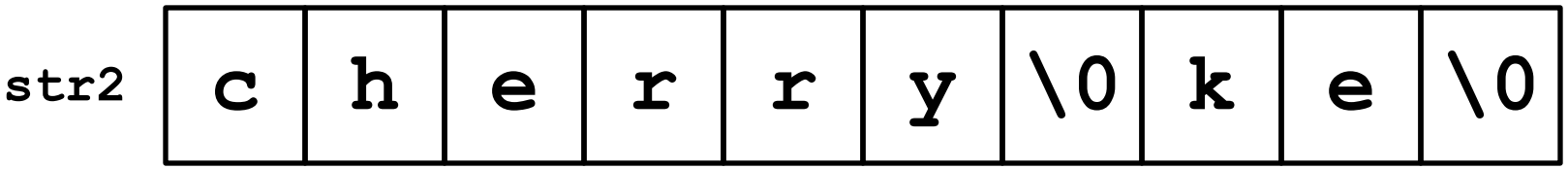
  `strcpy(char dest[], char src[]);`

  – 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?

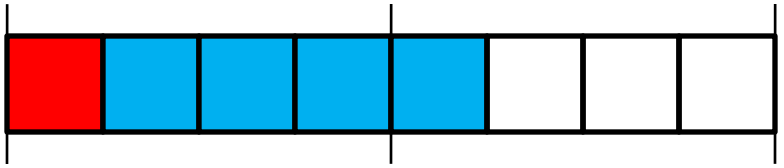
```
struct one {
   double b;
   int a;
} s1;

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:

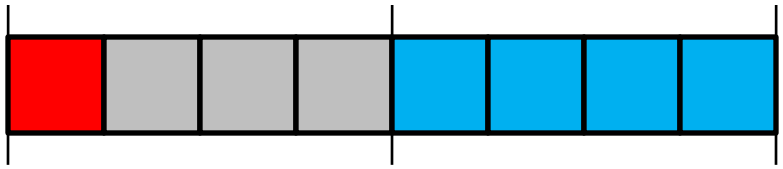
```
struct two {
   char a;
   int b;
} s2;
```



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!

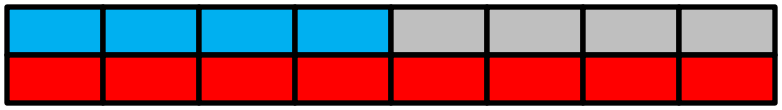
- Because arguments are passed and returned by value, you can use the parameters as variables:

```
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

Making unions more useful

- using an enum and struct along with the union can help keep track of which field is in use

```
typedef struct {
  enum { INT, DOUBLE } type;
  union {
    int i;
    double d;
  } value;
} Better_number;

void print_number(Better_number num) {
  switch (num.type) {
    case INT:    printf("%d", num.value.i);
                 break;
    case DOUBLE: printf("%f", num.value.d);
                 break;
    default:     printf("?????");
                 break;
  }
}
```