CS 11 C track: lecture 3

- This week:
  - Arrays
    - one-dimensional
    - multidimensional
  - Command-line arguments
  - Assertions

Arrays

- What is an "array"?
- A way to collect together data of a single type in a single object
- A linear sequence of data objects *e.g.*
  - array of `int`s
  - array of `char`s (string)

Creating and using arrays

- One-dimensional array of three ints:

```
int arr[3];
int sum;
arr[0] = 1;
arr[1] = 22;
arr[2] = -35;
sum = arr[0] + arr[1] + arr[2];
```

One-dimensional arrays (1)

- Arrays can be
  - initialized
  - partially initialized
  - not initialized
- Uninitialized space contains?
  - "garbage"

One-dimensional arrays (2)

- Examples:

```
int my_array[10];
  /* not initialized */
int my_array[5] = { 1, 2, 3, 4, 5 };
  /* initialized */
int my_array[] = { 1, 2, 3, 4, 5 };
  /* OK, initialized */
int my_array[4] = { 1, 2, 3, 4, 5 };
  /* warning */
int my_array[10] = { 1, 2, 3, 4, 5 };
  /* OK, partially initialized */
```

One-dimensional arrays (3)

- Note on partial initialization:

```
int my_array[10] = { 1, 2, 3, 4, 5 };
```

  - rest of array initialized to `0`

```
int my_array[10];
```

  - entire array uninitialized
  - contains garbage

One-dimensional arrays (4)

- Explicit initialization of arrays:

```
int i;
int my_array[10];
for (i = 0; i < 10; i++) {
    my_array[i] = 2 * i;
}
```

- This is the most flexible approach

One-dimensional arrays (5)

- Some bad things that can happen...

```
int my_array[10];
/* What happens here? */
printf("%d\n", my_array[0]);
/* What happens here? */
printf("%d\n", my_array[1000]);
```

- No checking!
- C is an UNSAFE language!

One-dimensional arrays (6)

- NOTE! The following is illegal:

```
int my_array[5];
my_array = { 1, 2, 3, 4, 5 }; /* WRONG */
```

- The `{ 1, 2, 3, 4, 5 }` syntax is *only* usable when declaring a new array, and not for reassigning the contents of the array

```
int my_array[5] = { 1, 2, 3, 4, 5 };  /* OK */
int my_array[] = { 1, 2, 3, 4, 5 };   /* OK */
```

Two-dimensional arrays (1)

```
int arr[2][3]; /* NOT arr[2, 3] */
int i, j;
int sum = 0;
arr[0][0] = 1;
arr[0][1] = 23;
arr[0][2] = -12;
arr[1][0] = 85;
arr[1][1] = 46;
arr[1][2] = 99;
/* continued on next slide */
```

Two-dimensional arrays (2)

```
for (i = 0; i < 2; i++) {
    for (j = 0; j < 3; j++) {
        sum += arr[i][j];
    }
}

printf("sum = %d\n", sum);
```

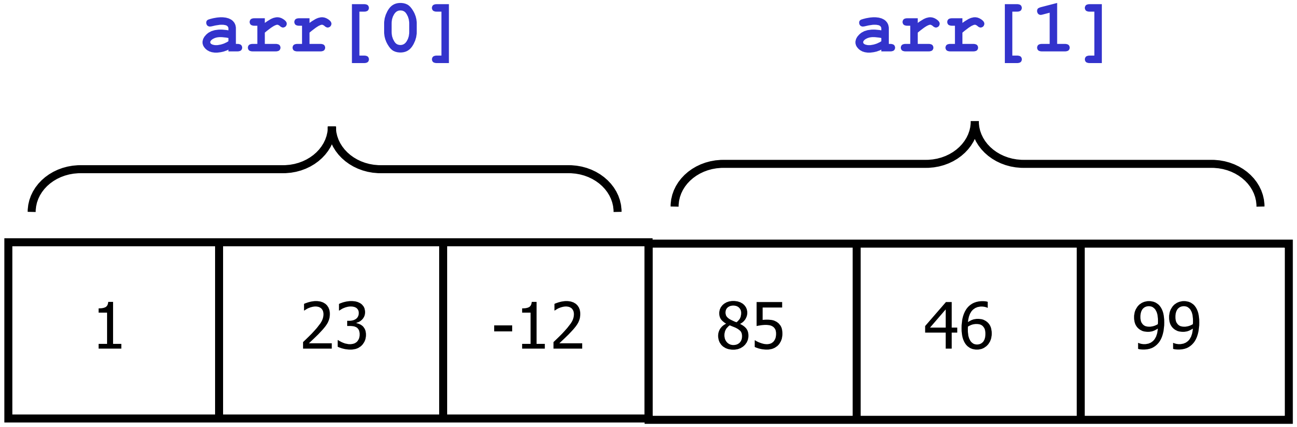
Two-dimensional arrays (3)

- Two-dimensional arrays can be split into component one-dimensional arrays:

```
int arr[2][3];
/* initialize... */
/* arr[0] is array of 3 ints */
/* arr[1] is another array of 3 ints */
```

Two-dimensional arrays (5)

- How `arr` is laid out in memory:



`arr[0]` `arr[1]`

1	23	-12	85	46	99

Two-dimensional arrays (6)

- Initializing two-dimensional arrays:

```
int my_array[2][3];
    /* not initialized */
int my_array[2][3]
  = { { 1, 2, 3 }, { 4, 5, 6 } };
    /* OK */
int my_array[2][3]
  = { 1, 2, 3, 4, 5, 6 };
    /* warning with -Wall */
```

Two-dimensional arrays (7)

```
int arr[2][]
  = { { 1, 2, 3 }, { 4, 5, 6 } };
  /* invalid */
int arr[][]
  = { { 1, 2, 3 }, { 4, 5, 6 } };
  /* invalid */
int arr[][3]
  = { { 1, 2, 3 }, { 4, 5, 6 } };
  /* OK */
```

Two-dimensional arrays (8)

```
int my_array[][3]
  = { 1, 2, 3, 4, 5, 6 };
    /* warning with -Wall */
int my_array[][3]
  = { { 1, 2, 3 }, { 4, 5 } };
    /* OK; missing value = 0 */
```

- Rule: all but leftmost dimension must be specified
- Compiler can compute leftmost dimension
- OK to specify leftmost dimension as well

Passing arrays to functions (1)

- What does this do?

```
void foo(int i) {
    i = 42;
}

/* later... */
int i = 10;
foo(i);  /* What is i now? */
```

Passing arrays to functions (2)

- Current value of `i` is *copied* into function argument `i`
- Passing a value to a function as an argument doesn't change the value
- We say that C is a "call-by-value" language
- But arrays are "different"!
  - (actually, not really, but it seems like they are; need pointers for full explanation)

Passing arrays to functions (3)

- Arrays passed to functions *can* be modified:

```
void foo(int arr[]) {
    arr[0] = 42; /* modifies array */
}

/* later... */
int my_array[5] = { 1, 2, 3, 4, 5 };
foo(my_array);
printf("%d\n", my_array[0]);
```

Passing arrays to functions (4)

- Last array dimension in declaration is ignored for one-dimensional arrays:

```
void foo2(int arr[5]) /* same as arr[] */
{
    arr[0] = 42;
}
```

- Same as `foo()`

Passing 2D arrays to functions (1)

- Two-dimensional (or higher-dimensional) arrays can also be passed to functions
- However, must specify all array dimensions except for the leftmost one (which is optional)
  - same rule as for initializing 2d arrays

Passing 2D arrays to functions (2)

```
int sum_2d_array(int arr[][3], int nrows) {
    int i, j;
    int sum = 0;
    for (i = 0; i < nrows; i++) {
        for (j = 0; j < 3; j++) {
            sum += arr[i][j];
        }
    }
    return sum;
}
```

Passing 2D arrays to functions (3)

- Also OK to specify leftmost dimension:

```
int sum_2d_array(int arr[2][3], int nrows){
    /*  same as before */
}
```

- Compiler still ignores leftmost dimension
  - May need to pass it in as an extra argument *e.g.* as `nrows` here

Command-line arguments (1)

- http://courses.cms.caltech.edu/cs11/material/c/mike/misc/cmdline_args.html
- When you type this at the unix prompt:

```
% myprog inputfile outputfile
```

- This is a *command line*
- First word is the program name (`myprog`)
- Other words are the program *arguments*
- Here: `inputfile`, `outputfile`

Command-line arguments (2)

- Arguments give program information it needs
  - *e.g.* names of files to read from/write to
  - or data the program needs
- Can also have *optional* arguments
- `sorter 5 1 3 2 4`
- `sorter -b 5 1 3 2 4`
  - `-b` is optional
  - changes the way the `sorter` program works
  - convention: all arguments starting with "`-`" are optional (unless they're *e.g.* negative numbers)

Command-line arguments (3)

- Recall: strings are arrays of characters (`char []`)
- Also written (`char *`) (see why later)
- Command line arguments are divided into
  - `int argc` (argument count)
  - `char *argv[]` (array of strings)
  - read as: `(char *) argv[]`
  - not allowed to write `char argv[][]`

Command-line arguments (4)

- To use command-line arguments, `main` function needs to have 2 new arguments: `argc` and `argv`

```
int main(int argc, char *argv[]) {
    /* argc is the number of arguments
     * argv is the arguments,
     * represented as an array of strings.
     */

    /* ... code goes here ... */
}
```

Command-line arguments (5)

- Cmdline args are `argv[0]`, `argv[1]`, ...
- `argv[0]` is name of program
- In previous example:
  - `argv[0]` → `"myprog"` (program name)
  - `argv[1]` → `"inputfile"`
  - `argv[2]` → `"outputfile"`

Command-line arguments (6)

- We usually process command-line arguments in `main()`:

```
#include <string.h>
int main(int argc, char *argv[]) {
    int i;
    /* process command-line arguments */
    for (i = 1; i < argc; i++) {
        if (strcmp(argv[i], "-b") == 0) {
            /* process optional argument */
        }
        /* process non-optional arguments */
    }
    /* ... rest of program ... */
}
```

Command-line arguments (7)

- Useful functions for command-line argument processing:
  - `atoi()` – converts string to `int`
    - `atoi("123")` → `123`
    - in `<stdlib.h>`
  - `strcmp()` – compares strings
    - `strcmp("foo", "foo")` → `0`
    - in `<string.h>`

Command-line arguments (8)

- Notes on `strcmp()`:
  - `strcmp()` returns `0` if strings are the same, nonzero otherwise
  - Do not use `==` to compare strings!
    - You *can* use it, but it won't do what you expect
    - Always use `strcmp()` instead

Assertions (1)

- Sometimes expect code to behave in a certain way
- *e.g.* `sort()` function should sort its input
- Would like to make programs self-checking
- An assertion is a "sanity check" on code
- "If there are no bugs in this code, this must be true at this point in the code."
  - This is the kind of thing assertions check

Assertions (2)

- Example:
- Assume have a function called `sorted()` that returns `1` if array sorted, else `0`
- Can use `assert()` in conjunction with `sorted()` to check arrays for sortedness every time they're sorted

Assertions (3)

```
#include <assert.h>
void sort(int arr[], int nelems) {
    /* ...sort the array somehow... */
    assert(sorted(arr));
    /* "sorted" defined somewhere else;
     * returns 1 if array is sorted;
     * otherwise returns 0. */
}
```

- If assertion fails, program terminates
  - file and line number of failure is printed

Assertions (4)

- Assertions make program slower
  - but usually not much
- Use only to check *logical correctness* of code
  - "What *must be true* at this point in the code?"
- Don't try to use them to check *e.g.* user input
  - Example: user should enter a number between 1 and 10
  - Don't use `assert()` to check this!

Assertions (5)

- After debugging, may not need them anymore (you know code is correct)
- Might not want the slowdown
- Might want to turn off assertions

Assertions (6)

- Command-line argument to `gcc` that turns off assertions:

```
% gcc -DNDEBUG program.c -o program
```

- `NDEBUG` means "Not DEBUGging"
- `-D` means "define" (don't worry for now)
- Now assertions are just ignored
- Program will run faster
  - but if assertion is violated, you won't know!

Next week

- Pointers!

  - The one hard topic in C programming
  - Will take several weeks to cover thoroughly