COMP1511 - Programming Fundamentals

Term 1, 2020 - Lecture 6

What did we learn yesterday?

Code Style and Code Reviews

- Coding for and with humans

Functions

- Separating code for reuse

What are we covering today?

Computers as theoretical tools

- Fundamentals of what a computer is
- How we use memory in C

Arrays

- Using multiple variables at once

What is a computer?

At the most fundamental level . . .

- A processor that executes instructions
- Some memory that holds information

The Turing Machine

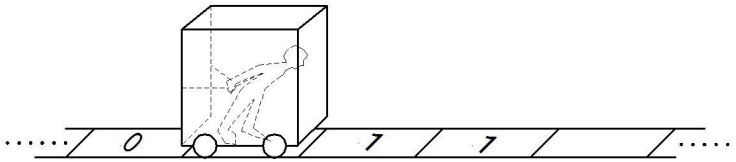
Originally a theoretical idea of computation

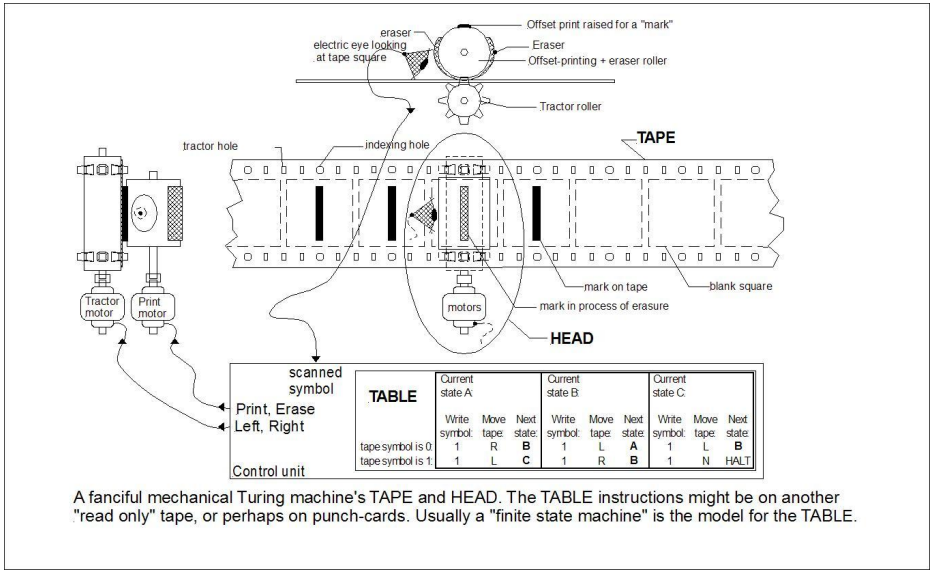
- There is a tape that can be infinitely long
- We have a “head” that can read or write to this tape
- We can move the head along to any part of the tape
- There’s a “state” in which the machine remembers its current status
- There’s a set of instructions that say what to do in each state

Turing Machines

Some images of Turing Machines

- A tape and a read/write head
- Some idea of control of the head





A fanciful mechanical Turing machine's TAPE and HEAD. The TABLE instructions might be on another "read only" tape, or perhaps on punch-cards. Usually a "finite state machine" is the model for the TABLE.

Images from Wikipedia (https://en.wikipedia.org/wiki/Turing_machine_gallery)

The Processor

We also call them Central Processing Units (CPUs)

- Maintains a “state”
- Works based on a current set of instructions
- Can read and write from/to memory

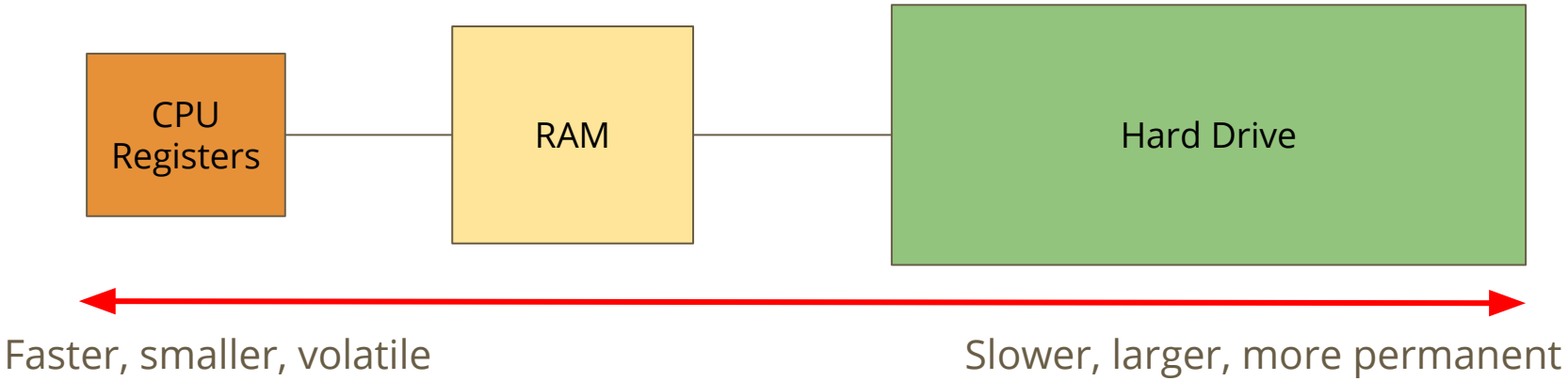
In our C Programming

- State - where are we up to in the code right now
- Instructions - compiled from our lines of code
- Reading/Writing - Variables

Memory

All forms of Data Storage on a computer

- From registers (tiny bits of memory on the CPU) through Random Access Memory (RAM) and to the Hard Disk Drive. All of these are used to store information



How does C use memory

- On the **Hard Drive**
- Our C source code files are stored on our Hard Drive
- Dcc compiles our source into another file, the executable program

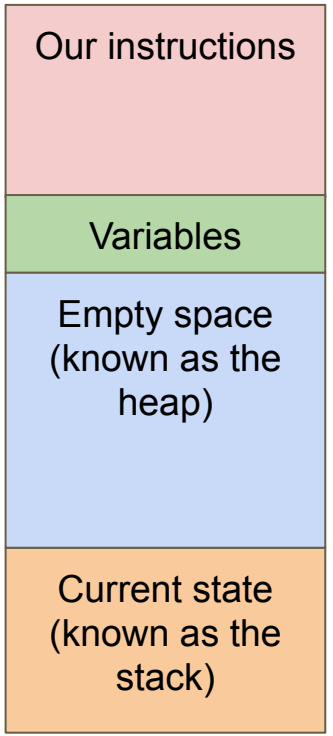
- In **Random Access Memory**
- When we run our program, all the instructions are copied into RAM
- Our CPU will work through memory executing our instructions in order
- Our variables are stored in RAM as well
- Reading and writing to variables will change the numbers in RAM

A snapshot of a program in memory

What happens in memory when we run a program?

- Our Operating System gives us a chunk of memory
- Our program copies its instructions there

- Some space is reserved for declared variables
- The **Stack** is used to track the current state
- The stack grows and shrinks as the program runs
- The **Heap** is empty and ready for use
- We can use the heap to store data while the program is running



There's more … later

Computers and programs are highly complex

- This was just an overview
- As you go through your learning, you will unlock more information
- For now, we have enough understanding to continue using C

Arrays

When we need a collection of variables together

- Sometimes we need a bunch of variables of the same type
- We also might need to process them all
- Our current use of ints and doubles might not be able to handle this

Let’s take a look at our current capability (and why we need arrays) . . .

An Example

Let's record everyone's marks at the end of the term

- We could do this as a large collection of integers . . .

```
int main (void) {
    int marksStudent1;
    int marksStudent2;
    int marksStudent3;
    int marksStudent4;
    // etc
```

If we want to test all these ints

We'd need a whole bunch of identical if statements

In this situation

- There's no way to loop through the integers
- Having to rewrite the same code is annoying and hard to read or edit
- So let's find a better way . . .

```c
int main (void) {
    int marksStudent1;
    int marksStudent2;
    int marksStudent3;
    int marksStudent4;
    // etc

    if (marksStudent1 >= 50) {
        // pass
    }
    if (marksStudent2 >= 50) {
        // pass
    }
    // etc
```

An Array of Integers

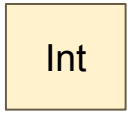
If our integers are listed as a collection

- We'll be able to access them as a group
- We'll be able to loop through and access each individual element

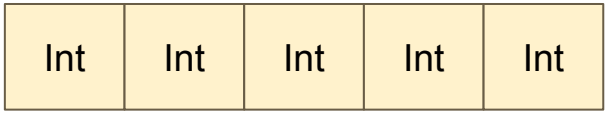
Arrays

What is an array?

- A variable is a small amount of memory
- An array is a larger amount of memory that contains multiple variables
- All of the elements (individual variables) in an array are the same type
- Individual elements don't get names, they are accessed by an integer index



A single integer worth of memory



An array that holds 5 integers

Declaring an Array

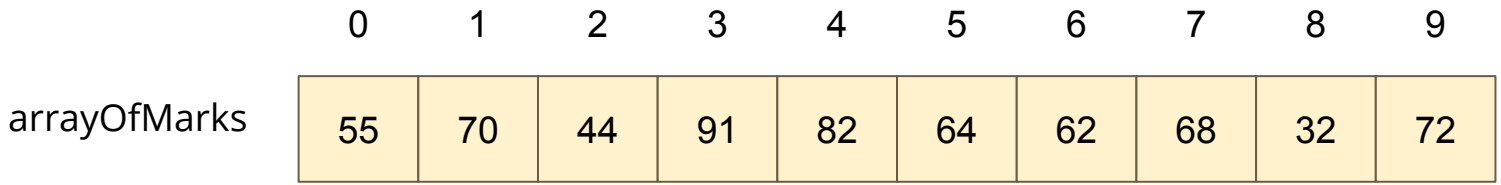
Similar, but more complex than declaring a variable

```
int main (void) {
    // declare an array
    int arrayOfMarks[10] = {0};
```

- `int` - the type of the variables stored in the array
- `[10]` - the number of elements in the array
- `= {0}` - Initialises the array as all zeroes
- `= {0,1,2,3,4,5,6,7,8,9}` - Initialises the array with these values

Array Elements

- An element is a single variable inside the array
- They are accessed by their index, an int that is like their address
- Indexes start from 0
- Trying to access an index outside of the array will cause errors



In this example, element 2 of arrayOfMarks is 44 and element 6 is 62

Accessing elements in C

C code for reading and writing to individual elements

```
int main (void) {
    // declare an array, all zeroes
    int arrayOfMarks[10] = {0};

    // make first element 85
    arrayOfMarks[0] = 85;
    // access using a variable
    int accessIndex = 3;
    arrayOfMarks[accessIndex] = 50;
    // copy one element over another
    arrayOfMarks[2] = arrayOfMarks[6];
    // cause an error by trying to access out of bounds
    arrayOfMarks[10] = 99;
```

Reading and Writing

Printf and scanf with arrays

- We can’t printf a whole array
- We also can’t scanf a line of user input text into an array
- We can do it for individual elements though!

The trick then becomes looping to access all individual elements one by one

User input/output with Arrays

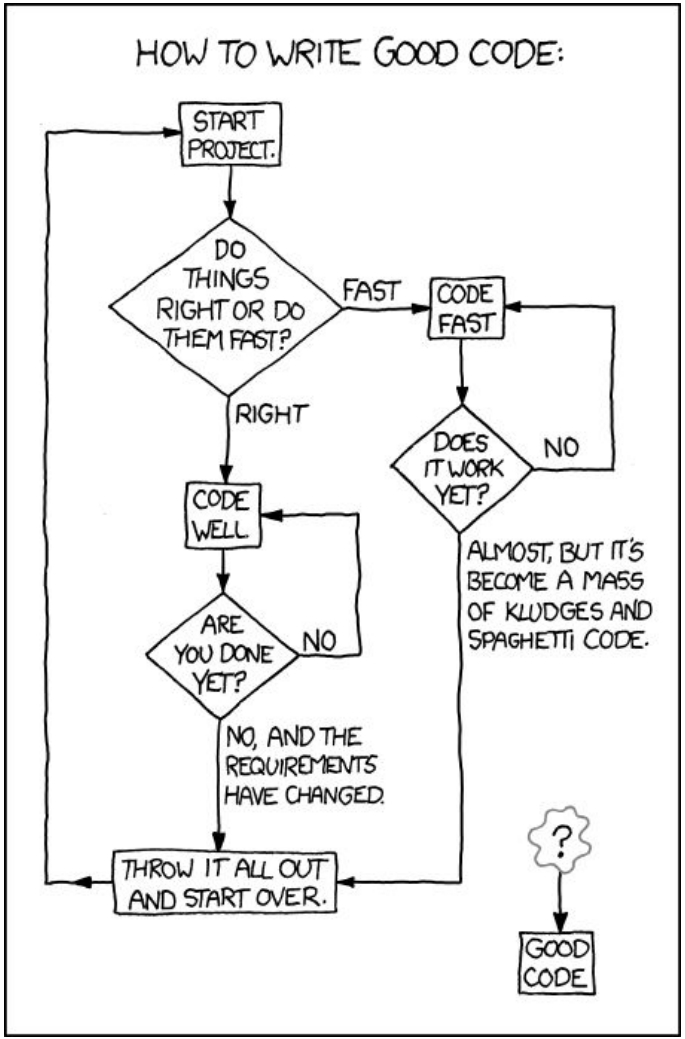
Using printf and scanf with Arrays

```
int main (void) {
    // declare an array, all zeroes
    int arrayOfMarks[10] = {0};

    // read from user input into 3rd element
    scanf("%d", &arrayOfMarks[2]);
    // output value of 5th element
    printf("The 5th Element is: %d", arrayOfMarks[4]);

    // the following code DOES NOT WORK
    scanf("%d %d %d %d %d %d %d %d %d %d", &arrayOfMarks);
```

Break Time

Writing "good" code

- It's never going to be easy!
- It's an ongoing struggle



https://xkcd.com/844/

A Basic Program using Arrays

Let's make a program to track player scores in a game

- We have four players that are playing a game together
- We want to be able to set and display their scores
- We also want to be able to see who's winning and losing the game
- The game needs to know how many points have been scored in total, so we'll also

Break down the program

What are the individual elements we need to make?

- First we create an array
- Then we use indexes to access the individual players and enter scores
- We're going to need while loops to step through the array
- Most of the extra functionality we want will be done by looping through the array

Create the Array and populate it

Setting the elements using indexes (manually for now)

```c
#include <stdio.h>

#define NUM_PLAYERS 4

int main(void) {
    int scores[NUM_PLAYERS] = {0};
    int counter;

    // assigning values directly to indexes
    scores[0] = 55;
    scores[1] = 84;
    scores[2] = 32;
    scores[3] = 61;
```

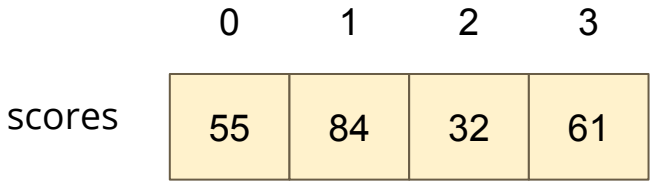
Let's loop through and see those values

Accessing all array elements by looping

```
// continued from last slide
// loop through and display all scores
int counter = 0;
while (counter < NUM_PLAYERS) {
    printf(
        "Player %d has scored %d points.\n",
        counter,
        scores[counter]
    );
    counter++;
}
```

Now that we have our array

It will look a bit like this:



Next, we can loop through to find:

- The lowest
- The highest
- And the total

Finding particular values in an array

If we see all the values, we can easily find the highest

- We'll loop through all the values in the array
- We'll save the highest value we've seen so far
- Then replace it if we find something higher
- By the time we reach the end, we will have the highest value

Finding the highest score

We could put this in a separate function!

```
int highest = 0;
int indexHighest = -1;
counter = 0;
while (counter < NUM_PLAYERS) {
    if (scores[counter] > highest) {
        highest = scores[counter];
        indexHighest = counter;
    }
    counter++;
}
printf(
    "Player %d has the highest score of %d.\n",
    indexHighest, highest
);
```

Finding the Total

This is even easier than the highest!

We just add all the values to a variable we're keeping outside the loop

```
int total = 0;
counter = 0;
while (counter < NUM_PLAYERS) {
    total += scores[counter];
    counter++;
}
printf("Total points scored across the players is %d", total);
```

Wait, what was that new syntax?

+= is another shorthand operator

It's used for accumulating values in a variable

```
int a = 0;
int b = 0;

// These two lines of code will do the same thing
a += 5;
b = b + 5;

// both a and b are now equal to 5
```

What about input into an array

Remember, we can't access the whole array, only individual elements

But we can definitely loop through the array entering values!

```
// assigning scores using user input
counter = 0;
while (counter < NUM_PLAYERS) {
    printf("Please enter Player %d's score: ", counter);
    scanf("%d", &scores[counter]);
    counter++;
}
```

A Score Tracker

We've built our first program using an array (and maybe some functions)

- We've accessed elements by index to set their values
- We've looped through to access values to output
- We've looped through to find highest and lowest
- We learnt about accumulating values
- We've also looked at reading values into the array
- We've seen how we can separate code into a function

What did we learn today?

Theory of a Computer

- A processor - carries out operations
- Some memory - stores information

Arrays

- Collections of identical variables
- Individual elements are accessed by indexes