ENGG1003 - Monday Week 4

`switch() { case: }`
Functions

Brenton Schulz

University of Newcastle

March 12, 2020

Subscript Notation

- Last chance to learn that we use:

$$x_1, x_2, x_3, ..., x_n \tag{1}$$

and

$$x_n = x_{n-1} + x_{n-2} \tag{2}$$

notation because it is the simplest method that gets the point across.

Subscript Notation

- x_n means that x is "some number" and n is an *integer* value
- n implies *uniqueness* (ie: x_1 and x_2 can differ)
- n implies an *order* to the x's
- A formal mathematical statement of the above would be something like:

$$x_n : \ x \in \mathbb{R} \text{ and } n \in \mathbb{Z} \tag{3}$$

- $\mathbb{R}$ is the set of real numbers
- $\mathbb{Z}$ is the set of all integers

Subscript Notation

- Without this notation it is *really* hard to write things like:

$$x_n = x_{n-1} + x_{n-2} \tag{4}$$

Subscript Notation

- Without this notation it is *really* hard to write things like:

$$x_n = x_{n-1} + x_{n-2} \tag{4}$$

- If you instead wrote:
"Calculate a sequence of numbers, $a, b, c, d, ...$"
how would you write the equation?

Considering Dropping?

- HECS census is Fri 22nd
- Before you drop:
  - Talk to me
  - Are you *legitimately* unprepared or experiencing "imposter syndrome"?
    - It is surprisingly common
  - Most of you have to pass eventually
  - There are some legitimate reasons
- Ignore unsolicited advice from demonstrators
  - Seriously, this isn't their job

switch() - case:

- Sometimes you want to code something like:

```
if(x == 0) {
  // stuff
} else if(x == 1) {
  // stuff
} else if(x == 2) {
  // stuff
} ...etc
```

- This is difficult to read and gets unwieldy. Fast.

switch() - case:

- Instead, C has:

```
switch(expression) {
  case constant:
      break;
  case constant:
      break;
  default:
}
```

- The *expression* is anything which evaluates to a number
- The *constant*s are either literals or variables declared as `const` (covered later)

switch() - case: Example

```
1  int x=1, y=2;
2
3  switch(x==y) { // Evaluates to 0 or 1
4    case 0:
5        printf("x and y differ\n");
6        break;
7    case 1:
8        printf("x and y are equal\n");
9        break;
10   default:
11       printf("Something went very wrong\n");
12 }
```

- The `default:` case happens if the expression doesn't match any other option

switch() - case: Example

- If the `break;` is omitted execution continues line by line - example:

```
1  #include<stdio.h>
2  int main() {
3    int x = 2;
4    switch(x) {
5      case 1: printf("x is 1\n");
6      case 2: printf("x is 2\n");
7      case 3: printf("x is 3\n");
8      default: printf("x is not 1, 2, or 3\n");
9    }
10   return 0;
11 }
```

`switch()` - `case`: Limits

- Because the `case` statements only accept *constants* there are some limitations
- Example, this doesn't translate well:

```
1 if(x < 0) {
2   // stuff
3 } else if (x == 0) {
4   // stuff
5 } else if (x > 0) {
6   // stuff
7 }
```

- `(x<0)`, `(x==0)`, and `(x>0)` are all 0 or 1
- Can't *easily* translate this into three unique constants

Functions

- A *function* is a block of code which can be *called* multiple times, from multiple places
- They are used when you want the same block of code to execute in many places throughout your code
- A function requires:
  - A name
  - (optional) A *return value*
  - (optional) One or more *arguments*

Functions in Mathematics

- In mathematics you saw functions written as:

$$y = f(x)$$

- Here, the function is called f, takes an argument of x and returns a value which is given to y
- C and pure mathematics have these general ideas in common

Functions in Mathematics

- In mathematics you saw functions written as:

$$y = f(x)$$

- Here, the function is called f, takes an argument of x and returns a value which is given to y
- C and pure mathematics have these general ideas in common
- The similarities stop there

Functions in Programming

- When a function is called:
  1. Program execution jumps to the function
  2. The function's code is executed
  3. Program execution jumps back to where it left off
- The code inside the function can be any valid C code, not just mathematics

Function Examples

- So far, some of you have used *library functions*
- These are functions which are pre-existing within the compiler (and its libraries)
- I have shown you:
  - `scanf();`
  - `printf();`
  - `rand();`

Function Syntax

- Function call syntax is:

  `name([arguments])`
- Not all functions take arguments
- The function can "turn into" its *return value*

Function Syntax

- Function call syntax is:

  `name([arguments])`
- Not all functions take arguments
- The function can "turn into" its *return value*
- Writing `rand()` in you code is *calling* the function
- The program execution "jumps" into the function's code, executes it, then jumps back

Function Examples

- Example 1:

```
1 x = rand();
```

  - `rand` is the function name
  - It returns a "random" integer
  - The return value is assigned to `x`
  - It doesn't take an argument

Function Examples

- Example 1:

```
1 x = rand();
```

  - `rand` is the function name
  - It returns a "random" integer
  - The return value is assigned to `x`
  - It doesn't take an argument

- Example 2:

```
1 y = sqrtf(x);
```

  - `sqrtf` is the function name
  - `x` is the argument
  - It returns the square root of `x`
  - The return value is assigned to `y`

Functions

- Function arguments and return values have pre-defined data types

Functions

- Function arguments and return values have pre-defined data types
- Example from documentation
  - `int rand(void);`
    - The return value is an `int`
    - The argument is type `void`
    - This just means "there are no arguments"

Functions

- Function arguments and return values have pre-defined data types
- Example from documentation
  - `int rand(void);`
    - The return value is an `int`
    - The argument is type `void`
    - This just means "there are no arguments"
  - `float sqrtf(float x);`
    - The return value is a `float`
    - The argument is a `float`
    - Argument is called `x` in documentation but you can pass it any `float` variable or literal

Return Values (an Engineer's View)

- The function's *return value* is the number a function gets "replaced with" in a line of code

Return Values (an Engineer's View)

- The function's *return value* is the number a function gets "replaced with" in a line of code
- Function return values, variables, and literals can all be used in the same places:
  - In arithmetic
  - In conditions
  - As arguments to other functions

Return Values (an Engineer's View)

- The function's *return value* is the number a function gets "replaced with" in a line of code
- Function return values, variables, and literals can all be used in the same places:
  - In arithmetic
  - In conditions
  - As arguments to other functions
- The C standard is *very* specific about what return values are but I will be informal for now
  - Technically, for example, an expression like `x=y+5.0;` also has a "return value" equal to the value assigned to `x`

Return Values

- I use functions from `math.h` in these examples, we'll cover them in a few slides
  - I should also discuss `.h` "header" files later, too

Return Values

- I use functions from `math.h` in these examples, we'll cover them in a few slides
  - I should also discuss `.h` "header" files later, too
- The following are all valid:
  - `x = rand();`
  - `printf("%f\n", sin(y));`
  - `if( (rand()%6) < 2)`
  - `while( sin(x) < 0 )`

Return Values

- I use functions from `math.h` in these examples, we'll cover them in a few slides
  - I should also discuss `.h` "header" files later, too
- The following are all valid:
  - `x = rand();`
  - `printf("%f\n", sin(y));`
  - `if( (rand()%6) < 2)`
  - `while( sin(x) < 0 )`
  - This next one is complicated...

Return Values

- I use functions from `math.h` in these examples, we'll cover them in a few slides
  - I should also discuss `.h` "header" files later, too
- The following are all valid:
  - `x = rand();`
  - `printf("%f\n", sin(y));`
  - `if( (rand()%6) < 2)`
  - `while( sin(x) < 0 )`
  - This next one is complicated...
  - `x = sin((double)rand());`

Return Values

- I use functions from `math.h` in these examples, we'll cover them in a few slides
  - I should also discuss `.h` "header" files later, too
- The following are all valid:
  - `x = rand();`
  - `printf("%f\n", sin(y));`
  - `if( (rand()%6) < 2)`
  - `while( sin(x) < 0 )`
  - This next one is complicated...
  - `x = sin((double)rand());`
    - Generates a random integer, casts to `double`, uses that number as an argument to the `sin()` function

Using Functions

- Before you use a function you must:
  - Read the documentation
  - `#include` the correct header file
  - Add the correct library to the compiler options
    - CodeBlocks *links* to the math library when *linking* with `g++`
    - `stdio` and `stdlib` are always included
  - Be aware of the data types
    - Do you need any type casting?
    - Are you using the correct function?

Maths Functions

- Since some of you have already used them, lets learn about the maths library...
- It includes functions for:
  - Trigonometry
  - Exponentials (base e) & logarithms (base e, 10, 2)
  - Exponents (`pow();`)
  - Rounding (`floor();` & `ceil();`)
  - Floating point modulus (`fmod();`)
    - Modulus and modulo are poorly defined in common language. This function is a "floating point remainder" and not "absolute value"
  - Square roots
  - ...etc

Maths Functions

- There are typically *different* functions for `float` and `double`
- This can have a huge speed impact
- Use the right ones!
- `float` maths functions typically end in '`f`'
  - `cosf();`
  - `sqrtf();`
  - `atanf();`
  - ...etc
- `double` maths functions **don't**
  - `cos();`
  - `log();`

Maths Functions

- Math functions are written by mathematicians
  - All angles are in radians

Maths Functions

- Math functions are written by mathematicians
  - All angles are in radians
  - `log();` is $\log_e$
    - `log10();` is $\log_{10}$
    - `log2();` is $\log_2$

Maths Functions

- Math functions are written by mathematicians
  - All angles are in radians
  - `log();` is $\log_e$
    - `log10();` is $\log_{10}$
    - `log2();` is $\log_2$
  - Inverse trig functions are called "arcus functions"
    - $\sin^{-1}$ is `asin();`
    - $\cos^{-1}$ is `acos();`
    - $\tan^{-1}$ is `atan();`

Maths Functions

- Math functions are written by mathematicians
  - All angles are in radians
  - `log();` is $\log_e$
    - `log10();` is $\log_{10}$
    - `log2();` is $\log_2$
  - Inverse trig functions are called "arcus functions"
    - $\sin^{-1}$ is `asin();`
    - $\cos^{-1}$ is `acos();`
    - $\tan^{-1}$ is `atan();`
  - The "4 quadrant" arctan function is `atan2();`
    - `atan(x);` returns $[-\pi/2, \pi/2]$
    - `atan2(x,y);` returns $[-\pi, \pi]$ depending on the quadrant of the point `x,y`
    - Very useful for polar to Cartesian coordinate transforms (probably beyond 1st semester 1st year)

Example - Quadratic Equation

Write a C program which uses the standard library function `sqrtf();` as part of the calculations required to produce solutions to a quadratic equation:

$$ax^2 + bx + c = 0 \tag{5}$$

using

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \tag{6}$$

...do it live

Example - `scanf();`'s Return Value

Read the `scanf();` documentation and observe that it returns an `int`. What does that `int` represent? Write some test code and experiment with its behaviour.

Demonstrate it live...

Writing Functions

- What about writing your own functions?

Writing Functions

- What about writing your own functions?
- Do the following:
  1. Define (for yourself) what the function needs to do

Writing Functions

- What about writing your own functions?
- Do the following:
  1. Define (for yourself) what the function needs to do
  2. Choose a name

Writing Functions

- What about writing your own functions?
- Do the following:
  1. Define (for yourself) what the function needs to do
  2. Choose a name
  3. Decide on the function arguments

Writing Functions

- What about writing your own functions?
- Do the following:
  1. Define (for yourself) what the function needs to do
  2. Choose a name
  3. Decide on the function arguments
  4. Decide on the return value

Writing Functions

- What about writing your own functions?
- Do the following:
  1. Define (for yourself) what the function needs to do
  2. Choose a name
  3. Decide on the function arguments
  4. Decide on the return value
  5. Write a *function prototype*
     - Write it at the top of your code [or in a header file]

Writing Functions

- What about writing your own functions?
- Do the following:
  1. Define (for yourself) what the function needs to do
  2. Choose a name
  3. Decide on the function arguments
  4. Decide on the return value
  5. Write a *function prototype*
     - Write it at the top of your code [or in a header file]
  6. Somewhere below `main()` (or in another `.c` file) write the function *definition*

Writing Functions

- What about writing your own functions?
- Do the following:
  1. Define (for yourself) what the function needs to do
  2. Choose a name
  3. Decide on the function arguments
  4. Decide on the return value
  5. Write a *function prototype*
     - Write it at the top of your code [or in a header file]
  6. Somewhere below `main()` (or in another `.c` file) write the function *definition*
- For now just keep everything in one file
  - Unless you study ahead. I won't stop you.

Function Prototypes

- Huh? What's a function prototype?

Function Prototypes

- Huh? What's a function prototype?
- Before a function is *called* the compiler needs to know:
  - Its name
  - Its argument's data type(s)
  - Its return data type

Function Prototypes

- Huh? What's a function prototype?
- Before a function is *called* the compiler needs to know:
  - Its name
  - Its argument's data type(s)
  - Its return data type
- A function prototype documents these things for the compiler

Function Prototypes

- The function prototype syntax is:

```
1 <returned data type> function_name(arguments);
```

Function Prototypes

- The function prototype syntax is:

```
1 <returned data type> function_name(arguments);
```

- The `arguments` section is a comma separated list with the following syntax:

```
1 (datatype name, datatype name, ...)
```

- Examples:
  - `float sqrtf(float x);`
  - `int rand(void);`
  - `double log(double x);`
  - `double atan2(double x, double y);`

Void

- If either the arguments or return value aren't required declare them as `void`
- This is an explicit way of saying "this item doesn't exist"

Function Prototypes

- The function prototype must be *before* the function's first use
- For "small" projects: above `main()`
- For "big" projects: in their own *header file*
  - We'll cover this later
- Don't leave the prototype's arguments blank
  - The compiler won't complain but it is a deprecated language feature

Function Definitions

- The function prototype tells the compiler how the function interacts with other code
- The function definition is the *actual code* that gets executed when the function is called

```
1 int add(int a, int b); // Prototype
2
3 main() {
4   // do stuff
5 }
6
7 int add(int a, int b) { // Definition
8   return a + b;
9 }
```

Function Prototypes Vs Definitions

- For the time being:
  - The prototype goes *above* `main()`
    - It is 1 line and ends with a semicolon ;
  - The definition goes *below* `main()`
    - It is the prototype repeated followed by a { } block
    - The code within the { } block is known as the function *body*

Writing Functions - Example 1

- Write a C function, `isEven()`, which takes a single `int` as an argument and returns 1 if the argument is even and zero otherwise.

Writing Functions - Example 1

- Write a C function, `isEven()`, which takes a single `int` as an argument and returns 1 if the argument is even and zero otherwise.
  - Name: `isEven`
  - Argument: `int x`
  - Return Value: `int`

Writing Functions - Example 1

- Write a C function, `isEven()`, which takes a single `int` as an argument and returns 1 if the argument is even and zero otherwise.
  - Name: `isEven`
  - Argument: `int x`
  - Return Value: `int`
- **NB:** The variable names given to each argument are the names you use when writing the function body

Writing Functions - Example 1

- The function prototype is therefore:

```
1 int isEven(int x); // Put before main()
```

- The function definition template is:

```
1 // Put after main()
2 int isEven(int x)
3 {
4 // Fill this in
5 }
```

Writing Functions - Example 1

- The function's definition can then be written

```
1 int isEven(int x)
2 {
3   if(x%2 == 0)
4     return 1;
5   else
6     return 0;
7 }
```

- In this example there is more than one `return` statement

Writing Functions - Example 1

- We can now write some test code around the function:

```
1  #include <stdio.h>
2  int isEven(int x);
3  int main() {
4    printf("%d\n", isEven(1));
5    printf("%d\n", isEven(2));
6  }
7  int isEven(int x)
8  {
9    if(x%2 == 0)
10     return 1;
11   else
12     return 0;
13 }
```

Writing Functions - Example 2

- Lets implement the Week 2 `sqrt` algorithm as a function
- ...Then compare with `sqrtf();`
- Keep it simple: fixed iteration count `n=10`

Writing Functions - Example 2

- In mathematics, calculate $\sqrt{k}$ by iterating:

$$x_n = \frac{1}{2}\left(x_{n-1} + \frac{k}{x_{n-1}}\right)$$

$$x_0 \neq 0$$

- In a code snippet:

```
1 // Calculate sqrt(k)
2 float k = 26; // Test value, sqrt(26)=5.0990
3 float xn = x/2.0; // x0 = x/2 because why not?
4 int n;
5 for(n = 0; n < 10; n++) {
6   xn = 0.5*(xn + k/xn);
7 }
```

Writing Functions - Example 2

- Lets make some design decisions:
  - Name: `mySqrt();`
  - Argument: `float k`
  - Return Value: `float`
- The function prototype is therefore:

```
1 float mySqrt(float k);
```

Writing Functions - Example 2

- Place the function prototype before `main()`:

```
1 #include <stdio.h>
2
3 float mySqrt(float k);
4
5 int main() {
6   // Do stuff
7 }
```

Writing Functions - Example 2

- Write the function definition below `main()`

```
1  #include <stdio.h>
2  float mySqrt(float k);
3  int main() {
4    printf("sqrt(26) = %f\n", mySqrt(26.0));
5  }
6
7  float mySqrt(float k) {
8    int n;
9    float xn = k/2.0;
10   for(n = 0; n < 10; n++)
11     xn = 0.5*(xn + k/xn);
12   return xn;
13 }
```