UNIX and C Programming (COMP1000)

Lecture 1: Basics and Revision

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Outline

What is C?

C is:

- A programming language – one of thousands.
  - Not the best, but perhaps the most *important*.
- An old language –
  - Simple and primitive, powerful and pervasive.
- A *compiled* language –
  - You write "source code".
  - Then, you convert it to "machine code" using a compiler.
  - The machine code is the final program.
- A *statically-typed* language –
  - Strict data types: integers, real numbers, chars, etc.
  - These are known at compile time ("static").
- A *procedural* language –
  - Not object orientated – no classes or objects.

The pervasiveness of C

- As of July 2015, the Ohloh website tracked about 75 thousand C projects with 5.9 *billion* lines of code [1].
- Well-known software written in C includes:
  - Much of a typical Linux distribution, particularly the kernel;
  - Android — the mobile phone/tablet OS (based on Linux);
  - Apache — the web server software that runs the majority of the world's websites.
- Much more software is written in languages based on C:
  - Microsoft Windows (C++).
  - Mac OS (Objective C).
  - Mozilla Firefox (C++).
  - Google Chrome (C++).
  - Internet Explorer (C++).

[1] https://www.ohloh.net/languages/c

Why use C?

Because:

- It's so widely used already (new graduates often have to maintain old code!).
- It's very efficient (if you know what you're doing).
- It's portable (to an extent).

A very, very brief history

- "C" itself is descended from other languages (most directly from "B").
- For a long time, C was not well standardised — unlike Java, there was no single organisation in control.
- Incompatibilities arose between different implementations.
- However, C standards do now exist — C89/C90, C99 and C11.
- C89 (ANSI) and C90 (ISO) are the same thing.
- C99 and C11 are minor updates.

C99 and C11

- The new versions — actually not very important.
- You need to know the *old* C (i.e. C89/C90).
  - The old C is the lowest common denominator; used everywhere.
  - If you want a "new" language, why use C at all? Use Java, C#, Python, etc. instead.
- Unfortunately, some C books (e.g. Kochan) don't say what's C99-specific and what isn't.
- The lectures will briefly mention C99 features where relevant.

C++

- A major extension to C, implementing object orientation (and other interesting features).
- Very widely used, alongside C.
- Some features of C++ have been retroactively added to C.
- Like C99, **C++ will not be assessed in this unit!**
- However, the last lecture will discuss C++, and it is well worth learning.

What is there to know about C?

- Pointers, pointers, pointers and pointers.
- Engineering Programming (COMP1004) mostly skips around pointers.
- Pointers are the heart and soul of C — most of C's more useful features are built on pointers.
- That said, you *also* need to know about:
  - The structure of a C program.
  - The environment (UNIX) in which you're working.

Things you should have seen before

These are (essentially) the same in both C and Java:

- Symbols like semicolons ("`;`"), braces ("`{...}`") and parentheses ("`(...)`").
- Simple data types (e.g. `int`, `double`, `char`).
- Variables and assignments (e.g. "`int v = 42;`").
- Expressions (e.g. "`v = 33 * x + z / 3;`").
- `if`, `else`, `switch`, `break`, `default`, `for`, `while`, `do`, `return`.
- Functions/methods; e.g.

```
double calculate(double x, double y)
{
    return x * y;
}
```


Remember variables and data types?

- Each variable stores a single value, depending on its data type.
- Simple data types include:

Signed integers:	`int`, `short`, `long`.
Unsigned integers:	`unsigned int`, `unsigned short`, `unsigned long` (cannot be negative).
Reals:	`float`, `double`, `long double`.
Characters:	`char` (letter, digit, symbol, etc.) – technically a kind of integer.

- Mainly use `int`, `double` and `char`.
- There are no classes or objects in C (unlike Java).
- Other special data types including pointers, arrays, `structs`, `unions` and `enums` (which we'll cover later).
- C has strings, but no formal "String" data type (we'll get to that too).

Variable declarations

- Variables must be *declared* before they can be used.
- A declaration consists of a datatype and a name:

```
float number;         /* Declaration */
number = 5.0 * 2.5;   /* Assignment  */
```

Here, `number` is declared (created) as a `float` (real number).

- Declarations can also *initialise* variables:

```
float number = 5.0 * 2.5;   /* Same as above */
```

- Multiple variables can be declared at once, if they have the same data type:

```
int alpha = 3, beta, gamma, delta = 6;
```

Here, `alpha`, `beta`, `gamma` and `delta` are all `ints`. Two of them have been initialised.

Variable names

- Should reflect the meaning of the variable!
- Should be concise, but not too concise.
- Can contain letters (a-z and A-Z), digits (0-9) and underscores (_).
- Cannot start with a digit.
- Case-sensitive (`size`, `SIZE` and `Size` are distinct names).
- Cannot be a reserved word (`auto`, `break`, `case`, `char`, `const`, `continue`, `default`, `do`, `double`, `else`, `enum`, `extern`, `float`, `for`, `goto`, `if`, `int`, `long`, `register`, `return`, `short`, `signed`, `sizeof`, `static`, `struct`, `switch`, `typedef`, `union`, `unsigned`, `void`, `volatile` or `while`).

A small difference from Java

How do you repeat something 100 times?

- In Java and C99 you can do this:

```
for(int i = 0; i < 100; i++) { ... }
```

- In C (in general), you cannot declare `i` inside the `for` statement. Instead, you must do this:

```
int i;
for(i = 0; i < 100; i++) { ... }
```


Comments

Use comments to describe code in natural language.

Block comments

Traditionally, comments are enclosed between `/*` and `*/`

```
/* Speed of light
(metres per second) */
int speed = 299792458;
```

Single-line comments (only C99!)

In C99, single-line comments start with "//".

```
int speed = 299792458; // Speed of light (m/s)
```

. . . but you can't do this in C89.

Comments, meaningful names, indentation and whitespace

- It's not just machines that read your code.
- Source code must frequently be fixed, updated, improved, etc.
- This requires that humans be able to read your code as well.
- **Comments** help remind you, and explain to others, what the code does and how it works.
- **Meaningful variable names** serve a similar purpose.
- **Indentation** helps you see the code structure instantly.
- **Whitespace** helps you see words and numbers more easily.
- You *must* use all these — properly — to make your code readable!

Revision

The following code is valid in both C and Java. Take a minute to figure out what it does.

```
int base = 3;
int exponent = 19;
int result = 1;
int i;

for(i = 0; i < exponent; i++)
{
    result = result * base;
}
```


More Revision

Do you know how functions or methods work?

```
int addCubes(void)
{
    int i, result = 0;
    for(i = 1; i < 5; i++)
        result += cube(i);
    return result;
}

int cube(int x)
{
    return x * x * x;
}
```

This will give you a result of $1^3 + 2^3 + 3^3 + 4^3 = 100$.

Jumps — `return`, `break`, `continue` and `goto`

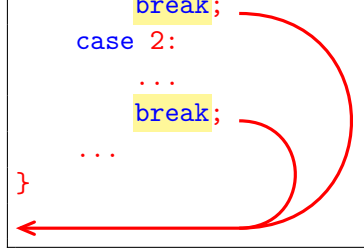
- These statements jump to another place [2].
- `return` and `break` are necessary in certain places.
- Many advise against `goto` under any circumstances.
- Some advise against `break` (outside of `switch`) and `continue` as well.
- Some advise against multiple `returns` in a single function.
- However, it's worth noting what they actually do.

[2] In fact, `if`, `switch`, `for`, `while` and `do-while` all jump as well, but they provide *structure* to it.

The `break` statement

- `break` immediately ends the current `switch`, `for`, `while` or `do-while` statement.
- Often used in a `switch` statement:

```
switch(...) {
    case 1:
        ...
        break;
    case 2:
        ...
        break;
    ...
}
```



This is normal, and necessary.

The break statement

- Can also end a loop (usually from within an `if`):

```
while(...) {
    ...
    if(...) {
        break;
    }
    ...
}
```

- This is *not* necessary — rearranging the `if` statement will achieve the same thing.
- `break` can lead to more compact code.
- `break` can also lead to unreadable code.

The continue statement

- `continue` ends the current *iteration* of a loop.
- Jumps back to the top of the loop, and continues with the next iteration, if any.

```
while(...) {
    ...
    if(...) {
        continue;
    }
    ...
}
```

- `continue` is never strictly necessary — `if` statements can achieve the same thing.
- Like `break`, continue can lead to more compact code.
- Like `break`, continue can also lead to unreadable code.

The goto statement

- A relic from the bad old days, now very poor practice.
- `goto` simply jumps somewhere else, ignoring all the rules about flow of control.
- The target location is marked by a *label* — a name followed by a colon (":").

```
while(x > 2.0) {          /* Never, ever do this!! */
    theLabel:
    x = x - 2.0;
}

if(x < 3.0) {
    x += 5.0;
    goto theLabel;
}
```

evil

Spaghetti code

- `goto` can easily turn your code into spaghetti:
  - Not clear what order things happen in.
  - Very difficult to read, understand and fix — easier to throw it out and start again.
  - Your life will be miserable!
- `break` and `continue` are more constrained, and so less dangerous, but can still do the same thing.
- Newer languages don't have `goto`, for good reason.
- However, in C, `goto` is sometimes used to separate error handling code from the main algorithm, because C lacks exception handling.

What is a function?

- C programs are broken up into functions.
- Each function is a chunk if code, which may "call" (or "invoke") other functions.
- Functions are *separate* — they cannot contain one another.
- Execution always starts with the `main()` function.
- When function `alpha()` calls function `beta()`:
  1. `alpha` is paused;
  2. `beta` receives "parameter" values (data) from `alpha`;
  3. `beta` performs its task;
  4. `beta` optionally "returns" a value (data) to `alpha`;
  5. `alpha` resumes where it left off.

  (Note: the words "call" and "invoke" always carry this precise meaning. You cannot "call" anything other than a function.)

C functions vs. Java methods

- For those having studied Java, a function is very similar to a method.
- Just like a method, a function has:
  - any number of parameters (imports);
  - an optional return value (an export);
  - its own set of "local" variables; and
  - a chunk of code that performs a specific task.
- However, functions are *stand-alone*, whereas methods occur inside classes (and classes don't exist in C).

Anatomy of a function

The following example function takes (imports) a real number and returns (exports) either the letter `L` or the letter `H`.

```
char indicator(float measurement)
{
    char result = 'L';
    if(measurement >= 0.5)
    {
        result = 'H';
    }
    return result;
}
```


Historical interest

- Pre-1989 C had a different function parameter syntax:

```
int someFunction(x, y)
    int x;
    float y;
{
    ...
}
```

- In modern C, this would be written as:

```
int someFunction(int x, float y)
{
    ...
}
```

- The old form is still valid C, but rarely used.

Function calls and returns

```
void calc(void) {
    ...
    int number = addTwo(5);
    ...
}

int addTwo(int param)
{
    int result = param + 2;
    return result;
}
```


Function calls and returns

```
void calc(void) {
    ...
    int number = addTwo(5);
    ...
}

int addTwo(int param)
{
    int result = param + 2;
    return result;
}
```

parameter value (5)

control

The call:

- Function `calc()` calls function `addTwo()`.
- `calc()` pauses, `addTwo()` begins.
- `param` becomes 5.

Function calls and returns

```
void calc(void) {
    ...
    int number = addTwo(5);
    ...
}

int addTwo(int param)
{
    int result = param + 2;
    return result;
}
```

control

return value (7)

The return:

- `addTwo()` finishes, `calc()` resumes.
- `number` takes the value of `result` (7).

The `return` statement

- Immediately ends a function — jumps back to the caller.
- Returns a value to the caller (if this function is non-void).
- Multiple return statements can lead to spaghetti code:

```
int badExample(void) {
    if(...) return x;
    if(...) return y;
    return z;
}
```

- Try for one return only, on the last line:

```
int goodExample(void) {
    ...
    return result;
}
```

Void

- Can show that a function does not return a value:

```
void outputProduct(int x, int y) {
    printf("The product is %d\n", x * y);
}
```

- Can show that a function has no parameters:

```
void hello(void) {
    printf("Hello world.\n");
}
```

(Note: *this* `void` is sometimes omitted altogether, but technically that means "anything goes".)

- `void` has a third use related to pointers, which we'll discuss in a couple of weeks.

Void returns

- A `void` function, returning no value, needs no `return` statement.
- These functions hand back control at the end, automatically:

```
void hello(void) {
    printf("Hello world.\n");
}
```

- However, you *can* technically do this:

```
void hello(void) {
    printf("Hello world.\n");
    return;
}
```

- You can abuse void returns much like the other jump statements, but you wouldn't do that, would you?

The `printf()` function

- Used to output text and other values.
- A pre-existing function available for you to use.
- Works differently from the Java `System.out.println()` method (but used for the same purpose).
- Described later in more detail.

Examples

```
printf("Hello world.\n");
```

```
printf("Coordinates: (%d, %d)\n", x, y);
```


The `scanf()` function

- Used to input values (like the reverse of `printf()`).
- Described later in more detail.

Example

```
int value;
printf("Enter value: ");
scanf("%d", &value);
```

(The `printf()` here is not strictly necessary.)

Expressions

- Expressions occur virtually *everywhere*.
- They are built up from:
  - operands — variables, function calls and "literal" values;
  - operators — +, *, >=, ++, &&, typecasts, etc.; and
  - parentheses — "`(...)`".
- They have a resulting data type, based on the operators and operands.
- Variables, function calls and literal values are syntactically interchangeable.
  - Variables and function calls are (generally) allowed anywhere that values are needed.

Statements that require expressions

These statements all use expressions:

- `someVariable =` **expression** `;`
- `someFunction(` **expression1** `,` **expression2** `, ...);`
- `if(` **expression** `) { ... }`
- `switch(` **expression** `) { ... }`
- `while(` **expression** `) { ... }`
- `do { ... } while(` **expression** `);`
- `for(` **expression1** `;` **expression2** `;` **expression3** `) { ... }`
- `return` **expression** `;`

There are no limits to how complex expressions can be! (However, simpler expressions are more readable.)

Function calls are values

```
/* Here we call beta and gamma, and then alpha. */
alpha(beta(), gamma() + 3.0);
...

float beta(void) {
    return 5.0;
}

float gamma(void) {
    return 7.0 ;
}

void alpha(float x, float y ) { ... }
```

Function calls can be part of any expression, just like variables.

Function calls are values

```
/* Here we call beta and gamma, and then alpha. */
alpha(beta(), gamma() + 3.0);
...

float beta(void) {
    return 5.0;
}

float gamma(void) {
    return 7.0 ;
}

void alpha(float x, float y ) { ... }
```

Here, `beta()` and `gamma()` are called first, and return their values.

Function calls are values

```
/* Here we call beta and gamma, and then alpha. */
alpha(beta(), gamma() + 3.0);
...

float beta(void) {
    return 5.0;
}

float gamma(void) {
    return 7.0 ;
}

void alpha(float x, float y ) { ... }
```

5.0

10.0 (7.0 + 3.0)

These values immediately become parameters to `alpha()`.

A simple C program

```
#include <stdio.h>

int main(void)
{
    printf("Hello world.\n");
    return 0;
}
```


Forward declarations

What's wrong with this code?

```
void printSum(int x, int y) {
    printNumber(x + y);
}

void printNumber(int number) {
    printf("%d\n", number);
}
```

In C, the order of declaration is important (unlike Java).

Forward declarations (2)

- In C, a function must be declared *above* its first use.
- If needed, you can place the function "prototype" at the top.

Example

```
void printNumber(int number);

void printSum(int x, int y) {
    printNumber(x + y);
}

void printNumber(int number) {
    printf("%d\n", number);
}
```

Forward declarations (3)

Some terms:

- A *prototype* consists of the name, parameters and return type of a function.
- A *forward declaration* gives the prototype by itself (usually at the top of the source code).
- A function *definition* gives the prototype *and* the actual code.

(You can sometimes just re-arrange the order of the functions, but this is often inconvenient or even impossible.)

C program structure

- A C program consists of one or more files.
- Each file contains one or more functions.
- One file contains the `main()` function.

C program structure

```c
#include <stdio.h>

void bananas(int n);
double mangos(void);

int main(void) {
    ...
    return 0;
}

void bananas(int n) { ... }

double mangos(void) { ... }
...
```


Compiling your C programs

- In Java you use `javac`.
- In C you can use `gcc`, though there are many alternatives.
- To convert your source code (`prog.c`) into an executable program (`prog`):

```
[user@pc]$ gcc prog.c -o prog
```

- "`-o` name" gives the output filename.
  - Without it, the executable will be called "`a.out`", which is silly.
- There are other options as well; e.g.
  - `-Wall` turns on "all warnings".
  - `-ansi` turns *off* C99 extensions (leaving C89 only).
  - `-pedantic` turns on additional checks for C89 compliance.
- These options help you produce better, more portable code.

```
[user@pc]$ gcc -Wall -ansi -pedantic prog.c -o prog
```

Running your C programs

- Unlike Java, C programs *don't* (typically) run on a "virtual machine"
- You don't need any other software installed, except for:
  - the operating system
  - any libraries your program uses (via `#include`)

Example

```
[user@pc]$ ./prog
```


That's all for now!

- Make sure you attempt the pre-lab exercises before coming to class.
- If you have any uncertainties, please see the lecturer or unit coordinator ASAP!