ENGG1003 - Tuesday Week 2

C Arithmetic
Datatypes
Calculating Pi

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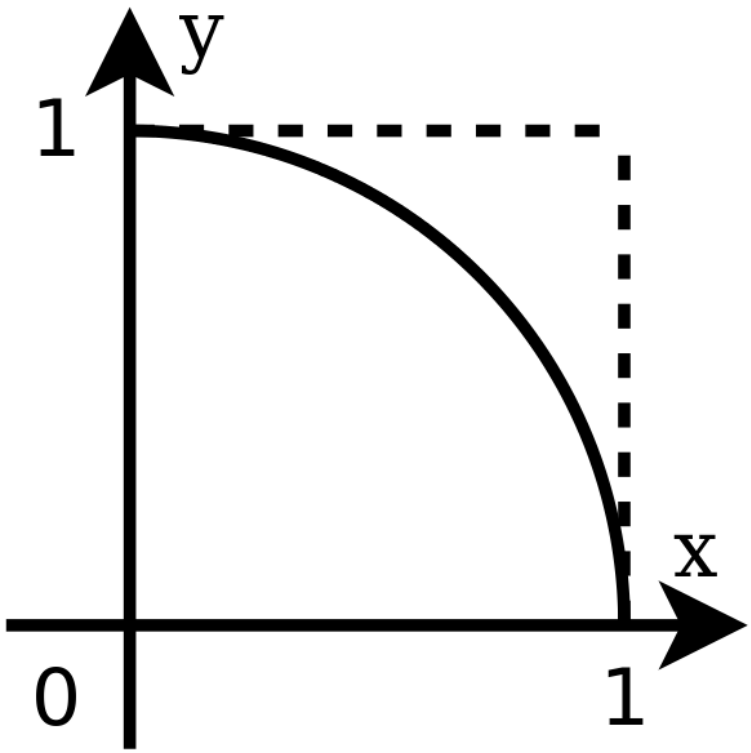
Case Study: Calulating π

- Computers are *really* good at repetitive things
- Lets use this fact to calculate π using a "monte-carlo" method
  - Informally, these are methods which solve problems by trying the same thing with different inputs until patterns emerge
  - It could repeat millions or billions of times
  - Name comes from the Monaco Principality's high concentration of casinos
- Algorithm pseudocode will be written before an implementation in C

Case Study: Calulating π

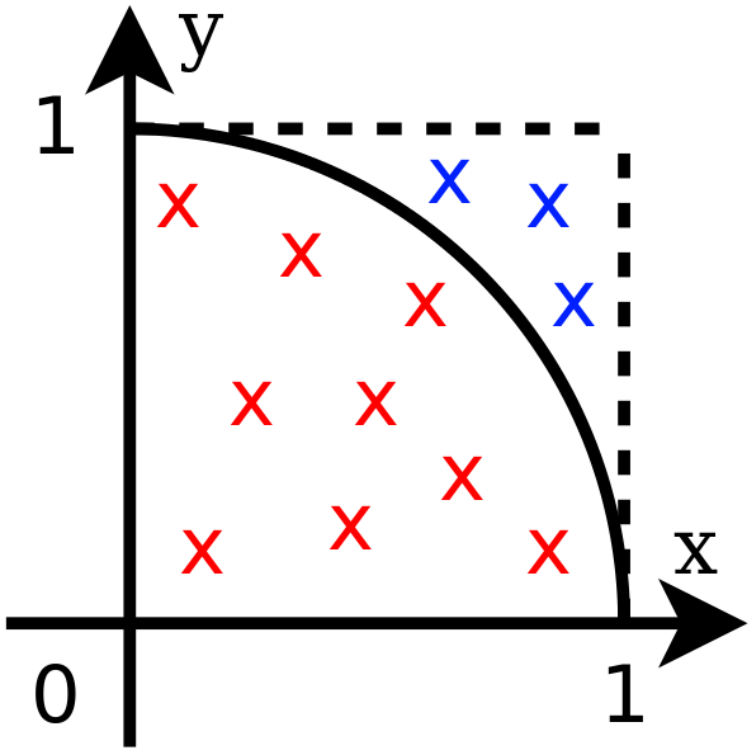
Consider a quadrant of a unit circle ($r = 1$) with a square around it:

- Area of the square $A_1 = 1$
- Area of the circle quadrant $A_2 = \frac{\pi r^2}{4} = \frac{\pi}{4}$
- Ratio of areas $\frac{A_2}{A_1} = \frac{\pi}{4}$
- Therefore $\pi = 4 \times \frac{A2}{A1}$



Case Study: Calulating π

- We can't calculate the area ratio without knowing π
- Estimate it by:
  - Randomly picking many points inside the square
  - Test if the point is inside the circle with $x^2 + y^2 < 1$



- $\pi \approx 4 \times \frac{\text{Number of points which land inside circle}}{\text{Total number of points tested}} = 4 \times \frac{9}{12} = 3$

Algorithm for Calculating π

- How can the above *mathematics* be turned into an *algorithm*?
- The algorithm needs to repeat the *same thing* multiple times
  - This implies use of a loop
- As the loop repeats, we need to keep track of the following *variables*:
  - The number of points which have been tested
  - The number of points which have been inside the circle
  - The (x, y) coordinates of the point under test
- The points get tested and incrememting of the "inside circle" count is *conditional*
  - This implies an IF...ENDIF flow control structure

Algorithm for Calculating π

- The number of points tested will be an *integer*, we will call it $\mathrm{countTotal}$
- The number of points found to be inside the circle is also an integer, we will call it $\mathrm{countInside}$
- The point under test needs two "real" variables: x and y
  - "Real" is the generic term for a number with integer and fractional components. Eg: 1.45
- The condition on incrementing $\mathrm{countInside}$ will be $x^2 + y^2 < 1$

Algorithm for Calculating π

```
BEGIN
   integer countTotal = 0
   integer countInside = 0
   WHILE countTotal < A large number
      x = random number between 0 and 1
      y = random number between 0 and 1
      countTotal = countTotal + 1
      IF x^2 + y^2 < 1
         countInside = countInside + 1
      ENDIF
   ENDWHILE
   pi = 4*countInside/countTotal
   PRINT pi
END
```

Missing Knowledge for C Implementation

- More information about arithmetic
  - Relational operators look useful
  - Is there a neat way to do $\mathrm{count}{=}\mathrm{count}{+}1$?
  - $\mathrm{countInside}$ and $\mathrm{countTotal}$ are both integers. What happens when we divide?
- Datatypes and how they are handled in arithmetic statements
- How do we generate random numbers?
- Syntax for WHILE loops and IF statements

C Arithmetic

- Basic arithmetic was seen in the lab
  - You all did the lab, right?

Operation	C Symbol
Addition	+
Subtraction	-
Multiplication	*
Division	/

Table: Basic arithmetic operators in C

- Complex expressions can be built from these operators and parentheses

C Arithmetic

Examples:

$$z = x^2 + 5(y + b) \qquad \mathrm{z = x*x + 5*(y + b);}$$

$$u = \frac{x+1}{x-1} \qquad \mathrm{u = (x + 1)/(x - 1);}$$

$$v = z^3 + \frac{5(y+b)}{2} \qquad \mathrm{v = z*z*z+(5*(y + b))/2;}$$

- Multiplication is not assumed. If you write $5(\mathrm{y+b})$ the compiler will generate a syntax error.
- To be valid C expressions the semicolon is required.

C Arithmetic

- C supports two time-saving *unary* operators:
  - Very useful in loops.

Operation	C Syntax	Replaces
Increment	x++; or ++x;	x = x + 1;
Decrement	x–; or –x;	x = x - 1;

- It also supports the following shorthand syntax:

x = x + y;	x += y;
x = x - y;	x -= y;
x = x * y;	x *= y;
x = x / y;	x /= y;

C Arithmetic

What's the difference between `x++` and `++x`?

- `x++` is a *post-increment*
- `++x` is a *pre-increment*
- If they appear in an arithmetic expression, pre-increment is processed *before* the variable is used and post-increment is processed *after* it is used.
- In isolation there is no difference.

Increment Example

```c
#include <stdio.h>
int main() {
   int x = 0;
   int y = 0;
   int z = 0;
   y = ++x + 10;
   printf("Pre-increment: %d\n", y);
   y = z++ + 10;
   printf("Post-increment: %d\n", y);
   return 0;
}
```

Pre/post-inc/decrements will be used when working with *arrays*, more details in coming weeks.

Modulus

- Computers frequently only deal with integers
- Integer division in C ignores (truncates) any fractional component
- The *modulus* operator provides the remainder after division
  - Implemented with the $\%$ character
  - $\mathrm{a} \ \% \ \mathrm{b} =$ remainder of $\mathrm{a} \ / \ \mathrm{b}$
  - Very useful for tasks performed every *nth* loop
- Example:
  - $10 \ / \ 3 = 3$
  - $10 \ \% \ 3 = 1$

Relational Operators

- C supports six *relational* operators:

Operation	C Symbol
Less than	<
Less than or equal to	<=
Greater than	>
Greater than or equal to	>=
Equal to	==
Not equal to	!=

Table: Relational operators in C

Relational Operators

- The result of a relational operation is 0 or 1
  - C treats 0 as Boolean FALSE and non-zero as TRUE
- They are typically used as flow control conditions
  - $\text{if(condition) } \{\text{statements}\}$
  - $\text{while(condition) } \{\text{statements}\}$
- While we're here: the above is the correct syntax for IF and WHILE flow control in C

Modulus Example 1 - Printing Every *nth* Loop

```c
#include <stdio.h>
int main() {
   int x = 0;
   while(x < 1000)
   {
      // Presumably something useful is done with x
      // inside this loop
      if(x%100 == 0)
         printf("%d\n", x);
   }
   return 0;
}
```

Modulus Example 2 - Finding Factors

```c
#include <stdio.h>
int main() {
  int input;
  int x;
  printf("Enter an integer to factorise: ");
  scanf("%d", &input);
  x = input;
  while(x > 0) {
    if(input % x == 0) // ie: if the remainder is zero
      printf("%d is a factor of %d\n", x, input);
    x--;
  }
  return 0;
}
```

Observe that the while() loop loops over every value of x from input to 1. We will discuss a flow control method designed for this (the for loop) later.

C Arithmetic Operator Precedence

- C has an "order of operations"
- eg: $1+5*2$ evaluates to 11
- Multiplication and division first
- Addition and subtraction second
- Relational operators somewhere below that
- If in doubt: force order with parentheses
  - This makes the code more readable
  - It doesn't cost you anything
  - C compilers understand algebra and will optimise inefficient expressions automatically

Data types

- You have hopefully noticed that all variables are *declared* before use
- Declaration specifies the variable's:
  - Datatype
  - Name
  - An *initialisation value* (optional)
    - Always assume uninitialised variables have random values! Behaviour varies between compilers and target platforms.
- C is a "strongly-typed" language
  - Every variable has a fixed type

Integer Data types

- Integer data types vary by their:
  - Size
  - Support for negative numbers
- C integer types can be 1, 2, 4, or 8 bytes long
- Each type can be *signed* or *unsigned*
  - Unsigned number are never negative but you get double the value range

TODO: Keep hacking until we've implemented π.