Introduction to the C++ Programming Language

Day 1

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Introduction

Who am I?

- Aleksandra Rylund Glesaaen
- ”A lattice guy”
- A mostly self-taught obsessive perfectionist
- Someone who believes IT should be taught by IT people {so you should all take a different course}

Who am I?

- Aleksandra Rylund Glesaaen

weird Norwegian name

- ”A lattice guy”
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Course material

Irubataru/cpp-lecture-2015

What will we learn?

- Basic C++ syntax
- Control structures
- Functions
- Structs and classes
- Templates and STL
- Exceptions

What will we learn?

- Basic C++ syntax (today)
- Control structures (today)
- Functions (Tuesday)
- Structs and classes (Wednesday and Thursday)
- Templates and STL (Thursday and Friday)
- Exceptions (Friday)

What will we learn?

- Basic C++ syntax (today)
- Control structures (today)
- Functions (Tuesday)
- Structs and classes (Wednesday and Thursday)
- Templates and STL (Thursday and Friday)
- Exceptions (Friday)

Look at the person sitting next to you

One of you won’t make it

Today’s topics

1. Introduction
2. Syntax and structure
3. Types and variables
4. Control Structures
5. Crash Introduction to IO
6. Coding Environments
7. Programming Practices
8. Recap

What is C?

A relic from the 70s, 80s and 90s that has had a huge influence on most modern programming languages.

What is C?

Notable features

- It is a procedural language
- It is statically typed
- It has low-level access to memory
- Readable syntax (in my opinion)

What is C++?

Anything you can do, I can do better.
I can do anything better than you.

Annie Get Your Gun

What is C++?

> Anything you can do, I can do better.
> I can do anything better than you.
>
> Annie Get Your Gun

C++ is a language built on top of the C programming language

What is C++?

Additional features

- Classes and inheritance
- Templates
- Exceptions
- A huge standard library
- … and it is in active development

Versions of C++

C++ is constantly evolving, hence there are many standards

- C++98
- C++03
- C++11
- C++14
- C++17

Versions of C++

C++ is constantly evolving, hence there are many standards

- C++98
- C++03 ← Current standard of many compilers
- C++11
- C++14
- C++17

Versions of C++

C++ is constantly evolving, hence there are many standards

- C++98
- C++03
- C++11
- C++14

  We will use these

- C++17

The slides

Things that are bad practice will be marked

Bad Practice

Things new to C++11 or C++14 will me marked

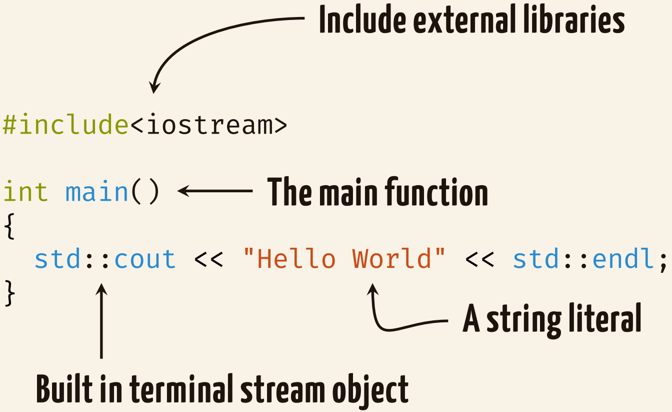
{C++11}
{C++14}

Syntax and structure

Hello World in C++

```cpp
#include<iostream>

int main()
{
  std::cout << "Hello World" << std::endl;
}
```

Hello World in C++



```
#include<iostream>

int main()
{
  std::cout << "Hello World" << std::endl;
}
```

Include external libraries

The main function

A string literal

Built in terminal stream object

A program in C++

In essence all C++ programs consist of two things

1. Sentences
2. Blocks

A program in C++

1 Sentences

```
#include<iostream>

int main()
{
  std::cout << "Hello World" << std::endl;
}
```

A complete instruction ending with a ;

A program in C++

2 Blocks

```
#include<iostream>

int main()
{
  std::cout << "Hello World" << std::endl;
}
```

A group of instructions inside of a pair of {}

Types and variables

What is a variable?

A variable is simply a named location in memory

```
int main()
{
  int n = 5;
  std::cout << &n << std::endl; //0x7fff27ea5464
}
```

name of location
in memory

What is a variable?

Its data type tells the compiler two important things

1. How much memory the variable needs
2. The allowed operations on the variable

Variable initialisation

```
double rate_of_decay = 0.75;
```

Variable initialisation

```
double rate_of_decay = 0.75;
```

Data type of the variable

Tells the compiler:

- `rate_of_decay` **is a** `double`
- **It needs 8 bytes of memory {usually}**

Variable initialisation

Name of the variable
Your hook to the newly allocated memory

↓

```
double rate_of_decay = 0.75;
```

Variable initialisation

```
double rate_of_decay = 0.75;
```

A `double` literal which will in this case be placed in the allocated memory slot

Variable initialisation

Assignment Style

```
double rate_of_decay = 0.75;
```

Variable initialisation

C++03 Constructor Style

```
double rate_of_decay (0.75);
```

Variable initialisation

C++11 Constructor Style

```
double rate_of_decay {0.75};
```

{C++11}

Variable initialisation

Undefined Declaration Style

```
double rate_of_decay;
```

Bad Practice

{for built in types}

Naming variables

```
([_a-zA-Z])[_a-zA-Z0-9]*
```

Naming variables

```
([_a-zA-Z])[_a-zA-Z0-9]*
```

Exceptions

- **Keywords defined by the language**
- **Names starting with _ or __ are reserved**

Keywords: `int`, `float`, `while`, `const`, `false`, …

Naming variables

One should find a system and stick to it

E.g. mixed style

Variables:	`snake_case`
Functions:	`mixedCase`
Classes:	`CamelCase`

Naming variables

One should find a system and stick to it

E.g. Stroustrup style

Variables:	`snake_case`
Functions:	`Mixed_case`
Classes:	`Mixed_case`

Built in data types

Basically four built in data types in C++

Boolean:	`bool`	`true`, `false`
Character:	`char`	`'c'`, `'#'`, `'7'`, …
Integer:	`int`	`0`, `12`, `-42`, …
Floating point:	`float`	`0.0`, `1.33`, `-4.11`, …

Type qualifiers

Type qualifiers manipulate the built in types

Type qualifiers

Manipulate memory size

```
short long
```

Manipulate value range

```
signed unsigned
```

Type qualifiers

Type	Size* (minimum)
`short int`	2 byte
`int`	2 byte
`long int`	4 byte
`long long int`	8 byte
`float`	4 byte
`double`	8 byte
`long double`	10 byte

* depending on compiler and architecture

Type qualifiers

Type	Value range
`int`	-32,768 to 32,767
`long int`	-2,147,483,648 to 2,147,483,647
`unsigned int`	0 to 65,535
`float`	± 1.175,494,3 10^{-38} to ± 3.402,823,4 10^{38}
`double`	± 2.225,073,858,507,201,4 10^{-308} to ± 1.797,693,134,862,315,7 10^{308}

Literals

Explicit values whose type are syntax dependent

- Integers are just numbers: `5`
- Floats have a decimal point: `4.5`
- Characters are surrounded by ’ ’: `'c'`
- Booleans are either `true` or `false`
- C strings are surrounded by ” ”: `"Hello"`
- Function literals: `[](int){ /* ... */ };` {C++11}

Literals

One can add qualifiers to literals as well

Literal	Type
`42u`	`unsigned int`
`167l`	`long`
`5.62`	`double`
`1.0e-2`	`double`
`4.12f`	`float`

Operators

Operators in programming are much the same as operators in mathematics

- Arithmetic operators: `+ - * / %`
- Logic operators: `and && or || !`
- Comparison operators: `== < != > <= >=`
- Combined operators: `+= -= *= /=`
- Others: `<< >> = ++ -- ? & :: ->`

Operators

Operators have different precedence levels

- `5+12*7/4-2`
- `4>3 and 7==8 or 16<=72`

Operators

Operators have different precedence levels

- `5+12*7/4-2` ⟵ **24**
- `4>3 and 7==8 or 16<=72`

Operators

Operators have different precedence levels

- `5+12*7/4-2` ⟵ 24
- `4>3 and 7==8 or 16<=72` ⟵ true

Whitespace does nothing in C++

Operators

Expressions can be grouped with `( )`

- `(5+12)*7/4-2`
- `(5+12)*7/(4-2)`

Operators

Expressions can be grouped with ( )

- `(5+12)*7/4-2` ⟵ 27
- `(5+12)*7/(4-2)`

Operators

Expressions can be grouped with ( )

- `(5+12)*7/4-2` ⟵ 27
- `(5+12)*7/(4-2)` ⟵ 59

Type casting

C++ is statically typed, but not strongly typed

One can change between the types using casting

```
int n = 5;
double cn = (double)n;
double cppn = static_cast<double>(n);
```

C style cast

C++ style cast

But you can never change the type of the variable n

Variable qualifiers: const

Constants are declared with `const`

```
const int size_of_arrays = 100;

/* ... */

size_of_arrays *= 2;
```

Compile error

Variable qualifiers: const

`mutable` ⇄ `const`

Variable qualifiers: const

`mutable` ⇄ `const`

In C++ variables are mutable by default

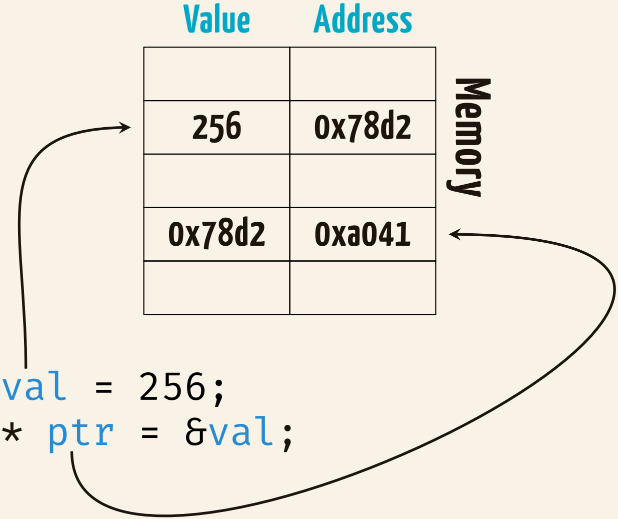
Different from languages like rust

Pointers

Variables are still just named locations in memory

We can work with these locations using pointers

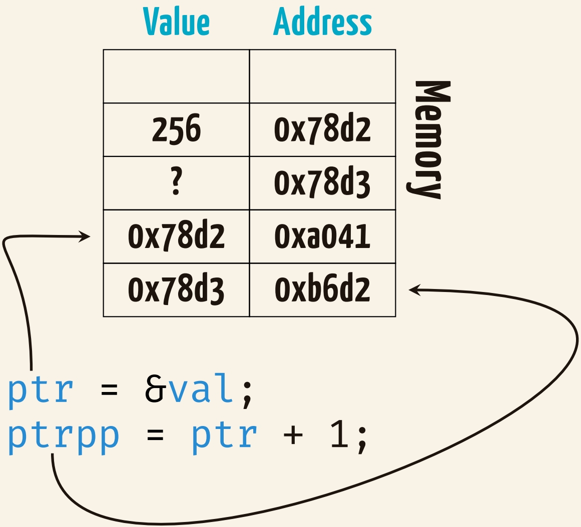
Pointers



Value	Address
256	0x78d2
0x78d2	0xa041

```
int val = 256;
int * ptr = &val;
```

Pointers

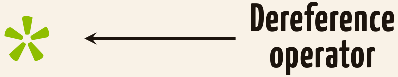


Value	Address
256	0x78d2
?	0x78d3
0x78d2	0xa041
0x78d3	0xb6d2

```
int * ptr = &val;
int * ptrpp = ptr + 1;
```

Pointers

You can access the value of the memory the pointer points to by dereferencing it



```
int * ptr = &val;
int half_val = *ptr / 2;
```

This is why the type of the pointer is important, so the program knows how many bits to read.

The null pointer

Sometimes it is useful to be able to say that the pointer doesn’t point to anything

```
double * ptr = NULL;
double * ptr = nullptr;
```

← Old style

← New style {C++11}

References

A reference works as an alias for a variable

```
int value = 134;
int & ref  = value;
int value_half = ref / 2;
&value == &ref;  ←  true
```

In many languages assignment automatically creates references and not copies, e.g. JavaScript

What's the deal with * and & ?

In type specifications:

- * declares a pointer
- & declares a reference

As operators

- * converts pointer to reference
- & converts reference to pointer {sort of}

The auto type

When assigning

type of variable = type of expression ;

These types are generally the same

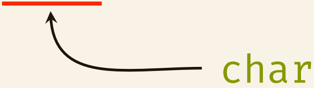
`auto` = whatever the type on the right is

{C++11}

The auto type

auto only picks up the base type

```
const char & char_ref = some_char;
auto var = char_ref;
```



char

But you can use type qualifiers on it

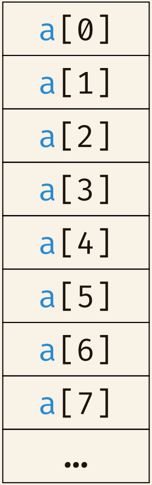
C Style Arrays

One can create a list of objects like this:

```
int array[10];
```

Places 10 integers consecutively in memory

Memory



a[0]

a[1]

a[2]

a[3]

a[4]

a[5]

a[6]

a[7]

...

C Style Arrays

As a type qualifier [] decides how much memory should be reserved

```
int fibonacci_numbers[10];
```

As an operator [] is used to access the various memory positions

```
fibonacci_numbers[5] = 8;
fibonacci_numbers[6] = 13;
```

C Style Arrays

The array is actually just a pointer in disguise

```
array[0] == *array
```

The [] operator is also just a shorthand

```
array[n] == *(array + n)
```

C Style Arrays

One can initialise the array with an initialiser list

```
int lucky[] = {4, 12, 42, 7};
```

Size of the array inferred from context

C Style Strings

A C style string is simply an array of characters

```
char message[] = "How are you all doing?";
```

The final entry is always the null character `'\0'`

(message has 23 elements)

Control Structures

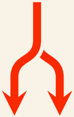
Controlling program flow

So far we have learned to write programs that execute ”in a straight line”

Controlling program flow

So far we have learned to write programs that execute ”in a straight line”

- What if we want to **branch**?



Controlling program flow

So far we have learned to write programs that execute ”in a straight line”

- What if we want to branch?
- What if we want to repeat?

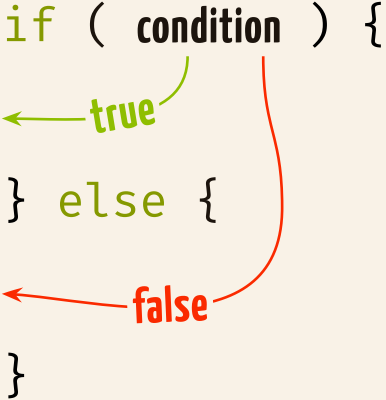
Controlling program flow

So far we have learned to write programs that execute ”in a straight line”

- What if we want to branch?
- What if we want to repeat?

Then we need control structures

Conditionals: if, else



```
if ( condition ) {

} else {

}
```

true

false

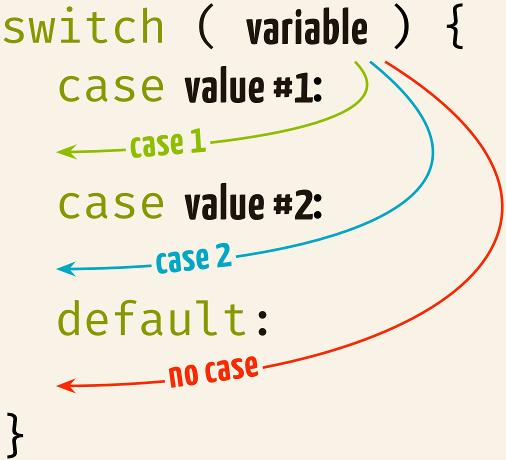
Conditionals: if, else

Can also do multiple statements

```
if ( condition ) {

} else if ( condition ) {

} else {

}
```

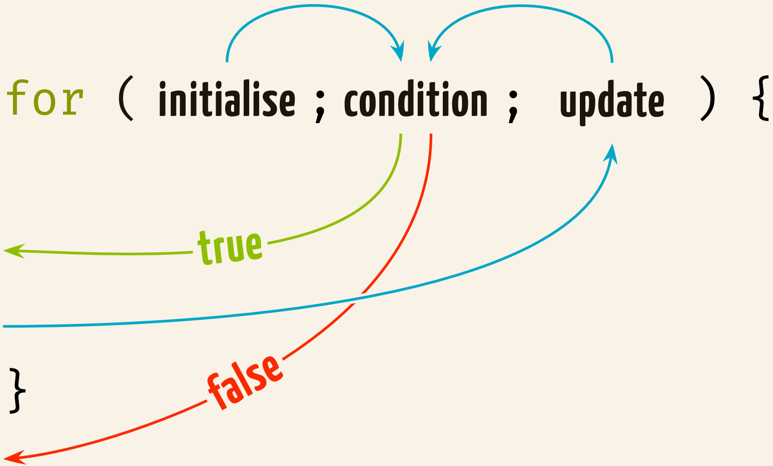
It chooses the first condition that matches

Conditionals: switch



```
switch ( variable ) {
   case value #1:

   case value #2:

   default:

}
```

Loops: for

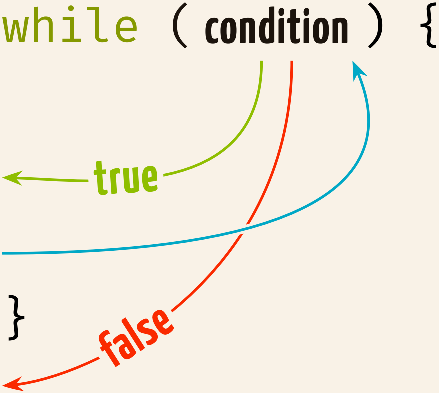


```
for ( initialise ; condition ;  update  ) {

}
```

Loops: for - example

```
int numbers[100];

for (auto i = 0; i < 100; ++i) {
  numbers[i] = i;
}
```

Loops: while



```
while ( condition ) {

}
```

true

false

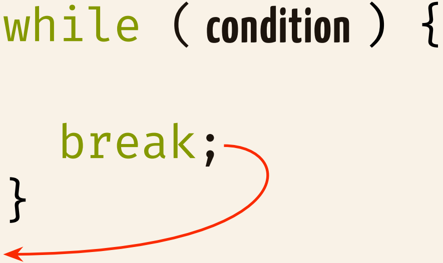
Loops: while - example

```
// Calculate 10!
unsigned factorial = 1;
unsigned counter = 10;

while (counter > 1) {
  factorial *= counter;
  --counter;
}

std::cout << "10! = " << factorial;
```

Exiting loops

There are two commands for altering loop flow

break and continue



```
while ( condition ) {

  break;
}
```

break exits the loop

Exiting loops

There are two commands for altering loop flow

break and continue

```
while ( condition ) {

   continue;
}
```

continue jumps back to the loop update

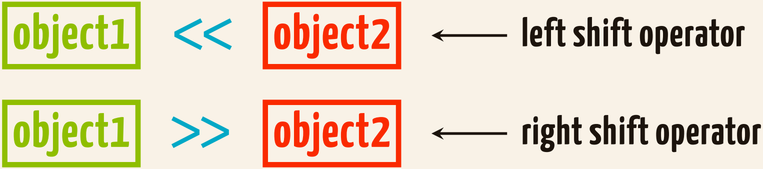
Crash Introduction to IO

Streams

In C++ IO is handled by something called streams

We use the shift operators to interact with the stream objects

Original meaning



object1 << object2 ← left shift operator

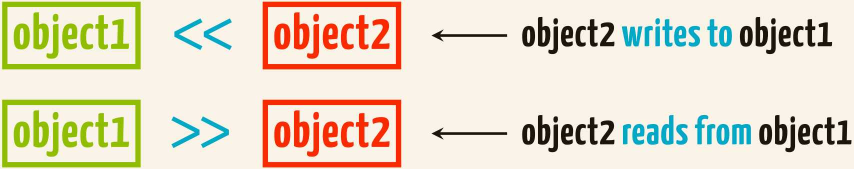
object1 >> object2 ← right shift operator

Streams

In C++ IO is handled by something called streams

We use the shift operators to interact with the stream objects

Meaning adopted by stream objects



object1 << object2 ← object2 writes to object1

object1 >> object2 ← object2 reads from object1

Standard in and out

The `iostream` library includes two convenient stream objects

std::cout for writing to console

std::cin for reading from keyboard

#include<iostream>

Standard in and out - example

```
#include<iostream>

int main()
{
  double input_from_user {0.};

  std::cin >> input_from_user;

  std::cout << "You wrote: \"" << input_from_user
    << "\"" << std::endl;
}
```

Standard in and out - example

```
#include<iostream>

int main()
{
  double input_from_user {0.};

  std::cin >> input_from_user;

  std::cout << "You wrote: \"" << input_from_user
    << "\"" << std::endl;
}
```

To gain access to std::cout and std::cin

Character escape

Flush stream and create newline

Coding Environments

Live Example

Programming Practices

Good Programming Practices

- Do not use global variables (constants are OK)
- Always initialise built in functions with a default value
- Always use descriptive variable names
  (and stay away from magic numbers)
- Use const consistently

Good Programming Practices

Stay away from C functionality that has been superseded

- Macros, especially `#define`
- Pointers to `void`
- `NULL` for empty pointers
- `printf` and `scanf` for IO

Recap

Recap Day 1

- A C++ program consists of sentences and blocks
- The type of the variable tells the compiler
  - How much memory the variable needs
  - What actions are allowed on the variable
- There are four basic types in C++
  - `bool`, `char`, `int`, `float`
- Types can be modified with qualifiers

Recap Day 1

- Use pointers to examine memory locations
- References if you want to alias a variable
- Use if and switch to make branches in your code
- Use for and while to repeat stuff