EDAF50 – C++ Programming

1. Introduction

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Outline

EDAF50: C++ programming, 7.5 hp

The course gives detailed knowledge about C++. Special emphasis is placed on the language constructs that make C++ a more advanced, and also more complex, language than Java.

Knowledge and understanding

- know about and be able to describe the differences between C++ and Java
- have detailed knowledge about C++ and the standard library STL

Competences and skills

- be able to choose the correct language construct to solve a given problem
- be able to use tools to develop C++ programs in a Unix environment

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Important differences to Java

New or extended concepts in C++
(compared to Java / introductory courses):

- Pointers and memory management
- Functions: call-by-value and call-by-reference
- Polymorphism: both static and dynamic
  (compare *templates* to *generics*)

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Examination details

The compulsory course items are

- laborations
- project
- written examination

The final grade is based on the result of the written examination.

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Administration

- Course plan
- Registration
  - Sign up for labs before friday 26/1
- Sign up for labs
  - On the web - link from the course web page
  - Sign up for a group – same time all weeks

History
C++ is a descendent of Simula and C.

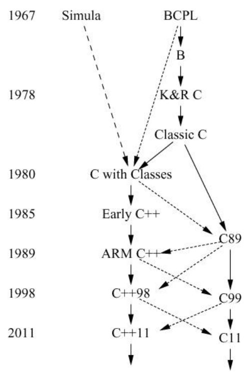
1967: Simula (Dahl & Nygaard)
1972: C (Dennis Ritchie)
1978: K&R C (Kernighan & Ritchie)
1980: C with Classes (Bjarne Stroustrup)
1985: C++ (Bjarne Stroustrup)

- ISO standard 1998

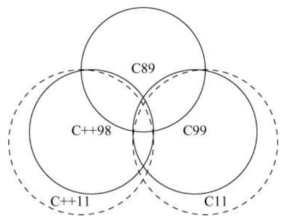
Other relatives:

1995: Java (James Gosling et al.)
2000: C# (Anders Hejlsberg)

- virtual machine
- automatic memory management
- *safe* languages



C++ is not a pure extension of C



- both ISO C and ISO C++ are descendants of K&R C, and are "siblings"
- some details are incompatible between ISO C och C++
- Areas are not to scale

In general: Don't write C++ as if it were C

What is C++?

The ISO standard for C++ defines two things

- *Core language features*, e.g.,
  - data types (e.g., `char`, `int`)
  - control flow mechanisms (e.g., `if` and `while` statements).
  - rules for declarations
  - templates
  - exceptions
- *Standard-library components*, e.g.,
  - Data structures (e.g., `string`, `vector`, and `map`)
  - Operations for in- and output (e.g., `<<` and `getline()`)
  - Algorithms (e.g., `find()` and `sort()`)
- The standard library is written in C++
  - Example of what is possible

A minimal program in C++

empty.cc

```
int main( ) { }
```

- has no parameters
- does nothing
- the return value of `main()` is interpreted by the system as an error code
  - non-zero means error
  - no explicit return value is interpreted as zero (NB! only in `main()`)
  - rarely used in Windows
  - often used on Linux/Mac

The first C++ program
Hello, World!

hello.cc

```
#include <iostream>
int main( )
{
    std::cout << "Hello, World!" << std::endl;
    return 0;
}
```

hello.cc

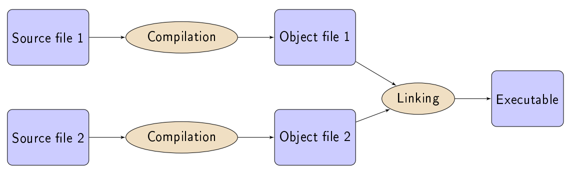
```
#include <iostream>
using std::cout;
using std::endl;

int main( )
{
    cout << "Hello, World!" << endl;
    return 0;
}
```


What is a program?

C++ is a compiled language

- Source code
- Object file(s)
- Executable file



A C++ program

Example: compute and print x^2.

```
#include <iostream>

double square(double x)
{
  return x*x;
}

void print_square(double d)
{
    std::cout << "the square of " << d <<
                 " is " << square(d) << std::endl;
}

int main( )
{
    print_square(1.234);
    return 0;
}
```


Functions
Declaration and definition

The main way of getting sonething done in C++:

- call a function
  - A function must have been *declared* before it can be called
  - A function declaration specifices
    - name
    - return type
    - types of the parameters
  - Example

```
int random();
void exit(int);
double square(double);
int pow(int x, int exponent);
```

- The compiler ignores parameter names
- Give names if it increases readability

- A function *definition* contains the implementation
  - Must only occur once

Difference from Java

- In Java, functions and variables can only be declared inside a class.
- In C++, functions and variables can exist independently of classes.
  - free functions: do not belong to a class
  - member functions in a class
  - global variables
  - member variables

Function declaration
Example

- Declaration and definition

Example: Mean value – variant 1

```
double mean(double x1, double x2) // Declaration and definition
{
   return (x1+x2)/2;
}

int main()
{
   double a=2.3, b=3.9;
   cout << mean(a, b) << endl;
}
```


Function definition
With previous declaration

- *Forward declaration*
- Fuction definition after main()

Example: mean – variant 2

```
double mean(double, double);        // declaration (prototype)

int main()
{
   double a=2.3, b=3.9;
   cout << mean(a, b) << endl;      // use
}

double mean(double x1, double x2)   //definition
{
   return (x1+x2)/2;
}
```


Function definition
With previous declaration

- *Forward declaration*
- Fuction definition after main()

Example: mean – variant 2

```
double mean(double, double);        // declaration (prototype)

#include "mean.h"

int main()
{
   double a=2.3, b=3.9;
   cout << mean(a, b) << endl;      // use
}

double mean(double x1, double x2)   //definition
{
   return (x1+x2)/2;
}
```

Functions
Function calls

The semantics of function argument passing is the same as copy initialization: *(Same as for primitive types in Java)*

- In a function call, the *values of the arguments* are
  - type checked, and
  - with implicit type conversion (if needed)
  - copied to the function parameters
- Example: with a function `double square(double d)`

```
double s2 = square(2);        // 2 is converted to double
                              // double d = 2;

double s3 = square("three");  // error
                              // double d = "three";
```


Functions
Function overloading

- Overloading ("överlagring")

```
void print(int);
void print(double);
void print(std::string);

void user()
{
    print(42);     // calls print(int);
    print(1.23);   // calls print(double);
    print(4.5f);   // calls print(double);
    print("Hello") // calls print(std::string);
}
```

- Cannot differ only in return type
- Must not be ambiguous

- Default arguments (sometimes) similar to overloading
  - `void print(int x, std::ostream& out = std::cout);`
  - The rules are complex. *Only use for trivial cases*
  - Risk of ambiguity if combined with overloading

Functions
Call - ambiguity

- With overloaded functions, the compiler selects "the best" function (after implicit type conversion)
- If two alternatives are "equally good matches " it is an error

```
void print2(int, double);
void print2(double, int);

void user()
{
    print2(0, 0);   // Error! ambiguous
}
```

- and also (with `print()` from last slide)

```
long l = 17;
print(l);        // Error! print(int) or print(double)?
```


Functions
Rule of thumb

Factor your code into small functions to

- give names to activities and document their dependencies
- avoid writing specific code in the middle of other code
- facilitate testing

- A function should perform a single task
- Keep functions as short as possible
- Rule of thumb
  - Max 24 lines
  - Max 80 columns
  - Max 3 block levels
  - Max 5–10 local variables
  - Inversely proportional to complexity

Call by value and call by reference
Call by value(*värdeanrop*)

In a 'normal' function call, the values of the arguments are copied to the formal parameters (which are local variables)

Example: swap two integer values

```
void swap(int a, int b)
{
   int tmp=a;
   a = b;
   b = tmp;
}
```

...and use:

```
int x = 2;
int y = 10;

swap(x, y);

cout << x ", " << y << endl;
```

2,10   x and y are not changed

Call by value and call by reference
Call by reference(*referensanrop*)

Use *call by reference* instead of *call by value*:

Example: swap two integer values

```
void swap(int& a, int& b)
{
   int tmp=a;
   a = b;
   b = tmp;
}
```

...and use:

```
int x = 2; int y = 10;

swap(x, y);
```

NB! The argument for a reference parameter must be an *lvalue*

The call `swap(x,15);` gives the error message

```
invalid initialization of non-const reference of type "int&"
from an rvalue of type 'int'
```

References

- A reference is *an alias* for a variable

Statements

Mostly the same syntax as in Java:

- **if**, **switch**
- **for**, **while**, **do while**
- **break**, **continue**

but **goto** *is spelled differently:*

- No **break** to a label
- **goto** (used in C, rarely used in C++)

Data types and variables

- Every name and every expression has a type
- some concepts:
  - a *declaration* introduces a *name* (and gives it a *type*)
  - a *type* defines the set of possible values and operations (for an *object*)
  - an *object* is a place in memory that holds a *value*
  - a *value* is a set of bits interpreted according to a *type*.
  - a *variable* is a named *object*

Unnamed objects

Unnamed objects include

- temporary values
- objects on the heap (allocated with **new**)

Data types
Primitive types

- Integral types: **char**, **short**, **int**, **long**, **long long**
  - **signed** (as in Java)
  - **unsigned** (*modulo* 2^N "non-negative" numbers, not in Java)
- Floting point types: **float**, **double**, **long double**
- **bool** (boolean in Java)
  - integer values are implicitly converted to **bool**
  - zero is **false**, non-zero is **true**
- The type **char** is "the natural size to hold a character" on a given machine (often 8 bits). Its size (in C/C++) is called "a byte" regardless of the number of bits.
- **sizeof(char)** $\equiv 1$ (1 byte)
- The sizes of all other data types are multiples of **sizeof(char)**.
  - sizes are *implementation defined*
  - **sizeof(int)** is commonly 4.

Operators

Operators and expressions quite similar to Java

The same as in Java

E.g., `+ - * / % ++ -- += -= *= && || & |` etc., and `[] . ?:`

The trinary operator ?:(like in Java)

```
z = (x>y) ? x : y;
```

```
if (x>y)
  z=x;
else
  z=y;
```

Many more, including

Pointer operators: `* & ->`

Input and output: `<< >>` (*overloaded shift operators*)

sizeof, **decltype** (*compile-time*)

Variables
Declaration and initialization

Declaration without initialization (avoid)

```
int x;          // x has an undefined value (if local)
                // (as local variables in Java)
```

Declaration and initialization

```
int x{7};      // C++ style (recommended if unsure)
int y = {7};   // C++ with extra =
int z = 7;     // C style

vector<int> v{1,2,3,4,5};
```

C style: Beware of implicit type conversion

```
int x = 7.8;   // x == 7. No warning
int y {7.8};   // Gives a warning (or error with -pedantic-errors)
```

Variables

Automatic type inference

auto: The compiler deduces the type from the initialization.

Declaration and initialization

```
auto x = 7;                // int x
auto c = 'c';              // char c
auto b = true;             // bool b
auto d = 7.8;              // double d

std::vector<int> v;
auto it = v.begin();       // std::vector<int>::iterator it

double calc_epsilon();
auto ep = static_cast<float>(calc_epsilon());  // float ep
```

In **float** ep = calc_epsilon(); *the narrowing is not obvious* NB!

with **auto** there is no risk of narrowing type conversion, so using = is safe.

Don't use **auto** if you need to be explicit about the declared type, e.g.

Suggested reading

References to sections in Lippman

Functions 6.1 (p 201–207)

Types, variables 2.1,2.2,2.5.2 (p 31–37, 41–47, 69)

Type aliases 2.5.1

Arithmetic 4.1-4.5, 4.11

Constants 2.4 2.4.4 (p 59–60, 65–66)

Pointers and references 2.3 (p 50–59)