Modern C++

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December 4, 2017

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Style & Good practices

Naming convention

- Bad idea

```
int main() {
   int a, b;
   double c;
}
```

- Good idea

```
int main() {
   unsigned int age = 20;
   int points = 0;
   float height = 1.7;
}
```

Naming convention

- Best idea [C++11]

```
1 int main() {
2    uint8_t age{10};
3    int64_t points{};
4    float height{};
5 }
```

- Freak! [C++11]

```
1 int main() {
2    auto age = uint8_t{20};
3    auto points = int64_t{0};
4    auto height = float{5.67};
5 }
```

Programming styles

- Variable names [3]

```
// Delimiter separated words
float daniel_height = 1.7;
// CamelCase (letter-case separated words)
float johnHeight = 1.7;
```

- Braces (use it always!) [2]

```
// K&R (Kernighan and Ritchie)
if () {

}
// Allman
if ()
{

}
```

Macros & global variables

- Avoid the use of macros

```
1  // Type?, Scope?
2  // Is not constant and can be undefined
3  #define PI 3.14159
4  #define SIZE 10
5
6  int main() {
7
8     // float PI = 10; → Would be: float 3.14159 = 10 ¿?
9
10    int numbers[SIZE];
11
12    #undef SIZE
13
14    // Error: "SIZE" is not declared ...
15    cout << SIZE << endl;
16 }
```

Macros & global variables

- Try NOT to use global variables

```
1  #include <vector>
2  #include <array>
3
4  // It leads to many problems... BAD IDEA
5  // Ambiguity ERROR with: std::__1::size
6  int size = 20; // Can a size be negative?
7
8  namespace utils { // This would be a safe alternative
9     constexpr size_t arraySize = 20;
10 }
11
12 // How do I pass an array? You don't know the size here
13 void doSomething(int arr[]) {}
14
15 void doSomething(int arr[size]) {} // NO...
16
17 // Valid option
18 void doSomething(int* arr, const size_t arrSize) {}
19
20 // If you know it's size
21 void doSomething(std::array<int,20> arr) {}
22
23 // If you DON'T know it's size
24 void doSomething(std::vector<int> arr) {}
```

Platform dependency

- The use of `system` can lead to many errors

```
1 // It doesn't work in the Windows command line (CMD)
2 std::system("ls -l > test.txt");
3
4 // Only works in Windows :/
5 std::system("pause");
```

- Some solutions:
  - We can use this class to list all files in a folder:

    `std::filesystem::recursive_directory_iterator`

  - To pause the program execution: `cin.ignore();`

Platform dependency

- If you use old and dependent libraries you can't get **portable** code [4]

```
1       #include <pthread.h>
2
3       void* print_message_function(void* ptr) {
4          char *message;
5          message = (char *) ptr;
6          printf("%s \n", message);
7       }
8
9       int main() {
10         int iret1 = pthread_create(&thread1, NULL, print_message_function,
                (void*) message1);
11      }
```

Platform dependency

- Try to use the own language libraries, or at least updated ones

```cpp
#include <thread>

void doSomething(int number) { ... }
void doSomething2(int& number) { ... }

int main() {

   int number = 0;

   // Pass by value
   std::thread thread1(doSomething, number + 1);

   // Pass by reference
   std::thread thread2(doSomething2, std::ref(number));

   // thread3 is running "doSomething2()", thread2 is no longer a thread
   std::thread thread3(std::move(thread2));

   thread1.join();
   thread3.join();
}
```

Semantic Versioning [7]

Naming: MAJOR.MINOR.PATCH

Example: **1.3.4**

Increment the version when you:

- **MAJOR**: make incompatible API changes
- **MINOR**: add functionality in a backwards-compatible manner
- **PATH**: make backwards-compatible bug fixes

Semantic Versioning

How you should do it:

- Start with the **0.1** version
- While the SW is in development increase the **0.x.y** version
- Use **v1.0.0** for production
- Try not to use really big numbers

New in C++

auto, type inference - [1]

- Basic types

```
auto number = 2; // int
auto width = 0.5; // double
auto name = "daniel"; // const char*
auto name = "daniel"s; // string
```

- More complex ones

```
vector<int> points{1,2,3};

for (vector<int>::iterator it = points.begin(); it != points.end(); ++it) {
   cout << *it << endl;
}
for (auto it = points.begin(); it != points.end(); ++it) {
   cout << *it << endl;
}
```

auto, type inference

- Can be used also in functions with large type names

```
1  std::chrono::time_point<std::chrono::high_resolution_clock> now() {
2     return std::chrono::high_resolution_clock::now();
3  }
4
5  auto now() {
6     return std::chrono::high_resolution_clock::now();
7  }
```

- Other ways

```
1  auto add(int value, double value2) -> decltype(value + value2) {
2     return value + value2;
3  }
4  auto calculateWeight( ... ) -> double {  ...  }
```

Fixed width integers types [C++11] & *brace initializer*

- Main types

```cpp
#include <cstdint>

int8_t, uint8_t // Signed/ Unsigned type with 8 bits
int16_t, uint16_t // 16 bits
int32_t, uint32_t // 32 bits
int64_t, uint64_t // 64 bits
intmax_t, uintmax_t // Largest capacity (usually 64 bits)
size_t // To represent array capacities [Unsigned 64 bits integer]
```

- Correctly initialising types

```cpp
uint64_t bigStuff {643456787654};
int32_t things = {3500000000};
// uint8_t age {-20}; // Compilation error
things += {2000000000};
// things = 1205032704 :(
// you can't avoid overflow...
```

~~NULL~~, nullptr

- NULL can lead to errors!

```
1  void doSomething(int* ptrI) { ... }
2  void doSomething(double* ptrD) { ... }
3  void doSomething(std::nullptr_t nullPointer) { ... }
4
5  int main() {
6
7     int* ptrI;
8     double* ptrD;
9
10    doSomething(ptrI);
11    doSomething(ptrD);
12    doSomething(nullptr); // ambiguous without void f(nullptr_t)
13    //doSomething(NULL); // ambiguous: all functions are candidates
14 }
```

- Assign null

```
1  int* something = NULL; // before C++11: NULL = 0
2  double* foo = nullptr; // C++11: std::nullptr_t
```

Alternative to *raw pointers*. `unique_ptr<int>`

- Automatic Memory Management

```
1  #include <memory>
2
3  using namespace std;
4
5  int* giveMeAnInt() {
6     return new int{100};
7  }
8
9  unique_ptr<int> giveMeACoolInt() {
10    return unique_ptr<int>(new int{100});
11 }
12
13 auto giveMeTheBestInt() {
14    return make_unique<int>(100);
15 }
16
17 int main() {
18    // unique_ptr automatically releases the memory, int* don't
19    auto number = giveMeTheBestInt();
20    cout << *number << endl;
21
22    int* otherNumber = giveMeAnInt();
23    delete otherNumber;
24 }
```

Alternative to *raw pointers*. unique_ptr<int>

- Automatic Memory Management

```
1  #include <iostream>
2  #include <memory>
3
4  using namespace std;
5
6  int main() {
7
8     constexpr size_t arrSize { 1000 };
9
10    unique_ptr<int[]> numbers(new int[arrSize]);
11    //[C++14] auto numbers = make_unique<int[]>(arrSize);
12
13    fill(&numbers[0], &numbers[arrSize], 10);
14
15    for (size_t i = 0; i < arrSize; i++) {
16       cout << numbers[i] << endl;
17    }
18 }
```

C++ Castings

- Normal Castings

```
int number = 100;
float height = (int)number; // C style
height = int(number); // C++ style
number = static_cast<int>(3.14);
// const_cast, dynamic_cast, reinterpret_cast
```

- Implicit and explicit conversions

```
struct Foo {
   // implicit conversion
   operator int() const { return 7; }
   // explicit conversion
   explicit operator int*() const { return nullptr; }
   explicit Foo(size_t elementsCount) { ... }
...
Foo x;
int* q = x; // Error
```

Range-based for loop. I/O manipulators

- Modern for-loop for collections [C++11]

```
1  vector<string> names{"daniel", "manuel"};
2
3  for (const auto& name: names) {
4     cout << names << endl;
5  }
```

- Display `true`/`false` with `bool` and use more `float` precision

```
1  #include <iomanip>
2
3  boolalpha(cout); // or: cout.flags(std::ios_base::boolalpha);
4  // "noboolalpha(cout)" to disable it
5  bool isHidden = false;
6  cout << true << ' ' << isHidden << endl; // true false
7
8  const long double pi = std::acos(-1.L);
9  cout.precision(std::numeric_limits<long double>::digits10 + 1);
10 cout << pi << endl; // 3.141592653589793239
```

numeric_limits and initializer_list

- Numeric limits

```
1 // Formerly [<climits>]
2 INT_MIN // -2147483648
3 LONG_MAX // 9223372036854775807
4
5 // Nowadays [<cstdint>] y [<limits>]
6 INT32_MIN // -2147483648
7 UINT8_MAX // 255
8 numeric_limits<uint16_t>::max() // 65535
9 numeric_limits<float>::lowest() // -3.40282e+38
```

- initializer_list

```
1 class vector {
2    vector( ... ) {}
3    vector(initializer_list ilist) {}
4  ...
5
6 vector numbers = {1,2,3,4}; // vector
7 auto moreNumbers = {1,3,5,7}; // initializer_list
```

Random number [C++11]

- Generate a random number in a range

```
1  #include <vector>
2  #include <random>
3
4  using namespace std;
5
6  int main() {
7
8     vector<int> numbers {1,2,3,4,5,6};
9
10    random_device randomDevice;
11    mt19937 generator(randomDevice());
12
13    uniform_int_distribution<int> randomValue(1, 90);
14    cout << randomValue(generator) << endl;
15 }
```

<algorithm> functions

- Sort, shuffle, fill, copy...

```
1  vector<int> numbers {1,2,3,4,5,6};
2
3  random_device randomDevice;
4  mt19937 generator(randomDevice());
5
6  // Possible output: 6 4 1 3 2 5
7  std::shuffle(numbers.begin(), numbers.end(), generator);
8
9  numbers = {1,2,3,4,5,6};
10
11 vector<int> numbers2 {9,10};
12
13 // numbers result: {9,10,3,4,5,6}
14 copy(numbers2.begin(), numbers2.end(), numbers.begin());
15
16 // Result: 3 4 5 6 9 10
17 sort(numbers.begin(), numbers.end());
18
19 // What if I want to change the order...?
```

Functional Programming

[C++11] Lambda expressions

- Inline functions as parameters

```
// Result: 10 9 6 5 4 3
sort(numbers.begin(), numbers.end(), [](int lhs, int rhs) {
   return lhs ⩾ rhs;
});
```

- Syntax

```
[ capture-list ] ( params ) → ret { body }

capture-list:
[a,&b] - Captures "a" by copy, "b" by reference
[this] - Captures the current object value
[&] - Captures variables by reference
[=] - Captures variables by copy
[] - Captures nothing
```

[C++11] Lambda expressions

- How to pass functions

```
1  #include <functional>
2
3  double operation(double lhs, double rhs,
4           std::function<double(double,double)> operationFunctor) {
5     return operationFunctor(lhs, rhs);
6  }
7
8  int main() {
9
10    double multiply = operation(10, 30.1, [](double lhs, double rhs) {
11       return lhs * rhs;
12    });
13
14    double add = operation(20.1, 70, [](double lhs, double rhs) {
15       return lhs + rhs;
16    });
17
18    double number = 1000;
19    double custom = operation(20.1, 70, [&](double lhs, double rhs){
20       return (number * lhs) + rhs;
21    });
22 }
```

Filter, Map & Reduce (evt::Array) [8]

- Filter

```
1 Array<string> names {"Daniel", "John", "Peter"};
2 auto filtered = names.filter([](const string& str) {
3    return str.size() > 4;
4 }); // ["Daniel", "Peter"]
```

- Map & Reduce

```
1 size_t totalSize = Array<string>({"names", "john"})
2    .map<size_t>([](auto str) {
3       return str.size();
4    }) // [5, 4]
5    .reduce<size_t>([](auto total, auto strSize) {
6       return total + strSize;
7    }); // 9
```

Advanced

Constant expressions (`constexpr`) [5]

- Functions

```
1  constexpr uint64_t factorial(int n) {
2     return n ⩽ 1 ? 1 : (n * factorial(n - 1));
3  }
4
5  int main {
6     // error: static_assert failed "wrong!"
7     static_assert(factorial(2) == 3, "wrong!");
8  }
```

- Variables

```
1  constexpr uint64_t factorialResult = factorial(2);
2  // static_assert(factorialResult == 3, "wrong!");
3
4  constexpr uint64_t other = factorialResult * 2;
5  static_assert(other == 4, "wrong!");
```

Constant expressions (`constexpr`)

- Objects

```
1  class Circle {
2     int x_;
3     int y_;
4     int radius_;
5  public:
6     constexpr Circle (int x, int y, int radius):
7        x_(x), y_(y), radius_(radius) {}
8     constexpr double area() const {
9        return radius_ * radius_ * 3.1415926;
10    }
11    // ...
12 };
13
14 int main() {
15    constexpr auto myCircle = Circle(10,20,30);
16    static_assert(myCircle.area() < 3000, "wrong!");
17 }
```

Constant expressions (constexpr)

- Compile-time check

```
1  #include <type_traits> // is_unsigned, is_object, etc
2
3  template <typename Type>
4  void doSomething(Type something) {
5     if constexpr (std::is_same<Type, int>()) {
6        Type number = something * 10;
7        cout << "int!!: " << number << endl;
8     }
9     else if constexpr (std::is_same<Type, string>()) {
10       Type str = something;
11       cout << "string!!: " << str.length() << endl;
12    }
13 }
14
15 int main() {
16    doSomething(800);
17    doSomething("Daniel"s);
18 }
```

Optional value

- Sometimes we should not (or we can't) return an specific value

```
#include <iostream>
#include <vector>
#include <experimental/optional>

using namespace std::experimental;

size_t indexOf(int number, std::vector<int> numbers) {
   for (size_t i = 0; i < numbers.size(); i++) {
      if (number == numbers[i]) {
         return i;
      }
   }
   return 0; // It's confusing... what if the valid returned position is 0
}

std::optional<size_t> safeIndexOf(int number, std::vector<int> numbers) {
   for (size_t i = 0; i < numbers.size(); i++) {
      if (number == numbers[i]) {
         return i;
      }
   }
   return nullopt;
}
```

Optional value

- The most secure (& elegant) way is by using an optional value

```
int main() {

   vector<int> otherNumbers{};

   size_t index = indexOf(100, otherNumbers);
   // Segmentation fault
   // cout << otherNumbers[index] << endl;

   vector<int> numbers{1,2,3,4,10};
   if (auto index2 = safeIndexOf(100, numbers)) {
      cout << numbers[*index2] << endl;
      // index2.value_or(0)
   }
}
```

Optional value

- Returned value by an array when you access a position

```
1 inline optional<Type> at(const size_t index) const {
2    if (index ⩾ count_) {
3       return nullopt;
4    } else {
5       return this→ values[index];
6    }
7 }
```

std::enable_if<>

- Template type constraints

```cpp
#include <type_traits>

template <typename ArithmeticType,
   typename = typename std::enable_if<
      std::is_arithmetic<ArithmeticType>::value
   >::type>
ArithmeticType doSomething(ArithmeticType number) {
   return number * 100;
}

int main() {

   doSomething(800); // OK

   // candidate template ignored: disabled by 'enable_if'
   doSomething("Daniel"s); // ERROR
}
```

Good practices and tips for classes [6]

- include/Human.hpp

```
1  #pragma once // instead of the classic guards (#ifndef ... )
2
3  #include <cstdint>
4  #include <string_view> // C++17
5  // using namespace std; // Don't use in .h, .hpp files
6
7  namespace evt { // HIGHLY recommended
8     class Human {
9        // Direct variable initialization [c++11]
10       // NEVER use underscores at the beginning of a name
11       uint8_t age_{};
12       std::string_view name_{};
13    public:
14       // constexpr Human(){} // Might or might not make sense
15       constexpr Human(const uint8_t age, const std::string_view& name):
               age_(age), name_(name) {}
16
17       constexpr uint8_t age() const {
18          return this→ age_;
19       }
20       constexpr std::string_view name() const {
21          return this→ name_;
22       }
23    };
24 }
```

Good practices and tips for classes

- Main.cpp

```cpp
#include "include/Human.hpp"

// using namespace evt; (optional)

// Is not advisable to pass complex types by copy ...
// void giveMeTheObject(evt::Human human) { ... }

// ... or by reference (the object could be modified)
// void giveMeTheObject(evt::Human& human) { ... }

// The best way is by constant reference
void giveMeTheObject(const evt::Human& human) { ... }

int main() {
   constexpr evt::Human daniel(10, "Daniel");
   static_assert(daniel.name() == "Daniel", "incorrect!");
}
```

Compilation

Compilation with new C++ versions

- Add the C++ version after `-std=`

```
g++ main.cpp -std=c++11
g++ main.cpp -std=c++14
g++ main.cpp -std=c++17 // o: 1z
```

- *Flags* recomendados

```
-Wall →  Enables important warnings
-Wextra →  Enables more warnings
-O1 / -O2 / -Os / -O3 / -fast →  Optimizations
~~
g++ main.cpp -std=c++14 -Wall -Wextra -Os
```

Makefile example

- Complete Example

```
## FLAGS ##
Libraries = -L lib
Headers = -I include
Sources = main.cpp $(Headers) $(Libraries)
CompilerFlags = -std=c++14 -Os -Wall -Wextra
OutputName = test

## TARGETS ##
all:
   @g++ $(CompilerFlags) $(Sources) -o $(OutputName)

clean:
   @rm -i $(OutputName)*
```

Reference

Reference i

- C++ reference.
  URL: http://en.cppreference.com/.
- Indentation style.
  URL: https://en.wikipedia.org/wiki/Indentation_style.
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- Posix thread (pthread) libraries.
  URL: http://www.yolinux.com/TUTORIALS/LinuxTutorialPosixThreads.html.

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- Alex Allain.
  Constexpr - generalized constant expressions in c++11.
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- lefticus.
  C++ best practices.
  URL: https://www.gitbook.com/book/lefticus/cpp-best-practices/details.
- Tom Preston-Werner.
  Semantic versioning.
  URL: http://semver.org.

Reference iii


Daniel Illescas Romero.
Array.hpp - fast & pretty container for c++.
URL:
`https://github.com/illescasDaniel/Array.hpp`.

Suggestions:

- `http://devdocs.io`
- `https://tex.stackexchange.com`