Modern C++ Programming

13. Code Conventions

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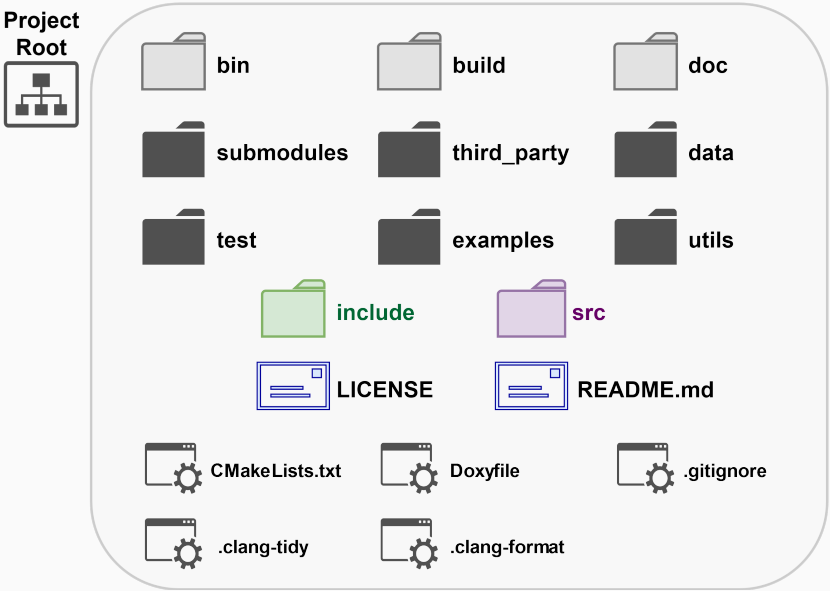
C++ Project Organization

“Common” Project Organization



Fundamental directories

`include` Project *public* header files

`src` Project source files and *private* headers

`test` (or `tests`) Source files for testing the project

Empty directories

`bin` Output executables

`build` All intermediate files

`doc` (or `docs`) Project documentation

Optional directories

`submodules`	Project submodules
`third_party`	(less often `deps`/`external`/`extern`) dependencies or external libraries
`data`	(or `extras`) Files used by the executables or for testing
`examples`	Source files for showing project features
`utils`	(or `tools`, or `script`) Scripts and utilities related to the project
`cmake`	CMake submodules (.cmake)

Project Files

`LICENSE`	Describes how this project can be used and distributed
`README.md`	General information about the project in `Markdown` format *
`CMakeLists.txt`	Describes how to compile the project
`Doxyfile`	Configuration file used by `doxygen` to generate the documentation (see next lecture)
others	`.gitignore`, `.clang-format`, `.clang-tidy`, etc.

---

* `Markdown` is a language with a syntax corresponding to a subset of HTML tags
`github.com/adam-p/markdown-here/wiki/Markdown-Cheatsheet`

Readme and License

README.md

- README template:
  - `Embedded Artistry README Template`
  - `Your Project is Great, So Let's Make Your README Great Too`

LICENSE

- Choose an open source license:
  `choosealicense.com`
- License guidelines:
  `Why your academic code needs a software license`

File extensions

Common C++ file extensions:

- **header** `.h` `.hh` `.hpp` `.hxx`
- **header implementation** `.i.h` `.i.hpp` `-inl.h` `.inl.hpp`
  1. separate implementation from interface for inline functions and templates
  2. keep implementation "inline" in the header file
- **source/implementation** `.c` `.cc` `.cpp` `.cxx`

Common conventions:

- `.h` `.c` `.cc` GOOGLE
- `.hh` `.cc`
- `.hpp` `.cpp`
- `.hxx` `.cxx`

Common Rules

The file should have the same name of the class/namespace that they implement

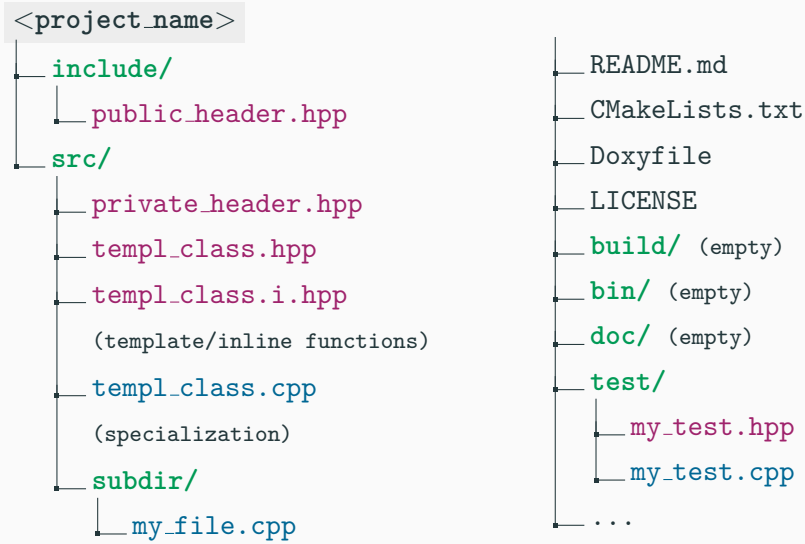
- `class MyClass`
  `my_class.hpp` (`MyClass.hpp`)
  `my_class.i.hpp` (`MyClass.i.hpp`)
  `my_class.cpp` (`MyClass.cpp`)

- `namespace my_np`
  `my_np.hpp` (`MyNP.hpp`)
  `my_np.i.hpp` (`MyNP.i.hpp`)
  `my_np.cpp` (`MyNP.cpp`)

“Common” Project Organization Notes

- Public **header(s)** in `include/`
- **source files**, private **headers**, **header implementations** in `src/` directory
- The **main** file (if present) can be placed in `src/` and called `main.cpp`
- **Code tests**, *unit* and *functional* (see `C++ Ecosystem I` slides), can be placed in `test/`, or **unit tests** can appear in the same directory of the component under test with the same filename and include `.test` suffix, e.g. `my_file.test.cpp`

"Common" Project Organization Example



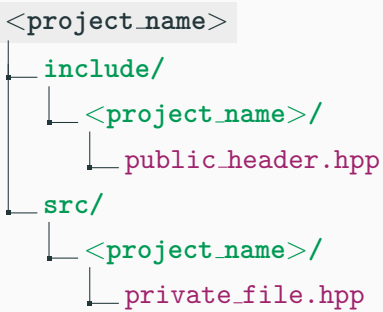
"Common" Project Organization - Improvements

The "common" project organization can be improved by adding the *name of the project* as subdirectory of `include/` and `src/`

This is particularly useful when the project is used as *submodule* (part of a larger project) or imported as an *external library*

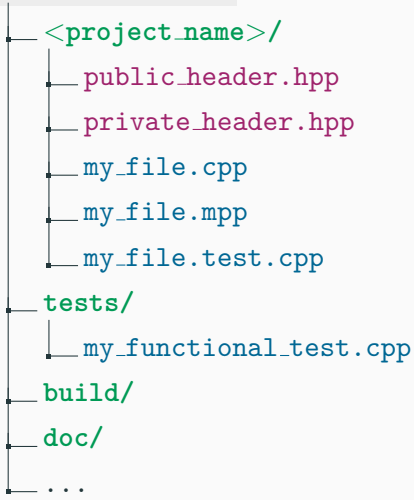
The includes now look like:

```
#include <my_project/public_header.hpp>
```

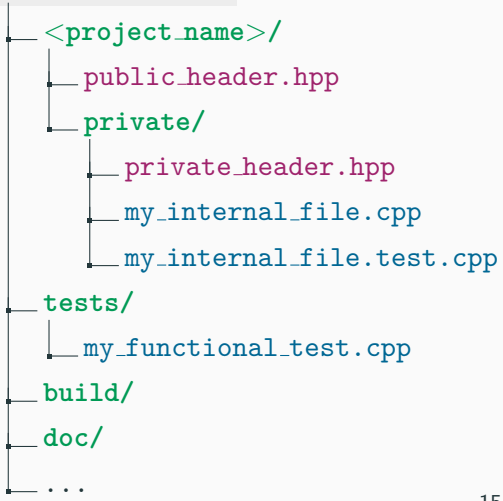


- *Header* and *source files* (or *module interface* and *implementation files*) are next to each other (no `include/` and `src/` split)
- *Headers* are included with `<>` and contain the project directory prefix, for example, `<hello/hello.hpp>` (no need of `""` syntax)
- *Header* and *source file* extensions are `.hpp` / `.cpp` (`.mpp` for module interfaces). No special characters other than `_` and `-` in file names with `.` only used for extensions
- A source file that implements a *module's unit tests* should be placed next to that *module's files* and be called with the module's name plus the `.test` second-level extension
- A project's functional/integration tests should go into the **`tests/`** subdirectory

<project_name> (v1)



<project_name> (v2)



References

- Kick-start your C++! A template for modern C++ projects
- The Pitchfork Layout
- Canonical Project Structure

Coding Styles and Conventions

"One thing people should remember is there is what you can do in a language and what you should do"

Bjarne Stroustrup

Most important rule:

BE CONSISTENT!!

“The best code explains itself”

GOOGLE

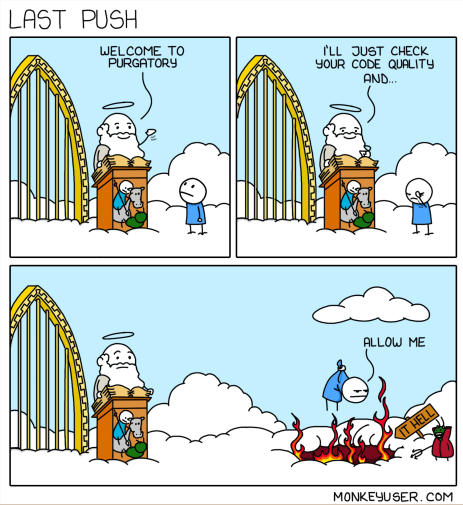
"80% of the lifetime cost of a piece of software goes to maintenance"

Unreal Engine

Code Quality

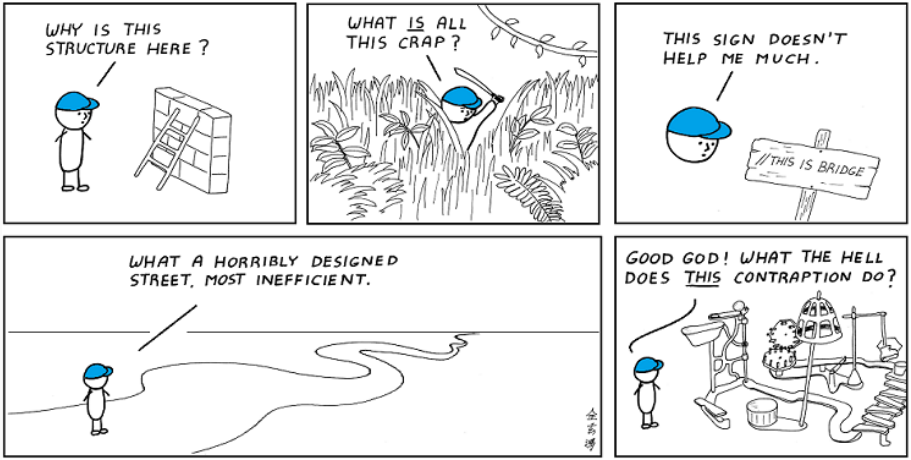
“The worst thing that can happen to a code base is size”

— Steve Yegge



Bad Code

How *my* code looks like for other people?



abstrusegoose.com/432

Coding styles are common guidelines to improve the *readability*, *maintainability*, prevent *common errors*, and make the code more *uniform*

- ***LLVM Coding Standards*** `llvm.org/docs/CodingStandards.html`
- ***Google C++ Style Guide*** `google.github.io/styleguide/cppguide.html`
- ***Webkit Coding Style***
  `webkit.org/code-style-guidelines`
- ***Mozilla Coding Style***
  `firefox-source-docs.mozilla.org`

- ***Chromium Coding Style***
  `chromium.googlesource.com`
  `c++-dos-and-donts.md`
- ***Unreal Engine - Coding Standard***
  `docs.unrealengine.com/en-us/Programming`
- ***μOS++***
  `micro-os-plus.github.io/develop/coding-style`
  `micro-os-plus.github.io/develop/naming-conventions`
- ***High Integrity C++ Coding Standard***
  `www.perforce.com/resources`
- ***CERT C++ Secure Coding***
  `wiki.sei.cmu.edu`

More educational-oriented guidelines

- ***C++ Guidelines***
  `isocpp.github.io/CppCoreGuidelines/CppCoreGuidelines`

Critical system coding standards

- ***Misra - Coding Standard***
  `www.misra.org.uk`
- ***Autosar - Coding Standard***
  `www.misra.org.uk`
- ***Joint Strike Fighter Air Vehicle***
  `www.perforce.com/blog/qac/jsf-coding-standard-cpp`

Legend

※ → **Important!**
Highlight potential code issues such as bugs, inefficiency, and can compromise readability. Should not be ignored

∗ → **Useful**
It is not fundamental, but it emphasizes good practices and can help to prevent bugs. Should be followed if possible

▪ → **Minor / Obvious**
Style choice or not very common issue

#include

※ **Every include must be self-contained**

- include every header you need directly
- do not rely on recursive `#include`
- the project must compile with any include order

LLVM, Google, Unreal, μOS++, Core

∗ **Include as less as possible, especially in header files**

- do not include unneeded headers
- minimize dependencies
- minimize code in headers (e.g. use forward declarations)

LLVM, Google, Chromium, Unreal, Hic, μOS++

Order of #include LLVM, WebKit, Core

(1) Main module/interface header, if exists (it is only one)

- space

(2) Local project includes (in lexicographic order)

- space

(3) System includes (in lexicographic order)

Note: **(2)** and **(3)** can be swapped Google

System includes are self-contained, local includes might not

Project includes LLVM, Google, WebKit, Hic, Core

* Use `""` syntax
* Should be absolute paths from the project include root
  e.g. `#include "directory1/header.hpp"`

System includes LLVM, Google, WebKit, Hic

* Use `<>` syntax
  e.g. `#include <iostream>`

※ **Always use an include guard**

- `macro include guard` vs. `#pragma once`
  - Use `macro include guard` if portability is a very strong requirement — LLVM, Google, Chromium, Core
  - `#pragma once` otherwise — WebKit, Unreal

- `#include` preprocessor should be placed immediately after the header comment and include guard — LLVM

Forward declarations vs. #includes

- *Prefer forward declaration*: reduce compile time, less dependency — Chromium
- *Prefer* `#include` : *safer* — Google

* **Use C++ headers instead of C headers:**
  `<cassert>` instead of `<assert.h>`
  `<cmath>` instead of `<math.h>`, etc.

- **Report at least one function used for each include**
  `<iostream>  // std::cout, std::cin`

```
#include "my_class.hpp"            // MyClass
                                   [ blank line ]
#include "my_dir/my_headerA.hpp"   // npA::ClassA, npB::f2()
#include "my_dir/my_headerB.hpp"   // np::g()
                                   [ blank line ]
#include <cmath>                   // std::fabs()
#include <iostream>                // std::cout
#include <vector>                  // std::vector
```

Macro and Preprocessing

- **Avoid defining macros**, especially in headers — Google
  - Do not use macro for enumerators, constants, and functions — WebKit, Google
- **Use a prefix for all macros** related to the project `MYPROJECT_MACRO` — Google, Unreal
- `#undef` **macros wherever possible** — Google
  - Even in the source files if *unity build* is used (merging multiple source files to improve compile time)

※ **Always use curly brackets for multi-line macro**

```
#define MACRO       \
{                   \
    line1;          \
    line2;          \
}
```

※ **Always put macros after** `#include` statements HIC

- Put macros outside namespaces as they don't have a scope

- Close `#endif` with the respective condition of the first `#if`

```
#if defined(MACRO)
    ...
#endif // defined(MACRO)
```

- The hash mark that starts a preprocessor directive should always be at the beginning of the line GOOGLE

```
#if defined(MACRO)
#   define MACRO2
#endif
```

- Place the `\` rightmost for multi-line macro

```
#define MACRO2                  \
    macro_def...
```

- Prefer `#if defined(MACRO)` instead of `#ifdef MACRO`

  Improve readability, help grep-like utils, and it is uniform with multiple conditions

```
#if define(MACRO1) && defined(MACRO2)
```

namespace

※ **Avoid `using namespace`-directives at global scope**
LLVM, Google, WebKit, Unreal, Hic, μOS++

∗ **Limit `using namespace`-directives at local scope** and prefer explicit namespace specification
Google, WebKit, Unreal

※ **Always place code in a namespace** to avoid *global namespace pollution*
Google, WebKit

* **Avoid *anonymous* namespaces in headers** GOOGLE, CERT

- `anonymous namespace` vs. `static`
  - Prefer `anonymous namespaces` instead of `static` variables/functions
    GOOGLE, CORE
  - Use `anonymous namespaces` only for inline class declaration, `static` otherwise
    LLVM, STATIC

* **Anonymous namespaces and source files:**
  Items local to a source file (e.g. `.cpp`) file should be wrapped in an anonymous namespace. While some such items are already file-scope by default in C++, not all are; also, shared objects on Linux builds export all symbols, so anonymous namespaces (which restrict these symbols to the compilation unit) improve function call cost and reduce the size of entry point tables CHROMIUM, CORE, HIC

- The content of namespaces is not indented — LLVM, Google, WebKit

```
namespace ns {

void f() {}

}
```

- Close namespace declarations — LLVM, Google

```
} // namespace <namespace_identifier>
} // namespace (for anonymous namespaces)
```

Variables and Arithmetic Types

※ **Place a variable in the *narrowest scope* possible, and *always initialize* variables in the declaration**

Google, Isocpp, Mozilla, Hic, *mu*OS, Cert

∗ **Avoid static (non-const) global variables** LLVM, Google, Core, Hic

- Use assignment syntax `=` when performing "simple" initialization Chromium

※ **Use fixed-width integer type** (e.g. `int64_t`, `int8_t`, etc.)
Exception: `int` Google, `int/unsigned` Unreal

* `size_t` vs. `int64_t`
- Use `size_t` for object and allocation sizes, object counts, array and pointer offsets, vector indices, and so on. (integer overflow behavior for signed types is undefined) Chromium
- Use `int64_t` instead of `size_t` for object counts and loop indices Google

▪ Use brace initialization to convert *constant* arithmetic types (narrowing) e.g. `int64_t{MyConstant}` Google

* Use `true`, `false` for boolean variables instead numeric values `0, 1` WebKit

- ※ **Do not shift $\ll$ signed operands** HIC, CORE, μOS
- ※ **Do not directly compare floating point** `==`, $<$, etc. HIC
- ※ **Use signed types for arithmetic** CORE

Style:

- Use floating-point literals to highlight floating-point data types, e.g. `30.0f`
  WEBKIT (opposite)
- Avoid redundant type, e.g. `unsigned int`, `signed int` WEBKIT

Functions

* **Limit overloaded functions**. Prefer default arguments GOOGLE, CORE

* **Split up large functions** into logical sub-functions for improving readability and compile time UNREAL, GOOGLE, CORE

- Use `inline` only for small functions (e.g. < 10 lines) GOOGLE, HIC

※ **Never return pointers for new objects**. Use `std::unique_ptr` instead CHROMIUM, CORE

```
int*                 f() { return new int[10]; } // wrong!!
std::unique_ptr<int> f() { return new int[10]; } // correct
```

- ※ **Prefer pass `by-reference` instead `by-value`** except for raw arrays and built-in types — WebKit
- ∗ **Pass function arguments by `const` *pointer* or *reference*** if those arguments are not intended to be modified by the function — Unreal
- ∗ **Do not pass `by-const-value` for built-in types**, especially in the declaration (same signature of `by-value`)
- ∗ **Prefer returning values** rather than output parameters — Google
- ∗ **Do not declare functions with an excessive number of parameters**. Use a wrapper structure instead — Hic, Core

- Prefer `enum` to `bool` on function parameters
- All parameters should be aligned if they do not fit in a single line (especially in the declaration) GOOGLE

```
void f(int         a,
       const int* b);
```

- Parameter names should be the same for declaration and definition CLANG-TIDY
- Do not use `inline` when declaring a function (only in the definition) LLVM
- Do not separate declaration and definition for template and inline functions GOOGLE

Structs and Classes

* **Use a `struct` only for passive objects that carry data; everything else is a `class`** Google

※ **Objects are fully initialized by constructor call** Google, WebKit, Core

* **Prefer in-class initializers to member initializers** Core

* **Initialize member variables in the order of member declaration** Core, Hic

- Use delegating constructors to represent common actions for all constructors of a class Core

* **Do not define implicit conversions**. Use the `explicit` keyword for conversion operators and constructors GOOGLE, CORE

* **Prefer `= default` constructors** over user-defined / implicit default constructors MOZILLA, CHROMIUM, CORE, HIC

* **Use `= delete` for mark deleted functions** CORE, HIC

- Mark *destructor* and *move constructor* `noexcept` CORE

- Use braced initializer lists for aggregate types `A{1, 2}` LLVM, Google
- Do not use braced initializer lists `{}` for constructors (at least for containers, e.g. `std::vector`). It can be confused with `std::initializer_list` LLVM
- Prefer braced initializer lists `{}` for constructors to clearly distinguish from function calls and avoid implicit narrowing conversion

※ **Avoid virtual method calls in constructors** GOOGLE, CORE, CERT

※ **Default arguments are allowed only on *non-virtual* functions**
GOOGLE, CORE, HIC

∗ **A class with a *virtual function* should have a *virtual or protected destructor***
(e.g. interfaces and abstract classes) CORE

- Does not use `virtual` with `final/override` (implicit)

see A hole in Clang's -Wsuggest-override

* ***Multiple inheritance*** **and** ***virtual inheritance*** **are discouraged**

GOOGLE, CHROMIUM

* **Prefer** ***composition*** **to** ***inheritance***

GOOGLE

* **A polymorphic class should suppress copying**

CORE

- **Declare class data members in special way***. Examples:
  - Trailing underscore (e.g. `member_var_`) — Google, μOS, Chromium
  - Leading underscore (e.g. `_member_var`) — .NET
  - Public members (e.g. `m_member_var`) — WebKit

  Personal Comment: Prefer `_member_var` as I read left-to-right and is less invasive

- Class inheritance declarations order: `public`, `protected`, `private` — Google, μOS
- First data members, then function members
- If possible, **avoid** `this->` keyword

* It helps to keep track of class variables and local function variables

* The first character is helpful in filtering through the list of available variables

```
struct A {        // passive data structure
    int   x;
    float y;
};

class B {
public:
    B();
    void public_function();

protected:
    int  _a;                    // in general, it is not public in derived classes
    void _protected_function(); // "protected_function()" is not wrong
                                // it may be public in derived classes
private:
    int   _x;
    float _y;

    void _private_function();
};
```

- In the constructor, each member should be indented on a separate line, e.g.

WebKit, Mozilla

```
A::A(int x1, int y1, int z1) :
    x{x1},
    y{y1},
    z{z1} {
```

Control Flow

※ **Avoid redundant control flow** (see next slide)

- Do not use `else` after a `return` / `break`

  LLVM, Mozilla, Chromium, WebKit

- Avoid `return true/return false` pattern
- Merge multiple conditional statements

∗ **Prefer `switch` to multiple `if`-statement** Core

∗ **Avoid `goto`** μOS, Core

▪ Avoid `do-while` loop Core

▪ Do not use default labels in fully covered switches over enumerations LLVM

```
if (condition) {    // wrong!!
    < code1 >
    return;
}
else // <-- redundant
    < code2 >
//--------------------------
if (condition) {    // Corret
   < code1 >
   return;
}
< code2 >
```

```
if (condition)    // wrong!!
    return true;
else
    return false;
//------------------------
return condition; // Corret
```

- Use *early exits* (`continue` , `break` , `return`) to simplify the code LLVM

```
for (<condition1>) {    // wrong!!
    if (<condition2>)
        ...
}
//-----------------------------
for (<condition1>) {    // Correct
    if (!<condition2>)
        continue;
     ...
}
```

- Turn predicate loops into predicate functions LLVM

```
bool var = ...;
for (<loop_condition1>) { // should be an external
   if (<condition2>) {    // function
       var = ...
       break;
   }
```

※ **Tests for `null/non-null`, and `zero/non-zero` should all be done with equality comparisons**

Core, WebKit
(opposite) Mozilla

```
if (!ptr)   // wrong!!
    return;
if (!count) // wrong!!
    return;
```

```
if (ptr == nullptr) // correct
    return;
if (count == 0)     // correct
    return;
```

※ **Prefer `(ptr == nullptr)` and `x > 0` over `(nullptr == ptr)` and `0 < x`**

Chromium

- Do not compare to `true/false`, e.g. `if (x == true)`

※ **Do not mix `signed` and `unsigned` types** HIC

∗ **Prefer signed integer for loop indices** (better 64-bit) CORE

- Prefer `empty()` method over `size()` to check if a container has no items
  MOZILLA
- Ensure that all statements are reachable HIC

∗ **Avoid *RTTI* (`dynamic_cast`) or *exceptions*** if possible
LLVM, GOOGLE, MOZILLA

※ **The `if` and `else` keywords belong on separate lines**

```
if (c1) <statement1>; else <statement2> // wrong!!
```

GOOGLE, WEBKIT

∗ Multi-lines statements and complex conditions require curly braces GOOGLE

```
if (c1 && ... &&
    c2 && ...) {  // correct
    <statement>
}
```

▪ Curly braces are not required for single-line statements (but allowed)
(`for, while, if`) GOOGLE, WEBKIT

```
if (c1) {  // not mandatory
    <statement>
}
```

Modern C++ Features

Use modern C++ features wherever possible

* `static_cast` `reinterpret_cast` instead of *old style cast* `(type)`
  GOOGLE, μOS, HIC

* **Do not define implicit conversions**. Use the `explicit` keyword for conversion operators and constructors
  GOOGLE, μOS

- **Use `constexpr` instead of *macro*** — Google, WebKit
- **Use `using` instead `typedef`**
- **Prefer `enum class` instead of plain `enum`** — Unreal, μOS
- **`static_assert` compile-time assertion** — Unreal, Hic
- **`lambda` expression** — Unreal
- **`move` semantic** — Unreal
- **`nullptr` instead of `0` or `NULL`**

LLVM, Google, Unreal, WebKit, Mozilla, Hic, μOS

※ **Use *range-based for loops* whatever possible**

LLVM, WebKit, Unreal, Core

※ **Use `auto`** to avoid type names that are noisy, obvious, or unimportant

```
auto array = new int[10];
auto var   = static_cast<int>(var);
```

lambdas, iterators, template expressions

LLVM, Google
Unreal (only)

∗ **Use `[[deprecated]]` / `[[noreturn]]` / `[[nodiscard]]`** to indicate deprecated functions / that do not return / result should not be discarded

▪ Avoid `throw()` expression. Use `noexcept` instead

Hic

※ **Always use `override/final` function member keyword**

WebKit, Mozilla, Unreal, Chromium, Hic

∗ **Use braced *direct-list-initialization* or *copy-initialization*** for setting default data member value. Avoid initialization in constructors if possible — Unreal

```
struct A {
    int x = 3;   // copy-initialization
    int x { 3 }; // direct-list-initialization (best option)
};
```

∗ Use `= default` constructors

∗ Use `= delete` to mark deleted functions

- Prefer *uniform initialization* when it cannot be confused with `std::initializer_list` — Chromium

Maintainability

※ **Avoid complicated template programming** GOOGLE

∗ **Write self-documenting code**

e.g. `(x + y - 1) / y` → `ceil_div(x, y)` UNREAL

∗ **Use symbolic names** instead of literal values in code HIC

```
double area1 = 3.14 * radius * radius; // wrong!!
```

```
constexpr auto Pi    = 3.14; // correct
double         area2 = Pi * radius * radius;
```

※ **Do not use `reinterpret_cast` or `union` for type punning** Core, Hic

※ **Enforce const-correctness** Unreal

- but **don't `const` all the things**
  - Pass by-`const` value: almost useless (copy), ABI break
  - `const` return: useless (copy)
  - `const` data member: disable assignment and copy constructor
  - `const` local variables: verbose, rarely effective

※ **Do not overload operators with special semantics `&&`, `^`** Hic

※ **Use `assert` to document preconditions and assumptions** LLVM

* **Address compiler warnings**. Compiler warning messages mean something is wrong UNREAL

* **Ensure ISO C++ compliant code** and avoid non-standard extension, deprecated features, or asm declarations, e.g. `register`, `__attribute__` HIC

* **Prefer** `sizeof(variable/value)` instead of `sizeof(type)` GOOGLE

* **Prefer core-language features** over library facilities, e.g. `char` vs. `std::byte`

Naming

"Beyond basic mathematical aptitude, the difference between good programmers and great programmers is verbal ability"

Marissa Mayer

- ※ **Use whole words**, except in the rare case where an abbreviation would be more canonical and easier to understand, e.g. `tmp` WebKit
- ∗ **Avoid short and very long names**. Remember that the average word length in English is 4.8
- ∗ The length of a variable should be **proportional to the size of the scope** that contains it. For example, `i` is fine within a loop scope.

※ **Do not use reserved names** CERT

- double underscore followed by any character `__var`
- single underscore followed by uppercase `_VAR`

- Use common loop variable names
  - `i, j, k, l` used in order
  - `it` for iterators

Naming Conventions for Functions

* **Should be descriptive verb** (as they represent actions) WebKit
* **Functions that return boolean values should start with boolean verbs**, like `is, has, should, does` μOS
  - Use `set` prefix for modifier methods WebKit
  - Do not use `get` for observer methods (`const`) without parameters, e.g. `size()` WebKit

Style Conventions

Camel style Uppercase first word letter (sometimes called *Pascal style* or *Capital case*) (less readable, shorter names)

```
CamelStyle
```

Snake style Lower case words separated by single underscore (good readability, longer names)

```
snake_style
```

Macro style Upper case words separated by single underscore (sometimes called *Screaming style*) (best readability, longer names)

```
MACRO_STYLE
```

Variable Variable names should be nouns

- Camel style e.g. `MyVar` — LLVM, Unreal
- Snake style e.g. `my_var` — Google, Std, μOS

Constant

- Camel style + `k` prefix, e.g. `kConstantVar` — Google, Mozilla
- Macro style e.g. `CONSTANT_VAR` — WebKit, OpenStack

Enum

- Camel style + `k`
  e.g. `enum MyEnum { kEnumVar1, kEnumVar2 }` — Google
- Camel style
  e.g. `enum MyEnum { EnumVar1, EnumVar2 }` — LLVM, WebKit

Namespace
- Snake style, e.g. `my_namespace` — Google, LLVM, Std
- Camel style, e.g. `MyNamespace` — WebKit

Typename Should be nouns
- Camel style (including `classes`, `structs`, `enums`, `typedefs`, etc.) e.g. `HelloWorldClass` — LLVM, Google, WebKit
- Snake style — μOS (class), Std

Macro Macro style, e.g. `MY_MACRO` — Google, Std, LLVM

File
- Snake style (`my_file`) — Google
- Camel style (`MyFile`), could lead Windows/Linux conflicts — LLVM

Function Names

- Lowercase Camel style, e.g. `myFunc()` — LLVM
- Uppercase Camel style for standard functions
  e.g. `MyFunc()` — Google, Mozilla, Unreal
- Snake style for cheap functions, e.g. `my_func()` — Google, Std

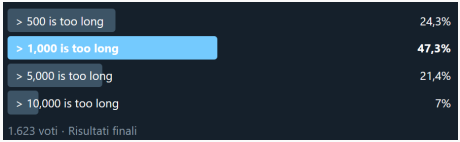
Personal Comment: *Macro style* needs to be used only for macros to avoid subtle bugs. I adopt *snake style* for almost everything as it has the best readability. On the other hand, I don't want to confuse `typenames` and variables, so I use *camel style* for the former ones. Finally, I also use *camel style* for compile-time constants as they are very relevant in my work and I need to identify what is evaluated at compile-time easily

Readability and Formatting

- **Write all code in English**, comments included
- **Limit line length (width)** to be at most **80 characters** long (or 100, or 120) → help code view on a terminal LLVM, Google, Mozilla, μOS

  Personal Comment: I was tempted several times to use a line length > 80 to reduce the number of lines, and therefore improve the readability. Many of my colleagues use split-screens or even the notebook during travels. A small line length is a good compromise for everyone.

- Do not write excessive long file



- `Is the 80 character limit still relevant in times of widescreen monitors?`

※ **Use always the same indentation style**

- tab → 2 spaces — Google, Mozilla, Hic, μOS
- tab → 4 spaces — LLVM, Webkit, Hic, μOS
- (actual) tab = 4 spaces — Unreal

Personal Comment: I worked on projects with both two and four-space tabs. I observed less bugs due to indentation and better readability with four-space tabs. 'Actual tabs' breaks the line length convention and can introduce tabs in the middle of the code, producing a very different formatting from the original one

※ **Separate commands, operators, etc., by a space** LLVM, Google, WebKit

```
if(a*b<10&&c)          // wrong!!
if (a * c < 10 && c)   // correct
```

* **Prefer consecutive alignment**

```
int           var1     = ...
long long int longvar2 = ...
```

- Minimize the number of empty rows
- Do not use more than one empty line

GOOGLE

* **Use always the same style for braces**
  - Same line, aka `Kernigham & Ritchie` — WebKit (func. only), Mozilla
  - Its own line, aka `Allman` — Unreal, WebKit (function) Mozilla (class)

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

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

Personal Comment: C++ is a very verbose language. "Same line" convention helps to keep the code more compact, improving the readability

- Declaration of pointer/reference variables or arguments may be placed with the asterisk/ampersand *adjacent* to either the *type* or to the *variable name* for all symbols in the same way — Google
  - `char* c;` — WebKit, Mozilla, Chromium, Unreal
  - `char *c;`
  - `char * c;`
- The same concept applies to `const`
  - `const int*` *West notation*
  - `int const*` *East notation*

Reduce Code Verbosity

- Use the **short name version** of built-in types, e.g.
  `unsigned` instead of `unsigned int`
  `long long` instead of `long long int`

- **Don't** `const` **all the things**. Avoid Pass by-`const`, `const` return, `const` data member, `const` local variables

- **Use same line braces** for functions and structures

- **Minimize the number of empty rows**

Other Issues

* **Use the same line ending** (e.g. `'\n'`) for all files — Mozilla, Chromium
* **Do not use UTF characters* for portability**, prefer ASCII
* If UTF is needed, **prefer `UTF-8` encoding for portability** — Chromium
- Declare each identifier on a separate line in a separate declaration — Hic, Misra
- Never put trailing white space or tabs at the end of a line — Google, Mozilla
- Only one space between statement and comment — WebKit
- Close files with a blank line — Mozilla, Unreal

* `Trojan Source attack for introducing invisible vulnerabilities`

Code Documentation

* **Any file start with a license** LLVM, Unreal

* **Each file should include**
  - `@author` name, surname, affiliation, email
  - `@date` e.g. year and month
  - `@file` the purpose of the file

  in both header and source files

- Document each entity (functions, classes, namespaces, definitions, etc.) and only in the declarations, e.g. header files

- The first sentence (beginning with `@brief`) is used as an abstract
- Document the input/output parameters `@param[in]`, `@param[out]`, `@param[in,out]`, return value `@return`, and template parameters `@tparam`
- Document ranges, impossible values, status/return values meaning — Unreal
- Use always the same style of comment
- Use anchors for indicating special issues: `TODO`, `FIXME`, `BUG`, etc. — WebKit, Chromium

- Be aware of the comment style, e.g.
  - Multiple lines

```
/**
 * comment1
 * comment2
 */
```

  - Single line

```
/// comment
```

- Prefer `//` comment instead of `/* */` → allow string-search tools like `grep` to identify valid code lines — Hic, μOS

- μOS++ Doxygen style guide link
- Teaching the art of great documentation, by Google