Modern C++ Programming

10. Debugging and Tools

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2018, v1.0

Agenda

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Debugging

Assertions

Assertions are intended to be used as a means of detecting programming bugs. Assertions represent an *invariant* in the code

Error/Exceptions can indicate "exceptional" conditions (invalid user input, missing files, etc.)

- **Exceptions** are more robust but slower
- **Error** are fast but difficult to handle in complex programs

```
#include <cassert>   // <-- needed
int sqrt(int value) {
    int ret = sqrt_internal(value);
    assert(ret >= 0 && (ret == 0 || ret == 1 || ret < value));
    return ret;
}
```

Assertions may slow down the execution. They can be disable by define the `NDEBUG` macro

```
#define NDEBUG
```

Execution Debugging (gdb) - Introduction 1/7

How to compile for debugging:

```
g++ [-g] -ggdb3 <program.cpp> -o program
```

-g Enable debugging

- stores the *symbol table information* in the executable
- for some compilers, it may disable certain optimizations
- slow down the compilation phase

-ggdb3 Produces debugging information specifically intended for gdb

- the last number produces extra debugging information, for example: including macro definitions
- in general, it is not portable across different compiler (supported by gcc, clang)

How to run the debugger:

```
gdb --args ./program <args...>
```

Execution Debugging (gdb) - Breakpoints/Watchpoints 2/7

Command	Abbr.	Description
breakpoint <*file*>:<*line*>	**b**	insert a breakpoint in a specific line
breakpoint <*function_name*>	**b**	insert a breakpoint in a specific function
breakpoint <*ref*> **if** <*condition*>	**b**	insert a breakpoint with a conditional statement
delete	**d**	delete all breakpoints or watchpoints
delete <*breakpoint_number*>		delete a specific breakpoint
clear [*function_name*/*line_number*]		delete a specific breakpoint
enable/disable <*breakpoint_number*>		enable/disable a specific breakpoint
watch <*expression*>		stop execution when the value of `expression` changes (variable, comparison, etc.)

Execution Debugging (`gdb`) - Control Flow 3/7

Command	Abbr.	Description
`run`	`r`	run the program
`continue`	`c`	continue the execution
`finish`	`f`	continue until the end of the current function
`step`	`s`	execute next line of code (follow function calls)
`next`	`n`	execute next line of code
`until` <*program_point*>		continue until reach line number, function name, address, etc.
`CTRL+C`		stop the execution (not quit)
`quit`	`q`	exit

Execution Debugging (gdb) - Stack and Info

Command	Abbr.	Description
list	**l**	print code
list <*function or #start,#end*>	**l**	print function/range code
up	**u**	move up in the call stack
down	**d**	move down in the call stack
backtrace	**bt**	prints stack backtrace (call stack)
backtrace <*full*>	**bt**	print values of local variables
help [<*command*>]	**h**	show help about command
info <*args/breakpoints/ watchpoints/registers/local*>		show information about program arguments/breakpoints/watchpoints/ registers/local variables

Execution Debugging (gdb) - Print

Command	Abbr.	Description
print <*variable*>	p	print variable
print/h <*variable*>	p/h	print variable in hex
print/nb <*variable*>	p/nb	print variable in binary (n bytes)
print/w <*address*>	p/w	print address in binary
p /s <*char array/address*>		print char array
p *array_var@n		print n array elements
p (int[4])<*address*>		print four elements of type int
p *(char**)&<*std::string*>		print std::string

Execution Debugging (gdb) - Disasseble

Command	Description
`disasseble` <*function_name*>	print variable
`disasseble` <*0xStart,0xEnd addr*>	print variable
`nexti` <*variable*>	execute next line of code (follow function calls)
`stepi` <*variable*>	execute next line of code
`x`/nfu <*address*>	examine address n number of elements, f format (**d**: int, **f**: float, etc.), u data size (**b**: byte, **w**: word, etc.)

Execution Debugging (`gdb`) - Notes 7/7

The debugger automatically stops when:

- breakpoint (by using the debugger)
- assertion fail
- segmentation fault
- trigger software breakpoint (e.g. SIGTRAP on Linux)
  `https://github.com/scottt/debugbreak`

Full story:
`https://www.yolinux.com/TUTORIALS/GDB-Commands.html`
(it also contains a script to *de-referencing* STL Containers)

gdb reference card V5 link

Memory Debugging (valgrind) 1/3

valgrind is a tool suite to automatically detect many memory management and threading bugs

Website: https://valgrind.org

Basic usage:

- compile with `-g`
-
```
valgrind ./program <args...>
```

Output example 1:

```
==60127== Invalid read of size 4             !!out-of-bound access
==60127==    at 0x100000D9E: f(int) (test01.C:86)
==60127==    by 0x100000C22: main (test01.C:40)
==60127==  Address 0x10042c148 is 0 bytes after a block of size 40 alloc'd
==60127==    at 0x1000161EF: malloc (vg_replace_malloc.c:236)
==60127==    by 0x100000C88: f(int) (test01.C:75)
==60127==    by 0x100000C22: main (test01.C:40)
```

Memory Debugging (valgrind) 2/3

Output example 2:

```
!!memory leak
==19182== 40 bytes in 1 blocks are definitely lost in loss record 1 of 1
==19182==    at 0x1B8FF5CD: malloc (vg_replace_malloc.c:130)
==19182==    by 0x8048385: f (a.c:5)
==19182==    by 0x80483AB: main (a.c:11)

==60127== HEAP SUMMARY:
==60127==     in use at exit: 4,184 bytes in 2 blocks
==60127==   total heap usage: 3 allocs, 1 frees, 4,224 bytes allocated
==60127==
==60127== LEAK SUMMARY:
==60127==    definitely lost: 128 bytes in 1 blocks    !!memory leak
==60127==    indirectly lost: 0 bytes in 0 blocks
==60127==      possibly lost: 0 bytes in 0 blocks
==60127==    still reachable: 4,184 bytes in 2 blocks  !!not deallocated
==60127==         suppressed: 0 bytes in 0 blocks
```

Memory Debugging (`valgrind`) 3/3

Advanced use flags:

- `--leak-check=full` print details for each "`definitely lost`" or "`possibly lost`" block, including where it was allocated
- `--show-leak-kinds=all` to combine with `--leak-check=full`. Print all leak kinds
- `--track-fds=yes` list open file descriptors on exit (not closed)
- `--track-origins=yes` tracks the origin of uninitialized values (very slow execution)

```
valgrind --leak-check=full --show-leak-kinds=all
         --track-fds=yes --track-origins=yes ./program <args...>
```

Track stack usage:

```
valgrind --tool=drd --show-stack-usage=yes ./program <args...>
```

Clang Sanitazers 1/2

Address Sanitazer is a memory error detector (out-of-bounds, use-after-free, etc.). It relies on code instrumentation at compile-time. Similar to valgrind but faster (2X slowdown)

Website: https://clang.llvm.org/docs/AddressSanitizer.html

```
clang++ -O1 -g -fsanitize=address -fno-omit-frame-pointer <program>
```

`-O1` disable inlining

`-g` generate symbol table

Memory Sanitazer is detector of uninitialized reads. It relies on code instrumentation at compile-time. Similar to valgrind but faster (3X slowdown)

Website: https://clang.llvm.org/docs/MemorySanitizer.html

```
clang++ -O1 -g -fsanitize=memory -fno-omit-frame-pointer <program>
```

Clang Sanitazers 2/2

LeakSanitizer is a run-time memory leak detector. It relies on code instrumentation at compile-time. Similar to valgrind but faster

Website: https://clang.llvm.org/docs/LeakSanitizer.html

```
clang++ -O1 -g -fsanitize=leak -fno-omit-frame-pointer <program>
```

UndefinedBehaviorSanitizer is a undefined behavior detector (signed integer overflow, enumerated not in range, etc.). It relies on code instrumentation at compile-time. Not included in valgrind

Website: https://clang.llvm.org/docs/UndefinedBehaviorSanitizer
html

```
clang++ -O1 -g -fsanitize=undefined -fno-omit-frame-pointer <program>
```

Demangling

Name mangling is a technique used to solve various problems caused by the need to resolve unique names

Transforming C++ ABI (Application binary interface) identifiers into the original source identifiers is called **demangling**

Example (linking error):

```
_ZNSt13basic_filebufIcSt11char_traitsIcEED1Ev
```

After demangling:

```
std::basic_filebuf<char, std::char_traits<char> >::∼basic_filebuf()
```

How to demangle:

-
  ```
  make | c++filt | grep -P '`.*(?=))'
  ```
- Online Demangler: `https://demangler.com`

How to Debug Common Errors

Segmentation fault/assertion fail

- `gdb`
- `valgrind`
- `Segmentation fault when just entered in a function` → `stack overflow`

Double free or corruption

- `valgrind`

Infinite execution

- `gdb` + (`CTRL + C`)

Incorrect results

- `valgrind` + `assertion` + `gdb` + `UndefinedBehaviorSanitizer`

CMake

CMake

`CMake` is an *open-source*, *cross-platform* family of tools designed to build, test and package software

Website: `https://cmake.org`

`CMake` is used to control the software compilation process using simple platform and compiler independent configuration files, and *generate* native `makefiles` and workspaces that can be used in the compiler environment of your choice

`CMake` features:

- Turing complete language
- Multi-platform (Windows, Linux, etc.)
- Open-Source
- Generate: `makefiles, ninja, etc.`
- Supported by many IDE: `Visual Studio, Eclipse, etc.`

CMake - Example 1 2/6

CMakeLists.txt minimal example:

```
PROJECT(my_project)                     # project name
CMAKE_MINIMUM_REQUIRED(VERSION 3.5)     # minimum version

ADD_EXECUTABLE(out_program program.cpp) # compile command
```

```
$cmake .     # CMakeLists.txt directory
$make        # makefile automatically generated
Scanning dependencies of target out_program
[100%] Building CXX object CMakeFiles/out_program.dir/program.cpp.o
Linking CXX executable out_program
[100%] Built target out_program
```

CMake - Example 2 3/6

```
PROJECT(my_project)                         # project name
CMAKE_MINIMUM_REQUIRED(VERSION 3.5)         # minimum version

# verify if a compiler flag is supported
CHECK_CXX_COMPILER_FLAG("-std=c++14" COMPILER_SUPPORTS_CXX14)
IF (COMPILER_SUPPORTS_CXX14)             # if statement
    ADD_COMPILE_OPTIONS("-std=c++14")    # if supported add the flag
ELSE()                                   # else statement
    # if not supported exit and print message
    MESSAGE(FATAL_ERROR "Compiler ${CMAKE_CXX_COMPILER} has no C++14"
                        "support.")
ENDIF()                                  # end if statement

# indicate include directory
INCLUDE_DIRECTORIES("${PROJECT_SOURCE_DIR}/include")
# find all .cpp file in src/ directory
FILE(GLOB_RECURSE SRCS ${PROJECT_SOURCE_DIR}/src/*.cpp)

ADD_EXECUTABLE(out_program ${SRCS}) # compile all *.cpp file
```

CMake - Example 3 4/6

```
PROJECT(my_project)                         # project name
CMAKE_MINIMUM_REQUIRED(VERSION 3.5)         # minimum version

IF (CMAKE_BUILD_TYPE STREQUAL "Debug")      # "Debug" mode
    ADD_COMPILE_OPTIONS("-g")
    ADD_COMPILE_OPTIONS("-O1")
    IF (CMAKE_COMPILER_IS_GNUCXX)           # if compiler is gcc
        ADD_COMPILE_OPTIONS("-ggdb3")
    ELSEIF (CMAKE_CXX_COMPILER_ID EQUAL "Clang") # if compiler is clang
        ADD_COMPILE_OPTIONS("-fsanitize=address")
        ADD_COMPILE_OPTIONS("-fno-omit-frame-pointer")
    ENDIF()
ELSEIF (CMAKE_BUILD_TYPE STREQUAL "Release") # "Release" mode
    ADD_COMPILE_OPTIONS("-O2")
ENDIF()

ADD_EXECUTABLE(out_program program.cpp)
```

```
$cmake -DCMAKE_BUILD_TYPE=Debug .
```

CMake - Example 4

```
PROJECT(my_project)                  # project name
CMAKE_MINIMUM_REQUIRED(VERSION 3.5)  # minimum version

FIND_PACKAGE(Boost 1.36.0 REQUIRED)  # compile only if Boost library
                                     # is found
IF (Boost_FOUND)
    INCLUDE_DIRECTORIES("${PROJECT_SOURCE_DIR}/include"
                        Boost_INCLUDE_DIRS) # automatic variable
ELSE()
    MESSAGE(FATAL_ERROR "Boost Lib not found")
ENDIF()

ADD_CUSTOM_TARGET(rm                                 # makefile target name
                  COMMAND rm -rf *.o      # real command
                  COMMENT "Clear build directory")

ADD_EXECUTABLE(out_program program.cpp)
```

```
$cmake .
$make rm
```

CMake - Notes 6/6

Generate JSON compilation database (`compile_commands.json`)

It contains the exact compiler calls for each file (used by other tools)

```
PROJECT(my_project)                      # project name
CMAKE_MINIMUM_REQUIRED(VERSION 3.5)      # minimum version

SET(CMAKE_EXPORT_COMPILE_COMMANDS ON)    # <--

ADD_EXECUTABLE(out_program program.cpp)
```

Change compiler:

```
CC=gcc CXX=g++ cmake .
```

Useful variables:

`https://cmake.org/Wiki/CMake_Useful_Variables`

Code Checking and Analysis

Compiler Warnings

Enable specific warnings:

```
g++ -W<warning> <args...>
```

Disable specific warnings:

```
g++ -Wno-<warning> <args...>
```

Common warning flags to minimize accidental mismatches:

`-Wall` Enables many standard warnings (∼50 warnings)

`-Wextra` Enables some extra warning flags that are not enabled by `-Wall` (∼15 warnings)

`-Wpedantic` Issue all the warnings demanded by strict ISO C/C++

Enable ALL warnings (only clang) `-Weverything`

Full list: `https://gcc.gnu.org/onlinedocs/gcc/Warning-Options.html`

Which Clang Warning Is Generating This Message?
`https://fuckingclangwarnings.com`

Static Analyzer (clang static analyzer)

The Clang Static Analyzer is a source code analysis tool that finds bugs in C/C++ programs at compile-time

Website: https://clang-analyzer.llvm.org

It find bugs by reasoning about the semantics of code (may produce false positives)

Example:

```
void test() {
    int i, a[10];
    int x = a[i]; // warning: array subscript is undefined
}
```

How to use:

```
scan-build make
```

scan-build is included in the LLVM suite

Static Analyzer (cppcheck/oclint)

Cppcheck provides code analysis to detect bugs, undefined behavior and dangerous coding constructs

Website: https://cppcheck.sourceforge.net or

```
cppcheck --enable=warning,performance,style,portability,information,error
          <src_file/directory>
```

```
cmake -DCMAKE_EXPORT_COMPILE_COMMANDS=ON .
cppcheck --enable=<enable_flags> --project=compile_commands.json
```

Oclint is a tool for improving quality and reducing defects by inspecting C/C++ code and looking for potential problems

Website: https://oclint.org

```
cmake -DCMAKE_EXPORT_COMPILE_COMMANDS=ON .
oclint-json-compilation-database -enable-global-analysis
                   -i <includes_dirs>
```

Static Analyzer (`PVS-Studio`)

`PVS-Studio` is a high-quality *proprietary* (free for students) static code analyzer supporting C, C++

Website: `https://www.viva64.com/en/pvs-studio/`

Code Quality

Linter (`clang-tidy`)

lint: The term was derived from the name of the undesirable bits of fiber

`clang-tidy` provides an extensible framework for diagnosing and fixing typical *programming errors*, like *style violations*, *interface misuse*, or *bugs* that can be deduced via static analysis

Website: `clang.llvm.org/extra/clang-tidy`

```
$cmake -DCMAKE_EXPORT_COMPILE_COMMANDS=ON .
$clang-tidy -p .
```

`clang-tidy` searches the configuration file `.clang-tidy` file located in the closest parent directory of the input file

`clang-tidy` is included in the LLVM suite

Linter (clang-tidy)

Coding Guidelines:

- CERT Secure Coding Guidelines
- C++ Core Guidelines
- High Integrity C++ Coding Standard

Supported Code Conventions:

- Fuchsia
- Google
- LLVM

Bug Related:

- Android related
- Boost library related
- Misc
- Modernize
- Performance
- Readability
- clang-analyzer checks
- bugprone code constructors

.clang-tidy

```
Checks: 'android-*,boost-*,bugprone-*,cert-*,cppcoreguidelines-*,
clang-analyzer-*,fuchsia-*,google-*,hicpp-*,llvm-*,misc-*,modernize-*,
performance-*,readability-*'
```

Linter (vera++)

Vera++ is tool for verification and analysis of C++ source code.

It is complementary to clang-tidy: It provides weaker checkers, more oriented to syntax, then semantic

- well-formed file names
- space rules
- variable names
- etc.

Website: bitbucket.org/verateam/vera/wiki/Home

```
vera++ --rule <rule_list> <src_file/include_file>
```

```
vera++ --profile <profile_name> <src_file/include_file>
```

Code Testing

ctest 1/2

CTest is a testing tool (integrated in CMake) that can be used to automate updating, configuring, building, testing, performing memory checking, performing coverage

```
PROJECT(my_project)
CMAKE_MINIMUM_REQUIRED(VERSION 3.5)
ADD_EXECUTABLE(program program.cpp)

ENABLE_TESTING()

ADD_TEST(NAME Test1        # check if "program" returns 0
         WORKING_DIRECTORY ${PROJECT_SOURCE_DIR}/build
         COMMAND ./program <args>) # command can be anything

ADD_TEST(NAME Test2        # check if "program" print "Correct"
         WORKING_DIRECTORY ${PROJECT_SOURCE_DIR}/build
         COMMAND ./program <args>)

SET_TESTS_PROPERTIES(Test2
                     PROPERTIES PASS_REGULAR_EXPRESSION "Correct")
```

ctest 2/2

Basic usage (call ctest):

```
$make test        # run all tests
```

ctest usage:

```
$ctest -R Python      # run all tests that contains 'Python' string
$ctest -E Iron        # run all tests that not contain 'Iron' string
$ctest -I 3,5         # run tests from 3 to 5
```

Each ctest command can be combined with other tools (e.g. valgrind)

catch-lib 1/2

Catch2 is a multi-paradigm test framework for C++

Alternatives: Google Test, Boost.Test, CppUnit, etc.

Website: catch-lib.net

Catch2 features

- Header only and no external dependencies
- Assertion macro
- Floating point tolerance comparisons

Basic usage:

- Create the test program
- Run the test

```
$./test_program [<TestName>]
```

Other commands:

github.com/catchorg/Catch2/blob/master/docs/command-line.md

catch-lib 2/2

```
#define CATCH_CONFIG_MAIN  // This tells Catch to provide a main()
#include "catch.hpp"        // only do this in one cpp file

unsigned int Factorial(unsigned int number) {
    return number <= 1 ? number : Factorial(number - 1) * number;
}

float floatComputation() { ... }

"Test description and tag name"
TEST_CASE( "Factorials are computed", "[Factorial]" ) {
    REQUIRE( Factorial(1) == 1 );
    REQUIRE( Factorial(2) == 2 );
    REQUIRE( Factorial(3) == 6 );
    REQUIRE( Factorial(10) == 3628800 );
}

TEST_CASE( "floatCmp computed", "[floatComputation]" ) {
    REQUIRE( floatComputation() == Approx( 2.1 ) );
}
```

Code Coverage 1/3

Code coverage is a measure used to describe the degree to which the source code of a program is executed when a particular test suite runs

`gcov` is a tool you can use in conjunction with `GCC` to test code coverage in programs

`lcov` is a graphical front-end for `gcov`. It collects `gcov` data for multiple source files and creates HTML pages containing the source code annotated with coverage information

Step for code coverage:

- compile with `--coverage` flag (objects + linking)
- run the test
- visualize the results with `gcov` or `lcov`

Code Coverage 2/3

program.cpp:

```
#include <iostream>
#include <string>

int main(int argc, char* argv[]) {
    int value = std::stoi(argv[1]);
    if (value % 3 == 0)
        std::cout << "first\n";
    if (value % 2 == 0)
        std::cout << "second\n";
}
```

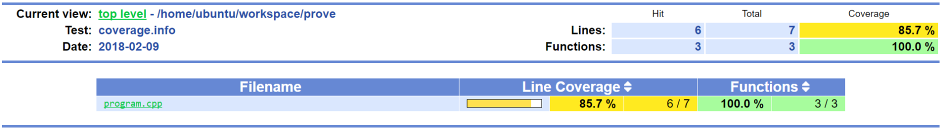
```
$gcc --std=c++11 --coverage program.cpp -o program
$./program 9
first
$gcov program.cpp
File 'program.cpp'
Lines executed:85.71% of 7
Creating 'program.cpp.gcov'
$lcov --capture --directory . --output-file coverage.info
$genhtml coverage.info --output-directory out
```

Code Coverage

program.cpp.gcov:

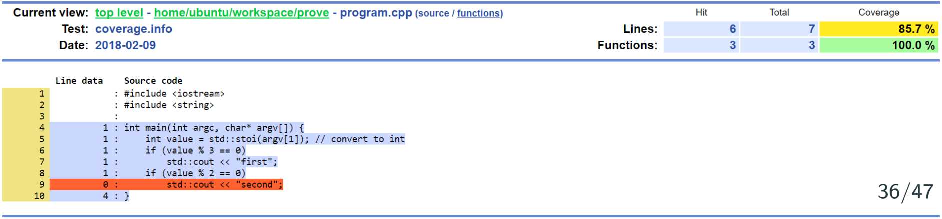
```
        1:    4:int main(int argc, char* argv[]) {
        1:    5:    int value = std::stoi(argv[1]);
        1:    6:    if (value % 3 == 0)
        1:    7:        std::cout << "first\n";
        1:    8:    if (value % 2 == 0)
    #####:    9:        std::cout << "second\n";
        4:   10:}
```

lcov output:



Current view:	top level - /home/ubuntu/workspace/prove		Hit	Total	Coverage
Test:	coverage.info	Lines:	6	7	85.7 %
Date:	2018-02-09	Functions:	3	3	100.0 %

Filename	Line Coverage ⇕			Functions ⇕	
program.cpp		85.7 %	6 / 7	100.0 %	3 / 3



Current view:	top level - home/ubuntu/workspace/prove - program.cpp (source / functions)		Hit	Total	Coverage
Test:	coverage.info	Lines:	6	7	85.7 %
Date:	2018-02-09	Functions:	3	3	100.0 %

```
   Line data    Source code
                : #include <iostream>
                : #include <string>
                :
              1 : int main(int argc, char* argv[]) {
              1 :     int value = std::stoi(argv[1]); // convert to int
              1 :     if (value % 3 == 0)
              1 :         std::cout << "first";
              1 :     if (value % 2 == 0)
              0 :         std::cout << "second";
              4 : }
```

Code Commenting

Code Commenting (`doxygen`) 1/6

`Doxygen` is the de facto standard tool for generating documentation from annotated C++ sources

Doxygen usage

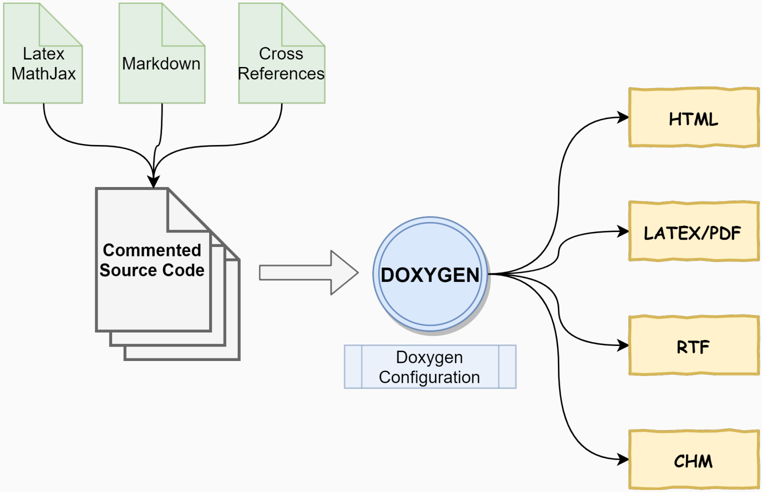
- comment the code with `///` or `/** comment */`
- generate doxygen base configuration file

```
$doxygen -g
```

- modify the configuration file `doxygen.cfg`
- generate the documentation

```
$doxygen <config_file>
```

Code Commenting (doxygen)



`Doxygen` provides support for:

- **Latex/MathJax** Insert latex math `$<code>$`
- **Markdown** (Markdown Cheatsheet link) Italic text `*<code>*`, bold text `**<code>**`, table, list, etc.
- **Automatic cross references** Between functions, variables, etc.
- **Specific highlight** Code `` `<code>` ``, parameter `@param <param>`

Code Commenting (`doxygen`) - Guidelines

Doxygen guidelines:

- Include in every file **copyright**, **author**, **date**, **version**
- Comment `namespaces` and `classes`
- Comment `template` parameters
- Distinguish `input` and `output` parameters
- Call/Hierarchy graph can be useful in large projects
  (should include `graphviz`)

  ```
  HAVE_DOT = YES
  GRAPHICAL_HIERARCHY = YES
  CALL_GRAPH = YES
  CALLER_GRAPH = YES
  ```

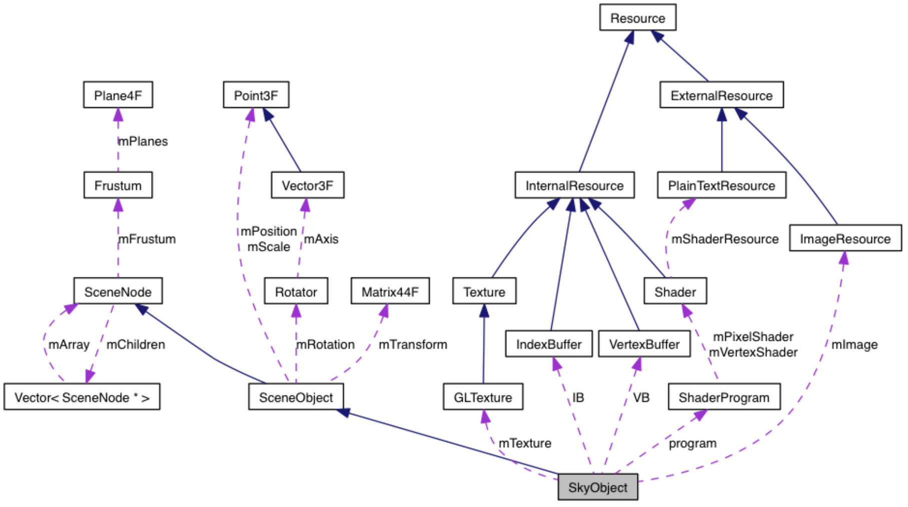
μOS++ Doxygen style guide link

Code Commenting (doxygen) - Example 5/6

```
/**
 * @copyright MyProject
 * license BSD3, Apache, MIT, etc.
 * @author MySelf
 * @version v3.14159265359
 * @date March, 2018
 * @file
 */

/// @brief Namespace brief
///        description
namespace my_namespace {

/// @brief "Class brief description"
/// @tparam R "Class template for"
template<typename R>
class A {
```

```
/**
 * @brief "What the function does?"
 * @details "Some additional details",
 *           Latex/MathJax: $\sqrt a$
 * @tparam T Type of input and output
 * @param[in] input Input array
 * @param[out] output Output array
 * @return `true` if correct,
 *         `false` otherwise
 * @remark it is *useful* if ...
 * @warning the behavior is **undefined** if
 *          @p input is `nullptr`
 * @see related_function
 */
template<typename T>
int my_function(const T* input, T* output);

/// @brief
void related_function;
```

Code Commenting (`doxygen`) - Call Graph



Code Statistics

Count Lines of Code (cloc)

Website: cloc.sourceforge.net

```
$cloc my_project/

4076 text files.
3883 unique files.
1521 files ignored.

http://cloc.sourceforge.net v 1.50  T=12.0 s (209.2 files/s, 70472.1 lines/s)
-------------------------------------------------------------------------------
Language                     files          blank        comment           code
-------------------------------------------------------------------------------
C                              135          18718          22862         140483
C/C++ Header                   147           7650          12093          44042
Bourne Shell                   116           3402           5789          36882
```

Features: filter by-file/language, SQL database, archive support, line count diff, etc.

Cyclomatic Complexity Analyzer (lyzard)

Website: github.com/terryyin/lizard

Cyclomatic Complexity: is a software metric used to indicate the complexity of a program. It is a quantitative measure of the number of linearly independent paths through a program's source code

```
$lizard my_project/


==============================================================
NLOC    CCN  token  param    function@line@file
--------------------------------------------------------------
10      2     29      2     start_new_player@26@./html_game.c
6       1      3      0     set_shutdown_flag@449@./httpd.c
24      3     61      1     server_main@454@./httpd.c
--------------------------------------------------------------
```

- CCN: cyclomatic complexity (should not exceed a threshold)
- NLOC: lines of code without comments
- token: Number of conditional statements
- param: Parameter count of functions

Other Tools

Code Formatting (clang-format)

clang-format is a tool to automatically format C/C++ code (and other languages)

Website: clang.llvm.org/docs/ClangFormat.html

```
$clang-format <file/directory>
```

clang-format searches the configuration file .clang-format file located in the closest parent directory of the input file

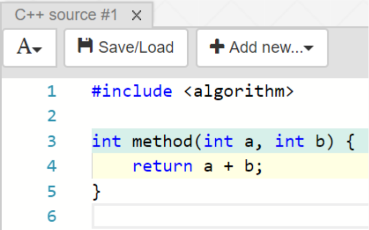
clang-format example:

```
IndentWidth: 4
UseTab: Never
BreakBeforeBraces: Linux
ColumnLimit: 80
SortIncludes: true
```

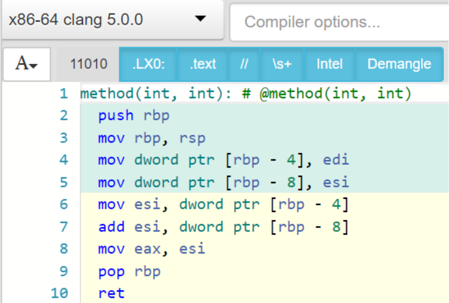
Assembly Explorer

`Compiler Explorer` is an interactive tool that lets you type source code and see assembly output, control flow graph, optimization hint, etc.

Website: `godbolt.org`



```cpp
#include <algorithm>

int method(int a, int b) {
    return a + b;
}

```

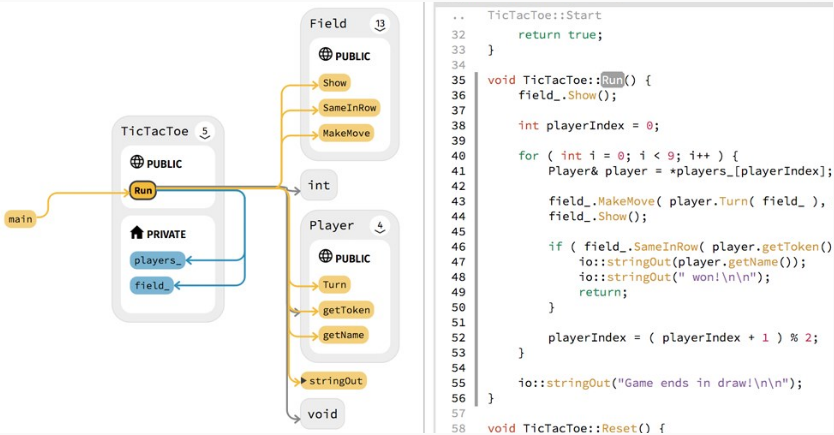


```asm
method(int, int): # @method(int, int)
  push rbp
  mov rbp, rsp
  mov dword ptr [rbp - 4], edi
  mov dword ptr [rbp - 8], esi
  mov esi, dword ptr [rbp - 4]
  add esi, dword ptr [rbp - 8]
  mov eax, esi
  pop rbp
  ret
```

SourceTrail

Sourcetrail is an interactive code explorer that simplifies navigation in complex source code

Website: `www.sourcetrail.com/#intro`



```
..  TicTacToe::Start
        return true;
    }

    void TicTacToe::Run() {
        field_.Show();

        int playerIndex = 0;

        for ( int i = 0; i < 9; i++ ) {
            Player& player = *players_[playerIndex];

            field_.MakeMove( player.Turn( field_ ),
            field_.Show();

            if ( field_.SameInRow( player.getToken()
                io::stringOut(player.getName());
                io::stringOut(" won!\n\n");
                return;
            }

            playerIndex = ( playerIndex + 1 ) % 2;
        }

        io::stringOut("Game ends in draw!\n\n");
    }

    void TicTacToe::Reset() {
```