Cross-Platform Development with CMake

Julien Jomier

MUREX

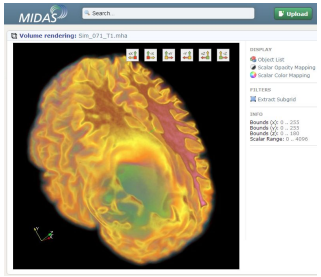
CODE RECKONS

Science to the CORE

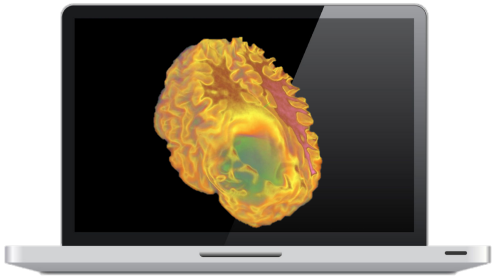
About me / Julien Jomier

- Involved with CMake for 20+ years
- C++ developer
- CDash creator
- CMake educator
- Open Source enthusiast

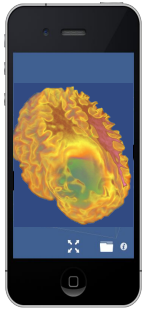
Kitware / Open Source Solutions



Web



Desktop



Mobile

Cloud /HPC

Universal Platforms

ParaView VTK ITK CMake

Resonant KWIVER 3DSlicer Pulse Physiology Engine mstk tomviz

Do I need a build system?

- **In the beginning there was the command line:**

```
% gcc hello.cxx -o hello
```

- **Then shell script:**

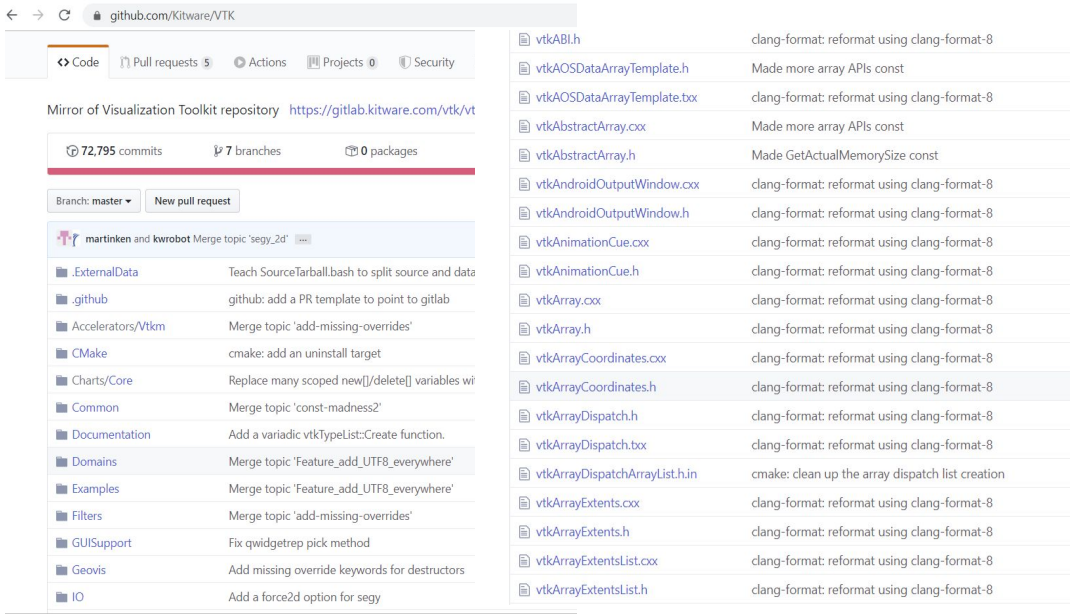
```
#!/bin/sh
gcc hello.cxx -o hello
% buildhello.sh
```

Do I need a build system?

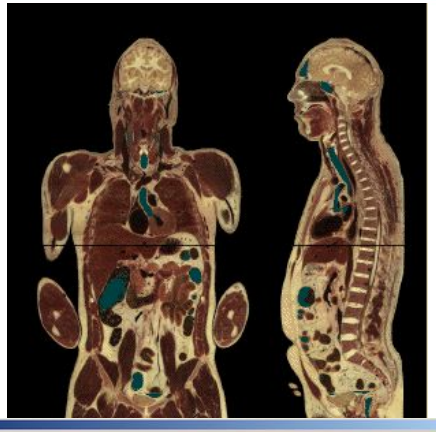
- **Then make files**

```
hello: hello.cxx
	gcc hello.cxx

% make hello
```

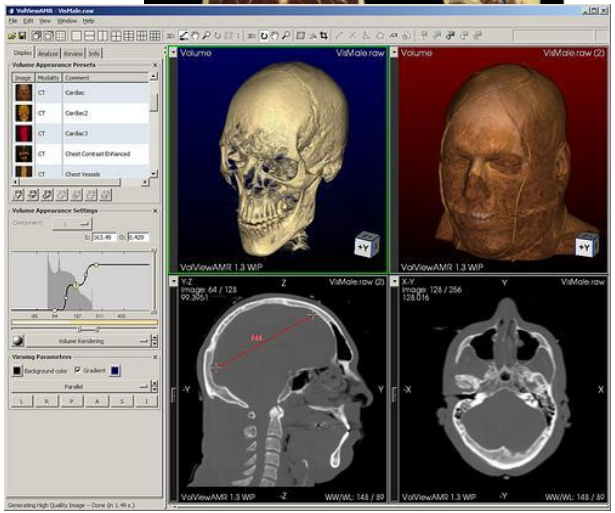
- **How to handle**
  - Complex projects?
  - Dependencies?
  - Cross-Platform?



Where is CMake coming from?



- Insight Segmentation and Registration Toolkit (ITK)
  http://www.itk.org
- Funded by National Library of Medicine (NLM)
  As part of the Visible Human Project
  - Data: CT/MR/Slice 1994/1995
  - Code: (ITK) 1999
- CMake Release-1-0 branch created in 2001



What is CMake?

- **Cross-platform**, **open-source build system generator**
- Let you use the **native development tools** you love the most.
- It takes **plain text files** as input and **produces** project files or make files
- Family of Software Development Tools
  - Build = CMake
  - Test = CTest/CDash
  - Package = CPack

Changing the way we build C++

- Boost aims to give C++ a set of useful libraries like Java, Python, and C#

- CMake aims to give C++ compile portability like the compile once and run everywhere of Java, Python, and C#
  - Same build tool and files for all platforms
  - Easy to mix both large and small libraries





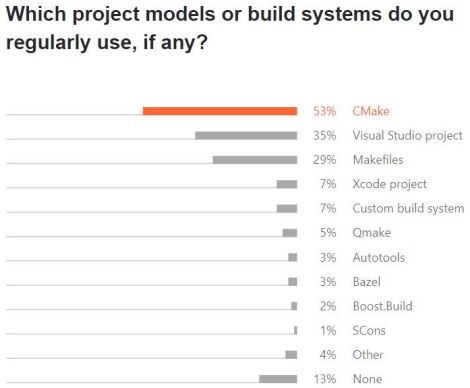
Build Tools Support

- **New IDE's and compilers**
  - Visual Studio releases supported weeks after beta comes out
  - Xcode releases supported weeks after beta comes out
  - ninja (command line build tool from Google) support contributed to CMake as ninja matured
  - Apple Silicon

- **New compiler support**
  - Clang
  - gcc versions

CMake Popularity

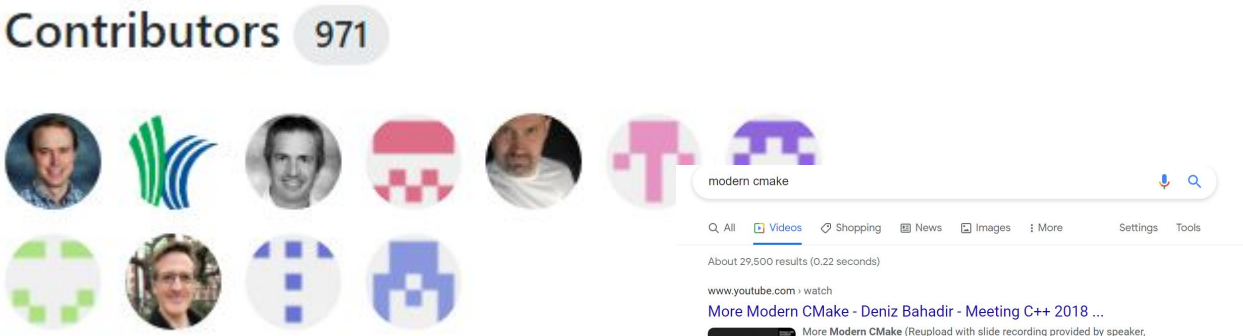
- Jetbrains IDE- CMake is the most popular build tool at 53%

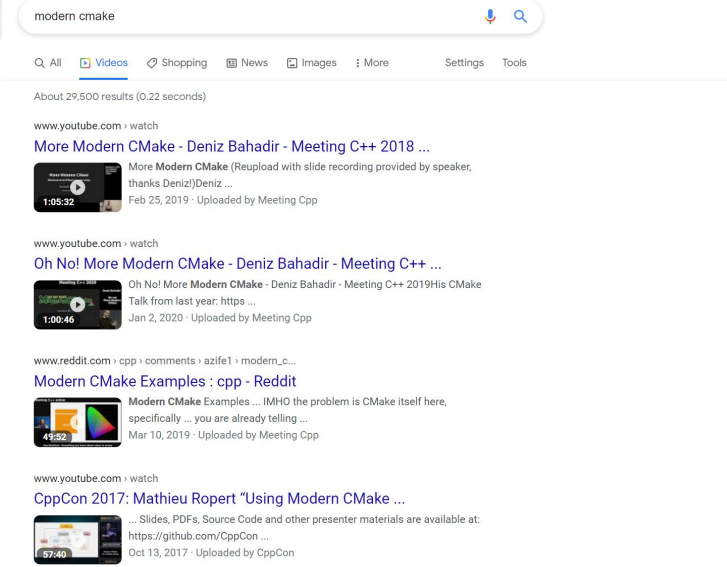


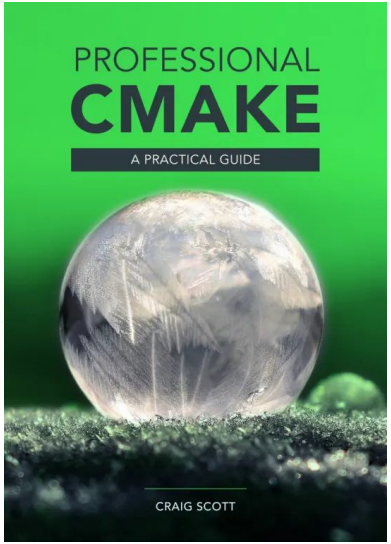
- Job openings requiring CMake experience:
  - Indeed.com, 464 jobs, at Tesla Motors, DOS Corp, Mindsource, Quanergy,
  - LinkedIn.com, 486 jobs, at Samsung, Johnson Controls, Apple, Uber, Toyota, Microsoft ...

Up from up from 42% the previous year.

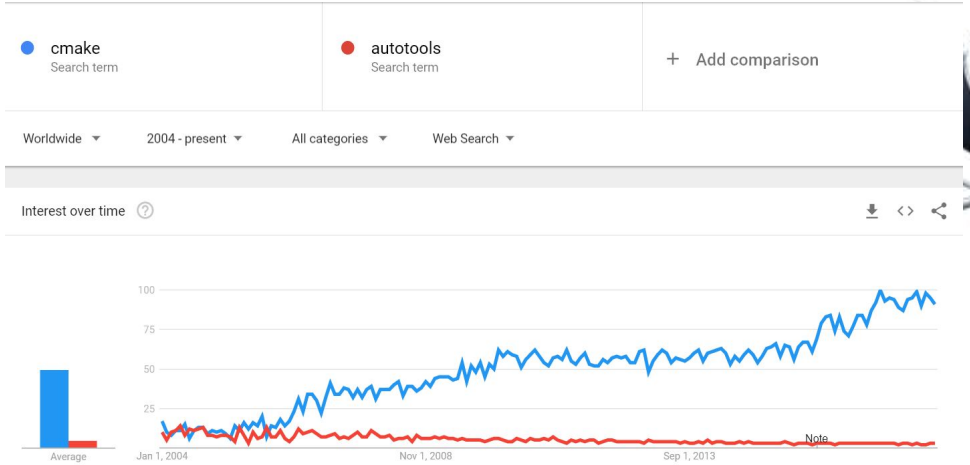
CMake is a community effort

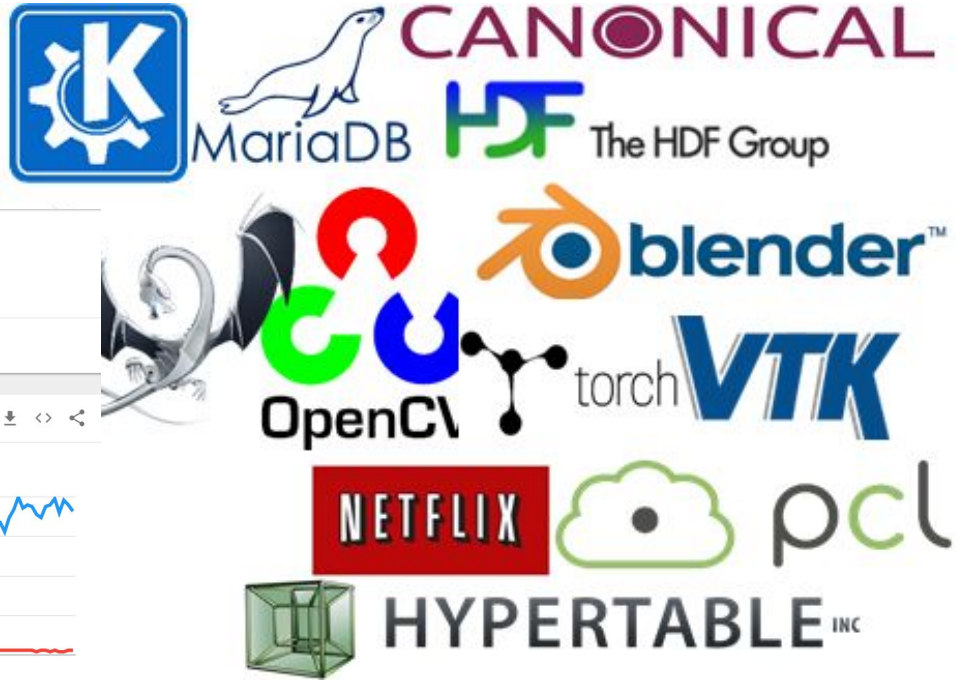






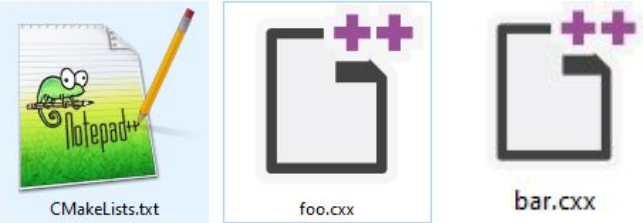
Growing Community





Writing CMake

Basic CMakeLists.txt




```
cmake_minimum_required(VERSION 3.15)
project(Example LANGUAGES CXX)

add_library(Bar STATIC bar.cxx)
add_executable(Foo foo.cxx)
target_link_libraries(Foo PRIVATE Bar)
```

Requiring CMake version

- First line of the top level CMakeLists.txt should always be **`cmake_minimum_required`**

- Allows projects to require a given version of CMake
- Allows CMake to be backwards compatible

project() command

- Necessary for the top-level CMake. Should be set after the **cmake_minimum_required command**

- VERSION: sets the PROJECT_VERSION_MAJOR/MINOR/TWEAK
- DESCRIPTION: sets the PROJECT_DESCRIPTION variable
- LANGUAGES:
  - C, CXX, FORTRAN, CSharp, CUDA, ASM
  - Default is C and CXX if not defined

Setting CMake Language Standards

- CMake offers a few different ways to specify which version of a language should be used.

```
set(CMAKE_CXX_STANDARD 11)
set(CMAKE_CXX_STANDARD_REQUIRED TRUE)
```

```
[ 50%] Building CXX object main.cxx.o
/usr/bin/c++  -std=gnu++11 -o main.cxx.o -c main.cxx
```

- CMAKE_CXX_EXTENSIONS controls if compiler specific extensions are enabled

Flow Control - conditional

```
if(my_var)
  set(result ${my_var})
endif()
if(NOT my_var)
if(my_var AND my_var2)
if(my_var OR my_var2)
if(my_var MATCHES regexp)
if(TARGET target)
if(EXISTS file)
if(my_var LESS my_var2)
if(my_ver VERSION_EQUAL "2.0.2")
```

Flow Control : loops

```
foreach(F IN ITEMS a b c)
  message(${F})
endforeach()

set(items a b c)
foreach(F IN LISTS items)
  message(${F})
endforeach()
```

```
while(MY_VAR)
  message(${MY_VAR})
  set(MY_VAR FALSE)
endwhile()
```

Describe your source tree

- `add_subdirectory()`

- Variable values are inherited by CMakeLists.txt files in sub directories

Extending CMake

```
function(showcase_args myarg)
  message("myarg: ${myarg}")
  message("ARGV0: ${ARGV0}")
  message("contents of myarg: ${${myarg}}")
  message("extra arguments: ${ARGN}")
  message("# of arguments: ${ARGC}")
endfunction()

set(items a b c)
showcase_args(items)
```

CMake Commands

All commands

- cmake --help-command-list
- cmake --help-command command_name
- https://cmake.org/cmake/help/latest/manual/cmake-commands.7.html

CMake Features

- Automatic **dependency** generation
- Parallel builds
- Out of source builds
- System **introspection** (try_compile/try_run)
- Advanced RPATH handling
- Supports cross compilation

CMake Tips

- Treat CMake as code
- Targets are your friends
- Export your interface
- Upgrade your version of CMake when you can

Running CMake

Getting CMake

- www.cmake.org/download
- From your Linux distribution
- Visual Studio 2017+

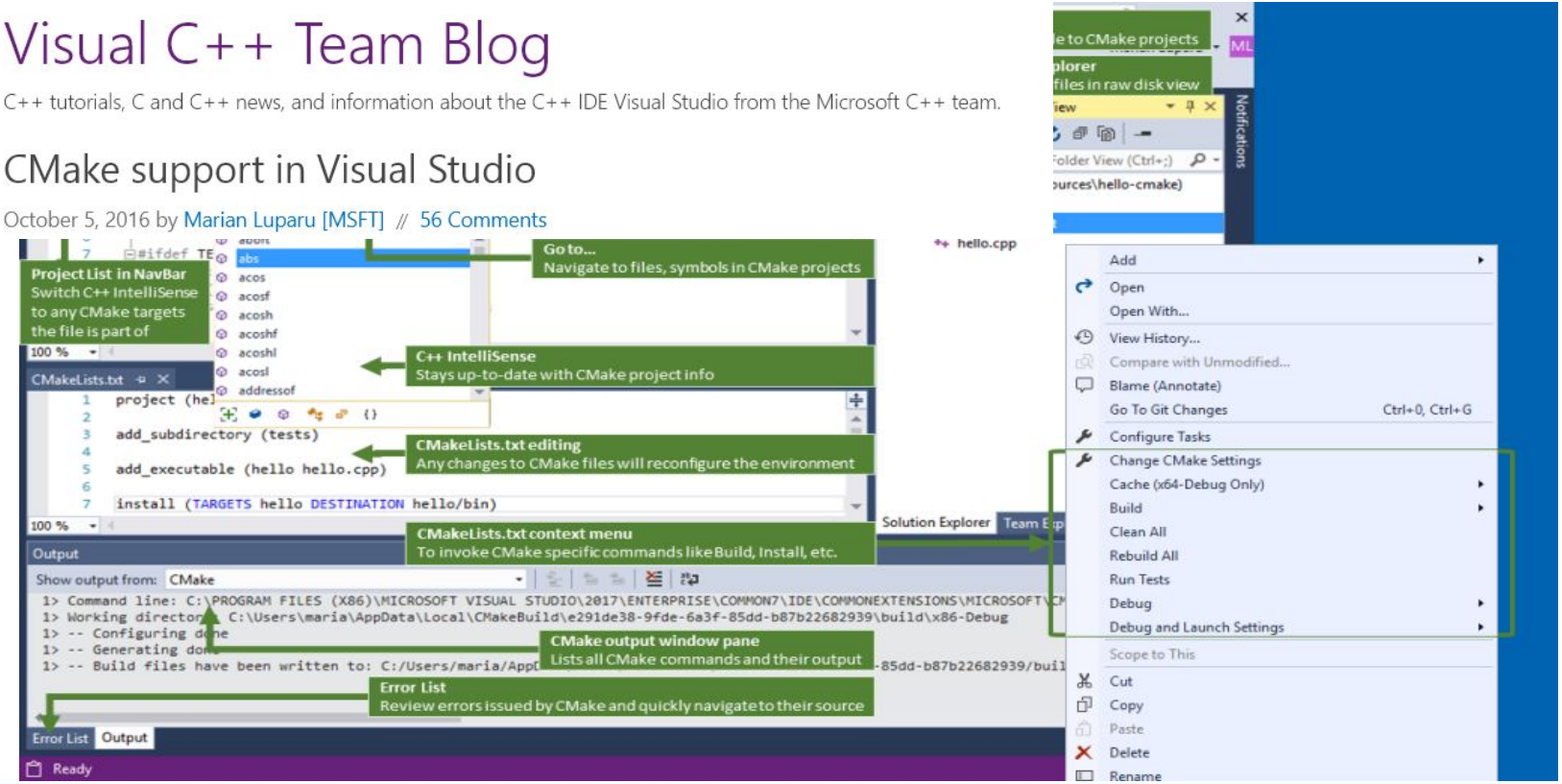
- apt.kitware.com for Debian and Ubuntu
- Snap universal linux package
- pip install cmake
- homebrew

Visual C++ Team Blog

C++ tutorials, C and C++ news, and information about the C++ IDE Visual Studio from the Microsoft C++ team.

CMake support in Visual Studio

October 5, 2016 by Marian Luparu [MSFT] // 56 Comments

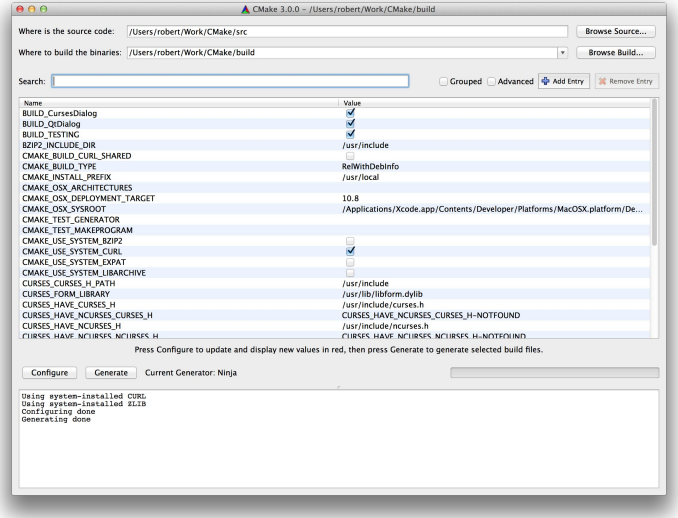


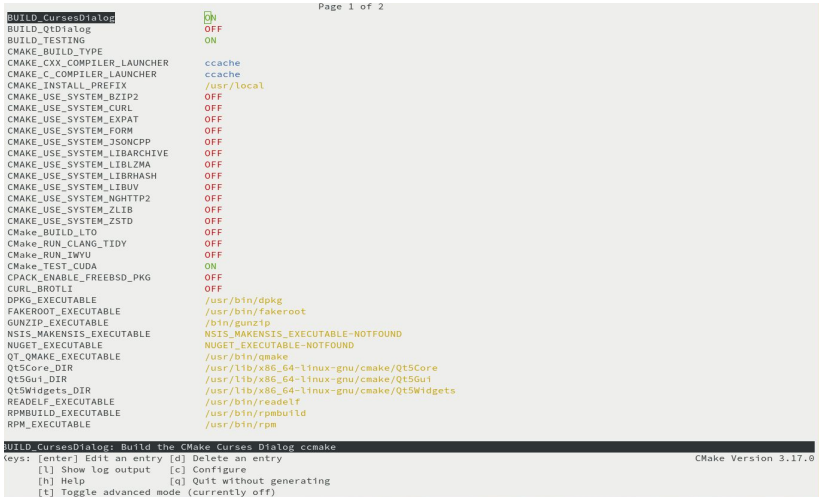
Running CMake

- Configure phase:
  - CMake parses its input files (CMakeLists.txt)
- Generate phase:
  - CMake writes out a build system for the specified generator (Makefile)

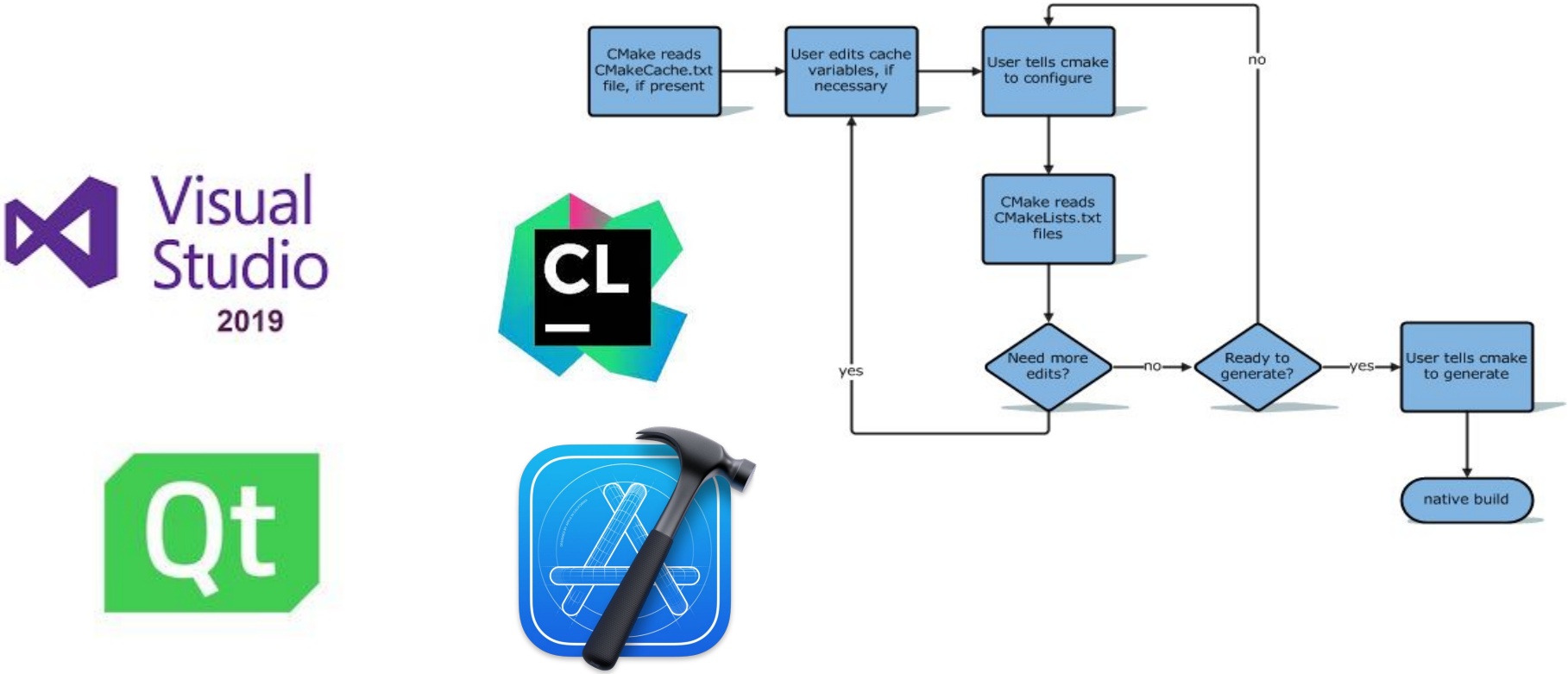
Running CMake

- cmake-gui (the Qt gui)
- ccmake (the terminal cli)
- cmake (non-interactive command line)

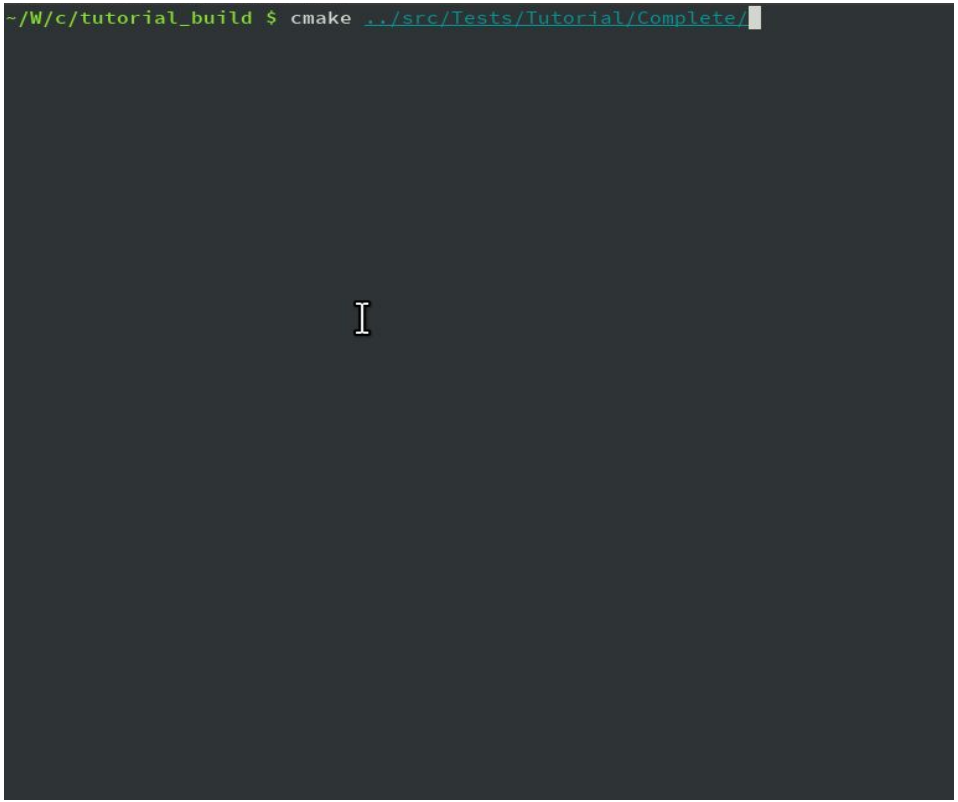




Running CMake



CMake Workflow



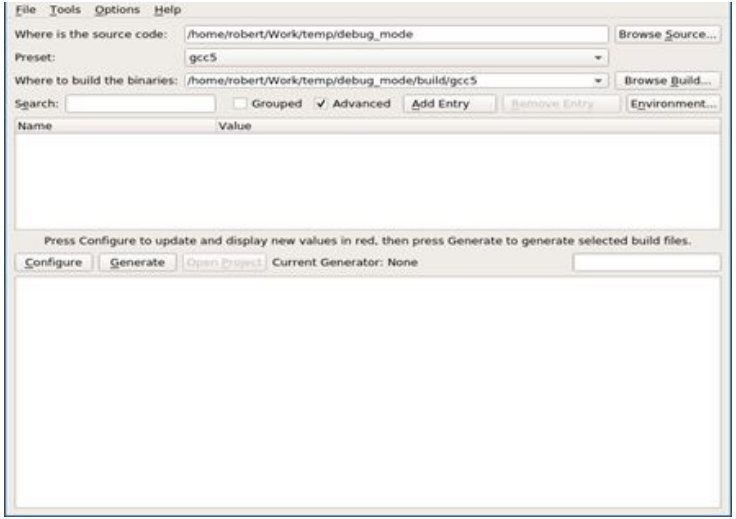
Presets

- Specify the build directory, generator, cache variables, environment variables, and command line options for the cmake executable
- Done via CMakePresets.json
- Available since CMake 3.19

```
{
  "version": 1,
  "configurePresets": [
    {
      "name": "base",
      "hidden": true,
      "binaryDir": "${sourceDir}/build/${presetName}",
      "environment": {
        "CXX": "clang++-9"
      }
    },
    {
      "name": "clang9",
      "inherits": "base",
      "generator": "Ninja",
      "environment": {
        "CXX": "clang++-9"
      }
    },
    {
      "name": "gcc5",
      "inherits": "base",
      "generator": "Unix Makefiles",
       "environment": {
        "CXX": "g++-5"
      }
    }
  ]
}
```

Presets

```
~/W/t/debug_mode $ ~/Work/cmake/build/bin/cmake -S . --list-presets
Available presets:

  "clang9"
  "gcc5"
```



Presets

```
~/W/t/debug_mode $ ~/Work/cmake/build/bin/cmake -S . --preset=gcc5
Preset environment variables:

  CXX="g++-5"

-- The CXX compiler identification is GNU 5.5.0
-- Detecting CXX compiler ABI info
-- Detecting CXX compiler ABI info - done
-- Check for working CXX compiler: /usr/bin/g++-5 - skipped
```

```
~/W/t/debug_mode $ ~/Work/cmake/build/bin/cmake -S . --preset=clang9
Preset environment variables:

  CXX="clang++-9"

-- The CXX compiler identification is Clang 9.0.0
-- Detecting CXX compiler ABI info
-- Detecting CXX compiler ABI info - done
-- Check for working CXX compiler: /usr/bin/clang++-9 - skipped
```

Dealing with Dependencies

CMake Find Modules

Our library “foo” needs PNG

```
find_package(PNG REQUIRED)
add_library(foo SHARED foo.cxx)
```

No different than if we built PNG as part of the project:

```
target_link_libraries(foo PRIVATE PNG::PNG)
```

FindPackage()

- Should work in all the following cases:
  a. The package is **build from source with CMake**
  b. The package is **installed**
  c. The package is **not build with CMake**

CMake Find Modules

- CMake provides over **150 find modules**
  - cmake --help-module-list
  - https://cmake.org/cmake/help/latest/manual/cmake-modules.7.html

How do we maintain these modules?

Exporting Targets

- Install rules can generate imported targets

```
add_library(parasite STATIC eat_leaf.cxx)
install(TARGETS parasite root trunk leaf
        EXPORT tree-targets)
install(EXPORT tree-targets
        DESTINATION lib/cmake/tree)
```

- Installs library and target import rules
  - *<prefix>/lib/libparasite.a*
  - *<prefix>/lib/cmake/tree/tree-targets.cmake*

External Projects

- Building/Importing targets **at build time**

```
ExternalProject_Add(foo
  GIT_REPOSITORY    git@github.com:FooCo/Foo.git
  GIT_TAG           origin/release/1.2.3
)

ExternalProject_Add(bar
  GIT_REPOSITORY    git@github.com:BarCo/Bar.git
  GIT_TAG           origin/release/2.3.4
  DEPENDS foo
)
```

FetchContent

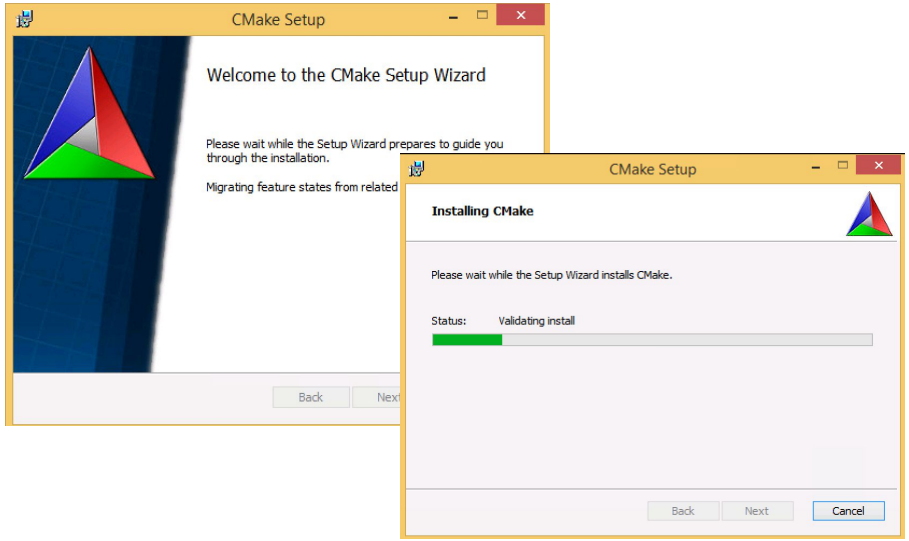
- Building/Importing targets **at configure time**

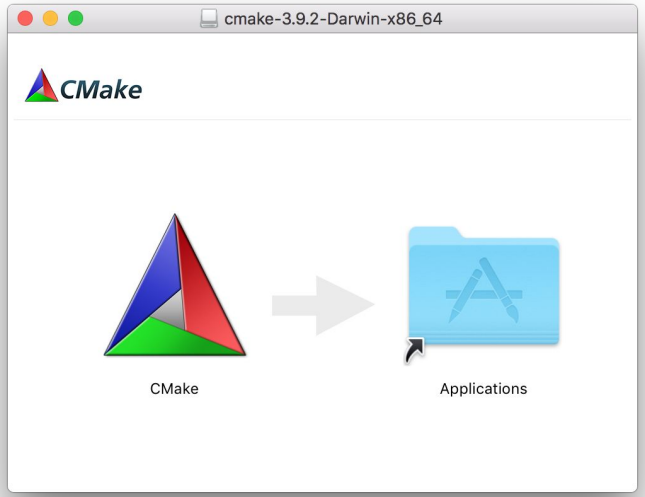
```
FetchContent_Declare(catch
  GIT_REPOSITORY https://github.com/catchorg/Catch2.git
  GIT_TAG        v2.2.1
)
FetchContent_GetProperties(catch)
if(NOT catch_POPULATED)
  FetchContent_Populate(catch)
  add_subdirectory(${catch_SOURCE_DIR} ${catch_BINARY_DIR})
endif()
```

Packaging

CPack

- CPack is bundled with CMake
- Creates professional platform specific installers





Using CPack

- On Windows install command line ZIP program, NSIS and WiX
- Setup your project to work with cpack
  - Get `make install` to work
    - install(…)
    - make sure your executables work with relative paths and can work from any directory
  - Set cpack option variables if needed
  - `include(CPack)`

Continuous Integration

CTest/CDash

- CTest : Testing driver
- CDash: Web-based dashboard for collecting test results

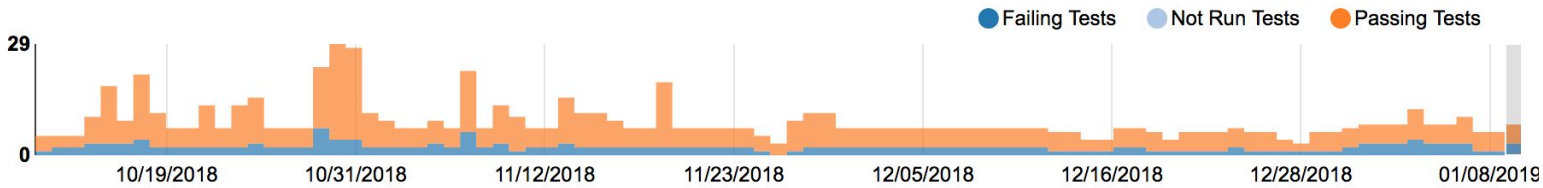
Scan Build — 1 build

Site	Build Name	Update Revision	Configure Error	Configure Warn	Build Error	Build Warn	Start Time
elysium-linux.kitware	Linux-clang-scanbuild	8c3071	0	0	0	0	10 hours ago

Nightly Expected — 96 of 108 builds

Site	Build Name	Update Revision	Configure Error	Configure Warn	Build Error	Build Warn	Test Not Run	Test Fail	Test Pass	Start Time
trinsic.kitware	vs14-64-ninja	8c3071	0	0	0	0	0	2 +2	479 -2	13 hours ago
trinsic.kitware	mingw64-make	8c3071	0	0	0	0	0	1 +1	449 -1	6 hours ago
hythloth.kitware	Linux-ninja-gcov	8c3071	0	0	0	0	0	1	519	7 hours ago
trinsic.kitware	vs14-64-ide-v90	8c3071	0	0	0	0	0	1 +1 -1	387 -1	8 hours ago
vesper.kitware	watcom	8c3071	0	0	0	0	0	1 +1	368 -1	8 hours ago
trinsic.kitware	vs9-64-ide	8c3071	0	0	0	0	0	1 +1	381 -1	9 hours ago
vesper.kitware	bcc55	8c3071	0	0	0	0	0	1 +1	370 -1	9 hours ago
dash3win7.kitware	vs14-64	8c3071	0	0	0	0	0	1 +1 -1	460 +1 -1	9 hours ago
dashsun1.kitware.com	Solaris-10-8.11_Oracle-12.3	8c3071	0	0	0	0	0	0	415	1 hour ago

Track test health over time



Update

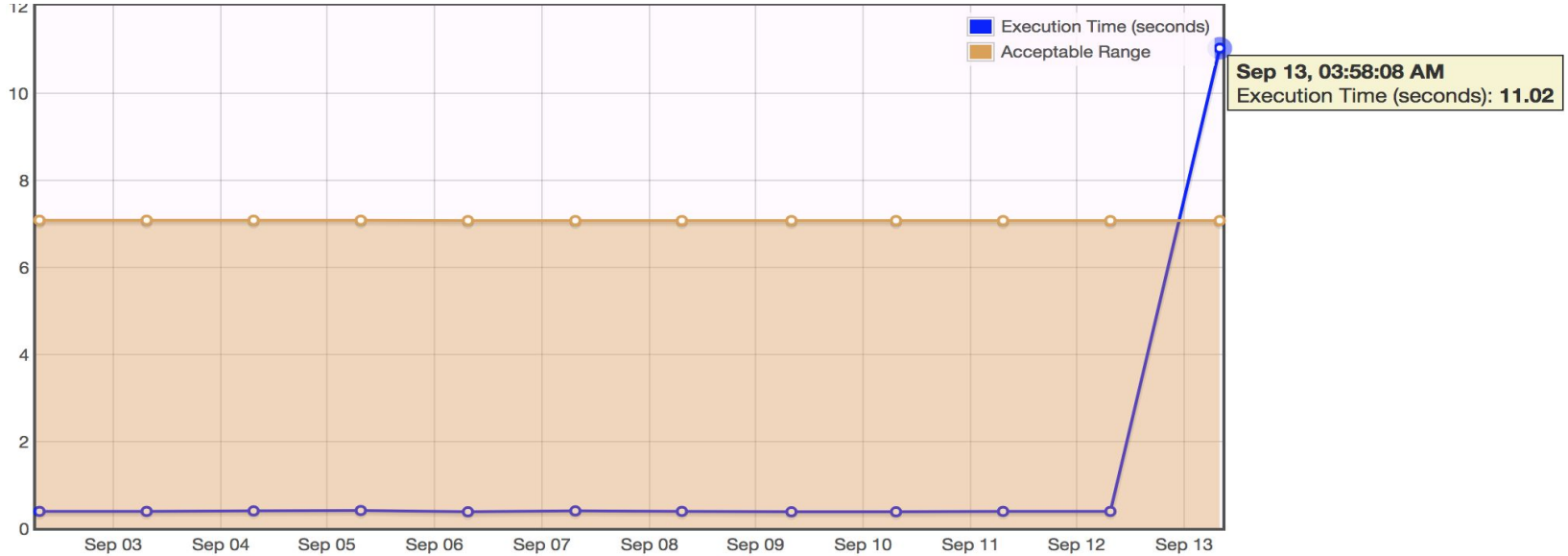
Show Filters

28 tests failed during this time period.

Non-Experimental Builds ⇕ ☐ Include passing tests

Test Name ⌄	Failure ⌄	Timeout	Total Runs	Time
viewBuildError	100%	0%	2	21s 570ms
upgrade	100%	0%	2	1m 33s 790ms

Track test timing



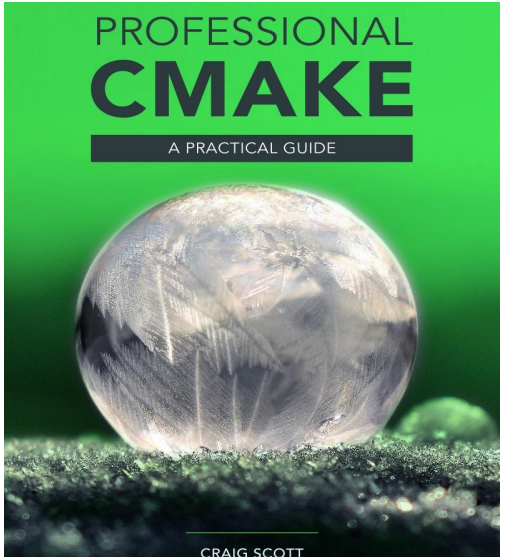
Test output

```
WaitForSingleObject returned unexpected status 0x102
In function testConsole, line 718: WaitForSingleObject#2 failed!
Failed with error: 0x2!
Error message: The system cannot find the file specified.
```

Learn more about CMake

Learning CMake

- ~~Copy some CMake code from 2010..~~
- Watch a talk on “Modern CMake”
- Professional CMake by Craig Scott
- Discourse Forum
  - *discourse.cmake.org*
- Documentation
  - *www.cmake.org/cmake/help/latest/*
- Tutorial
  - *cmake.org/cmake/help/latest/guide/tutorial/index.html*



CMake Technical Guides

CMake Testing Doc Code

```
Specify the C++ Standard
------------------------

Next let's add some C++11 features to our project by replacing ``atof`` with
``std::stod`` in ``tutorial.cxx``.  At the same time, remove
``#include <cstdlib>``.

.. literalinclude:: Step2/tutorial.cxx
  :language: c++
  :start-after: // convert input to double
  :end-before: // calculate square root

We will need to explicitly state in the CMake
correct flags. The easiest way to enable suppo
in CMake is by using the :variable:`CMAKE_CXX_
tutorial, set the :variable:`CMAKE_CXX_STANDAR
``CMakeLists.txt`` file to 11 and :variable:`C
True. Make sure to add the ``CMAKE_CXX_STANDAR
to ``add_executable``.

.. literalinclude:: Step2/CMakeLists.txt
  :language: cmake
  :end-before: # configure a header file to pa
```

```
// A simple program that computes the square root of a number
#include <cmath>
#include <iostream>
#include <string>

#include "TutorialConfig.h"

int main(int argc, char* argv[])
{
  if (argc < 2) {
    // report version
    std::cout << argv[0] << " Version " << Tutorial_VERSION_MAJOR << "."
              << Tutorial_VERSION_MINOR << std::endl;
    std::cout << "Usage: " << argv[0] << " number" << std::endl;
    return 1;
  }

  // convert input to double
  const double inputValue = std::stod(argv[1]);

  // calculate square root
  const double outputValue = sqrt(inputValue);
                                                    lue << " is " << outputValue
```

Specify the C++ Standard

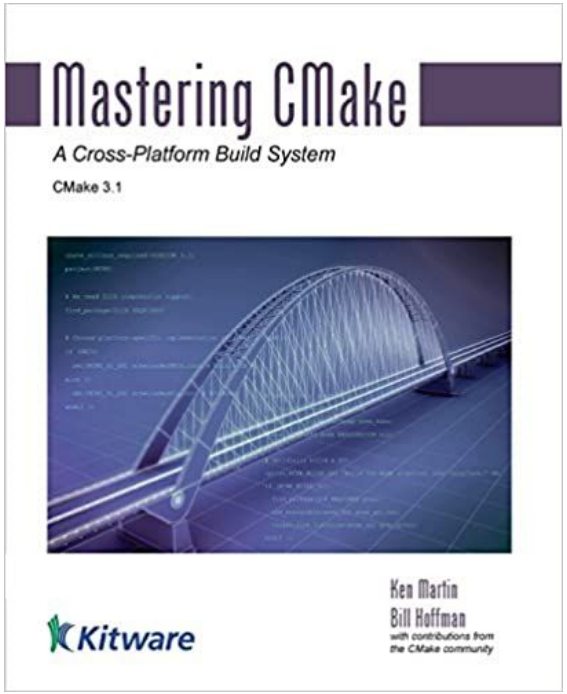
Next let's add some C++11 features to our project by replacing `atof` with `std::stod` in `tutorial.cxx`. At the same time, remove `#include <cstdlib>`.

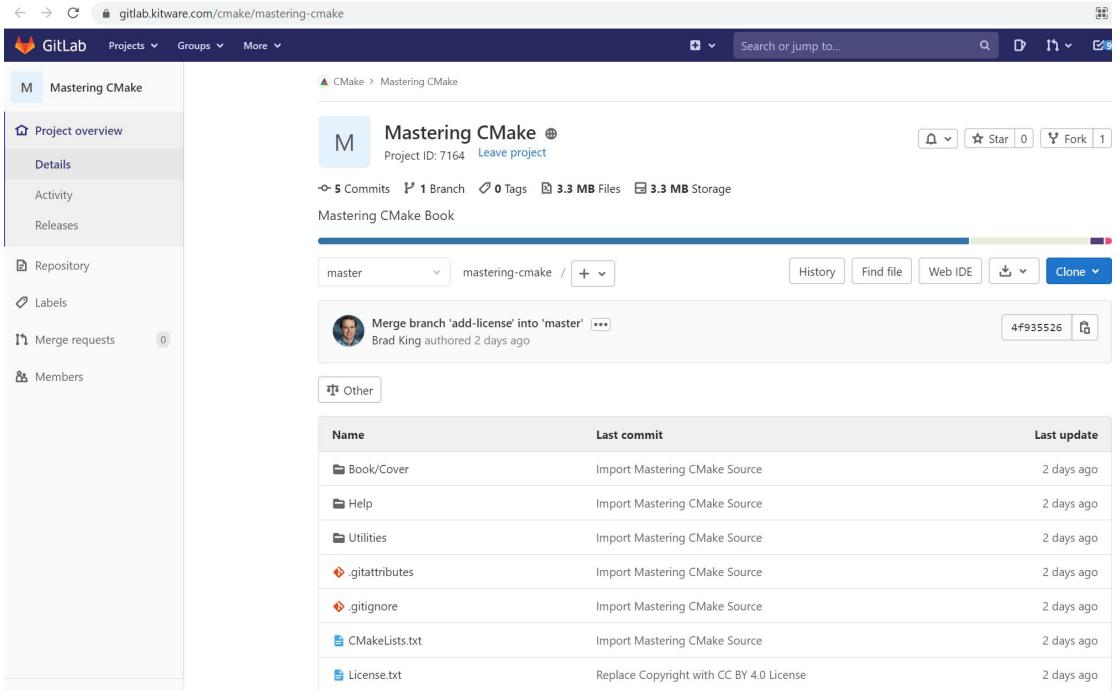
```
  const double inputValue = std::stod(argv[1]);
```

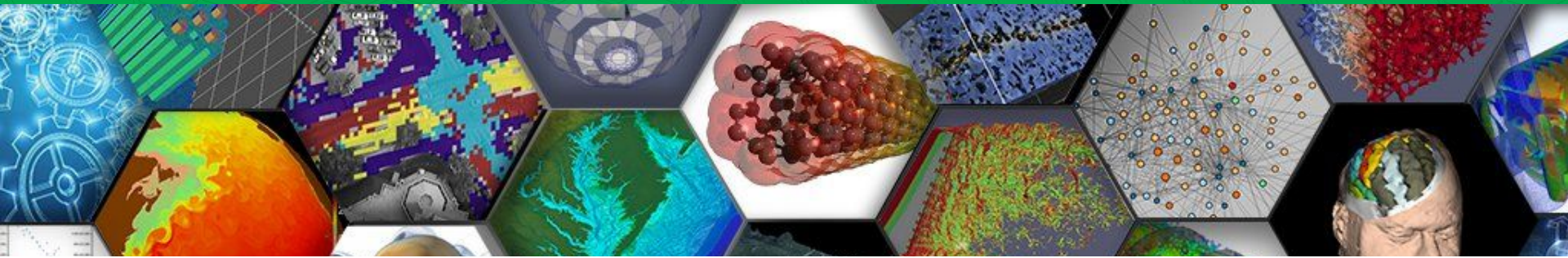
We will need to explicitly state in the CMake code that it should use the correct flags. The easiest way to enable support for a specific C++ standard in CMake is by using the `CMAKE_CXX_STANDARD` variable. For this tutorial, set the `CMAKE_CXX_STANDARD` variable in the `CMakeLists.txt` file to 11 and `CMAKE_CXX_STANDARD_REQUIRED` to True. Make sure to add the `CMAKE_CXX_STANDARD` declarations above the call to `add_executable`.

```
cmake_minimum_required(VERSION 3.10)

# set the project name and version
project(Tutorial VERSION 1.0)

# specify the C++ standard
set(CMAKE_CXX_STANDARD 11)
set(CMAKE_CXX_STANDARD_REQUIRED True)
```

Mastering CMake is now open







Thank You!
Merci!

Julien Jomier
julien.jomier@kitware.com