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# Getting started with CMake

CMake is a group of tools that allow to build, test, and package applications. Just like Qt, it is available on all major development platforms. It is also supported by various IDE's, including [Qt Creator](#).

In this section we will show the most basic way to use Qt in a CMake project. First, we create a basic console application. Then, we extend the project into a GUI application that uses [Qt Widgets](#).

If you want to know how to build an existing CMake project with Qt, see the documentation on [how to build projects with CMake on the command line](#).

## Building a C++ console application

A CMake project is defined by files written in the CMake language. The main file is called `CMakeLists.txt`, and is usually placed in the same directory as the actual program sources.

Here is a typical `CMakeLists.txt` file for a console application written in C++ using Qt:

```
cmake_minimum_required(VERSION 3.16)

project(helloworld VERSION 1.0.0 LANGUAGES CXX)

set(CMAKE_CXX_STANDARD 17)
set(CMAKE_CXX_STANDARD_REQUIRED ON)

find_package(Qt6 REQUIRED COMPONENTS Core)
qt_standard_project_setup()

add_executable(helloworld
    main.cpp
)

target_link_libraries(helloworld PRIVATE Qt6::Core)
```

Let's go through the content.

```
cmake_minimum_required(VERSION 3.16)
```

`cmake_minimum_required()` specifies the minimum CMake version that the application requires. Qt 6.4 requires at least CMake version 3.16. If you use a Qt that was built statically - the default in [Qt for iOS](#) and [Qt for WebAssembly](#) - you need CMake 3.21.1 or newer.

```
project(helloworld VERSION 1.0.0 LANGUAGES CXX)
```

`project()` sets a project name and the default project version. The `LANGUAGES` argument tells CMake that the program is written in C++.

```
set(CMAKE_CXX_STANDARD 17)
set(CMAKE_CXX_STANDARD_REQUIRED ON)
```

Qt 6 requires a compiler supporting C++ version 17 or newer. Enforcing this by setting the `CMAKE_CXX_STANDARD`, `CMAKE_CXX_STANDARD_REQUIRED` variables will let CMake print an error if the compiler is too old.

```
find_package(Qt6 REQUIRED COMPONENTS Core)
```

This tells CMake to look up Qt 6, and import the `Core` module. There is no point in continuing if CMake cannot locate the module, so we do set the `REQUIRED` flag to let CMake abort in this case.

If successful, the module will set some CMake variables documented in [Module variables](#). It furthermore imports the `Qt6::Core` target that we use below.

For `find_package` to be successful, CMake must find the Qt installation. There are different ways you can tell CMake about Qt, but the most common and recommended approach is to set the CMake cache variable `CMAKE_PREFIX_PATH` to include the Qt 6 installation prefix. Note that [Qt Creator](#) will handle this transparently for you.

```
qt_standard_project_setup()
```

The `qt_standard_project_setup` command sets project-wide defaults for a typical Qt application.

Among other things, this command sets the `CMAKE_AUTOMOC` variable to `ON`, which instructs CMake to automatically set up rules so that Qt's [Meta-Object Compiler \(moc\)](#) is called transparently, when required.

See `qt_standard_project_setup`'s reference for details.

```
add_executable(helloworld
    main.cpp
)
```

`add_executable()` tells CMake that we want to build an executable (so not a library) called `helloworld` as a

explicitly listed so that they are processed by the [Meta-Object Compiler \(moc\)](#).

For less trivial projects, you may want to call `qt_add_executable()` instead. It is a wrapper around the built-in `add_executable()` command, providing additional logic to automatically handle things like linking of Qt plugins in static Qt builds, platform-specific customization of library names and so on.

For creating libraries, see [qt\\_add\\_library](#).

```
target_link_libraries(helloworld PRIVATE Qt6::Core)
```

Finally, `target_link_libraries` tells CMake that the `helloworld` executable makes use of [Qt Core](#) by referencing the `Qt6::Core` target imported by the `find_package()` call above. This will not only add the right arguments to the linker, but also makes sure that the right include directories, compiler definitions are passed to the C++ compiler. The `PRIVATE` keyword is not strictly necessary for an executable target, but it is good practice to specify it. If `helloworld` was a library rather than an executable, then either `PRIVATE` or `PUBLIC` should be specified (`PUBLIC` if the library mentions anything from `Qt6::Core` in its headers, `PRIVATE` otherwise).

## Building a C++ GUI application

In the [last section](#) we showed the `CMakeLists.txt` file for a simple console application. We will now extend it to create a GUI application that uses the [Qt Widgets](#) module.

This is the full project file:

```
cmake_minimum_required(VERSION 3.16)

project(helloworld VERSION 1.0.0 LANGUAGES CXX)

set(CMAKE_CXX_STANDARD 17)
set(CMAKE_CXX_STANDARD_REQUIRED ON)

find_package(Qt6 REQUIRED COMPONENTS Widgets)
qt_standard_project_setup()

add_executable(helloworld
    mainwindow.ui
    mainwindow.cpp
    main.cpp
)

target_link_libraries(helloworld PRIVATE Qt6::Widgets)

set_target_properties(helloworld PROPERTIES
    WIN32_EXECUTABLE ON
    MACOSX_BUNDLE ON
)
```

Let's walk through the changes we have made.

In the `find_package` call, we replace `Core` with `Widgets`. This will locate the `Qt6Widgets` module and provide the `Qt6::Widgets` targets we later link against.

Note that the application will still link against `Qt6::Core`, because `Qt6::Widgets` depends on it.

```
qt_standard_project_setup()
```

In addition to `CMAKE_AUTOMOC`, `qt_standard_project_setup` sets the `CMAKE_AUTOUIC` variable to `ON`. This will automatically create rules to invoke Qt's [User Interface Compiler \(uic\)](#) on `.ui` source files.

```
add_executable(helloworld
    mainwindow.ui
    mainwindow.cpp
    main.cpp
)
```

We add a [Qt Designer](#) file (`mainwindow.ui`) and its corresponding C++ source file (`mainwindow.cpp`) to the application target's sources.

```
target_link_libraries(helloworld PRIVATE Qt6::Widgets)
```

In the `target_link_libraries` command, we link against `Qt6::Widgets` instead of `Qt6::Core`.

```
set_target_properties(helloworld PROPERTIES
    WIN32_EXECUTABLE ON
    MACOSX_BUNDLE ON
)
```

Finally, we set properties on our application target with the following effects:

- › Prevent the creation of a console window on Windows.
- › Create an application bundle on macOS.

See the [CMake Documentation](#) for more information about these target properties.

## Structuring projects

Projects that contain more than just one target will benefit from a clear project file structure. We will use CMake's [subdirectory feature](#).

As we plan to extend the project with more targets, we move the source files of the application into a subdirectory and create a new `CMakeLists.txt` in there.

```
├── CMakeLists.txt
├── src
│   └── app
│       ├── CMakeLists.txt
│       ├── main.cpp
│       ├── mainwindow.cpp
│       ├── mainwindow.h
│       └── mainwindow.ui
```

The top-level `CMakeLists.txt` contains the overall project setup, `find_package` and `add_subdirectory` calls:

```
cmake_minimum_required(VERSION 3.16)

project(helloworld VERSION 1.0.0 LANGUAGES CXX)

set(CMAKE_CXX_STANDARD 17)
set(CMAKE_CXX_STANDARD_REQUIRED ON)

find_package(Qt6 REQUIRED COMPONENTS Widgets)
qt_standard_project_setup()

add_subdirectory(src/app)
```

Variables that are set in this file are visible in subdirectory project files.

The application's project file `src/app/CMakeLists.txt` contains the executable target:

```
add_executable(helloworld
    mainwindow.ui
    mainwindow.cpp
    main.cpp
)

target_link_libraries(helloworld PRIVATE Qt6::Widgets)

set_target_properties(helloworld PROPERTIES
    WIN32_EXECUTABLE ON
    MACOSX_BUNDLE ON
)
```

Such a structure will make it easy to add more targets to the project such as libraries or unit tests.

## Building libraries

As the project grows, you may want to turn parts of your application code into a library that is used by the application and possibly unit tests. This section shows how to create such a library.

For the sake of simplicity, the library consists of just one C++ source file and its corresponding header file that is included by the application's `main.cpp`:

```
<project root>
├── CMakeLists.txt
└── src
    ├── app
    │   ├── ...
    │   └── main.cpp
    └── businesslogic
        ├── CMakeLists.txt
        ├── businesslogic.cpp
        └── businesslogic.h
```

Let's have a look at the library's project file (`src/businesslogic/CMakeLists.txt`).

```
add_library(businesslogic STATIC
    businesslogic.cpp
)
target_link_libraries(businesslogic PRIVATE Qt6::Core)
target_include_directories(businesslogic INTERFACE ${CMAKE_CURRENT_SOURCE_DIR})
```

Let's go through the content.

```
add_library(businesslogic STATIC
    businesslogic.cpp
)
```

The `add_library` command creates the library `businesslogic`. Later, we will let the application link against this target.

The `STATIC` keyword denotes a static library. If we wanted to create a shared or dynamic library, we would use the `SHARED` keyword.

```
target_link_libraries(businesslogic PRIVATE Qt6::Core)
```

We have a static library and don't actually have to link other libraries. But as our library uses classes from `QtCore`, we add a link dependency to `Qt6::Core`. This pulls in the necessary `QtCore` include paths and preprocessor defines.

```
target_include_directories(businesslogic INTERFACE ${CMAKE_CURRENT_SOURCE_DIR})
```

automatically added as an include path to all targets using our library.

This frees us in `main.cpp` from using relative paths to locate `businesslogic.h`. Instead, we can just write

```
#include <businesslogic.h>
```

Last, we must add the library's subdirectory to the top-level project file:

```
add_subdirectory(src/app)
add_subdirectory(src/businesslogic)
```

## Using libraries

To use the library we created in the [previous section](#), we instruct CMake to link against it:

```
target_link_libraries(helloworld PRIVATE
    businesslogic
    Qt6::Widgets)
```

This ensures that `businesslogic.h` is found when `main.cpp` is compiled. Furthermore, the `businesslogic` static library will become a part of the `helloworld` executable.

In CMake terms, the library `businesslogic` specifies *usage requirements* (the include path) that every consumer of our library (the application) has to satisfy. The `target_link_libraries` command takes care of that.

## Adding resources

We want to display some images in our application, so we add them using the [Qt Resource System](#).

```
qt_add_resources(helloworld imageresources
    PREFIX "/images"
    FILES logo.png splashscreen.png
)
```

The `qt_add_resources` command automatically creates a Qt resource containing the referenced images. From the C++ source code, you can access the images by prepending the specified resource prefix:

```
logoLabel->setPixmap(QPixmap(":/images/logo.png"));
```

The `qt_add_resources` command takes as the first argument either a variable name or a target name. We recommend to use the target-based variant of this command as shown in the example above.

Translations of strings in a Qt project are encoded in `.ts` files. See [Internationalization with Qt](#) for details.

To add `.ts` files to your project, use the `qt_add_translations` command.

The following example adds a German and a French translation file to the `helloworld` target:

```
qt_add_translations(helloworld
    TS_FILES helloworld_de.ts helloworld_fr.ts)
```

This creates build system rules to automatically generate `.qm` files from the `.ts` files. By default, the `.qm` files are embedded into a resource and are accessible under the `"/i18n"` resource prefix.

To update the entries in the `.ts` file, build the `update_translations` target:

```
$ cmake --build . --target update_translations
```

To trigger the generation of the `.qm` files manually, build the `release_translations` target:

```
$ cmake --build . --target release_translations
```

For more information about how to influence the handling of `.ts` files and the embedding into a resource, see the [qt\\_add\\_translations documentation](#).

The `qt_add_translations` command is a convenience wrapper. For more fine-grained control of how `.ts` files and `.qm` files are handled, use the underlying commands `qt_add_lupdate` and `qt_add_lrelease`.

## Further reading

The official [CMake Documentation](#) is an invaluable source for working with CMake.

The official [CMake Tutorial](#) covers common build system tasks.

The book [Professional CMake: A Practical Guide](#) provides a great introduction to the most relevant CMake features.

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