A CMake build system for deal.II

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Part I

A build system for deal.II

Introducing CMake

An overview of build systems

What is a build system, anyway?

A build system should

- configure and set up external dependencies

  `MPI / BLAS / LAPACK / etc.`

- build and install the library and executables
- provide configuration for external projects
- run tests
- (other demands)

Over 150 known “build tools” listed on Wikipedia. . .

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An overview of build systems

(The usual rant)

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MakeMake

qmake

Cabal

Shake

SCons

GNU Build Tools

*.Jam

CMake

MSBuild

SBuild

GYP

xmake

Ant

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The rest, aka
the abyss

The land of the
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`CMake`

Introducing CMake

- *CMake [is a] cross-platform, open-source build system, [it is] a familiy of tools designed to build, test and package software.*
- Started 1999 as a cross-platform build system for the *Insight Segmentation and Registration Toolkit* (ITK)
- Maintained by Kitware; 3-clause BSD license
- References: KDE, Blender, LLVM & Clang, ROOT, Reference BLAS, Reference LAPACK

- Good cross-platform support
- CMake is a flexible Makefile generator
- Fast, scales well (the cache. . .)
- Has a simple and expressive (but sometimes awkward) scripting language

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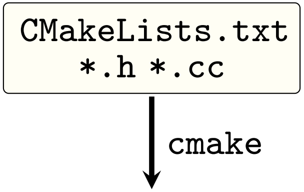
Introducing CMake

```
CMakeLists.txt
  *.h *.cc
```

- platform independent

Introducing CMake



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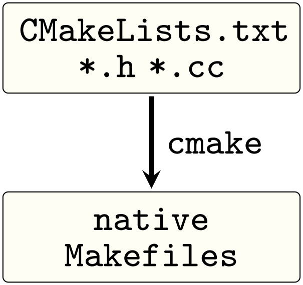
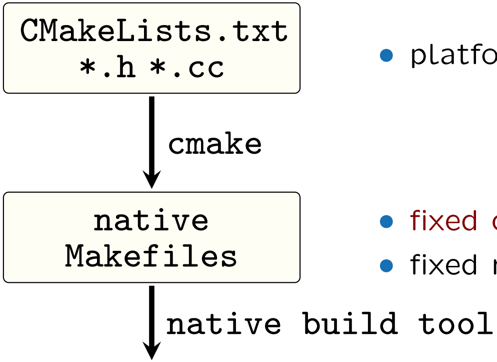
Introducing CMake



- platform independent

- fixed configuration
- fixed native build tool/compiler

Introducing CMake



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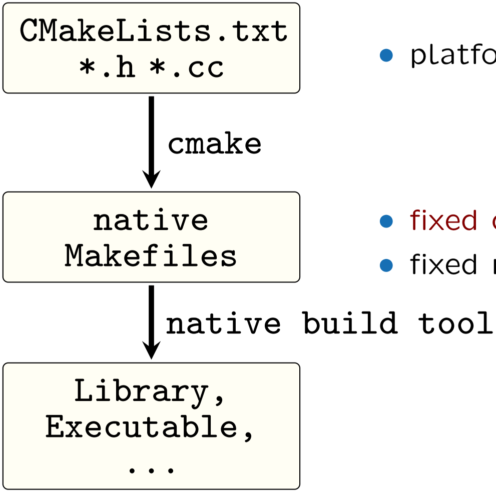

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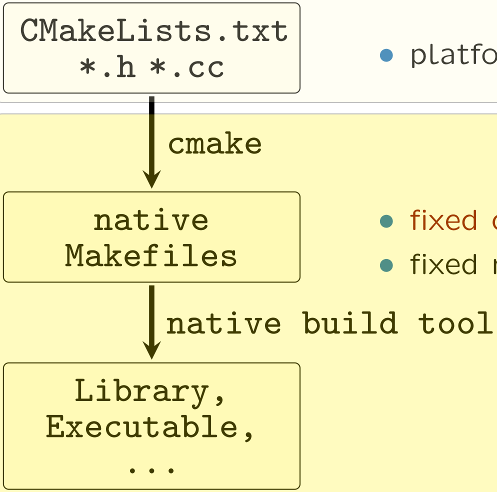
Introducing CMake

Developers

- platform independent



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- fixed native build tool/compiler

Users

Introducing CMake

`CMakeCache.txt` - the CMake cache

- Variables are held in a global table (private scope for subfolders and functions)
- Upon invocation of cmake:
  - Read in all cached variables out of `CMakeCache.txt` and populate the global table
  - `SET(foobar ...)` manipulates the table
  - `SET(foobar ... CACHE)` sets variable in cache and table iff not already present in cache.

This allows for efficient caching of configuration and search results.

For dealII: Initial 17.6 sec, subsequent 0.690 sec.

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A build system for deal.II

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Design goals

- Cross-platform support with a minimal set of dependencies:
  - CMake and a native build tool (no Perl, Python)
  - a native C++-compiler
- Flexible support of external dependencies
  - compiled by user
  - compiled and installed by user
  - packaged by a distribution
- Be as easy to use as possible (autodetection)
- . . . but try to support uncommon use cases
- Provide a possibility to easily override any configuration
- Support out-of source builds

A build system for deal.II

External libraries (insanity can't be far away. . .)

I want to link an external library `foobar`:

- `-L<..> -lfoobar` is not enough
- full transitive link interface might be needed
  (static archives, C++ code with templates)

And how to get the transitive link interface?

- There are solutions for this. . .
  (libtool's la-files, pkg-config, package provides config)
- . . . but none is guaranteed to be available.

So, do it (mostly) by hand. . .

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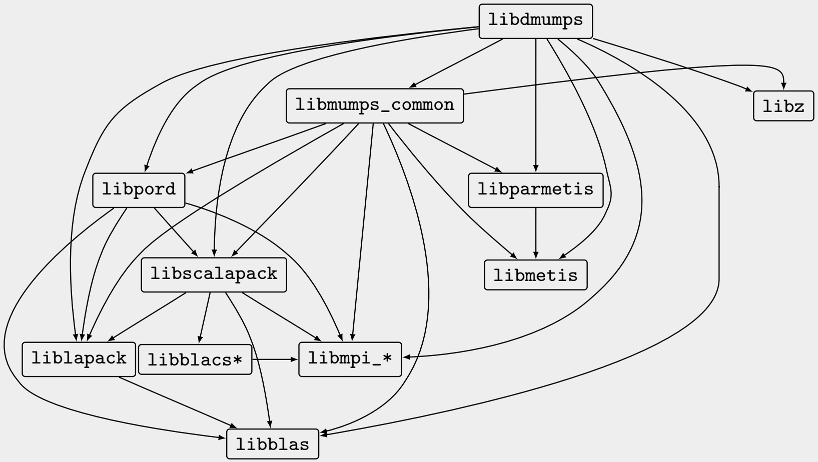
An example:



Now, try this with Trilinos or PETSc.

A build system for deal.II

A quick overview:

- External dependencies are controlled with `DEAL_II_WITH_*` variables
- Options to override behaviour
  - `DEAL_II_ALLOW_AUTODETECTION`
  - `DEAL_II_ALLOW_BUNDLED`
  - `DEAL_II_FORCE_*`
- `deal.II/doc/development/Config.sample`

Some statistics:

External dependencies:	1841 SLOC (3495 total)
Platform and Compiler checks:	683 SLOC (1749 total)
Complete build system:	4658 SLOC (9548 total)

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Demo

Demo

Configure and let's see what happens:

```
deal.II % ls
CMakeLists.txt cmake include source [...]

deal.II % mkdir build
deal.II % cd build

build % cmake ..
```

Demo

```
build % cmake ..
-- This is CMake 2.8.11.1
[...]
-- Configuring done. Proceed to target definitions now.
###
#
#  deal.II configuration:
#       CMAKE_BUILD_TYPE:        DebugRelease
#       BUILD_SHARED_LIBS:       ON
#       CMAKE_INSTALL_PREFIX:    /usr/local
#       CMAKE_SOURCE_DIR:        /tmp/deal.II (Version 8.1.pre)
#       CMAKE_BINARY_DIR:        /tmp/deal.II/build
[...]
#  Configured Features:
#         DEAL_II_WITH_BOOST set up with external dependencies
#       ( DEAL_II_WITH_METIS = OFF )
[...]
#  Component configuration:
#       ( DEAL_II_COMPONENT_DOCUMENTATION = OFF )
[...]
#
###
-- Configuring done
-- Generating done
-- Build files have been written to: /tmp/deal.II/build
```

Demo

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-- Configuring done
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Demo

So let's correct for this:

```
build % cmake -DCMAKE_INSTALL_PREFIX=$PWD .
```

```
build % cmake -DDEAL_II_WITH_METIS=ON \
              -DMETIS_DIR=/tmp/metis .
```

Remark

- In many cases the `DEAL_II_` prefix can be omitted on the command line and will be automatically expanded (for `_WITH_`, `_ALLOW_`, `_FORCE_`)
- Alternatively, use the graphical editor!

```
build % ccmake .
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```
build % ccmake .
```

Demo

And what if the `METIS_DIR` is accidently omitted?

```
build % cmake -DDEAL_II_WITH_METIS=ON .
[...]
CMake Error at cmake/macros/macro_configure_feature.cmake:116 (MESSAGE)

  Could not find the metis library!

  Could not find a sufficient modern metis installation: Version 5.x
  required!

  Please ensure that a suitable metis library is installed on your
  computer.

  If the library is not at a default location, either provide some
  hints for autodetection,

      $ METIS_DIR="..." cmake <...>
      $ cmake -DMETIS_DIR="..." <...>

  or set the relevant variables by hand in ccmake.
[...]
build %
```

Demo

Finally, build and install the library:

```
build % make -j8
build % make install
```

Tip:

Try **ninja**!

```
build % cmake -GNinja ..
build % ninja
build % ninja install
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Remark:

And if you just don't care about out-of-source builds:

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Part II

Using CMake in user projects

Hello Deallog

Hello World

Just a **`hello_world.cc`** file:

Project:

```
project % ls
CMakeLists.txt hello_world.cc
```

CMakeLists.txt

```
ADD_EXECUTABLE(hello_world
  hello_world.cc
  )
```

Hello Deallog

A **`hello_deallog.cc`** file with dependency on deal.II:

CMakeLists.txt

```
CMAKE_MINIMUM_REQUIRED(VERSION 2.8.8)
PROJECT(hello_world CXX)

FIND_PACKAGE(deal.II 8.0 REQUIRED)

ADD_EXECUTABLE(hello_deallog
  hello_deallog.cc
  )
DEAL_II_SETUP_TARGET(hello_deallog)
```

`DEAL_II_SETUP_TARGET` will

- add include directories
- add compile definitions
- add linker flags and the link interface

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DEAL_II_SETUP_TARGET will

- add include directories
- add compile definitions
- add linker flags and the link interface

Hello Deallog

And with build type handling and compiler flags:

CMakeLists.txt

```
CMAKE_MINIMUM_REQUIRED(VERSION 2.8.8)

FIND_PACKAGE(deal.II 8.0 REQUIRED)
DEAL_II_INITIALIZE_CACHED_VARIABLES()
PROJECT(hello_world CXX)

ADD_EXECUTABLE(hello_deallog
  hello_deallog.cc
  )
DEAL_II_SETUP_TARGET(hello_deallog)
```

DEAL_II_INITIALIZE_CACHED_VARIABLES will

- setup CMAKE_BUILD_TYPE (Debug, Release)
- setup CMAKE_CXX_FLAGS (*_DEBUG, *_RELEASE)

Hello Deallog

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```

`DEAL_II_INITIALIZE_CACHED_VARIABLES` will

- setup `CMAKE_BUILD_TYPE` (`Debug`, `Release`)
- setup `CMAKE_CXX_FLAGS` (`*_DEBUG`, `*_RELEASE`)

Hello Deallog

Dependency on an external library:

```
# If there is a FindFOO.cmake module:
FIND_PACKAGE(foo 8.0 REQUIRED)
INCLUDE_DIRECTORIES(${FOO_INCLUDE_DIRS})

ADD_EXECUTABLE(hello_deallog hello_deallog.cc)
DEAL_II_SETUP_TARGET(hello_deallog)
TARGET_LINK_LIBRARIES(hello_deallog
   ${FOO_LIBRARIES}
   )
```

```
# And with pkg-config:
FIND_PACKAGE(PkgConfig)
PKG_CHECK_MODULES(FOO REQUIRED foo)
# Rest as above (Better write a FindFOO.cmake)
```

Hello Deallog

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```

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FIND_PACKAGE(PkgConfig)
PKG_CHECK_MODULES(FOO REQUIRED foo)
# Rest as above (Better write a FindFOO.cmake)
```

Hello Deallog

Declare compile definitions:

```
...
ADD_DEFINITIONS(-DFOO -DNAME="Matthias␣Maier")

...
ADD_EXECUTABLE(hello_deallog hello_deallog.cc)
```

Or the modern way to do this:

```
...
ADD_EXECUTABLE(hello_deallog hello_deallog.cc)
SET_PROPERTY(TARGET hello_deallog
  APPEND PROPERTY COMPILE_DEFINITIONS
  FOO
  NAME="Matthias␣Maier"
  )
```

Hello Deallog

Declare compile definitions:

```
...
ADD_DEFINITIONS(-DFOO -DNAME="Matthias␣Maier")

...
ADD_EXECUTABLE(hello_deallog hello_deallog.cc)
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  )
```

Advanced example

Advanced example

An advanced example:

- A support library **`Kiyo`** providing wrappers for third party libraries
- A library **`Grendel`** that provides multiscale data structures and algorithms
- An executable **`Cynder`**

Project structure:

```
project % ls

cynder/{*.h|*.cc}
grendel/{*.h|*.cc}
kiyo/{*.h|*.cc}
```

Advanced example

The top level `CMakeLists.txt` file:

./CMakeLists.txt

```
CMAKE_MINIMUM_REQUIRED(VERSION 2.8.8)

FIND_PACKAGE(deal.II 8.0 REQUIRED
  HINTS ${DEAL_II_DIR} $ENV{DEAL_II_DIR}
  )

DEAL_II_INITIALIZE_CACHED_VARIABLES()

PROJECT(cynder CXX)

ADD_SUBDIRECTORY(kiyo)
ADD_SUBDIRECTORY(grendel)
ADD_SUBDIRECTORY(cynder)
```

Advanced example

The top level **`CMakeLists.txt`** file:

./CMakeLists.txt

```
CMAKE_MINIMUM_REQUIRED(VERSION 2.8.8)

FIND_PACKAGE(deal.II 8.0 REQUIRED
  HINTS ${DEAL_II_DIR} $ENV{DEAL_II_DIR}
  )

DEAL_II_INITIALIZE_CACHED_VARIABLES()

PROJECT(cynder CXX)

ADD_SUBDIRECTORY(kiyo)
ADD_SUBDIRECTORY(grendel)
ADD_SUBDIRECTORY(cynder)
```

Advanced example

The top level **`CMakeLists.txt`** file:

./CMakeLists.txt

```
CMAKE_MINIMUM_REQUIRED(VERSION 2.8.8)

FIND_PACKAGE(deal.II 8.0 REQUIRED
  HINTS ${DEAL_II_DIR} $ENV{DEAL_II_DIR}
  )

DEAL_II_INITIALIZE_CACHED_VARIABLES()

PROJECT(cynder CXX)

ADD_SUBDIRECTORY(kiyo)
ADD_SUBDIRECTORY(grendel)
ADD_SUBDIRECTORY(cynder)
```

Advanced example

For the support library **Kiyo**:

kiyo/CMakeLists.txt

```
FIND_PACKAGE(quantim REQUIRED)

INCLUDE_DIRECTORIES(
  ${QUANTIM_INCLUDE_DIRS}
  )

ADD_LIBRARY(kiyo SHARED
  boundary_values.cc
  coefficients.cc
  ...
  )
DEAL_II_SETUP_TARGET(kiyo)
TARGET_LINK_LIBRARIES(kiyo ${QUANTIM_LIBRARIES}
```

Advanced example

For the support library `Kiyo`:

kiyo/CMakeLists.txt

```
FIND_PACKAGE(quantim REQUIRED)

INCLUDE_DIRECTORIES(
  ${QUANTIM_INCLUDE_DIRS}
  )

ADD_LIBRARY(kiyo SHARED
  boundary_values.cc
  coefficients.cc
  ...
  )
DEAL_II_SETUP_TARGET(kiyo)
TARGET_LINK_LIBRARIES(kiyo ${QUANTIM_LIBRARIES}
```

Advanced example

Grendel that provides data structures and algorithms:

grendel/CMakeLists.txt

```
INCLUDE_DIRECTORIES(
  ${CMAKE_SOURCE_DIR}/kiyo
  )

ADD_LIBRARY(grendel SHARED
  averaged_tensor.cc
  diffusion_problem.cc
  ...
  )
DEAL_II_SETUP_TARGET(grendel)
```

Advanced example

Grendel that provides data structures and algorithms:

grendel/CMakeLists.txt

```
INCLUDE_DIRECTORIES(
  ${CMAKE_SOURCE_DIR}/kiyo
  )

ADD_LIBRARY(grendel SHARED
  averaged_tensor.cc
  diffusion_problem.cc
  ...
  )
DEAL_II_SETUP_TARGET(grendel)
```

Advanced example

Finally, the executable **Cynder**:

cynder/CMakeLists.txt

```
SET(DIM 2 CACHE STRING "The␣dimension")
INCLUDE_DIRECTORIES(
  ${CMAKE_SOURCE_DIR}/grendel
  ${CMAKE_SOURCE_DIR}/kiyo
  )
ADD_EXECUTABLE(cynder
  cynder.cc
  loop.cc
  )
DEAL_II_SETUP_TARGET(cynder)
TARGET_LINK_LIBRARIES(cynder grendel kiyo)
SET_PROPERTY(TARGET cynder APPEND
  PROPERTY COMPILE_DEFINITIONS DIM=${DIM}
  )
```

Advanced example

Finally, the executable **Cynder**:

cynder/CMakeLists.txt

```
SET(DIM 2 CACHE STRING "The␣dimension")
INCLUDE_DIRECTORIES(
  ${CMAKE_SOURCE_DIR}/grendel
  ${CMAKE_SOURCE_DIR}/kiyo
  )
ADD_EXECUTABLE(cynder
  cynder.cc
  loop.cc
  )
DEAL_II_SETUP_TARGET(cynder)
TARGET_LINK_LIBRARIES(cynder grendel kiyo)
SET_PROPERTY(TARGET cynder APPEND
  PROPERTY COMPILE_DEFINITIONS DIM=${DIM}
  )
```

Advanced example

A run folder and a **make run**-target for **Cynder**:

./CMakeLists.txt

```
# Copy folder run to build directory:
FILE(COPY run DESTINATION ${CMAKE_BINARY_DIR})
```

cynder/CMakeLists.txt

```
ADD_EXECUTABLE(cynder cynder.cc loop.cc)
SET_PROPERTY(TARGET cynder
  PROPERTY RUNTIME_OUTPUT_DIRECTORY
  ${CMAKE_BINARY_DIR}/run
  )
ADD_CUSTOM_TARGET(run
  COMMAND cynder
  WORKING_DIRECTORY ${CMAKE_BINARY_DIR}/run
  )
```

Advanced example

A run folder and a **make run**-target for **Cynder**:

./CMakeLists.txt

```
# Copy folder run to build directory:
FILE(COPY run DESTINATION ${CMAKE_BINARY_DIR})
```

cynder/CMakeLists.txt

```
ADD_EXECUTABLE(cynder cynder.cc loop.cc)
SET_PROPERTY(TARGET cynder
  PROPERTY RUNTIME_OUTPUT_DIRECTORY
  ${CMAKE_BINARY_DIR}/run
  )
ADD_CUSTOM_TARGET(run
  COMMAND cynder
  WORKING_DIRECTORY ${CMAKE_BINARY_DIR}/run
  )
```

Advanced example

A run folder and a **`make run`**-target for **`Cynder`**:

./CMakeLists.txt

```
# Copy folder run to build directory:
FILE(COPY run DESTINATION ${CMAKE_BINARY_DIR})
```

cynder/CMakeLists.txt

```
ADD_EXECUTABLE(cynder cynder.cc loop.cc)
SET_PROPERTY(TARGET cynder
  PROPERTY RUNTIME_OUTPUT_DIRECTORY
  ${CMAKE_BINARY_DIR}/run
  )
ADD_CUSTOM_TARGET(run
  COMMAND cynder
  WORKING_DIRECTORY ${CMAKE_BINARY_DIR}/run
  )
```

Advanced example

Install the project:

cynder/CMakeLists.txt

```
INSTALL(TARGETS cynder DESTINATION bin)
```

grendel/CMakeLists.txt

```
INSTALL(TARGETS grendel DESTINATION lib)
```

kiyo/CMakeLists.txt

```
INSTALL(TARGETS kiyo DESTINATION lib)
```

./CMakeLists.txt

```
INSTALL(DIRECTORY run/ DESTINATION run)
```

And beyond that...

Thank you for your attention!