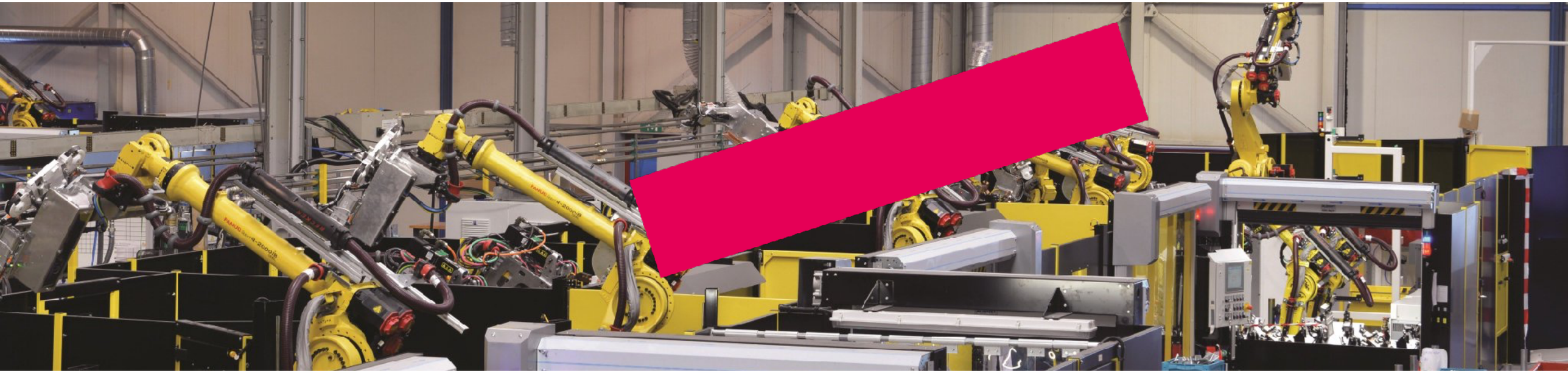
Programming 6



Workshop on CMake

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V1.0 Nov 2025

HAN_UNIVERSITY
OF APPLIED SCIENCES

Workshop Topics overview

Clean code (beyond SOLID)

CMake

Unit testing

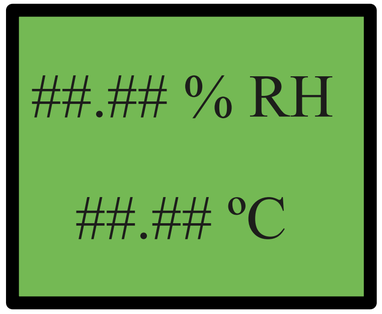
Commentaar

Patterns (Clean architecture)

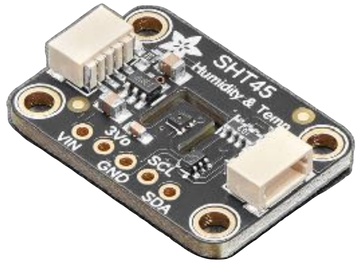
Example project for today

SHT45

- Temperature
- Humidity Sensor



Lab Environment Monitor



Pragmatic start - Stepping stone 1

Welcome | main.cpp ×

main.cpp > main()

```cpp
// Our starter project
// Cmake Workshop Prog 6
//
// HAN University of Applied Sciences
// Johan Korten - v1.0 2025
//
// main.cpp
// compile using: g++ main.cpp -o sensor_app

#include <iostream>

int main() {
    std::cout << "Reading SHT45 sensor..." << std::endl;
    return 0;
}
```

Pragmatic start - Stepping stone 1

Welcome | main.cpp

main.cpp > main()

```cpp
// Our starter project
// Cmake Workshop Prog 6
//
// HAN University of Applied Sciences
// Johan Korten - v1.0 2025
//
// main.cpp
// compile using: g++ main.cpp -o sensor_app

#include <iostream>

int main() {
    std::cout << "Reading SHT45 sensor..." << std::endl;
    return 0;
}
```

Compile and test:

```
jakorten@device-35 SimpleProject % g++ main.cpp -o sensor_app
jakorten@device-35 SimpleProject % ./sensor_app
Reading SHT45 sensor...
jakorten@device-35 SimpleProject %
```

Towards a library - Stepping stone 2

Welcome | main.cpp

main.cpp > main()

```cpp
// Our starter project
// Cmake Workshop Prog 6
//
// HAN University of Applied Sciences
// Johan Korten - v1.0 2025
//
// main.cpp
// compile using: g++ main.cpp -o sensor_app

#include <iostream>

int main() {
    std::cout << "Reading SHT45 sensor..." << std::endl;
    return 0;
}
```

Compile and test:

Towards a library - Stepping stone 2

```cpp
// Our starter project
// Cmake Workshop Prog 6
//
// HAN University of Applied Sciences
// Johan Korten - v1.0 2025
//
// main.cpp
// compile using: g++ main.cpp -o sensor_app

#include <iostream>

int main() {
    std::cout << "Reading SHT45 sensor..." << std::endl;
    return 0;
}
```

Compile and test: (Whoops…)

```
jakorten@device-35 SimpleLibrary % g++ main.cpp -o sensor_app
Undefined symbols for architecture arm64:
  "SHT45::read_temperature()", referenced from:
      _main in main-ecf635.o
ld: symbol(s) not found for architecture arm64
clang++: error: linker command failed with exit code 1 (use -v to see invocation
)
```

Towards a library - Stepping stone 2

Welcome | main.cpp

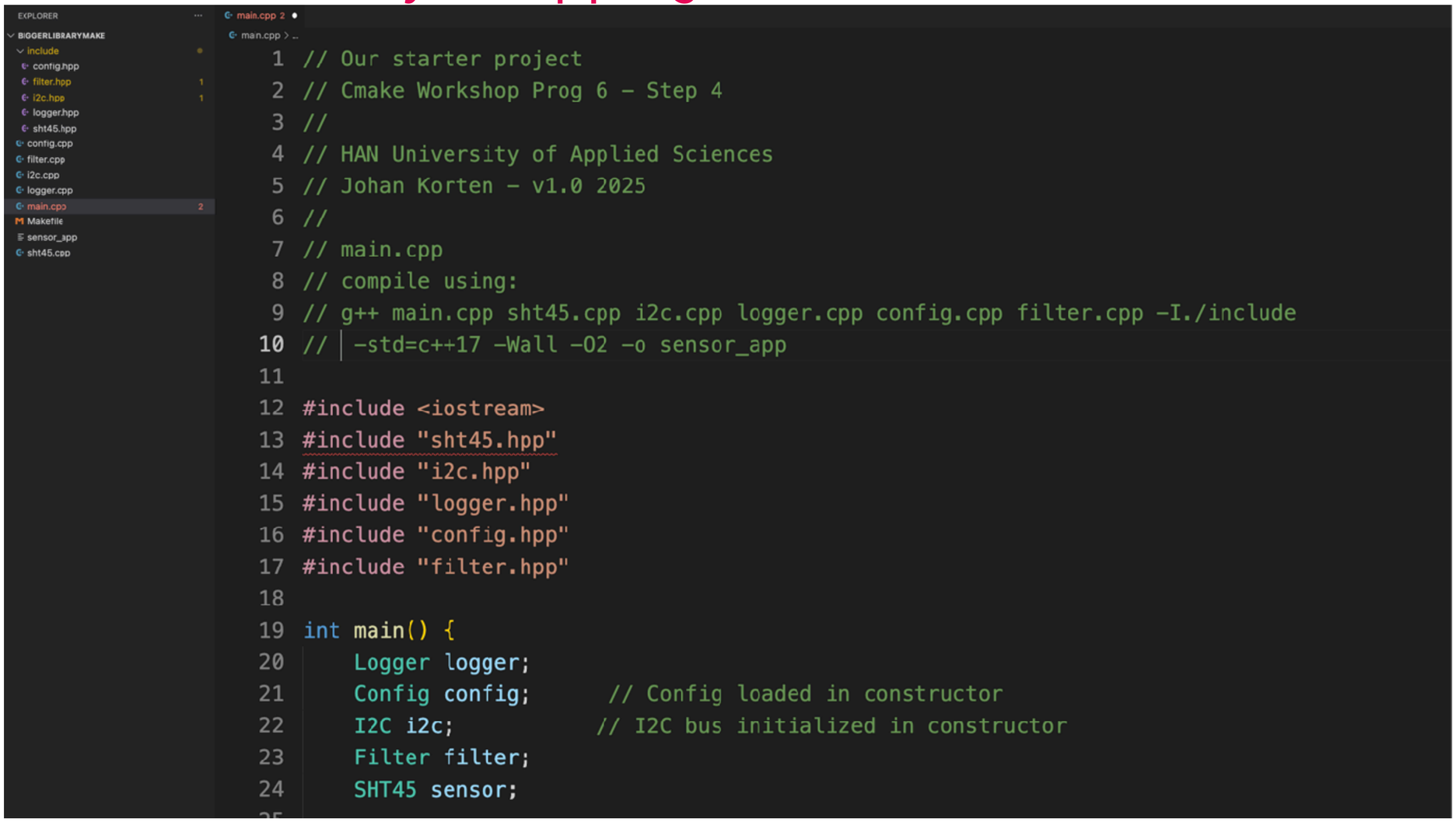
main.cpp > main()

```cpp
// Our starter project
// Cmake Workshop Prog 6
//
// HAN University of Applied Sciences
// Johan Korten - v1.0 2025
//
// main.cpp
// compile using: g++ main.cpp -o sensor_app

#include <iostream>

int main() {
    std::cout << "Reading SHT45 sensor..." << std::endl;
    return 0;
}
```

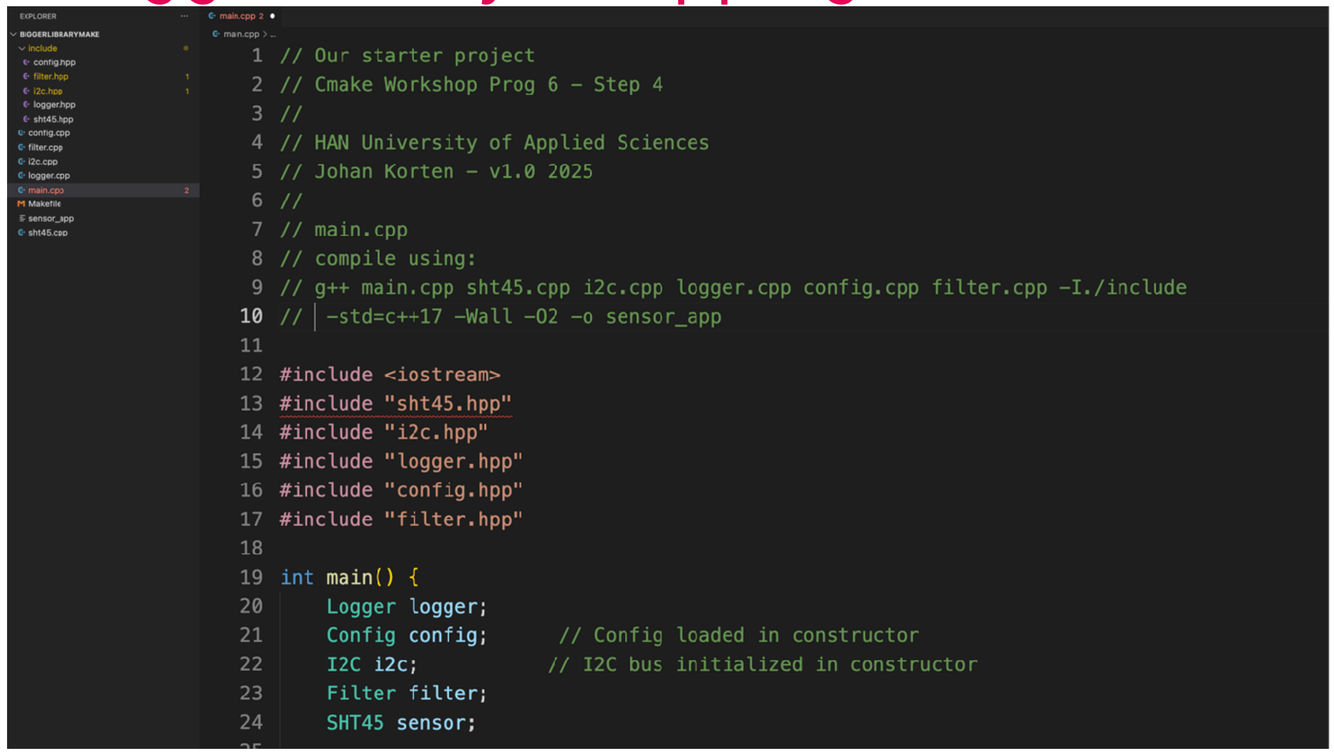
Compile and test: (Pfwiew, we got away for now…)

```
jakorten@device-35 SimpleLibrary % g++ main.cpp -o sensor_app
Undefined symbols for architecture arm64:
  "SHT45::read_temperature()", referenced from:
      _main in main-ecf635.o
ld: symbol(s) not found for architecture arm64
clang++: error: linker command failed with exit code 1 (use -v to see invocation
)
jakorten@device-35 SimpleLibrary % g++ main.cpp sht45.cpp -o sensor_app
jakorten@device-35 SimpleLibrary %
```

Towards a library - Stepping stone 3



A bigger library - Stepping stone 4




```
g++ main.cpp sht45.cpp i2c.cpp logger.cpp config.cpp filter.cpp -I./include -std=c++17 -Wall -O2 -o sensor_app
```

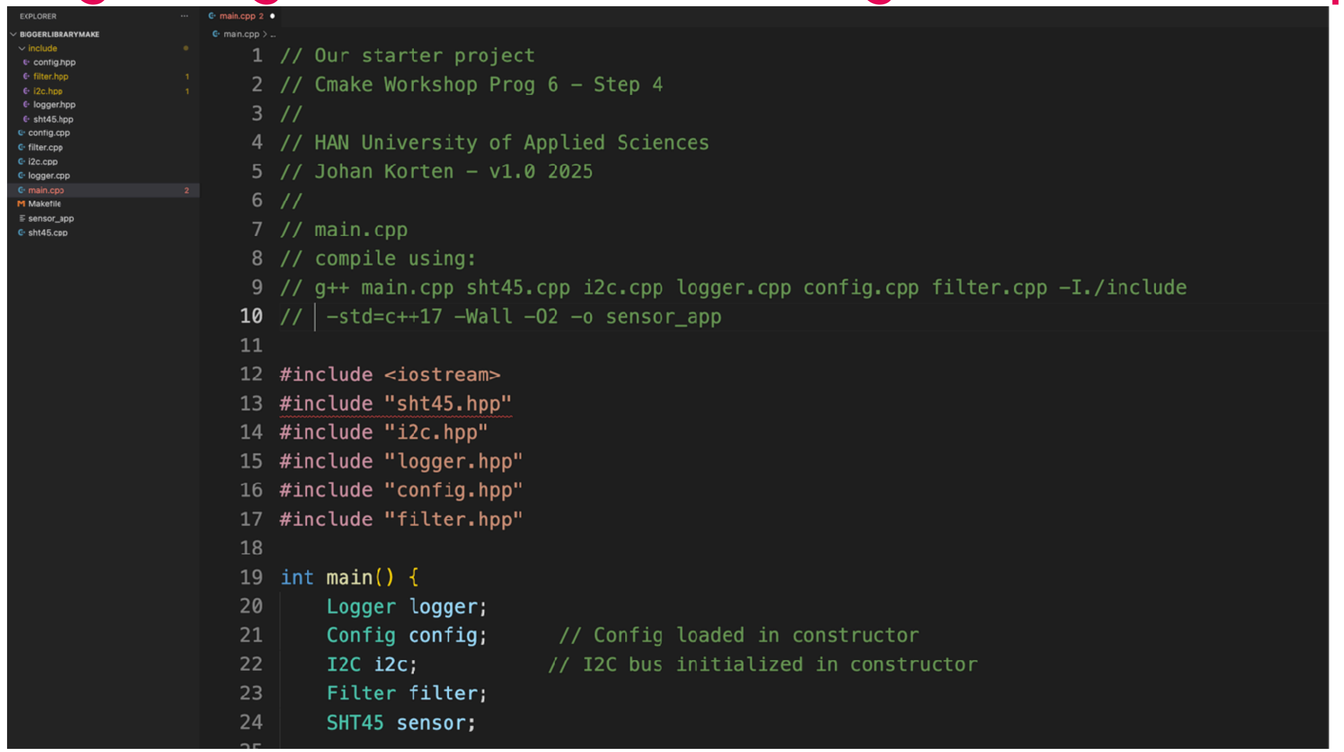
Fighting Commandline Nightmares - Stepping stone 5

```
g++ main.cpp sht45.cpp i2c.cpp logger.cpp config.cpp filter.cpp -I./include -std=c++17 -Wall -O2 -o sensor_app
```

Alternative: Makefile

```
# Makefile for Sensor Application
# CMake Workshop - HAN University of Applied Sciences
# Johan Korten - v1.0 2025

# Compiler and flags
CXX = g++
CXXFLAGS = -std=c++17 -Wall -Wextra -O2 -I./include
LDFLAGS =

# Target executable
TARGET = sensor_app

# Source files
SOURCES = main.cpp sht45.cpp i2c.cpp logger.cpp config.cpp filter.cpp

# Object files (replace .cpp with .o)
OBJECTS = main.o sht45.o i2c.o logger.o config.o filter.o

# Header files (for dependency tracking)
HEADERS = include/sht45.hpp include/i2c.hpp include/logger.hpp include/config.hpp include/filter.hpp

# Default target
all: $(TARGET)

# Link object files to create executable
$(TARGET): $(OBJECTS)
        $(CXX) $(OBJECTS) $(LDFLAGS) -o $(TARGET)
        @echo "Build complete: $(TARGET)"

# Compile main.cpp
main.o: main.cpp $(HEADERS)
        $(CXX) $(CXXFLAGS) -c main.cpp

# Compile sht45.cpp
sht45.o: sht45.cpp include/sht45.hpp
        $(CXX) $(CXXFLAGS) -c sht45.cpp

# Compile i2c.cpp
i2c.o: i2c.cpp include/i2c.hpp
        $(CXX) $(CXXFLAGS) -c i2c.cpp

# Compile logger.cpp
logger.o: logger.cpp include/logger.hpp
        $(CXX) $(CXXFLAGS) -c logger.cpp

# Compile config.cpp
config.o: config.cpp include/config.hpp
        $(CXX) $(CXXFLAGS) -c config.cpp

# Compile filter.cpp
filter.o: filter.cpp include/filter.hpp
        $(CXX) $(CXXFLAGS) -c filter.cpp

# Clean build artifacts
clean:
        rm -f $(OBJECTS) $(TARGET)
        @echo "Clean complete"

# Rebuild everything from scratch
rebuild: clean all

# Run the application
run: $(TARGET)
        ./$(TARGET)

# Show help
help:
        @echo "Available targets:"
        @echo "  all     - Build the application (default)"
        @echo "  clean   - Remove all build artifacts"
        @echo "  rebuild - Clean and build from scratch"
        @echo "  run     - Build and run the application"
        @echo "  help    - Show this help message"

.PHONY: all clean rebuild run help
```

Fighting Commandline Nightmares - Stepping stone 5




```
jakorten@device-35 BiggerLibraryMake % make
g++ -std=c++17 -Wall -Wextra -O2 -I./include -c main.cpp
g++ -std=c++17 -Wall -Wextra -O2 -I./include -c sht45.cpp
g++ -std=c++17 -Wall -Wextra -O2 -I./include -c i2c.cpp
g++ -std=c++17 -Wall -Wextra -O2 -I./include -c logger.cpp
g++ -std=c++17 -Wall -Wextra -O2 -I./include -c config.cpp
g++ -std=c++17 -Wall -Wextra -O2 -I./include -c filter.cpp
g++ main.o sht45.o i2c.o logger.o config.o filter.o  -o sensor_app
Build complete: sensor_app
jakorten@device-35 BiggerLibraryMake % make run
./sensor_app
[LOG] Starting sensor application...
Temperature: 20.25
[LOG] Application complete
jakorten@device-35 BiggerLibraryMake %
```

```
jakorten@device-35 BiggerLibraryMake % make clean
rm -f main.o sht45.o i2c.o logger.o config.o filter.o sensor_app
Clean complete
jakorten@device-35 BiggerLibraryMake %
```

```
cd BiggerLibraryMake
make              # Build the project
make run          # Build and run
make clean        # Clean up
make help         # See available commands
```

The problem of makefiles

Makefiles: Easily 00+ lines for a simple project

IDE lock-in: Can't share code between STM32CubeIDE / VS Code / CLion / whatever.

Fighting Commandline Nightmares - Stepping stone 5

From the cli nightmare to the make nightmare…

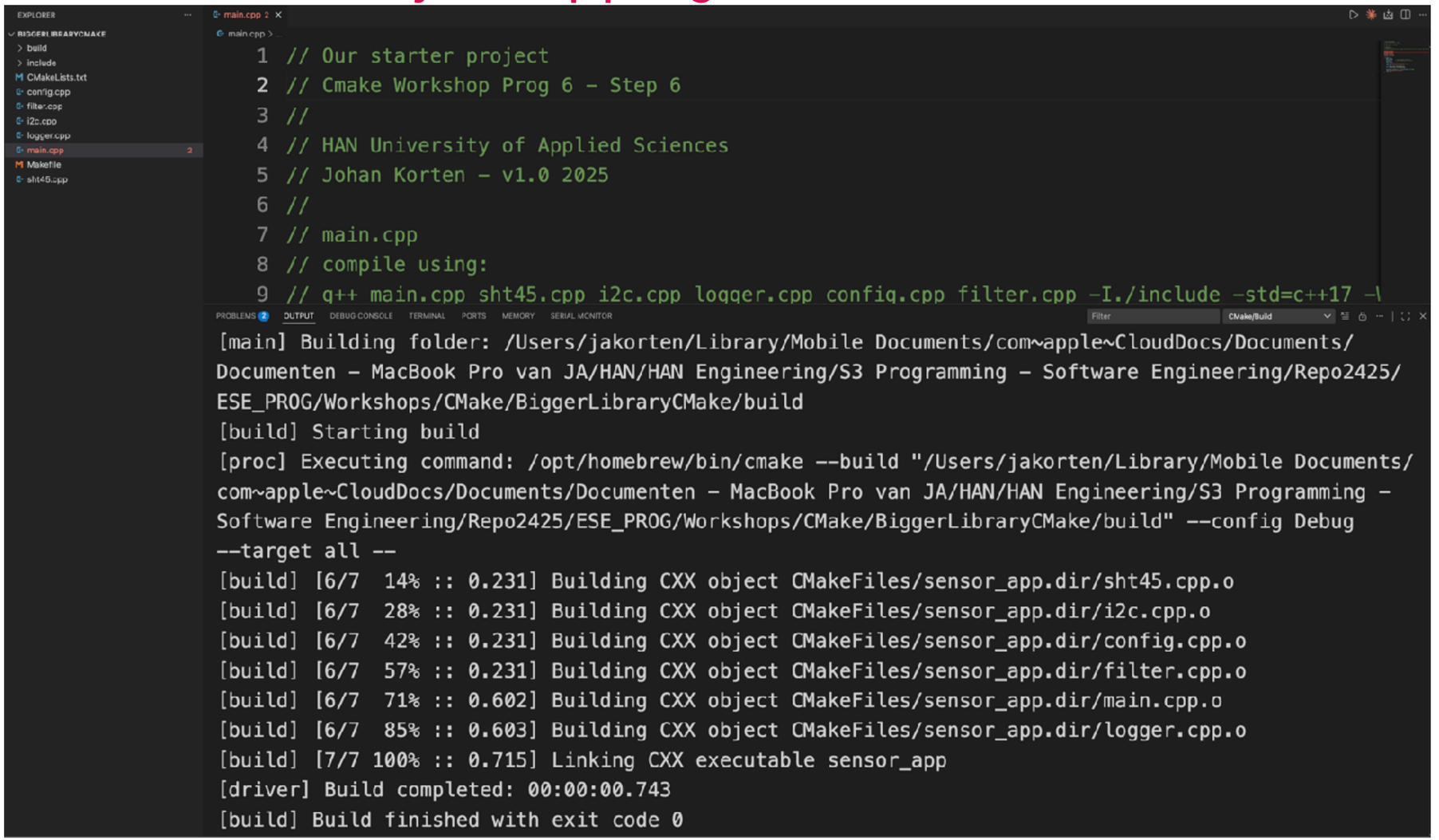
Pro’s:

1. Incremental compilation - Only recompiles changed files
2. Dependency tracking - Recompiles when headers change
3. Clean separation - Variables for compiler, flags, sources
4. Helper targets - clean, rebuild, run, help
5. Standard conventions - Uses CXX, CXXFLAGS, etc.

Con’s:

1. Manual listing - Every .cpp and .o file must be listed
2. Repetitive rules - 6 nearly identical compilation rules
3. Manual dependency tracking - Have to specify which .cpp depends on which .hpp
4. Platform-specific - Won't work on Windows without changes
5. Hard-coded compiler - g++ might not be available everywhere
6. Tedious maintenance - Add new file = edit 3+ places in Makefile

Towards a library - Stepping stone 6




```
cd BiggerLibraryCMake
mkdir build
cd build
cmake ..          # Generate build system
make              # Build (or 'cmake --build .')
./sensor_app      # Run
```

Towards a library - Stepping stone 6

Makefile

```
# Makefile for Sensor Application
# CMake Workshop – HAN University of Applied Sciences
# Johan Korten – v1.0 2025

# Compiler and flags
CXX = g++
CXXFLAGS = -std=c++17 -Wall -Wextra -O2 -I./include
LDFLAGS =

# Target executable
TARGET = sensor_app

# Source files
SOURCES = main.cpp sht45.cpp i2c.cpp logger.cpp config.cpp filter.cpp

# Object files (replace .cpp with .o)
OBJECTS = main.o sht45.o i2c.o logger.o config.o filter.o
```

```
cd BiggerLibraryCMake
mkdir build
cd build
cmake ..        # Generate build system
make            # Build (or 'cmake --build .')
./sensor_app    # Run
```

Makefile 1/5 1..17

Towards a library - Stepping stone 6

Makefile

```
18
19 # Header files (for dependency tracking)
20 HEADERS = include/sht45.hpp include/i2c.hpp include/logger.hpp include/config.hpp include/
21
22 # Default target
23 all: $(TARGET)
24
25 # Link object files to create executable
26 $(TARGET): $(OBJECTS)
27     $(CXX) $(OBJECTS) $(LDFLAGS) -o $(TARGET)
28     @echo "Build complete: $(TARGET)"
29
30 # Compile main.cpp
31 main.o: main.cpp $(HEADERS)
32     $(CXX) $(CXXFLAGS) -c main.cpp
33
34 # Compile sht45.cpp
```

```
cd BiggerLibraryCMake
mkdir build
cd build
cmake ..          # Generate build system
make              # Build (or 'cmake --build .')
./sensor_app      # Run
```

Makefile 2/5 18..33

Towards a library - Stepping stone 6

Makefile

```
34 # Compile sht45.cpp
35 sht45.o: sht45.cpp include/sht45.hpp
36     $(CXX) $(CXXFLAGS) -c sht45.cpp
37
38 # Compile i2c.cpp
39 i2c.o: i2c.cpp include/i2c.hpp
40     $(CXX) $(CXXFLAGS) -c i2c.cpp
41
42 # Compile logger.cpp
43 logger.o: logger.cpp include/logger.hpp
44     $(CXX) $(CXXFLAGS) -c logger.cpp
45
46 # Compile config.cpp
47 config.o: config.cpp include/config.hpp
48     $(CXX) $(CXXFLAGS) -c config.cpp
49
50 # Compile filter.cpp
```

```
cd BiggerLibraryCMake
mkdir build
cd build
cmake ..          # Generate build system
make              # Build (or 'cmake --build .')
./sensor_app      # Run
```

Makefile 3/5 34..49

Towards a library - Stepping stone 6

Makefile

```
47 config.o: config.cpp include/config.hpp
50 # Compile filter.cpp
51 filter.o: filter.cpp include/filter.hpp
52     $(CXX) $(CXXFLAGS) -c filter.cpp
53
54 # Clean build artifacts
55 clean:
56     rm -f $(OBJECTS) $(TARGET)
57     @echo "Clean complete"
58
59 # Rebuild everything from scratch
60 rebuild: clean all
61
62 # Run the application
63 run: $(TARGET)
64     ./$(TARGET)
65
```

```
cd BiggerLibraryCMake
mkdir build
cd build
cmake ..        # Generate build system
make            # Build (or 'cmake --build .')
./sensor_app    # Run
```

Makefile 4/5 47..64

Towards a library - Stepping stone 6

Makefile

```
63  run: $(TARGET)
65
66  # Show help
67  help:
68      @echo "Available targets:"
69      @echo "  all     - Build the application (default)"
70      @echo "  clean   - Remove all build artifacts"
71      @echo "  rebuild - Clean and build from scratch"
72      @echo "  run     - Build and run the application"
73      @echo "  help    - Show this help message"
74
75  .PHONY: all clean rebuild run help
76
```

```
cd BiggerLibraryCMake
mkdir build
cd build
cmake ..        # Generate build system
make            # Build (or 'cmake --build .')
./sensor_app    # Run
```

Makefile 5/5 47..64

Towards a library - Stepping stone 6

CMakeLists.txt

```cmake
# CMakeLists.txt for Sensor Application
# CMake Workshop – HAN University of Applied Sciences
# Johan Korten – v1.0 2025

# Minimum CMake version required
cmake_minimum_required(VERSION 3.10)

# Project name and version
project(SensorApp VERSION 1.0 LANGUAGES CXX)

# Set C++ standard
set(CMAKE_CXX_STANDARD 17)
set(CMAKE_CXX_STANDARD_REQUIRED ON)
set(CMAKE_CXX_EXTENSIONS OFF)

# Compiler flags
add_compile_options(-Wall -Wextra -O2)
```

```
cd BiggerLibraryCMake
mkdir build
cd build
cmake ..        # Generate build system
make            # Build (or 'cmake --build .')
./sensor_app    # Run
```

CMakeLists.txt
1/2 1..17

Towards a library - Stepping stone 6

CMakeLists.txt

```
17 add_compile_options(-Wall -Wextra -O2)
18
19 # Include directories
20 include_directories(include)
21
22 # Source files
23 set(SOURCES
24     main.cpp
25     sht45.cpp
26     i2c.cpp
27     logger.cpp
28     config.cpp
29     filter.cpp
30 )
31
32 # Create executable
33 add_executable(sensor_app ${SOURCES})
34
35 # Print build information
36 message(STATUS "Building ${PROJECT_NAME} version ${PROJECT_VERSION}")
37 message(STATUS "C++ Standard: C++${CMAKE_CXX_STANDARD}")
38
```

```
cd BiggerLibraryCMake
mkdir build
cd build
cmake ..        # Generate build system
make            # Build (or 'cmake --build .')
./sensor_app    # Run
```

CMakeLists.txt
2/2 17..37

Makefile versus CMakeLists.txt

1. No manual .o file listing - CMake figures it out
2. No repetitive rules - One add_executable() does it all
3. Automatic dependency tracking - CMake scans headers
4. Cross-platform - Same file works on Windows/Linux/Mac
5. Modern build system - Generates Makefiles, Visual Studio projects, Ninja, etc.

Makefile versus CMakeLists.txt

```
# Just list the sources
set(SOURCES
    main.cpp
    sht45.cpp
    i2c.cpp
    logger.cpp
    config.cpp
    filter.cpp
)

# CMake figures out the rest!
add_executable(sensor_app ${SOURCES})
```

Recap

- Without build system: Type long commands repeatedly
- With Makefile: Works on one platform, breaks on others
- With CMake: Write once, works everywhere

More on CMake

What is CMake

General Tips

More Advanced CMake

More on CMake

What is CMake

General Tips

More Advanced CMake

Next week

Unit Testing

Unit Testing + CMake

https://github.com/AEAEmbedded/ESE_PROG/tree/main/Workshops

Great Resources

C++ Core Guidelines (Stroustrup et al., ISO C++ Standards Committee)

Sutter & Alexandrescu (2005): C++ Coding Standards: 101 Rules, Guidelines, and Best Practices

JSF AV C++ (Lockheed Martin, 2005): Safety-critical embedded systems standard (221 rules)

MISRA C++:2023: Automotive/medical device coding guidelines for critical systems

Google C++ Style Guide: Industry best practices for large-scale development

Kolpackov's "Canonical Project Structure" (ISO C++ Paper P1204R0, 2018)

Sutter & Alexandrescu (2005): Coding standards promote consistency and international collaboration

Great Resources

C++ Core Guidelines (Stroustrup et al., ISO C++ Standards Committee)

Sutter & Alexandrescu (2005): C++ Coding Standards: 101 Rules, Guidelines, and Best Practices

JSF AV C++ (Lockheed Martin, 2005): Safety-critical embedded systems standard (221 rules)

MISRA C++:2023: Automotive/medical device coding guidelines for critical systems

Google C++ Style Guide: Industry best practices for large-scale development

Kolpackov's "Canonical Project Structure" (ISO C++ Paper P1204R0, 2018)

Sutter & Alexandrescu (2005): Coding standards promote consistency and international collaboration

“

That’s all…

Any questions?