CMPT 373
Software Development Methods

Building Software

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What does it mean to build software?

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  - Really.
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- How many of you have heard terms like
  - Build Engineering?
  - Release Engineering?
  - Build Configuration?
  - Build Automation?
  - Dependency Management?
  - Continuous Integration?
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Just getting something to compile reproducibly can be nontrivial
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- It is the foundation of getting anything done.
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Incredibuild? CloudBuild?
Travis? Jenkins? CircleCI?
JUnit? Cucumber? Pytest? Gtest?
Coverity? Clang Static Analyzer?
OpenTelemetry? Prometheus? Jaeger?
...

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  - What tools do you use?
  - What workflow?
  - What are the painful points?
  - What are the risks?
  - What benefits do you get?
  - Why haven't you made them less painful?
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This defines the *dependency graph* of a project.
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- The dependency graph can already help to analyze our project!
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What must the build system perform?

We can consider C++, but it applies in general (even for many dynamic languages)
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-  json.cpp
-  libjson.a
-  format.cpp
-  libformat.a
Modeling a Build

- To build software, we must consider:
  - Components & Objectives
  - Dependencies between them
- The dependency graph can already help to analyze our project!
  - A good dependency graph is a prerequisite for effective build management.
- Modern build management uses the dependency DAG to drive build processes.

What must the build system perform?

- Client
- Server
- JSON
- Networking
- Formatting

[Diagram showing interdependencies between client, server, JSON, networking, and formatting with specific components like json.cpp, format.cpp, libjson.a, and libformat.a marked.]
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What must the build system perform?

json.cpp  <...>/format.h  <...>/libformat.a
libjson.a

Client

Server

Networking

JSON

Formatting

Program

Library

Library
Modeling a Build

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- To build software, we must consider:
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  - A good dependency graph is important
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Can you think of problems that may arise?
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- To build software, we must consider components and objectives.
- Dependencies between them.
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- To build software, we must consider:
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- The dependency graph can already help to simplify your project!
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- Modern build management uses the dependency DAG to drive build processes.

Conflicts

What must the build system perform?
Can you think of problems that may arise?
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Linked libraries for Client should change
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• Let’s dive into one specific system to see how this is done....
What will be be using?

- CMake
  - Cross-platform build management tool
  - Used by large projects like KDE, Wireshark, LLVM, ...
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- **What does it do?**
  - Given a specification & configuration of your project, CMake creates the build commands for you
  - Analogous to autoconf (but easier to use)
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You describe the dependency graph. It figures out how to build the software.
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What does this add?

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    • Compilers
    • Libraries
    • Build Modes
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    - ...
  - May need different source files for different “”
  - Specification can clearly capture
    - Libraries, versions, & even how to download them automatically
    - Semantics of compilation & how to use in analysis tools
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[DEMO]
Preliminary: Out of source builds

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  - Makes clean builds complicated
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- Use “out of source” builds instead
Using CMake

- CMakeLists.txt
  - A script in every directory of your project that controls how to build “things” in that directory
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  - A script in every directory of your project that controls how to build “things” in that directory

- **Simple syntax**
  - Case insensitive commands
    ```command( argument1 argument2 argument3 ...)
    ```
  - Let's revisit demo 1!
Targets & Commands

• CMake allows you to specify targets
  – Executables, libraries, “objects”

```cpp
add_executable(helloworld)
add_library(hellohelper STATIC)
```
Targets & Commands

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  - Executables, libraries, “objects”
    - `add_executable(helloworld)`
    - `add_library(hellohelper STATIC)`

- And commands that can describe how to build those targets
  - Automatic for executable & library
  - `add_custom_command` can build others
    - Documentation
    - Media
Specifying Requirements

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Using Libraries

- You can simply specify the libraries that a target directly uses:

  ```
  target_link_libraries(helloworld
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  target_link_libraries(hellohelper
      INTERFACE fancyformatting ccc
  )
  ```
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- Include directories, etc. From libraries will also be inferred:

  ```
  <...>/format.h  <...>/hellohelper.h  <...>/libhellohelper.a  ...
  hello.cpp  <...>/hello.h  <...>/libfancyformatting.a
  ```

  ```
  bin/helloworld
  ```
Using Libraries

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- How might this affect program structure and design?
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Consider how this relates to SOA and microservices as well!
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- How might it help us begin to handle complexity?
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CMake has several other mundane build system facilities...
General project management

- **Specifying project properties**
  - Define a project to access variables that control that project
    
    ```
    project(projectname)
    ```
General project management

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  - Define a project to access variables that control that project
    `project(projectname)`

- Print information out during the build process
  `message("Built with flags: ${CMAKE_CXX_FLAGS}"`
General project management

- Specifying project properties
  - Define a project to access variables that control that project
    ```
    project(projectname)
    ```
- Print information out during the build process
  ```
  message("Built with flags: ${CMAKE_CXX_FLAGS}")
  ```
- Controlling where things are built
  ```
  set(CMAKE_RUNTIME_OUTPUT_DIRECTORY
       "${PROJECT_BINARY_DIR}/bin")
  set(CMAKE_LIBRARY_OUTPUT_DIRECTORY
       "${PROJECT_BINARY_DIR}/lib")
  ```
General project management

- Finding a resource that you need to use

```cpp
find_package(externalproject)
find_library(library)
```
General project management

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  ```
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- Installation
  
  ```
  install(TARGETS target1 target2 ... 
  DESTINATION /tmp/ 
  )
  ```
Control structures

- **IF**

  ```
  if(condition)
  elsif(condition2)
  else()
  endif()
  ```
Control structures

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- **Looping**
  
  ```
  foreach(loop_var arg1 arg2 ...)
  command(${loop_var})
  endforeach(loop_var)
  while(condition)...
  ```
Control structures

- **IF**
  - if(condition)
  - elsif(condition2)
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  - endif()

- **Looping**
  - foreach(loop_var arg1 arg2 ...)
    - command(${loop_var})
  - endforeach(loop_var)
  - while(condition)...

- **Functions**
  - function(function_name arg1 arg2 ...)
    - command(${arg1})
  - endFunction(function_name)
Analyzing Project Structure

- CMake can dump out the dependence graph in graphviz format
  
  ```
  cmake -graphviz=deps.gv <path to project>
  dot -Tpng deps.gv -o deps.svg
  ```
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CMake has extensive documentation, and you can find additional CMake specific information online.
More Advanced Build Issues

- Build systems are a foundation of workflow and DevOps
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- Build systems are a foundation of workflow and DevOps
  - They provide a “choke point” for controlling development
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- Improving performance
  - Parallel builds
  - Caching build results
  - Distributed & cached builds can be provided via, e.g. MS CloudBuild & Incredibuild
  - Larger companies like Google have their own.
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Suppose different component change frequently. (high velocity, API churn, ...)

A

B

C

D

E

F

G

H

I

All
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“Unity builds” can be popular in game dev.
In Summary

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- Dependency graphs enable
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- **Dependency graphs enable**
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  2) *compositional* reasoning about modules and build management
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- One dominant system for C and C++ is Cmake
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- Dependency graphs enable
  1) inference of build and usage requirements
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- One dominant system for C and C++ is Cmake
- You will get more personal experience with it over the semester if you have not already