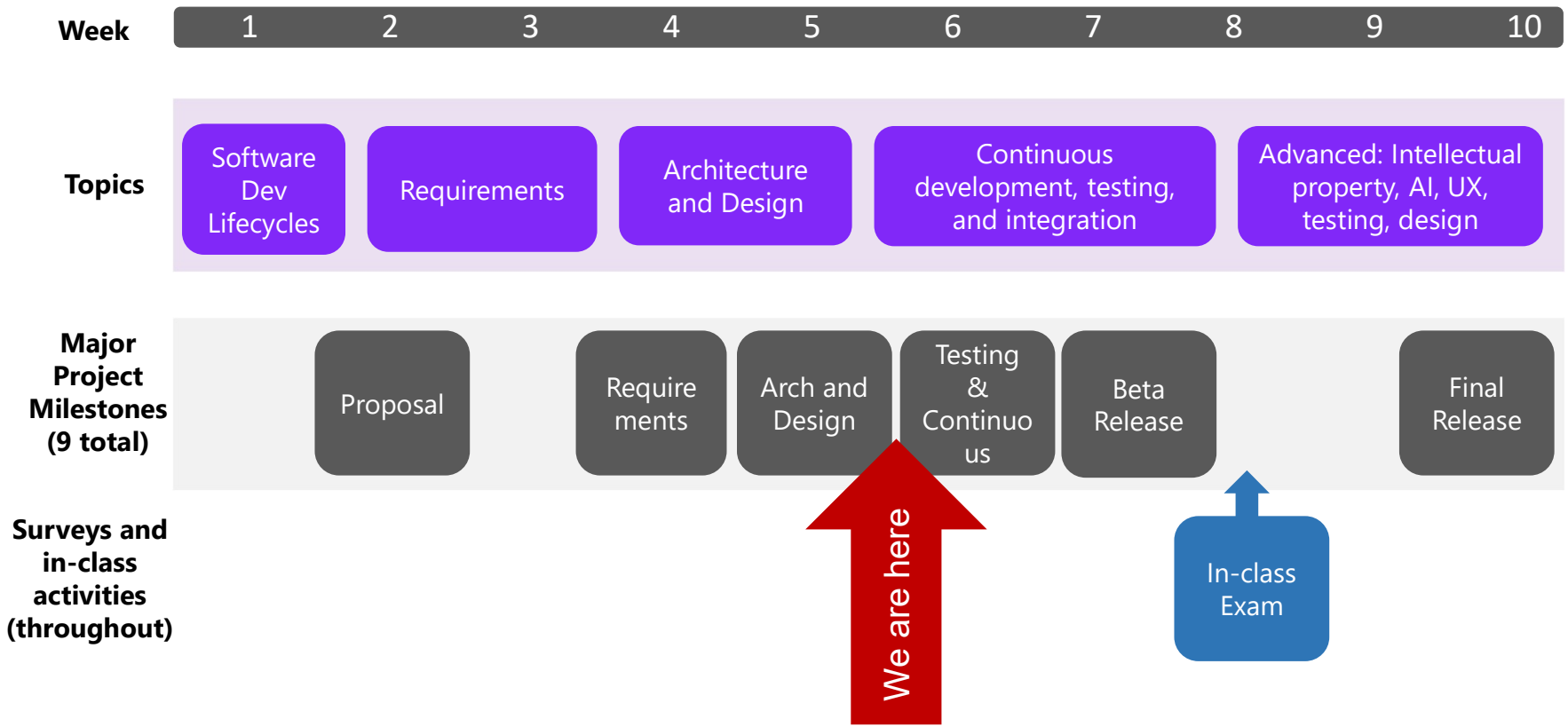
Build systems & continuous integration and deployment

CSE 403 Software Engineering
Winter 2025

Course overview: schedule

Important: See Calendar and Canvas for current details of topics and assignments



Today's outline

- Build systems
- Continuous integration and deployment systems
  - What are these
  - How do they relate
  - Best practices
  - Ideas to explore for your projects

Have a question for Zach Sperske (industry speaker from Affirm, Inc., next Wed)?
Question link on Calendar and in Ed.

What does a developer do?

The code is written … now what?

- Get the source code
- Install dependencies
- Run static analysis
- Compile the code
- Generate documentation
- Run tests
- Create artifacts for customers
- Ship!
- Operate, monitor, repeat

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Which of these tasks should be handled manually?

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Which of these tasks should be handled manually?

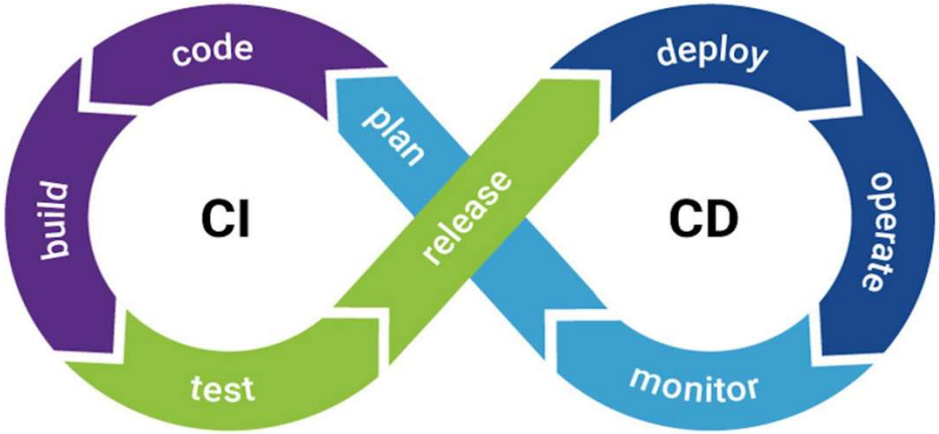
NONE!

Instead, orchestrate with a tool

Build system: a tool for automating compilation and related tasks

- Is a component of a **continuous integration/deployment system** as today we automate more than just the build step of producing shippable software

- ✓ Get the source code
- ✓ Install dependencies
- ✓ Run static analysis
- ✓ Compile the code
- ✓ Generate documentation
- ✓ Run tests
- ✓ Create artifacts for customers
- ✓ Ship!
- ✓ Operate, Monitor, Repeat



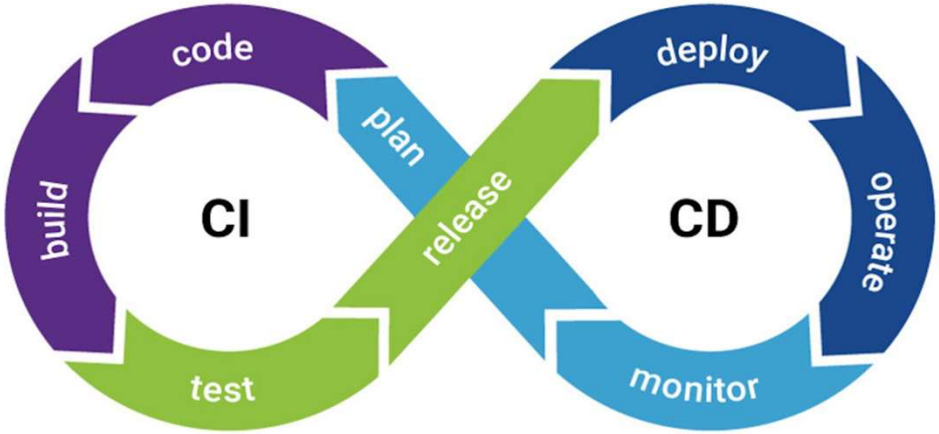
Instead, orchestrate with a tool

Build system: a tool for automating compilation and related **tasks**

- Is a component of a **continuous integration/deployment system** as today we automate more than just the build step of producing shippable software

These are all tasks!

- ✓ Get the source code
- ✓ Install dependencies
- ✓ Run static analysis
- ✓ Compile the code
- ✓ Generate documentation
- ✓ Run tests
- ✓ Create artifacts for customers
- ✓ Ship!
- ✓ Operate, Monitor, Repeat

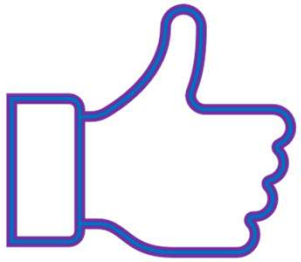


Even build system tasks are code

- Should be tested
- Should be code-reviewed
- Should be checked into version control

Adding to our software engineering best practices list

- Automate, automate, automate everything!
- Always use a build tool (one-step build) ☺
- Use a continuous integration tool to build and test your code on every commit
- Don’t depend on anything that’s not in the build file
- Don’t break the build!



A good build system is valuable to us

1. **Dependency management**
   1. Identifies dependencies between files (including externals)
   2. Runs the compiles in the right order to pick up the right dependencies
   3. Only runs the compiles needed due to dependency changes

2. **Efficiency and reliability**
   1. Automates the build process so that new and old team members, even working in different dev environments, can move quickly from development to shipping code
   2. Eliminates the chance of missing steps due to tribal knowledge and/or simply errors

A build system has three main roles

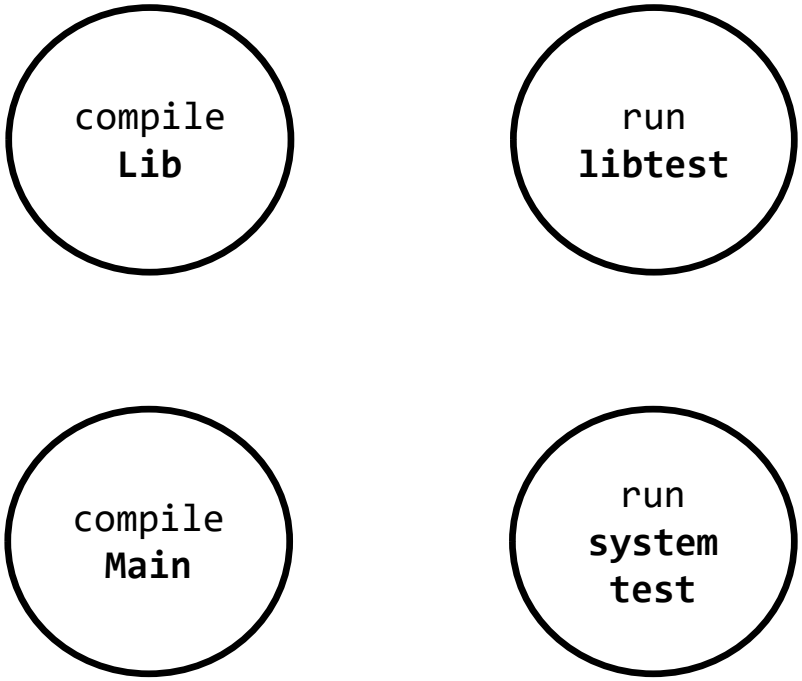
1. Defines **tasks** (and external resources, such as libraries)
2. Defines **dependencies** among tasks (a graph)
3. **Executes** the tasks

Here is a simple example code illustrating dependency management

```
% ls src/
   Lib.java
   LibTest.java
   Main.java
   SystemTest.java
```

Build systems: identify dependencies between tasks

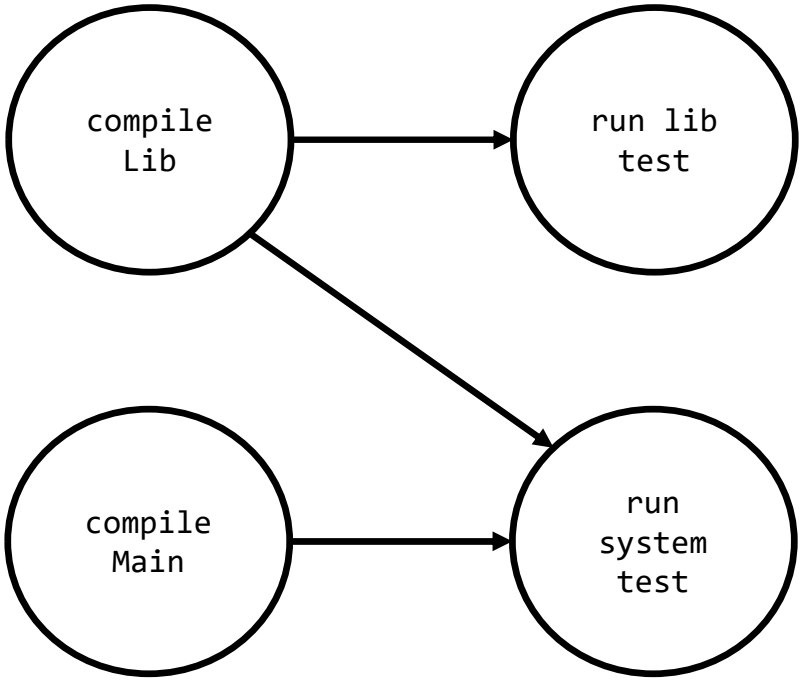
```
% ls src/
    Lib.java
    LibTest.java
    Main.java
    SystemTest.java
```



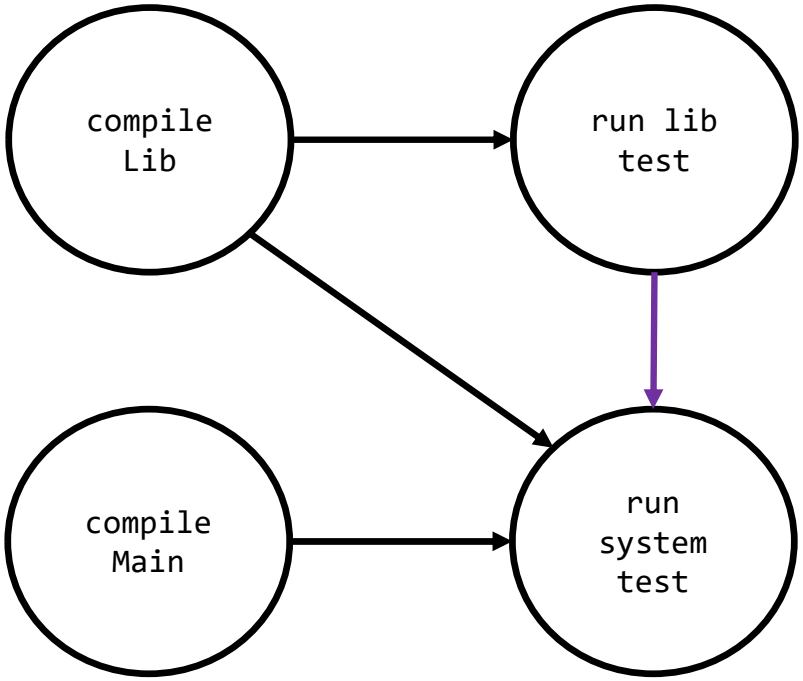
What are the dependencies between these tasks?

And why do I care?

Build systems: identify dependencies between tasks

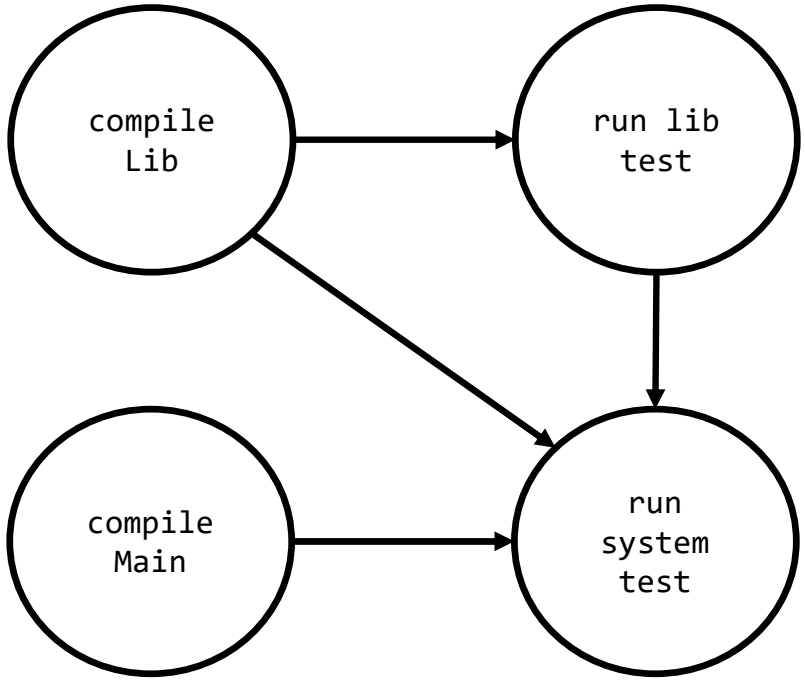


Build systems: identify dependencies between tasks



Build systems: identify dependencies between tasks

In what order should we run these tasks?



Tip: look for tasks with no dependencies and run those first

Build systems can determine task order

Large projects have thousands of tasks

- Dependencies between tasks form a directed acyclic graph
- Build tools use a topological sort to create an order to compiles
  - Order nodes such that all dependencies are satisfied
  - Implemented by computing indegree (number of incoming edges) for each node
  - No dependencies go first and open door to the others
  - See Appendix for example

External code (libraries) also can be complex

- Build systems can manage these dependencies as well!

A build system has three main roles

1. Defines **tasks** (and external resources, such as libraries)
2. Defines **dependencies** among tasks (a graph)
3. **Executes** the tasks

Consider a task for automated testing before the compile step, such as **static analysis**

Static analysis

Run before the compile step

Examples:

- Credential scan
- Date scan
- Personal data scan
- Sensitive data scan

What might be others?

Is this worthwhile?

Build systems: opportunity for static analysis

github.com/Yelp/detect-secrets

README.md

detect-secrets-ci failing | pypi package 1.4.0 | homebrew 1.4.0 | PRs welcome | Donate Charity

detect-secrets

About

`detect-secrets` is an aptly named module for (surprise, surprise) **detecting secrets** within a code base.

However, unlike other similar packages that solely focus on finding secrets, this package is designed with the enterprise client in mind: providing a **backwards compatible**, systematic means of:

1. Preventing new secrets from entering the code base,
2. Detecting if such preventions are explicitly bypassed, and
3. Providing a checklist of secrets to roll, and migrate off to a more secure storage.

Could these types of static analysis tools be run earlier than build?

github.com/bearer/bearer

README.md

bearer

Scan your source code against top **security** and **privacy** risks.

Bearer CLI is a static application security testing (SAST) tool that scans your source code and analyzes your data flows to discover, filter and prioritize security and privacy risks.

Here's an example build system 'input'

Basic-Stats
"ant"
build.xml

(from last week's in-class exercise)

Simple-C
"make"
Makefile

Milestone 04: Research, evaluate and choose a build system for your project

Many other options!

Over to you to research

JAVA+		
	gradle	Open-source successor to **ant** and **maven**
	bazel	Open-source version of Google's internal build tool (blaze)
PYTHON		
	hatch	Implements standards from the Python standard (uses TOML files, has PIP integration)
	poetry	Packaging and dependence manager
	tox	Automate and standardize testing
JAVASCRIPT		
	npm	Standard package/task manager for Node, "Largest software registry in the world."
	webpack	Module bundler for modern JavaScript applications
	gulp	Tries to improve dependency and packing

Today’s outline

- Build systems
- **Continuous integration and delivery/deployment systems**
  - What are these and
  - How do they relate
  - Best practices
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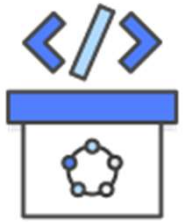
CI/CD: What's the difference?

Continuous Integration (CI)

- Devs regularly integrate code into a shared repository
- System builds/tests automatically with each update
- Complements local developer workflows (e.g., may run diff tests)
- **Goal:** to find/address bugs quicker, improve quality, reduce time to get to working code

Continuous Deployment (CD) [Continuous **Delivery**]

- Builds on top of CI
- Automatically pushes changes to [staging environment and then] production
- **Goal:** always have a deployment-ready build that has passed through a standardized testing process



Milestone 04: Research, evaluate and choose a continuous integration system for your project

Jenkins

GitHub Actions

AWS CodePipeline

Azure Pipelines

Travis CI

GitLab

circleci

Bitbucket Pipelines

Continuous integration basics

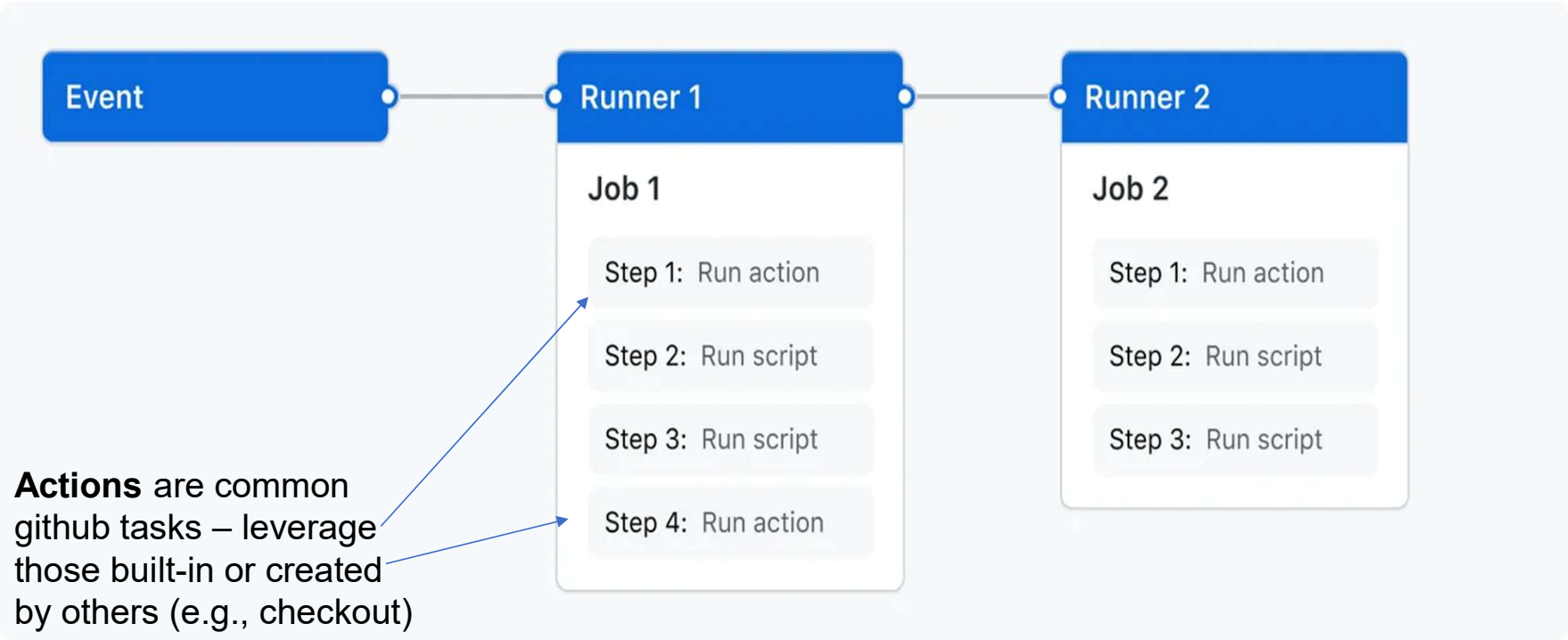
- A CI **workflow** is **triggered** when an **event** occurs in your [shared] repo
  - Example events
    - Push
    - Pull request
    - Issue creation

- A workflow contains **jobs** that run in a defined order
  - A job is like a shell-script and can have multiple steps
  - Jobs run in their own vm/container called a **runner**
  - Example jobs
    - Run static analysis
    - Compile, test
    - Deploy to test, deploy to prod

Using GitHub CI terminology but concepts span other CI systems

CI basics (w/ GitHub CI)

What SW architecture is this using?



Actions are common github tasks – leverage those built-in or created by others (e.g., checkout)

Example: CI with Github actions

Unit tests are triggered on every push of new code

```yaml
name: CI - UnitTesting
on: [push]
jobs:
  test:
    runs-on: ubuntu-latest
    strategy: <2 keys>

    steps:
    - uses: actions/checkout@v3
    - name: Set up Python ${{ matrix.python-version }}
      uses: actions/setup-python@v3
      with: <1 key>
    - name: Set up MongoDB ${{ matrix.mongodb-version }}
      uses: supercharge/mongodb-github-action@1.8.0
      with: <1 key>
    - name: Install dependencies
      run: python3 -…tall hatch
    - name: Pre-fly setup
      run: cp $GITHU…GITHUB_ENV
    - name: Test with hatch
      run: |
        hatch run test:test
```

Workflow name

Trigger

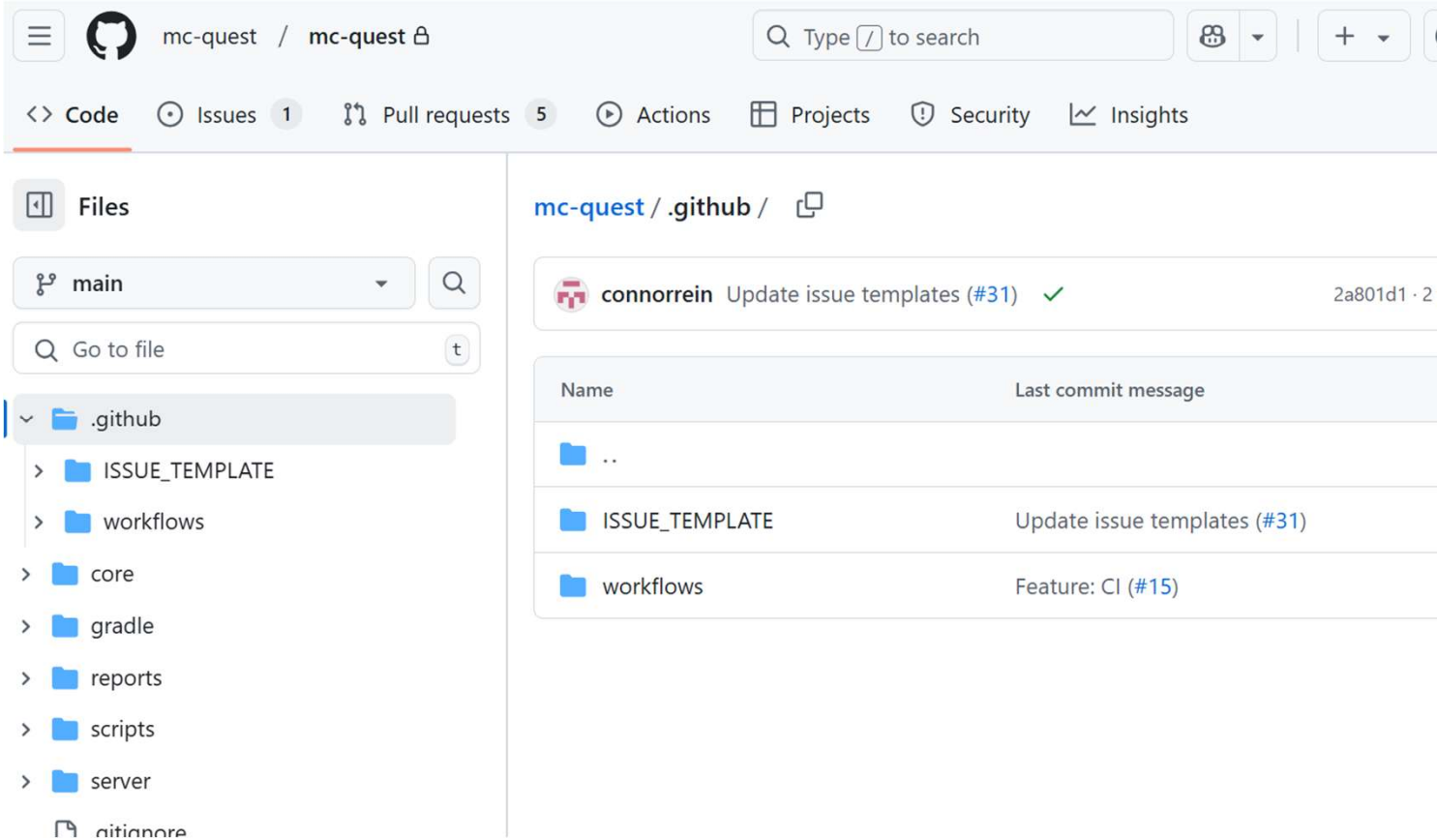
Linux OS environment

Code reuse with established “actions”

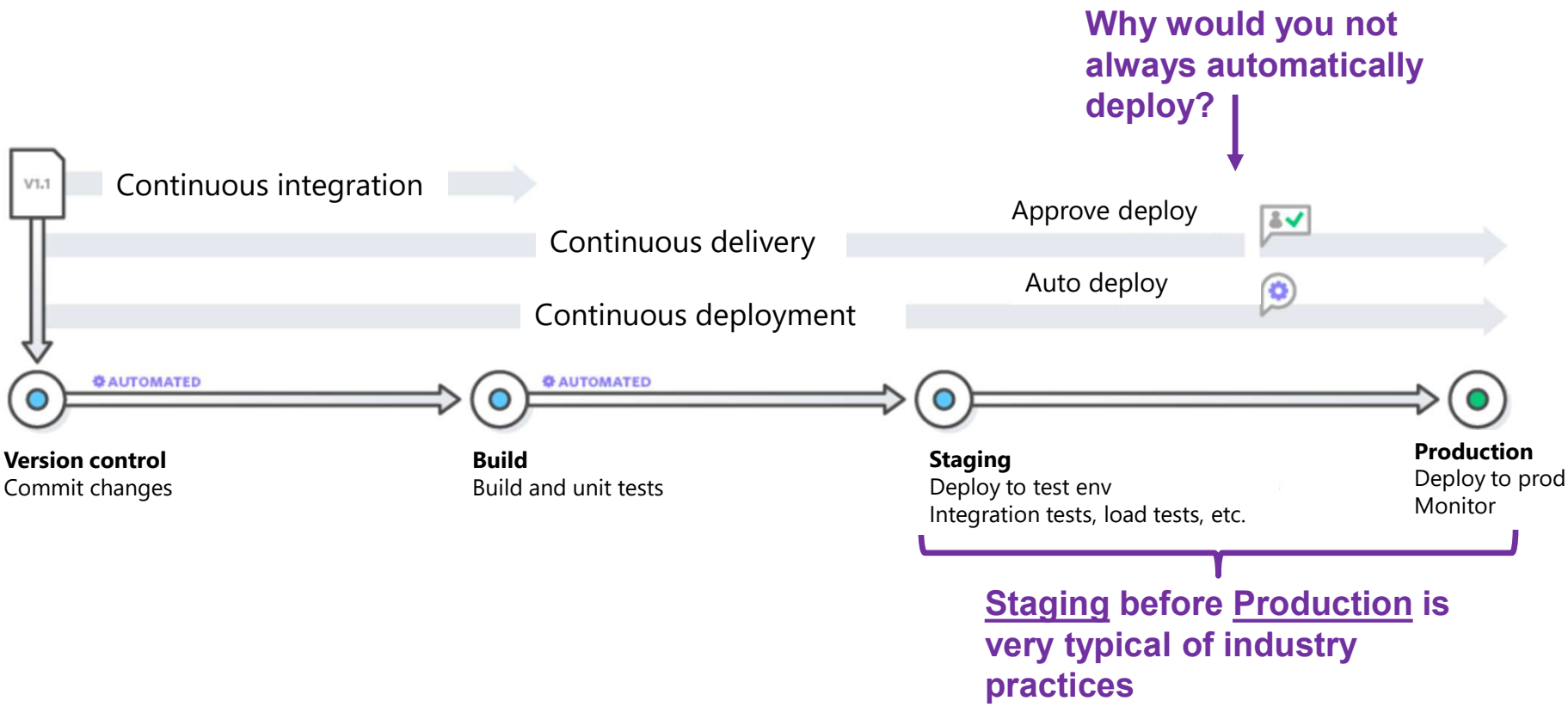
One command to run test suite

Let’s look at a CI workflow from the MC-Quest CSE 403 project

Connor’s team’s repo



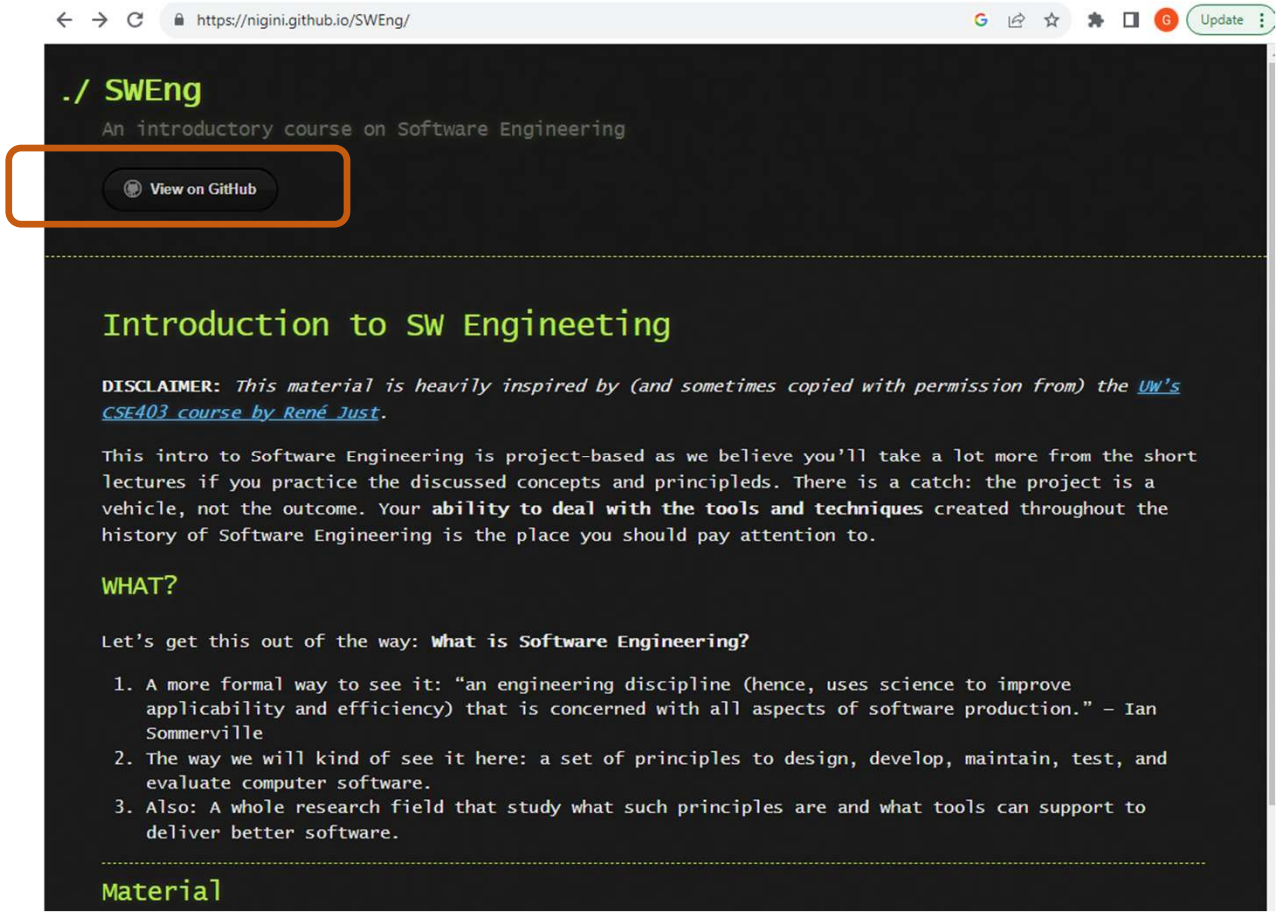
Continuous delivery/deployment basics



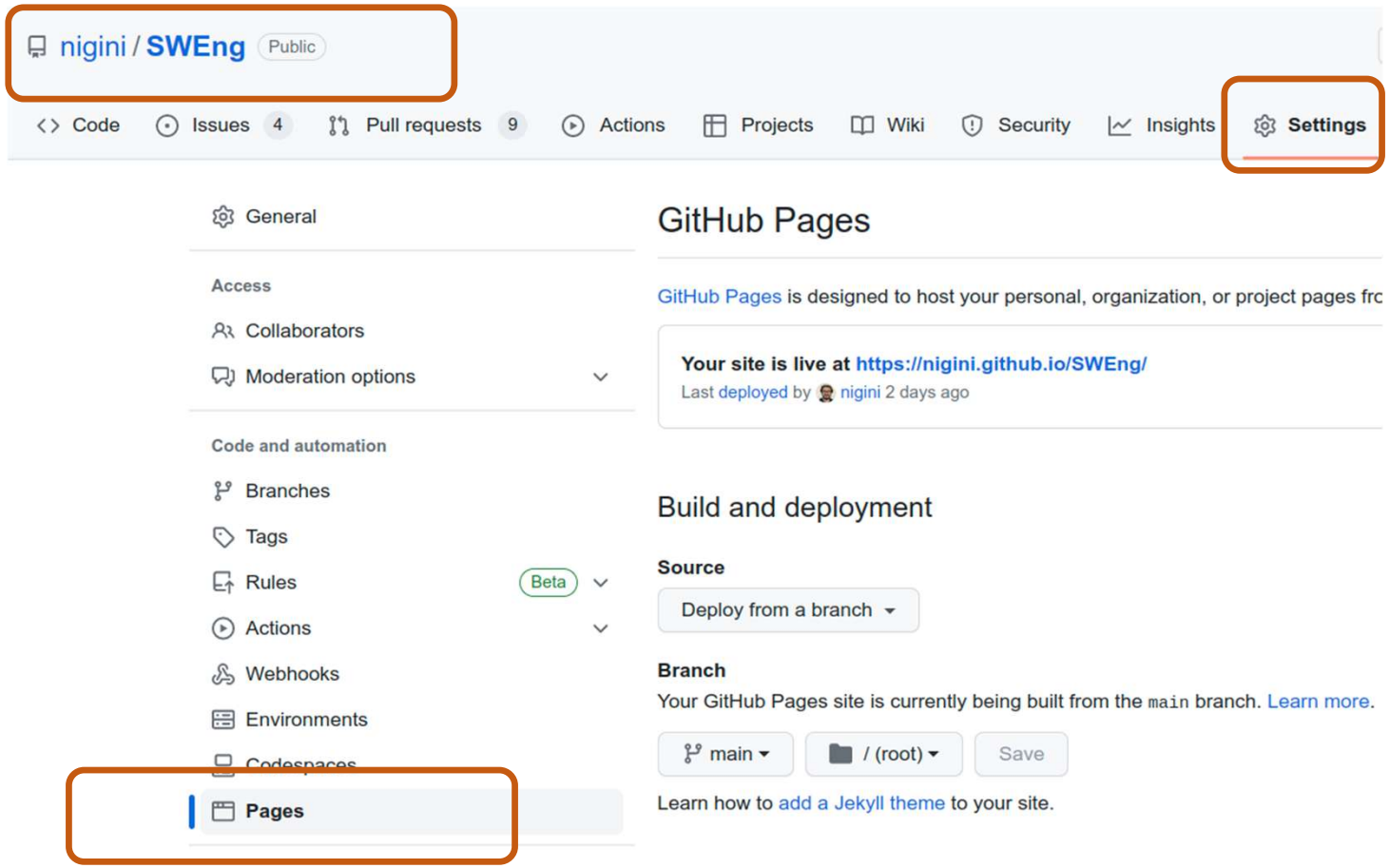
Amazon example

Example: continuous deployment with GitHub Pages (https://pages.github.com/)

Content updates trigger publishing the website update



Example: continuous deployment config



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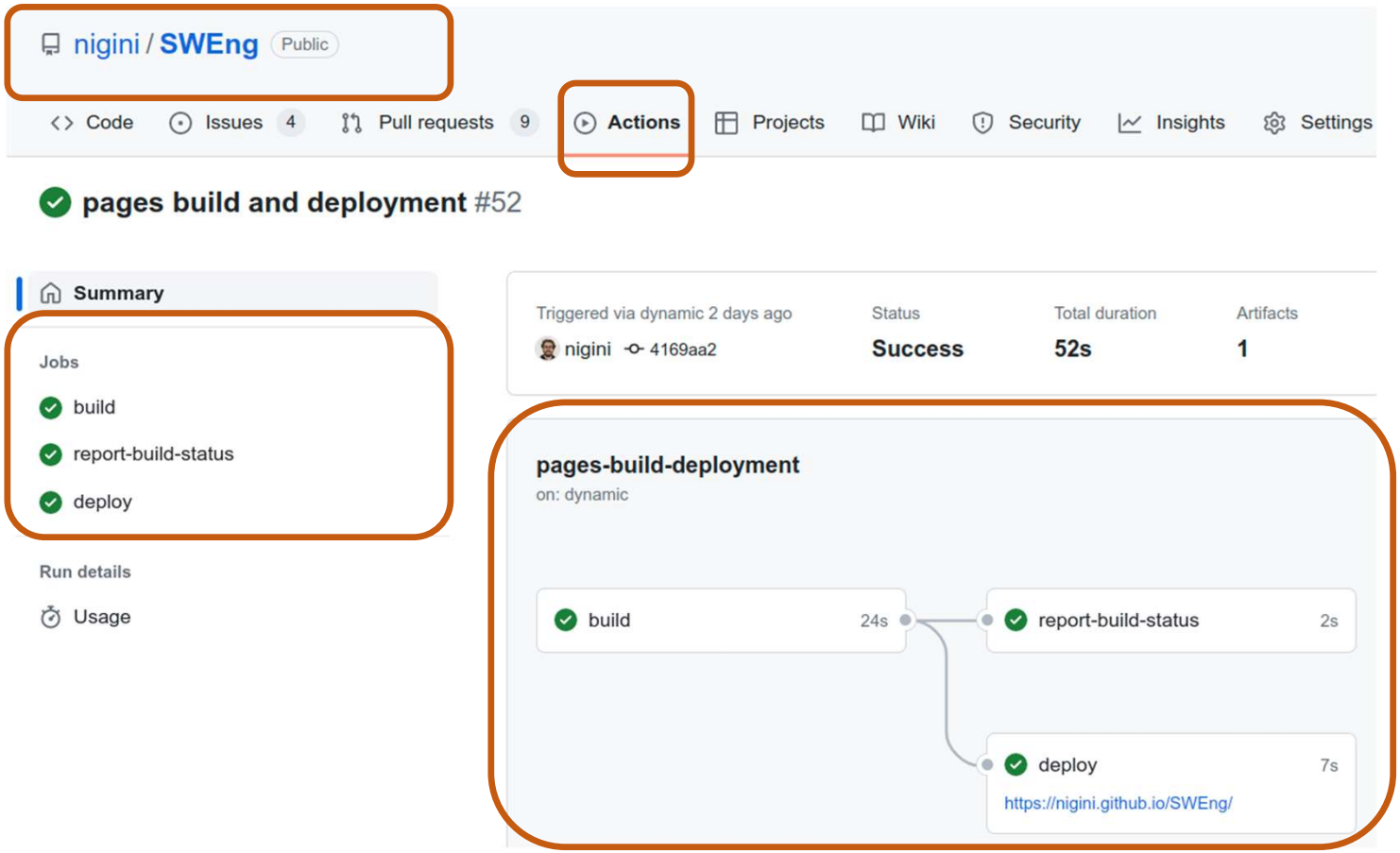
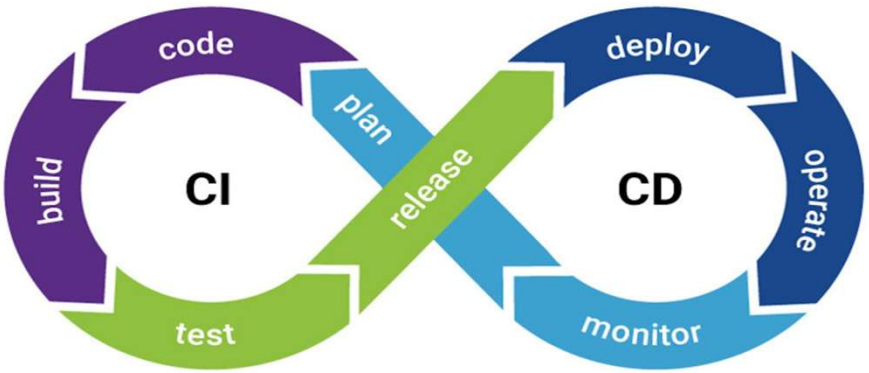


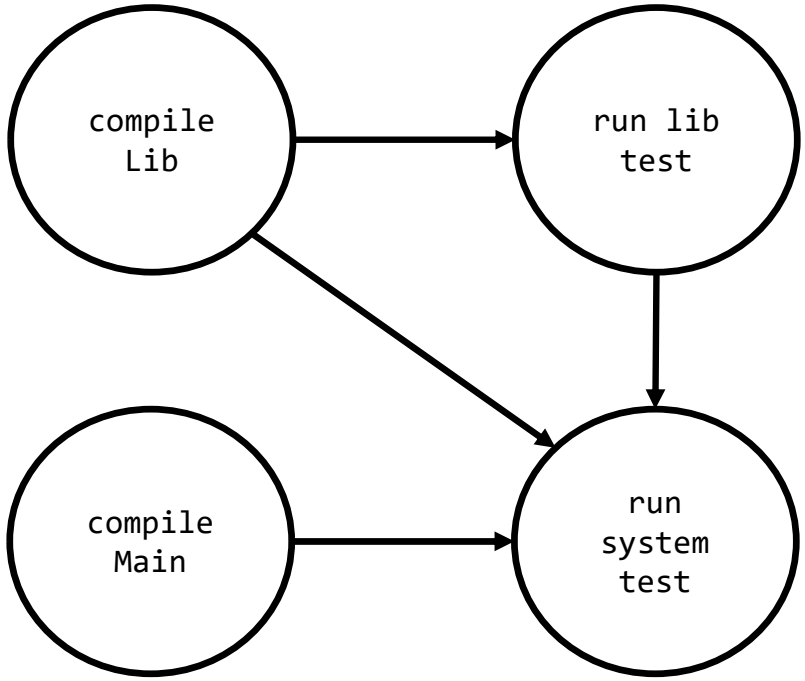
Summary of best practices for build and continuous integration

- Automate, automate, automate everything!
- Always use a build tool (one-step build)
- Use a CI tool to build and test your code on every commit
- Don't depend on anything that's not in the build file
- Don't break the build!



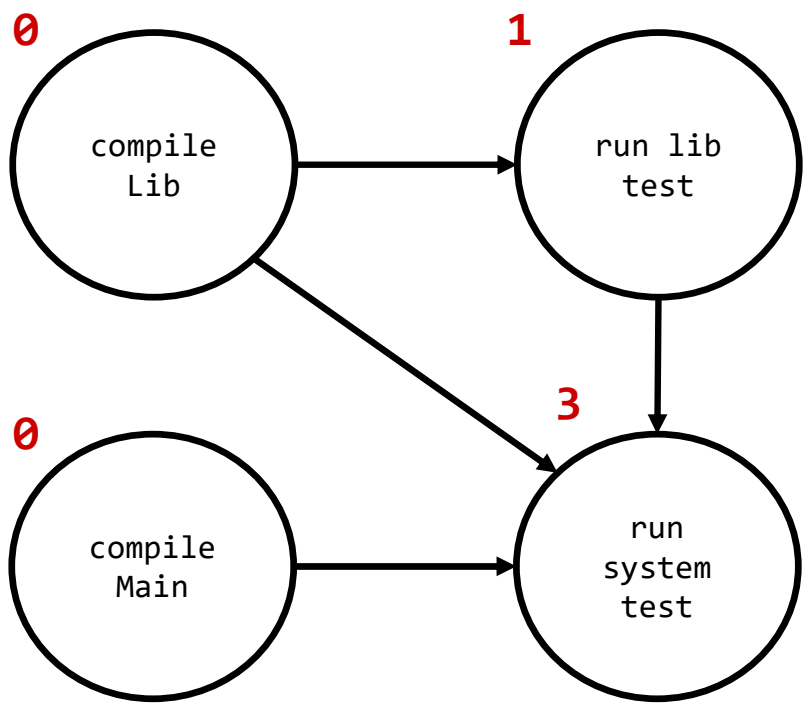
Appendix - Topological sort example

Build systems: topological sort

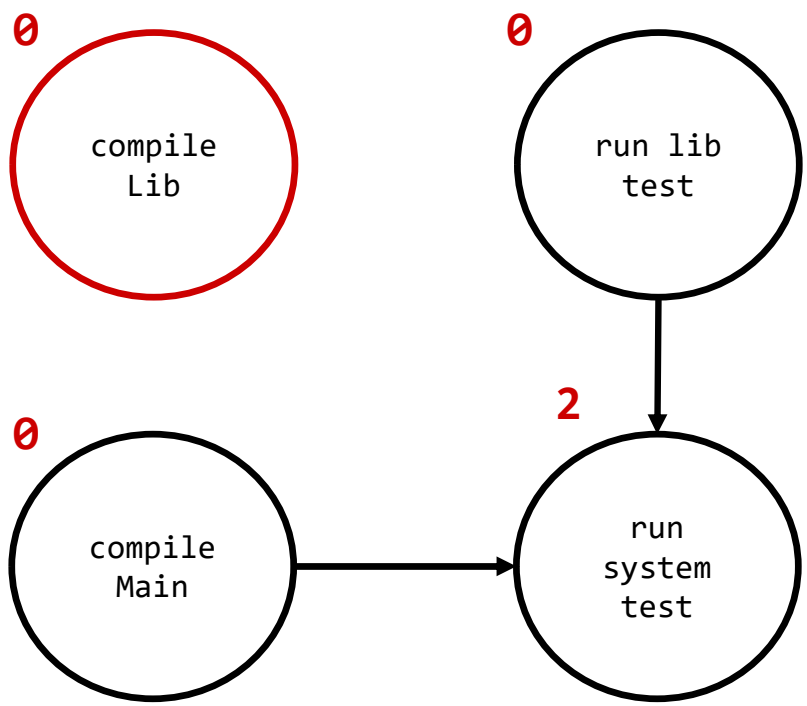


What's the indegree of each node?

Build systems: topological sort



Build systems: topological sort



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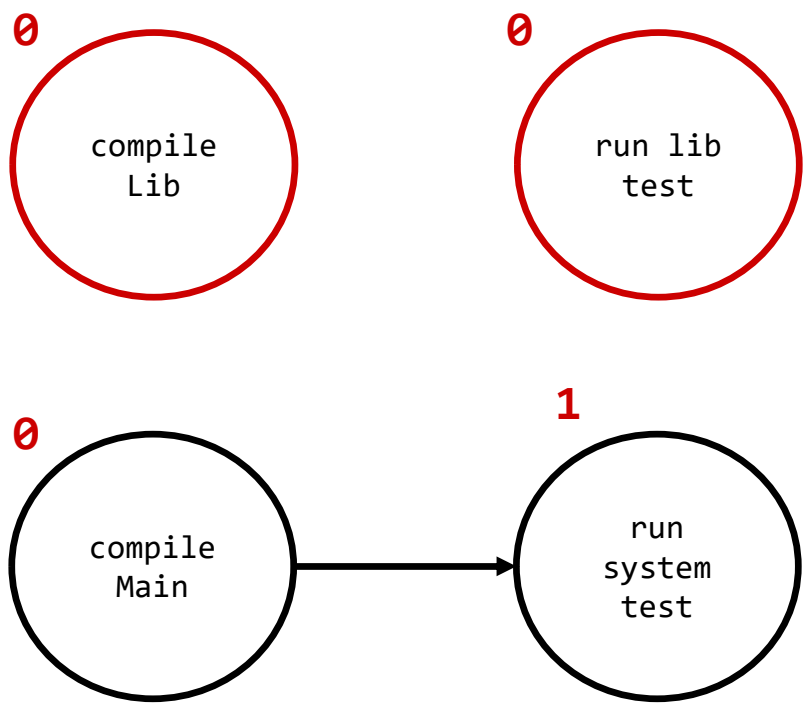

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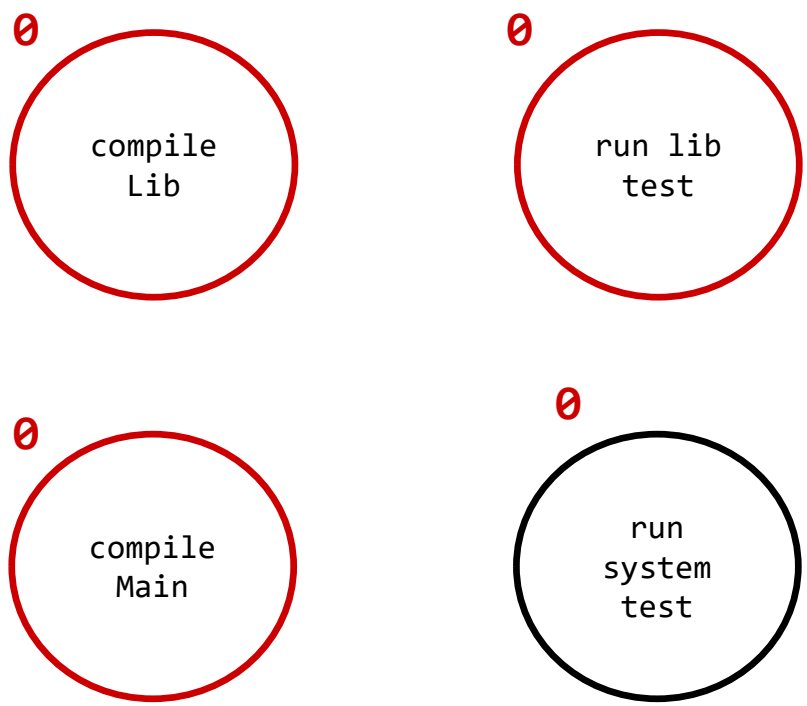

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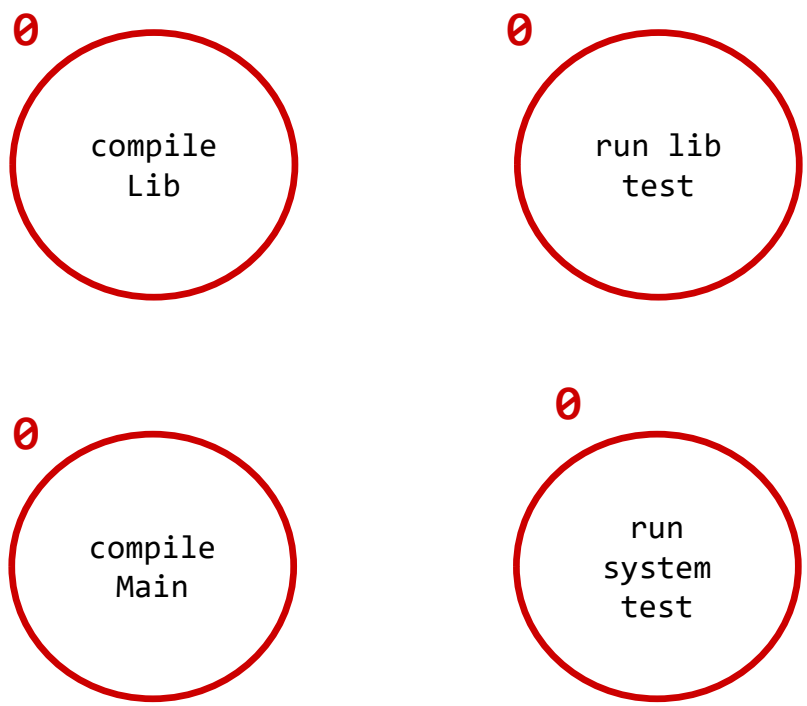


Build systems: topological sort

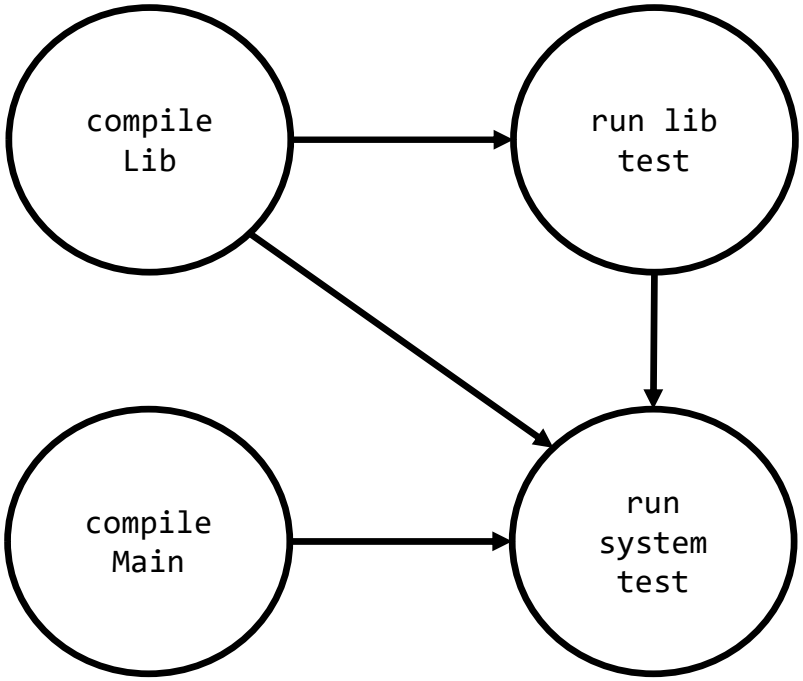
Valid sorts:

1. compile Lib, run lib test, compile Main, run system test

2. compile Main, compile Lib, run lib test, run system test

3. compile Lib, compile Main, run lib test, run system test

Which is preferable?



Let’s try writing our own simple CI workflow

Follow along at:

https://github.com/alv880/UW-CSE403-Alv-Projects

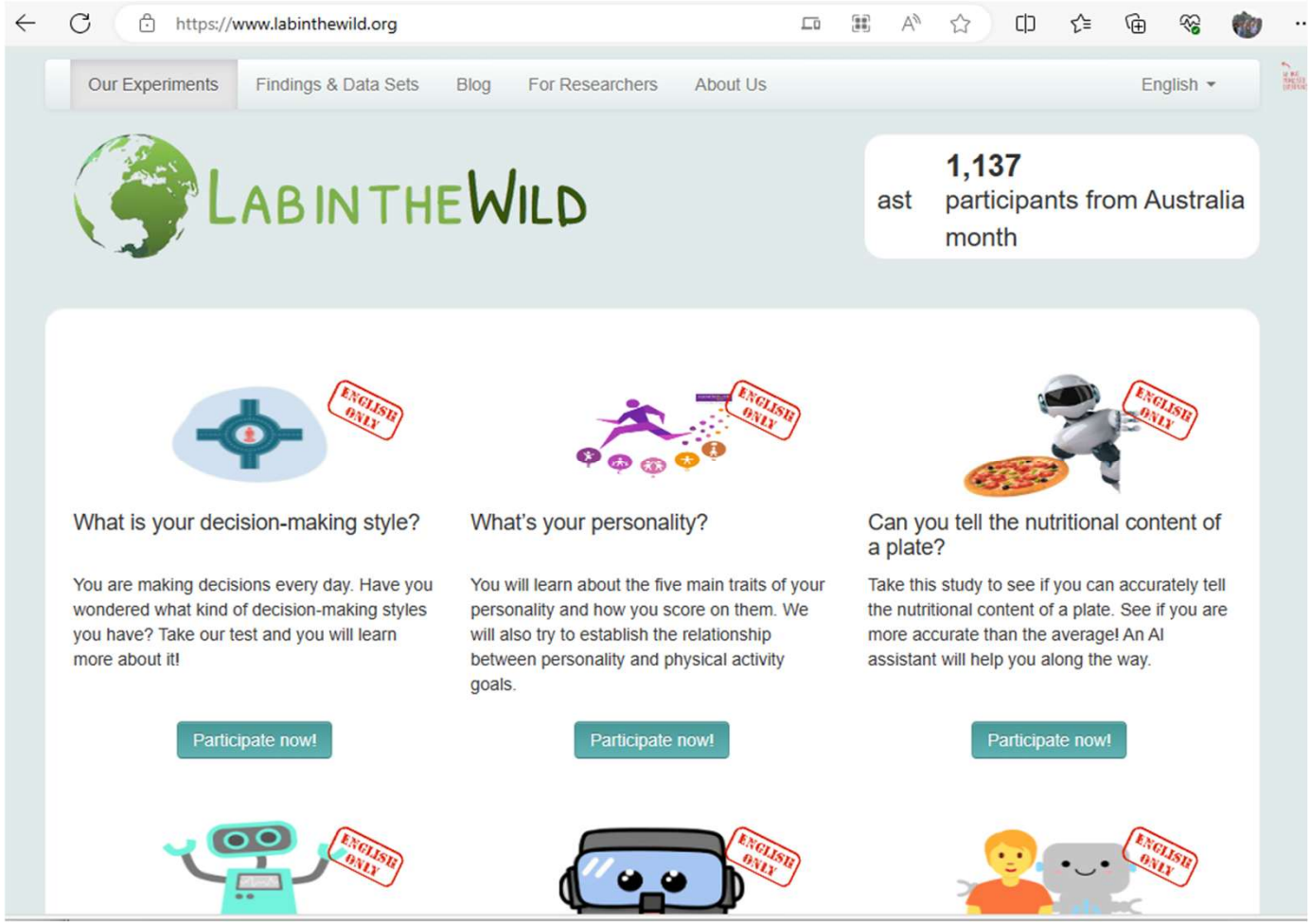
Github Actions resource:

https://docs.github.com/en/actions/learn-github-actions/understanding-github-actions

Example: CI at work in CSE

[Lab In The Wild](#) is a research project drawing survey input from diverse community

– Nigini Oliveira
UW researcher provided this example



Example: CI with Github actions