Git Workflows & Continuous Integration

Better Scientific Software Tutorial

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Argonne National Laboratory

ISC High Performance Conference

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License, citation, and acknowledgements

License and Citation

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Acknowledgements

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- Anshu Dubey, Klaus Weide, Saurabh Chawdhary, and Carlo Graziani
- Iulian Grindeanu
- Alicia Klinvex

Git Workflows

Goals

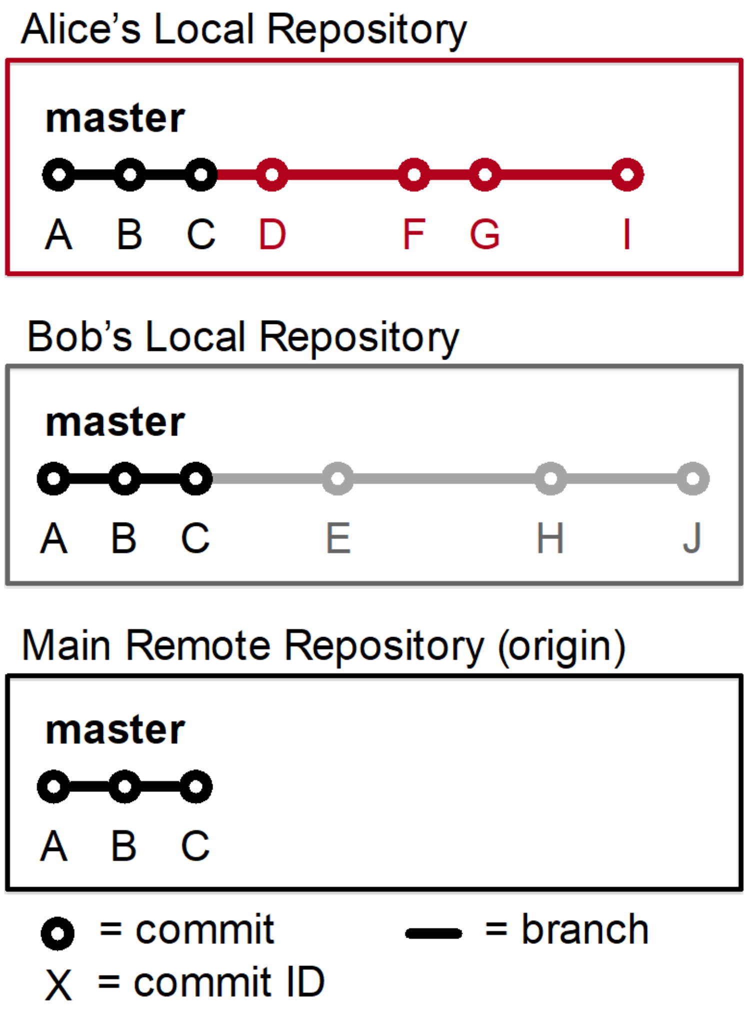
Development teams would like to use version control to collaborate productively and ensure correct code

- Understand challenges related to parallel code development *via* distributed version control
- Understand extra dimensions of distributed version control & how to use them
  - Local vs. remote repositories
  - Branches
  - Issues, Pull Requests, & Code Reviews
- Exposure to workflows of different complexity
- What to think about when evaluating different workflows
- Motivate continuous integration

Distributed Version Control System (DVCS)

Two developers collaborating *via* Git

- Local copies of master branch synched to origin
- Each develops on **local** copy of master branch
- All copies of master immediately diverge
- How to **integrate** work on origin?



Alice's Local Repository

master

A B C D F G I

Bob's Local Repository

master

A B C E H J

Main Remote Repository (origin)

master

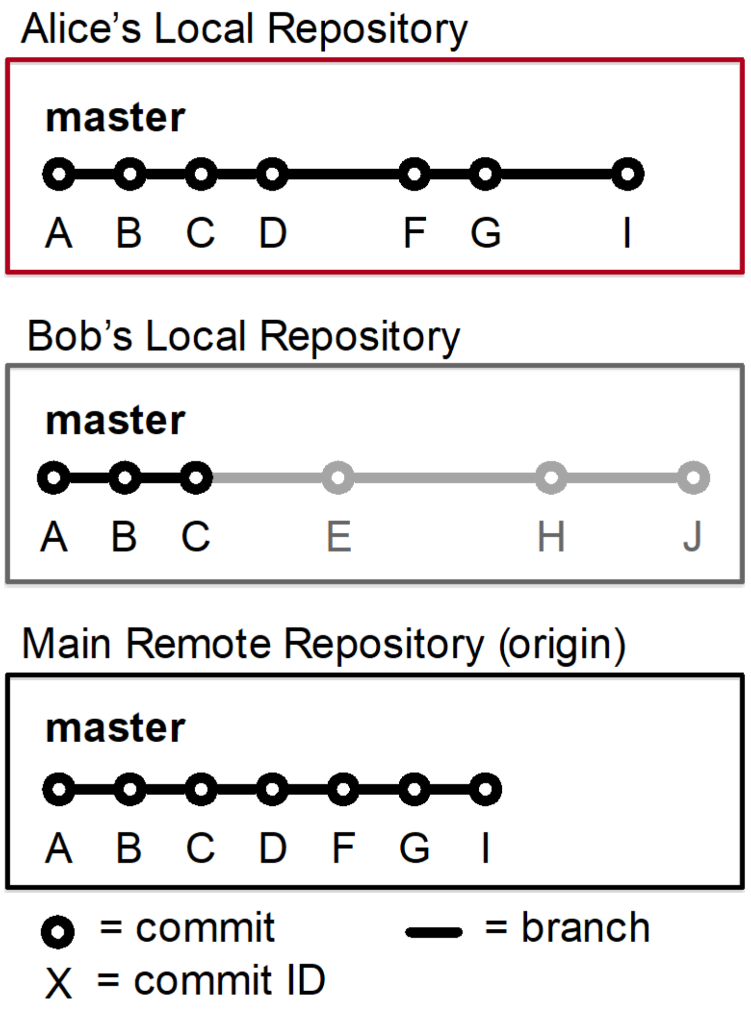
A B C

○ = commit
X = commit ID
▬ = branch

DVCS Race Condition

Integration of independent work occurs when local repos interact with remote repo

- Alice pushes her local commits to remote repo first
- No integration conflicts
- No risk
- Alice's local repo identical to remote repo

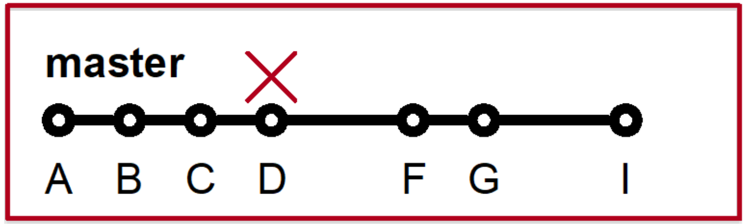


Integration Conflicts Happen

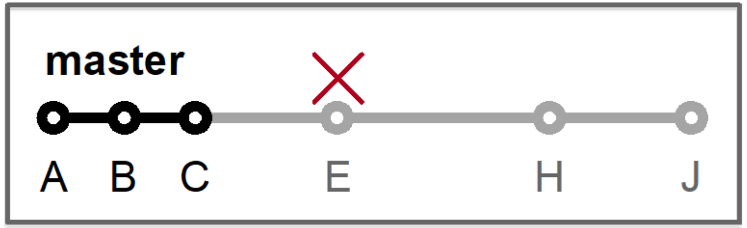
Bob’s push to remote repo is rejected

- Alice updated code in commit D
- Bob updated same code in commit E
- Alice and Bob need to study conflict and decide on resolution at pull (time-consuming)
- Possibility of introducing bug on master branch (risky)

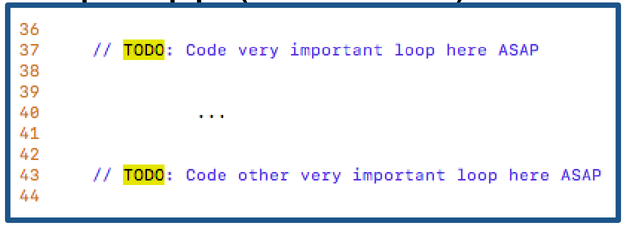
Alice’s Local Repository



Bob’s Local Repository

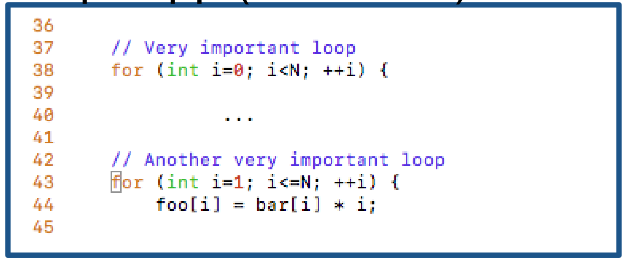


loops.cpp (commit C)



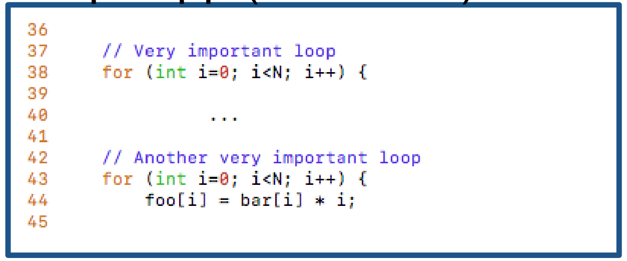
```cpp

    // TODO: Code very important loop here ASAP


              ...


    // TODO: Code other very important loop here ASAP

```

loops.cpp (commit D)



```cpp

    // Very important loop
    for (int i=0; i<N; ++i) {

              ...

    // Another very important loop
    for (int i=1; i<=N; ++i) {
        foo[i] = bar[i] * i;

```

loops.cpp (commit E)



```cpp

    // Very important loop
    for (int i=0; i<N; i++) {

              ...

    // Another very important loop
    for (int i=0; i<N; i++) {
        foo[i] = bar[i] * i;

```

Our First Workflow

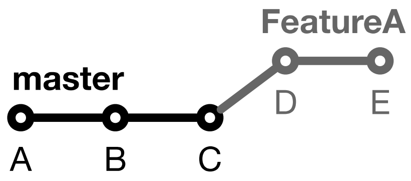
This process of collaborating *via* Git is called the **Centralized Workflow**

- See Atlassian/BitBucket for more information
- “Simple” to learn and “easy” to use
- Leverages local vs. remote repo dimension
  - Integration in local repo when local repos interact with remote repo
- What if you have many team members?
- What if developers only push once a month?
- What if team members works on different parts of the code?
- Working directly on master

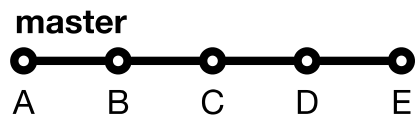
Branches

Branches are independent lines of development

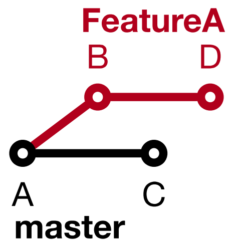
- Use branches to protect master branch
- Feature branches
  - Organize a new feature as a sequence of related commits in a branch
- Branches are usually combined or **merged**
- Develop on a branch, test on the branch, and merge into master
- Integration occurs at merge commits



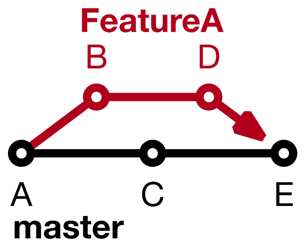
Fast-Forward



No Merge



Divergence

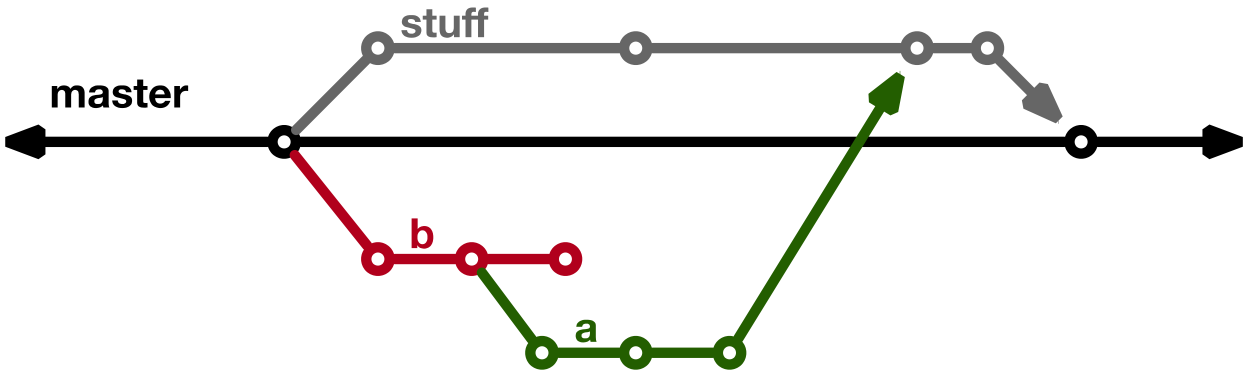


Merge Commit

Control Branch Complexity

Workflow policy is needed

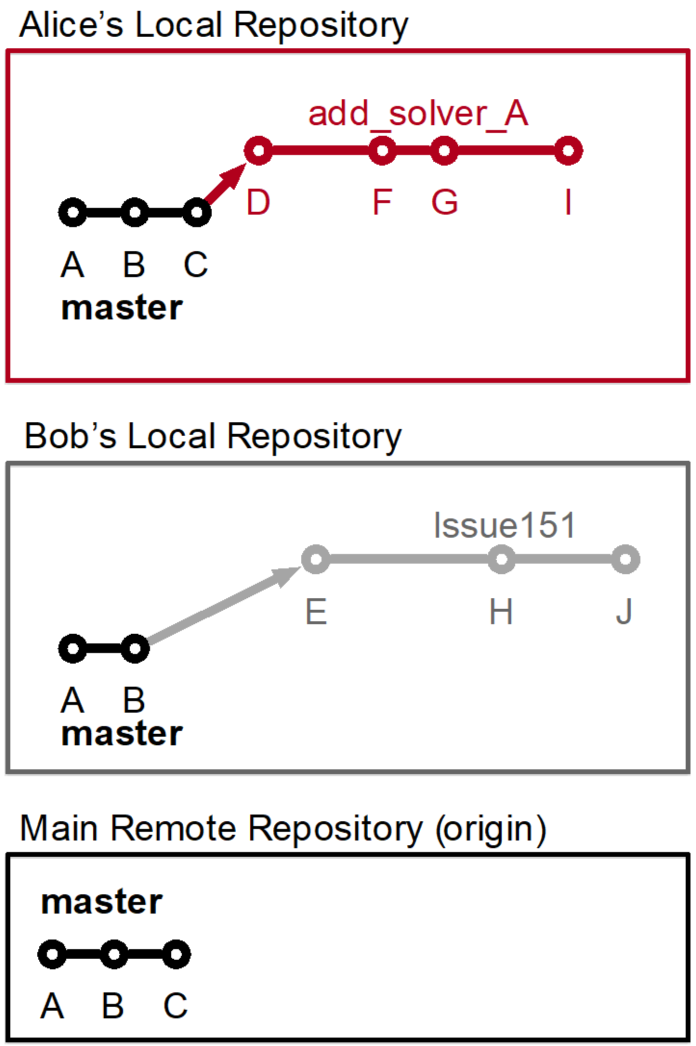
- Descriptive names or linked to issue tracking system
- Where do branches start and end?
- Can multiple people work on one branch?



Feature Branches

Extend Centralized Workflow

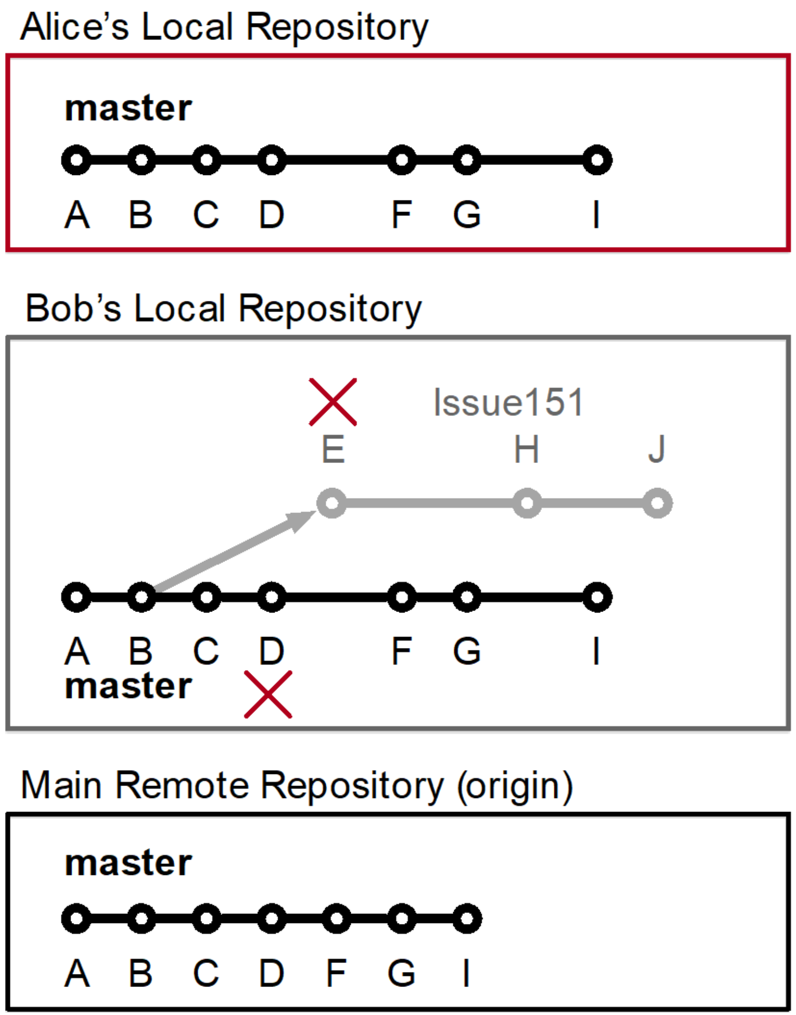
- Remote repo has commits A & B
- Bob pulls remote to synchronize local repo to remote
- Bob creates local feature branch based on commit B
- Commit C pushed to remote repo
- Alice pulls remote to synchronize local repo to remote
- Alice creates local feature branch based on commit C
- Both develop independently on local feature branches



Feature Branch Divergence

Alice integrates first without issue

- Alice does fast-forward merge to local master
- Alice deletes local feature branch
- Alice pushes master to remote
- Meanwhile, Bob pulls master from remote and finds Alice’s changes
- Merge conflict between commits D and E



Alice’s Local Repository

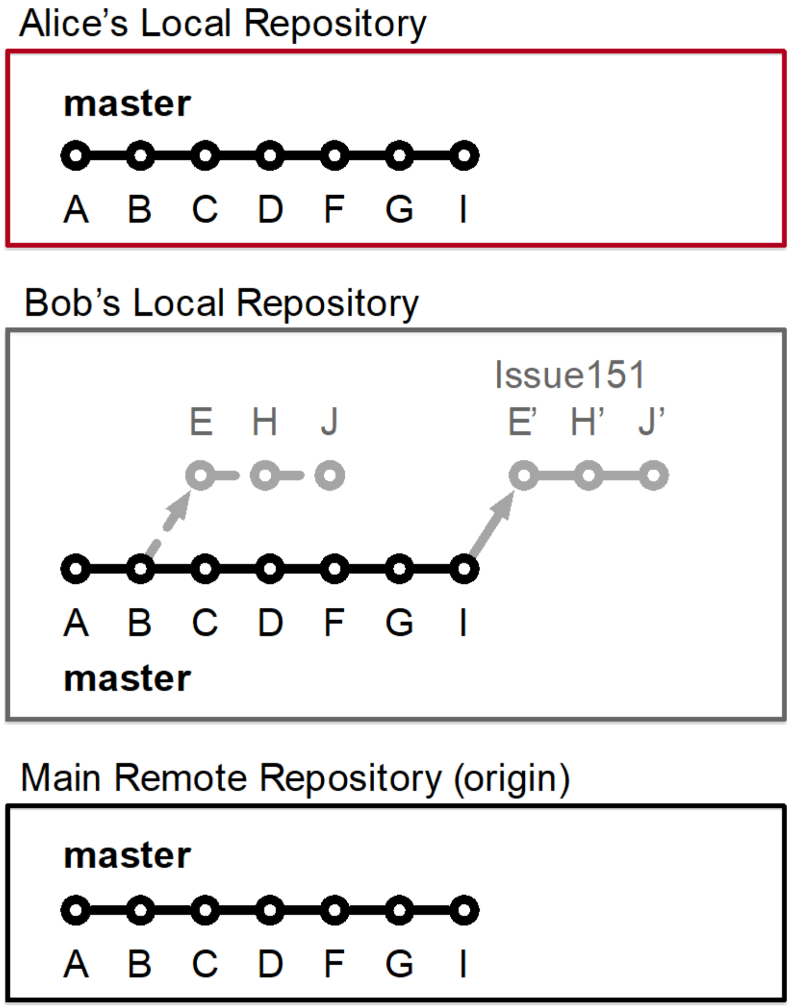
Bob’s Local Repository

Main Remote Repository (origin)

Feature Race Condition

Integration occurs on Bob's local repo

- Bob laments not having fast-forward merge
- Bob **rebases** local feature branch to latest commit on master
  - E based off of commit B
  - E' based off of Alice's commit I
  - E' is E integrated with commits C, D, F, G, I
- Merge conflict resolved by Bob & Alice on Bob's local branch when converting commit E into E'
- Can test on feature branch and merge easily and cleanly



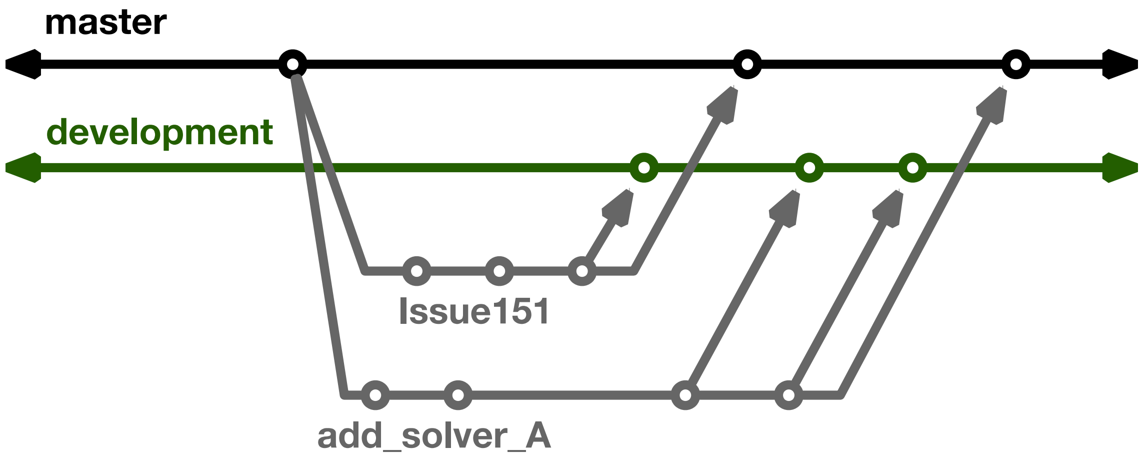
Feature Branches Summary

- Multiple, parallel lines of development possible on single local repo
- Easily maintain local master up-to-date and useable
- Integration with rebase on local repo is safe and can be aborted
- Testing before updating local and remote master branches
- Rebase is advanced Git command
  - Rebase can cause complications and should be used carefully.
- Hide actual workflow
  - History in repo is not represent actual development history
  - Less communication
  - Fewer back-ups using remote repo
- Does it scale with team size? What if team integrates frequently?
- Commits on master can be broken
- See Atlassian/BitBucket for a richer Feature Branch Workflow

More Branches

Branches with infinite lifetime

- Base off of master branch
- Exist in all copies of a repository
- Each provides a distinct **environment**
  - Development vs. pre-production



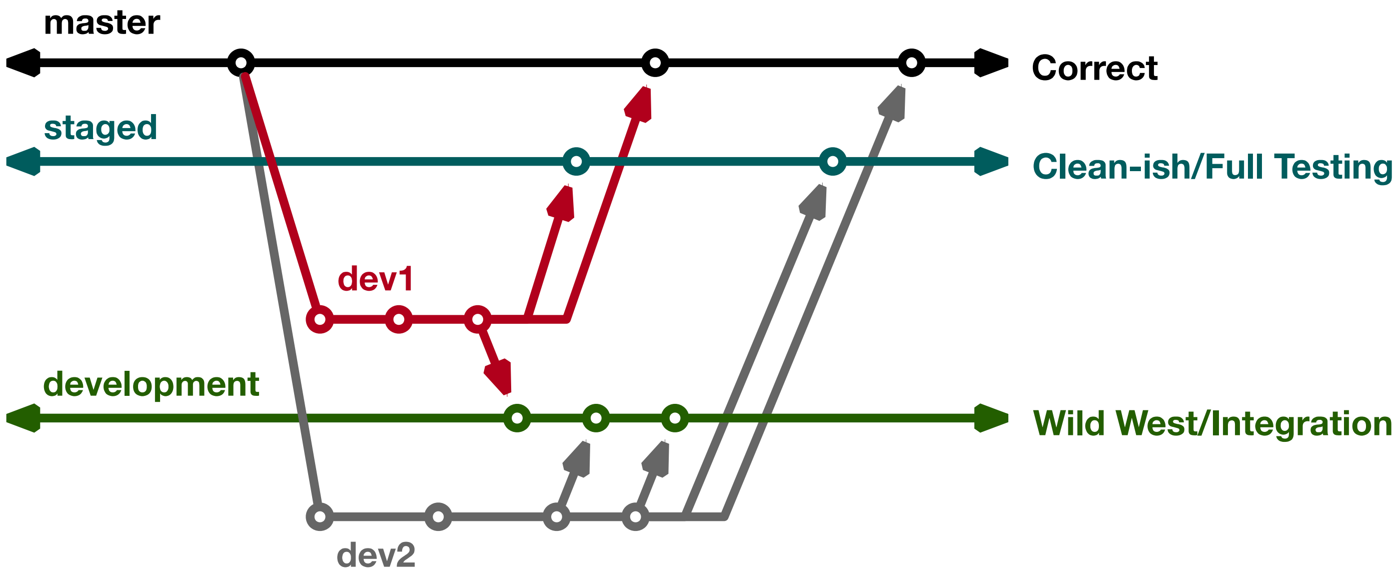
Current FLASH5 Workflow

Test-driven workflow

- Feature branches start and end with master
- All feature branches are merged into development for integration & manual testing
- All feature branches are then merged into staged for full, automated testing

Workflow designed so that

- All commits in master are in staged & development
- infinite branches don't diverge
- Merge conflicts first exposed on development



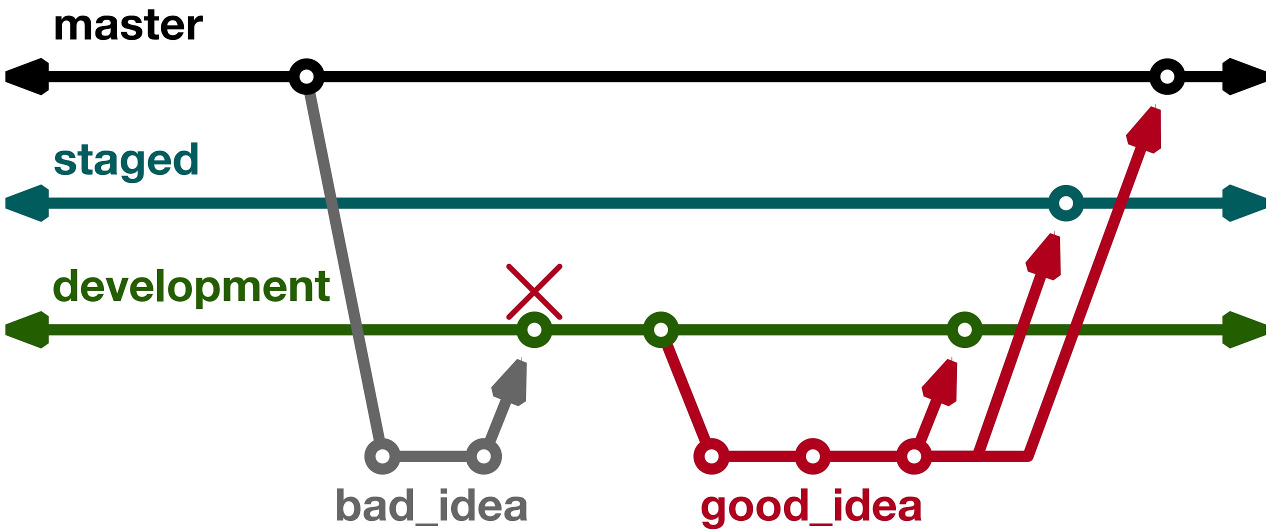
Branch Rules

Why base feature branches off master?

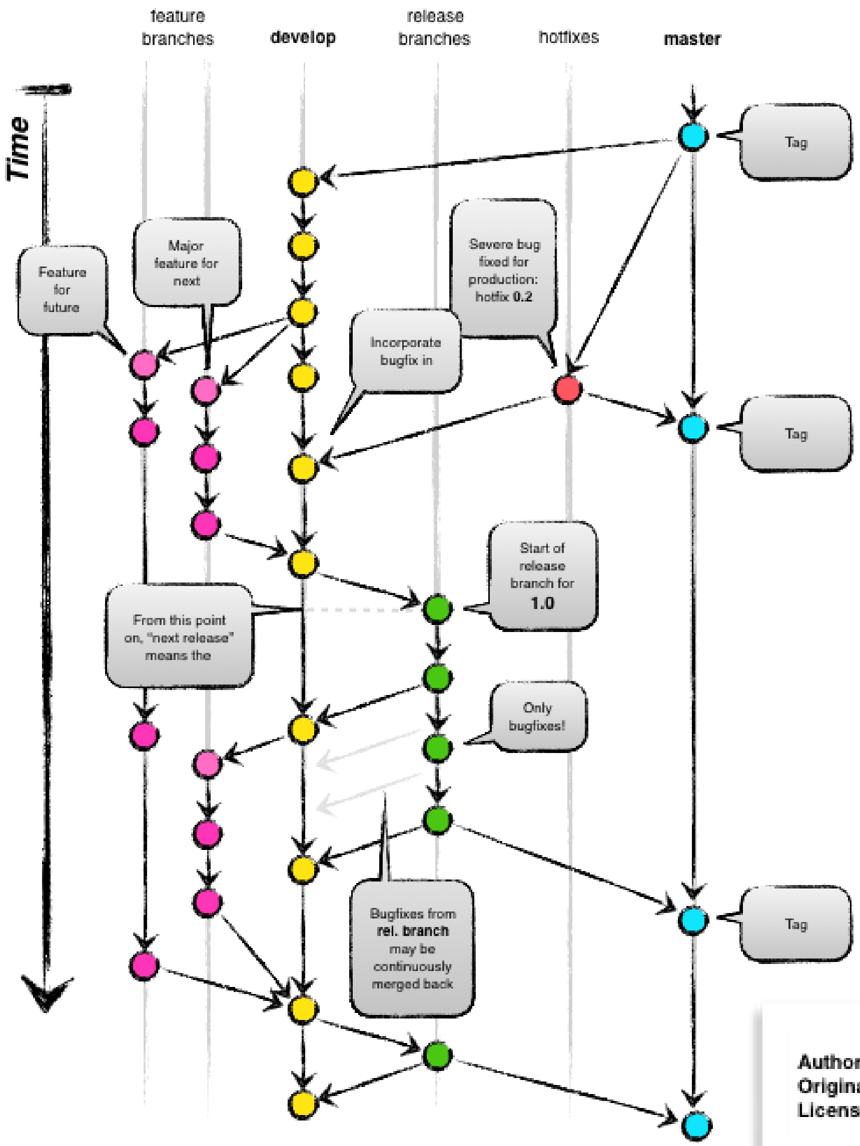
- Start from correct, verified commit
- Clean and simple to learn/enforce
- Isolate master from integration environment

Motivates more rules

- Development never merged into another branch
- Staged never merged into another branch



Git Flow


feature branches
develop
release branches
hotfixes
master
Time
Tag
Major feature for next
Feature for future
Severe bug fixed for production: hotfix 0.2
Incorporate bugfix in
Tag
Start of release branch for 1.0
From this point on, "next release" means the
Only bugfixes!
Bugfixes from rel. branch may be continuously merged back
Tag

Author: Vincent Driessen
Original blog post: http://nvie.com/archives/323
License: Creative Commons

- Full-featured workflow
- Increased complexity
- Designed for SW with official releases
- Feature branches based off of develop
- Git extensions to enforce policy
- How are develop and master synchronized?
- Where do merge conflicts occur and how are they resolved?

GitHub Flow

http://scottchacon.com/2011/08/31/github-flow.html

- Published as viable alternative to Git Flow
- No structured release schedule
- Continuous deployment & continuous integration allows for simpler workflow

Main Ideas

1. All commits in master are **deployable**
2. Base feature branches off of master
3. Push local repository to remote constantly
4. Open Pull Requests early to start dialogue
5. Merge into master after Pull Request review

GitLab Flow

https://docs.gitlab.com/ee/workflow/gitlab_flow.html

  - Published as viable alternative to Git Flow & GitHub Flow
  - Semi-structured release schedule
  - Workflow that simplifies difficulties and common failures in synchronizing infinite lifetime branches

Main Ideas

- Master branch is staging area
- Mature code in master flows downstream into pre-production & production infinite lifetime branches
- Allow for release branches with downstream flow
  - Fixes made upstream & merged into master.
  - Fixes cherry picked into release branch

Things to Think About When Choosing a Git Workflow

Want to establish a clear set of polices that

- results in correct code on a particular branch (usually master),
- ensures that a team can develop in parallel and communicate well,
- minimizes difficulties associated with parallel and distributed work, and
- minimizes overhead associated with learning, following, and enforcing policies.

Adopt what is good for your team

- Consider team culture and project challenges
- Assess what is and isn’t feasible/acceptable
- Start with simplest and add complexity where and when necessary

Continuous Integration

The Short & Sweet of Continuous Integration

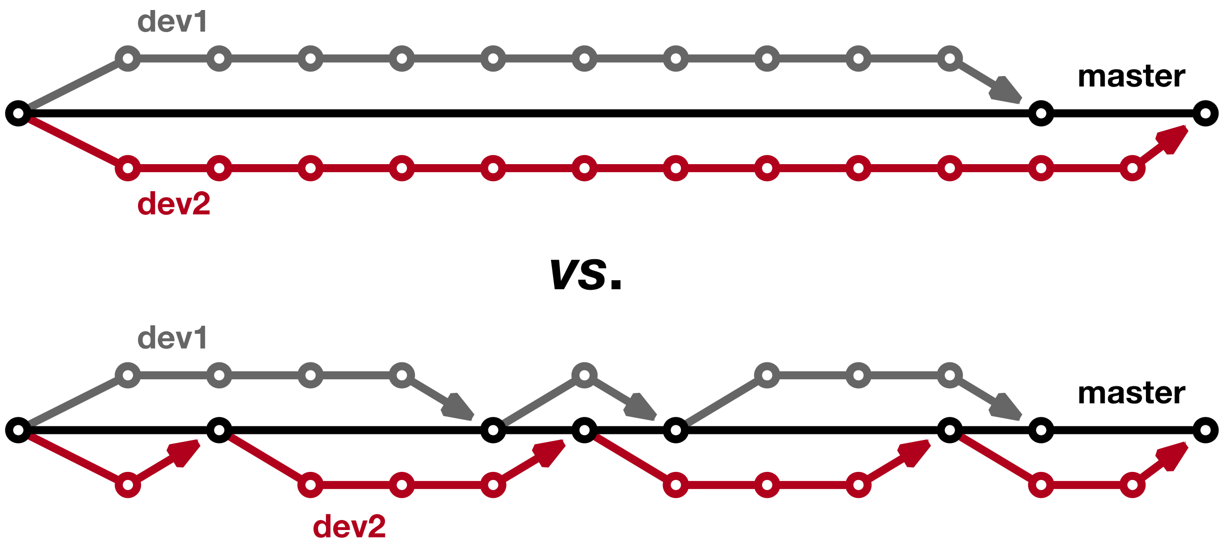
A master branch that always works

- DVCS workflow isolate master from integration environment
- Extend workflow to address difficulties of integrating
  - Minimize likelihood of merge conflict
  - Detect bugs immediately
  - Make debugging process quick and easy

Work Decomposition

Commit and integrate often

- Limit divergence between feature and master branches
- Decreased probability of conflict
- Conflict resolution is simpler and less risky



Error Detection

Test at integration to identify failures immediately

- Control quality of code
- Isolate failure to few commits
- No context switching for programmer

We want a system that

- triggers automated builds/tests on target environments when code changes and
- ideally tests on proposed merge product without finalizing merge.

Test Servers

Servers that

- automate the execution of a test suite or a subset of a test suite,
- allow for running tests on different environments,
- host an interface for viewing results, and
- allows for configuring when the tests are run.

Examples

- CTest/CDash
- Jenkins
- Travis CI and GitLab CI

Cloud-based Test Servers

- Linked to VCS hosts
  - GitHub & Travis CI
  - GitLab CI
  - BitBucket Pipelines
- Automated builds/tests triggered *via* pushes and pull requests
- Builds/tests can be run on cloud systems
- Test results are reported in repository's web interface
- Can trigger code coverage analysis & documentation build

Continuous integration (CI)

- Has existed for some time and interest is growing
- HPC community working to adapt CI for HPC machines
- Setup, maintenance, and monitoring required
- Prerequisites
    - A reasonably automated build system
    - An automated test system with significant test coverage & useful feedback
    - Builds/tests must finish in reasonable about of time
    - Ability to bundle subset of tests

CI Hello World

Simplest CI example

- https://github.com/jrdoneal/CI_HelloWorld
- https://travis-ci.org/jrdoneal/CI_HelloWorld

CI example w/ multiple platforms and specific compiler versions

- https://github.com/jrdoneal/CI_Multiplatform

Code coverage, testing and CI tutorial (C++)

- https://github.com/amklinv/morpheus

Code coverage, testing, and CI example (Fortran, C++)

- https://github.com/jrdoneal/infrastructure

Agenda

Time	Module	Topic	Speaker
2:00pm-2:40pm	01	Overview of Best Practices in HPC Software Development	Anshu Dubey, ANL
2:40pm-3:20pm	02	Better (Small) Scientific Software Teams	David E. Bernholdt, ORNL
3:20pm-4:00pm	03	Improving Reproducibility through Better Software Practices	David E. Bernholdt, ORNL
4:00pm-4:30pm		*Break*	
4:30pm-5:15pm	04	Verification & Refactoring	Anshu Dubey, ANL
5:15pm-6:00pm	05	Git Workflow & Continuous Integration	Jared O'Neal, ANL

Additional Software-Related Events at ISC 2019

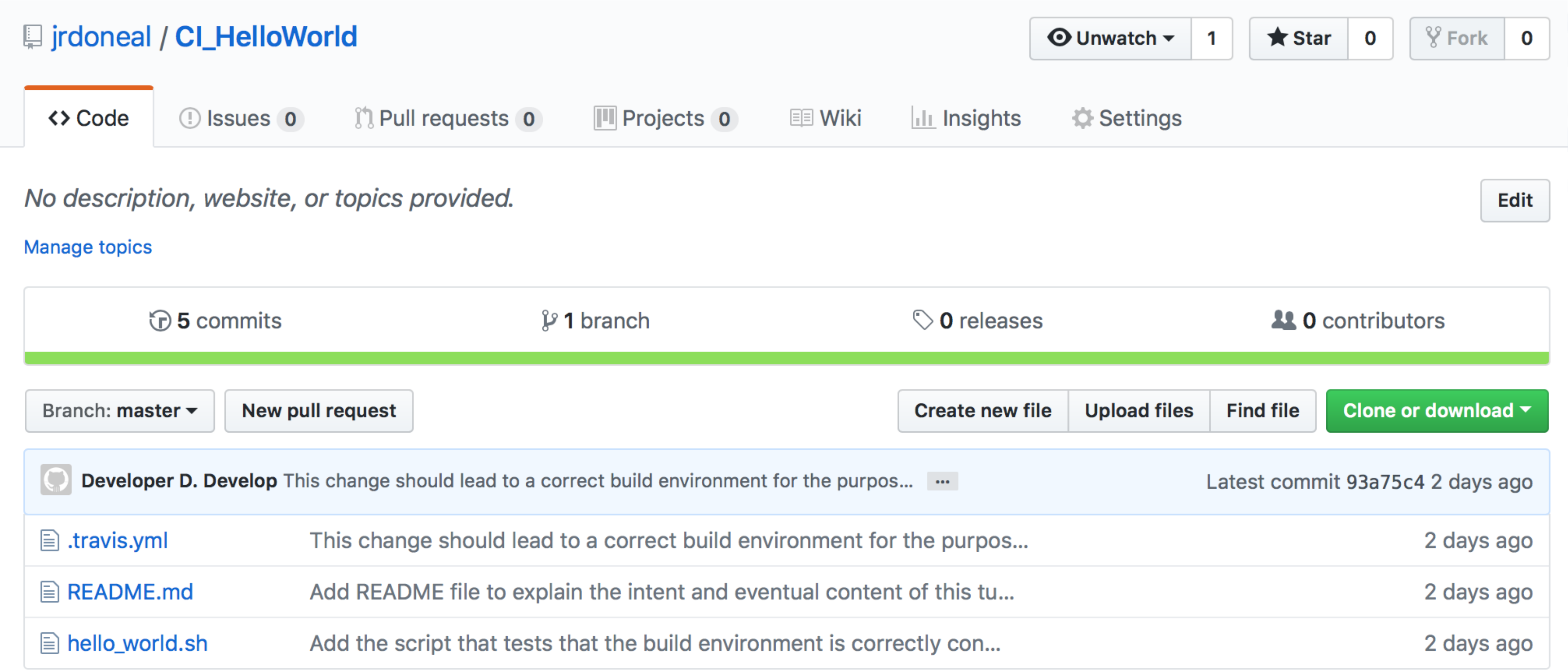
- **Tuesday — BOF — Spack Community BOF**
- Tuesday - Presentation - Parallel Programming - Painful or Productive?
- Tuesday - Poster - (WHPC04) Research Software Engineering enabling HPC
- Tuesday - Poster - (PP06): The International HPC Certification Program
- Tuesday - Poster - (PP09): EPEEC: Productivity at Exascale
- **Tuesday — Poster — (PP24): Helping You Improve Software Sustainability and Development Productivity: An Overview of the IDEAS Project**
- Wednesday — Focus Session — New Approaches, Algorithms Towards Exascale Computing
- **Wednesday — BOF — Software Engineering and Reuse in Computational Science and Engineering (additional details: http://bit.ly/swe-cse-bof)**
- Wednesday - BOF - Performance Portability and Productivity: Panel Discussion

Note: **Bold font** denotes events (co-)organized by the IDEAS Productivity project

CI Hello World – Backup Slides

GitHub Repository Page

https://github.com/jrdoneal/CI_HelloWorld



jrdoneal / **CI_HelloWorld**

No description, website, or topics provided.

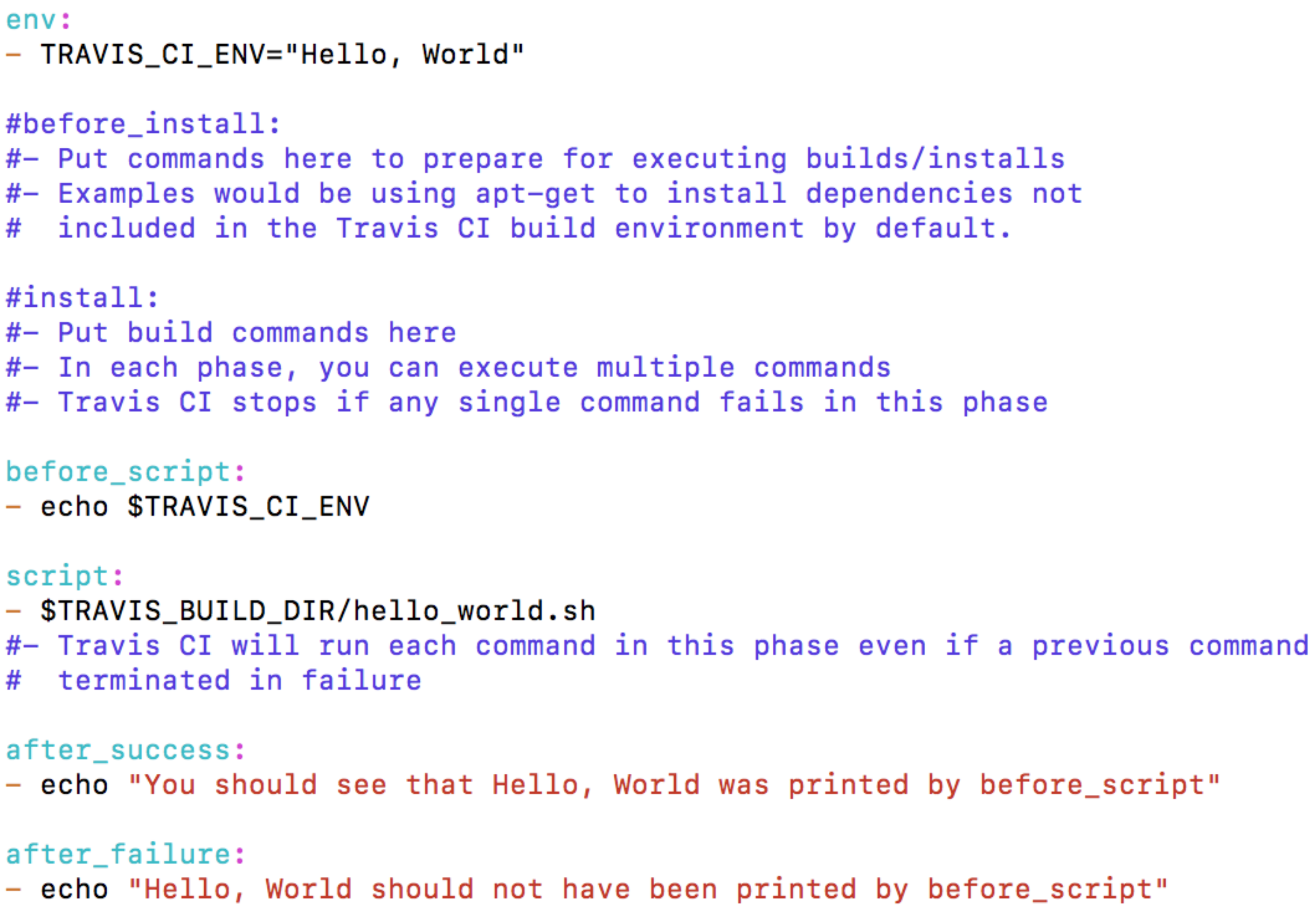
5 commits · **1** branch · **0** releases · **0** contributors

Developer D. Develop This change should lead to a correct build environment for the purpos... Latest commit 93a75c4 2 days ago

.travis.yml	This change should lead to a correct build environment for the purpos...	2 days ago
README.md	Add README file to explain the intent and eventual content of this tu...	2 days ago
hello_world.sh	Add the script that tests that the build environment is correctly con...	2 days ago

Travis CI Configuration File

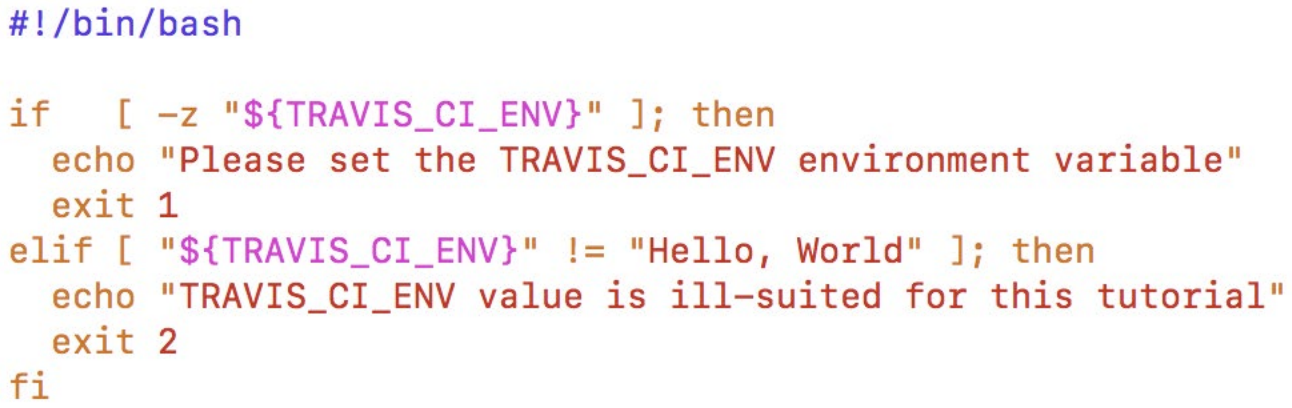
.travis.yml



```
env:
- TRAVIS_CI_ENV="Hello, World"

#before_install:
#- Put commands here to prepare for executing builds/installs
#- Examples would be using apt-get to install dependencies not
#  included in the Travis CI build environment by default.

#install:
#- Put build commands here
#- In each phase, you can execute multiple commands
#- Travis CI stops if any single command fails in this phase

before_script:
- echo $TRAVIS_CI_ENV

script:
- $TRAVIS_BUILD_DIR/hello_world.sh
#- Travis CI will run each command in this phase even if a previous command
#  terminated in failure

after_success:
- echo "You should see that Hello, World was printed by before_script"

after_failure:
- echo "Hello, World should not have been printed by before_script"
```

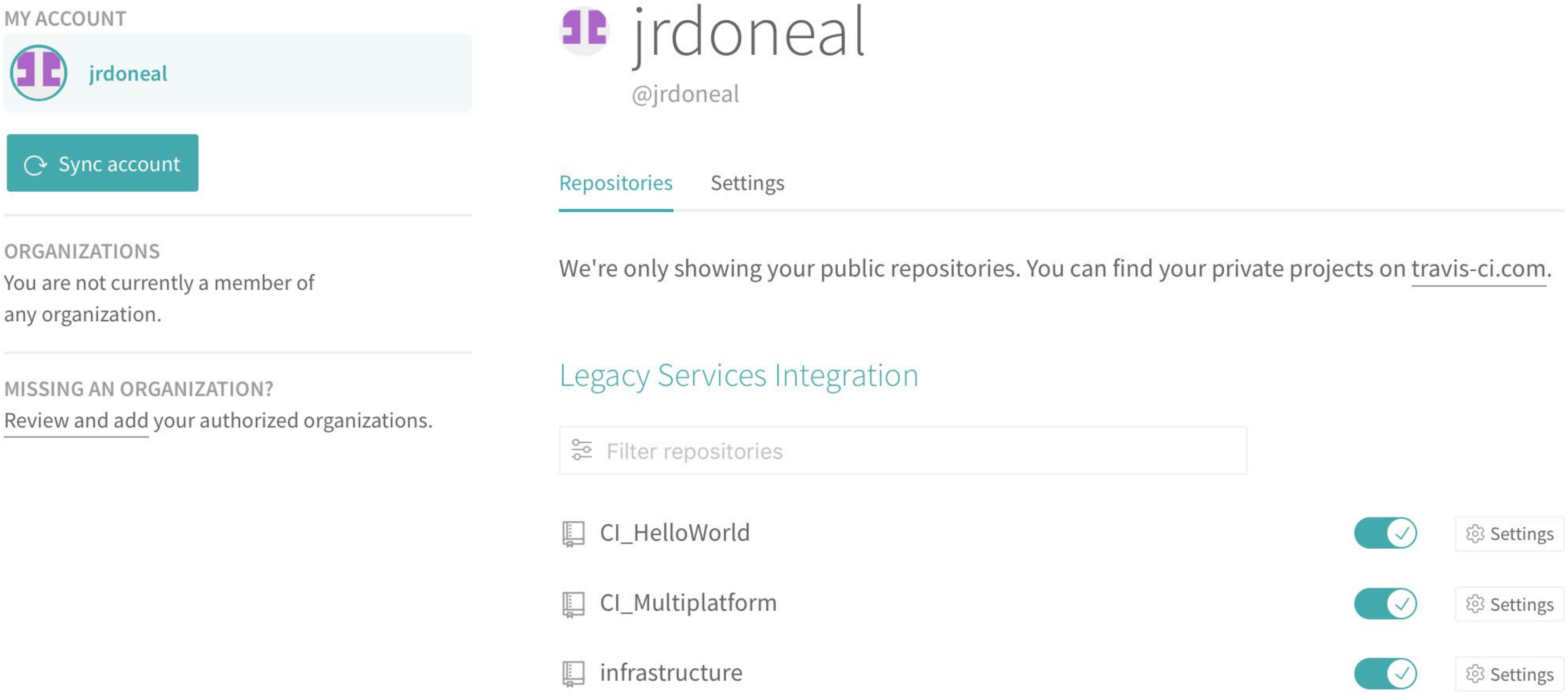
The Script Phase

hello_world.sh



```bash
#!/bin/bash

if   [ -z "${TRAVIS_CI_ENV}" ]; then
  echo "Please set the TRAVIS_CI_ENV environment variable"
  exit 1
elif [ "${TRAVIS_CI_ENV}" != "Hello, World" ]; then
  echo "TRAVIS_CI_ENV value is ill-suited for this tutorial"
  exit 2
fi
```

Connecting GitHub & Travis CI



MY ACCOUNT

jrdoneal

ORGANIZATIONS

You are not currently a member of any organization.

MISSING AN ORGANIZATION?

Review and add your authorized organizations.

jrdoneal

@jrdoneal

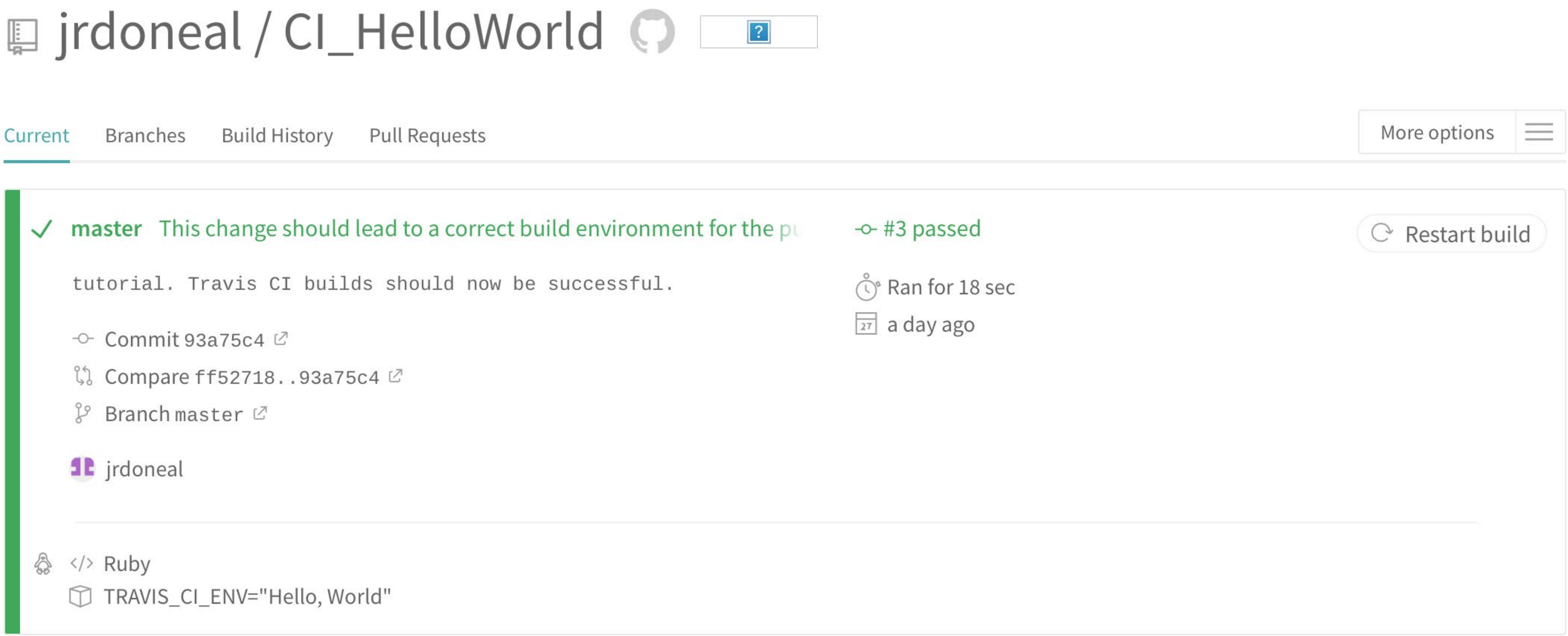
We're only showing your public repositories. You can find your private projects on travis-ci.com.

Legacy Services Integration

- CI_HelloWorld ✓ Settings
- CI_Multiplatform ✓ Settings
- infrastructure ✓ Settings

Repository in Travis CI

https://travis-ci.org/jrdoneal/CI_HelloWorld



jrdoneal / CI_HelloWorld

✓ master This change should lead to a correct build environment for the pu

tutorial. Travis CI builds should now be successful.

Commit 93a75c4

Compare ff52718..93a75c4

Branch master

jrdoneal

#3 passed

Ran for 18 sec

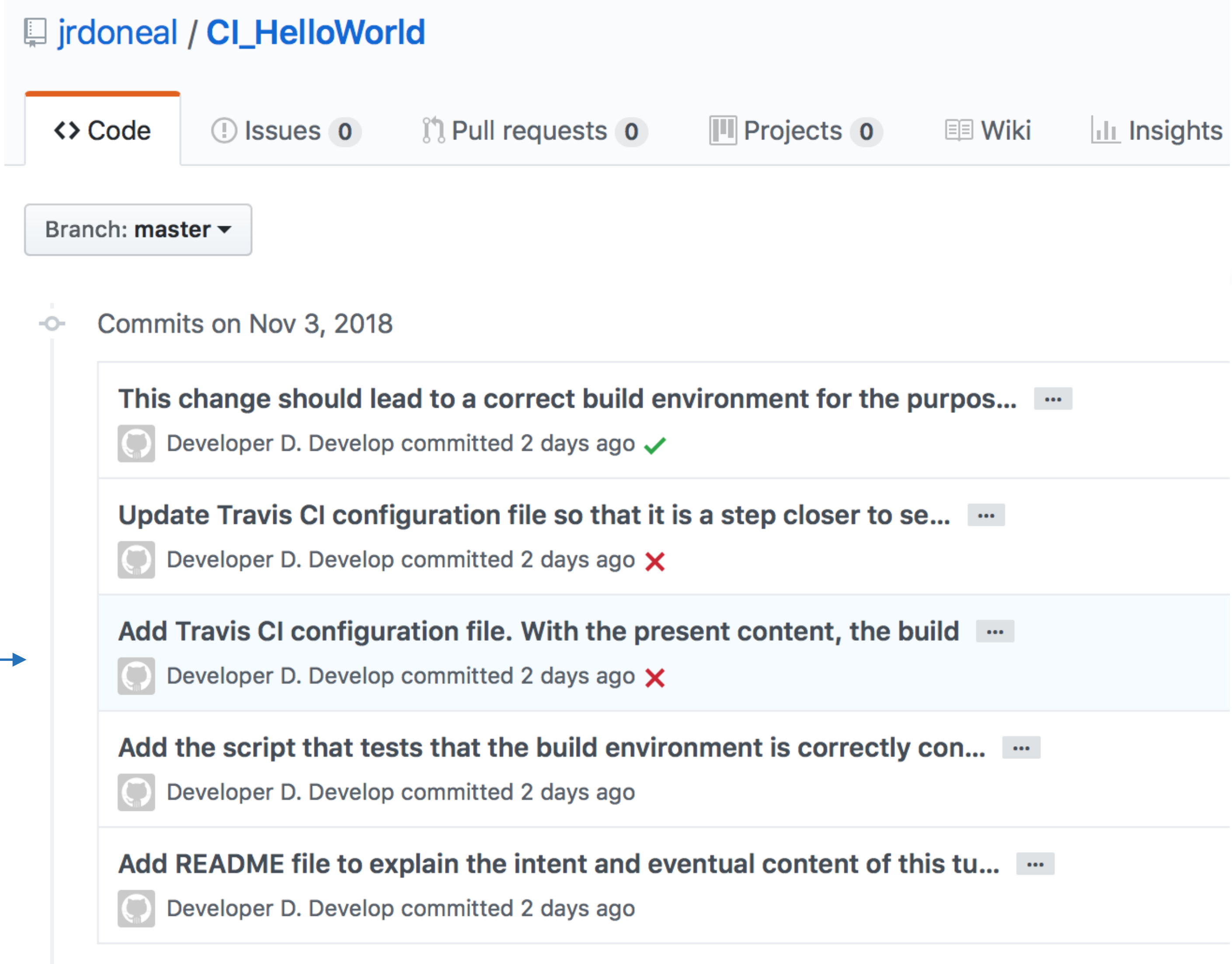
a day ago

Ruby

TRAVIS_CI_ENV="Hello, World"

Commit History

.travis.yml added



Commits on Nov 3, 2018

This change should lead to a correct build environment for the purpos... ...
Developer D. Develop committed 2 days ago ✓

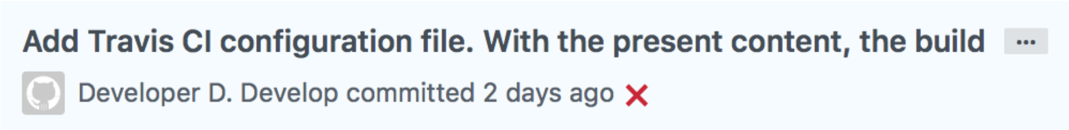
Update Travis CI configuration file so that it is a step closer to se... ...
Developer D. Develop committed 2 days ago ✗

Add Travis CI configuration file. With the present content, the build ...
Developer D. Develop committed 2 days ago ✗

Add the script that tests that the build environment is correctly con... ...
Developer D. Develop committed 2 days ago

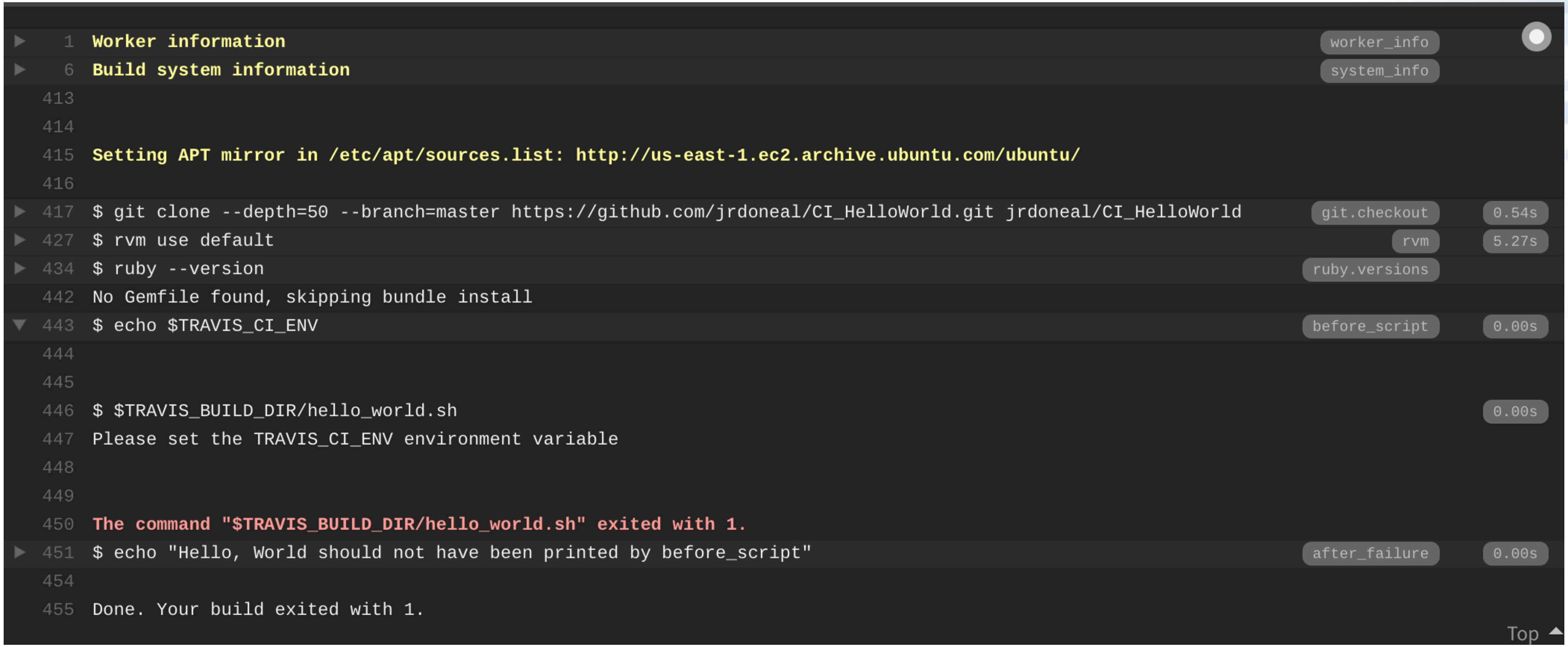
Add README file to explain the intent and eventual content of this tu... ...
Developer D. Develop committed 2 days ago

Travis CI Build History



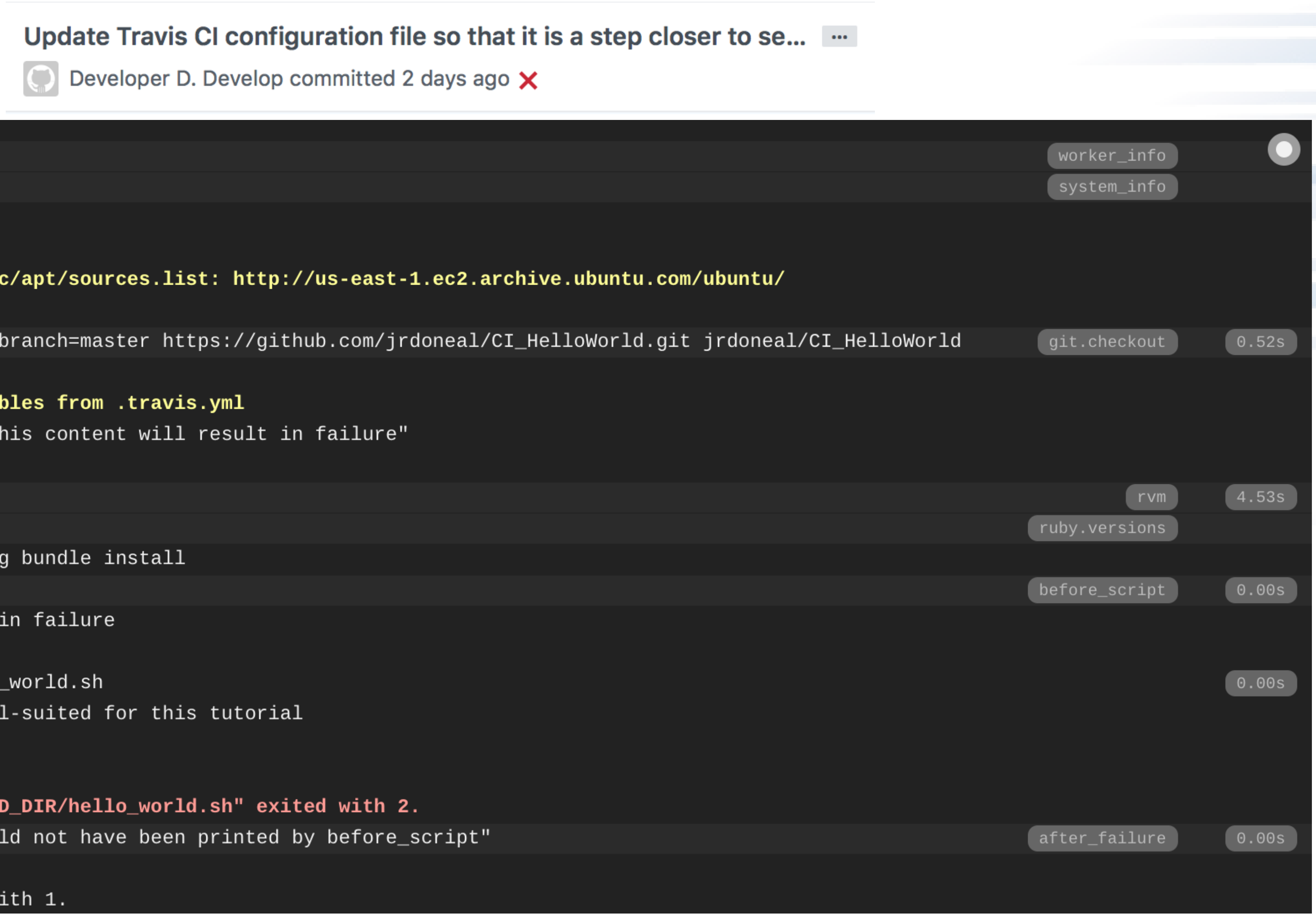
Add Travis CI configuration file. With the present content, the build

Developer D. Develop committed 2 days ago ✗



```
Worker information
Build system information


Setting APT mirror in /etc/apt/sources.list: http://us-east-1.ec2.archive.ubuntu.com/ubuntu/

$ git clone --depth=50 --branch=master https://github.com/jrdoneal/CI_HelloWorld.git jrdoneal/CI_HelloWorld
$ rvm use default
$ ruby --version
No Gemfile found, skipping bundle install
$ echo $TRAVIS_CI_ENV


$ $TRAVIS_BUILD_DIR/hello_world.sh
Please set the TRAVIS_CI_ENV environment variable


The command "$TRAVIS_BUILD_DIR/hello_world.sh" exited with 1.
$ echo "Hello, World should not have been printed by before_script"

Done. Your build exited with 1.
```

Travis CI Build History



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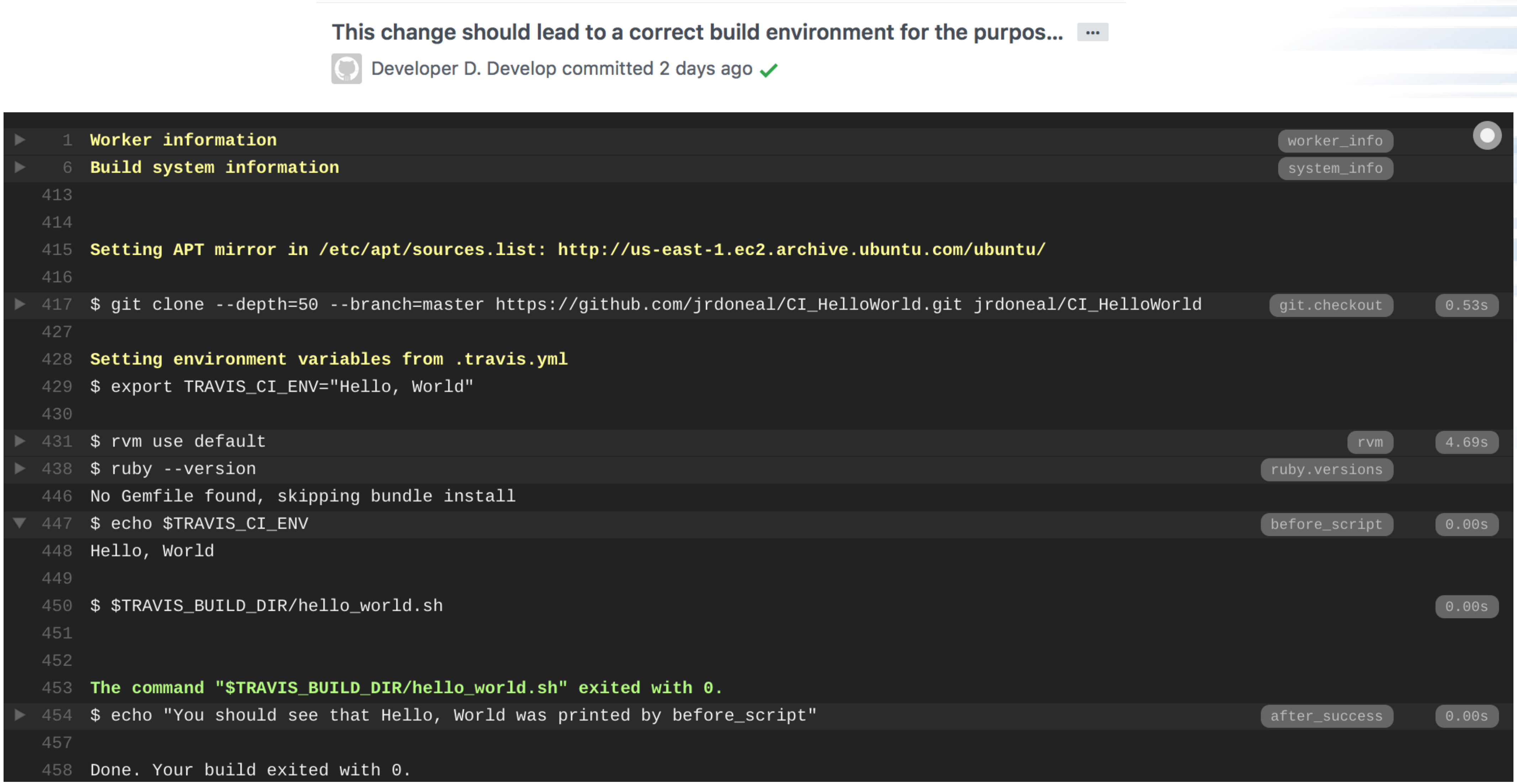
Developer D. Develop committed 2 days ago ✗

```
Worker information
Build system information


Setting APT mirror in /etc/apt/sources.list: http://us-east-1.ec2.archive.ubuntu.com/ubuntu/

$ git clone --depth=50 --branch=master https://github.com/jrdoneal/CI_HelloWorld.git jrdoneal/CI_HelloWorld

Setting environment variables from .travis.yml
$ export TRAVIS_CI_ENV="This content will result in failure"

$ rvm use default
$ ruby --version
No Gemfile found, skipping bundle install
$ echo $TRAVIS_CI_ENV
This content will result in failure

$ $TRAVIS_BUILD_DIR/hello_world.sh
TRAVIS_CI_ENV value is ill-suited for this tutorial


The command "$TRAVIS_BUILD_DIR/hello_world.sh" exited with 2.
$ echo "Hello, World should not have been printed by before_script"

Done. Your build exited with 1.
```

Travis CI Build History



This change should lead to a correct build environment for the purpos... ···

Developer D. Develop committed 2 days ago ✓

```
▶ Worker information                                                                                      worker_info
▶ Build system information                                                                                system_info


Setting APT mirror in /etc/apt/sources.list: http://us-east-1.ec2.archive.ubuntu.com/ubuntu/

▶ $ git clone --depth=50 --branch=master https://github.com/jrdoneal/CI_HelloWorld.git jrdoneal/CI_HelloWorld   git.checkout   0.53s

Setting environment variables from .travis.yml
$ export TRAVIS_CI_ENV="Hello, World"

▶ $ rvm use default                                                                                       rvm     4.69s
▶ $ ruby --version                                                                                        ruby.versions
No Gemfile found, skipping bundle install
▼ $ echo $TRAVIS_CI_ENV                                                                                   before_script   0.00s
Hello, World

$ $TRAVIS_BUILD_DIR/hello_world.sh                                                                                        0.00s


The command "$TRAVIS_BUILD_DIR/hello_world.sh" exited with 0.
▶ $ echo "You should see that Hello, World was printed by before_script"                                  after_success   0.00s

Done. Your build exited with 0.
```

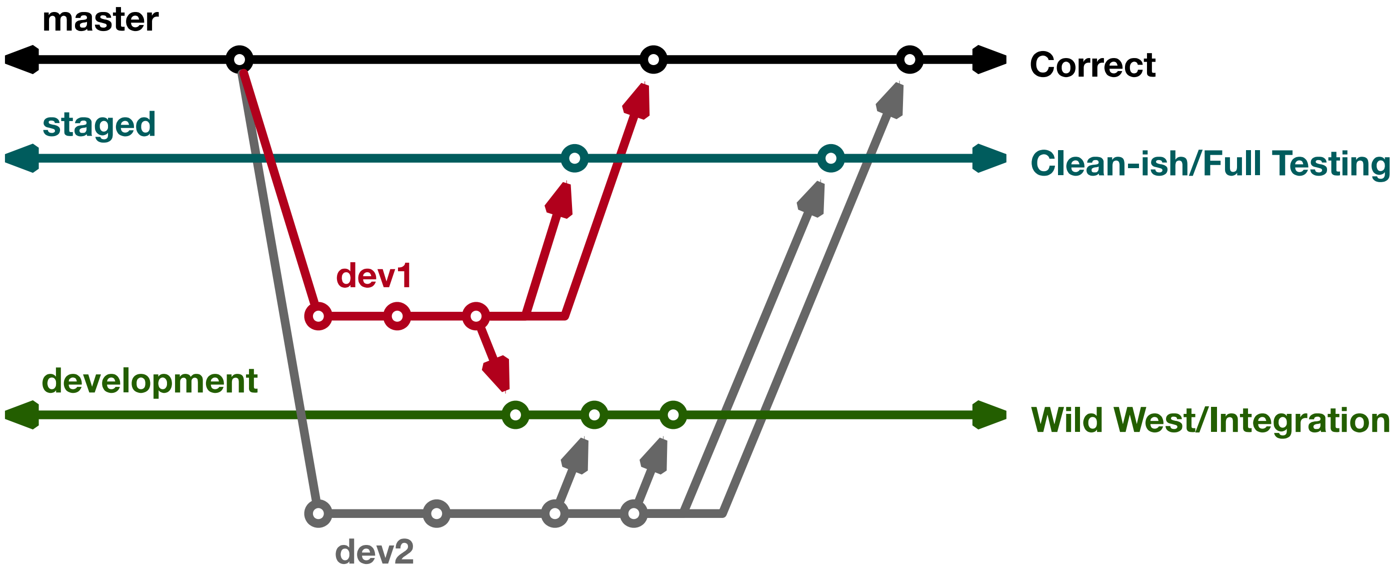
! →

Extra Slides

More Branch Rules

Is staged really necessary?

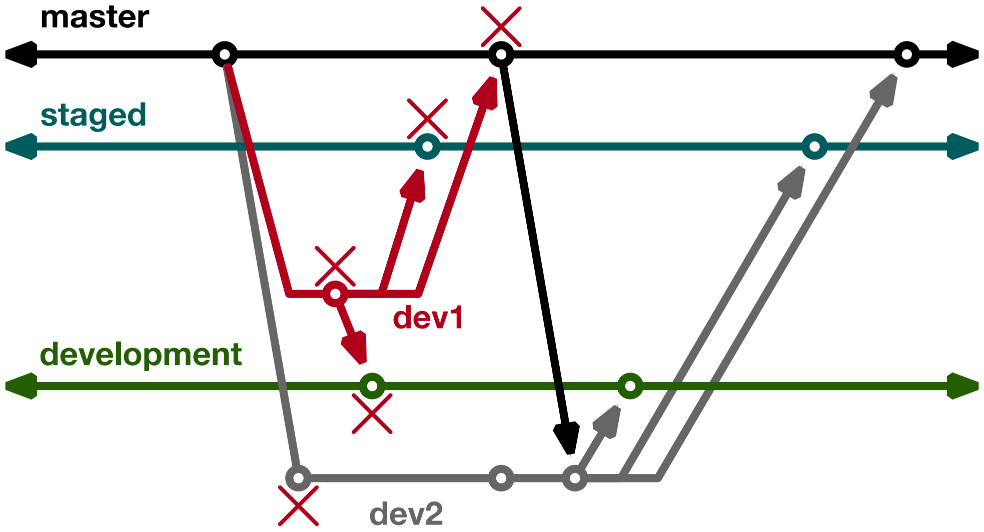
- Contains only changes intended for master
- No integration means cleaner branch
- Allows for extra stage of testing with more tests
- Extra buffer for protecting master branch



Merge Conflicts

How are merge conflicts resolved in FLASH5 Workflow?

- Merge conflict with master means merge conflict with staged and development
- We want to avoid conflict resolution when merging into master
- Directly on feature branch if resolution is there
- One idea is to merge master into feature branch



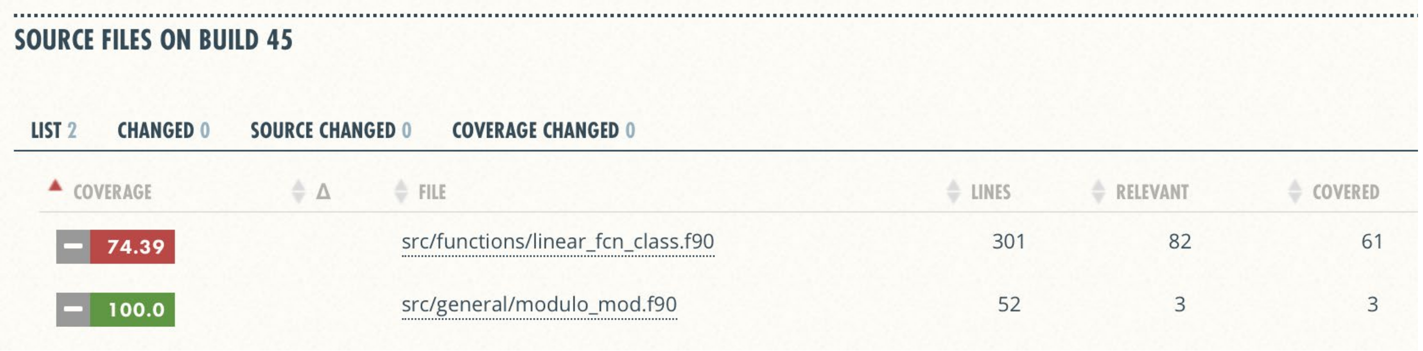
How do we determine what other tests are needed?

Code coverage tools

- Expose parts of the code that aren't being tested
- gcov
  - standard utility with the GNU compiler collection suite
  - Compile/link with –coverage & turn off optimization
  - counts the number of times each statement is executed
- lcov
  - a graphical front-end for gcov
  - available at http://ltp.sourceforge.net/coverage/lcov.php
- Hosted servers (*e.g.* coveralls, codecov)
  - graphical visualization of results
  - push results to server through continuous integration server

Code Coverage Output

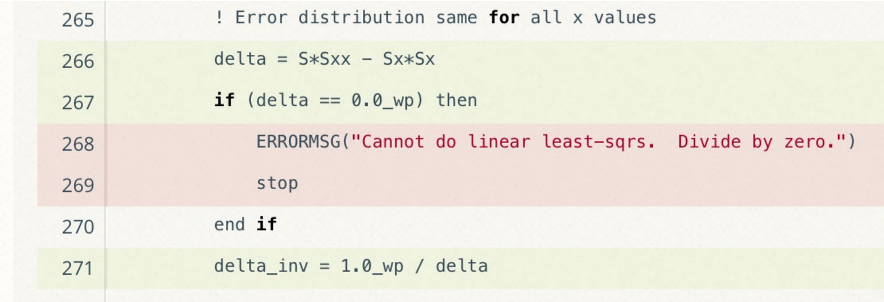
Overall Analysis



SOURCE FILES ON BUILD 45

COVERAGE	Δ	FILE	LINES	RELEVANT	COVERED
− 74.39		src/functions/linear_fcn_class.f90	301	82	61
− 100.0		src/general/modulo_mod.f90	52	3	3

Detailed Analysis



```
        ! Error distribution same for all x values
        delta = S*Sxx - Sx*Sx
        if (delta == 0.0_wp) then
            ERRORMSG("Cannot do linear least-sqrs.  Divide by zero.")
            stop
        end if
        delta_inv = 1.0_wp / delta
```

https://github.com/jrdoneal/infrastructure

Code Coverage is Popular

- gcov also works for C and Fortran
- Other tools exist for other languages
  - JCov for Java
  - Coverage.py for python
  - Devel::Cover for perl
  - profile for MATLAB
  - *etc*.

Special Notes for Morpheus Tutorial

- A code coverage and testing tutorial can be found at the Morpheus repository doxygen pages
  - https://amklinv.github.io/morpheus/index.html
- **STEP 1**: These exercises must be run on your own local machine or on a remote machine that you have access to.
- If you cannot generate your own gcov output, the associated lcov output is online
  - https://amklinv.github.io/morpheus/lcovFiles/index.html