Tools for Controlling Change in Your Software

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This talk *could* cover a *lot* of ground.

- These topics belong to an area (software engineering practices) that is not part of the formal training of most “computational scientists.”
- I don’t know what you know already!
- Don’t worry about absorbing all of this at once.
- Sorry if some of this is old news for some of you.

Overview

- What is version control (and why do we care)?
- Centralized vs distributed version control
- Git: motivation, basic concepts, usage, learning resources
- GitHub as a collaborative development platform
- Tracking progress and prioritizing issues
- Pull requests as a mechanism for code changes
- Continuous integration

Version control is an **essential** component in software development.

- Also called “source code control,” “revision control,” “source code versioning”

- Has been used by software developers for decades

- Source code lives in one or more *repositories* (repos) available to team members/contributors.

- Developers make changes, incorporate changes from collaborators, merge changes into the “master” version of code in the repository.

- **A repo is a computational scientist’s laboratory notebook.**

Version control is an **essential** component in software development.

- Establishes a common context for code contributions and the exchange of ideas

- Establishes a chronological sequence of events

- Serves as “ground truth” for a software project

- If you don’t have a common reference for your source code, *there is nothing to for your team to discuss*.

- **Results from uncontrolled code are *not reproducible*.**

Sharing code with tarballs / file sharing is a recipe for disaster

- Recall your most frustrating document-sharing experience…
- … and imagine it continuing for months or years, with a changing cast of characters, with an ever-expanding set of documents.
- (It doesn’t work.)

Sharing code with version control is easy

- A repo can tell you exactly what version you are looking at (with a unique identifier)…
- … and identify any local changes you have made…
- … so that everyone can agree on whether they are looking at the same thing.
- If there are conflicts, your version control system will tell you, and *you will need to resolve them*.

“What if I’m developing software by myself?”

- Version control offers you the same advantages/ legitimacy of a laboratory notebook

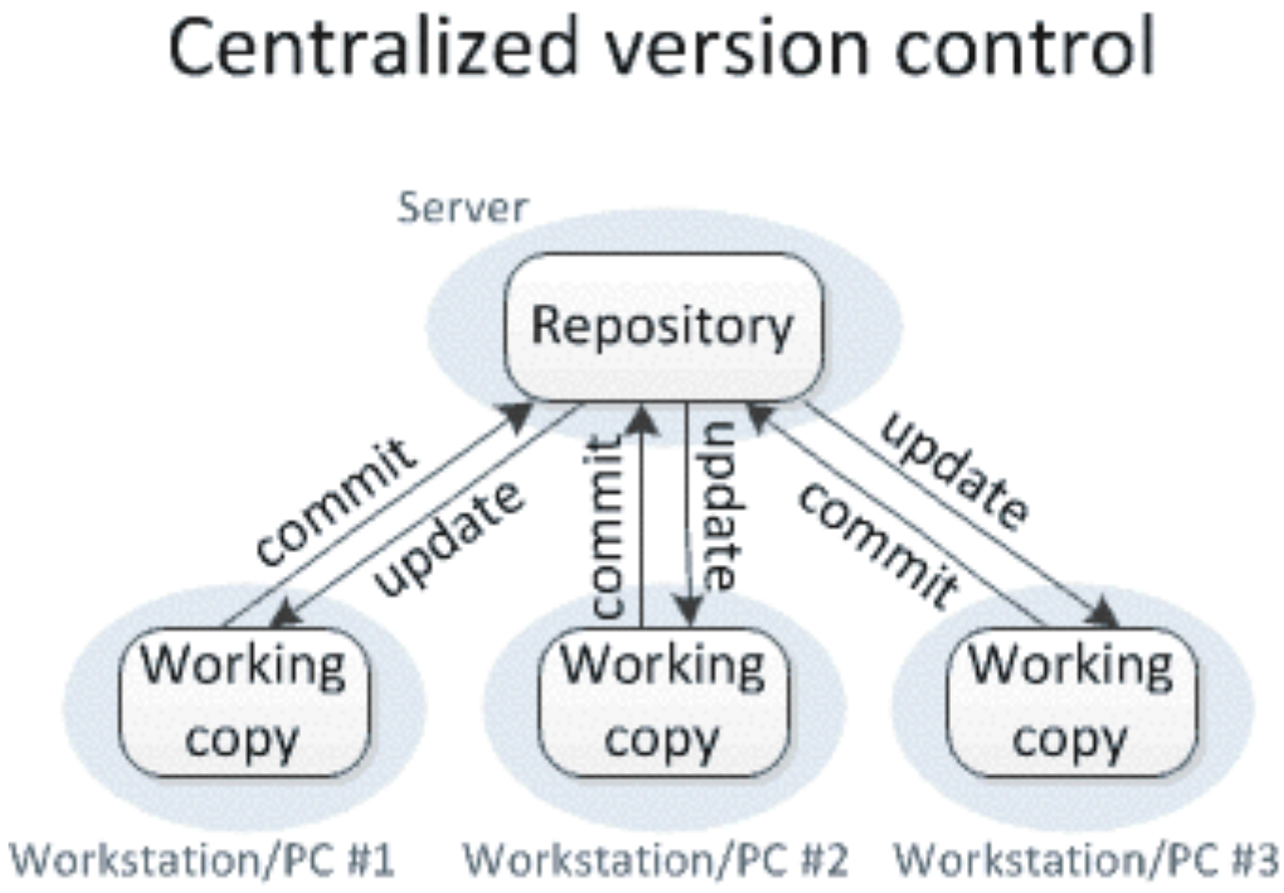
- If you’re developing your software on more than one machine, you still need to keep it consistent across these machines.

- If you want to collaborate with someone, congratulations! You’re now in the same boat as software teams.

The simplest version control systems are *centralized.*

- There is one repository containing the master version (the “trunk”) of the source code.
- Everyone syncs with this repository, *checks out* files, *changes* them, and *commits* these changes.
- People must cooperate to make sure their changes don’t conflict with each other.
- Simple, but limited.
  - Most centralized systems (SCCS, RCS, CVS, SVN) don’t allow the creation of separate development branches (though some fake it)
  - Requires coordination to keep people from stepping on each other’s toes.

Centralized version control

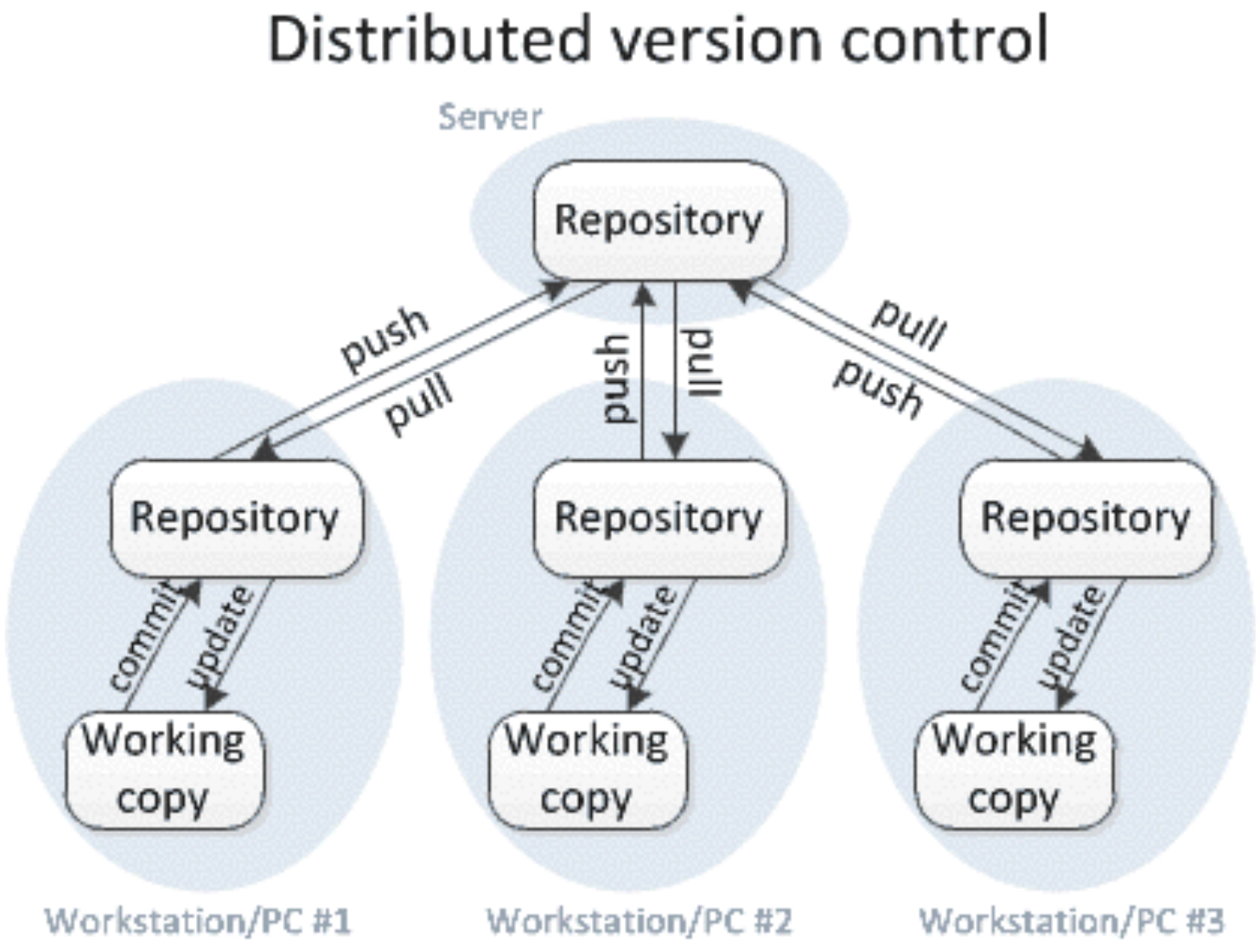


(Courtesy Michael Ernst, University of WA)

More recently, distributed version control systems (DVCS) have emerged.

- Everyone has a copy of the entire repo and its history(!)
- There is a “main” repo, agreed upon by convention.
- People typically work in development *branches*, with their changes isolated from others until merges are performed.
- Greater flexibility for design development procedures.
- Greater complexity (more concepts, fewer set rules).

Distributed version control



(Courtesy Michael Ernst, University of WA)

Git and Mercurial are the most popular DCVS tools.

- Git was written by Linus Torvalds, who *hated* Subversion, and has an interface that is alien to SVN users.

- Mercurial caters to Subversion veterans, with similar command syntax.

- Both support similar features.

- Git focuses on power, flexibility, and correctness, while Mercurial favors ease of use.

- More teams are using Git than Mercurial these days.

A version control tool is *just a tool*.

- It will not allow you to write code without communicating with others (including Future You).

- It does not define a process for developing software by yourself or on a team.

- You/your team should choose an approach based on the needs of your project and staff, and a tool that will support this approach.

- DVCS are interesting because they accommodate a wider range of approaches to software development. Even so, some still prefer centralized version control.

Software teams need to think about their process.

- Team software development is hard (because collaborative work in general is hard).

- Different teams have different needs.
  - What should be easy (happens often)?
  - What can be more complicated (happens rarely)?

- Designing a development process takes time, but pays for itself over time.

Let’s talk about Git!

- Git is difficult to learn without putting in some time.
  - The command syntax is pretty confusing.
  - Git evangelists sometimes talk about “the DAG” as if everyone knows what one of those is.
  - It’s difficult to understand how Git works without knowing the underlying concepts.
- Teams that use Git well often have one or more “Git people” that help the others.

Git can definitely help you do what you want to do, *and it works.*

- It's usually easy to fix mistakes if you find them early.
- Operations are not left in an intermediate state unless they can't be finished.
- It can support *arbitrarily elaborate* workflows.
- It doesn't get in your way once you know what you're doing.
- Perversely, it's easier to learn Git (and DVCS in general) if you haven't used SVN/CVS.

Git nouns and verbs

- *Repos*
- *Clones*/*cloning* of repos (making a copy of a repo)
- *Commits*/*committing* within repos (making code changes)
- *Branches*/*branching* within repos (isolated development)
- *Remotes*: references to other repos
- *Pulls*/*pulling* changes from one repo to another
- *Pushes*/*pushing* changes from one repo to another
- *Revisions* <—> commits (*hashes*)
- Workspace (*index*)
- *History* / the *graph* / the “DAG”

Git mechanics: creating a new repo

```
% mkdir example
% cd example
% echo “This is file A” > A
% echo “This is file B” > B
% ls
% git init
% git status
```

Git mechanics: adding files

```
% git add A
% git status
% git add B
% git status
% git commit -am “First commit.”
% git status
```

Git mechanics: changing files

```
% echo " xtra stuff" >> A
% git status
% git diff
% git checkout A
% git status
% echo " Xtra stuff" >> A
% git commit -am "Xtra A stuff"
```

Git mechanics: using the log/history

```
% git log
% git log —graph
% git show HEAD
% git show HEAD~1
% git reset —hard HEAD~1
% git log
```

(Long dashes are double dashes)

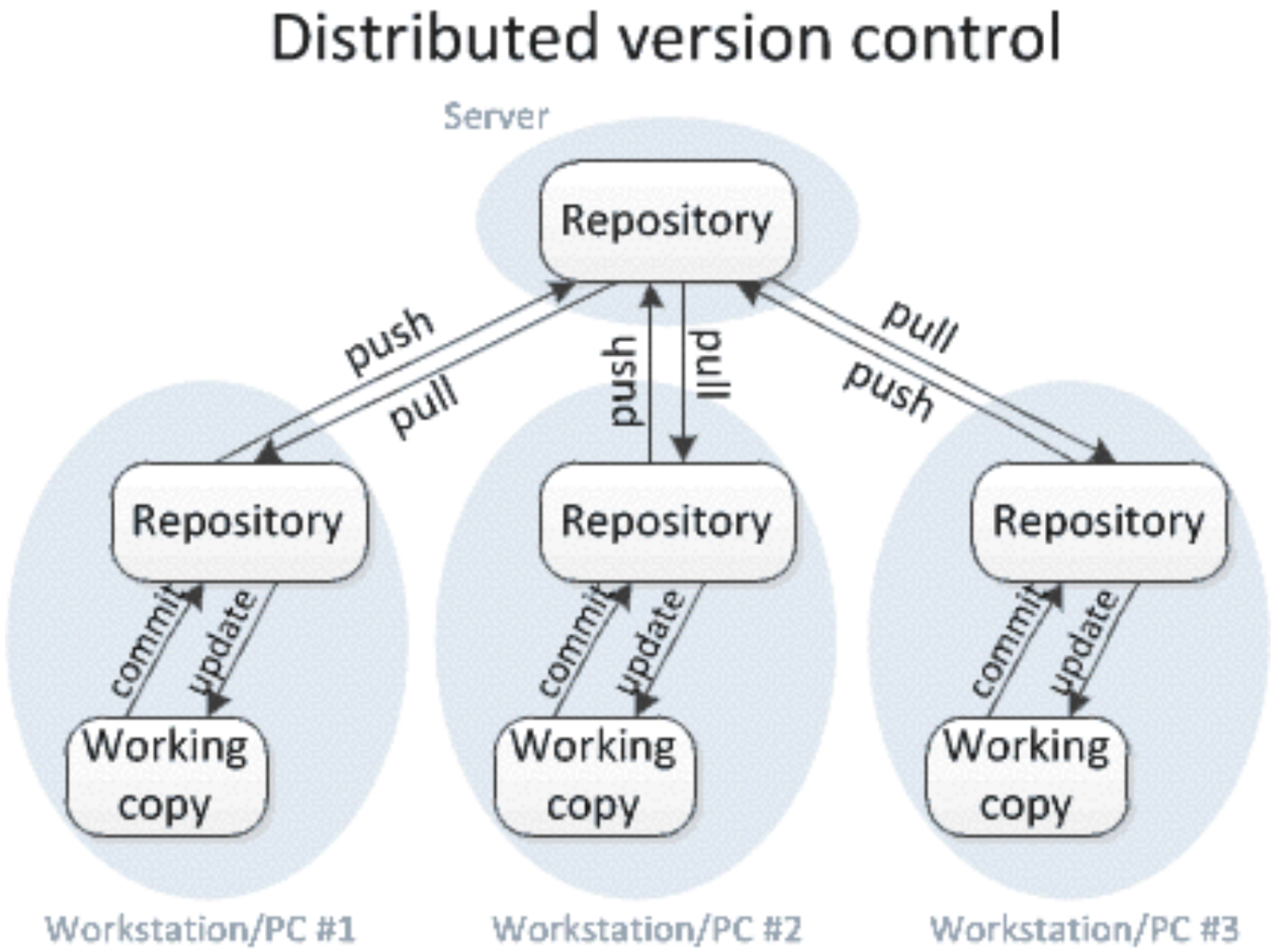
Git mechanics: creating a new branch

```
% git branch newA
% git status
% git branch
% git checkout newA
% git status
% echo “New A stuff” >> A
% git diff
% git commit -am “New A stuff”
% git log
```

Git mechanics: merging the branch

```
% git checkout master
% git status
% git log
% git merge newA
% git log
% git branch -d newA
```

Git mechanics: remotes



Git mechanics: remotes

```
% git remote -v
% git remote add upstream http://
www.example.com/example-us.git
% git remote add downstream http://
www.example.com/example-ds.git
% git remote -v
% git pull upstream master
% git push downstream master
```

It’s a good time to learn Git.

- Tutorials
  - Getting Git Right: https://www.atlassian.com/git/
  - Interactive play space from Code School: https://try.github.io/levels/1/challenges/1
  - Exploring Git’s branching model: http://learngitbranching.js.org/
  - Video course: https://www.codeschool.com/courses/git-real
  - Git: The Simple Guide: http://rogerdudler.github.io/git-guide/

It’s a good time to learn Git.

- References
  - “The Git book”
    https://git-scm.com/book/en/v2
  - Learning Version Control With Git
    https://www.git-tower.com/learn/git/ebook/en/command-line/introduction
  - “The Git Reference”
    http://gitref.org
  - Git Magic
    http://www-cs-students.stanford.edu/~blynn/gitmagic/ch01.html
  - Git Cheatsheet
    http://www.ndpsoftware.com/git-cheatsheet.html

It’s a good time to learn Git.

- Tools
  - Tower (Mac OS X)
    https://www.git-tower.com/
  - Tortoise Git (Windows)
    https://tortoisegit.org/
  - Editor / IDE integration
    - Magit (emacs)
    - Fugitive (vim)
    - (your favorite IDE here)

It’s a good time to learn Git.

- Check out offerings in your local community!
  - Git/software engineering “bootcamps,” often cheap or free
  - Software workshops / conferences
  - Your CS/IS department would probably love to tell you more about this stuff
  - *You don’t need to learn it all by yourself!*

If you decide to use Git, check out GitHub.

- http://www.github.com
- Free repositories for Open Source projects
- Implements several helpful process “building blocks” (in easy-to-use forms)
  - Pull requests
  - Forks
- Includes some simple niceties (issue tracker, wiki, pretty log/graph visualizations)

If you decide to use Git, check out GitHub.

- Integrates with several interesting services
  - JIRA / Confluence (project management tools)
  - Slack / HipChat (team communication tools)
  - Travis CI (continuous integration)
  - many others
- Other similar services exist (Bitbucket, GitLab, …)
  - Mostly differ in how payment plans are organized, service integrations offered

GitHub provides some useful items for collaborative development.

- Issue tracking: a database for bugs and feature requests

- Fork: a clone of a repository, to be used for a specific purpose (e.g., by a single developer, or to create an alternative implementation of a piece of software)

- Pull request: a formal mechanism for reviewing a set of changes to be merged into the master branch

Sample GitHub project

https://github.com/jnjohnsonlbl/example

```
% git clone https://github.com/jnjohnsonlbl/example.git
```

Issue tracker

https://github.com/jnjohnsonlbl/example

A *fork* is just a clone of a repo with its own identity on GitHub.

- Useful if you are doing work that requires more isolation, or if you have your own process and don't want to inflict it upon others.

- Can be used to submit changes/fixes to repos for which you don't have direct write access.

- Use with caution if your team isn't using forks as part of their process.

Fork the example repo

- Create a GitHub account
- Log into your account
- Navigate to https://github.com/jnjohnsonlbl/example
- Press the Fork button on the upper right
- In practice, there’s more to setting up a fork, but this illustrates the basic mechanism

A *pull request* formalizes the process of incorporating changes to software.

- A developer does some work in a branch, which exists in several commits on that branch.

- The developer wants to merge those commits into the master branch.

- He or she creates a *pull request*, with a description of the changes, helpful tags (“bug”, “testing”, “enhancement”, “data”).

- Colleagues can be notified of the request and asked to review changes using GitHub’s “diff” views.

A *pull request* formalizes the process of incorporating changes to software.

- *One or more automated events can be triggered by a pull request!*

- A reviewer may ask for changes to be made before the merge proceeds

- If/when reviewers are satisfied with the changes, the developer (or someone else assigned to merge the changes) can perform the merge, which closes the pull request.

Submit a pull request to the example repo

- Clone your fork of the example repo (to your workstation/ laptop).

- Modify a file within your workspace and commit the change.

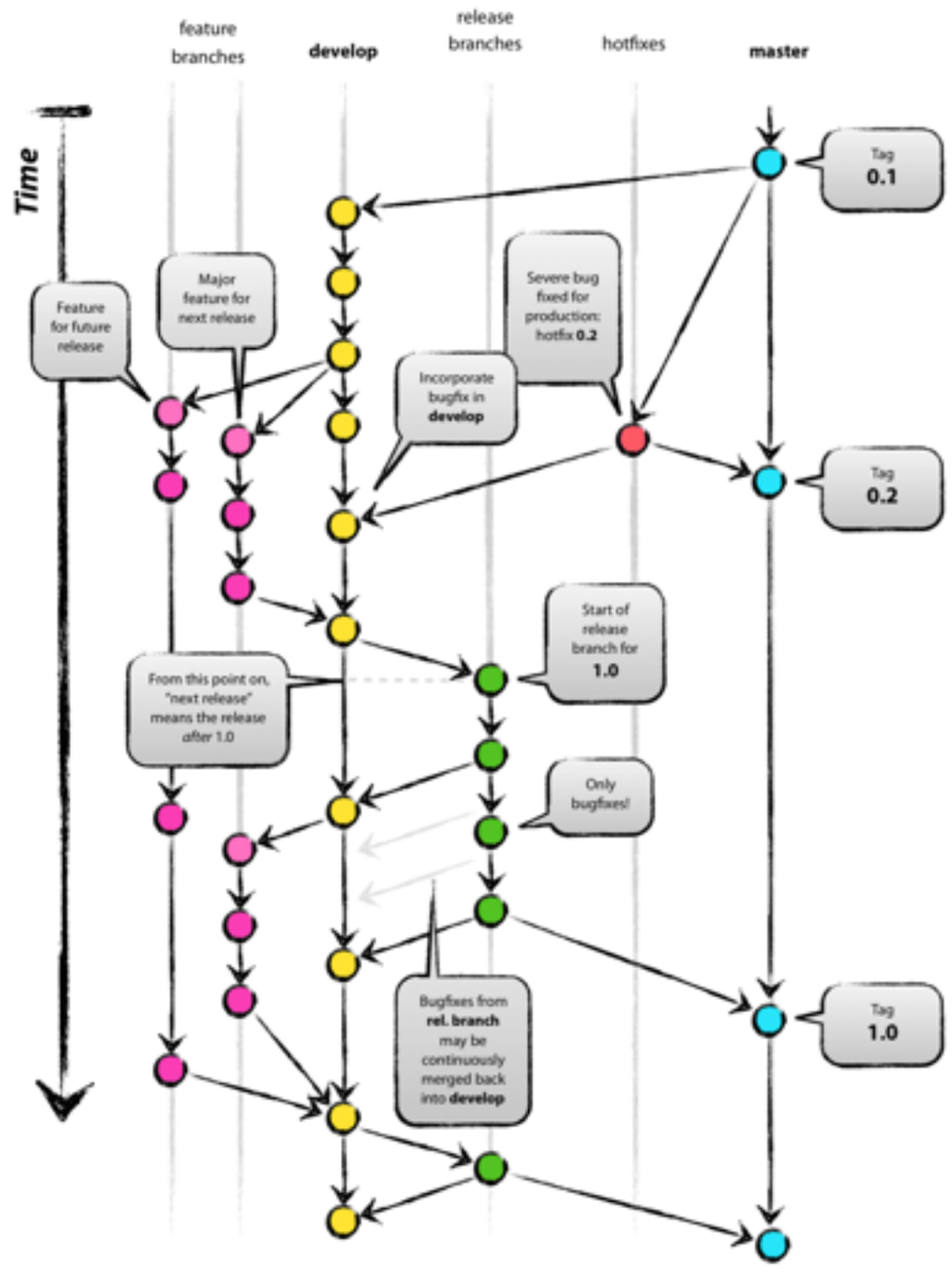
- Push your change to your fork:
  `% git push origin master`

- Navigate to your fork's GitHub page: https://github.com/yourname/example

- Click the "Pull request" button to the right of "this branch is 1 commit ahead of jnjohnsonlbl:master."

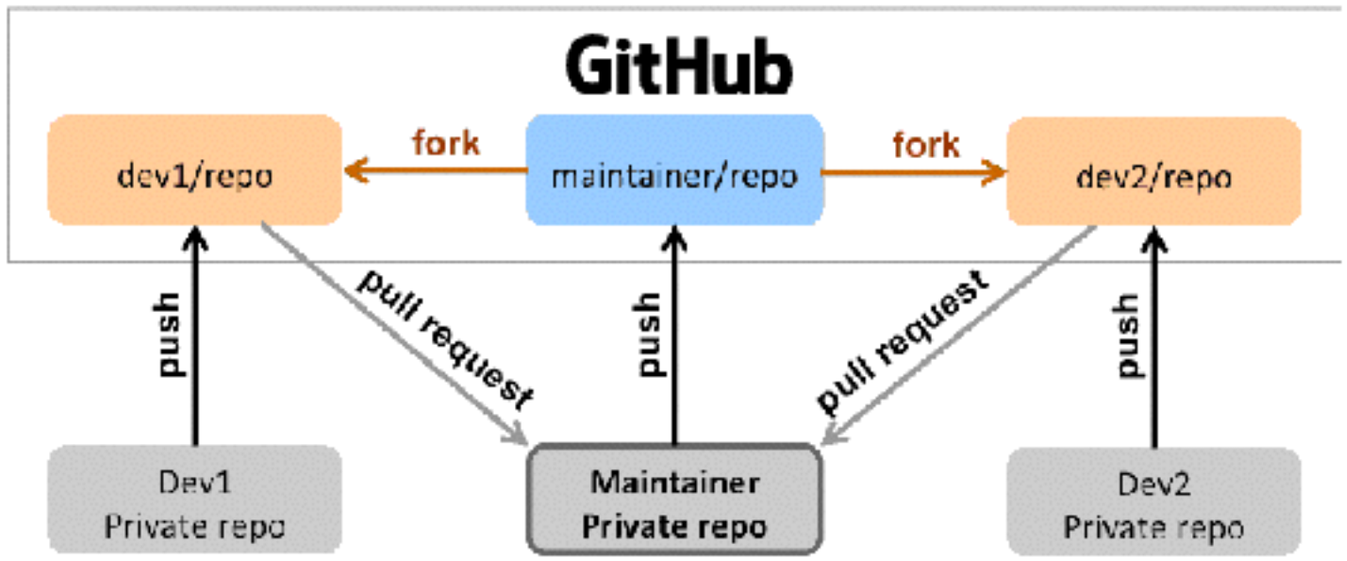
GitHub’s popularity has spawned some interesting development processes

- “Git flow” model and variants



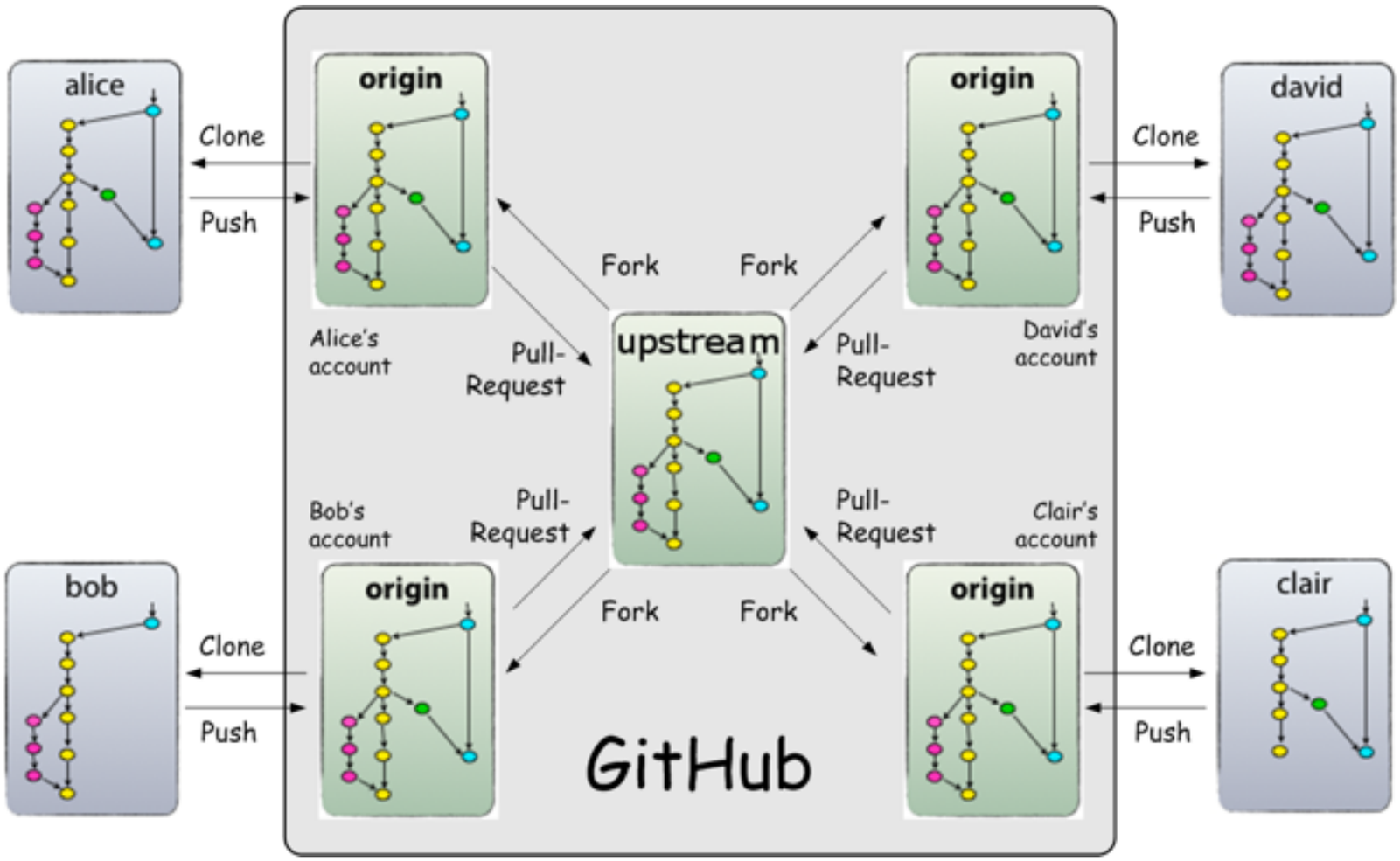
GitHub's popularity has spawned some interesting development processes

- Forking workflow



GitHub's popularity has spawned some interesting development processes

- Mix-n-match (?!)



These processes have been studied by lots of people, and analysis is ongoing…

- Gitflow:
  http://nvie.com/posts/a-successful-git-branching-model/
  http://danielkummer.github.io/git-flow-cheatsheet/

- Fork-and-branch workflow:
  http://blog.scottlowe.org/2015/01/27/using-fork-branch-git-workflow/

- Comparison of Git workflows:
  https://www.atlassian.com/git/tutorials/comparing-workflows/

- Gitflow considered harmful(!):
  http://endoflineblog.com/gitflow-considered-harmful

Continuous integration (CI): a master branch that always works

- Code changes trigger automated builds/tests on target platforms.
- Builds/tests finish *in a reasonable amount of time*, providing useful feedback when it's most needed.
- Immensely helpful!
- Requires some work, though:
  - A reasonably automated build system
  - An automated test system with significant test coverage
  - A set of systems on which tests will be run, and a controller.

Continuous integration (CI): a master branch that always works

- Has existed for some time
- Adoption has been slow
- Setting up and maintaining CI systems is difficult, labor-intensive (typically requires a dedicated staff member)
- *You have to be doing a lot of things right to even consider CI*

Cloud-based CI is available as a service on GitHub.

- Automated builds/tests can be triggered via pull requests.
- Builds/tests run on cloud systems — no server in your closet. *Great use of the cloud!*
- Test results are reported on the pull request page (with links to detailed logs).
- Already being used successfully by scientific computing projects, with noticeable benefits to productivity.
- Not perfect, but *far* better than not doing CI.

Travis CI is a great choice for HPC

- Integrates easily with GitHub
- *Free* for Open Source projects
- Supports environments with C/C++/Fortran compilers (GNU, Clang, Intel[?])
- Linux, Mac platforms available
- *Relatively* simple, *reasonably* flexible configuration file
  - Documentation is sparse, but we now have working examples.

Travis CI

https://github.com/LBL-EESA/alquimia-dev

Wrap-up

- Your software projects need version control
- Distributed Version Control Systems (DVCS) are becoming more popular, because they allow greater flexibility.
- Git seems to be the tool of choice in industry.
    - You don’t need anything more powerful.
    - Lots of documentation, knowledge and experience to draw from.
    - Learning it is an investment, but the payoff is real (but you might want to train up a “Git person”).

Wrap-up

- GitHub and similar sites provide capable, cost-effective development platforms.

- These sites offer useful services that can simplify common processes and improve your engineering practices.

- Continuous Integration (CI) is a very effective practice that improves code quality, and is now within the reach of small teams.