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
It’s a good time to learn Git.

- References
  - “The Git book”
  - Learning Version Control With Git
  - “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](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:**

- **Fork-and-branch workflow:**

- **Comparison of Git workflows:**
  [https://www.atlassian.com/git/tutorials/comparing-workflows/](https://www.atlassian.com/git/tutorials/comparing-workflows/)

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