



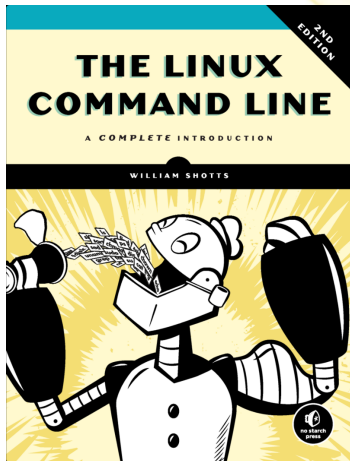
UMD DATA605 - Big Data Systems

Lesson 2.1: Git

Instructor: Dr. GP Saggese, gsaggese@umd.edu

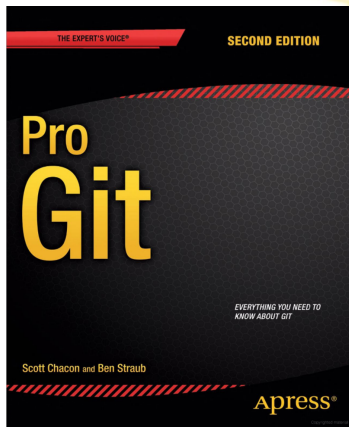
Bash / Linux: Resources

- **How Linux works**
 - Processes
 - File ownership and permissions
 - Virtual memory
 - How to administer a Linux box as root
- **Easy**
 - [Command-Line for Beginners](#)
 - E.g., find, xargs, chmod, chown, symbolic, and hard links
- **Mastery**
 - [The Linux Command Line](#)



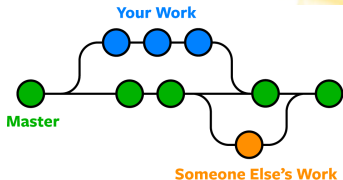
Git Resources

- Concepts in the slides
- Tutorial: [Tutorial Git](#)
- We will use Git during the project
- Mastery: [Pro Git](#) (free)
- Web resources:
 - <https://githowto.com>
 - dangitgit.com (without swearing)
 - [Oh Sh*t, Git!?!](#) (with swearing)
- Playgrounds
 - <https://learngitbranching.js.org>



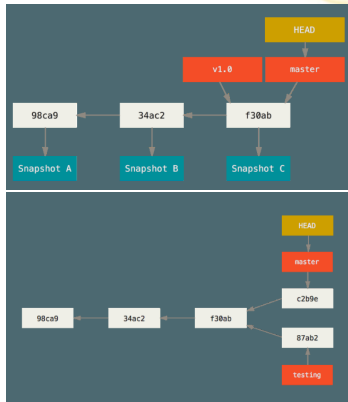
Git Branching

- **Branching**
 - Diverge from main development line
- **Why branch?**
 - Work without affecting main code
 - Avoid changes in main branch
 - Merge code downstream for updates
 - Merge code upstream after completion
- **Git branching is lightweight**
 - Instantaneous
 - Branch is a pointer to a commit
 - Git stores data as snapshots, not file differences
- **Git workflows branch and merge often**
 - Multiple times a day
 - Surprising for users of distributed VCS
 - E.g., branch before lunch
 - Branches are cheap
 - Use them to isolate and organize work



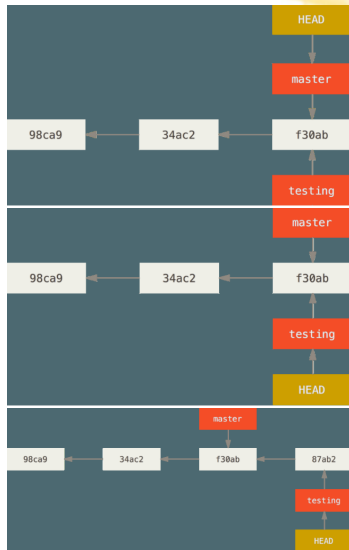
Git Branching

- master (or main) is a normal branch
 - Pointer to the last commit
 - Moves forward with each commit
- HEAD
 - Pointer to the local branch
 - E.g., master, testing
 - git checkout <BRANCH> moves across branches
- git branch testing
 - Create a new pointer testing
 - Points to the current commit
 - Pointer is movable
- Divergent history
 - Work progresses in two “split” branches



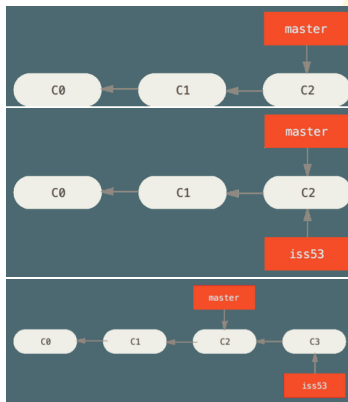
Git Checkout

- `git checkout` switches branch
 - Move HEAD pointer to new branch
 - Change files in working dir to match branch pointer
- E.g., two branches, master and testing
 - You are on master
 - `git checkout testing`
 - Pointer moves, working dir changes
 - Keep working and commit on testing
 - Pointer to testing moves forward



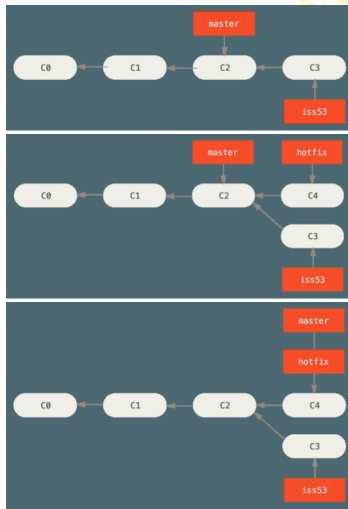
Git Branching and Merging

- Tutorials
 - [Work on main](#)
 - [Hot fix](#)
- Start from a project with some commits
- Branch to work on a new feature “Issue 53”
 - > `git checkout -b iss53`
 - work ... work ... work
 - > `git commit`



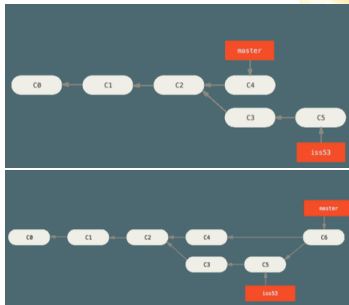
Git Branching and Merging

- **Need a hotfix** to master
 - > `git checkout master`
 - > `git checkout -b hotfix`
 - fix ... fix ... fix
 - > `git commit -am "Hot fix"`
 - > `git checkout master`
 - > `git merge hotfix`
- **Fast forward**
 - Now there is a divergent history between master and iss53



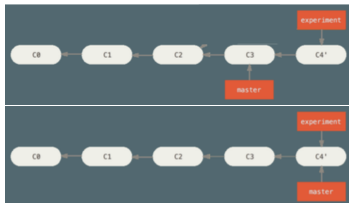
Git Branching and Merging

- Keep working on iss53
 - > `git checkout iss53`
 - work ... work ... work
 - The branch keeps diverging
- At some point you are done with iss53
 - You want to merge your work back to master
 - Go to the target branch
 - > `git checkout master`
 - > `git merge iss53`
- Git can't fast forward
- Git creates a new snapshot with the 3-way “merge commit” (i.e., a commit with more than one parent)
- Delete the branch
 - > `git branch -d iss53`



Fast Forward Merge

- **Fast forward merge**
 - Merge a commit X with a commit Y that can be reached by following the history of commit X
- There is not divergent history to merge
 - Git simply moves the branch pointer forward from X to Y
- **Mental model:** a branch is just a pointer that says where the tip of the branch is
- E.g., C4' is reachable from C3
 - > `git checkout master`
 - > `git merge experiment`
- Git moves the pointer of master to C4'



Merging Conflicts

- Tutorial:
 - [Merging conflicts](#)
- Sometimes **Git can't merge**, e.g.,
 - The same file has been modified by both branches
 - One file was modified by one branch and deleted by another
- **Git:**
 - Does not create a merge commit
 - Pauses to let you resolve the conflict
 - Adds conflict resolution markers
- **User merges manually**
 - Edit the files git mergetool
 - git add to mark as resolved
 - git commit
 - Use PyCharm or VS Code

```
<<<<<< HEAD:index.html
<div id="footer">contact : email.support@github.com</div>
=====
<div id="footer">
  please contact us at support@github.com
</div>
>>>>>> iss53:index.html

$ git merge iss53
Auto-merging index.html
CONFLICT (content): Merge conflict in index.html
Automatic merge failed; fix conflicts and then commit the result.

$ git status
On branch master
You have unmerged paths.
  (fix conflicts and run "git commit")

Unmerged paths:
  (use "git add <file>..." to mark resolution)

   both modified:   index.html

no changes added to commit (use "git add" and/or "git commit -a")

$ git status
On branch master
All conflicts fixed but you are still merging.
  (use "git commit" to conclude merge)

Changes to be committed:

   modified:   index.html
```

Git Rebasing

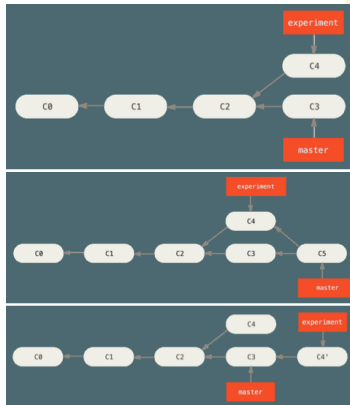
- In Git there are **two ways of merging divergent history**
 - E.g., master and experiment have a common ancestor C2

- **Merge**

- Go to the target branch
 - > `git checkout master`
 - > `git merge experiment`
- Create a new snapshot C5 and commit

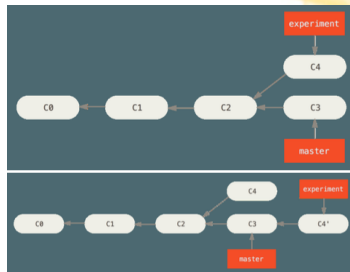
- **Rebase**

- Go to the branch to rebase
 - > `git checkout experiment`
 - > `git rebase master`
- Rebase algo:
 - Get all the changes committed in the branch (C4) where we are on (experiment) since the common ancestor (C2)
 - Sync to the branch that we are rebasing onto (master at C3)
 - Apply the changes C4
 - Only current branch is affected
 - Finally fast forward experiment



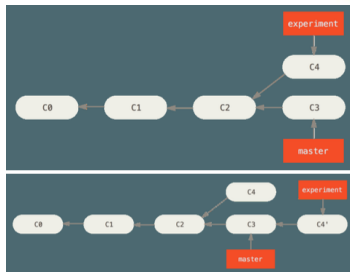
Uses of Rebase

- **Rebasing makes for a cleaner history**
 - The history looks like all the work happened in series
 - Although in reality it happened in parallel to the development in master
- **Rebasing to contribute to a project**
 - Developer
 - You are contributing to a project that you don't maintain
 - You work on your branch
 - When you are ready to integrate your work, rebase your work onto origin/master
 - The maintainer
 - Does not have to do any integration work
 - Does just a fast forward or a clean apply (no conflicts)



Golden Rule of Rebasing

- **Remember:** rebasing means abandoning existing commits and creating new ones that are similar but different
- **Problem**
 - You push commits to a remote
 - Others pull commits and base work on them
 - You rewrite commits with `git rebase`
 - You push again with `git push --force`
 - Collaborators must re-merge work
- **Solution**
 - Strict: *"Do not ever rebase commits outside your repository"*
 - Loose: *"Rebase your branch if only you use it, even if pushed to a server"*

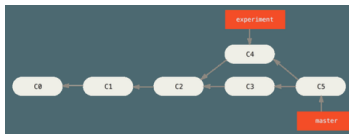


Rebase vs Merge: Philosophical Considerations

- Deciding **Rebase-vs-merge** depends on the answer to the question:
 - What does the commit history of a repo mean?*

1. History is the record of what actually happened

- "History should not be tampered with, even if messy!"*
- Use `git merge`



2. History represents how a project should have been made

- "You should tell the history in the way that is best for future readers"*
- Use `git rebase` and `filter-branch`



Rebase vs Merge: Philosophical Considerations

- Many man-centuries have been wasted discussing rebase-vs-merge at the watercooler
 - Total waste of time! Tell people to get back to work!
- When you contribute to a project often people decide for you based on their preference
- **Best of the merge-vs-rebase approaches**
 - Rebase changes you've made in your local repo
 - Even if you have pushed but you know the branch is yours
 - Use `git pull --rebase` to clean up the history of your work
 - If the branch is shared with others then you need to definitively `git merge`
 - Only `git merge` to master to preserve the history of how something was built
- **Personally**
 - I like to squash-and-merge branches to master
 - Rarely my commits are “complete”, are just checkpoints

Remote Branches

- **Remote branches** are pointers to branches in remote repos

```
git remote -v  
origin  git@github.com:gpsaggese/umd_classes.git (fetch)  
origin  git@github.com:gpsaggese/umd_classes.git (push)
```

- **Tracking branches**
 - Local references representing the state of the remote repo
 - E.g., master tracks origin/master
 - You can't change the remote branch (e.g., origin/master)
 - You can change tracking branch (e.g., master)
 - Git updates tracking branches when you do `git fetch origin` (or `git pull`)
- To share code in a local branch you need to push it to a remote
 - > `git push origin serverfix`
- To work on it
 - > `git checkout -b serverfix origin/serverfix`



Git Workflows

- **Git workflows** = ways of working and collaborating using Git
- **Long-running branches** = branches at different level of stabilities, that are always open
 - master is always ready to be released
 - develop branch to develop in
 - topic / feature branches
 - When branches are “stable enough” they are merged up



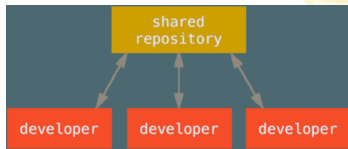
Centralized Workflow

- **Centralized workflow in centralized VCS**

- Developers:
 - Check out the code from the central repo on their computer
 - Modify the code locally
 - Push it back to the central hub (assuming no conflicts with latest copy, otherwise they need to merge)

- **Centralized workflow in Git**

- Developers:
 - Have push (i.e., write) access to the central repo
 - Need to fetch and then merge
 - Cannot push code that will overwrite each other code (only fast-forward changes)



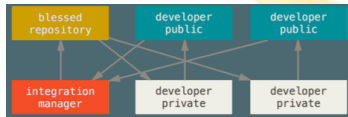
Forking Workflows

- Typically devs don't have permissions to update directly branches on a project
 - Read-write permissions for core contributors
 - Read-only for anybody else
- **Solution**
 - "Forking" a repo
 - External contributors
 - Clone the repo and create a branch with the work
 - Create a writable fork of the project
 - Push branches to fork
 - Prepare a PR with their work
 - Project maintainer
 - Reviews PRs
 - Accepts PRs
 - Integrates PRs
 - In practice it's the project maintainer that pulls the code when it's ready, instead of external contributors pushing the code
- **Aka "GitHub workflow"**
 - "Innovation" was forking (Fork me on GitHub!)
 - GitHub acquired by Microsoft for 7.5b USD



Integration-Manager Workflow

- This is the classical model for open-source development
 - E.g., Linux, GitHub (forking) workflow



1. **One repo is the official project**

- Only the project maintainer pushes to the public repo
- E.g., causify-ai/csfy

2. **Each contributor**

- Has read access to everyone else's public repo
- Forks the project into a private copy
 - Write access to their own public repo
 - E.g., gpsaggese/csfy
- Makes changes
- Pushes changes to his own public copy
- Sends email to maintainer asking to pull changes (pull request)

3. **The maintainer**

- Adds contributor repo as a remote
- Merges the changes into a local branch
- Tests changes locally
- Pushes branch to the official repo

Git log

- `git log` reports info about commits
- **refs** are references to:
 - HEAD (commit you are working on, next commit)
 - origin/master (remote branch)
 - experiment (local branch)
 - d921970 (commit)
- `^` after a reference resolves to the parent of that commit
 - HEAD[^] = commit before HEAD, i.e., last commit
 - `^2` means `^^`
 - A merge commit has multiple parents



Dot notation

- **Double-dot notation**

- 1..2 = commits that are reachable from 2 but not from 1
- Like a “difference”
- `git log master..experiment` → D,C
- `git log experiment..master` → F,E



- **Triple-dot notation**

- 1...2 = commits that are reachable from either branch but not from both
- Like “union excluding intersection”
- `git log master...experiment` → F,E,D,C



Advanced Git

- **Stashing**
 - Copy state of your working dir (e.g., modified and staged files)
 - Save it in a stack
 - Apply later
- **Cherry-picking**
 - Apply a single commit from one branch onto another
- **rerere**
 - = “Reuse Recorded Resolution”
 - Git caches how to solve certain conflicts
- **Submodules / subtrees**
 - Project including other Git projects

Advanced Git

- **bisect**
 - `git bisect` helps identifying the commit that introduced a bug
 - Bug appears at top of tree
 - Unknown revision where it started
 - Script returns 0 if good, non-0 if bad
 - `git bisect` finds revision where script changes from good to bad
- **filter-branch**
 - Rewrite repo history in a script-able way
 - E.g., change email, remove sensitive file
 - Check out each version, run command, commit result
- **Hooks**
 - Run scripts before commit, merging,

GitHub



- GitHub acquired by MSFT for 7.5b
- **GitHub: largest host for Git repos**
 - Git hosting (100m+ open source projects)
 - PRs, forks
 - Issue tracking
 - Code review
 - Collaboration
 - Wiki
 - Actions (CI / CD)
- **"Forking a project"**
 - Open-source communities
 - Negative connotation
 - Modify and create a competing project
 - GitHub parlance
 - Copy a project to contribute without push/write access