



## UMD DATA605 - Big Data Systems

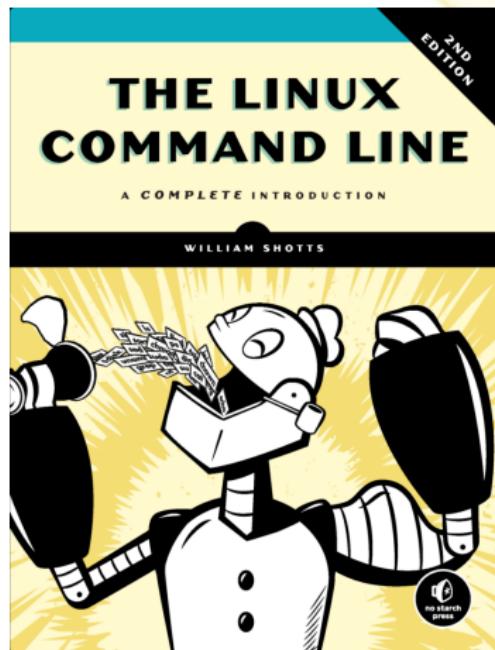
### Lesson 2.1: Git

**Instructor:** Dr. GP Saggese, [gsaggese@umd.edu](mailto:gsaggese@umd.edu)

# Bash / Linux: Resources

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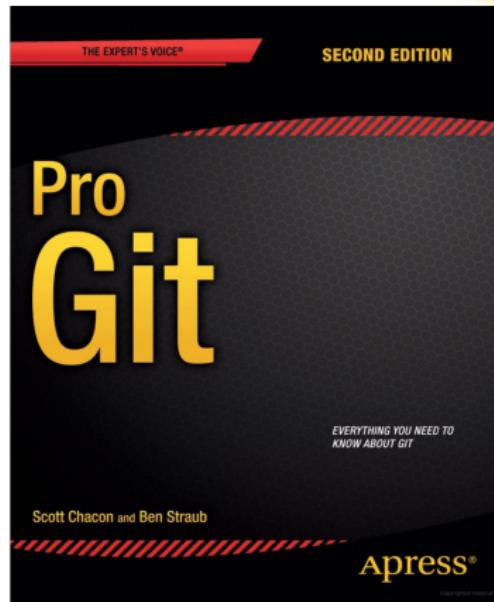
- **How Linux works**
  - Processes
  - File ownership and permissions
  - Virtual memory
  - How to administer a Linux box as root
- **Easy**
  - [Command-Line for Beginners](#)
  - E.g., find, xargs, chmod, chown, symbolic, and hard links
- **Mastery**
  - [The Linux Command Line](#)



# Git Resources

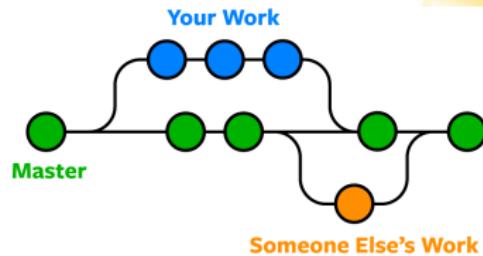
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- Concepts in the slides
- Tutorial: [Tutorial Git](#)
- We will use Git during the project
- Mastery: [Pro Git](#) (free)
- Web resources:
  - <https://githowto.com>
  - [dangitgit.com](http://dangitgit.com) (without swearing)
  - [Oh Sh\\*t, Git!?!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

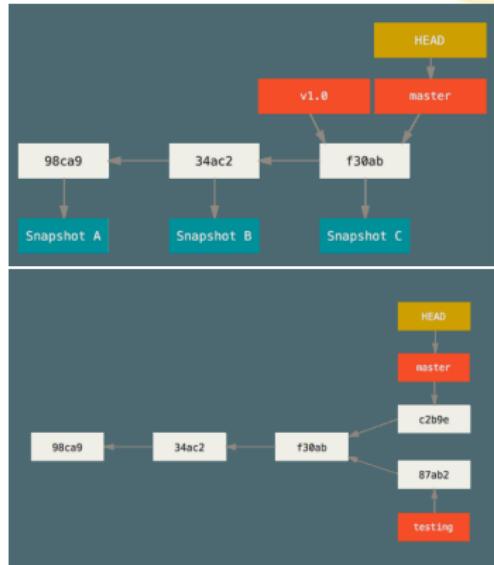


- **Git branching is lightweight**
    - Instantaneous
    - Branch is a pointer to a commit
    - Git stores data as snapshots, not file differences
  - **Git workflows branch and merge often**
    - Multiple times a day
    - Surprising for users of distributed VCS
      - E.g., branch before lunch
    - Branches are cheap
      - Use them to isolate and organize work



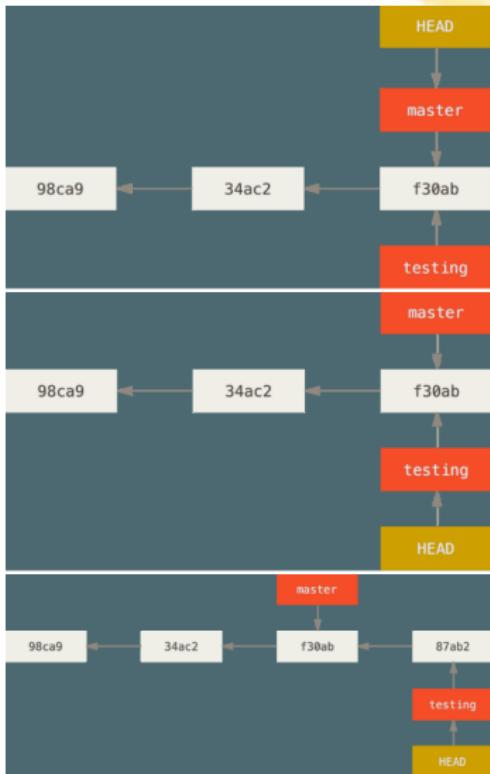
# Git Branching

- 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



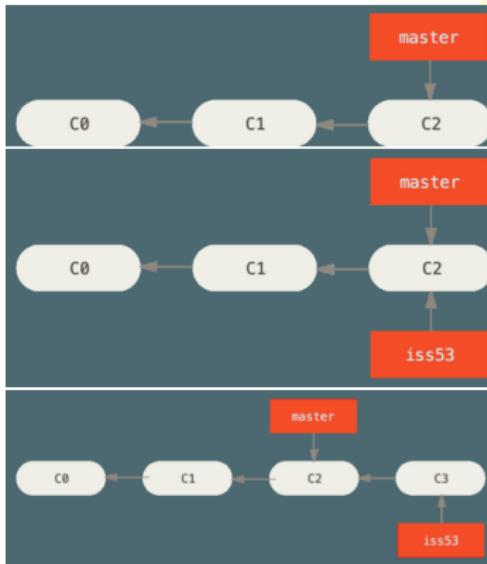
# Git Checkout

- 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



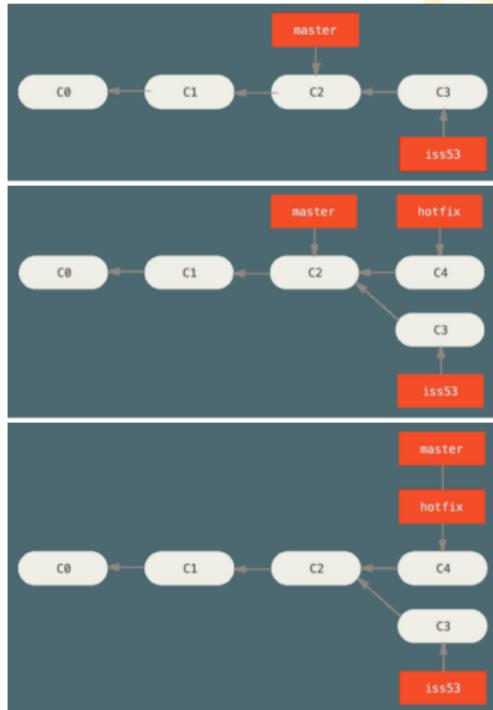
# Git Branching and Merging

- 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`



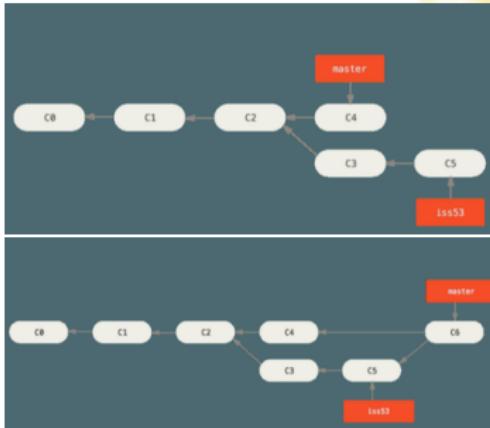
# Git Branching and Merging

- 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



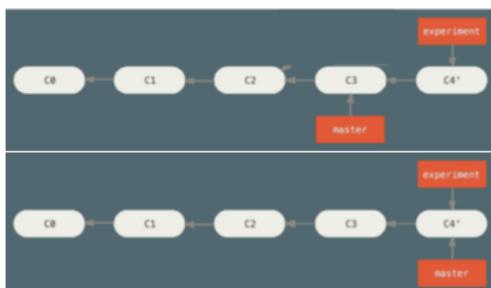
# Git Branching and Merging

- 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

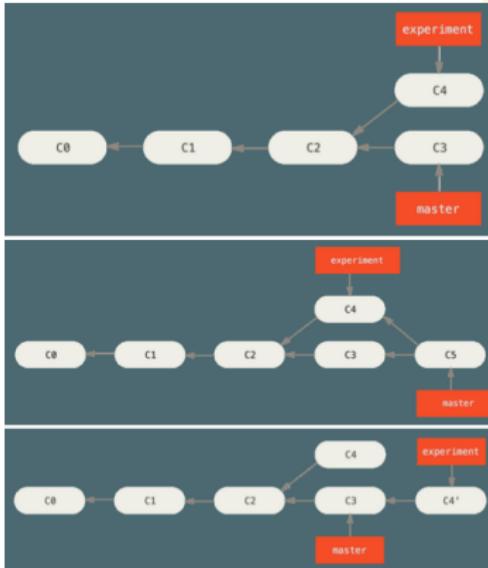
- In Git there are **two ways of merging divergent history**
  - E.g., master and experiment have a common ancestor C2

## • 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*”

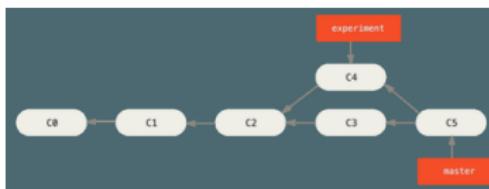


# Rebase vs Merge: Philosophical Considerations

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

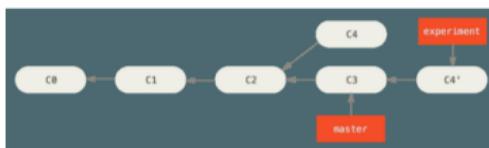
## 1. History is the record of what actually happened

- "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

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- 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 definitely `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

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- **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`

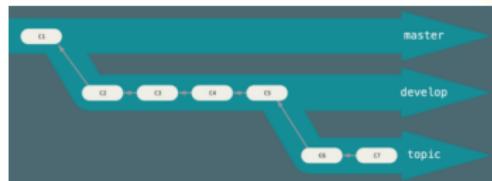
- To work on it

```
> git checkout -b serverfix origin/serverfix
```

# Git Workflows

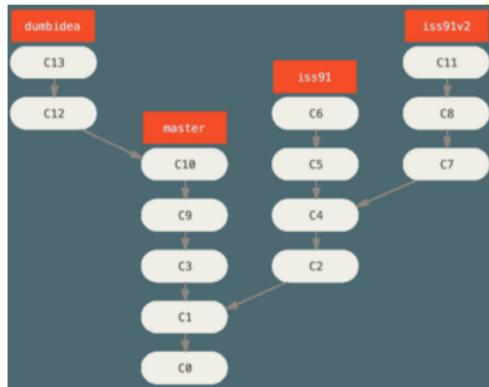
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- **Git workflows** = ways of working and collaborating using Git
- **Long-running branches** = branches at different level of stabilities, that are always open
  - master is always ready to be released
  - develop branch to develop in
  - topic /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



# Git Workflows

- **Topic branches** = short-lived branches for a single feature
  - E.g., hotfix, wip-XYZ
  - Easy to review
  - Silo-ed from the rest
  - This is typical of Git since other VCS support for branches is not good enough
  - E.g.,
    - You start iss91, then you cancel some stuff, and go to iss91v2
    - Somebody starts dumbidea branch and merge to master (!)
    - You squash-and-merge your iss91v2



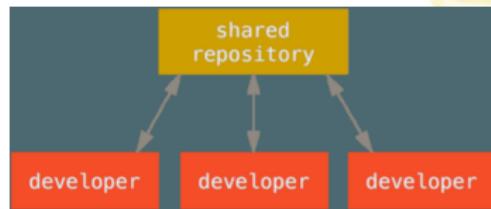
# Centralized Workflow

- **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

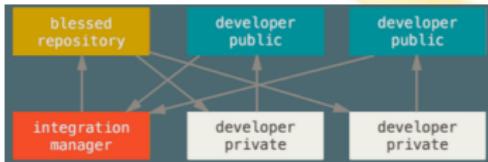
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- Typically devs don't have permissions to update directly branches on a project
  - Read-write permissions for core contributors
  - Read-only for anybody else
- **Solution**
  - "Forking" a repo
  - External contributors
    - Clone the repo and 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

Fork me on GitHub

# 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)

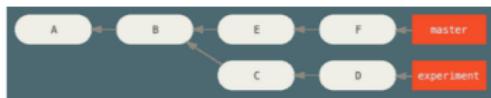
## 3. The maintainer

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

# Git log

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- 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

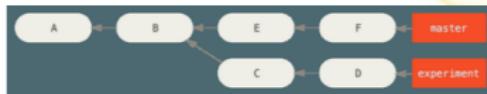


# Dot notation

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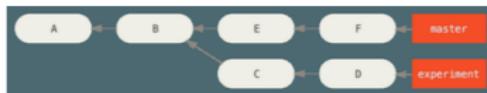
- **Double-dot notation**

- $1..2$  = 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

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- **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

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- **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

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- 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

