Software Engineering

Configuration Management with Git

SoftEng
http://softeng.polito.it

Version 2.0
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Configuration Management

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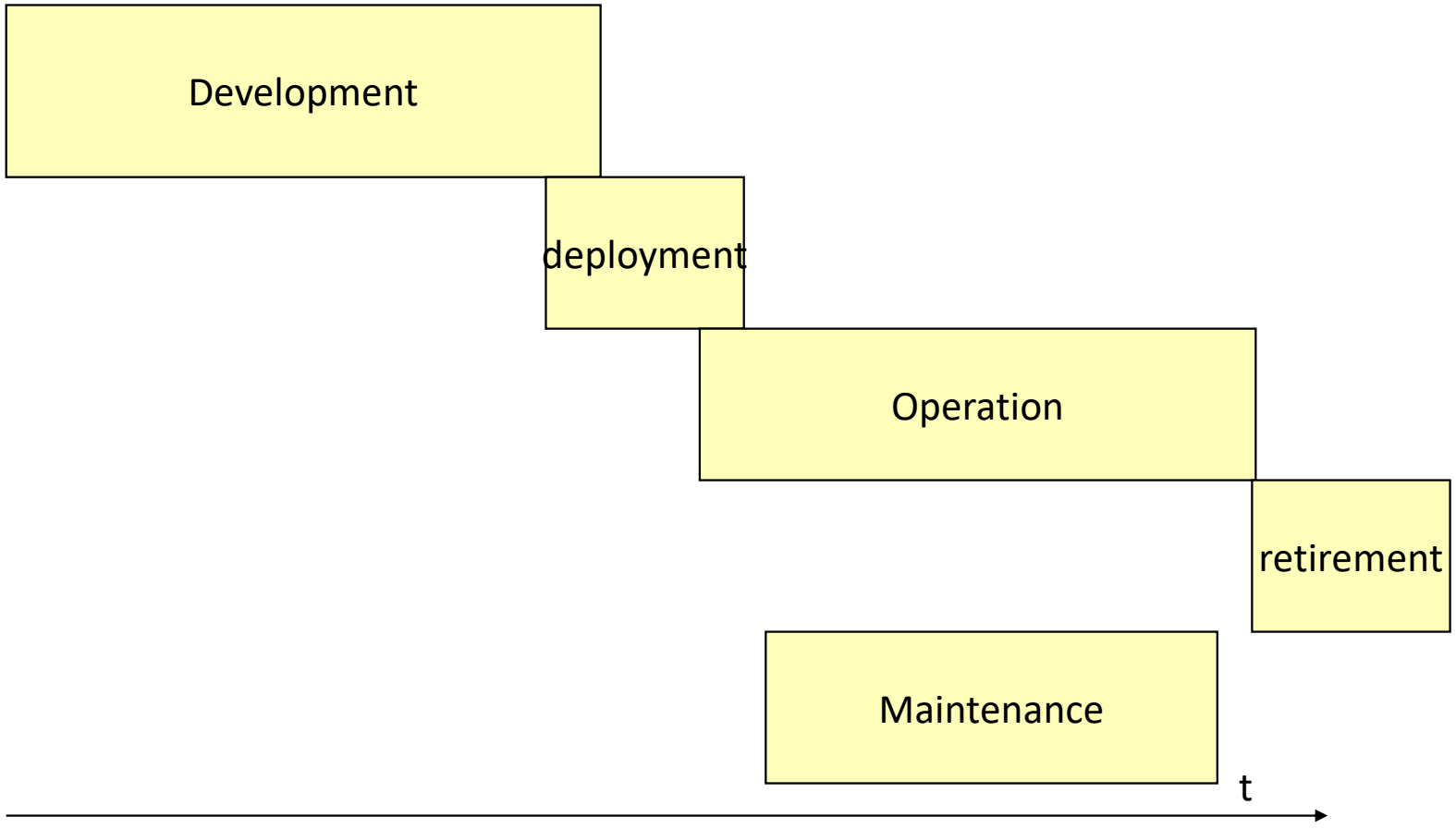
Main Phases



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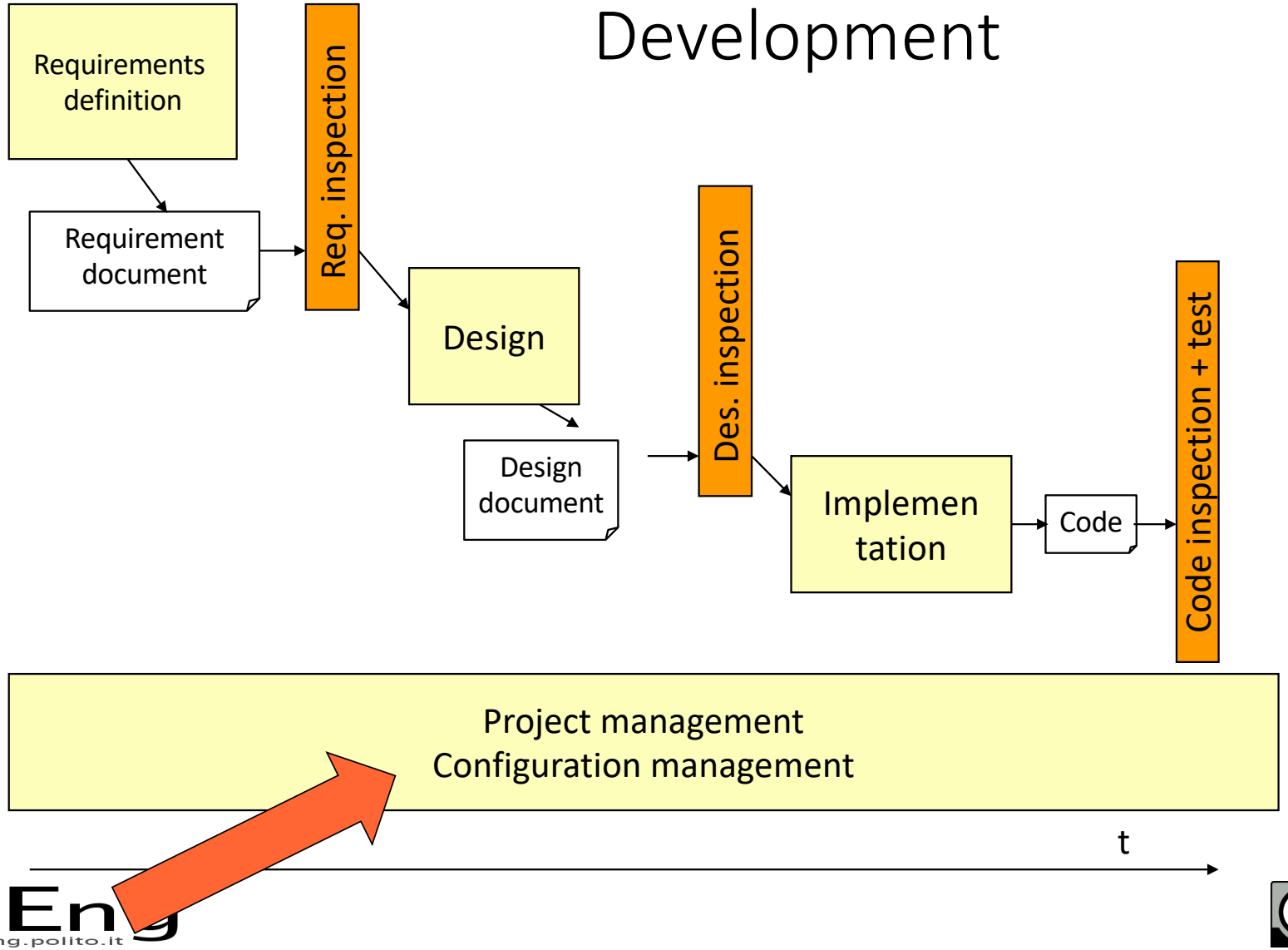
Development



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Motivation

- Many persons need to work on the same documents
  - Remember: software made of requirements, design, code, user manual, data,..

  for a long period of time
  - development, operation and maintenance

- Where are the documents?
- Who can change what, when?
  - Concurrent access and modification of documents
- Who did modify what?
- Which was the last working version?

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Motivation - 2

- Documents have dependencies, in most cases dependencies are not formalized
  - Ex of formal dependency: ‘import’ class or package in java
  - Ex of non formal dependency: requirement document vs design document vs code vs test cases

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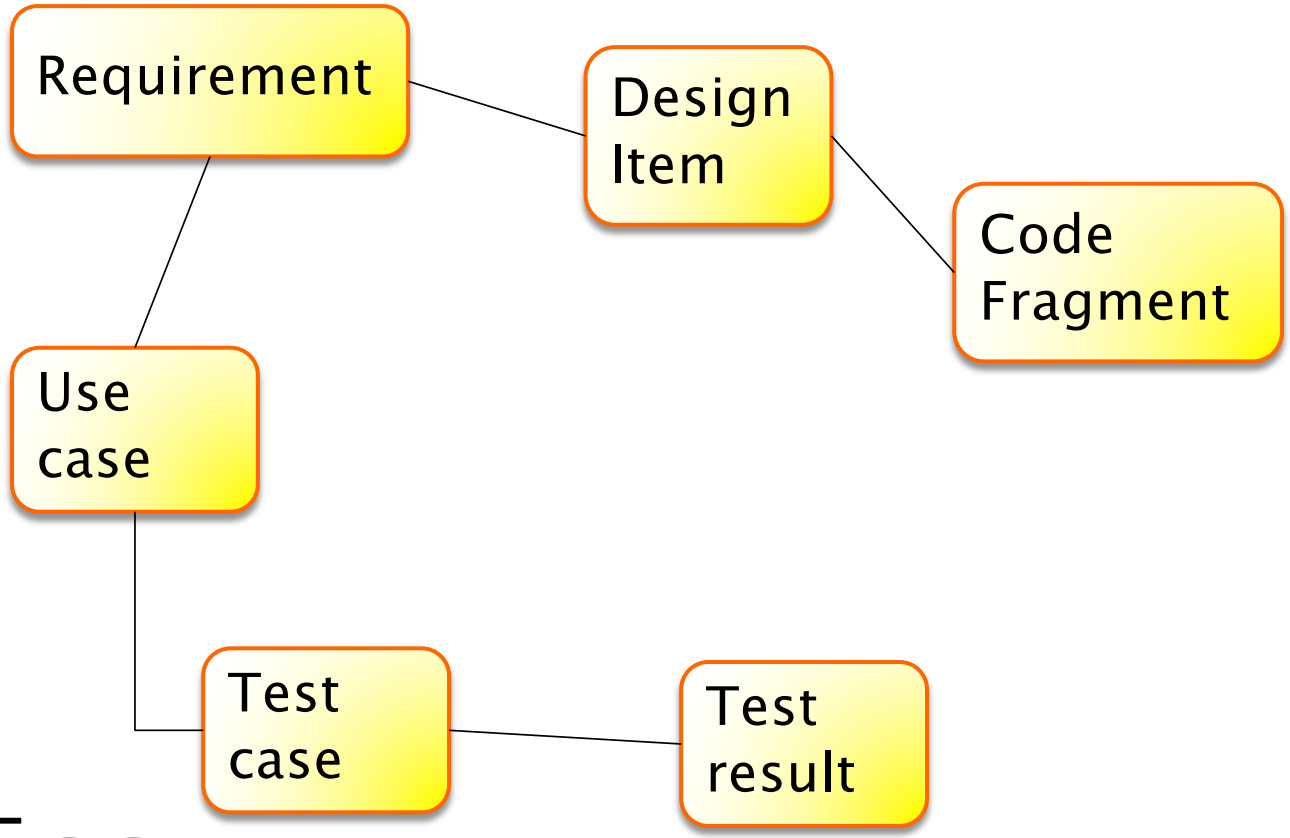
Dependencies



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CM Concepts

- Configuration Item (CI)
  - Unit under configuration management
    - Can be composed of one (ex requirement document) or more files (C++ class in two files)
- Configuration
  - Set of CIs
    - Can be consistent CIs (CIs where all dependencies are correct) or not
- Repository
  - Logical / physical place where CIs are

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CM Concepts

- Versioning
  - Capability of storing / rebuilding all past versions of a CI or configuration
- Change control
  - Capability of granting right of reading / writing a CI to a defined user

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CM concepts

- Check-in Check-out
  - Formal operations made by a user to notify the CMS that a CI is being accessed and modified
  - Checkout: notification that a CIs is being accessed by a certain user
  - Checkin: notification that a CIs is no longer accessed, and has been modified

    (‘check in’ also called ‘commit’)

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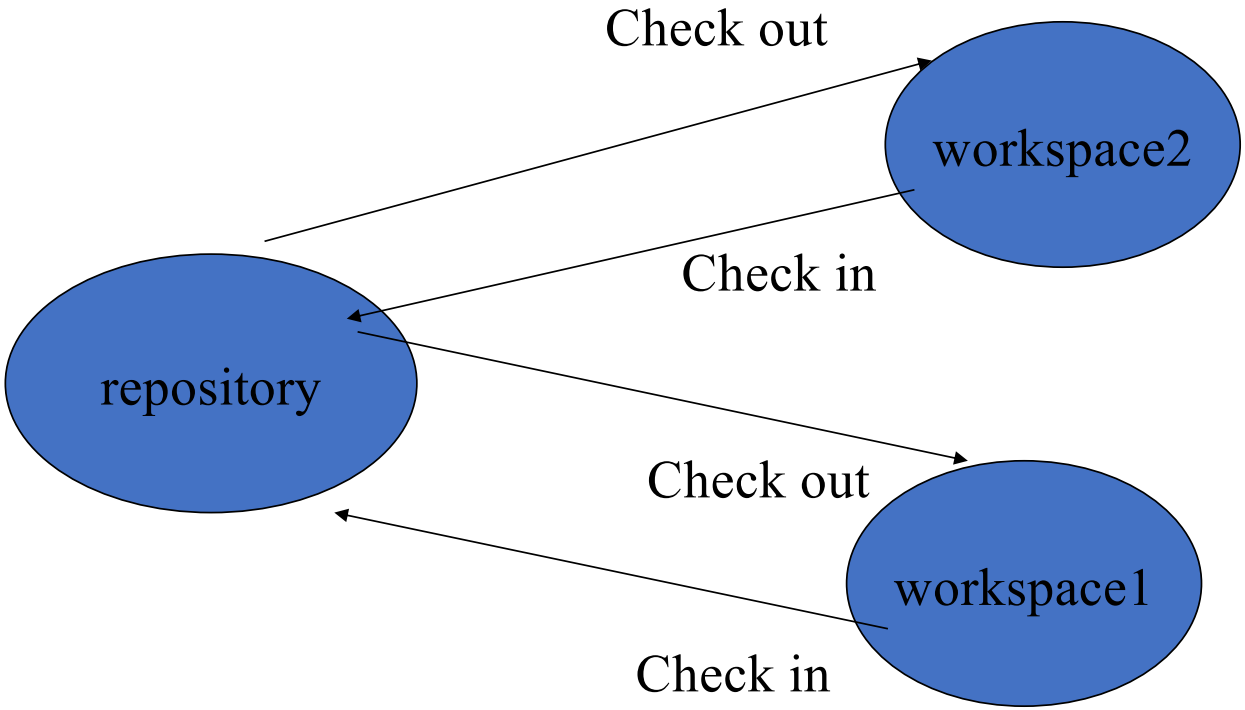
Check out
workspace2
Check in
repository
Check out
workspace1
Check in

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CM Concepts

Change control models

- Lock modify unlock: the first user locks the CIs, no other user can access it until first user unlocks
  - PRO: no concurrent modifications
  - CON: obliges to serialize work, first user often forgets to unlock

- Copy modify merge: many users can checkout in parallel and work on copies
  - PRO: allows parallel work
  - CON: conflicts (== inconsistent modifications of the same CI by different users) are possible, merge operation is delicate, time consuming and possibly error prone

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CM choices

- What becomes a CI
  - Not all documents / files in a project become CI
  - A CI has advantages (versioning access control etc) but at a cost of an overhead (check in check out)
- Lock model or not
- Time distance between commits
  - Every week? day? hour?
- CM manager role
  - Defined or not
- CMS tool

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Configuration Management System (CMS)

- Software application capable of
  - Storing and versioning CIs
  - Storing and versioning configurations
  - Change control

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CMS Functionalities

- Revert CI back to a previous version
- Revert configuration back to a previous version
- Compare changes over time
- Control access (who can read / write what Cis)
- Track who modified what when

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- Where are the documents?
  - → repository, CIs, configurations
- Who can change what, when?
  - → change control
- Who did modify what?
  - → tracking
- Which was the last working version?
  - → configurations, versioning

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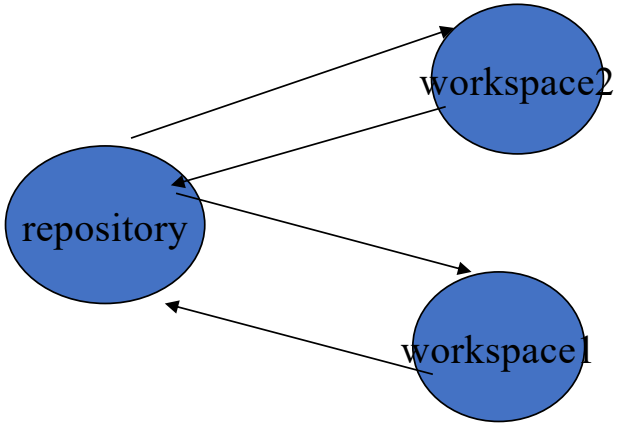
CMS Taxonomy



- Local CMS
  - Only one machine, repository and workspace on the same machine
- Centralized CMS
  - Server contains repository (all CIs all versions), clients contain copy
- Distributed CMS
  - Server contains repository, each client mirrors the repository locally

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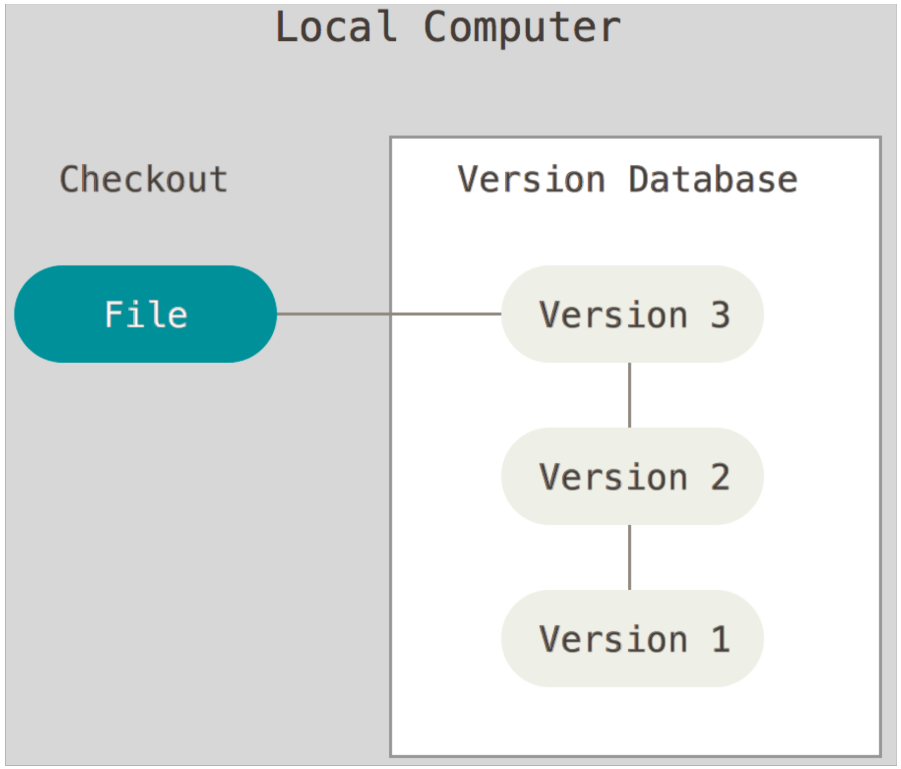
Local CMS



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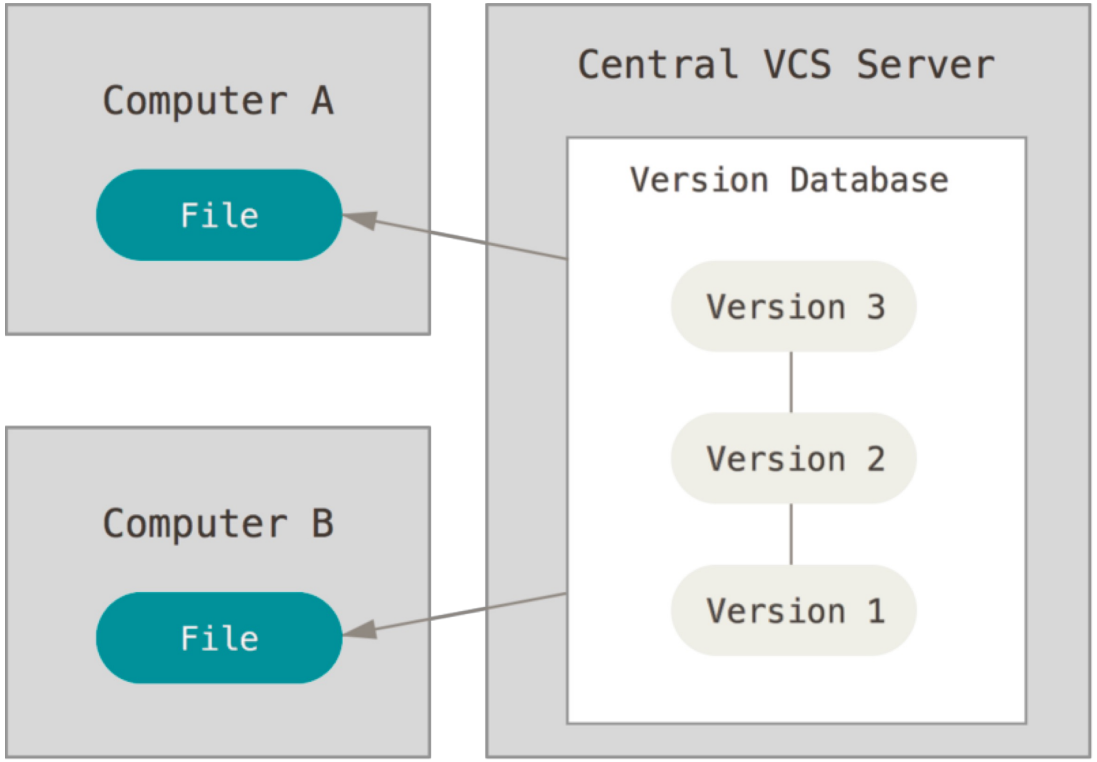
Centralized CMS



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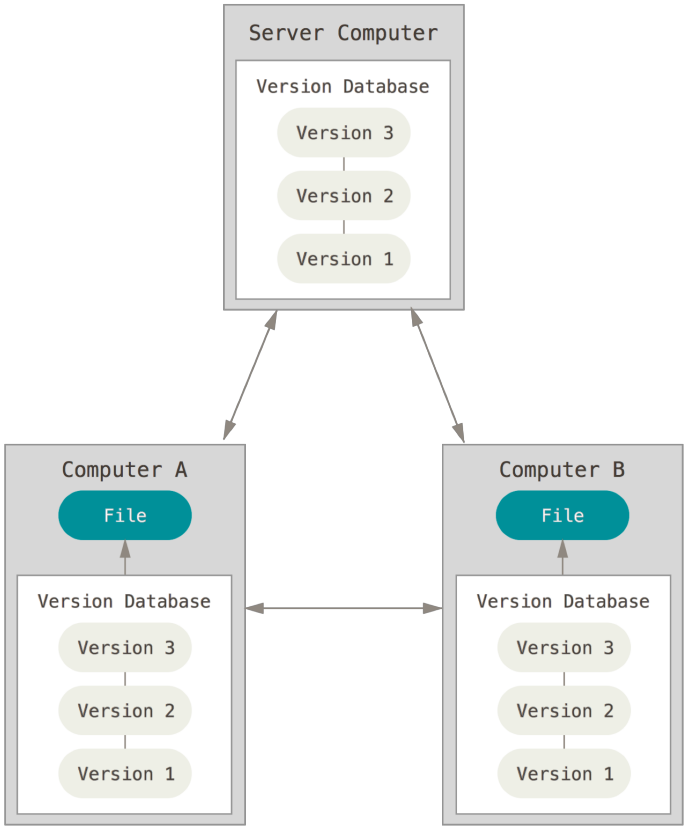
Distributed CMS



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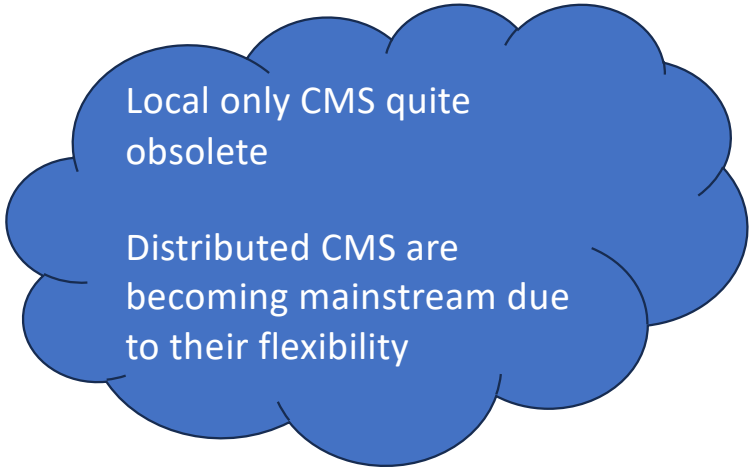
Examples

- Local CMS
  - RCS
- Centralized CMS
  - CVS
  - Subversion
  - Perforce
- Distributed CMS
  - Git
  - Mercurial
  - Bazaar or Darcs



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Storage Models

- Deltas
  - For a CI the root version is stored, for next versions only the differences are stored

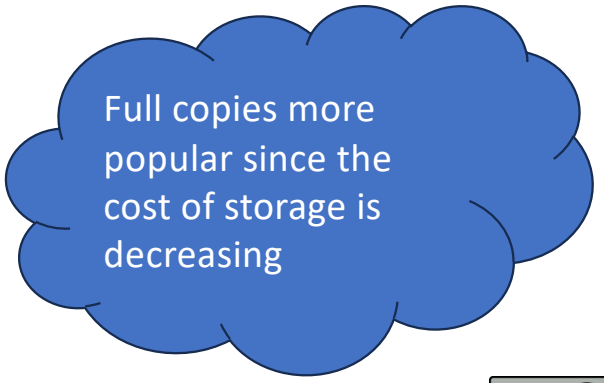
  PRO. Less space is used

  CON. Reconstructing a version can take time

- Full copies
  - For a CI a full copy of each version is stored

  PRO. More space is used

  CON. Each version available in zero time



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Configuration management models

- Differences (ex svn)
  - A commit by a user changes the version of a CI (only)

- Snapshot (ex git)
  - A commit by a user defines a new snapshot, including all CIs
  - A snapshot is made of all CIs in the project
  - If a CI did not change version, a link to the previous one is used

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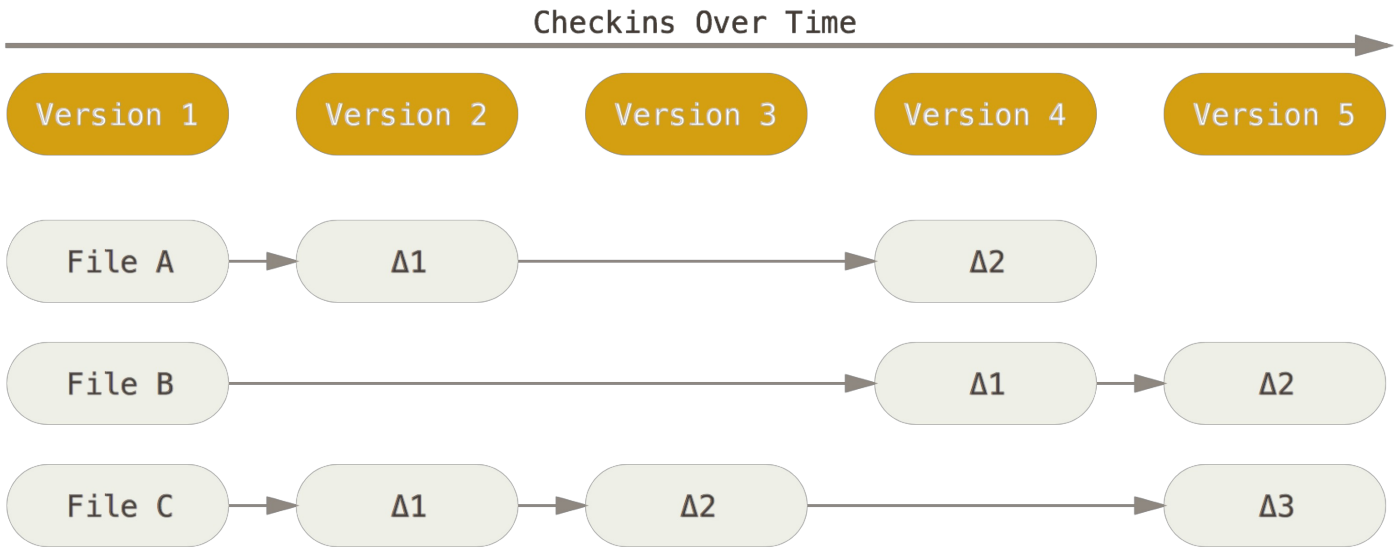
Differences



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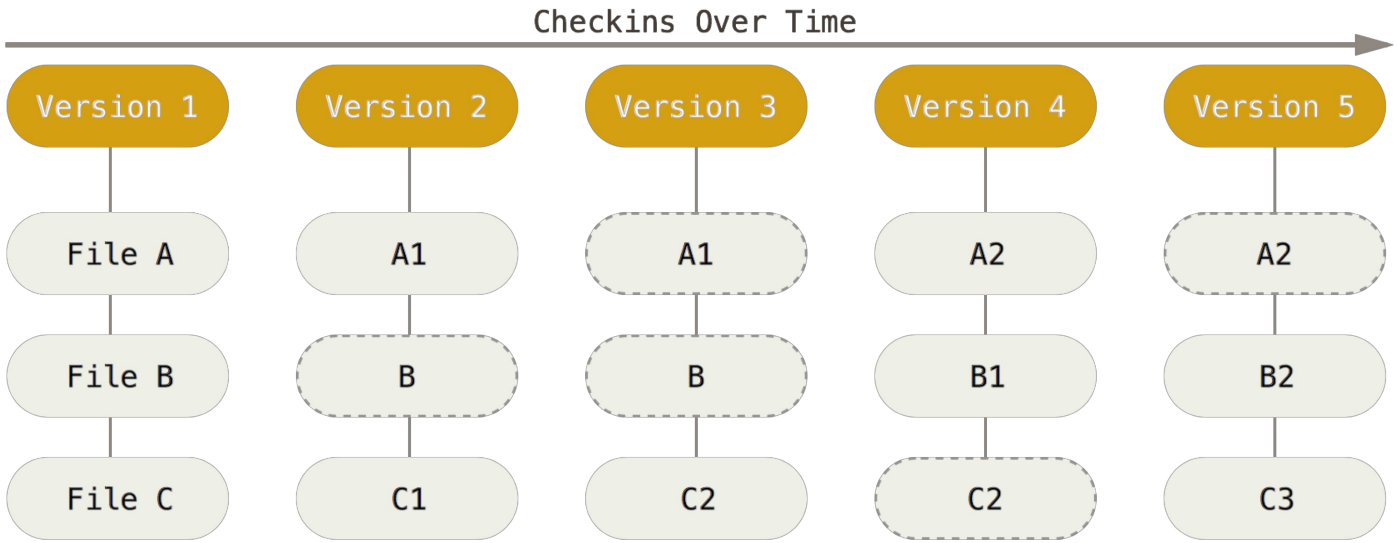
Snapshots



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Introduction to Git

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Git

- Started by Linus Torvalds in 2005 to support Linux development
- Radically different from previous CMSs
- Focus on
  - Speed
  - Support for large projects, with thousand of branches
  - Support for distributed, non linear development model

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Git

- Distributed CMS
- Snapshots as configuration model
  - All files together, not one by one
- Local operations
  - No information is needed from other computer(s) (server or else) → speed
- Integrity
  - Everything is check-summed before it is stored and is referred to by that checksum → any change is recognized, no untracked change of any file or directory
- Additive
  - Information is added, never deleted → No worry about messing up things

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GitHub

- Online code hosting service built on top of git
- Mainly used by OSS projects
- Commercial use is growing
  - Used by

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GitLab

- Another Online code hosting service built on top of git

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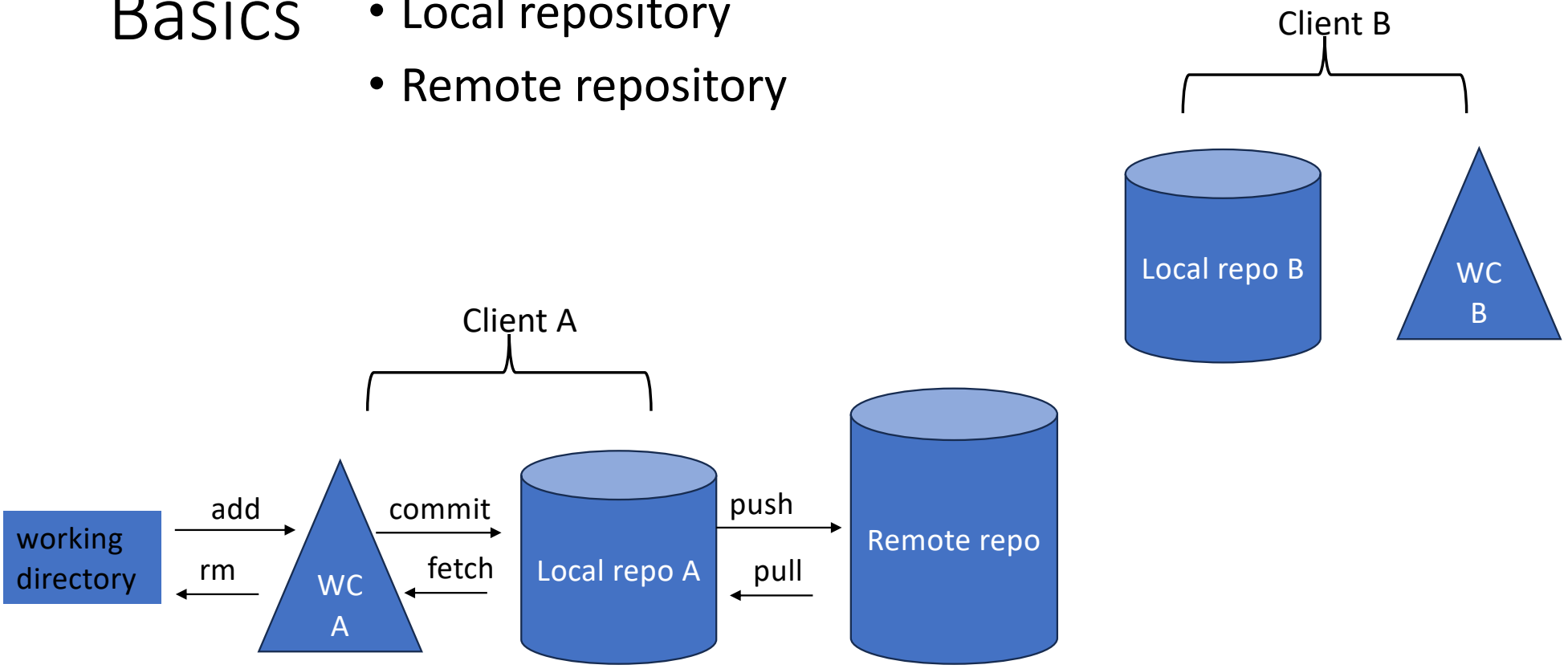
Basics

- Working copy (WC)
- Local repository
- Remote repository



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Client side

- Folder and file system, or working directory or working tree
  - Files and folders
- Working copy (WC), or index, or staging area
  - Files and folders to be committed, but not yet versioned
    - Add: enters a file from file system into working copy
    - Rm: removes file from working copy
- Local repository
  - Files and folders, versioned
    - Commit: enters all files (snapshot) from WC to local repository
    - Fetch, rebase: copies snapshot from local repository to WC, merge them

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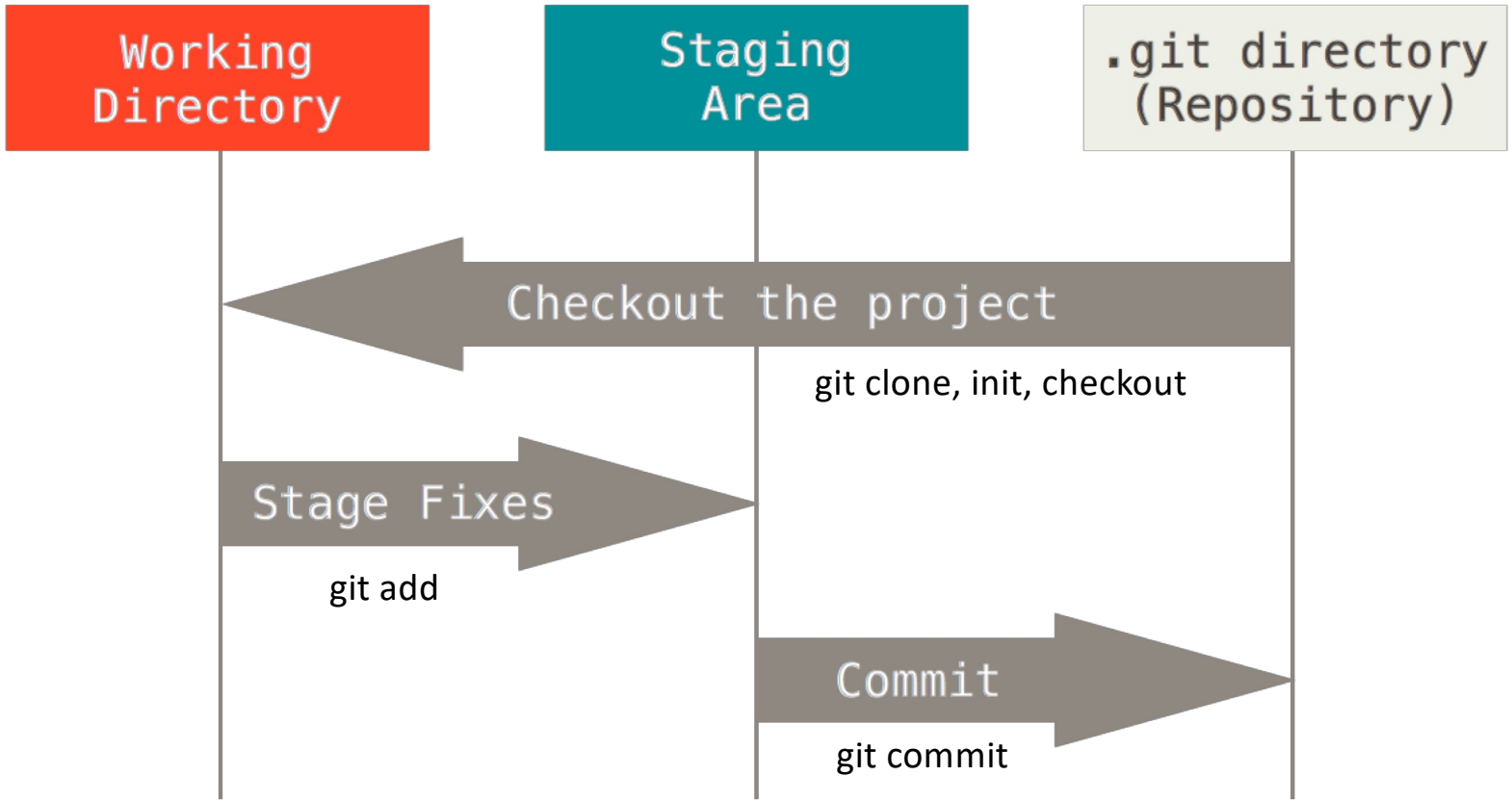
Typical Workflow



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Client side: commit

- Modifies the local repository
- Atomic operation
  - Either succeeds completely, or fails completely
    - If many Cis are committed and one fails, no CI is committed
  - The integrity of the repository is assured
- It is mandatory to provide a log message (or comment) with the commit
  - to explain the changes made
  - the message becomes part of the history of the repository

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Cls states

- Untracked: in the working folder but not tracked (monitored) by git
- Staged (tracked): in WC (or staged area) - add command
  - Modified
  - Unmodified
- Committed: versioned, in the local repository – commit command

(another option is to explicitely exclude files from version control using the .gitignore file so that such files and folders will not be staged)

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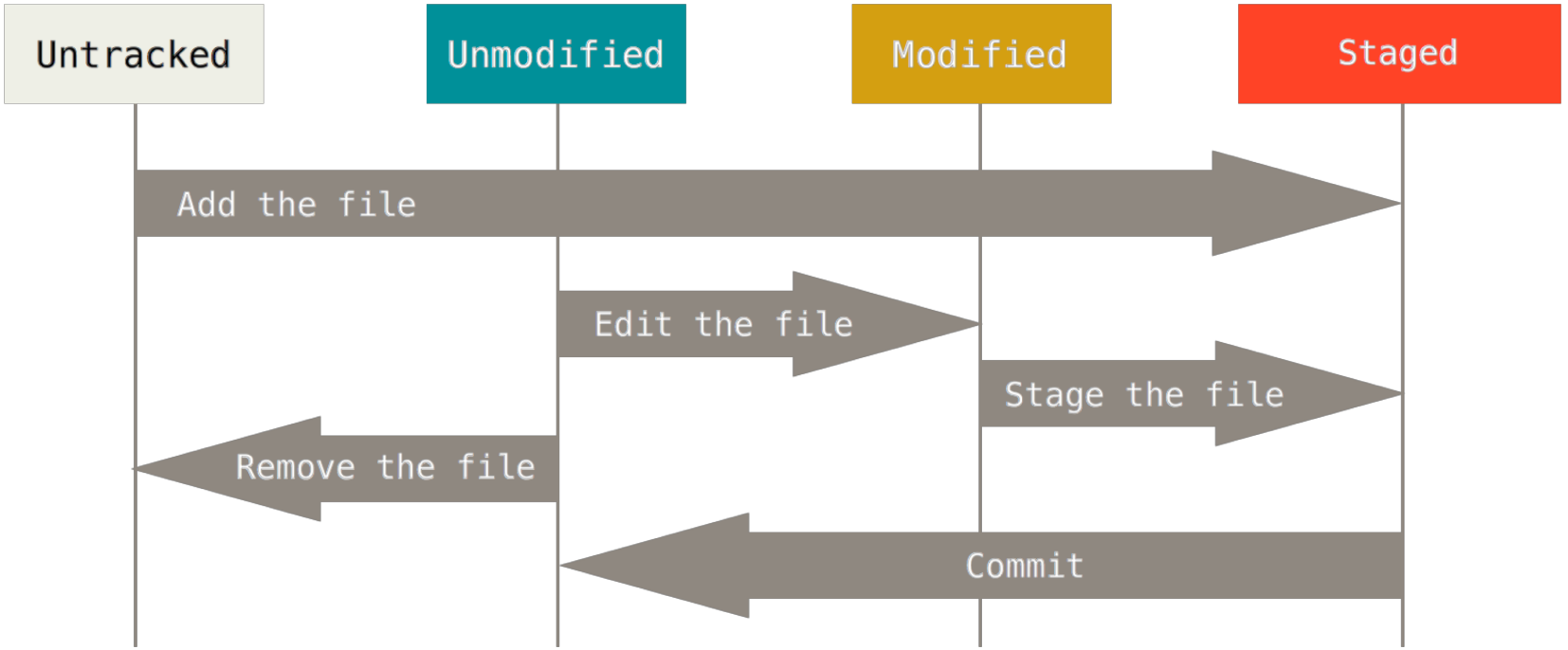
Cls States



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Snapshot

- Set of all files (CIs) in a repository, in a certain version
- Identified by a unique ID (commit hash) computed at commit time

  Ex long version 8406cb12bff17d95a92ee0ac704d2dc037fa97

  short version 8406cb1

  You get id with

  git log

  git rev-parse HEAD

  git rev-parse –short HEAD

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Server side

- Remote repository, shared by all clients
  - Push: uploads a snapshot from local repository to remote repository (sync of repositories)
  - Pull: downloads snapshot from remote repository to local

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Summary of commands

- Set up user
  - Config –global user.name «my_name»
  - Config –global user.email «my_email»
- Set up repo
  - Local
    Init : creates a local repo in current folder
  - Remote
    Remote add: connects local repo with remote repo
- Work on local repo
  - Add, rm, mv
  - Commit
  - Checkout <hashcode>
  - Fetch, Rebase
  - Log, status, diff
- Work on remote repo
  - Push, pull

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Commands - set up

- `git config –global user.name «my_name»`
- `git config –global user.email «my_email»`

  Define name and email of user – to be done once

- `git init`

  Initializes an empty local repository in the current folder

  creates a .git directory inside it
- `git remote add origin http://server.com/project.git`

  Adds a new remote repository

  Origin is the ‘standard’ name for indicating the principal remote

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Commands - understand

- `git status`

  Show which files are in which state

- `git diff`

  Similar to previous, but shows also lines changed

- `git log`

  Show history of what happened in a repository

- `git ls-files`

  Show tracked files

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Commands - modify local repo

- `git add <file>`
  - add <file> to the WC (<file> changes will be tracked from now on)
- `git rm <file>`
  - Remove <file> from the WC (changes will not be tracked anymore) and file system
- `git restore <file>`
  - Restore file in file system
- `git mv <file>`
  - Rename a file
  - Git doesn't explicitly tracks renaming. No metadata is stored in Git that tells it the file was renamed
- `git commit`
  - Commit changes from WC to local repo
- `git commit -a`
  - Commits all tracked files, without need to add them to staging area

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Basic Concepts: fetch, rebase

- Updates the working copy with respect to the repository
  - Fetch gets changes from the repository
  - merge such changes with the ones you have made to your working copy, if necessary

  - checkout

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Commands – work with remote repo

- `git pull`
  - fetch and then merge remote repo on local repo
- `git push`
  - upload local repo on remote repo

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Commands – help

- `git help  <command>`
- `git <command> -help`

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Common scenarios

Start a project from scratch. Create local repo, work on it, sync on remote repo

- Git init
- … work on files file1 file2 filen
- Add file1, file2, filen
- Commit
- Remote add
- push

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Common scenarios

A project has already been created by others, sync locally, work on it, sync remotely

- Git init
- Git add remote
- Pull
- .. Work on files
- Add
- Commit
- Push

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Common scenario

- Modifying a project, build fails, cant understand why. Retrieve previous version that did build
  - Git checkout <commit id>
  - Git checkout –b <new branch> <commit id>

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Branching

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Branching - motivation

- Two modes of development in a project
  - Linear
  - Branching

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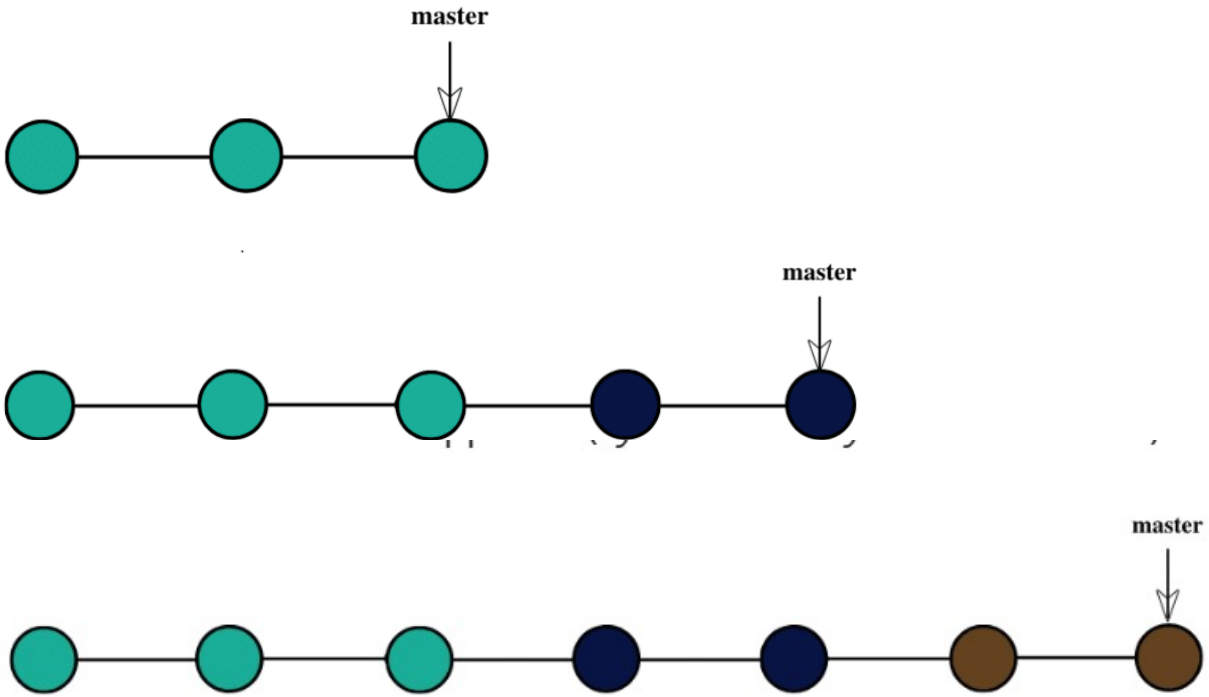
Linear development



- Initial status of project
- Add feature 1 (blue)
- Add feature 2 (brown)

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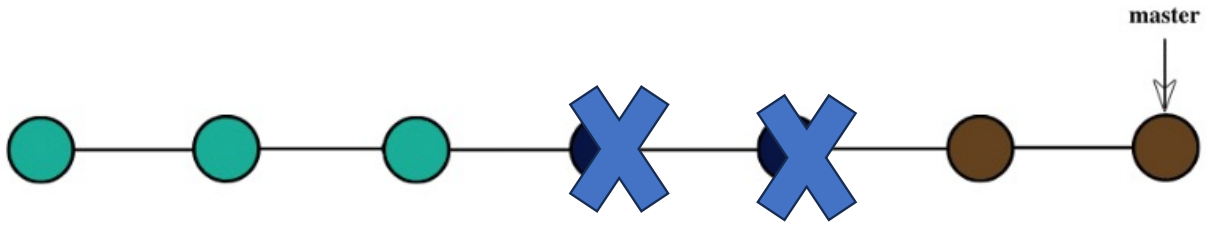
Linear development

- For some reason (ex client rejects feature 1, but wants feature 2) the project needs to delete feature 1 and keep feature 2
- However, changes are intertwined, doing this will be very difficult



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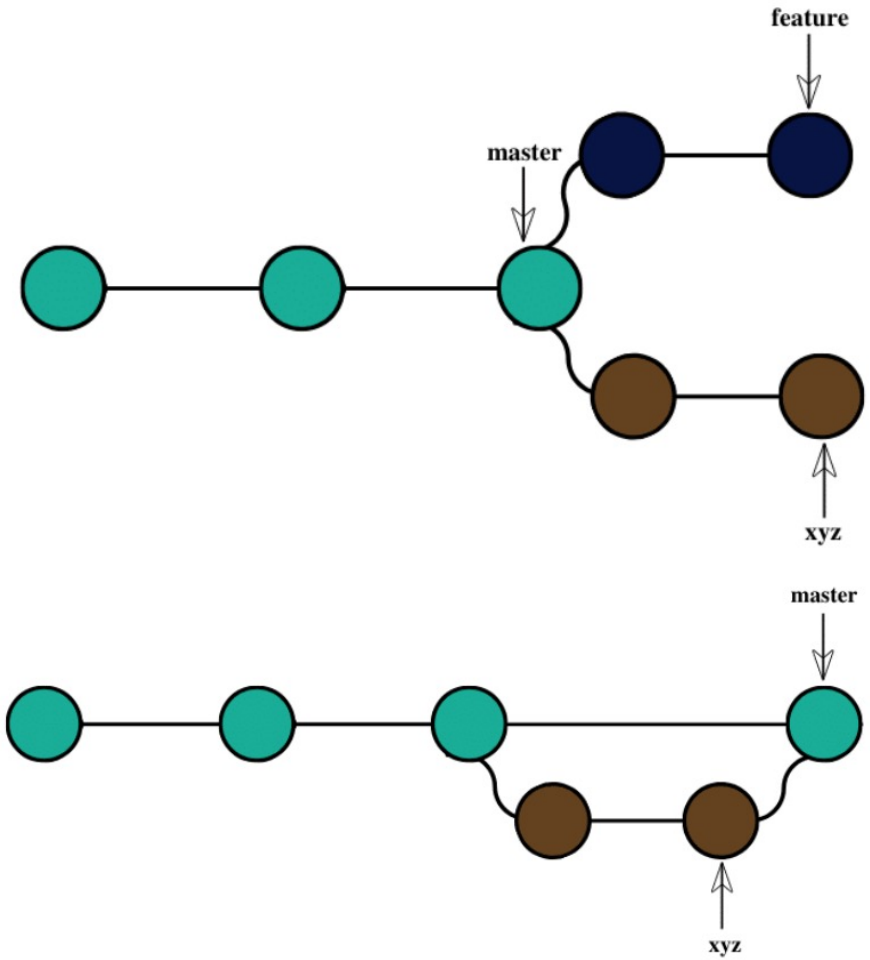
Branching



- One branch per feature, master remains unchanged
- To cancel blue feature just delete its branch, and merge brown branch into master

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Git Branching

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Commands

- Create a new branch
  - git branch <new branch>
  - git checkout -b

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Data Storage in Git

- Git stores a commit object that contains
  - a pointer to the snapshot of the content you staged
  - pointers to the commit or commits that directly came before this commit (its parent or parents)
- Staging the files
  - checksums each one
  - stores that version of the file (blobs)
  - adds that checksum to the staging area

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Example

- Given a directory containing three files, stage them all and commit

- Git repository now contains five objects
  - one blob for the contents of each of the three files
  - one tree that lists the contents of the directory and specifies which file names are stored as which blobs
  - one commit with the pointer to that root tree and all the commit metadata

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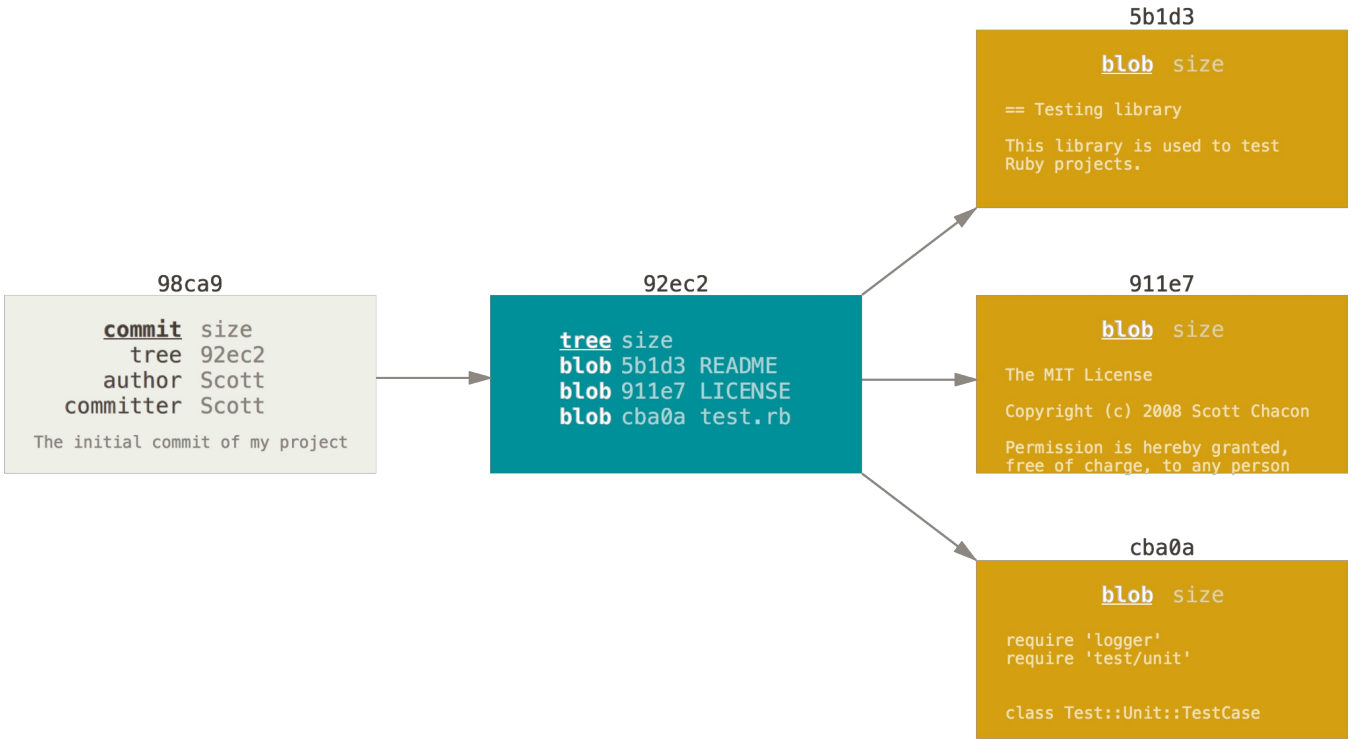
Example



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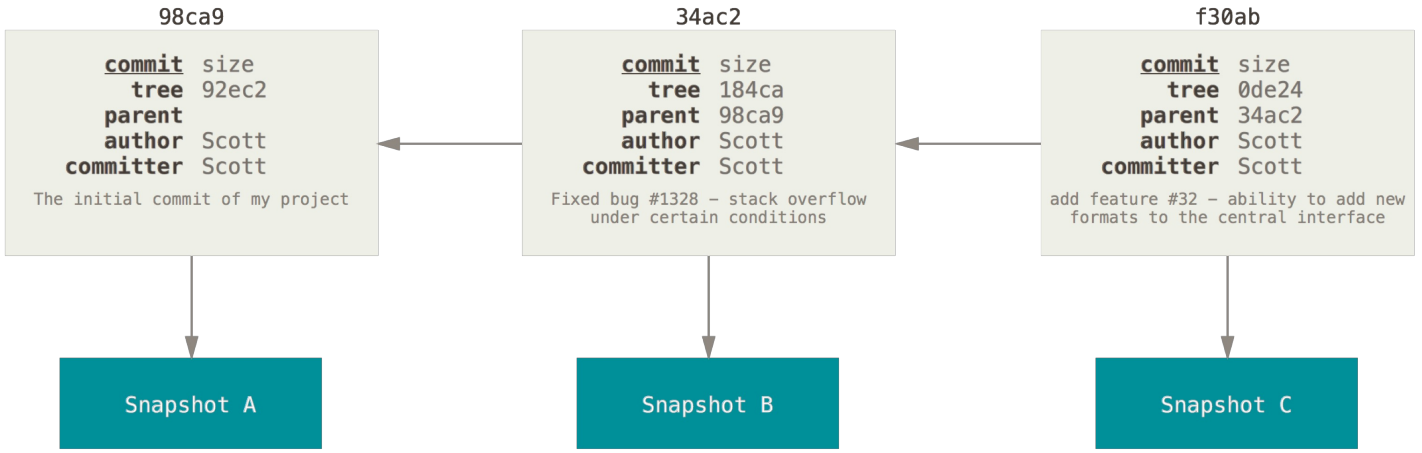
Example

- The next commit stores a pointer to the commit that came immediately before it



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Branches

- A branch in Git is simply a lightweight movable pointer to one of these commits
  - Git branch <name> // creates a branch, ie creates a pointer
- HEAD points to the current branch
  - The default branch name in Git is master
- Every commit, HEAD moves forward automatically
- HEAD can be moved in other ways too
  - Git checkout <name> // HEAD now points to <name>
  - Git checkout –b <new branch> <commit id> // creates branch and moves HEAD

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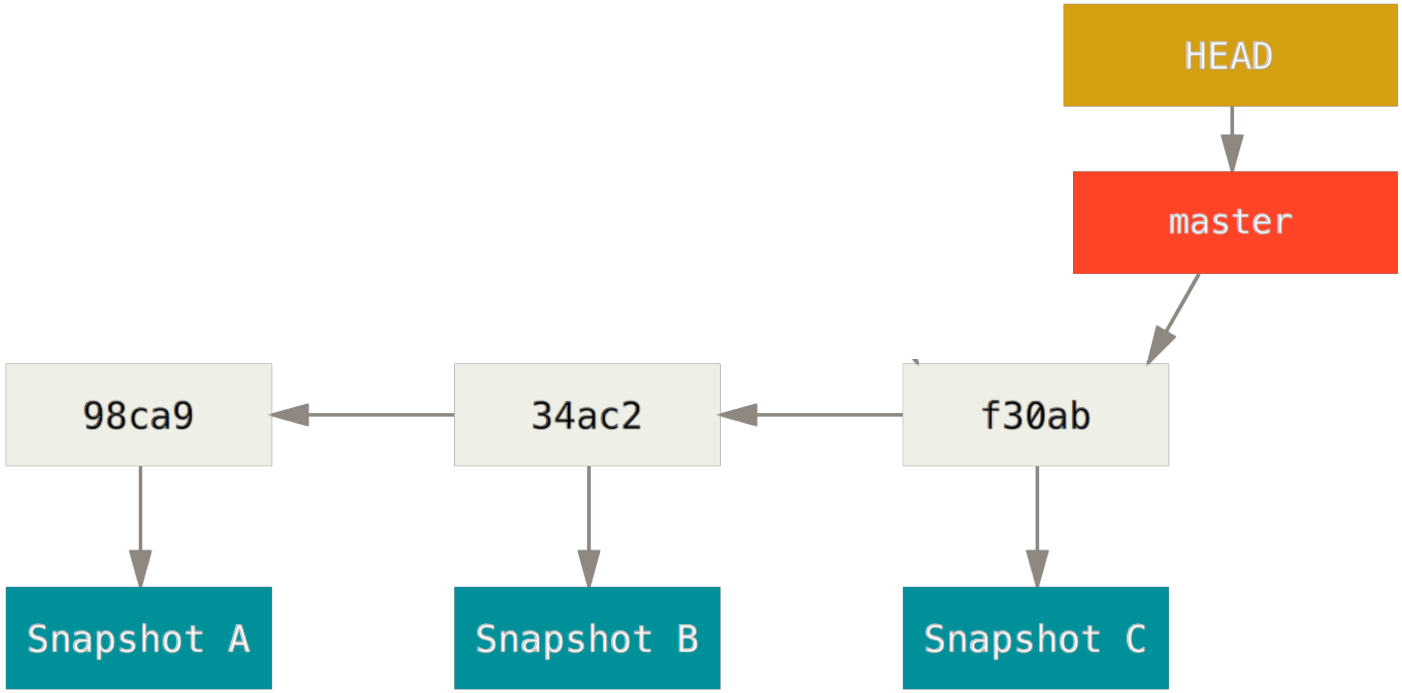
Branches



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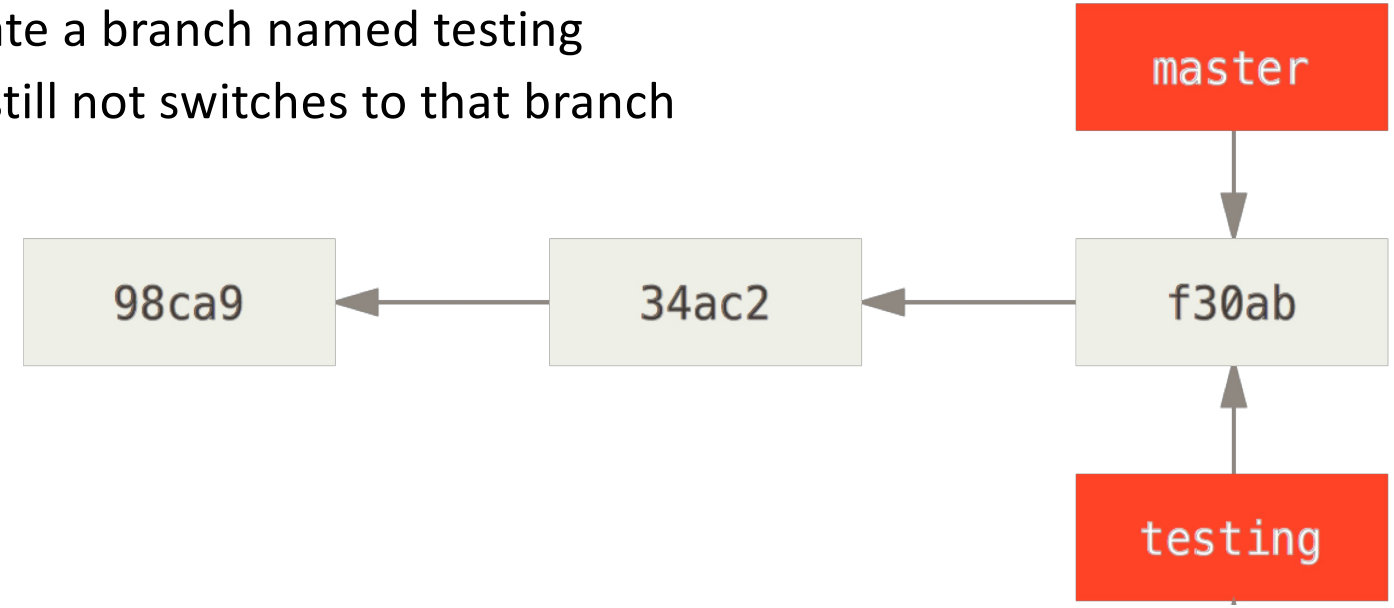
Creating a Branch

- `git branch testing`
  - Create a branch named testing
  - Git still not switches to that branch



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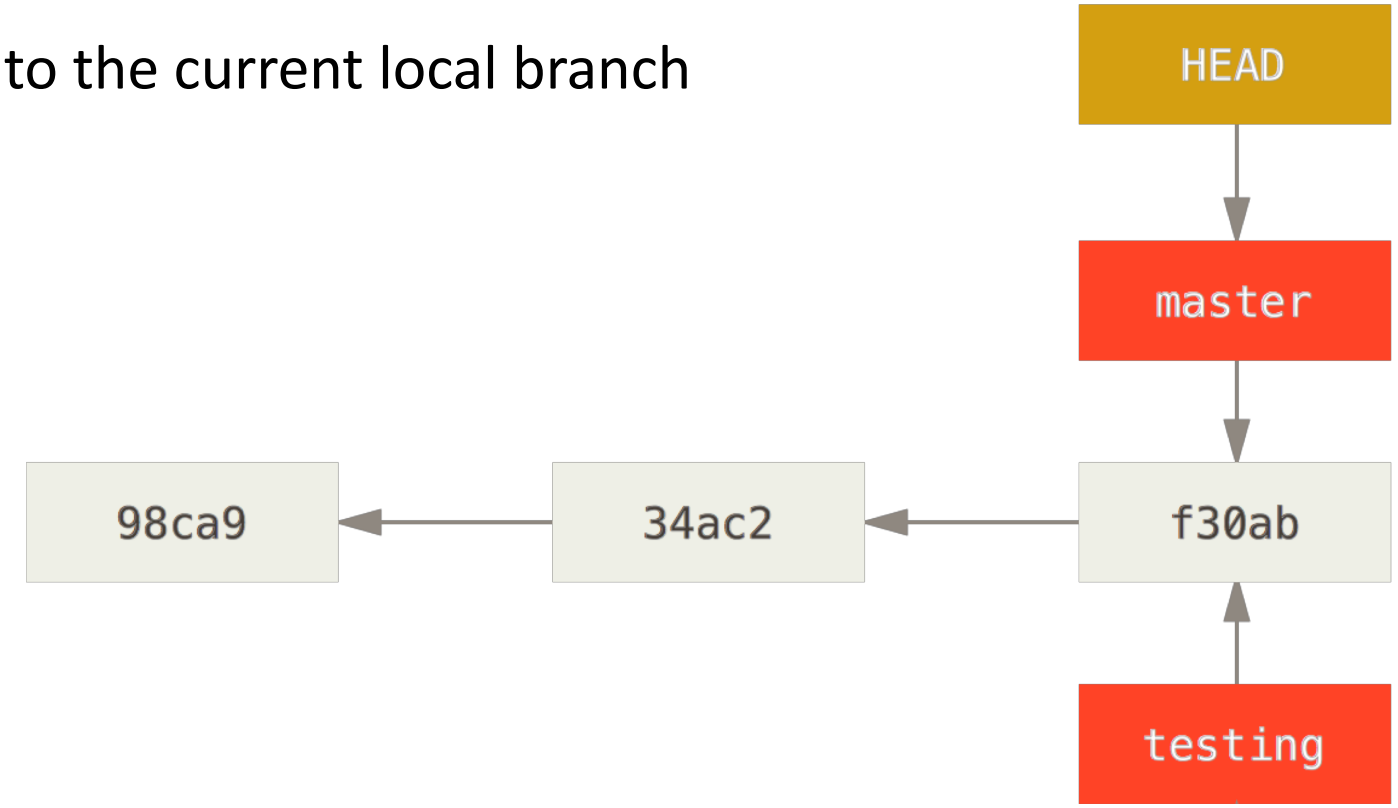
Head Pointer

- Pointer to the current local branch



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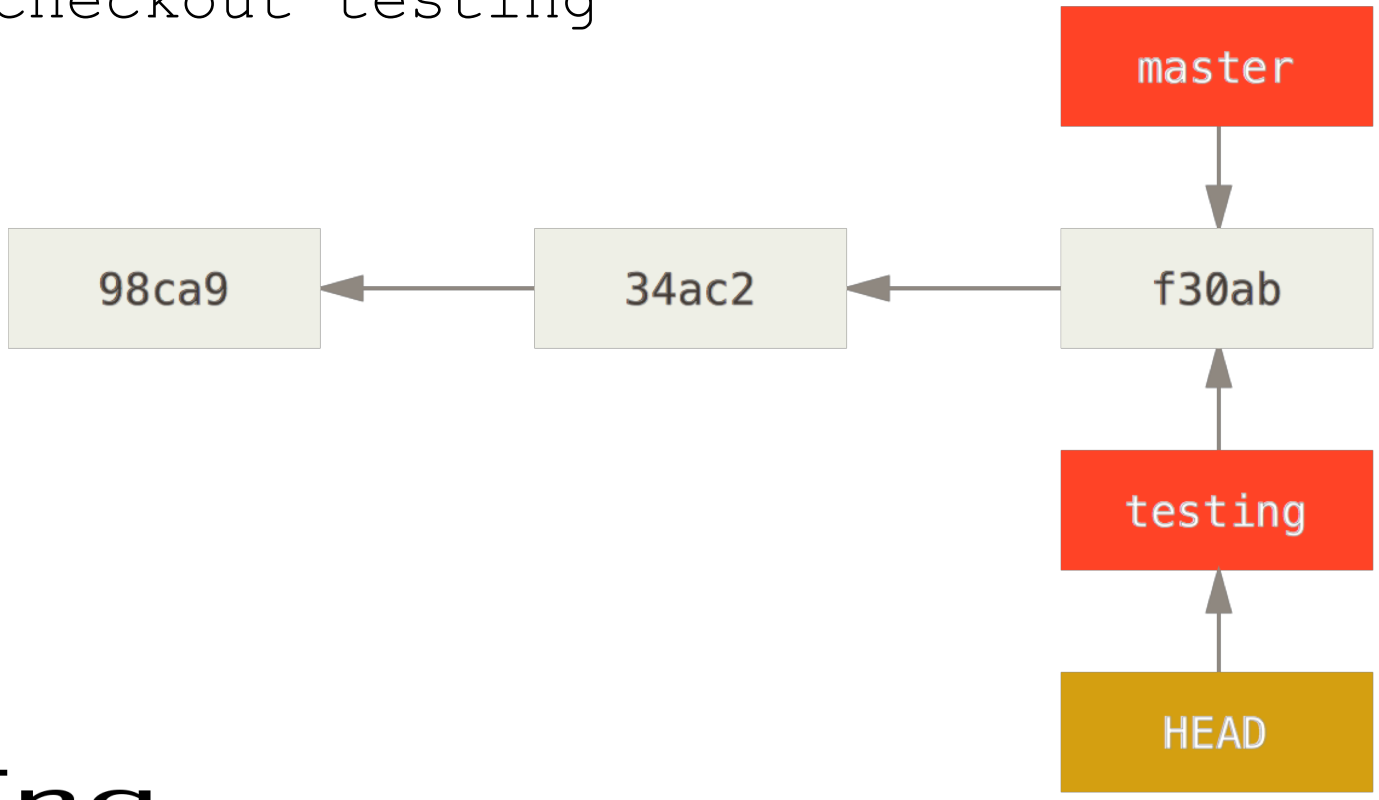
Switching Branches

- `git checkout testing`



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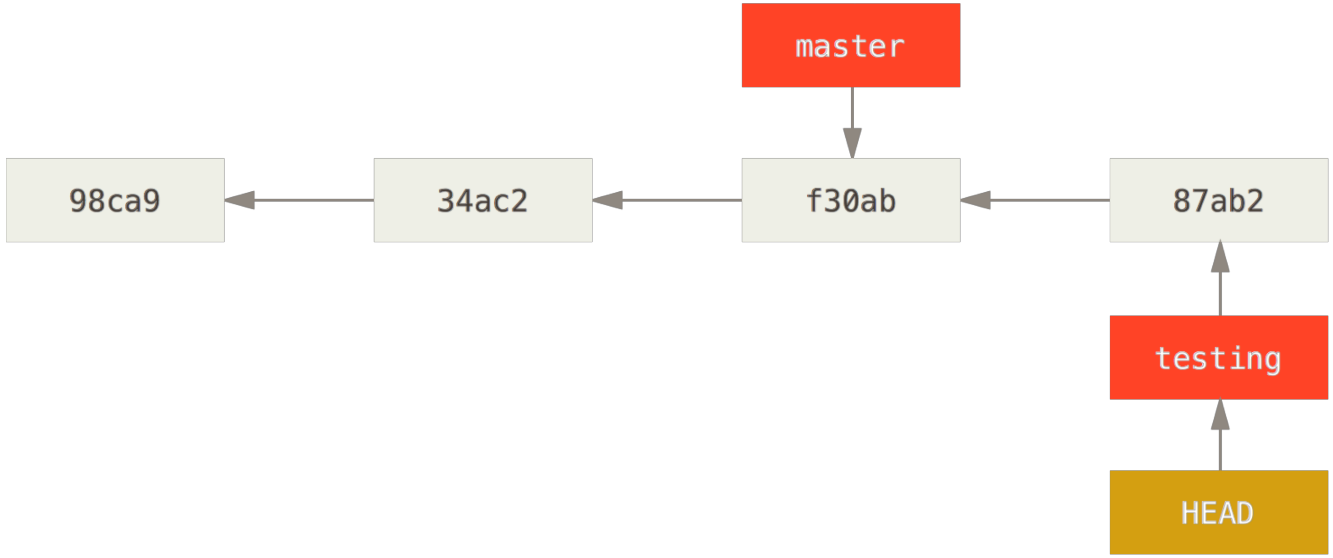
Switching Branches

- After another commit



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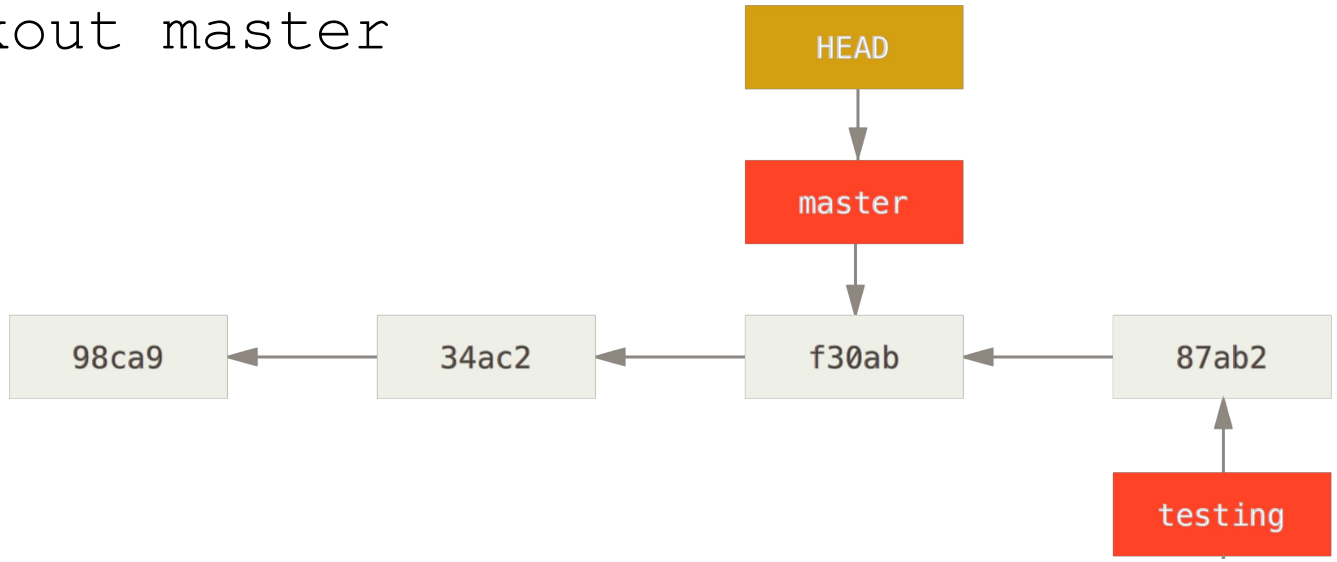
Switching Branches

- `git checkout master`



- Not only moves HEAD, also switches WC (files in .git folder now are the files of snapshot f30ab)
-

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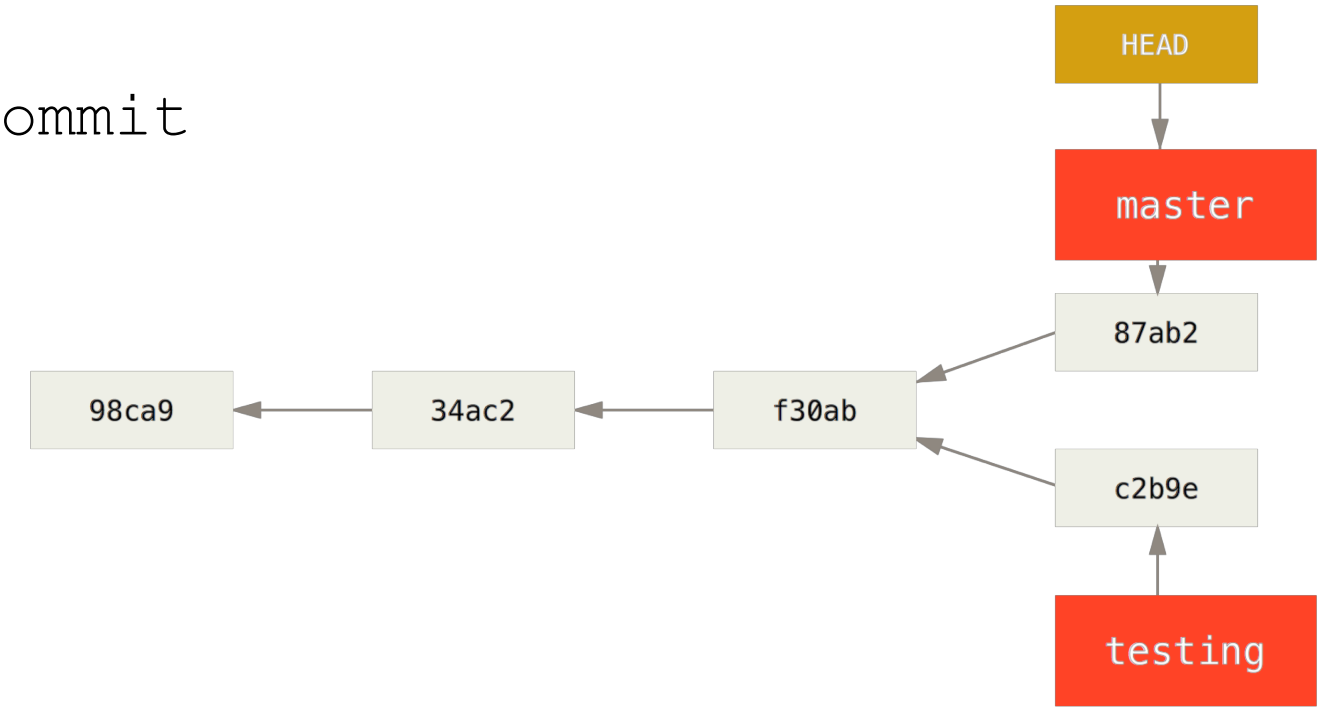
Switching Branches

- `git commit`



- commits from this point on will diverge (‘divergent history’)

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Switching – git log

- Git log
  - Will show only one flow of commits (master)
- Git log testing
  - Will show flow of commits for ‘testing’ branch
- Git log –all
  - Will show all flows

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Merging branches

- Without divergent history
- With divergent history

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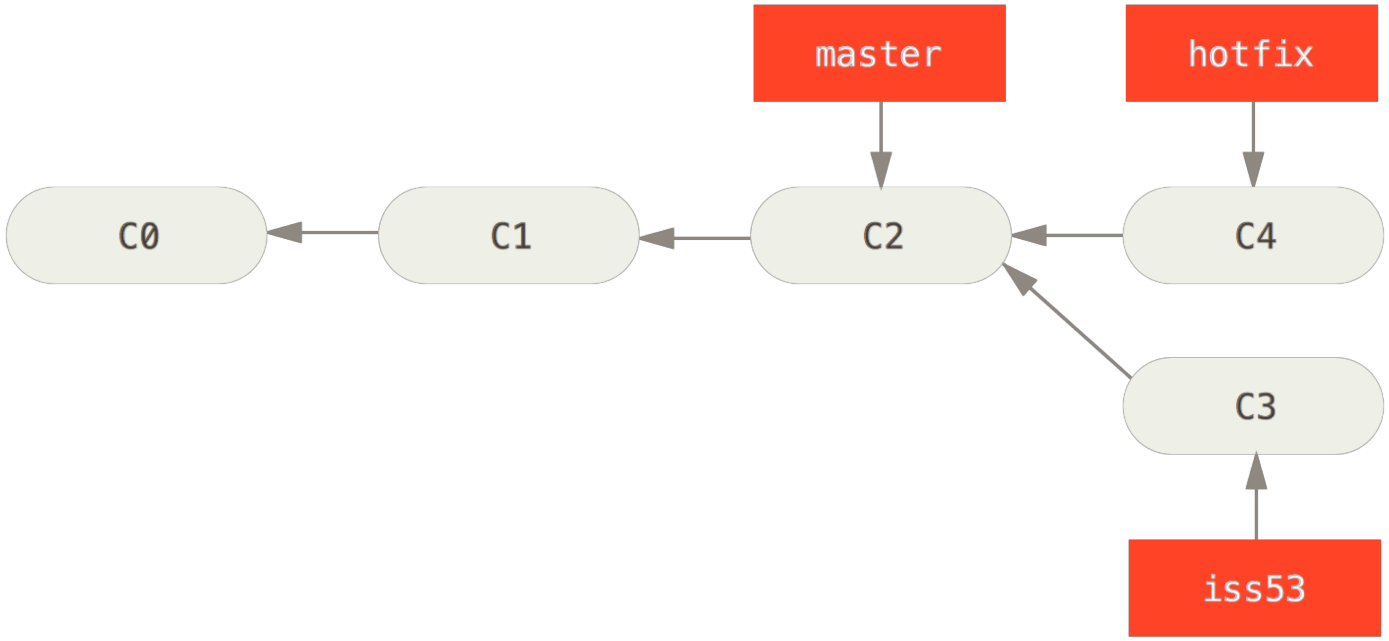
Merging Branches – no divergence

- Initial situation (HEAD → hotfix)



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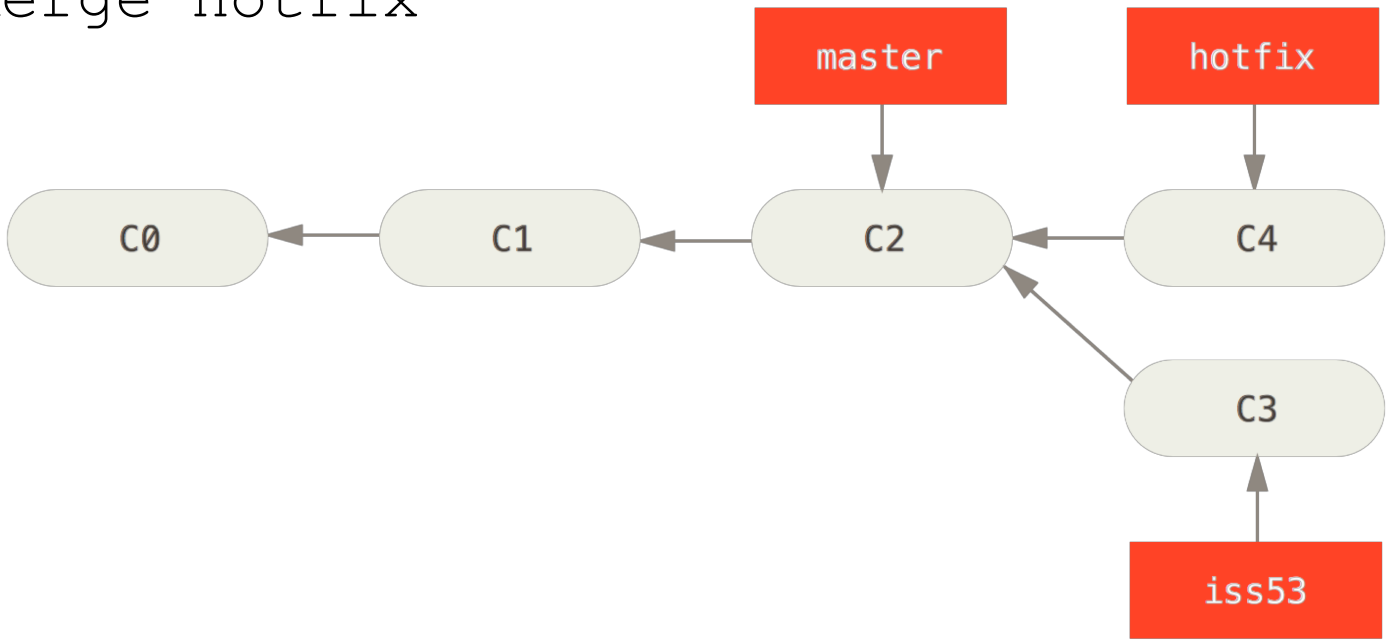
Merging Branches – no divergence

- Merging hotfix with master:
- `git merge hotfix`



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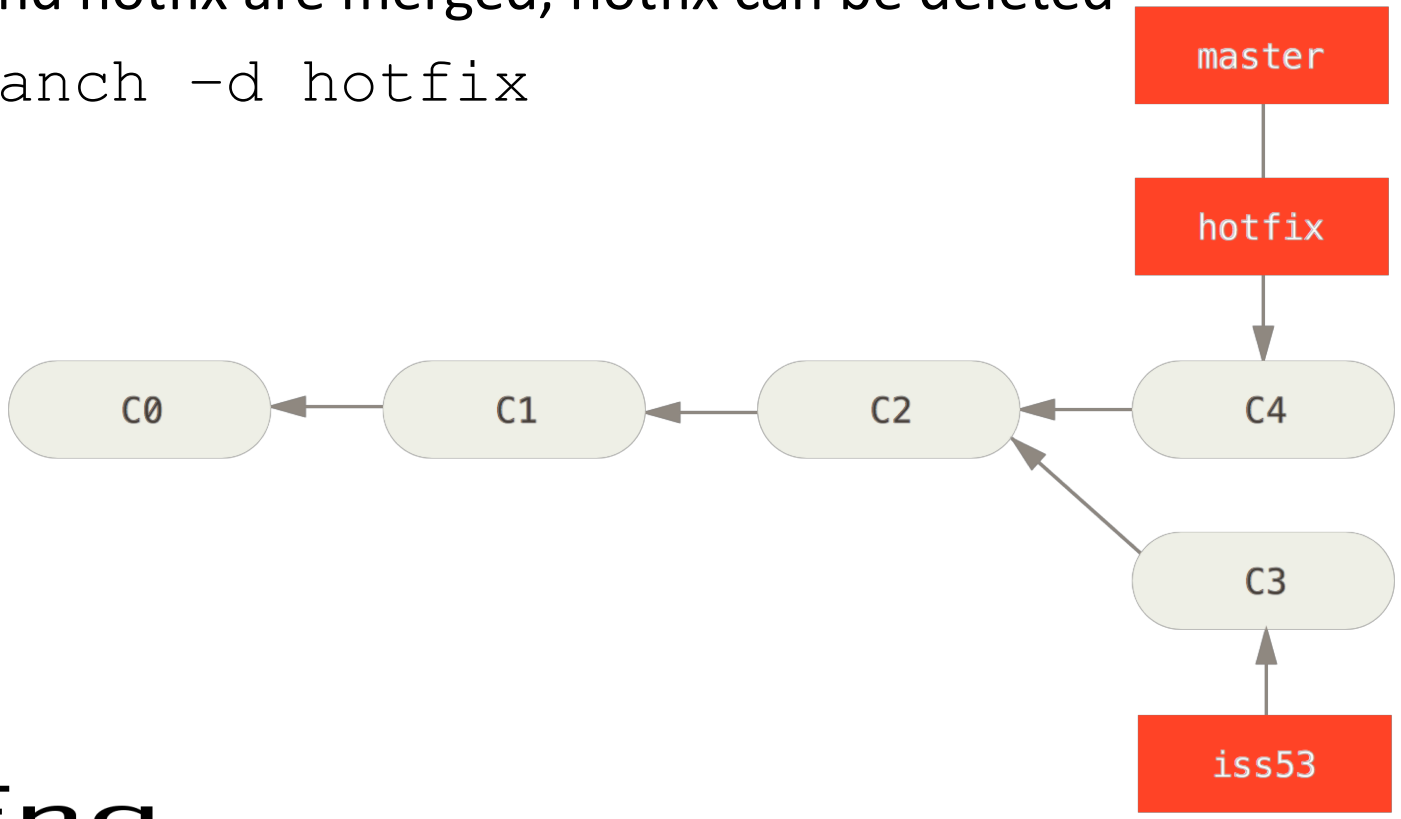
Merging Branches – no divergence

- Master and hotfix are merged, hotfix can be deleted
- `git branch -d hotfix`



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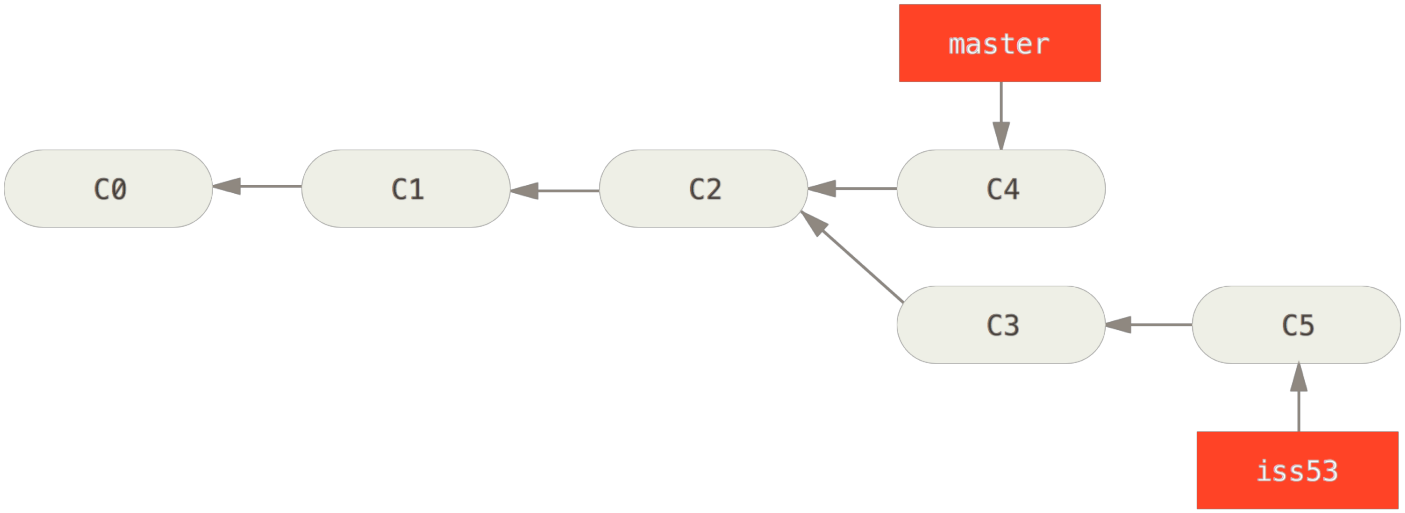
Merging Branches – with divergence

- New commit on iss53



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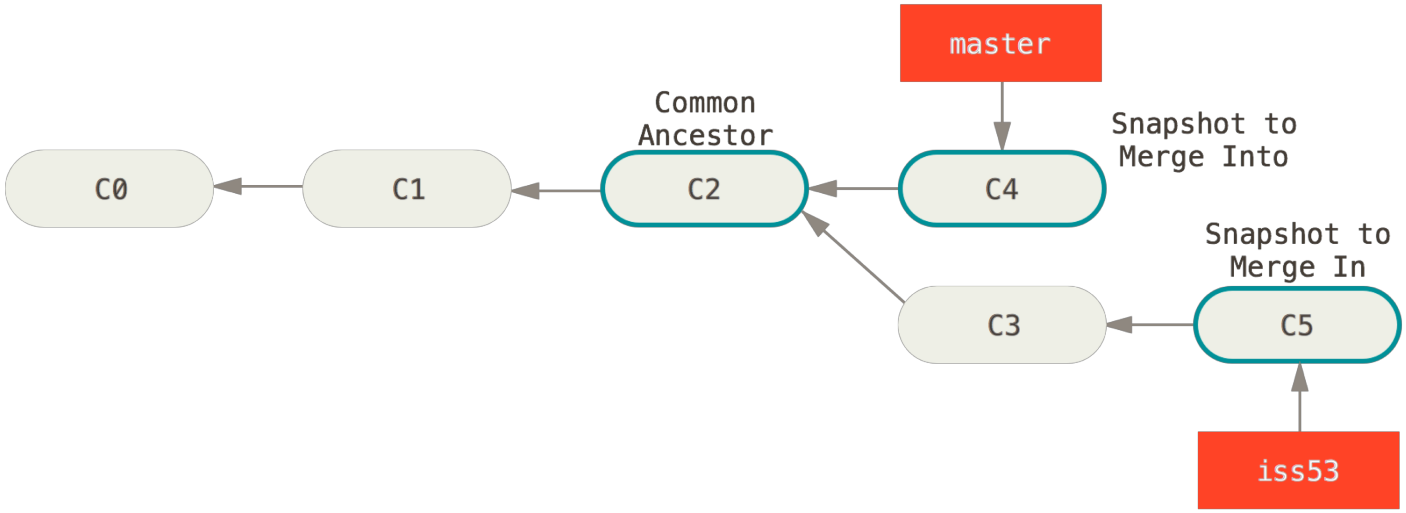
Merging Branches – with divergence

- `git checkout master`
- `git merge iss53`



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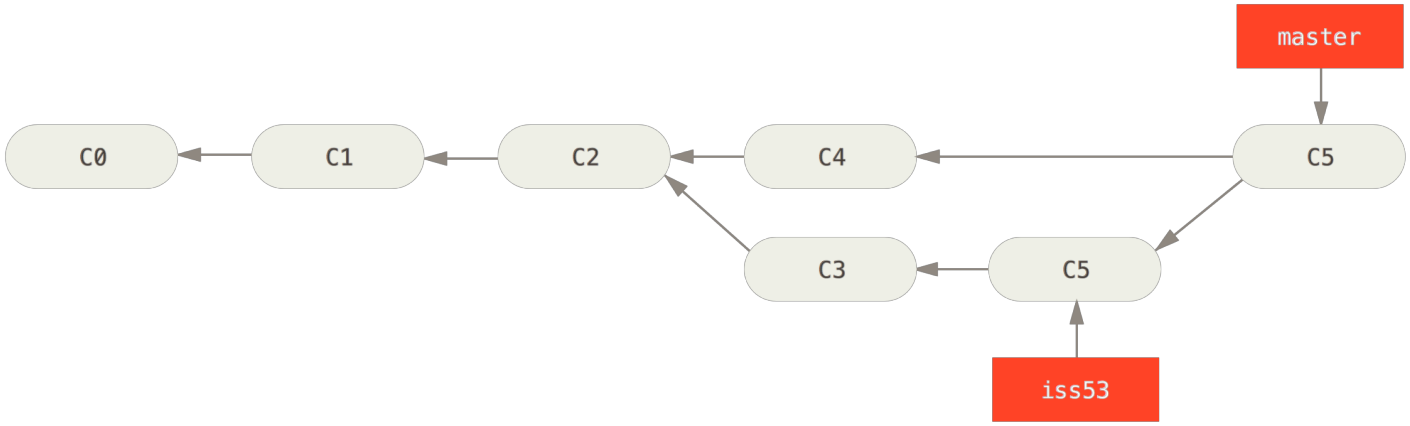
Merging Branches – with divergence

- Final result:



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Merging Branches – with divergence

- Instead of just moving the branch pointer forward, Git creates a new snapshot that results from this three-way merge and automatically creates a new commit that points to it
  - Three way: C4, C5, C2 (common ancestor)
- This is referred to as a merge commit, and is special in that it has more than one parent
- Git determines the best common ancestor to use for its merge base

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Merging - conflicts

- Conflicts are possible,
  - Ex same file modified in same part in C4 and C5
- in this case merging is not done until conflicts are managed

- `git mergetool`

  Helps in managing conflicts

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Rebase

- Another way of merging
- Rebase applies changes of one snapshot history to another

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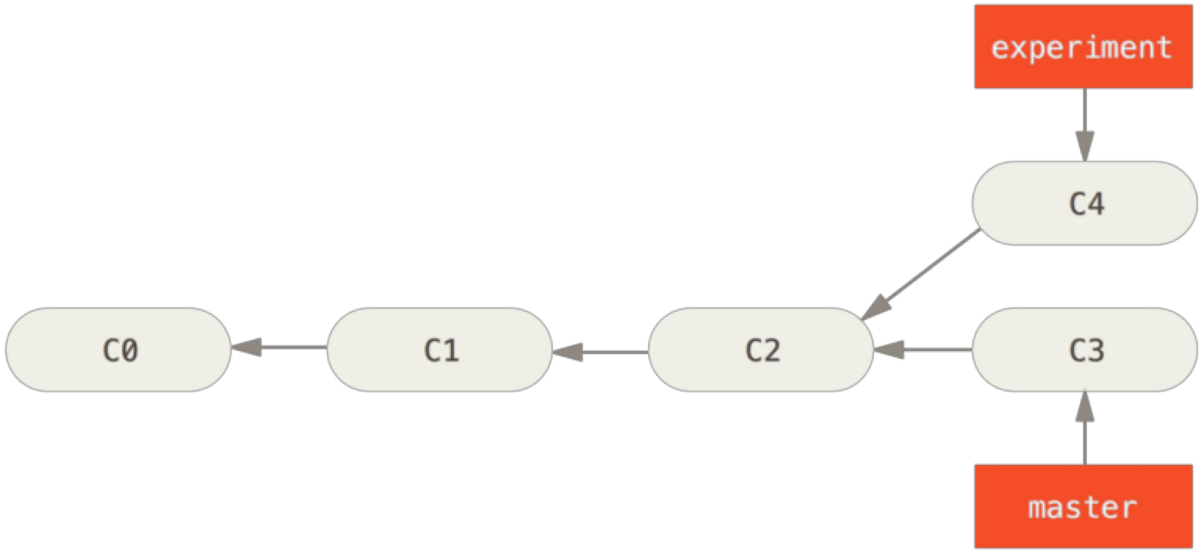
- Starting point



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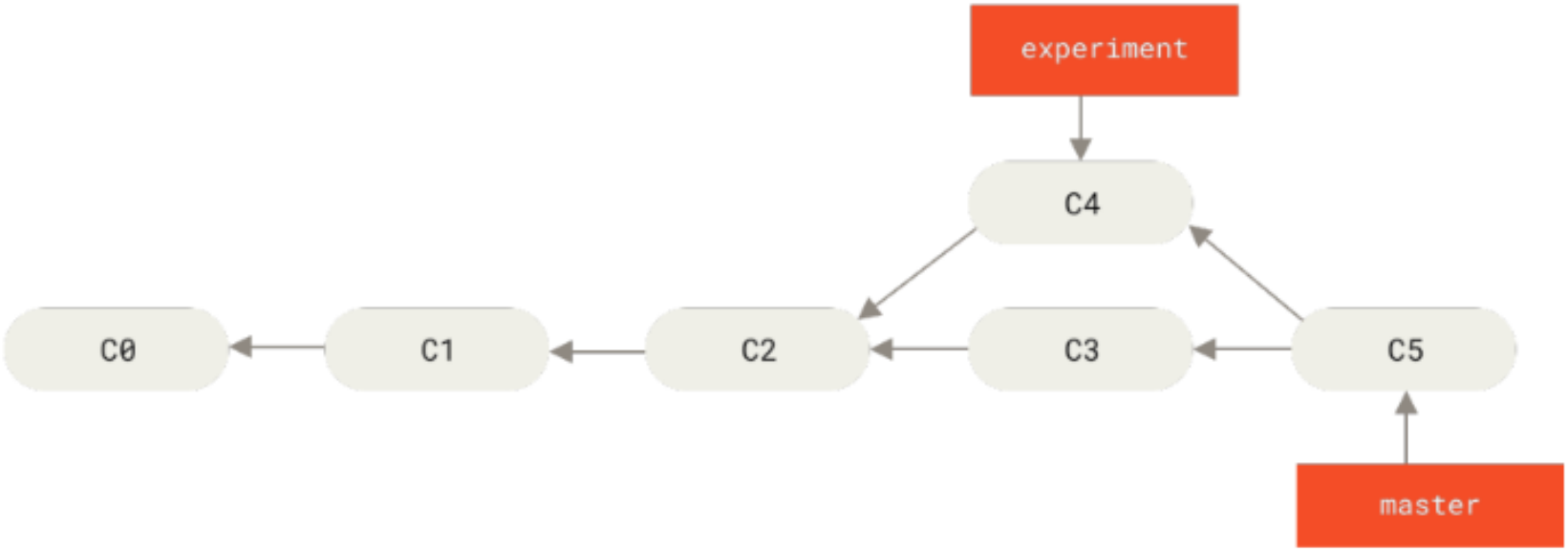
- Result
- `git checkout master`
- `git merge experiment`



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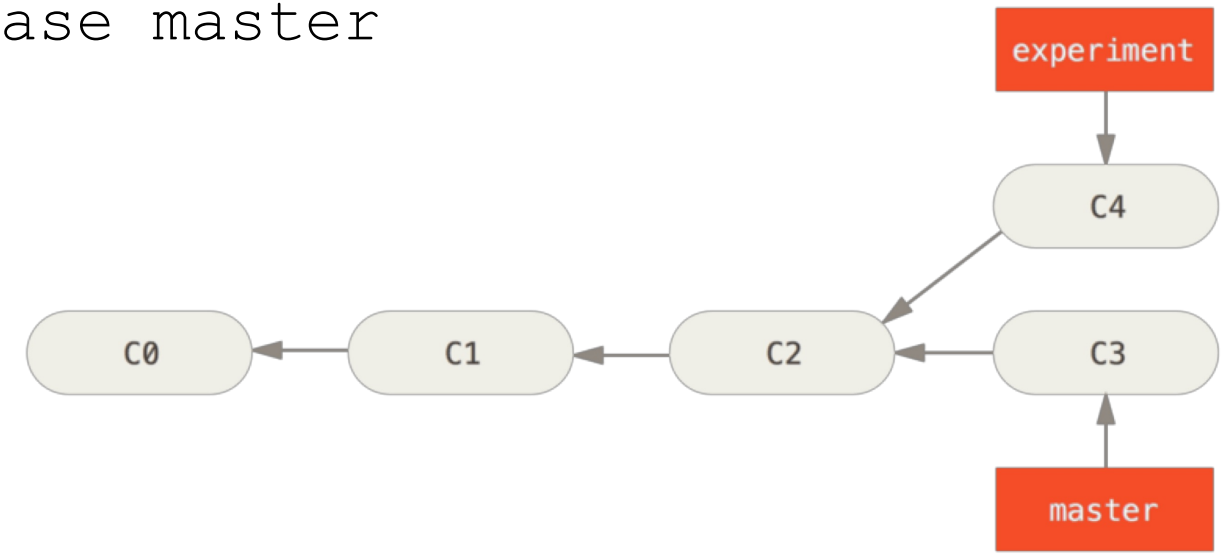
Rebase

- `git checkout experiment`
- `git rebase master`



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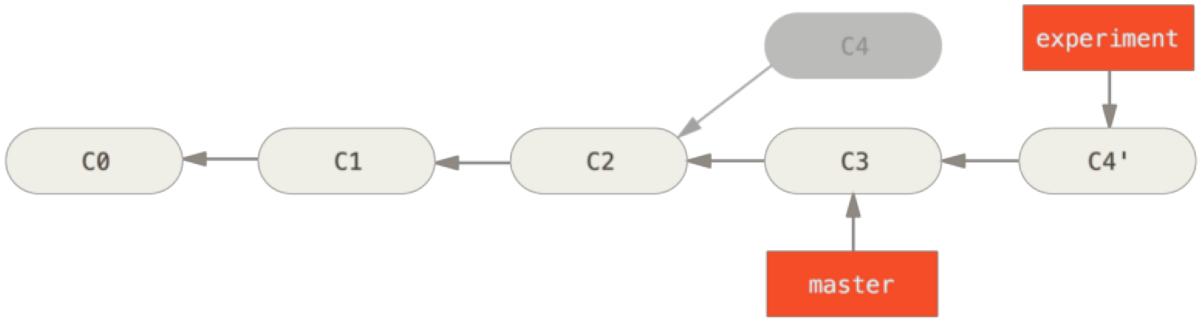
Rebase

- `git checkout master`
- `git merge experiment`



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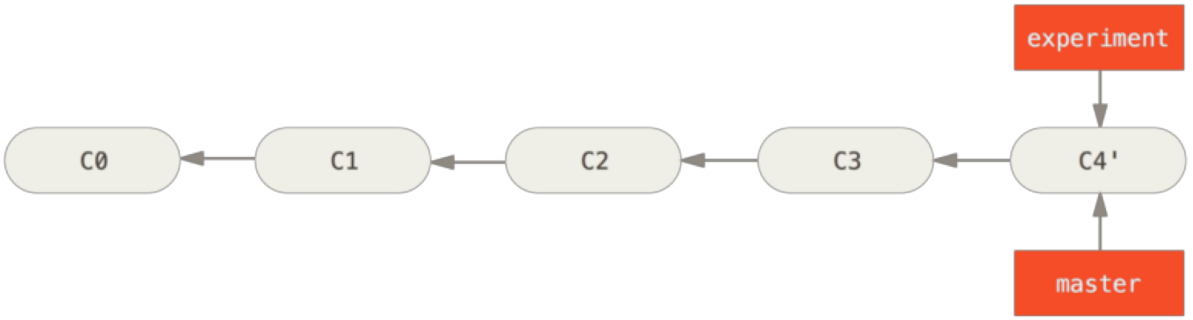
Rebase

- Result



- Be careful, rebase rewrites the repository history!

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Rebase

- It is also possible to organize/edit your commits
- Some useful cases:
  - the commit message is wrong, or it does not make sense.
  - the order of the commits is not nice regarding to git history.
  - there are more than one commit which make similar changes (or even the same thing).
  - a commit grouped a lot of different code, and it makes sense divide it in smaller commits.

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Rebase

- `git rebase -i HEAD~4`
  - `-i => interactive mode`
  - `~4 =>number of commits we want to target.`

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Changing Commit Order with Rebase

- `git rebase -i HEAD~4`

- `pick 0a0cf97 document`
- `pick d09e470` **`add paragraph`**
- `pick 59b2309` **`add second document`**
- `pick 16013c6 change title`

- Change the order of these lines (cut and paste)

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Changing Commit Order with Rebase

- `git rebase -i HEAD~4`

- `pick 0a0cf97 document`
- `pick 59b2309` **`add second document`**
- `pick d09e470` **`add paragraph`**
- `pick 16013c6 change title`

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Edit Commit Messages

- `git rebase -i HEAD~4`
- `pick 0a0cf97 document`
- `pick 59b2309 add second document`
- **`reword`** `d09e470 add paragraph`
- `pick 16013c6 change title`

- Change pick with reword for editing the commit message

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Merge Commits

- `git rebase -i HEAD~4`
- `pick 0a0cf97 document`
- **`squash`** `59b2309 add second document`
- `pick d09e470 add paragraph`
- `pick 16013c6 change title`

- Change **pick** with **squash** for merging the second commit with the first

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Merge Commits

- The result will be:

```
# This is a combination of 2 commits.  # The first commit's message is:
document
# This is the 2nd commit message:
add second document
# Please enter the commit message for your changes.
```

- Delete all this lines and write a message for the new commit

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Rebase vs. Merge

- The main differences between rebase and merge are:
  - merge combines the commit history of two branches, while rebase creates a linear commit history.
  - merge creates a new merge commit, while rebase rewrites the commit history of the feature branch.
  - merge is better suited for integrating changes from different branches, while rebase is better suited for keeping a cleaner commit history.

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Rebase vs. Merge

- merge is generally considered safer than rebase because it preserves the original commit history and creates a new merge commit, which makes it easier to undo the merge if necessary.
- Graph structure: Every merge commit increases the connectivity of the commit graph by one. A rebase, by contrast, does not change the connectivity and leads to a more linear history

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Models for Collaborative Development

- People collaborate on GIT in two ways:
  - Shared repository
  - Fork and pull

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Shared Repository

- With a shared repository, individuals and teams are explicitly designated as contributors with read, write, or administrator access.

- This simple permission structure, combined with features like protected branches and Marketplace, helps teams progress quickly when they adopt GitHub.

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Fork and Pull

- For projects to which anyone can contribute, managing individual permissions can be challenging, but a fork and pull model allows anyone who can view the project to contribute.
- A fork is a copy of a project under a developer's personal account.
- Every developer has full control of their fork and is free to implement a fix or new feature.
- Work completed in forks is either kept separate or is surfaced back to the original project via a pull request.

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Fork

- A fork is a copy of a repository that a developer manages.
- Forks let the developer make changes to a project without affecting the original repository.
- The developer can fetch updates from or submit changes to the original repository with pull (or merge) requests.

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Pull (GitHub) or Merge (GitLab) requests

- Pull requests let the developer tell others about changes he or she has pushed to a branch in a repository on git.

- Once a pull (or merge) request is opened, the developer can discuss and review the potential changes with collaborators and add follow-up commits before your changes are merged into the base branch.

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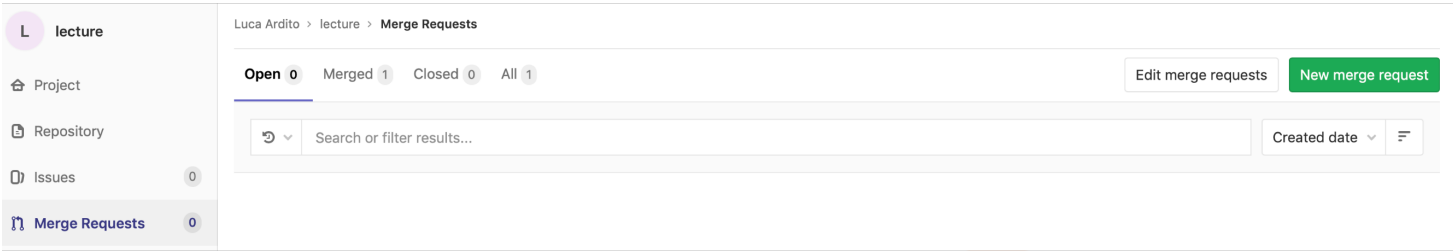
Merge Requests

- Create a new branch
- Work on the new branch
- Commit and push your work
- Open the project on Gitlab and create a new merge request



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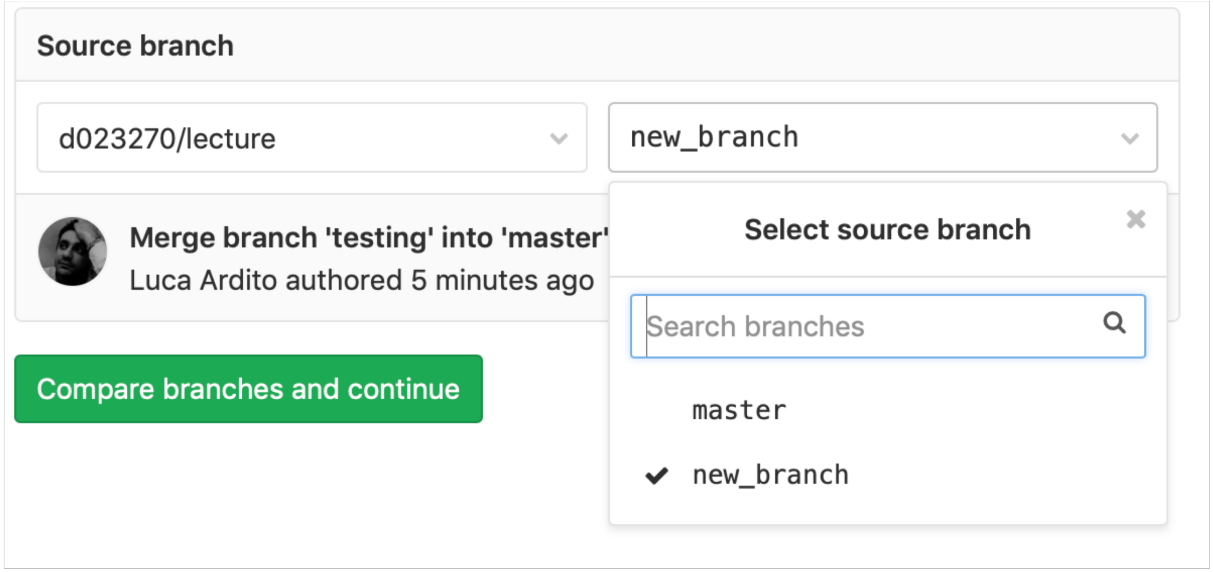
Merge Requests



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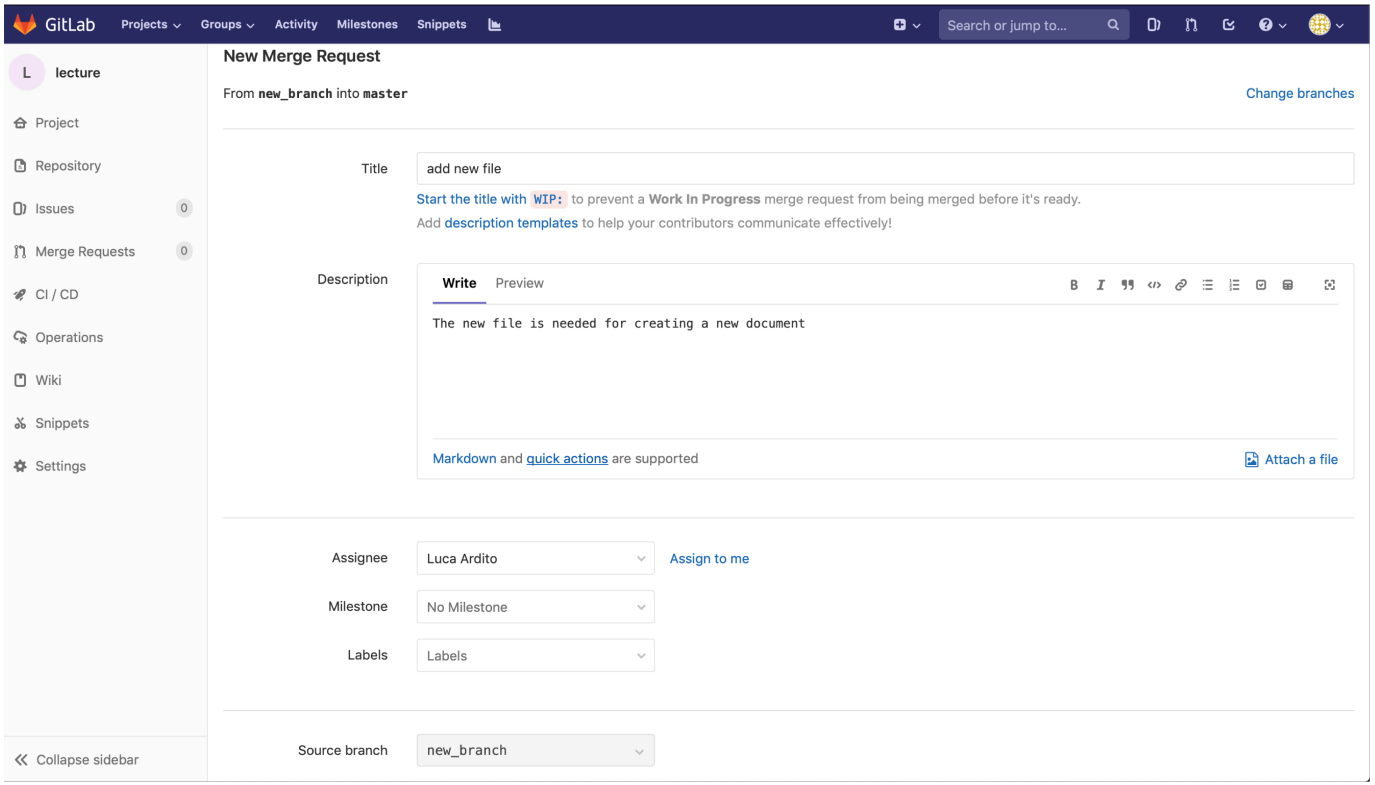
Merge Requests



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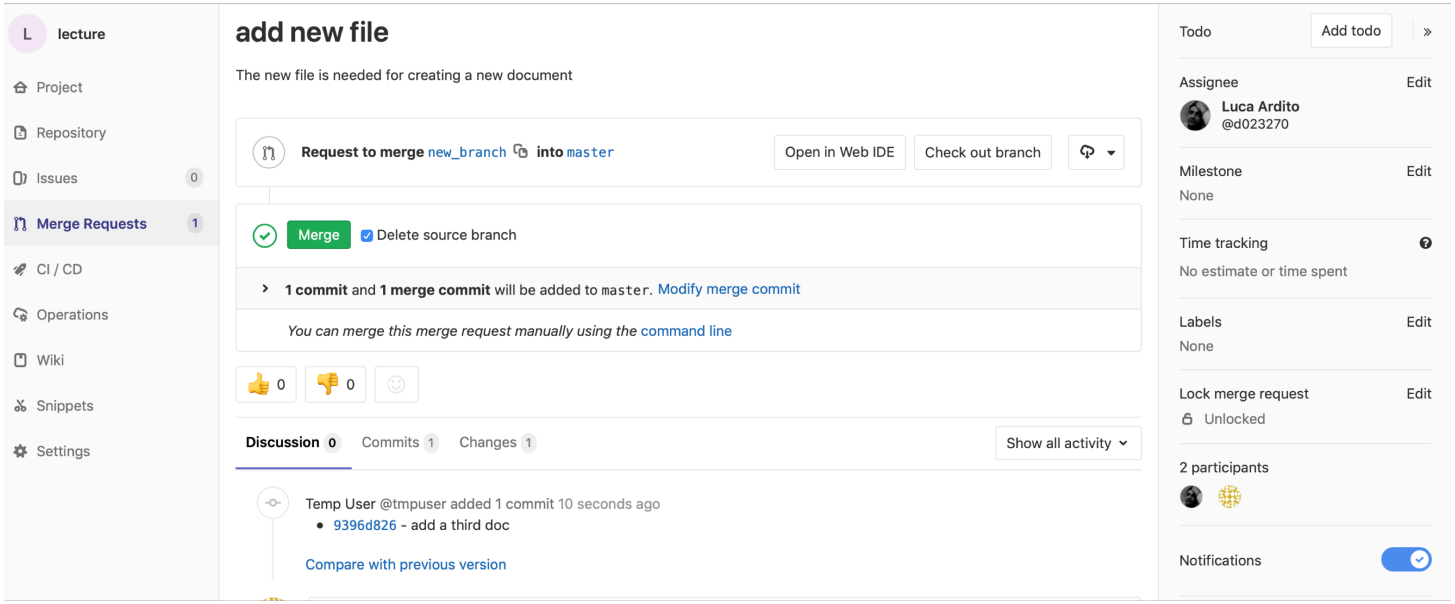
Merge Requests



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What to do when you think you are lost

DON’T PANIC!

`git reflog` is your friend!

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What to do when you think you are lost

- Git will try to preserve your changes.

- Uncommitted changes to git-controlled-files will only get overwritten if running one of the commands:
  - `git checkout <file-or-directory>`
  - `git reset --hard`
- And of course any non-git commands that change files

- Files unknown to Git will only get lost with:
  - `git clean`
  - any non-git commands that change files

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Conventional Commits

- Lightweight convention on top of commit messages
- Provides an easy set of rules for creating an explicit commit history
  - `feat: allow provided config object to extend other configs`
  - `feat!: send an email to the customer when a product is shipped`
  - `BREAKING CHANGE: \`extends\` key in config file is now used for extending other config files`
- https://www.conventionalcommits.org/en/v1.0.0/#specification

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Recorded Examples

https://www.youtube.com/watch?v=UMcXoJbBGRI

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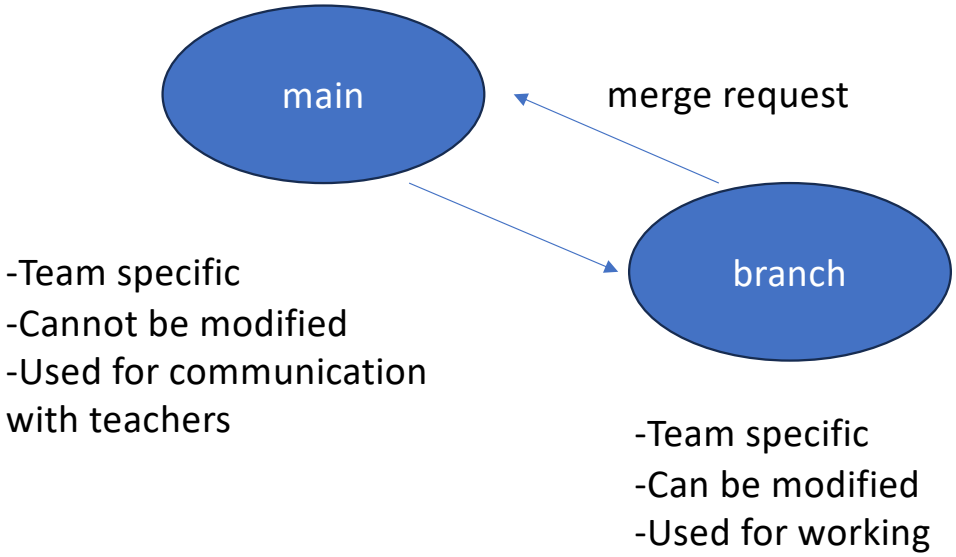
How to use git in project



- Each team has a repo
- ‘Main’ branch, ‘branch’

- Team works in ‘branch’
- Deliveries are made via merge requests vs ‘main’
- To be accepted by teachers

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Rules

- No changes to main
- Project deliveries must refer to one branch only
  - If you define many branches below ‘branch’ merge them before doing merge request

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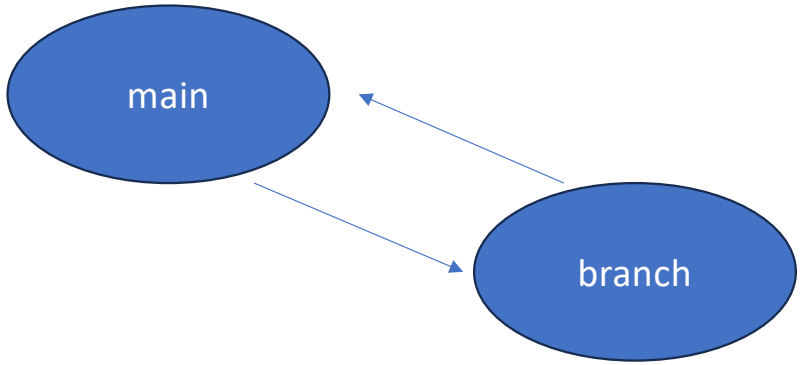
How to use git



- Options in your branch
  - Do other branches
    - Per person
    - Per task
  - No other branches

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How to use git

- Branching should be used wisely
  - Need to merge at reasonable intervals to check consistency
- Suggestions
  - Single documents (ex requirements): no branches, all team members work on same file
  - Group of related files (ex .js files of code part, test part, GUI prototype):
    - Either no branches, each member works on a different file
    - Or, branch for each team member, then merge the branches

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Git Additional Resources

- Reference guide
  - http://git-scm.com/doc
- Book
  - https://git-scm.com/book/en/v2
- GUI tools for git
  - https://git-scm.com/downloads/guis

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