Lecture 18
Git Version Control

CS211 – Fundamentals of Computer Programming II

Branden Ghena – Spring 2023

Slides adapted from:
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Administrivia

- Projects are due on Friday!
  - Submissions to Gradescope are available now
  - It will check that your submitted code compiles properly
    - Submit as many times as you want to
    - Make sure to submit `Resources/` files!!
- Evaluation guide will be due over the weekend
  - For each spec item, tell us how to confirm you did it
  - Also identify your "non-trivial" model tests
- Quiz today at 3pm (warn your absentee friends)

Today’s Goals

- Understand concepts behind Version Control Systems
  - Why are they important?
  - How do we use them?

- Describe one specific Version Control System: Git
  - How does Git work conceptually?
  - How do we use Git?

  - Where does Github fit into this?

Guides for learning Git

- Understanding Git commits and branches
  - https://learngitbranching.js.org/

- Remember git commands
  - https://education.github.com/git-cheat-sheet-education.pdf

- Learning more about Git
  - https://www.atlassian.com/git/tutorials/learn-git-with-bitbucket-cloud
  - https://git-scm.com/book/en/v2

Outline

- **Version Control Overview**
- Systems for Version Control

- Git Commit Structure
- Using Git
- Using Github
- Best Practices

Simplest ideas of version control

- Undo/Redo in programs
  - Keeps track of prior actions and lets you go back to them

- Manual file renaming

Project Report

Project Report v2

Project Report v3

Project Report final

Project Report final v2

- What if I told you there was a better way?

You mean there’s a better way?

Building a better system: backup naming

- Start with a system capable of doing the file rename for you
  - When you choose to “commit” the file, the system makes a backup copy
  - Backup copies are kept with metadata
  - Examples:
    - What time was this version saved
    - Who made the changes to the file
    - Message from the user about what changed

Need some way to “revert” to an old version

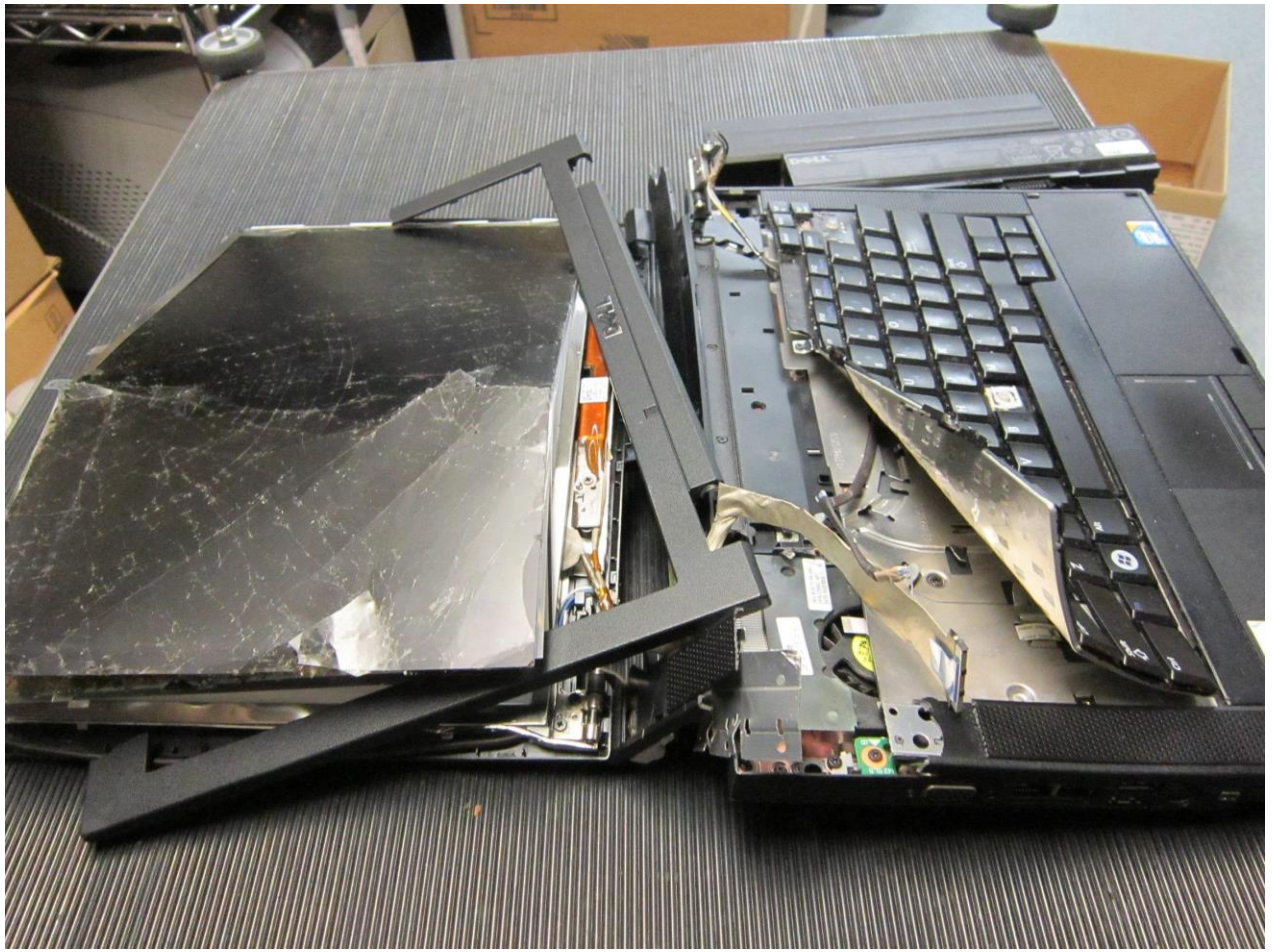
- Oh no! This most recent version broke something

- Change back to a previous version of the file
  - Or maybe several versions ago

- Might also ask to see what changed since previous version
  - One of those lines must be what broke it

  - How we do this depends on the file
    - Code: line-by-line comparison
    - Word documents: more complicated…

How do we survive tragic computer accidents?



- Need backups on another computer

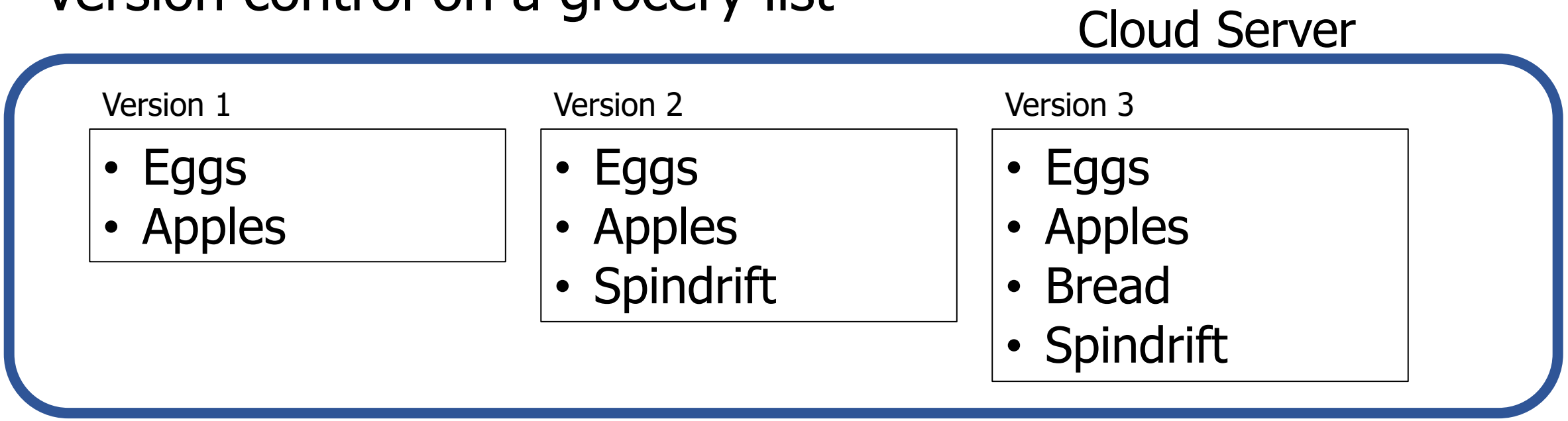
Improve reliability with cloud backups

- Sync files up to the cloud
  - Includes all versions of all files
  - Probably does some stuff to optimize space
    - Only keep the changes, not the whole file

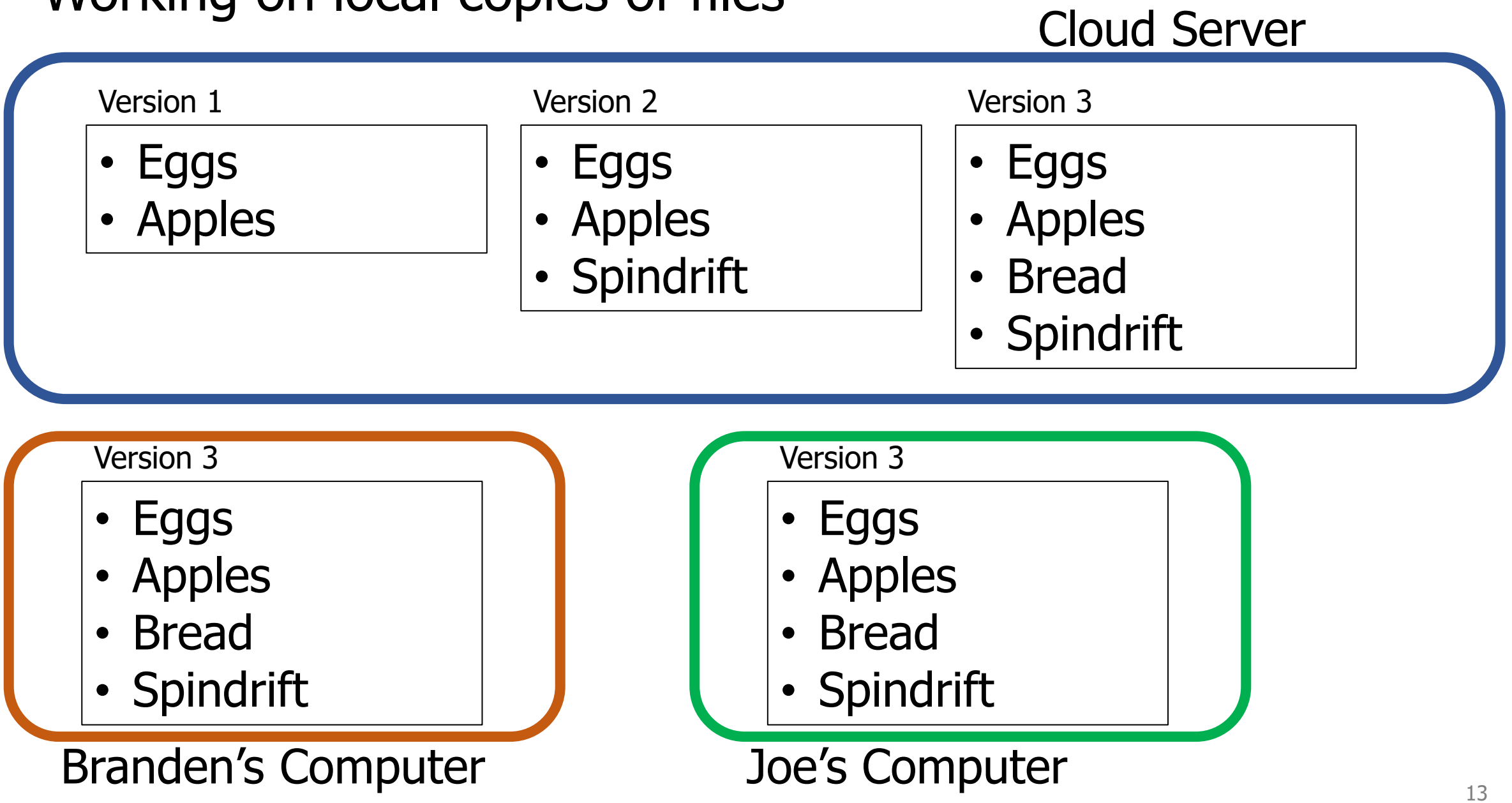
- Download files from the cloud
  - Provides the most recent file (“Head”)

  - Enables sharing files across multiple computers!
    - Across one or multiple people

Version control on a grocery list



Working on local copies of files



Making a new version of a file

Cloud Server

Version 1

- Eggs
- Apples

Version 2

- Eggs
- Apples
- Spindrift

Version 3

- Eggs
- Apples
- Bread
- Spindrift

Version 4

- Eggs
- Oranges
- Bread
- Spindrift

Branden's Computer

Version 3

- Eggs
- Apples
- Bread
- Spindrift

Joe's Computer

Conflicts when editing files!

Cloud Server

Version 1

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Branden's Computer

Version 4

- Eggs
- Apples
- Spindrift

Joe's Computer

Problem: simultaneous edits

- Multiple editors can lead to file conflicts!

- Whoever commits first wins, loser has to handle the problem

- How does the system handle “merging” the files?
  - Sometimes just ask the human to figure it out

  - Sometimes realize that changes are to different parts of the file and just apply both

Fundamental version control operations

- **Commit** file(s)
  - Save a new version of them
- **Revert** file(s)
  - Return to a previous version of them
- **Compare** file(s) across version
- **Push** file(s) to a server
- **Pull** file(s) from a server
- **Merge** changes to a file and handle conflicts

Version Control Systems are essential

- Not just for software, any files!
  - Code
  - Documents
  - Data files
  - Lecture slides

- Often designed with source code in mind
  - Work particularly well on human-readable text files
    - Comparisons can happen line-by-line (diff)
    - Text is easily compressed for transfer and storage

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- **Systems for Version Control**

- Git Commit Structure
- Using Git
- Using Github
- Best Practices

Version control terminology

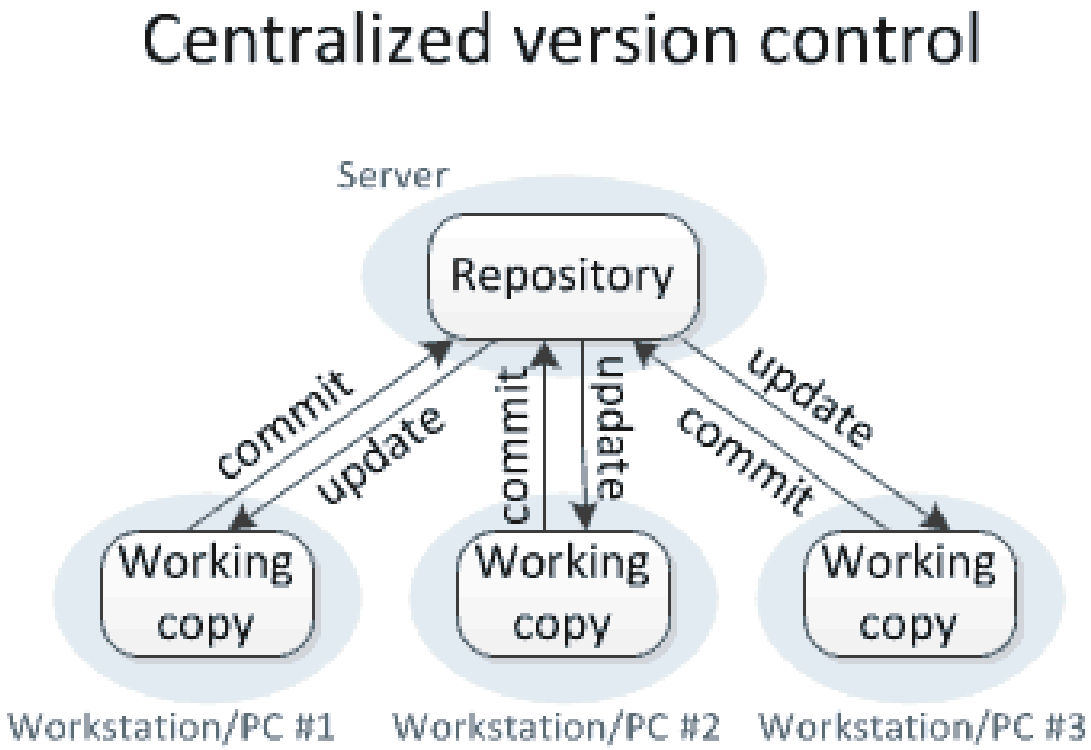
- Repository (a.k.a. repo)
  - Holds all of the versions of all of the files for a project
  - You commit files to a repo
    - And push to it, if it's on a different computer

- Local versions of files are known as the "Working Copy"
  - You can edit these files and then commit them to the repo

- The most recent version of a file is known as the "Head"

Older systems: Centralized version control

- Local computers only ever have a working copy
  - Must request version information from repo on a server



Centralized version control systems

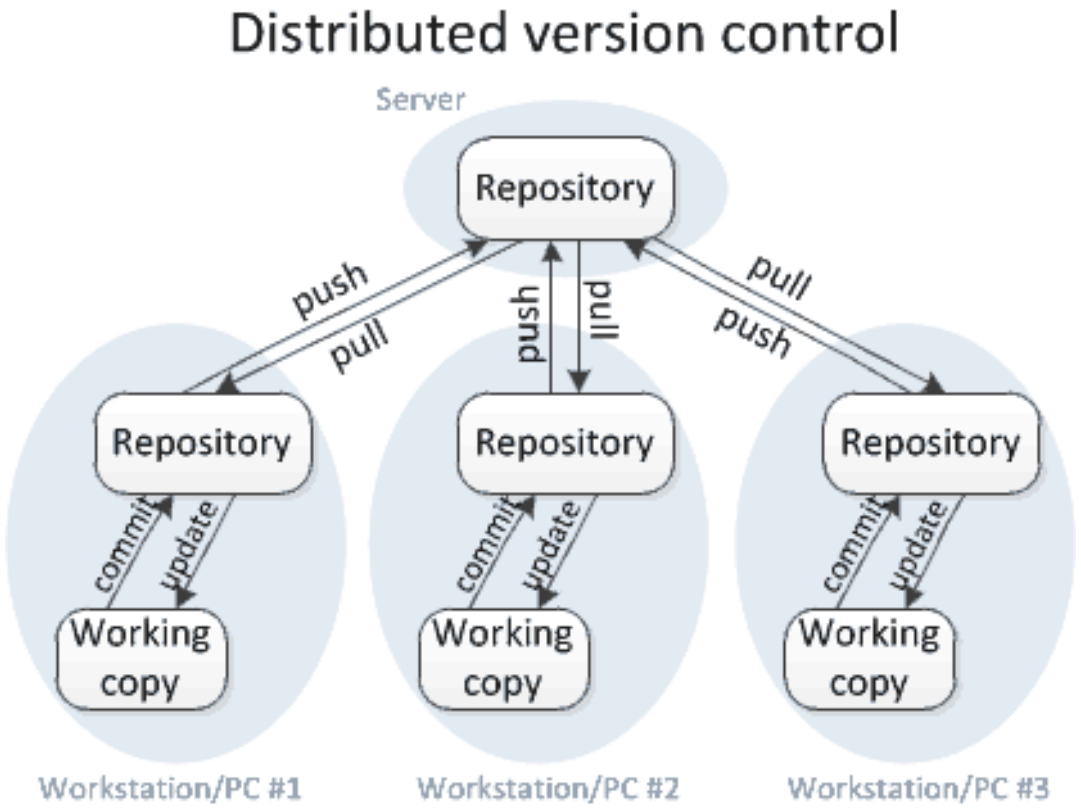
- Revision Control System (RCS), 1982
  - Basic idea of versioning for single files
- Concurrent Versions System (CVS), 1990
  - Expands version to an entire project of files
- Subversion (SVN), 2000
  - A "Commit" includes changes across multiple files
    - Often multiple source/header files might be changed together!
  - Ensures *atomic* changes to the repo

1st Generation

2nd Generation

Modern systems: Distributed version control

- Local computers have their own copy of the repository
  - Along with the working copy that users directly edit



Distributed version control systems

- Bazaar (bzr), 2005
  - No longer developed
- Mercurial (hg), 2005
  - Still developed, not widely used
- Git (git), 2005
  - Most popular version control system

3rd Generation

- All provide methods for enabling distributed version control
  - Changes can be made and tracked locally
  - Sets of changes can be sent to others as needed
    - Often to a central shared server

Sidebar: what happened in 2005?

- Bazaar (bzr), 2005
- Mercurial (hg), 2005
- Git (git), 2005

- Bitkeeper, a proprietary distributed version control system decided to end free access for open-source projects
  - Including Linux!

  - Led to simultaneous development of new systems
    - And the death of Bitkeeper

Break + xkcd

https://xkcd.com/1597/

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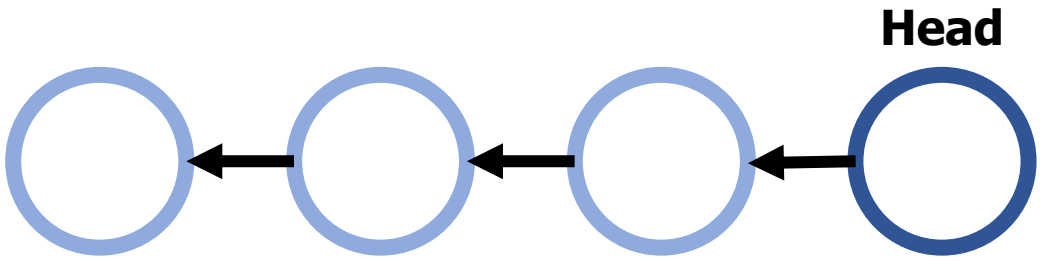
Commits are the units of change in Git

- A Commit contains
  - File modifications
  - Timestamps
  - Author of commit
  - Commit message
  - Parent of Commit

- Git commits each have a name
  - Example: 42e2e5af9d49de268cd1fda3587788da4ace418a
    - 160-bit SHA1 hash of the commit data (guaranteed unique)
    - Usually referred to by first 7 digits (268 million choices, likely unique)
      - Example: 42e2e5a

Every commit has a parent

- Simplest structure of commits can form a sort of linked list



The commit history can branch

- Multiple commits can have the same parent

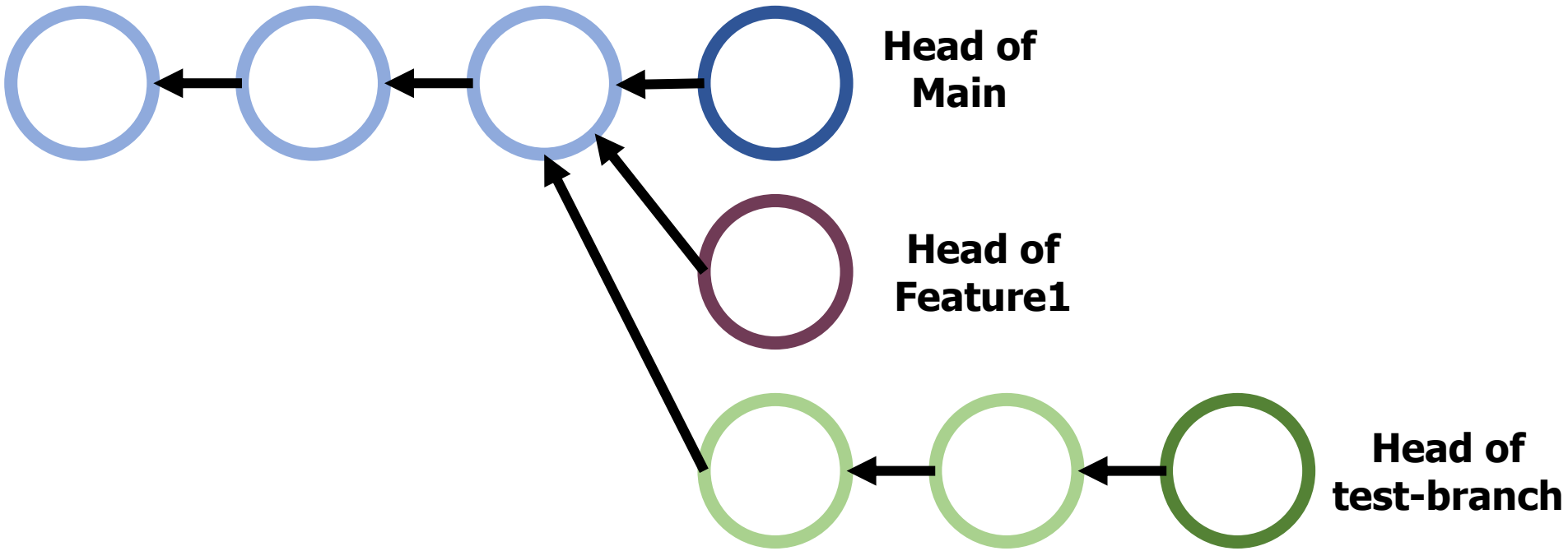
- Branching intentionally forms a new path for commits
  - Starts at a parent from the main “branch”
  - Continues on separately from there

  - Often used for development of new features

- Original code path is known as Main
  - Occasionally referred to as “master” in legacy projects

Some parents have multiple children

- Simplest structure of commits can form a sort of linked-list
- With branches, commits can form a tree structure



Branches may later merge back into Main

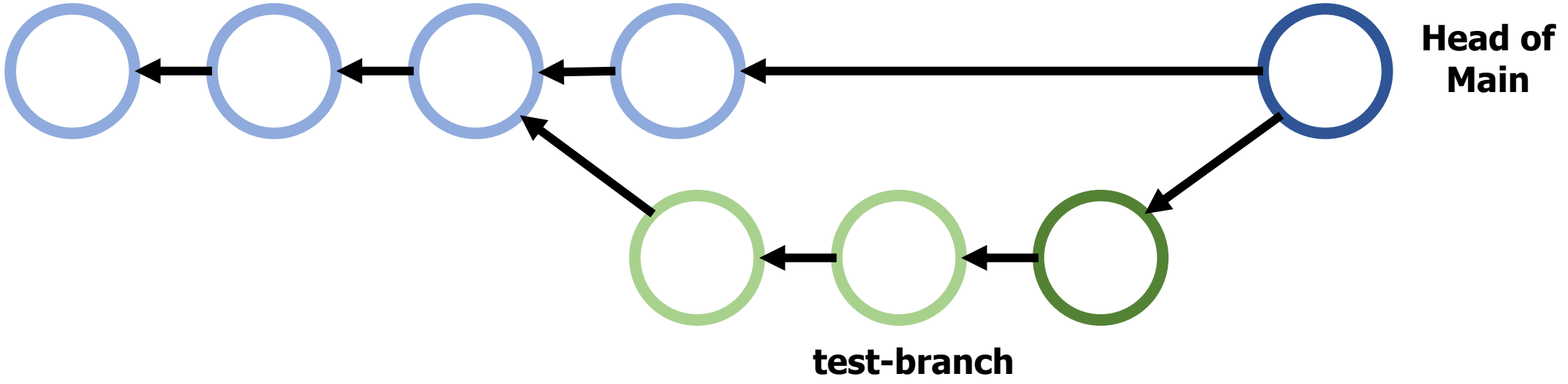
- Combining two branches requires a “merge” operation
  - Might include conflicts if both branches modify the same file!
  - Git is pretty good at automatically resolving conflicts
    - Unless the two branches both modify the same line of code

- Merge commit gets added to list the multiple parent commits

- There is an alternative: a “rebase” operation
  - Change branch’s parent to the current head of Main
    - Probably works as long as nothing major has changed

Git's true nature is a graph structure

- Simplest structure of commits can form a sort of linked-list
- With branches, commits can form a tree structure
- Reality of Git: Directed, acyclical graph
  - Each commit has one *or more* parents
  - There are no cycles (parents that are children of themselves)



Tags let you refer to specific commits from repo's history

- Git history can start to get rather complicated
  - What if you want to point to something other than the Head of Main?

- Tags are alternative names given to specified commits
  - Can be reverted to
  - Can be compared against
  - Usually for major versions of your project

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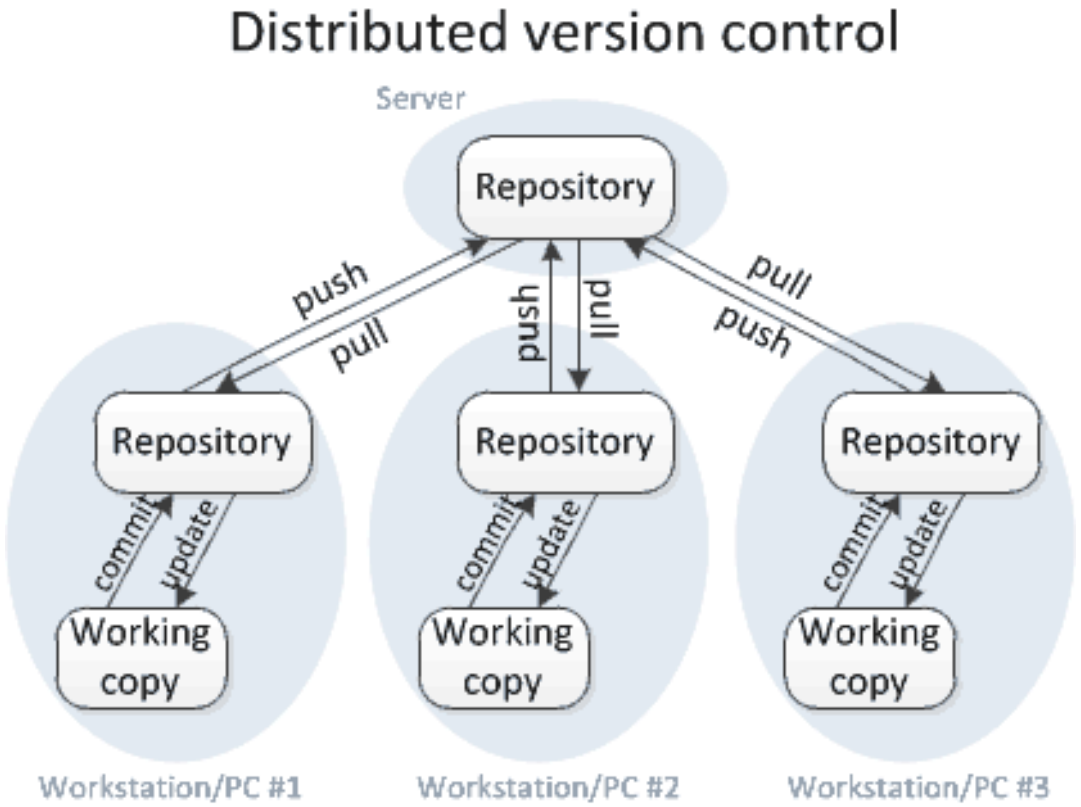
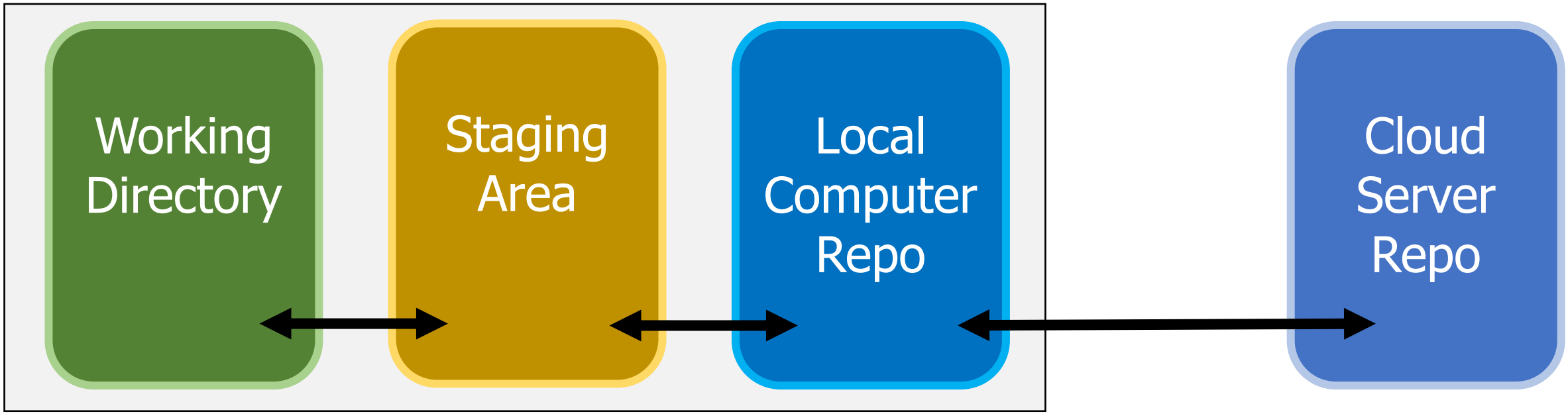
Git is a distributed version control system

- There will be one (or more!) server repositories
- Each user will also have their own local repository clone



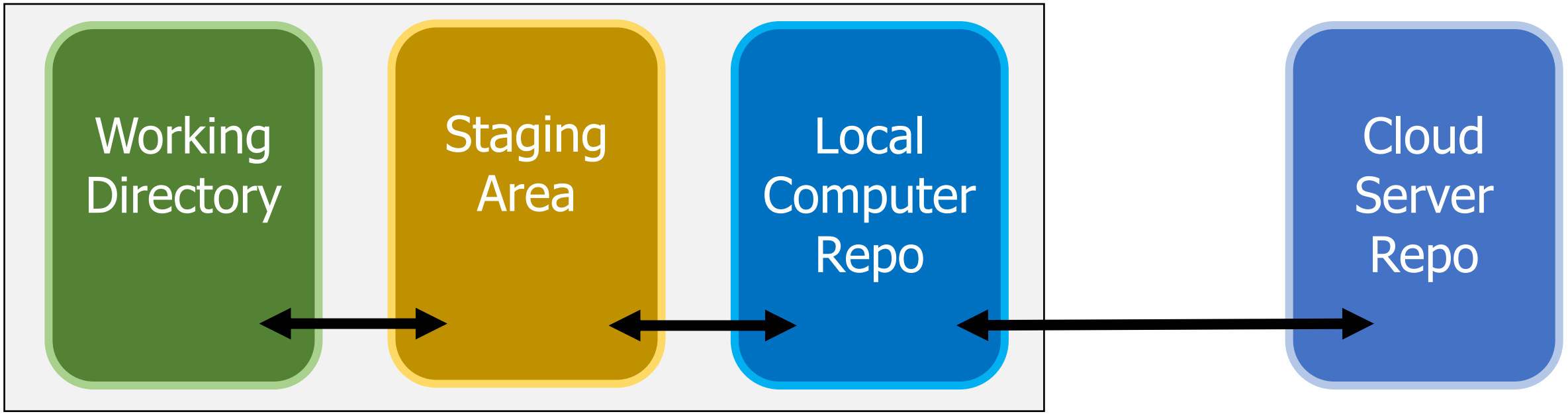
Git splits the local computer into several parts

- Local computer repo
  - A copy of the repo from the cloud
  - Might have various local commits/branches that aren't on the cloud



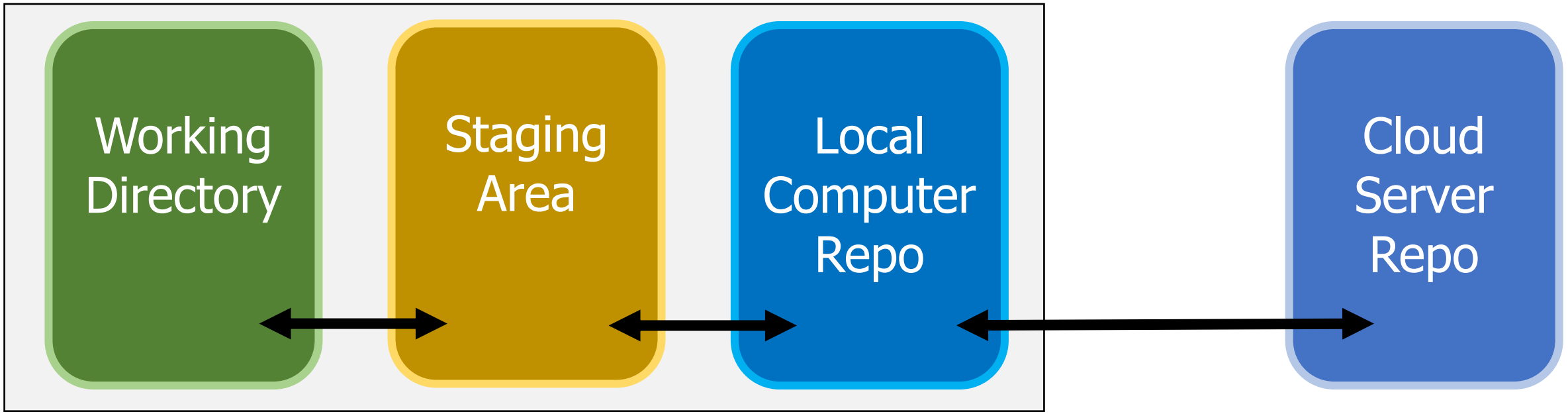
Git splits the local computer into several parts

- Staging Area
  - Where files are held that are ready to be committed
  - User selects files that are ready to commit and first adds them to staging area

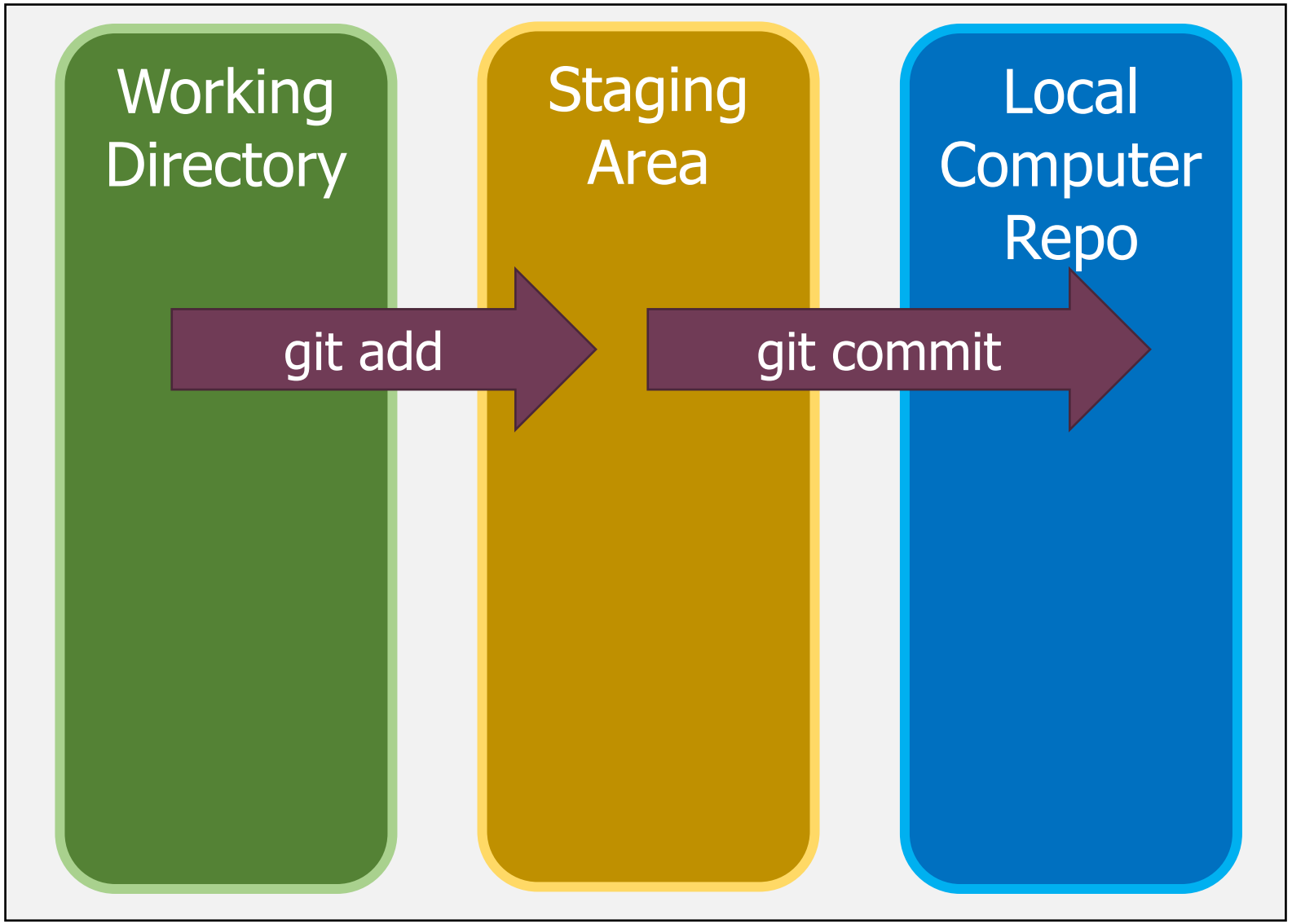


Git splits the local computer into several parts

- Working Directory
  - Files actually in use on the local computer
  - Initially matches a commit in the repo
    - Might include local edits that haven't been staged

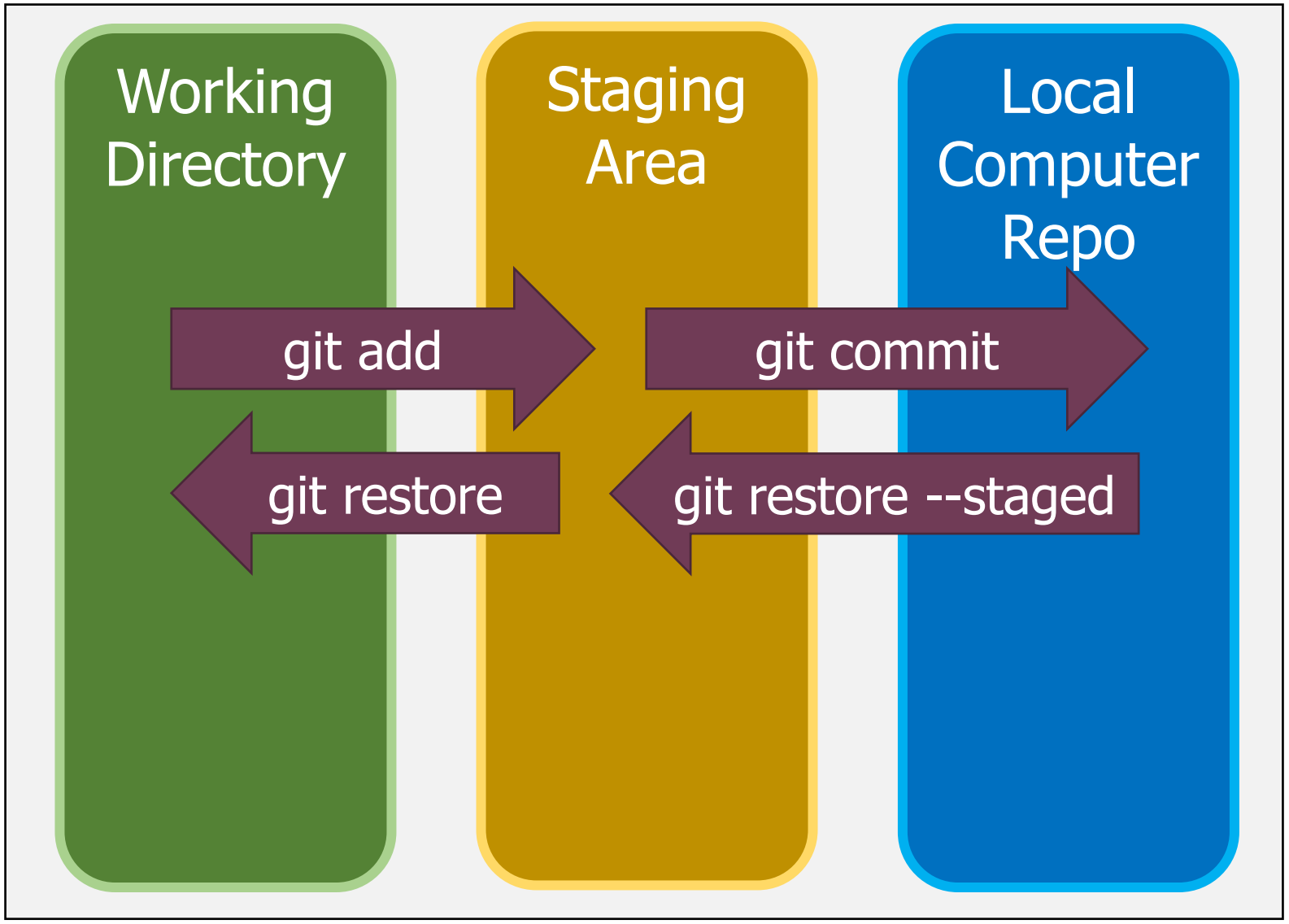


Git commands modify files in different areas



Cloud Server Repo

Git commands modify files in different areas



Cloud Server Repo

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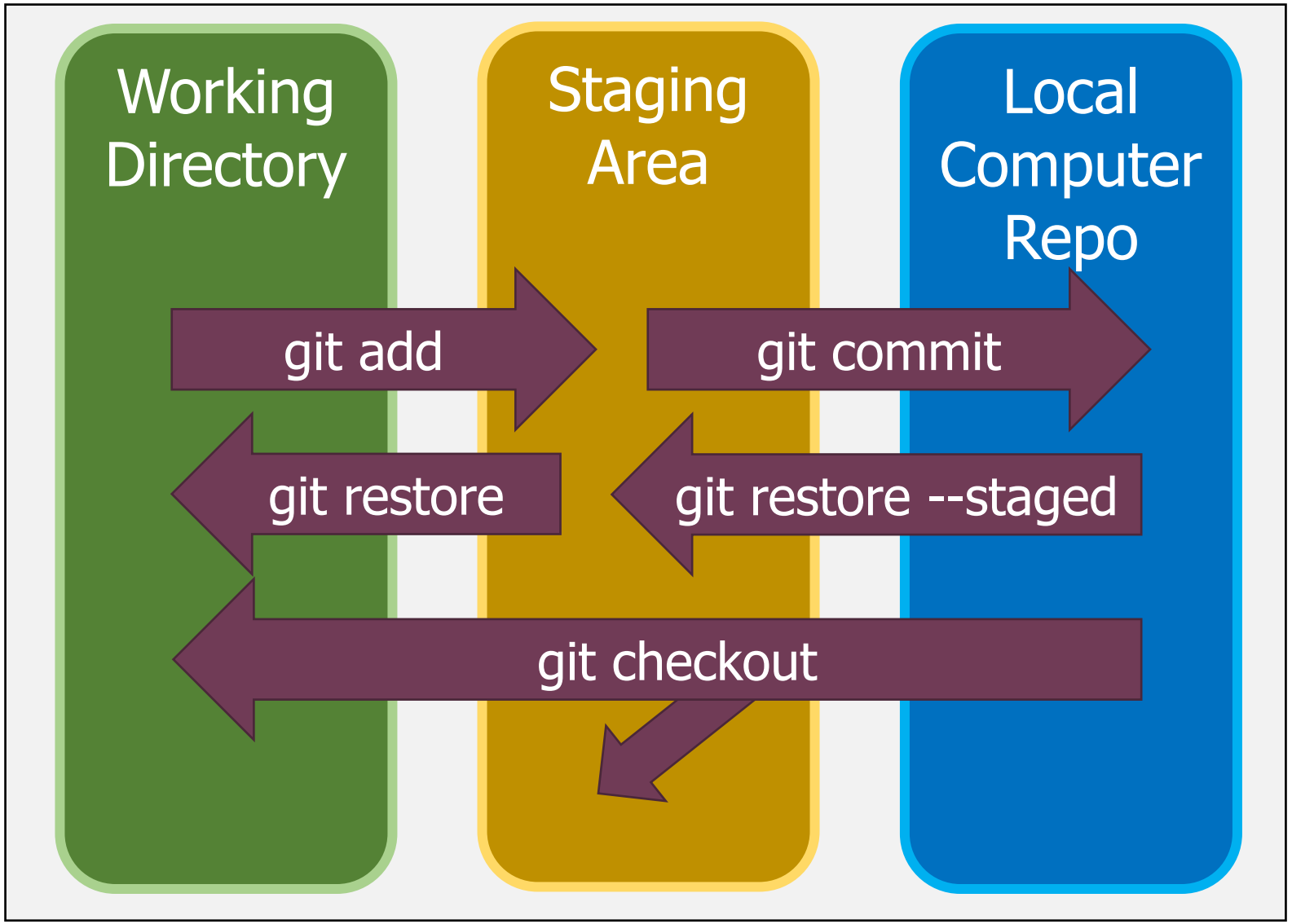

Cloud Server Repo

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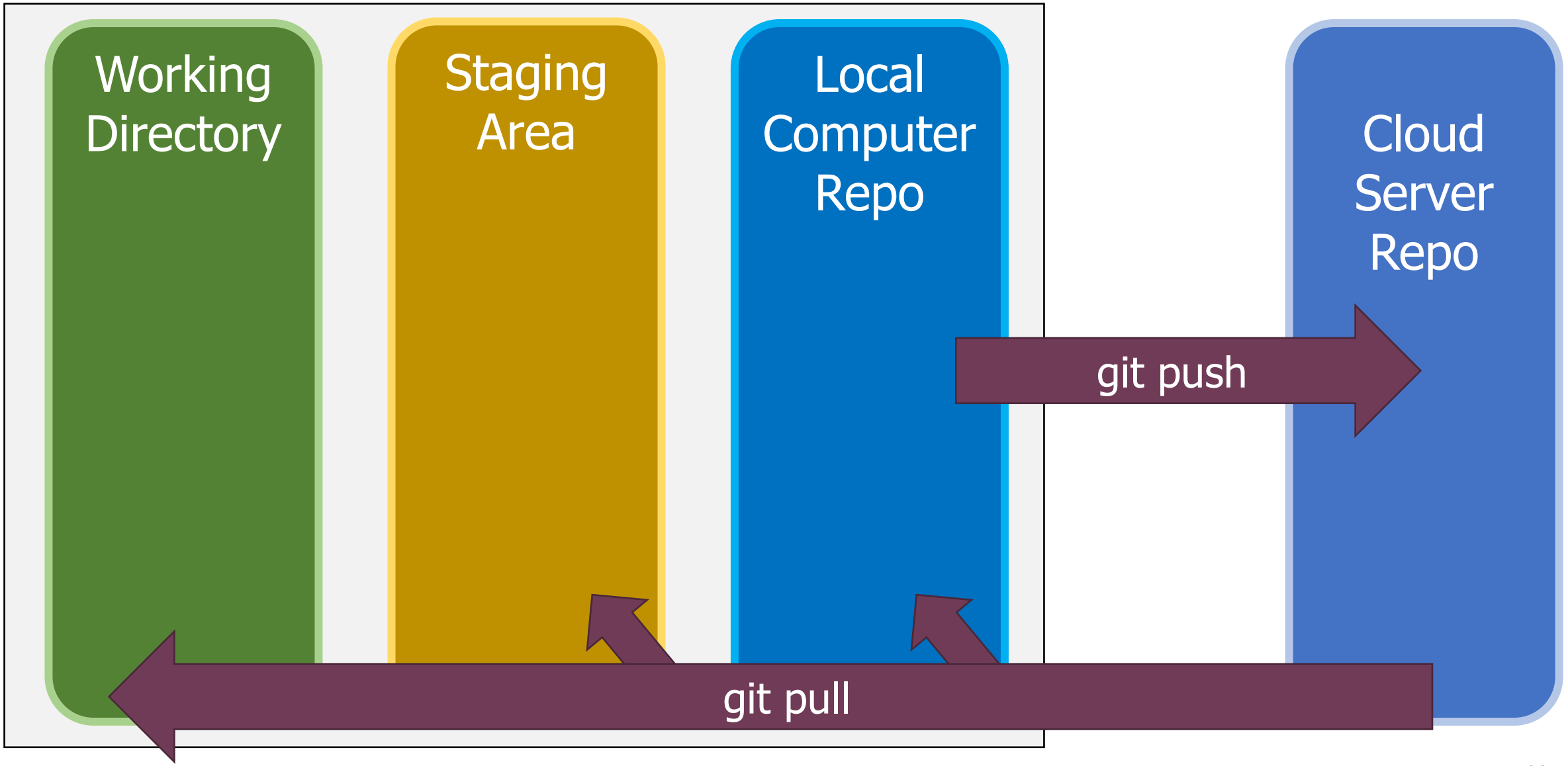
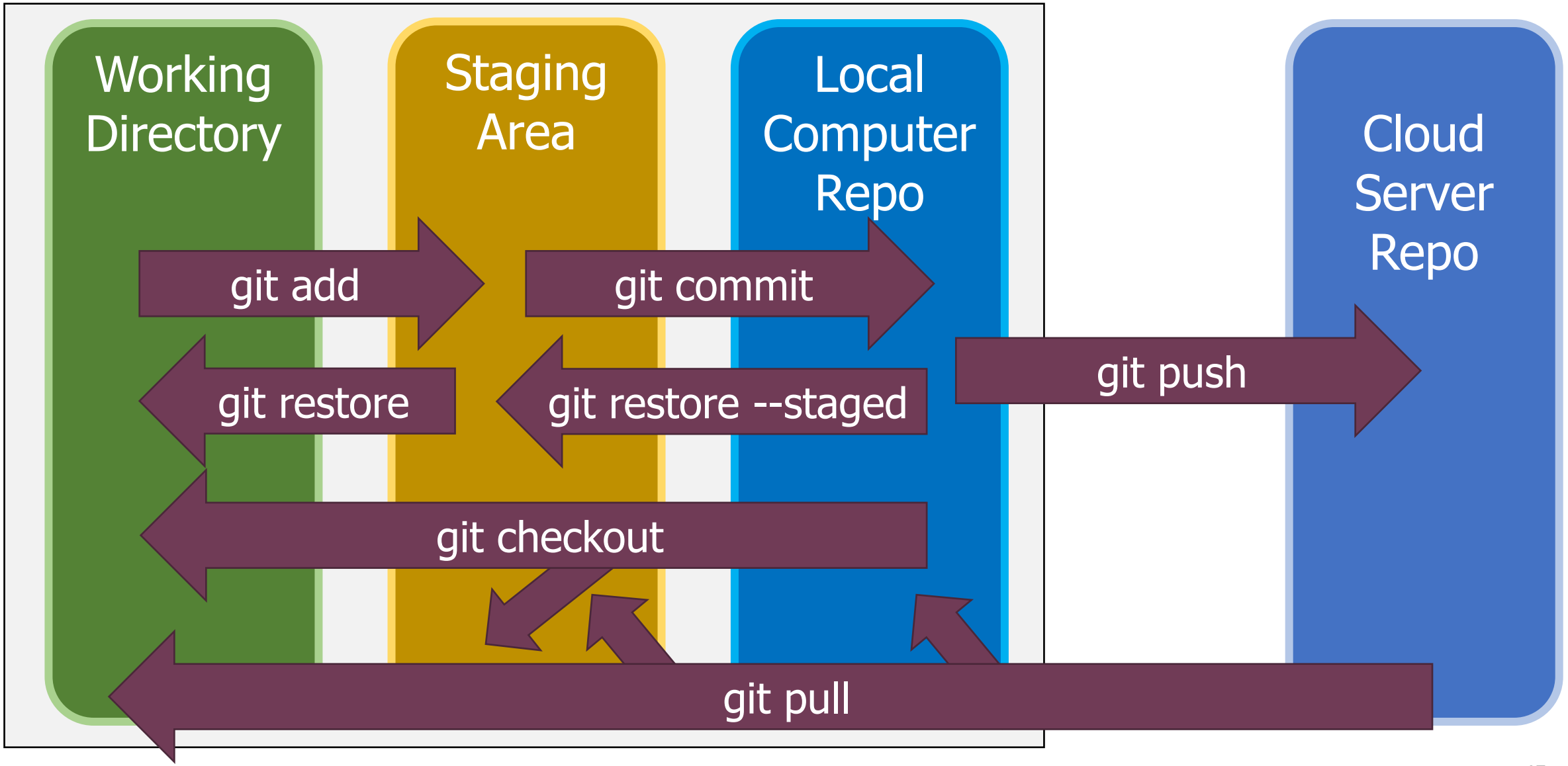
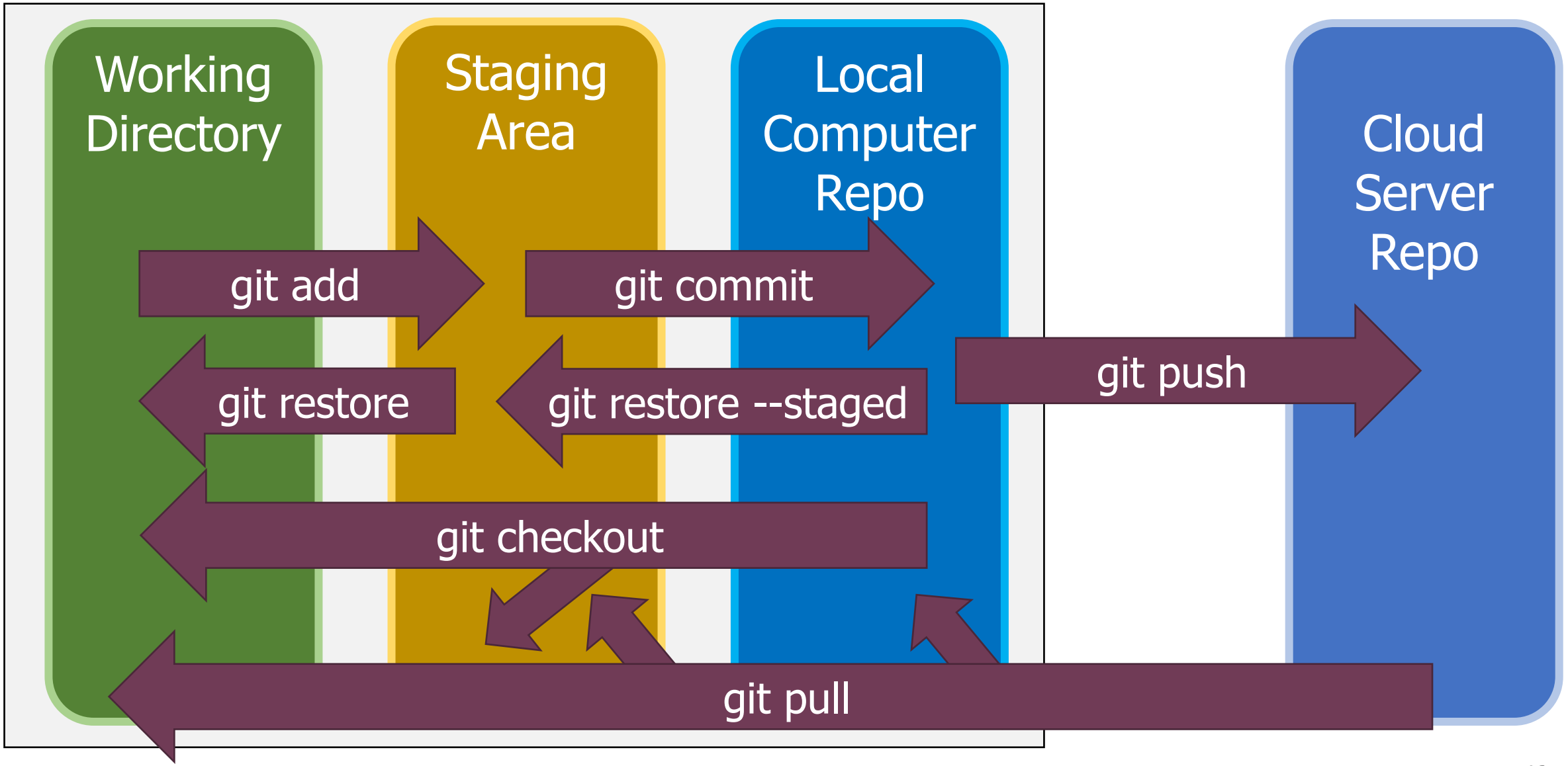


Overview of moving files



Break + Question: how would I share a new file with everyone?



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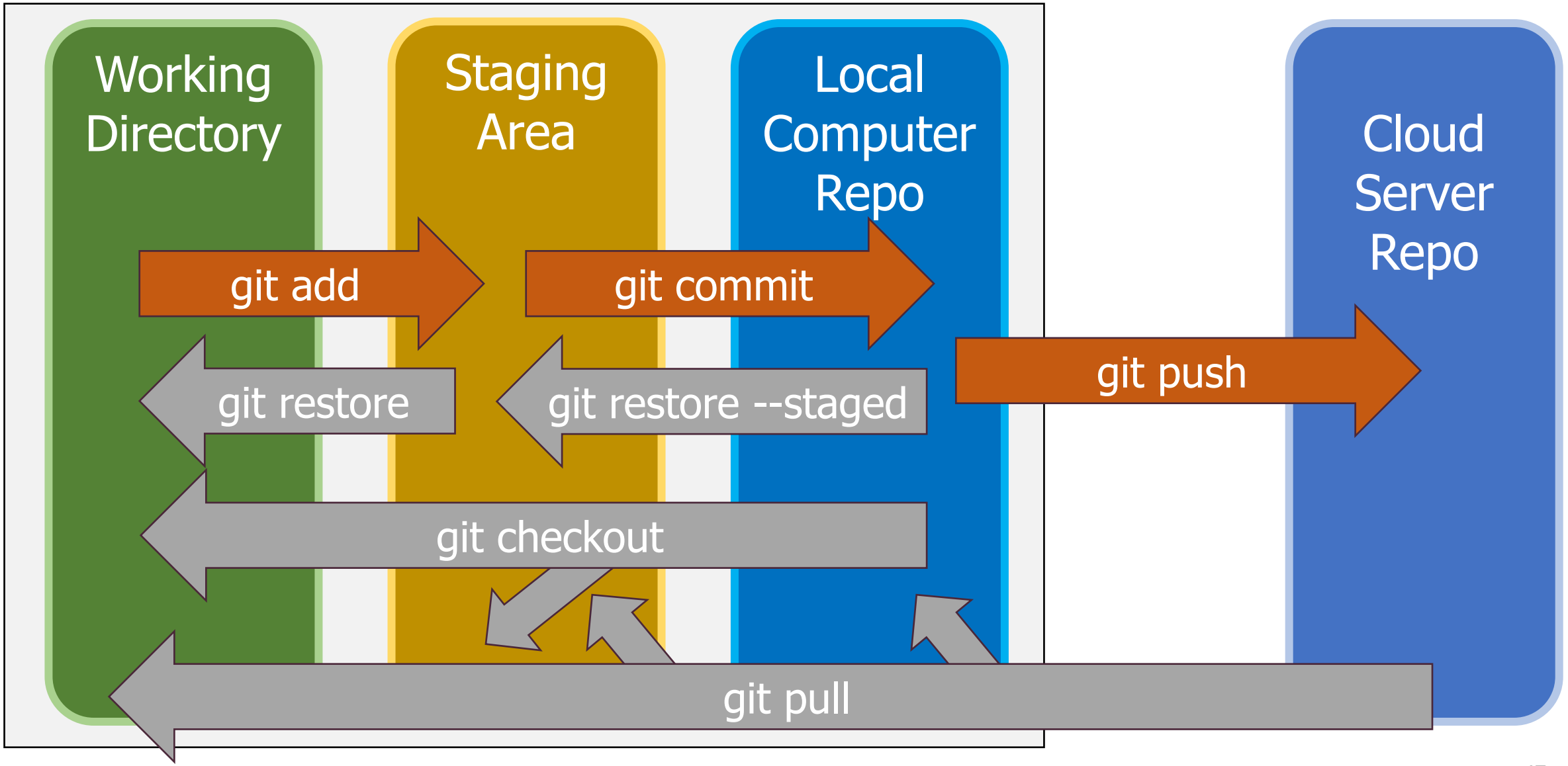

Keeping your file revisions safe

- Many of these commands will fail rather than overwrite changes in your working directory or staging area

- Exception: `git restore` will overwrite whatever is in your Working Directory with the version from the Staging Area

Other important commands

- `git clone`
  - Makes a local repo that's a copy of some remote server repo

- `git status`
  - Lists all modified Working Directory files
  - Lists all files currently in the Staging Area

- `git diff`
  - Lists all modifications from the Staging Area for all files
  - `git diff FILE` lists differences for a single file

Other important commands

- `git branch`
  - Creates a new branch with a parent of the current commit

- `git checkout`
  - Changes which commit or branch is the current one

- `git log`
  - Lists commit history previous to the current commit
  - `git log -N` lists details from the last N commits

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What is Github?

- A website that hosts remote repos
  - Can be the one shared cloud repo that everyone pulls from and pushes to
  - Could just be a copy of that repo for public access

- There are many websites that provide this
  - Github
  - Bitbucket
  - Gitlab

- Often provide additional features as well
  - Viewing history of the repo in a GUI
  - Managing community input about a project

Public and Private Repos

- A repo hosted by Github can be Public or Private
  - Public repos are accessible by anyone
  - Private repos are accessible by only specified users

- Generally, want to make repos Public if possible
  - That's how you share neat work with others and build off their work

- Specifically, make sure any class files are in Private repos
  - Otherwise, you could be accused of academic dishonesty

Pull Requests

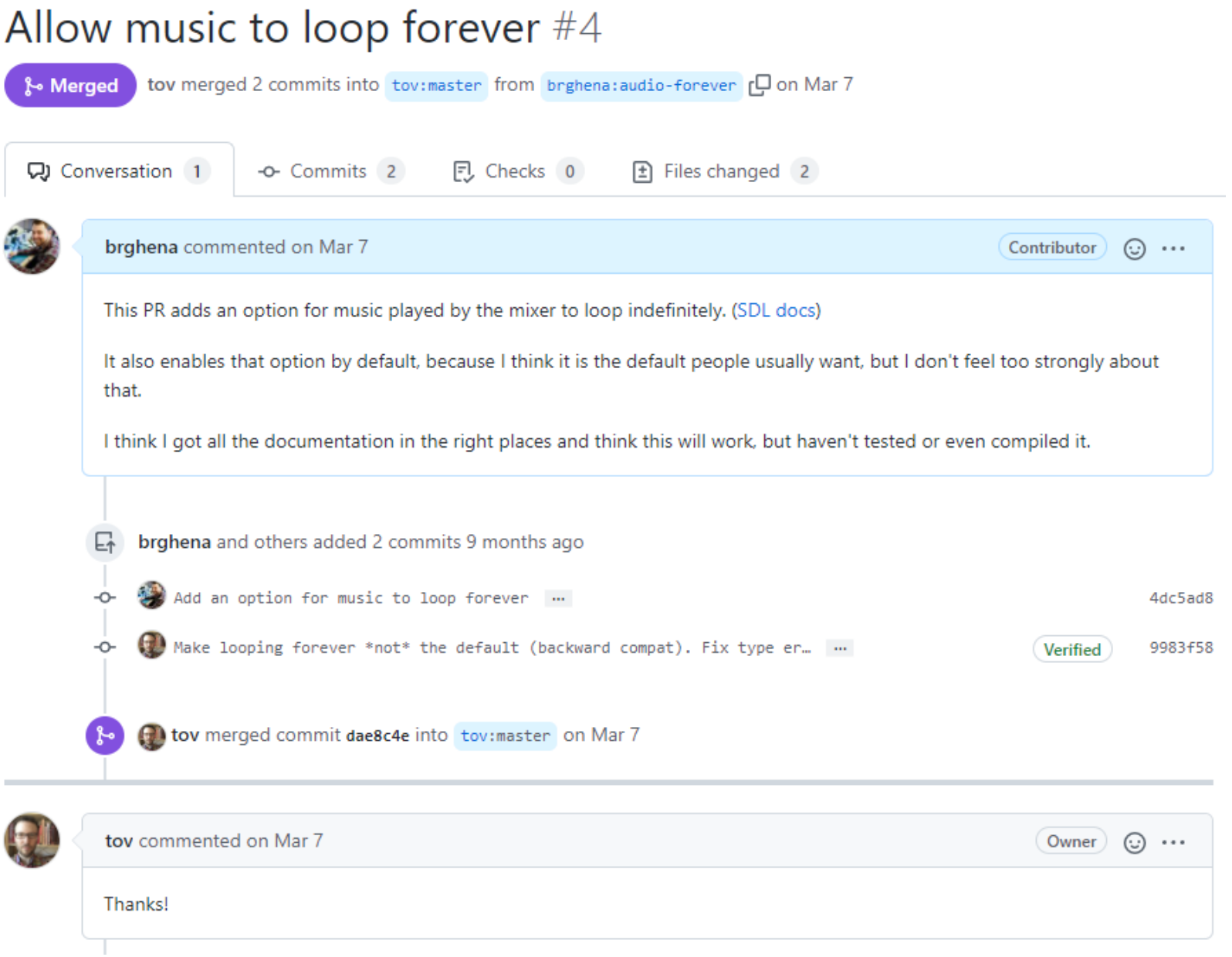
- Pull Requests are a feature of hosting websites
  - Literally: a request for the remote repo to pull from your copy

- Repo maintainers can review pull requests, comment on them, make changes, and eventually pull them to add the commits to their project

- These are how you contribute to open source projects
  1. Copy their repo
  2. Make changes to it
  3. Pull request so they can get your changes

Example Pull Request

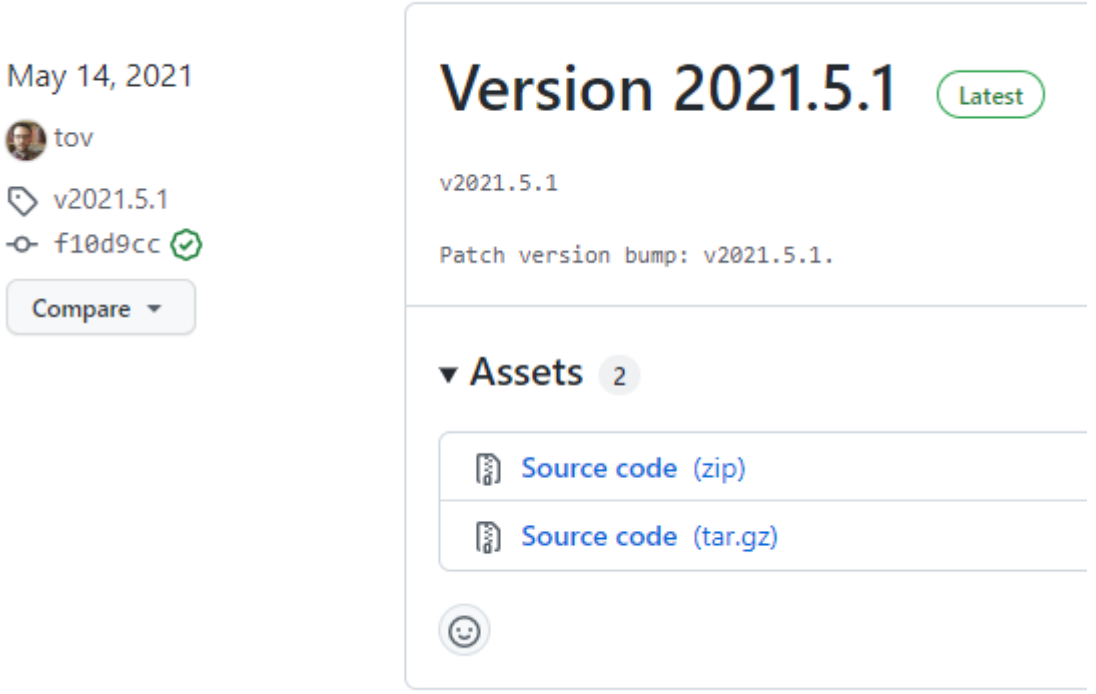
- Adds a commit and explains why it is useful
- Maintainer adds their own commit and then merges



https://github.com/tov/ge211/pull/4

Github also hosts releases

- A release is
  - A tagged commit
  - Plus the built files that you want to distribute
- Users can clone the repo and checkout the code for that particular release
- Or, they can just download the pre-compiled files



https://github.com/tov/ge211/releases

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Pull often

- Especially when working on group projects
  - Don’t want to be working with old versions of the files
  - Might end up fixing the same bug someone else already did

- Helps to avoid conflicts
  - If you’re working on the most up-to-date version of a file, you’ll only conflict if someone else modifies it while you do

Commits should be a sensible unit

- Commits should include every file related to a change
  - And should NOT included files with unrelated changes

- The goal is that any commit is valid and compiles
  - Otherwise collaborators will get upset when they pull…

- Advanced users can re-write commits to combine or split them allowing them to fix this later
  - Git has all kinds of crazy features for rewriting local history before sending up to the remote repo

Don’t commit generated files

- Source code and build system should be committed

- Built artifacts should not be committed
  - .o files
  - Executables
    - Any user can regenerate them whenever they are needed

  - Non-text files don’t play well with version control
    - Can only detect if anything changed, not what
    - Often hard to compress

Use .gitignore files

- Enable you to list which files should NEVER be committed
  - Example from one of my repos:
    - build/
    - *.pdf
    - *.tgz
    - .DS_Store
    - *~
    - .idea/
- Definitely use these to keep accidents from happening

Don’t force anything

- If the version control system doesn’t let you do something, there’s usually a good reason

- Example: you cannot push commits that don’t align with the history of the branch in the remote repo
  - Because that would mess things up for anyone else using it

  - If you know that no one else is using it, then you can force push to overwrite the old commits with the new ones

Git demo

- https://github.com/brghena/git-example

- Clone the repo
  - Check the log of commits
  - Diff what changed in those commits

- Make some modifications
  - Demonstrate adding and restoring

- Commit files

- Push changes

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