Introduction to Version Control Systems 1

DATA 4010 Seminar – Fall 2024

Stefano Ansaloni

University of Manitoba

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Digital Research Alliance of Canada

About me

Stefano Ansaloni

Cloud Computing Specialist at University of Manitoba
(part of the Advanced Reasearch Computing team)

Software Developer and DevOps Specialist since 2017

Linux User/Admin since 2005

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What is a version control system?

From Wikipedia (Version Control):

> *Version control (also known as revision control, source control, or source code management) is a class of systems responsible for managing changes to computer programs, documents, large web sites, or other collections of information.*

Brief History Of Version Control Systems

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Revision Control System (RCS)

- First release in 1982
- Latest stable release in 2022
- Operates only on single files
- Only one user can work on a file at a time
- No network support

Wikipedia [Revision Control System]

History

Concurrent Versions System (CVS)

- First release in 1990
- Latest stable release in 2008
- Based on RCS (front-end to RCS)
- Repository-level change tracking
- Client-server model

Wikipedia [Concurrent Versions System]

Subversion (SVN)

- First release in 2000
- Latest stable release in 2023
- Commits as true atomic operations
- Repository-level change tracking
- Path-based authorization

History

Git

- First release in 2005
- Latest stable release in 2024
- Distributed approach
- Non-linear workflows
- Safeguards against corruption (accidental or malicious)

Wikipedia [Git]

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Distributed VS Centralized

Distributed VCS	Centralized VCS
peer-to-peer approach	client-server approach
users can work offline	users need access to the central server
local copies can function as remote backups	central server is a single point of failure
complete codebase (including full history) mirrored locally	only requested revision mirrored locally
slower initial checkout	faster initial checkout
more storage required	less storage required

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Wikipedia [Distributed revision control]

Workflow Examples For Version Control Systems

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Centralized Workflow

One central hub (or repository) can accept code, and everyone synchronizes their work with it.

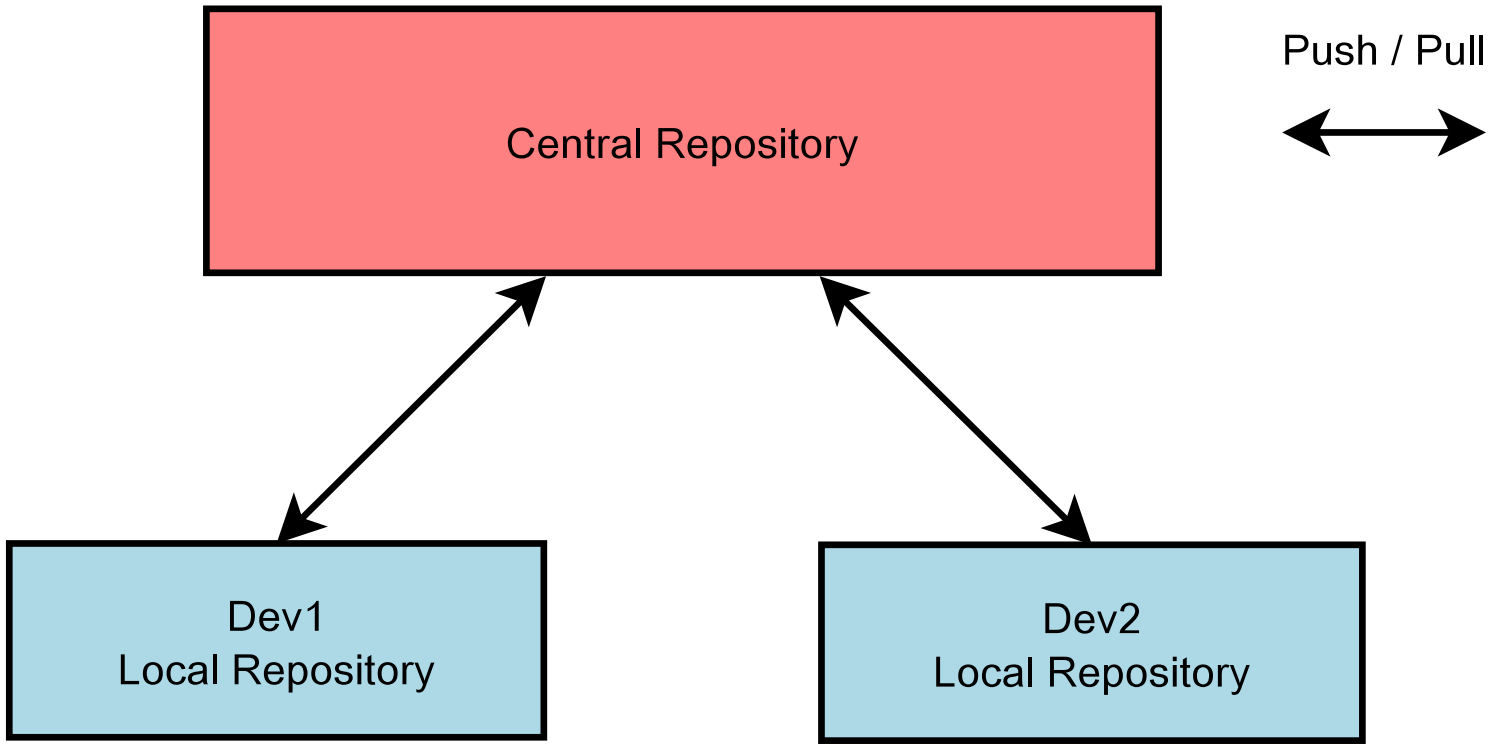
The repository is usually accessed through a network connection to ease the code sharing among the developers.

If two developers clone from the hub and both make changes, the first to push the changes to the repository can do so with no problems.

The second developer must merge in the first one's work before pushing the local changes.

Workflow examples

Centralized Workflow



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Integration-Manager Workflow

The project maintainer creates the official repository.

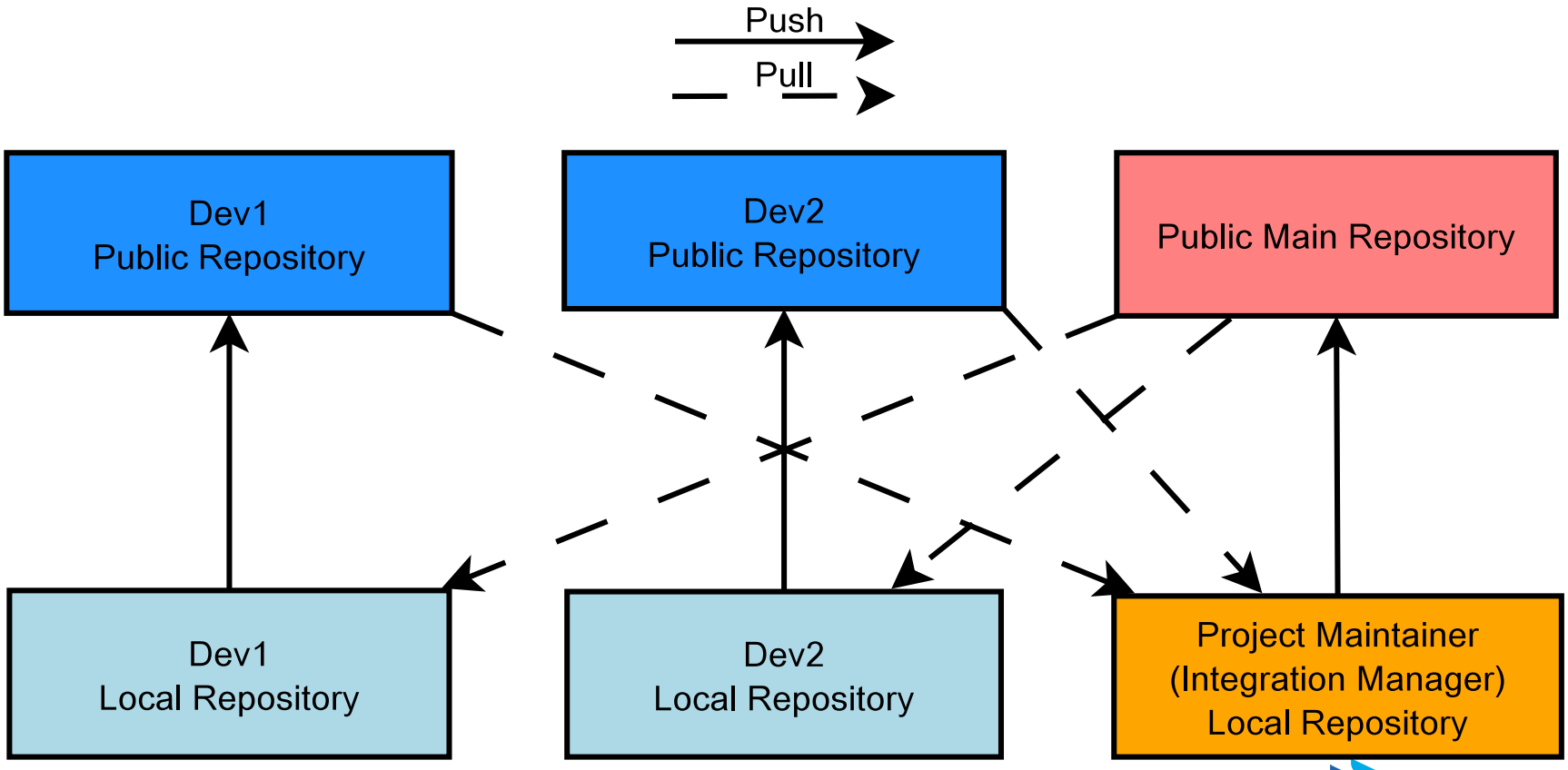
Developers create public clones of the official repository, and start adding changes.

When a developer is done, sends a pull-request to the project maintainer.

The maintainer reviews the changes and decides whether to merge them or not into the official repository.

Workflow examples

Integration-Manager Workflow



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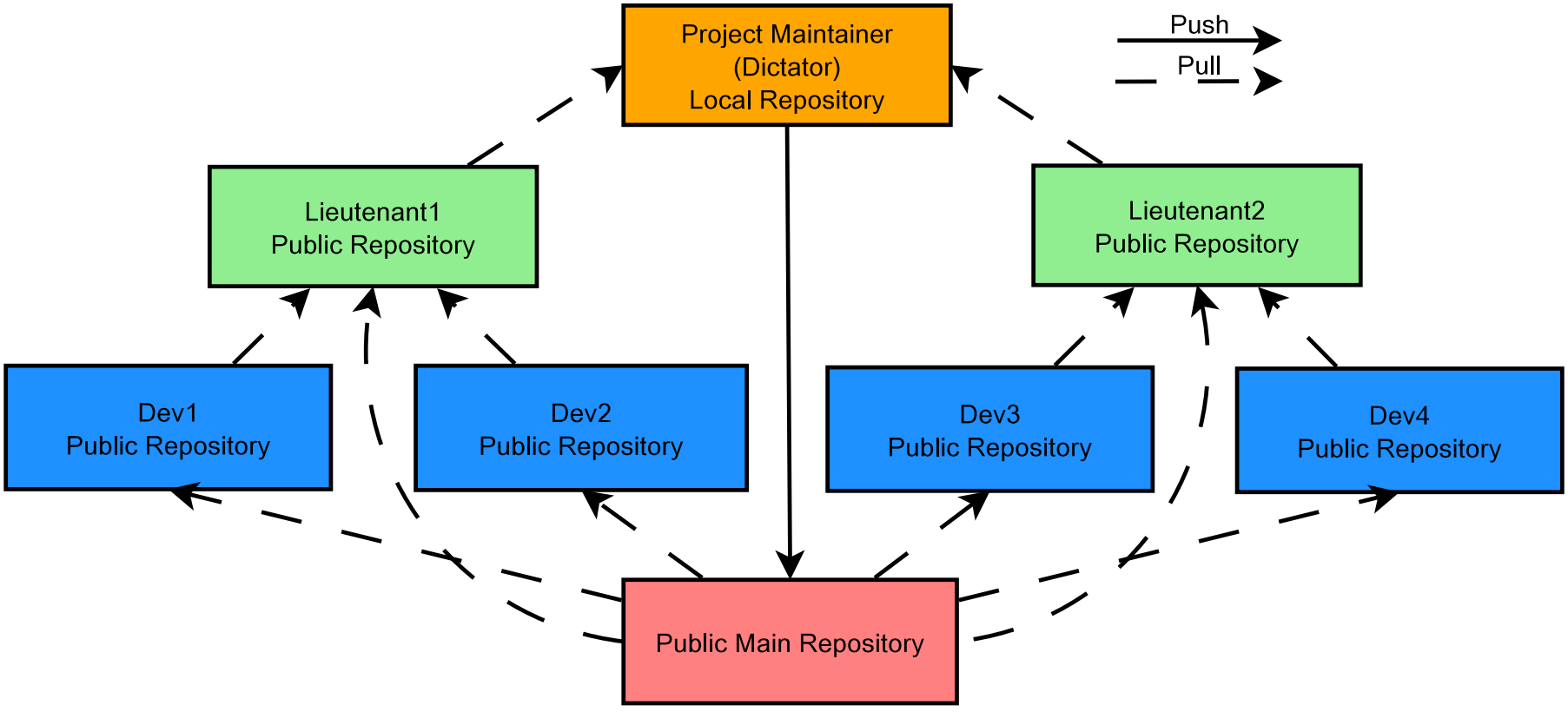
Dictator and Lieutenants Workflow

This is a variant of the Integration-Manager workflow, where a second level of "integration-managers" is added.

This workflow is usually adopted for huge projects with hundreds (or thousands) of collaborators.

Workflow examples

Dictator and Lieutenants Workflow



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Version Control Systems
Building Blocks

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What is a repository?

A *repository* is a data structure that stores metadata for a set of files or directory structure.

The main purpose of a *repository* is to store information about a set of files, as well as the history of changes made to those files.

In the case of Git, the whole set of information is duplicated on every user's system.

Wikipedia [Repository]

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What is a working copy?

The *working copy* (or *working tree*) is the local copy of files from a repository, at a specific time or revision.

All work done to the files in a repository is initially done on a *working copy*, and for this reason it could be seen as a sandbox.

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Wikipedia [Version control system - Working copy]

What is a commit?

A *commit* (or *revision*) is a set of alterations packaged together, along with meta information about those alterations.

It describes the exact differences between two successive versions in the version control system's repository of changes.

Commits are typically treated as an atomic unit.

Wikipedia [Changeset]

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What is a commit operation?

A *commit operation* is an action which saves the changes made on the working copy to the repository, creating a new revision of the repository.

Wikipedia [Commit]

What is a tag?

A *tag* is a textual label that can be associated with a specific commit.

This allows to define a meaningful name to be given to a particular state of the project.

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Wikipedia [Revision tag]

What is a branch?

A *branch* is a duplicated set of files that allows the two copies of those files to be independently developed at different speeds, or in different ways.

Wikipedia [Branching (version control)]

What is a merge operation?

A *merge operation* (or *merging*) is the action of reconciling multiple changes made to a set of files.

Usually, this is necessary when one or more files are modified on two independent branches.

The result is a single collection of files that contains both sets of changes.

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Wikipedia [Merge (version control)]

What is a rebase operation?

A *rebase operation* (or *rebasing*) is the action of importing changes from a different branch, and reapply current branch commits on top of those.

Depending on the control version system used, the *rebase operation* could change the commit history of the current branch.

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Wikipedia [Rebasing]

Focusing On Git

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Git – What is a remote?

A *remote* (or *remote repository*) is a copy of a local repository hosted on the Internet or network somewhere.

Remote repositories are used to ease the collaboration between multiple developers by pushing and pulling data to and from them when they need to share work.

Git – What is the staging area?

The *staging area* is a place to record files before committing them.

All (and only) files inside the *staging area* will be taken into account when creating a commit.

Git – What is a stash?

A *stash* is a state of the working directory (i.e. the modified files) that has been recorder in a special Git stack of unfinished changes.

This can be useful to avoid committing half-done work, when temporarily working on a different part of the project/code.

It is possible to have multiple *stashes*, and apply them individually at any time on any branch.

Git – What is a branch? (again)

Two possible definitions:

1. a name for a particular commit and all the commits that are ancestors of it
2. a line of development (or better: a directed acyclic graph (DAG) of development, where the commits represent the graph's nodes)

A *branch* can be local (if it exists in a local repository), remote (if it exists on a configured remote), or both.

Git – What is a tag? (again)

A *tag* is a reference that points to a specific commit.

The pointed commit never changes (no further history of commits).

A *tag* is like a branch that does not change.

Git – Credential storage

When interacting with remote repositories, you could be asked to provide some sort of credentials in order to access those.

For simple cases (i.e. when only a username and password is needed), this can be managed directly by Git.
However, an increasing number of online services is moving to multifactor authentication systems.

To handle that type of authentication, you could use an external Git credential system like *Git Credential Manager* (available at https://github.com/git-ecosystem/git-credential-manager).

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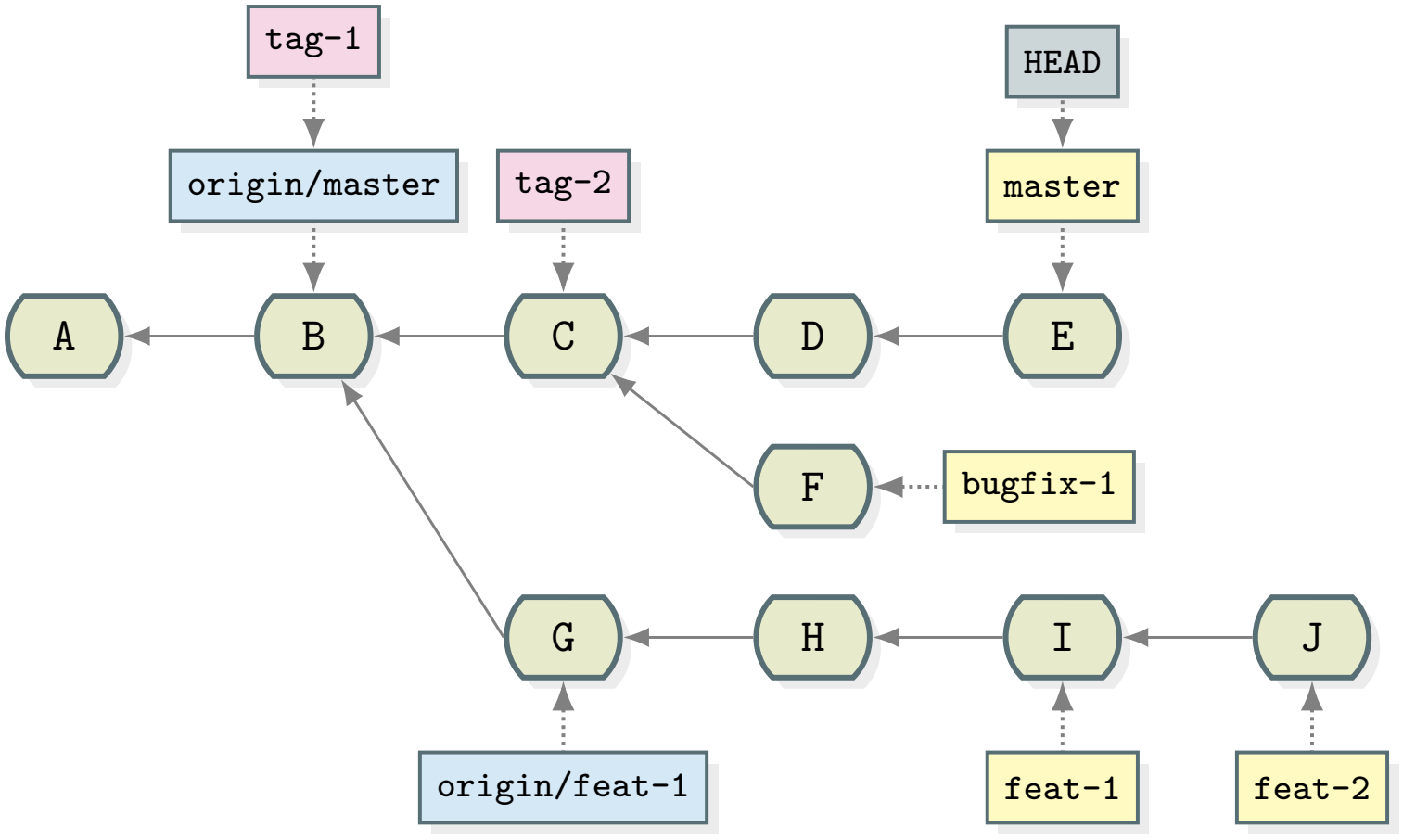
Git examples

Branches



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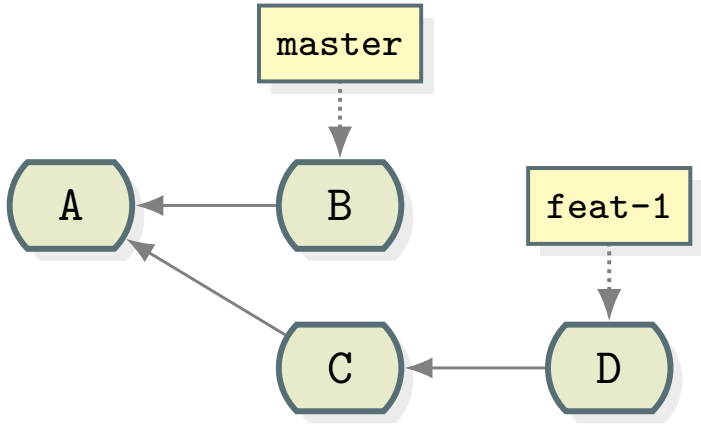
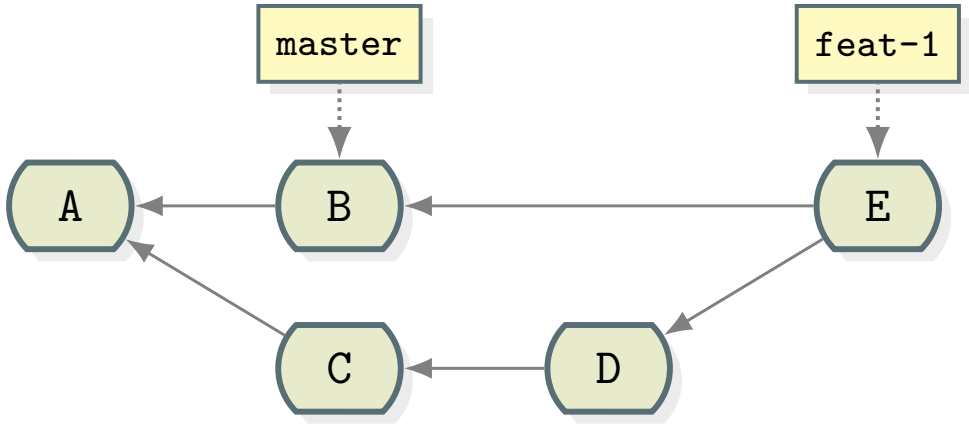
Git examples

Merge



Before merge



After merging `master` into `feat-1`

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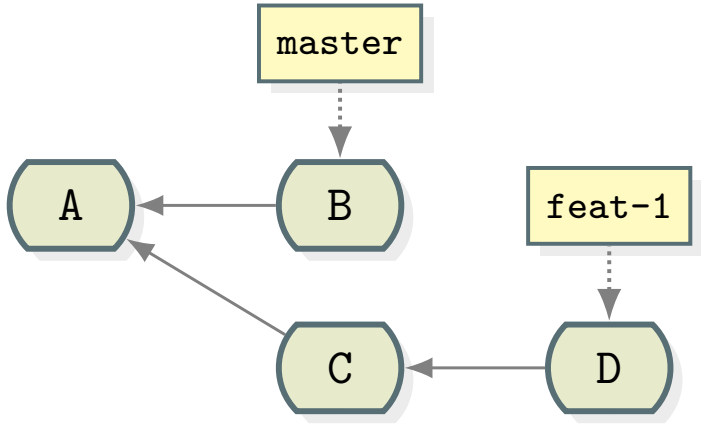
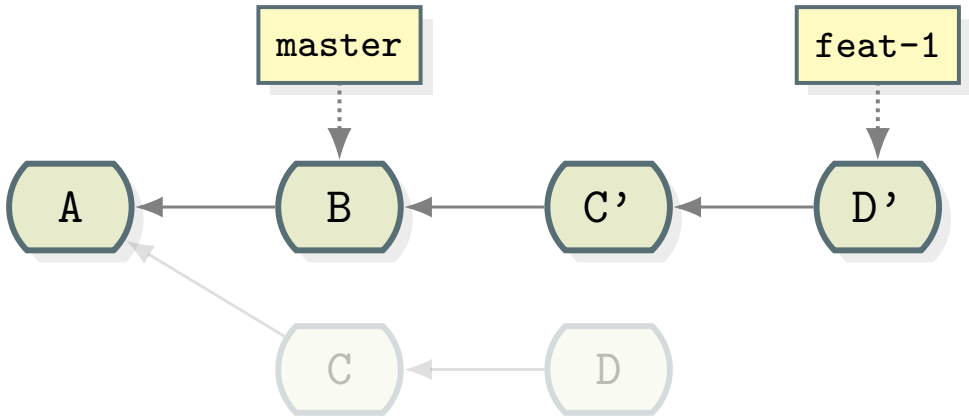
Git examples

Rebase



Before rebase



After rebasing `feat-1` onto `master`

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Workflow Examples For Git

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Git – Workflow Examples

Gitflow

Gitflow is a Git branching model that involves the use of feature branches and multiple primary branches for production releases.

Gitflow has numerous, long-lived branches and (sometimes) large commits.

Under this model, developers create a feature branch and delay merging it to the main branch until the feature is complete.

These long-lived feature branches require more collaboration to merge and have a higher risk of introducing conflicting updates.

Vincent Driessen [A successful Git branching model]
Atlassian [Gitflow workflow]

Git – Workflow Examples

Trunk-based development

Trunk-based development is a version control management practice where developers merge small, frequent updates to a main branch.

It streamlines merging and integration phases, helping to achieve continuous integration.

Trunk-based development increases software delivery and organizational performance.

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Atlassian [Trunk-based development]

Git Commands

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Creating a Git repository

To create a new local Git repository, move to the desired directory and execute "`git init`" (this will create an empty Git repository in the current directory).

If you want to create a local copy of a remote repository, you can use "`git clone <remote_url> [<local_dir>]`".

Checking the status of a Git repository

To determine which files are in which state within a Git repository, you can use "`git status`".

```
user@host:~/repo$ git status
On branch master

No commits yet

nothing to commit (create/copy files and use
    "git add" to track)
```

Adding files to a Git repository

By default Git does not keep track of newly added files.

```
user@host:~/repo$ touch file1
user@host:~/repo$ git status
On branch master

No commits yet

Untracked files:
  (use "git add <file>..." to include in what will be
      committed)
  file1

nothing added to commit but untracked files present
    (use "git add" to track)
```

Adding files to a Git repository

To add a new file to a Git repository you can use "git add <filename_or_directory>".

```
user@host:~/repo$ git add file1
user@host:~/repo$ git status
On branch master

No commits yet

Changes to be committed:
  (use "git rm --cached <file>..." to unstage)
  new file:   file1
```

Adding commits to a Git repository

To add a new commit to a Git repository, the staging area must not be empty, then you can use "`git commit`" to commit the changes.

```
user@host:~/repo$ git commit -m "Initial commit"
[master (root-commit) 99fca70] First commit
 1 file changed, 0 insertions(+), 0 deletions(-)
 create mode 100644 file1
user@host:~/repo$ git status
On branch master
nothing to commit, working tree clean
```

Viewing commits history of a Git repository

To show the history of a repository, you can use "`git log`".

```
user@host:~/repo$ git log
commit 99fca709626fc96ac1c2f744f5f3b25feaf542c6 (HEAD
    -> master)
Author: Name Here <email_here@example.org>
Date:   Sun Jan 1 00:00:00 2023 -0500

    First commit
```

Unstaging files in a Git repository

If you mistakenly added a file to the staging area, you can remove it using "`git reset <filename>`", or "`git restore --staged <filename>`".

```
user@host:~/repo$ git status
On branch master
Changes to be committed:
  (use "git restore --staged <file>..." to unstage)
  modified:   file1
  new file:   file2
user@host:~/repo$ git reset file1
Unstaged changes after reset:
M file1
```

Restoring files in a Git repository

To restore a file to a previous commit, you can use "git checkout <ref> -- <filename>", or "git restore -s <ref> <filename>".

```
user@host:~/repo$ git log --oneline
546bb0c (HEAD -> master) Second commit
99fca70 First commit
user@host:~/repo$ git checkout 99fca70 -- file1
user@host:~/repo$ git status
On branch master
Changes to be committed:
  (use "git restore --staged <file>..." to unstage)
  modified:   file1
user@host:~/repo$ git restore --staged file1
user@host:~/repo$ git restore file1
```

Stashing files in a Git repository

To stash the current working tree changes, you can use "`git stash`".

```
user@host:~/repo$ git status
On branch master
Changes not staged for commit:
  (use "git add <file>..." to update what will be committed)
  (use "git restore <file>..." to discard changes in working
       directory)
  modified:   file1

no changes added to commit (use "git add" and/or "git commit
     -a")
user@host:~/repo$ git stash
Saved working directory and index state WIP on master: 546
    bb0c Second commit
user@host:~/repo$ git stash list
stash@{0}: WIP on master: 546bb0c Second commit
```

Stashing files in a Git repository

To apply a stash, you can use
"`git stash apply <stash_ref>`", or
"`git stash pop <stash_ref>`" (to also delete the stash).

```
user@host:~/repo$ git stash list
stash@{0}: WIP on master: 546bb0c Second commit
user@host:~/repo$ git stash pop stash@{0}
On branch master
Changes not staged for commit:
  (use "git add <file>..." to update what will be committed)
  (use "git restore <file>..." to discard changes in working
       directory)
  modified:   file1

no changes added to commit (use "git add" and/or "git commit
     -a")
Dropped refs/stash@{0} (
    c8b6181cb502f8a6b372c9c381c22d5b47751571)
```

Managing branches in a Git repository

To list, create, or delete branches you can use "`git branch`".

To switch branch you can use "`git checkout <branch_name>`", or "`git switch <branch_name>`".

```
user@host:~/repo$ git branch
* master
user@host:~/repo$ git branch new-branch
user@host:~/repo$ git branch
* master
  new-branch
user@host:~/repo$ git switch new-branch
Switched to branch 'new-branch'
user@host:~/repo$ git branch
  master
* new-branch
user@host:~/repo$ git switch master
user@host:~/repo$ git branch -d new-branch
Deleted branch new-branch (was 99fca70).
```

Merging branches in a Git repository

To merge two branches, you can use "git merge <src_branch_name>".

```
user@host:~/repo$ git switch -c fix
Switched to a new branch 'fix'
user@host:~/repo$ touch file2
user@host:~/repo$ git add file2
user@host:~/repo$ git commit -am "Important fix"
[fix c87f330] Important fix
 1 file changed, 0 insertions(+), 0 deletions(-)
 create mode 100644 file2
user@host:~/repo$ git switch master
Switched to branch 'master'
user@host:~/repo$ git merge fix
Updating 546bb0c..c87f330
Fast-forward
 file2 | 0
 1 file changed, 0 insertions(+), 0 deletions(-)
 create mode 100644 file2
```

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Rebasing branches in a Git repository

To rebase a branch onto another, you can use "git rebase <other_branch_name>".

```
user@host:~/repo$ git branch fix2
user@host:~/repo$ touch file3
user@host:~/repo$ git add file3
user@host:~/repo$ git commit -am "New file"
[master 23943fb]] New file
 1 file changed, 0 insertions(+), 0 deletions(-)
 create mode 100644 file3
user@host:~/repo$ git switch fix2
Switched to branch 'fix2'
user@host:~/repo$ git rebase master
Successfully rebased and updated refs/heads/fix2.
```

Managing remotes in a Git repository

To list, create, or delete remotes you can use "`git remote`".

Usually Git commands use "*origin*" as default remote name when no specific configuration is present.

```
user@host:~/repo$ git remote
user@host:~/repo$ git remote add src-git https://
    github.com/git/git.git
user@host:~/repo$ git remote
src-git
user@host:~/repo$ git fetch src-git
...
user@host:~/repo$ git branch -r
  src-git/master
  src-git/next
  src-git/todo
...
user@host:~/repo$ git remote remove src-git
```

Synchronizing changes from/to a remote in a Git repository

To download changes from a remote, you can use "`git fetch <remote_name>`" (a "`git merge`", or "`git rebase`" is needed to update the local branch).

To upload changes to a remote, you can use "`git push <remote_name> <branch_name>`".

```
user@host:~/repo$ git fetch src-git
remote: Enumerating objects: 354353, done.
remote: Counting objects: 100% (913/913), done.
remote: Compressing objects: 100% (913/913), done.
remote: Total 354347 (delta 0)              <...>
Receiving objects: 100% (354347/354347)   <...>
Resolving deltas: 100% (266375/266375), done.
From https://github.com/git/git
 * [new branch]     master     -> src-git/master
 * [new branch]     next       -> src-git/next
 * [new branch]     todo       -> src-git/todo
 * [new tag]        v2.46.1    -> v2.46.1
...
```

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Synchronizing changes from/to a remote in a Git repository

If the current branch is set up to track a remote branch, you can use "`git pull`" to automatically synchronize your local branch with the remote branch.

Depending on the configuration, "`git pull`" will fetch the remote branch and (choose one):

- merge it into the current local branch
- rebase the current local branch onto it

In the end, your local branch will include all the commits that are present in the remote branch.

Commit and tag messages

Sometimes Git will ask you for a message as part of the action you requested.

In those occasions, you will be presented with a text editor.

Unfortunately, Git may choose a default text editor that is unexpected or unintuitive.

Editor	Enter Insert Mode	Exit Insert Mode	Save File	Exit Editor	Show Help
Vim	i	Esc	:w	:q	:h or F1
Nano			Ctrl + o	Ctrl + x	Ctrl + g

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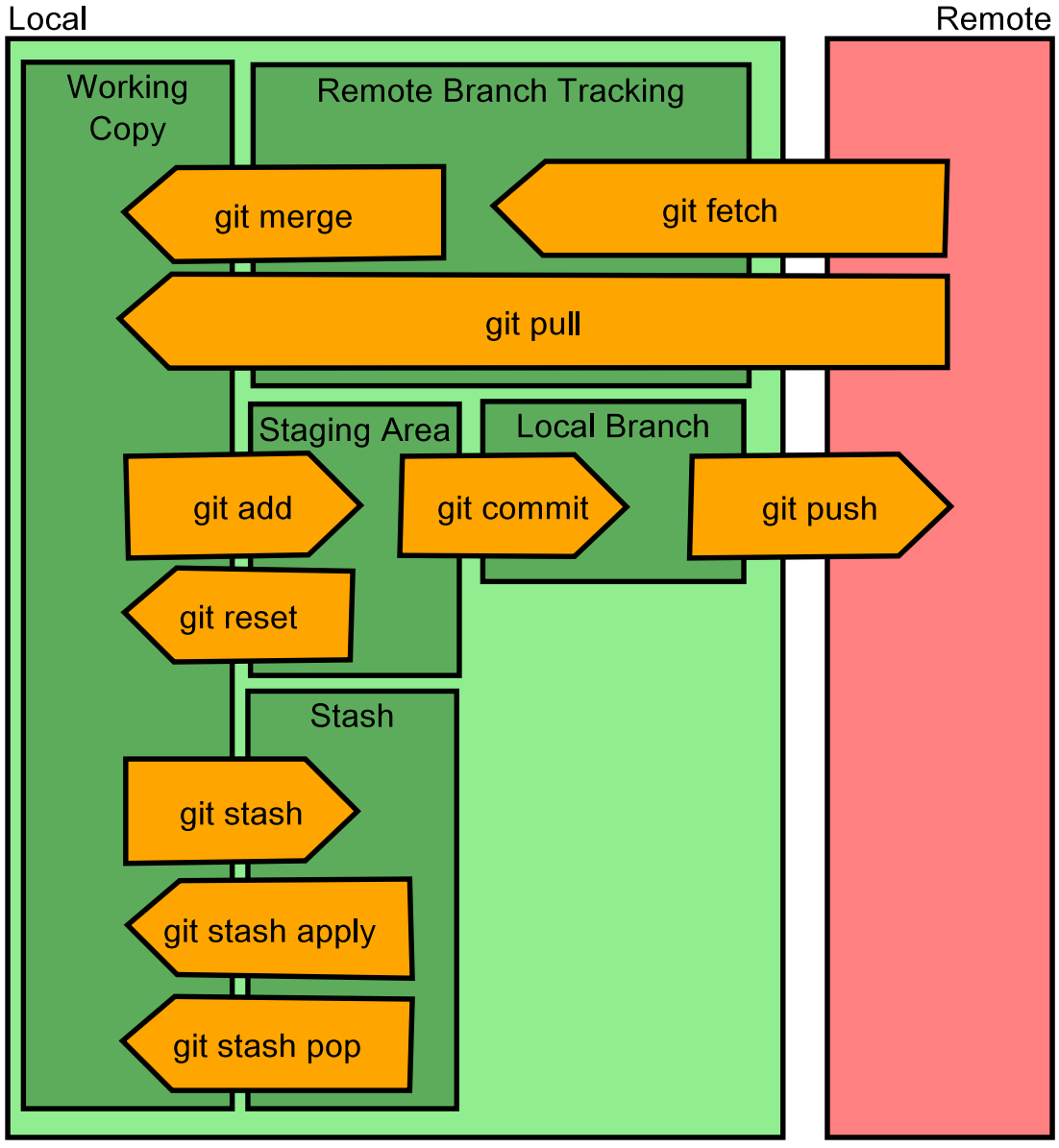
Pro Git book [8.1 Customizing Git - Git Configuration]

Git cheat-sheet



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Git GUI clients

Free, open-source, multiplatform (Windows, Mac, Linux):

- MeGit – https://github.com/eclipsesource/megit
- Gitnuro – https://github.com/JetpackDuba/Gitnuro
- Gittyup – https://github.com/Murmele/Gittyup

Free, open-source, multiplatform (Windows, Mac):

- GitHub Desktop – https://github.com/apps/desktop

Free, closed-source, multiplatform (Windows, Mac):

- Sourcetree – https://www.sourcetreeapp.com

Note: remember that the only real client is the "`git`" command line tool.

Useful links

- Official Git documentation: https://git-scm.com/doc
- "Pro Git" book (free): https://git-scm.com/book

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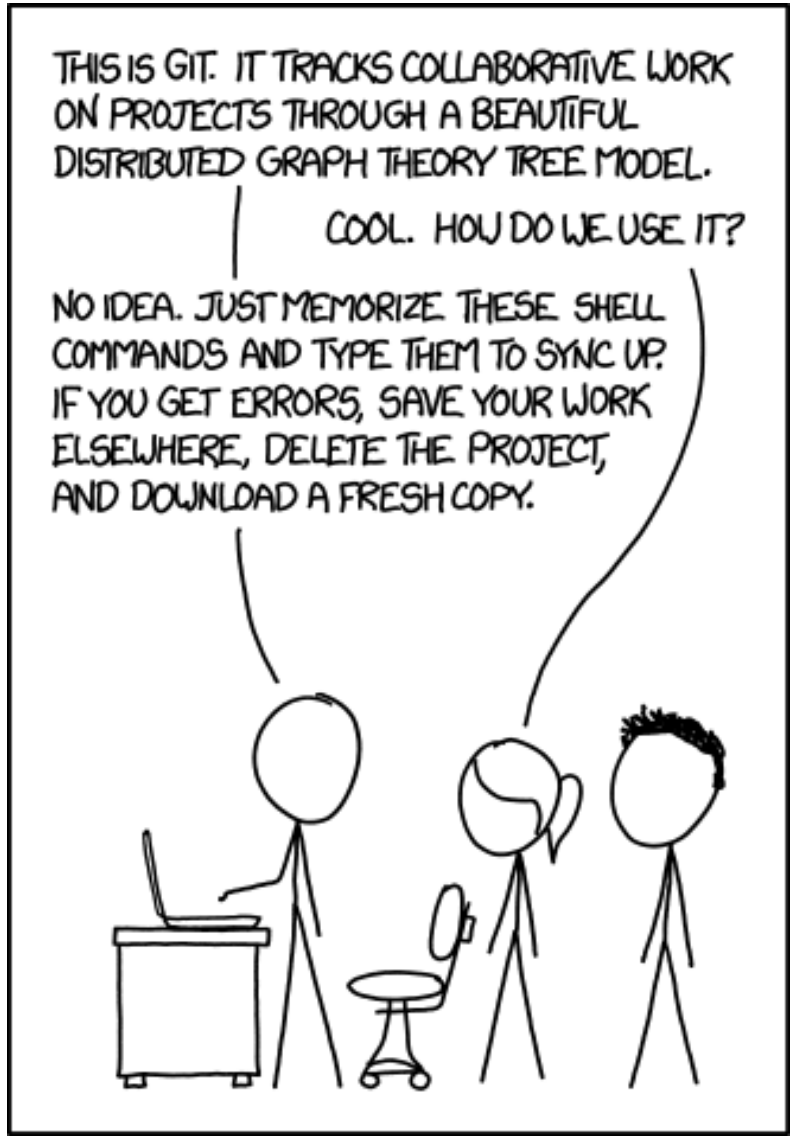

XKCD [1597]

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Questions?

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Thank you

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