Chair of Connected Mobility
TUM Department of Informatics
Technical University of Munich

Open Source Lab

Git Basics

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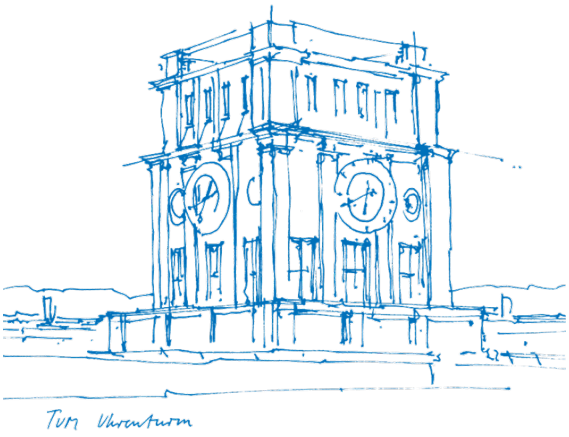


Credits

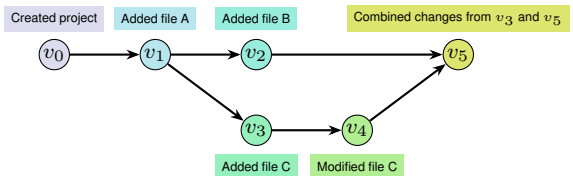
These slides are based on the awesome materials from:

Moritz Sichert (sichert@in.tum.de)
Michael Freitag (freitagm@in.tum.de)
} Systems Programming in C++ (Practical Course)

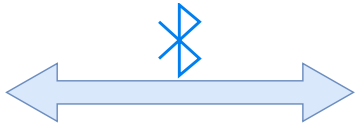
Pro Git book: https://git-scm.com/book

Version Control Systems (VCS)

- Code projects evolve gradually
- Incremental changes, also called *versions*, should be tracked to allow:
  - Documentation of the project history
  - Selective inspection/modification of specific versions
  - Efficient collaboration when working in a team
- A **V**ersion **C**ontrol **S**ystem (VCS) manages versions, usually represent them in a directed acyclic graph



A more concrete example. . .



A more concrete example...

```
int mo6312r(int i, int i2, int i3, int i4) {
  byte[] bArr = arr1;
  int i5 = i2 >> 4;
  return mo6308n(mo6308n((bArr[mo6308n((((arr2[mo6308n((((bArr[mo6308n((i + i2) + i3) % 16] + i4) +
       mo6308n(i5)) - i2) - i3) % 16] + i3) + i2) - i4) - mo6308n(i5)) % 16] - i2) - i3) % 16);
}
```

A more concrete example...

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  byte[] bArr = arr1;
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}
```

```
int mo6308n(int i) {
while (i > 255) {
  i += InDevComp.SOURCE_ANY; // -256
}
while (i < 0) {
  i += 256;
}
  return i;
}
```

- Looks like a fancy `mod256` for Java.
- So let's replace it...

A more concrete example...

```
int mo6312r(int i, int i2, int i3, int i4) {
  byte[] bArr = arr1;
  int i5 = i2 >> 4;
  return mod256(mod256((bArr[mod256((((arr2[mod256((((bArr[mod256((i + i2) + i3) % 16] + i4) + mod256(i5
      )) - i2) - i3) % 16] + i3) + i2) - i4) - mod256(i5)) % 16] - i2) - i3) % 16);
}
```

A more concrete example...

```
int mo6312r(int i, int i2, int i3, int i4) {
  byte[] bArr = arr1;
  int i5 = i2 >> 4;
  return mod256(mod256(bArr[mod256((((arr2[mod256(((bArr[mod256(i + i2 + i3) % 16] + i4) + mod256(i5) -
       i2) - i3) % 16] + i3) + i2) - i4) - mod256(i5)) % 16] - i2 - i3) % 16);
}
```

- Let's continue simplifying and remove parentheses...

A more concrete example...

```
uint8_t shuffle(int dataNibble, int nibbleCount, int keyLeftNibbel, int keyRightNibbel) {
  uint8_t i5 = mod256(nibbleCount >> 4);
  uint8_t tmp1 = numbers1[mod256(dataNibble + nibbleCount + keyLeftNibbel) % 16];
  uint8_t tmp2 = numbers2[mod256(tmp1 - keyRightNibbel + i5 - nibbleCount - keyLeftNibbel) % 16];
  uint8_t tmp3 = numbers1[mod256(tmp2 + keyLeftNibbel + nibbleCount - keyRightNibbel - i5) % 16];
  return mod256(tmp3 - nibbleCount - keyLeftNibbel) % 16;
}
```

- And now split it up and rename everything...

A more concrete example...

```
uint8_t shuffle(int dataNibble, int nibbleCount, int keyLeftNibbel, int keyRightNibbel) {
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  uint8_t tmp2 = numbers2[mod256(tmp1 - keyRightNibbel + i5 - nibbleCount - keyLeftNibbel) % 16];
  uint8_t tmp3 = numbers1[mod256(tmp2 + keyLeftNibbel + nibbleCount - keyRightNibbel - i5) % 16];
  return mod256(tmp3 - nibbleCount - keyLeftNibbel) % 16;
}
```

- And now split it up and rename everything...

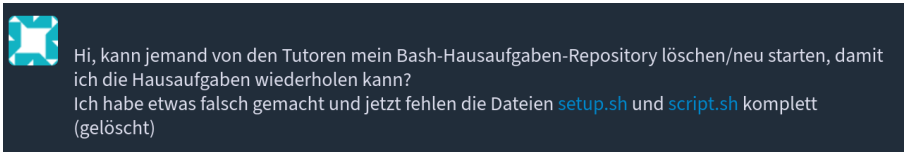
And then we notice, our tests do not produce the same results as the Java code any more.

What do we do now?
Reset and start over?
Spend hours debugging?

An other example

Hi, kann jemand von den Tutoren mein Bash-Hausaufgaben-Repository löschen/neu starten, damit ich die Hausaufgaben wiederholen kann?
Ich habe etwas falsch gemacht und jetzt fehlen die Dateien setup.sh und script.sh komplett (gelöscht)

An other example



He deleted his code and asks us whether we could reset it for him, so he could start over again.
But since he uses git, he can go back to any version of his code by himself.

- Many VCS exist, Git is a very popular one: Used by projects like Linux, GCC, LLVM, etc.
- Git in particular has the following advantages compared to other version control systems (VCS):
  - Open source (LGPLv2.1)
  - Decentralized, i.e. no server required
  - Efficient management of *branches* and *tags*
- All Git commands are document with man-pages (e.g. type `man git-commit` to see documentation for the command `git commit`)
- Pro Git book: https://git-scm.com/book
- Git Reference Manual: https://git-scm.com/docs

Git History

- Initiator Linus Torvalds
- Goals speed, ”simple” design, fully distributed, able to handle large projects, . . .
- git is British slang for ”pig headed, think they are always correct, argumentative”
- Quoting Linus ”I’m an egotistical bastard, and I name all my projects after myself. First ’Linux’, now ’Git’.”[1]

[1] https://git.wiki.kernel.org/index.php/GitFaq#Why_the_.27Git.27_name.3F
[2] https://marc.info/?l=git&m=117254154130732

Git History

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- Quoting Linus ”I’m an egotistical bastard, and I name all my projects after myself. First ’Linux’, now ’Git’.”[1]

- 1991-2002 Changes were passed as patches and archived files.
- 2002 The Linux kernel project began using a proprietary DVCS called BitKeeper.
- April 2005 The relationship between the commercial company behind BitKeeper and the Linux Kernel community broke down.
  - SourcePuller was created by reverse engineering the BitKeeper protocols.
  - Free use licence got withdrawn.

⇒ Linus Torvalds started working on an alternative, called git.

- 7. April 2005 git is self-hosted[2]

[1] https://git.wiki.kernel.org/index.php/GitFaq#Why_the_.27Git.27_name.3F
[2] https://marc.info/?l=git&m=117254154130732

Git Concepts

Tree: A collection of files (not directories!) with their path and other metadata. This means that Git does *not* track empty directories.

Commit: A snapshot of a *tree*. Identified by a SHA1 hash. Each commit can have multiple parent commits. The commits form a directed acyclic graph.

Branch: A named reference to a *commit*. Every repository usually has at least the `master` (`main`) branch and contains several more branches, like `fix-xyz` or `feature-abc`.

Tag: A named reference to a *commit*. In contrast to a branch a tag is usually set once and not changed. A branch regularly gets new commits.

Repository: A collection of Git objects (*commits* and *trees*) and references (*branches* and *tags*).

Creating a Git Repository

Create a new directory (home) for our repository and change into it.

```
mkdir myRepo && cd myRepo
```

Initialize a new Git repository.

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git init
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Set the name that will be used when creating a commit.*

```
git config --global user.name Firstname Lastname
```

Set the e-mail address that will be used when creating a commit.*

```
git config --global user.email first.last@in.tum.de
```

Shows the current status and information for this repository.

```
git status
```

*Required only for the first time you create a Repository.

Creating a Git Repository

```
$ git config --global user.name Firstname Lastname
$ git config --global user.email first.last@in.tum.de
$ mkdir myRepo && cd myRepo
$ git init
Initialized empty Git repository in /tmp/myRepo/.git/
$ git status
On branch main

No commits yet

nothing to commit (create/copy files and use "git add" to track)
$ ls -la # Show the contents of the directory
total 0
drwxrwxr-x. 3 user  user   60 Sep 7 13:16 .
drwxrwxrwt. 31 root root  780 Sep 7 13:35 ..
drwxrwxr-x. 7 user  user  200 Sep 7 13:16 .git
```

Cloning an existing Git Repository

Usually we do not want to start a new repository, instead we want to contribute to an existing one.
Creating a local copy (cloning) some remote repository.

```
git clone <remote>
```

Example cloning the `cpr` repository from GitHub.

```
git clone https://github.com/libcpr/cpr.git
Cloning into 'cpr'...
remote: Enumerating objects: 4969, done.
remote: Counting objects: 100% (557/557), done.
remote: Compressing objects: 100% (309/309), done.
remote: Total 4969 (delta 324), reused 356 (delta 224), pack-reused 4412
Receiving objects: 100% (4969/4969), 1004.03 KiB | 3.16 MiB/s, done.
Resolving deltas: 100% (3300/3300), done.
```

Branches

A branch is a named reference to a specific commit.

Gives you a list of all (local) branches and which is currently active.

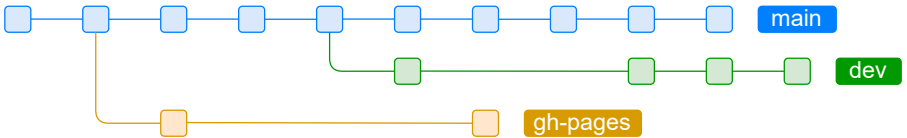
```
git branch
```

Create a new branch from the current commit.

```
git branch <name>
```

Switch to another branch, i.e. change all files in the working directory so that they are equal to the tree of the other branch.

```
git switch <name>
```



Tags

A named reference to a commit. In contrast to a branch, a tag is usually set once and not changed. A branch regularly gets new commits.

Gives you a list of all (local) tags.

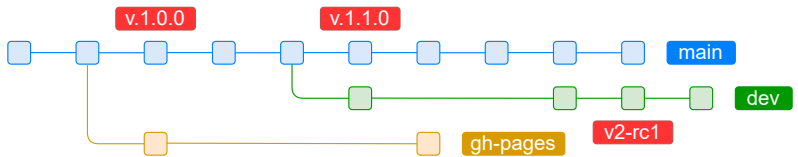
```
git tag
```

Create a new tag from the current commit. With the "-s" option you can sign it using a PGP key.

```
git tag [-s] <name>
```

Checkout the given tag. Be aware to make changes you need to create a branch first!

```
git checkout <tag>
```



Exercise

- Clone: https://gitlab.lrz.de/open-source-lab/git-demo-cpr
- Checkout tag: "1.8.2 "
- Create a new branch called: "1.8.3_yourName "
- Switch to the new branch.

Commits

A snapshot of a *tree*. Identified by a SHA1 hash. Each commit can have multiple parent commits. The commits form a directed acyclic graph.

Stages all changes inside the given file and starts tracking it in case it is not already being tracked.

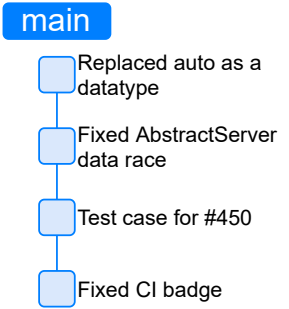
```
git add <file>
```

With this you can bundle all your `staged` changes (`git add`) to one commit with a commit message.
The "-S" option allows you to sign commits using a PGP key.

```
git commit [-S] -m "Some message"
```

This enables signing commits by default for all your repositories.

```
git config --global commit.gpgsign true
```



Commit Messages

A few guidelines for creating commits:

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Dos

- Commit early and often.
- Split up your work into atomic commits.
- Make commit messages meaningful.
- Subject should be less than 50 characters.
- Do not end the subject line with a ”.”
- Separate the subject and body by a blank line.

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Don’ts

Figure 1 ”Git Commit” by xkcd

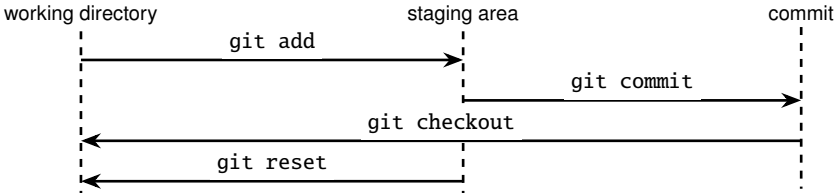
Funny, but not recommended: http://whatthecommit.com

Git Working Directory and Staging Area

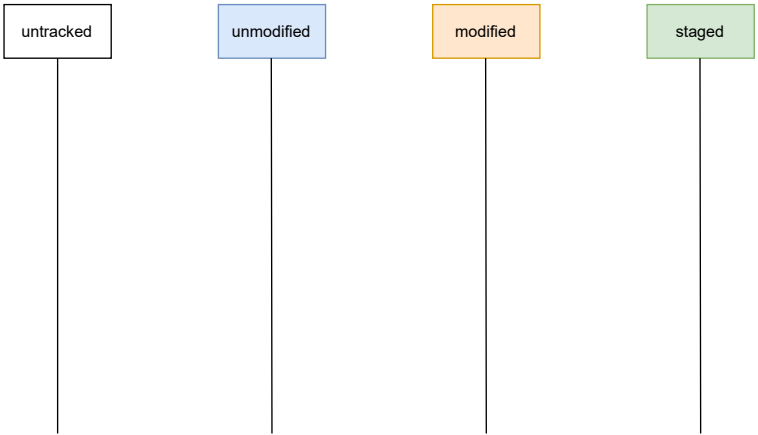
When working with a Git repository, changes can live in any of the following places:

- In the working directory (when you edit a file)
- In the staging area (when you use `git add`)
- In a commit (after a `git commit`)

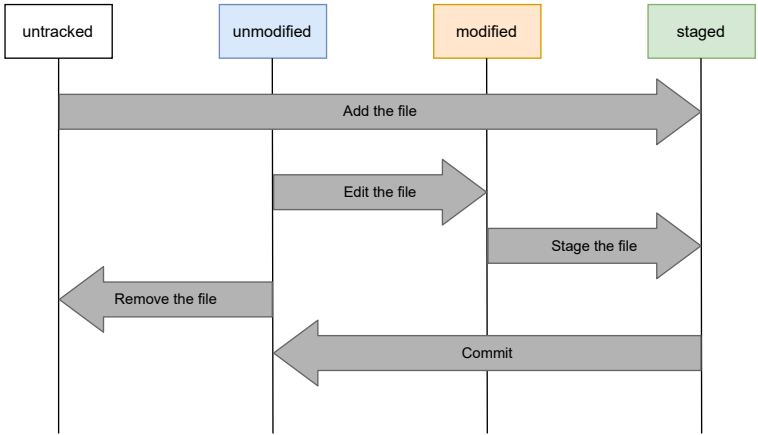
Once a change is in a commit and it is referenced by at least one branch or tag you can always restore (go back to) it, even if you remove the file.



Lifecycle of a File



Lifecycle of a File



History

Allows you to inspect the git commit history.
"`--online`" condenses every commit into one line.
"`--graph`" shows the git history as an ASCII graph

```
git log [--oneline] [--graph]
```

Example

```
$ git log --oneline --graph
*   bc2a09a (HEAD -> main) Merge branch 'feature-print'
|\
| * ad80c4c (feature-print) Fixed print helper new line
| * 7fce54f Added print helper framework
* | 17fdfab Added reader framework
|/
* 3783ea8 Added main call
```

Exercise

- Open the `README.md` file and replace "Fabian Sauter" with your name as a contributor.
- Create a commit with those changes.
- Take a look at the commit history using: `git log`

Pushing and Pulling

When working in a team, it is required to synchronize changes between the individual team members.
⇒ For this a remote repository is being used where everybody pushes its changes (commits) to.
Usually called "`origin`".

Upload the current branch to a remote repository.
⚠ "`-f`" force overrides the remote branch. Required in case you changed the git history (deleting commits/rebasing/...). Be extremely careful with this option!

```
git push [-f]
```

Retrieve the latest metadata from `origin` and check if there are changes available.

```
git fetch
```

Fetches changes from `origin` and merges/rebases them with your local changes.

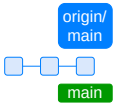
```
git pull [--rebase]
```

Enables rebasing instead of merging by default.

```
git config --global pull.rebase true
```

Push and Pull in Action

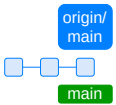
Local



Remote

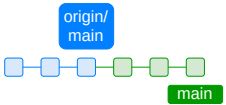
Push and Pull in Action

Local



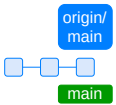
Remote

You create three new commits.



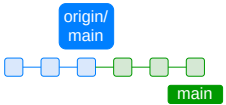
Push and Pull in Action

Local

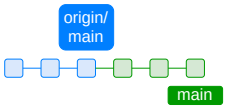


Remote

You create three new commits.



In the meantime, somebody else pushed two new commits to remote.



Push and Pull in Action

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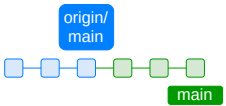
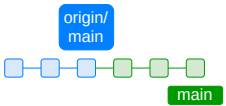


Remote

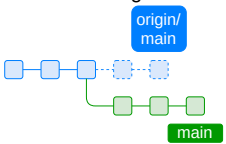
Push and Pull in Action

Local



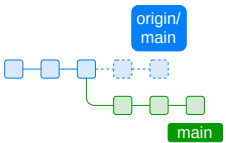
Remote

Fetch for changes from remote with `git fetch`



Push and Pull in Action

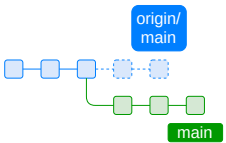
Local



Remote

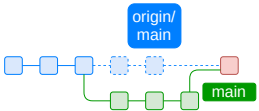
Push and Pull in Action

Local



Remote

To apply changes we have found with `git fetch`, we use `git pull`
By default this will merge changes and create a so called ”merge commit”.
In some cases, creating a merge commits is considered bad practice. More on that later...



Push and Pull in Action

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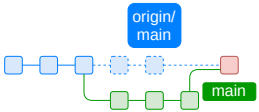
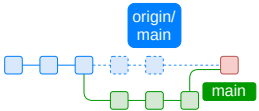


Remote

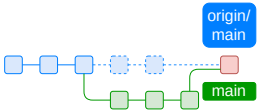
Push and Pull in Action

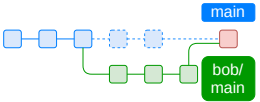
Local



Remote

To push our changes to remote, we use `git push`

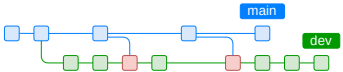




Now both, our local and remote branch have the same history and we are done.

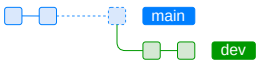
Merge and Rebase

To stay up to date with the changes in `main`, we merged them into our `dev` branch twice until now.
As a result we got two (red) merge commits, each with their own commit message.



This is considered bad practice. Instead we should rebase.


```
git rebase main
```



While a `merge` keeps your history, `rebase` will rewrite it for all commits in our `dev` branch!

Dealing with Merge Conflicts

Merge conflicts occur when git is unable to merge changes from two commits since both change the same lines in a file. They can happen when...

- merging a branch.
- rebasing a branch.
- cherry picking a commit.

Now **you** have to decide which code to keep!

Example

```
$ git merge feature-main
Auto-merging reader.cpp
CONFLICT (content): Merge conflict in reader.cpp
Automatic merge failed; fix conflicts and then commit the result.
```

Dealing with Merge Conflicts

Git changed the `reader.cpp` file in a way, so now have to decide what to keep.

```
<<<<<<< HEAD
int main(int /*argc*/, char** /*argv*/) { }
=======
int main(void) { }
>>>>>>> feature-main
```

Once we are done, we can commit our decision.

```
git commit -m "Merged feature-main into main"
```

Reverting Changes

Create a new commit that is the ”inverse” of the specified commit.

```
git revert <commit-hash>
```

Reset the current branch to the last commit. No files are changed.
”<commit-hash>” allows you to specify a specific commit to revert to.
⚠ ”--hard” resets all files in the current working directory back to the specified commit.

```
git reset [--hard] [<commit-hash>]
```

Shows a history of SHA1 commit hashes that were added or removed.
Allows to restore removed commits if they were not garbage collected yet.

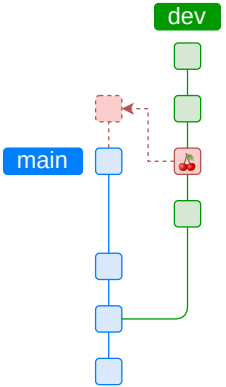
```
git reflog
```

Cherry Picking

Useful when you committed changes to the wrong branch.
Allows you to apply the changes from one commit to your current branch.
Use sparingly to prevent duplicate commits, which will result in merge conflicts later on.

```
git cherry-pick <commit-hash>
```

Sometimes merging or rebasing is more appropriate.



Exercise

- Cherry pick the commit "916975853aeebb3b5beaabeeafe2081641d74c83"(fix initalization order).
- Push your new branch to `origin` (`git push --set-upstream origin 1.8.3_yourName`).
- In GitLab create a PR and resolve all issues by rebasing onto the latest `master` branch.

Worktree

Motivation: It's often necessary to quickly switch between branches. This can be a bit of a hassle.

```
git stash
git switch <new_branch>
... # Possibly stashing of new changes and commits in branch.
git switch <old_branch> # Switch back to previous branch.
git stash pop
```

`git worktree` helps managing multiple worktrees and therefore simplifies the workflow when constantly switching branches.

Worktree

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`git worktree` helps managing multiple worktrees and therefore simplifies the workflow when constantly switching branches.

You can start from a existing repository and create/add a new worktree in a specified directory.

```
# Creates a new directory that contains the <branch>.
git worktree add <directory> <branch>
# List all worktrees for the current repository.
git worktree list
```

Worktree

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# Creates a new directory that contains the <branch>.
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# List all worktrees for the current repository.
git worktree list
```

Alternatively, you can start from a bare repository to avoid the initial checked out working tree.

```
git clone --bare <repo> <directory>
```

Bisect

Problem: In large projects it can be really difficult to find a commit that introduced a bug.

⇒ Use `git bisect` to find the commit that introduced the bug via a binary search.

Example

```
git bisect start # Start the bisect session.
git bisect good <commit> # Mark a commit as good.
git bisect bad <commit> # Mark a commit as bad.
git bisect bad/good <commit> # Continue marking commits until search terminates.
...
git bisect reset # End bisect session and reset branch.
```

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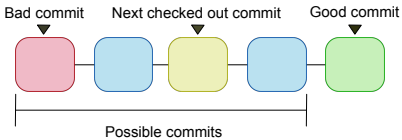


Exercise

- Clone: https://gitlab.lrz.de/open-source-lab/bisect-example.git
- Use "`git-bisect`" to find the commit, that broke the html formatting.
- You know the first (oldest) commit is good and the last (newest) is good.
- Use "`git checkout <hash>`" to switch between commits.

.gitignore

Allows you to specify intentionally untracked (ignored) files.
Patters:

- "!" negates the following pattern.
- "$*$" matches anything except a "\".
- "$**$" matches anything before or after the given path.

Example

```
# Build directory
build/
!build/bin/**
# Debug files
*.dSYM/
*.su
```

A collection of `.gitignore` templates: https://github.com/github/gitignore

.gitattribute

Allows you to specify attributes for paths. For example to normalize line endings.
Line format:

```
pattern attr1 attr2 ...
```

Here the `pattern` is the same as for `.gitignore` without negative patterns.

Example

```
*               text=auto
*.txt           text
*.vcproj        text eol=crlf
*.sh            text eol=lf
```

`.gitattribute` generator: https://gitattributes.io

The right Tool for the right Job

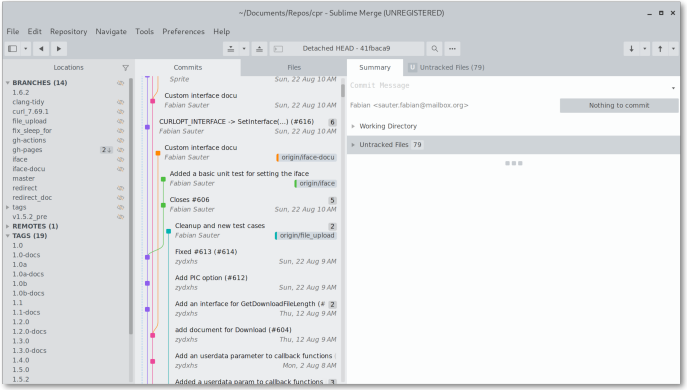
Sometimes using git in a terminal is too cumbersome or degrades to just copy and pasting complex commands from Stack Overflow...

- There exist a bunch of graphical user interfaces for git[3].
- They support you in performing ”complex” actions like merging, rebasing and solving merge conflicts.
- Most code editors come with basic git support (like in visual studio (code) or the Jetbrains IDEs).
- Two popular alternatives:
  - Sublime Merge
  - GitKraken

[3] https://git-scm.com/downloads/guis

Sublime Merge[4]

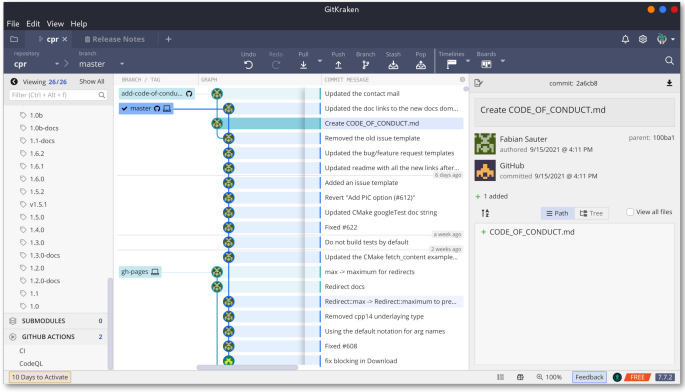
Platforms: Linux, Mac, Windows
Price: $99/user, $75 annual business sub, free eval
License: Proprietary



[4] https://www.sublimemerge.com/

GitKraken[5]

Platforms: Linux, Mac, Windows
Price: Free / $29 / $49
License: Proprietary



[5]https://www.gitkraken.com/

Summary

1. a) Create repository

```
git init
```

1. b) Clone repository

```
git clone <remote>
```

2. Make changes
3. Add changes

```
git add <file>
```

3. Commit changes

```
git commit -m "Some message."
```

4. Done? No - Go back to 2. Yes - Continue

5. Rebase

```
git pull --rebase
```

6. Push

```
git push
```

Figure 2 "Git" by xkcd