Karlsruhe Institute of Technology

Steinbuch Centre for Computing

Git Introduction

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Motivation

Why Use Version Control?

- Collaboration
  - Code sharing / distribution
  - Resolving code conflicts
- Version History
  - Track changes over time
  - Meta data
    - Who made the change?: Author
    - When was it made?: Date
    - Why was it made?: Message
  - Which commit broke something , e.g. a unit test?
- Backup: Restoring previous versions
- Data Integrity

Motivation (continued)

Git Pros

- Distributed system (no central repository) / enables easy collaborative work
- Work offline (Entire repository is stored locally)
- Fast (All operations can be performed locally)
- Powerful (extensive functionality)
- Strong ecosystem (GitLab, GitHub), tools

Git Cons

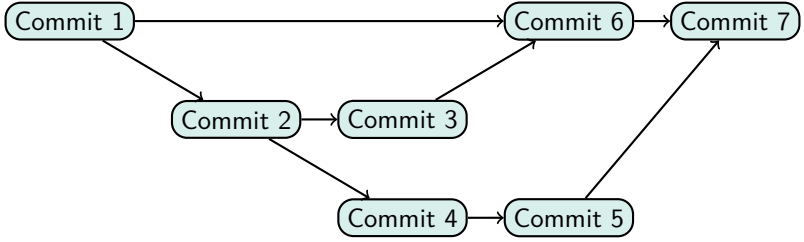
- No central repository (Question: What is the latest state of development)
- Problems with large repositories, as stored locally (Workarounds: LFS, Shallow Copy)
- No tracking of copies and renaming of files: Detection with similarity heuristics
- Complex: Steep learning curve

Git: Data structures

- Git manages files and directories
- **Repository** a git managed directory with all its files and directories
- **Commit** A specific temporal state of a repository (snapshot)
- **History** A successive sequence of commits
- **Directed Acyclic Graph**
  - Graph $\rightarrow$ Vertices and Edges
  - Directed edges
  - Will never form a closed loop

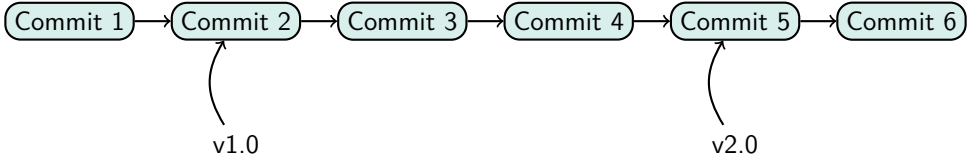
Git: Data structures (continued)

- Directed Acyclic Graph



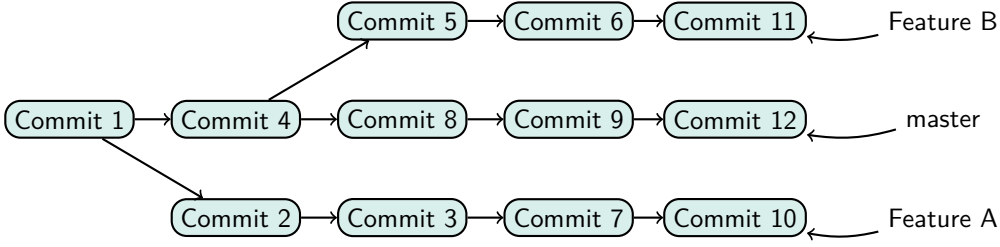
Git: Data structures (continued)

- Tags: Human readable references to commits



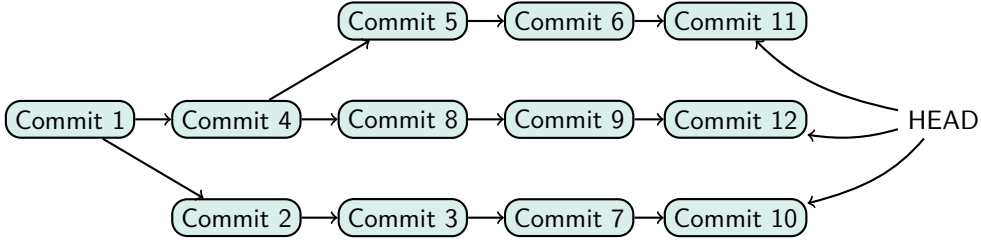
Git: Data structures (continued)

- Branches
  - master
    - Name of default branch
    - Configurable
    - Common alternative names: main, trunk, development



Git: Data structures (continued)

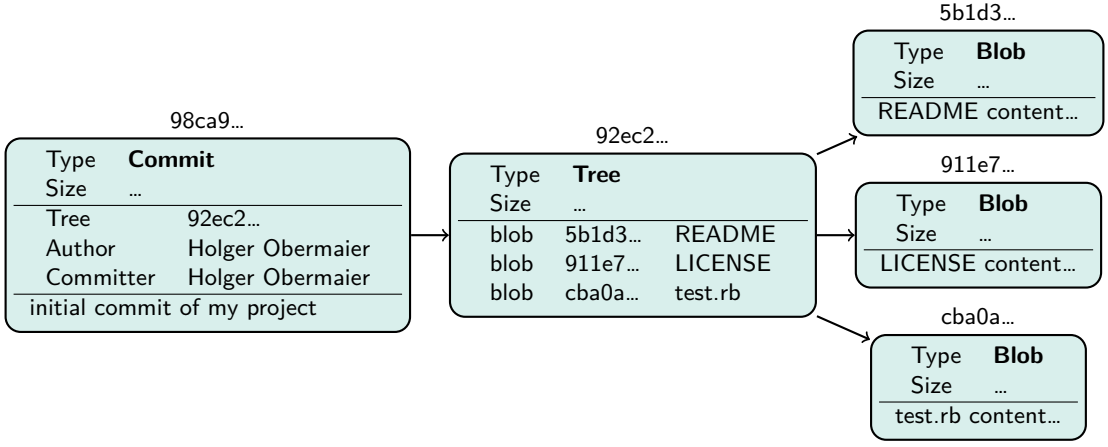
- HEAD Reference to the last commit on the current branch
- detached HEAD Reference to the currently checked out commit



Git: Data structures (continued)

- All data and metadata is stored in objects
- Three types of objects: Commit, Tree, Blob
- All objects are identified by hash codes (not simple numbers)
- Hash function maps from object contents to (hex) number e.g.:
  Text 1 $\mapsto$ `e7d3fcbbd2c090f63c3b88585b9400932e0926b1`
  Text 2 $\mapsto$ `abdf644dbb8d2e6cac179cb17f3e5c2e0257e2d5`
- Objects are considered equal if their hash code matches
- Danger of collisions $\Rightarrow$ Migration from sha1 (160 bit) to stronger hash function

Git: Data structures (continued)



Simple Workflow

- Git requires a first-time setup
- Non permanent configuration through environment variables

```
export GIT_COMMITTER_NAME="Holger Obermaier"
export GIT_COMMITTER_EMAIL="Holger.Obermaier@kit.edu"
export GIT_AUTHOR_NAME="Holger Obermaier"
export GIT_AUTHOR_EMAIL="Holger.Obermaier@kit.edu"
```

- Permanent configuration through configuration files (`${HOME}/.gitconfig`)

```
git config --global user.name "Holger Obermaier"
git config --global user.email holger.obermaier@kit.edu
```

Simple Workflow

- Initialize an empty Git repository

```
mkdir myFirstRepository
cd    myFirstRepository
git  init
```

```
...
Initialized empty Git repository in .../myFirstRepository/.git/
```

- Creates hidden directory `.git`
- Git objects and references are stored in `.git`

Simple Workflow (continued)

- Review status of the repository

```
git status
```

```
On branch master

No commits yet

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

Simple Workflow (continued)

- Create file `helloWorld.c` with the editor of your choice

```c
int main(int* argc, char *argv[]) {
  printf("Hello World\n");
}
```

Simple Workflow (continued)

- Review status of the repository

```
git status
```

```
On branch master

No commits yet

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

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

Simple Workflow (continued)

- Commits are prepared in the staging area (also called cache or index)
- Multiple changes can be staged before a commit
- Only staged changes are part of a commit. Unstaged changes are ignored
- Add file `helloWorld.c` to the staging area

```
git add helloWorld.c
```

Simple Workflow (continued)

- Review status of the repository

```
git status
```

```
On branch master

No commits yet

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

Simple Workflow (continued)

- Commit changes to repository

```
git commit -m "Add hello world"
```

```
[master (Root-Commit) 31231f5] Add hello world
 1 file changed, 3 insertions(+)
 create mode 100644 helloWorld.c
```

- Choose appropriate and short commit message!
  This helps to understand the changes made.

Simple Workflow (continued)

- Review status of the repository

```
git status
```

```
On branch master
nothing to commit, working tree clean
```

Simple Workflow (continued)

- Review history on the current branch

```
git log
```

```
commit aebed842803f58b9b08c7e9755bb1a562f2abb8e
Author: Holger Obermaier <holger.obermaier@kit.edu>
Date:   Tue Oct 19 10:55:34 2021 +0200

    Add hello world
```

- `git log` shows flattened history ignoring graph structure of repository
- `git log --all --decorate --graph` shows history with graph structure

Simple Workflow (continued)

- Modify file `helloWorld.c` with the editor of choice. Add missing include directive

```c
#include <stdio.h>

int main(int* argc, char *argv[]) {
  printf("Hello World\n");
}
```

Simple Workflow (continued)

- Review status of the repository

```
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:   helloWorld.c

no changes added to commit (use "git add" and/or "git commit -a")
```

Simple Workflow (continued)

- Review changes of modified files

```
git diff
```

```
diff --git a/helloWorld.c b/helloWorld.c
index f1ad8d5..f319c4a 100644
--- a/helloWorld.c
+++ b/helloWorld.c
@@ -1,3 +1,5 @@
+#include <stdio.h>

 int main(int* argc, char *argv[]) {
     printf("Hello World\n");
 }
```

Simple Workflow (continued)

- Directly commit changes to repository, without using staging area

```
git commit -m "Added missing include directive" helloWorld.c
```

```
[master db8e376] Added missing include directive
1 file changed, 2 insertions(+)
```

Simple Workflow (continued)

- Review history on the current branch

```
git log
```

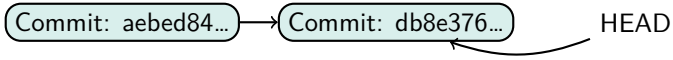
```
commit db8e376d5c52d3605e516022eeefd476cc813369 (HEAD -> master)
Author: Holger Obermaier <holger.obermaier@kit.edu>
Date:   Tue Oct 19 15:38:27 2021 +0200

    Added missing include directive

commit aebed842803f58b9b08c7e9755bb1a562f2abb8e
Author: Holger Obermaier <holger.obermaier@kit.edu>
Date:   Tue Oct 19 10:55:34 2021 +0200

    Add hello world
```

Simple Workflow (continued)



Simple Workflow (continued)

Various useful Git commands

- `git show <Commit>`
  Show changes made in the commit
- `git checkout <Commit>`
  Return to a previous commit
- `git rm <File>`
  Remove files, directories or links in the repository
- `git restore <File>`
  Restore a modified file
- `git mv <Source> <Destination>`
  Move / rename a file, directory or link in the repository
- `git grep <Pattern>`
  Search in the repository

Simple Workflow (continued)

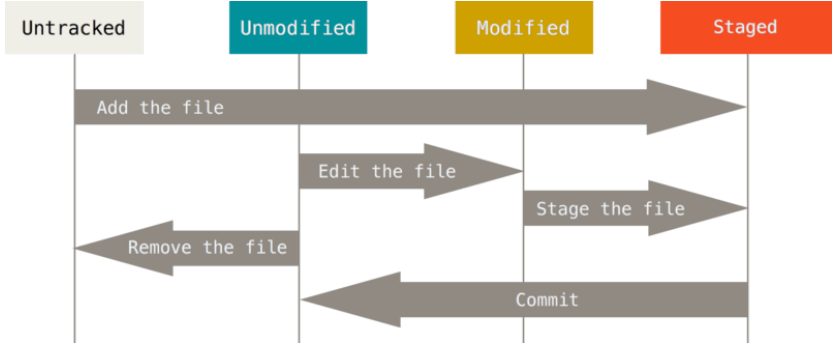


Figure: The life cycle of the status of your files (from [**Pro-Git**])

Working with Tags

- Create an empty repository

```
git init WorkingWithTags
cd      WorkingWithTags
```

- Create an executable shell script `HelloWorld.sh`

```
#!/usr/bin/bash

echo "Hello World"
```

- First commit

```
git add HelloWorld.sh
git commit -m "Hello World"
```

Working with Tags (continued)

- Create an annotated tag

```
git tag -a v1.0 -m "Final version of Hello World"
```

- List tags

```
git tag
```

```
v1.0
```

Working with Tags (continued)

- Review history

```
git log
```

```
commit db4257601ac325d47bf35f9998ab439fd3d78f41 (HEAD -> master, tag: v1.0)
Author: Holger Obermaier <Holger.Obermaier@kit.edu>
Date:   Tue Nov 9 16:15:30 2021 +0100

    Hello World
```

Working with Tags (continued)

- Tags can be used as references to commits (e.g. in show command)

```
git show v1.0
```

```
tag v1.0
Tagger: Holger Obermaier <Holger.Obermaier@kit.edu>
Date:   Tue Nov 9 16:20:37 2021 +0100

Final version of Hello World

commit db4257601ac325d47bf35f9998ab439fd3d78f41 (HEAD -> master, tag: v1.0)
Author: Holger Obermaier <Holger.Obermaier@kit.edu>
Date:   Tue Nov 9 16:15:30 2021 +0100

    Hello World
```

Working with Tags (continued)

- Delete a tag

```
git tag --delete v1.0
```

```
Deleted tag 'v1.0' (was 45bfb7a)
```

- Caution: Tags are not transferred to remote servers by default

Working with Branches

Git Branching "Philosophy"

- Create branches for each feature $\Rightarrow$ parallel development branches
- Avoid clashes caused by making changes on the master branch
- Commit often to track small changes
- Merge changes as one feature update (Squash commits)

Working with Branches (continued)

- Create an empty repository

```
git init WorkingWithBranches
cd      WorkingWithBranches
```

- Create an executable shell script `HelloWorld.sh`

```
#!/usr/bin/bash

echo "Hello World"
```

- First commit on master branch

```
git add HelloWorld.sh
git commit -m "Hello World"
```

Working with Branches (continued)

- Create new branch HelloWorldForCats

```
git branch HelloWorldForCats
git branch
```

```
  HelloWorldForCats
* master
```

- Switch to branch HelloWorldForCats

```
git switch HelloWorldForCats
git branch
```

```
* HelloWorldForCats
  master
```

- `git switch / restore` separate functionality of the overloaded `git checkout` command

Working with Branches (continued)

- Add feature helloWorldForCats to script `HelloWorld.sh`

```
#!/usr/bin/bash

case "$1" in
  cats) echo "Hello World for Cats" ;;
     *) echo "Hello World"          ;;
esac
```

- Commit changes to branch helloWorldForCats

```
git commit -m "Hello World for Cats" HelloWorld.sh
```

Working with Branches (continued)

- Return to master branch

```
git switch master
```

- Create and switch to new branch HelloWorldForDogs

```
git switch -c HelloWorldForDogs
git branch
```

```
  HelloWorldForCats
* HelloWorldForDogs
  master
```

Working with Branches (continued)

- Add feature helloWorldForDogs to script `HelloWorld.sh`

```
#!/usr/bin/bash

case "$1" in
  dogs) echo "Hello World for Dogs" ;;
     *) echo "Hello World"          ;;
esac
```

- Commit changes to branch helloWorldForDogs

```
git commit -m "Hello World for Dogs" HelloWorld.sh
```

Working with Branches (continued)

- Return to master branch

```
git switch master
```

- Integrate feature developed on branch HelloWorldForCats

```
git merge HelloWorldForCats
```

```
Updating 148a364..01de454
Fast-forward
 HelloWorld.sh | 5 ++++-
 1 file changed, 4 insertions(+), 1 deletion(-)
```

Working with Branches (continued)

- Integrate feature developed on branch HelloWorldForDogs

```
git merge HelloWorldForDogs
```

```
Auto-merging HelloWorld.sh
CONFLICT (content): Merge conflict in HelloWorld.sh
Automatic merge failed; fix conflicts and then commit the result.
```

Working with Branches (continued)

- Review repository status

```
git status
```

```
On branch master
You have unmerged paths.
  (fix conflicts and run "git commit")
  (use "git merge --abort" to abort the merge)

Unmerged paths:
  (use "git add <file>..." to mark resolution)
        both modified:   HelloWorld.sh

no changes added to commit (use "git add" and/or "git commit -a")
```

Working with Branches (continued)

- Conflict markers in the script `HelloWorld.sh` help to resolve the conflicts

```
#!/usr/bin/bash

case "$1"in
<<<<<<< HEAD
  cats) echo "Hello World for Cats" ;;
=======
  dogs) echo "Hello World for Dogs" ;;
>>>>>>> HelloWorldForDogs
     *) echo "Hello World"          ;;
esac
```

Working with Branches (continued)

- Review changes

```
git diff
```

```
diff --cc HelloWorld.sh
index 7fd1fa7,ea975f8..0000000
--- a/HelloWorld.sh
+++ b/HelloWorld.sh
@@@ -1,6 -1,6 +1,7 @@@
  #!/usr/bin/bash

  case "$1" in
 +  cats) echo "Hello World for Cats" ;;
+   dogs) echo "Hello World for Dogs" ;;
       *) echo "Hello World"          ;;
  esac
```

Working with Branches (continued)

- Continue integrating feature from branch HelloWorldForDogs

```
git add HelloWorld.sh
git merge --continue
```

```
[master e8dbfdc] Merge branch 'HelloWorldForDogs'
```

- Merge can be aborted, when unable to resolve conflicts

```
git merge --abort
```

Working with Branches (continued)

- Review history

```
git log --all --graph --oneline
```

```
*   e8dbfdc (HEAD -> master) Merge branch 'HelloWorldForDogs'
|\
| * 4e3387b (HelloWorldForDogs) Hello World for Dogs
* | 01de454 (HelloWorldForCats) Hello World for Cats
|/
* 148a364 Hello World
```

Working with Branches (continued)

- Remove unneeded branches

```
git branch --delete HelloWorldForCats HelloWorldForDogs
git branch
```

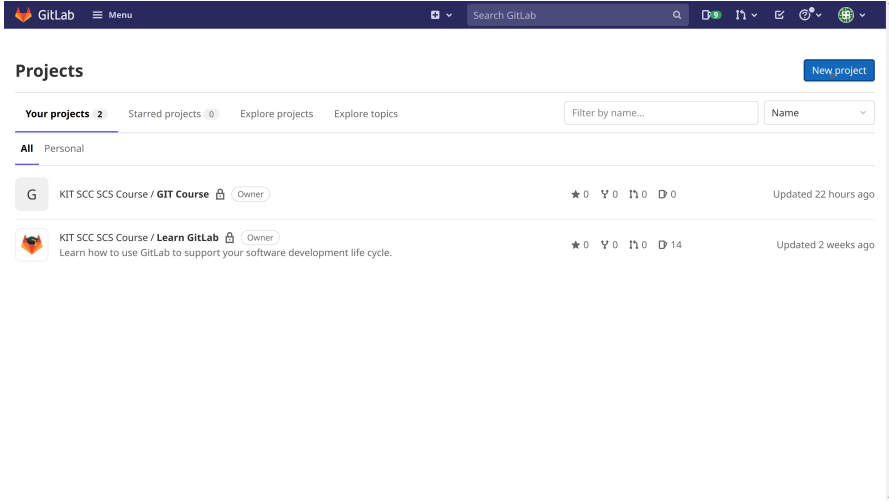
```
* master
```

- Caution: Branches are not transferred to remote servers by default

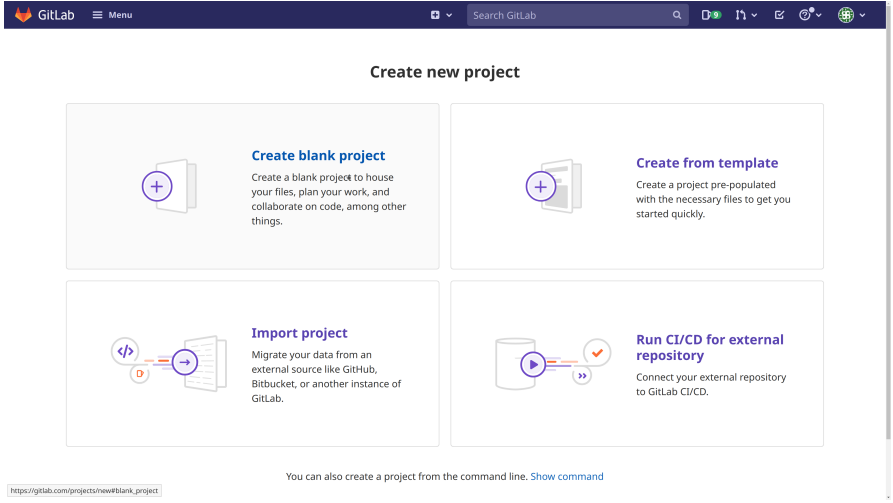
Working with Remote Servers

- Collaboration
- Code sharing / distribution
- All repositories are equal: No distinction between local and remote repository
- Git provides commands to keep local and remote repositories in sync
- Hosting services: Bitbucket, GitHub, GitLab, ...
- Private and public repositories
- Transport protocol
  - `ssh://git@`, authentication via ssh-key, all users use the same remote username `git`
  - `https://`, authentication via username / password, token or without
  - `git@<host>:<path>` scp syntax for ssh-protocol

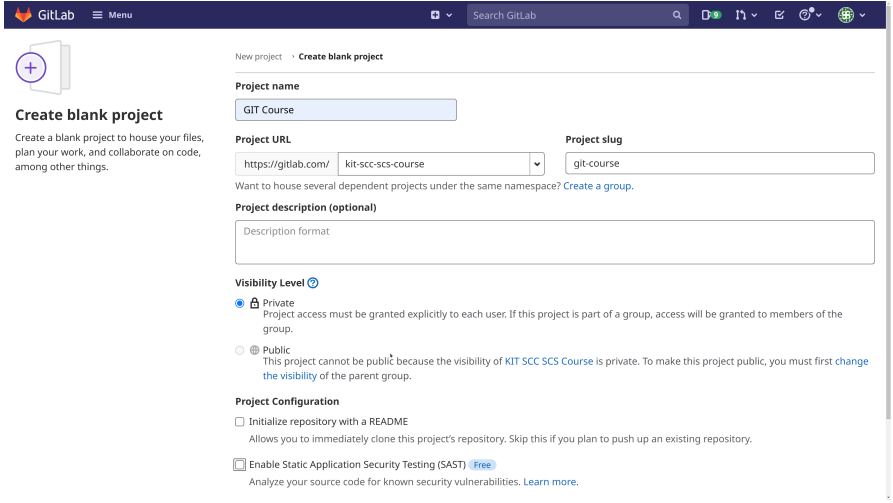
Working with Remote Servers (GitLab: Projects)



Working with Remote Servers (GitLab: New Project)



Working with Remote Servers (GitLab: Blank Project)



Working with Remote Servers (continued)

- Clone a remote GitLab repository via ssh or https protocol

```
git clone git@gitlab.com:kit-scc-scs-course/git-course.git
```

```
git clone https://gitlab.com/kit-scc-scs-course/git-course.git
```

```
Cloning into 'git-course'...
Username for 'https://gitlab.com': holger.obermaier
Password for 'https://holger.obermaier@gitlab.com':
remote: Enumerating objects: 3, done.
remote: Counting objects: 100% (3/3), done.
remote: Total 3 (delta 0), reused 0 (delta 0), pack-reused 0
Receiving objects: 100% (3/3), done.
```

Working with Remote Servers (continued)

- Remote servers have a name and a corresponding URL
- Default name: `origin`
- Multiple remote servers can be configured. All git commands only use one at a time.
- Show name and URL of the remote server.

```
cd git-course
git remote -v
```

```
origin  git@gitlab.com:kit-scc-scs-course/git-course.git (fetch)
origin  git@gitlab.com:kit-scc-scs-course/git-course.git (push)
```

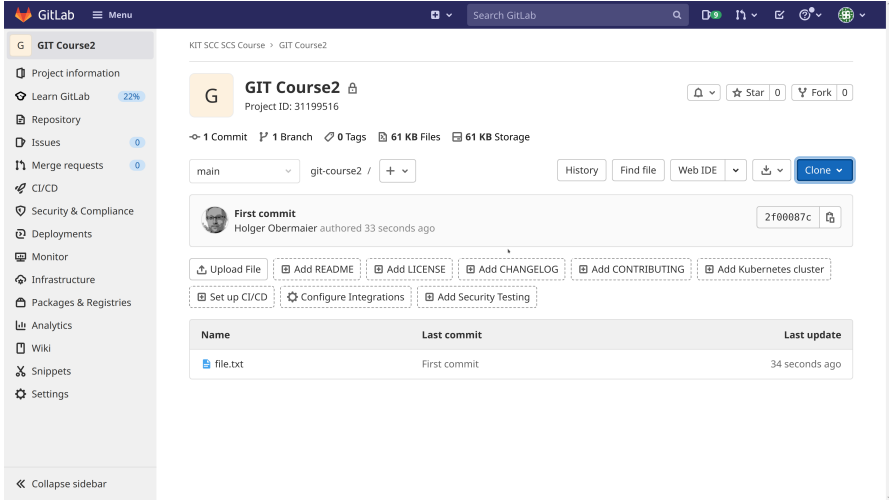
Working with Remote Servers (continued)

- Create a local commit and send changes to the remote server

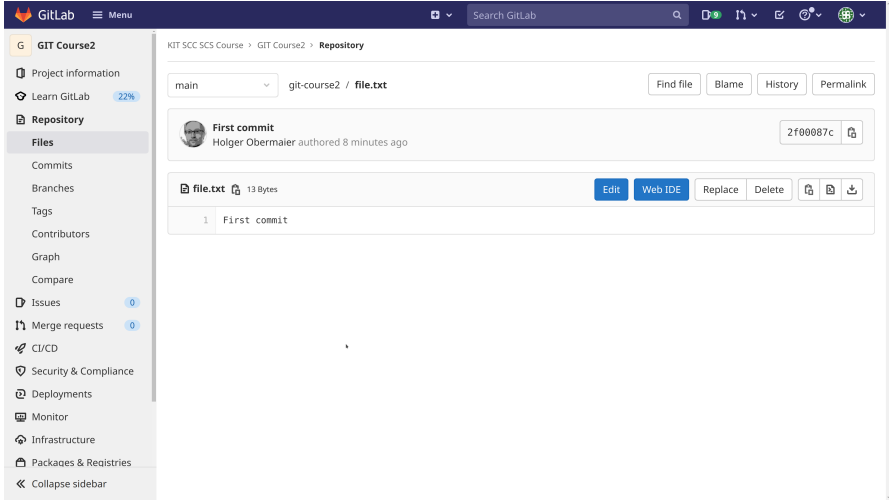
```
echo "First commit" > file.txt
git add file.txt
git commit -m "First commit"
git push
```

```
Enumerating objects: 4, done.
Counting objects: 100% (4/4), done.
Delta compression using up to 8 threads
Compressing objects: 100% (2/2), done.
Writing objects: 100% (3/3), 290 bytes | 290.00 KiB/s, done.
Total 3 (delta 0), reused 0 (delta 0), pack-reused 0
To gitlab.com:kit-scc-scs-course/git-course.git
   29366ff..d1652b2  main -> main
```

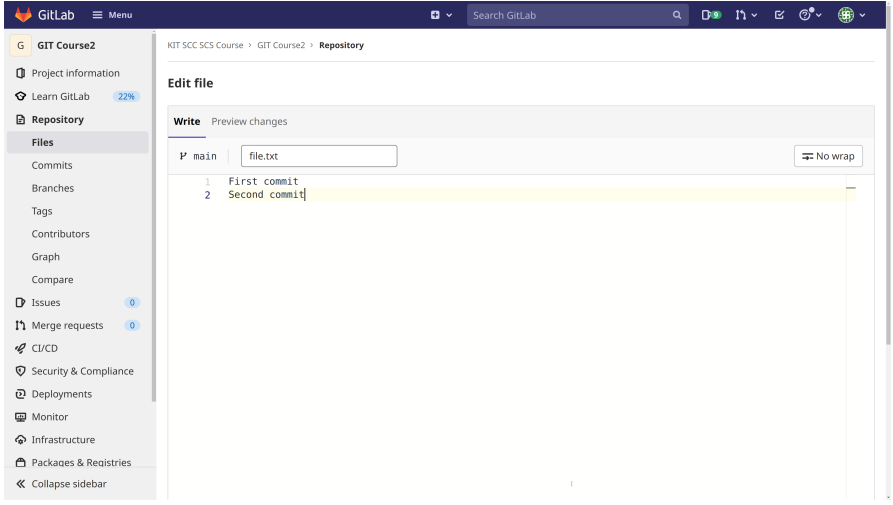
Working with Remote Servers (GitLab: Project Page)



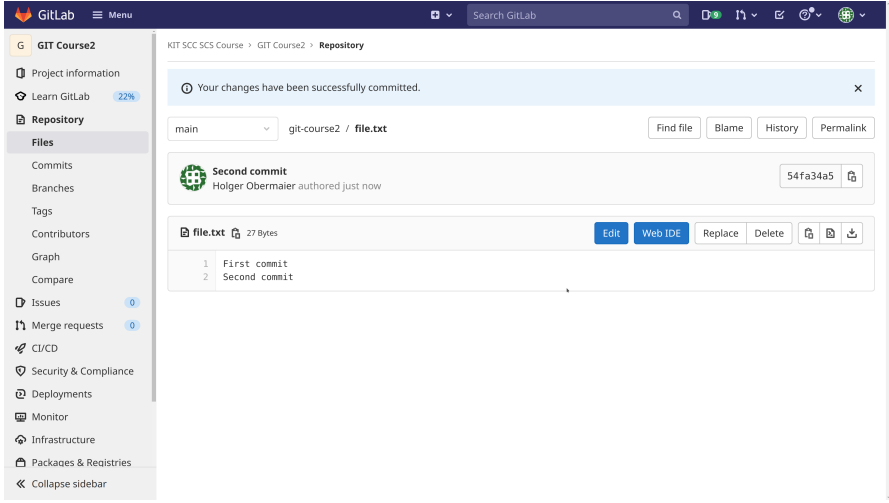
Working with Remote Servers (GitLab: `file.txt`)



Working with Remote Servers (GitLab: Edit File)



Working with Remote Servers (GitLab: Commited)



Working with Remote Servers (continued)

- Preparation: Insert one line into file `file.txt` on GitLab
- All git commands work local. Changes on the server are invisible
- Fetch changes from the remote repository

```
git fetch
```

```
remote: Enumerating objects: 5, done.
remote: Counting objects: 100% (5/5), done.
remote: Compressing objects: 100% (2/2), done.
remote: Total 3 (delta 0), reused 0 (delta 0), pack-reused 0
Unpacking objects: 100% (3/3), 281 bytes | 281.00 KiB/s, done.
From gitlab.com:kit-scc-scs-course/git-course
   d1652b2..61ddece  main       -> origin/main
```

Working with Remote Servers (continued)

- Review status of the repository

```
git status
```

```
On branch main
Your branch is behind 'origin/main' by 1 commit, and can be fast-forwarded.
  (use "git pull" to update your local branch)

nothing to commit, working tree clean
```

Working with Remote Servers (continued)

- Review changes made on the remote server

```
git diff HEAD @{upstream}
```

```
diff --git a/file.txt b/file.txt
index 6eaf244..6a3adff 100644
--- a/file.txt
+++ b/file.txt
@@ -1 +1,2 @@
 First commit
+Second commit
```

Working with Remote Servers (continued)

- Integrate changes made on the remote server

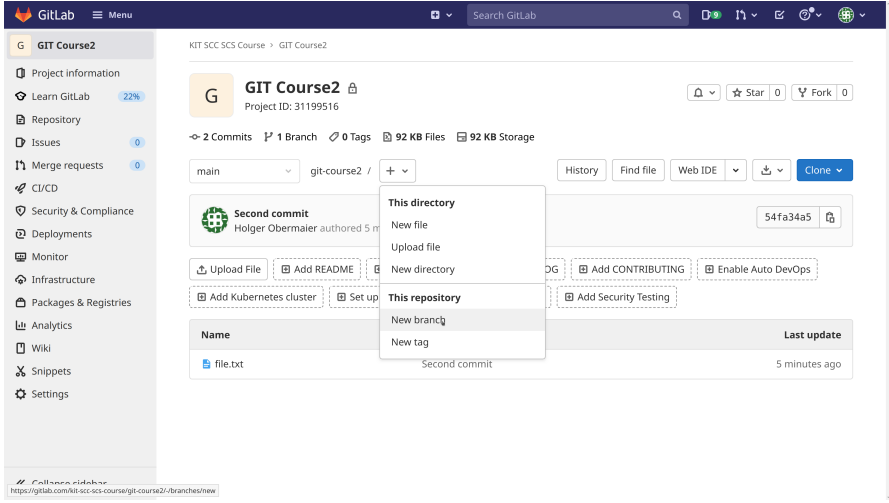
```
git pull
```

```
Updating d1652b2..61ddece
Fast-forward
 file.txt | 1
 1 file changed, 1 insertion(+)
```

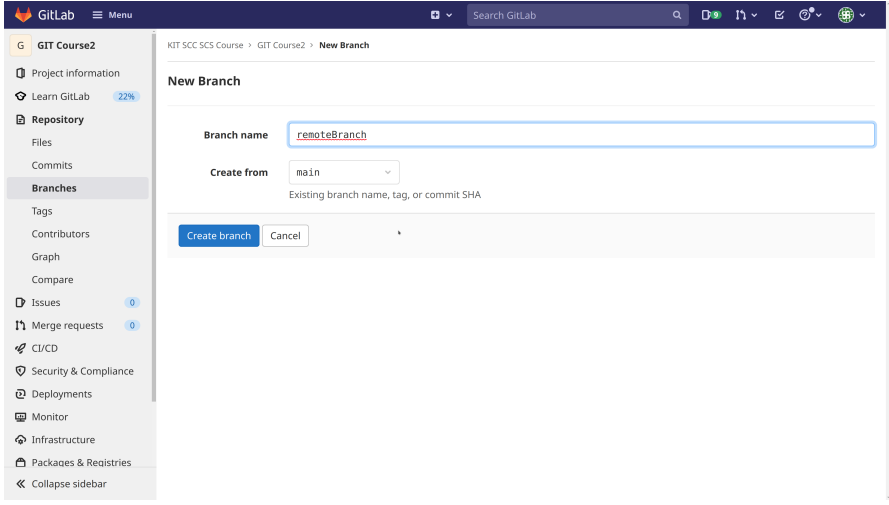
```
cat file.txt
```

```
First commit
Second commit
```

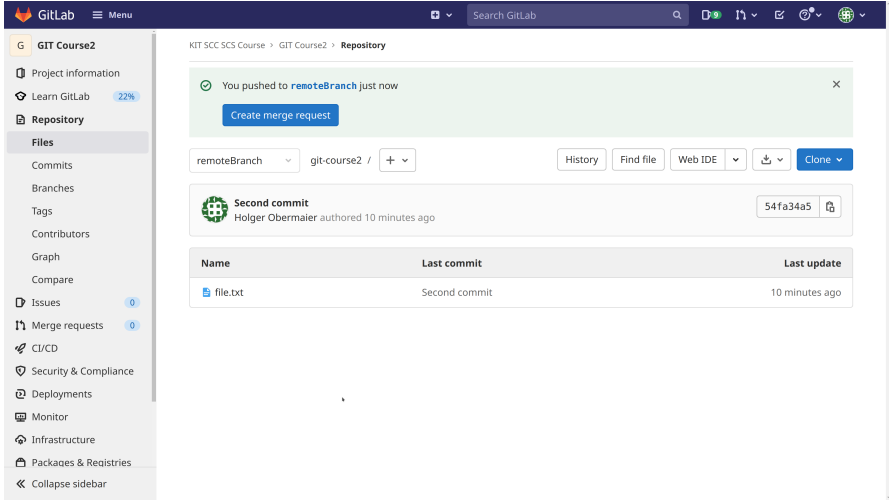
Working with Remote Servers (GitLab: New Branch)



Working with Remote Servers (GitLab: New Branch)



Working with Remote Servers (GitLab: New Branch)



Working with Remote Servers (remote branches)

- Preparation: Create a branch `remoteBranch` on GitLab
- Get remote branches

```
git pull
```

```
From gitlab.com:kit-scc-scs-course/git-course
* [new branch]      remoteBranch -> origin/remoteBranch
Already up to date.
```

- Track remote branch

```
git switch remoteBranch
```

```
Branch 'remoteBranch' set up to track remote branch 'remoteBranch' from
↪  'origin'.
Switched to a new branch 'remoteBranch'
```

Working with Remote Servers (local branches)

- Create a local branch and try sending it to the remote server

```
git switch -c localBranch
git push
```

```
fatal: The current branch localBranch has no upstream branch.
To push the current branch and set the remote as upstream, use

    git push --set-upstream origin localBranch
```

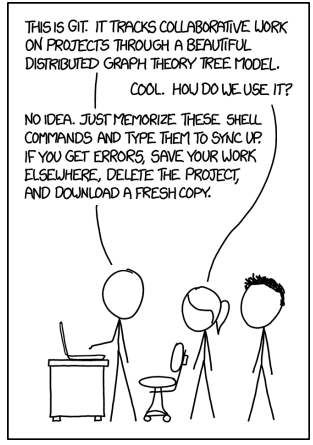
Working with Remote Servers (local branches)

- Send local branch to remote server

```
git push --set-upstream origin localBranch
```

```
Total 0 (delta 0), reused 0 (delta 0), pack-reused 0
remote:
remote: To create a merge request for localBranch, visit:
remote:
↪  https://gitlab.com/kit-scc-scs-course/git-course/-/merge_requests/new?merge_req
remote:
To gitlab.com:kit-scc-scs-course/git-course.git
 * [new branch]      localBranch -> localBranch
Branch 'localBranch' set up to track remote branch 'localBranch' from
↪  'origin'.
```

Questions?



https://xkcd.com/1597/

References

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