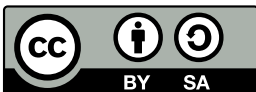**IMT Atlantique**
Bretagne-Pays de la Loire
École Mines-Télécom

Version Control Systems (VCS): Introduction to Git

J.-C. Bach

ILSD – ◆ – 2025-2026

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Important notes

- If you do not understand something, please ask your questions. *We cannot answer the questions you do not ask*
- If you disagree with us, please say it (politely)
- People don't learn computer science by only reading few academic slides: practicing is fundamental

Concerning this lecture

▶ Most of the slides come from the VCS lecture of the DCL TAF

⇒ students from the DCL TAF should be familiar with Git and should not learn anything with this lecture

▶ This is not an exhaustive course on Git (time is limited)

⇒ this lecture is NOT sufficient to be fluent with Git

▶ Consider this lecture as a starting point (or a reminder for the former DCL students)

▶ Understanding and using VCS is mandatory in software development

Progress

1 Context

2 Git concepts – Git guts

3 Workflows

4 Git in practice

5 Git by the example

Sentences one would have preferred not to hear

▶ *Aaaaah! Three months of work lost!*

▶ *Oops Was this file really important?*

▶ *Great, everyone has finished! Who integrates all the parts?*

▶ *Why did I wrote this piece of code?*

▶ *Great functionality, but I think the last week version was better. Uh which one?*

▶ *I cannot find the version we have made 6 years ago for BigCustomer Inc., I need it immediately for a new contract!*

▶ *I have already done this bugfix on my laptop I left at home.*

▶ *It doesn't work anymore! Who messed up my code?*

Motivations

▶ Software traceability: tracking and documenting changes, retrieving former versions

▶ Flexibility: feature trials, quick rollbacks

▶ Parallelism and team work: multi-sites, multi-computers, multi-developers and multi-activities

▶ Safety: "backup" with history

  ▶ though VCS are not (space) efficient backup systems

  ⇒ One needs tools to solve these problems

Version Control Systems (VCS)
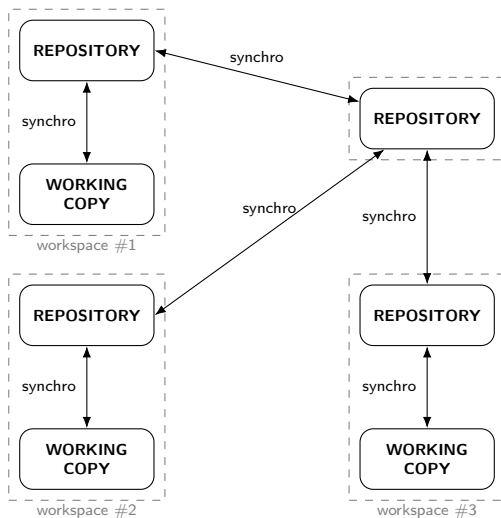
- Used for
  - storing files
  - keeping track of changes on those tracked files
  - sharing
- Each collaborator works on a local copy
- Synchronization with one (or several) remote server(s)
- 2 families of VCS
  - centralized (Subversion, CVS,)
  - distributed (Git, Mercurial, Darcs,)

Architecture of a centralized VCS
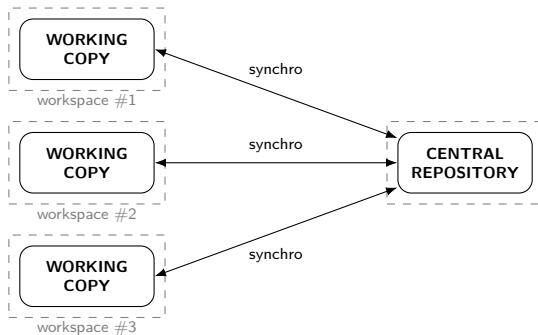
Architecture of a distributed VCS

Focus on a specific VCS: Git ◈

Why Git?

▶ very popular

▶ many platforms provide Git-based services (Bitbucket, Codeberg, Gitlab, Gitea, GitHub, SourceHut, . . .)

▶ a bit less intuitive than other VCS for beginners, therefore if you are able to use Git, you will be able to use other VCS
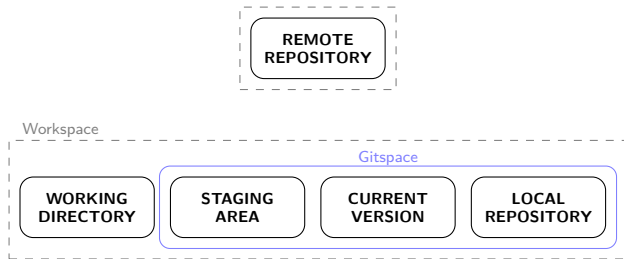
▶ and because we had to choose a tool

Progress

Git architecture and vocabulary


```
┌─────────────────┐
│ REMOTE          │
│ REPOSITORY      │
└─────────────────┘

Workspace
                                    Gitspace
┌──────────┐  ┌──────────┐  ┌──────────┐  ┌──────────┐
│ WORKING  │  │ STAGING  │  │ CURRENT  │  │ LOCAL    │
│ DIRECTORY│  │ AREA     │  │ VERSION  │  │ REPOSITORY│
└──────────┘  └──────────┘  └──────────┘  └──────────┘
```
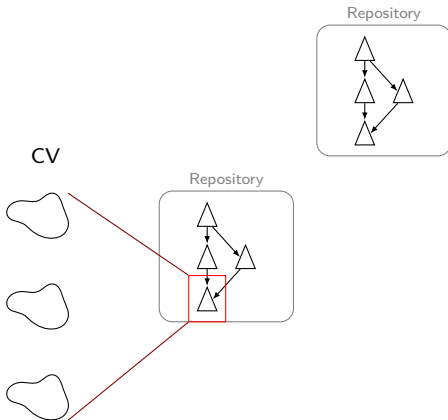
- ▶ working directory = files where changes are made
- ▶ staging area = current selected changes
- ▶ current version = current reference version
- ▶ (remote/local) repository = a database of changes

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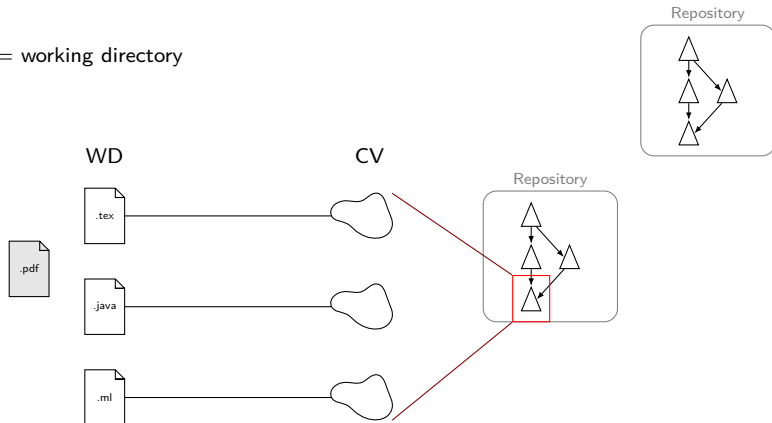École Mines-Télécom

Diving into Git core
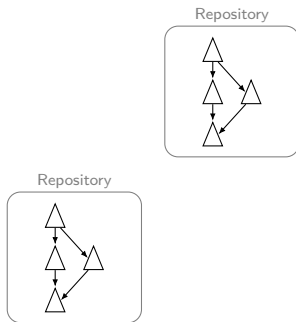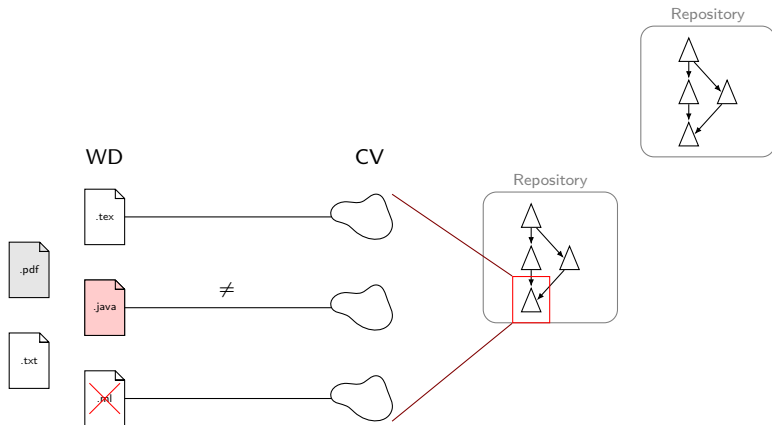
Diving into Git core

CV = current version

Diving into Git core

WD = working directory

Diving into Git core

Diving into Git core

SA = staging area
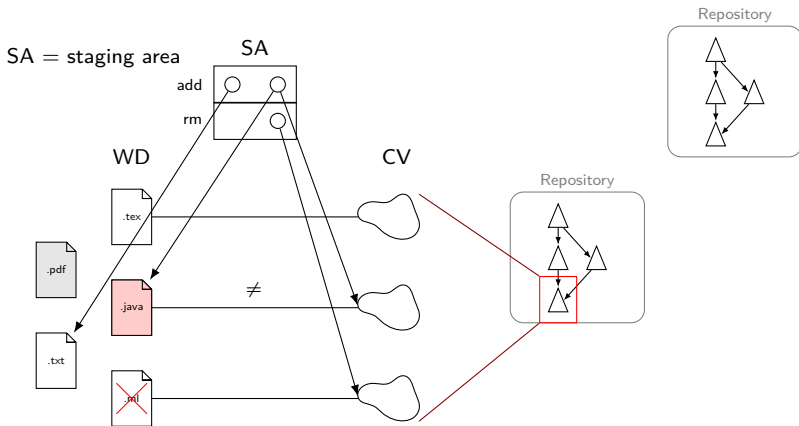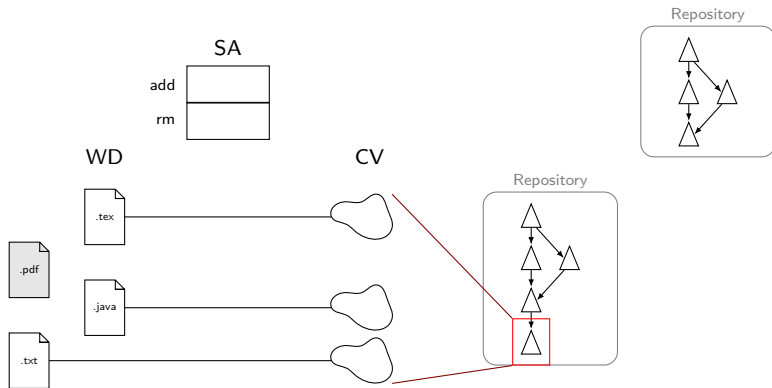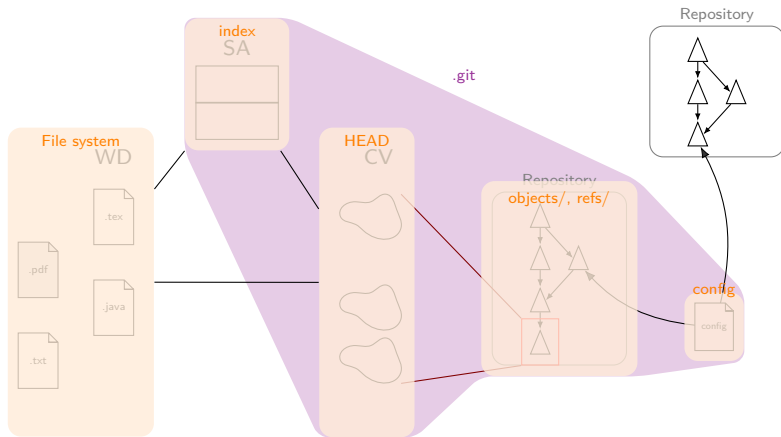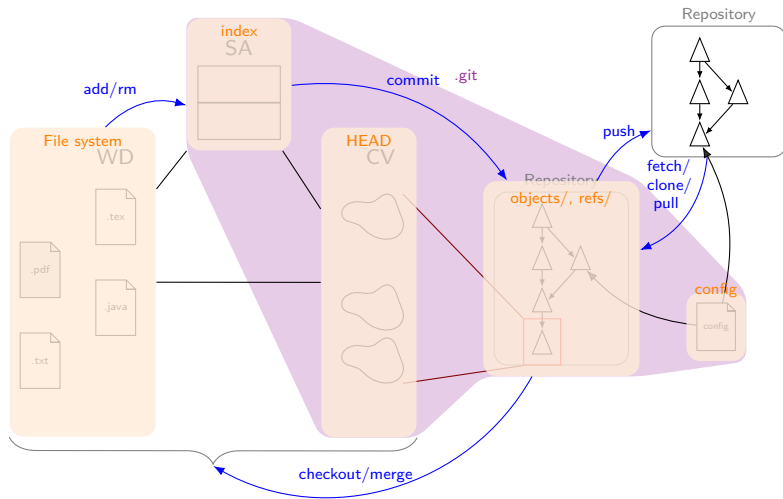
Diving into Git core

Diving into Git core

Diving into Git core

Structure of a versioned project with Git

```
jcbach@minitel2#11:32:20>taf-ilsd$ls -lah
total 72K
drwxr-xr-x  14 jcbach jcbach 4.0K Aug 12 09:58 .
drwxr-xr-x 258 jcbach jcbach  12K Aug 19 10:54 ..
drwxr-xr-x   7 jcbach jcbach 4.0K Jan 10  2025 adm
drwxr-xr-x   6 jcbach jcbach 4.0K Aug 12 09:58 contenu
drwxr-xr-x   2 jcbach jcbach 4.0K Aug 12 09:58 descriptions
drwxr-xr-x   8 jcbach jcbach 4.0K Jun 25  2019 fiches
drwxr-xr-x   2 jcbach jcbach 4.0K May  3  2024 fichesPASS
drwxr-xr-x   7 jcbach jcbach 4.0K Aug 22 10:42 .git
-rw-r--r--   1 jcbach users    50 Dec 11  2024 .gitignore
drwxr-xr-x   2 jcbach users  4.0K Aug 12 09:58 logo
drwxr-xr-x   4 jcbach users  4.0K Aug 12 09:58 poster
drwxr-xr-x   4 jcbach users  4.0K Aug 19 15:07 presentations
drwxr-xr-x   4 jcbach users  4.0K Aug 12 09:58 projets-procom
-rw-r--r--   1 jcbach users   494 Aug 12 09:58 README
drwxr-xr-x   2 jcbach jcbach 4.0K Dec  1  2020 reunions
drwxr-xr-x   6 jcbach users  4.0K Aug 13 17:52 semainerentree
```

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.git structure

```
jcbach@minitel2#11:36:28>.git$ls -lah
total 84K
drwxr-xr-x   7 jcbach jcbach 4.0K Aug 22 10:42 .
drwxr-xr-x  14 jcbach jcbach 4.0K Aug 12 09:58 ..
-rw-r--r--   1 jcbach jcbach   20 Sep 17  2024 COMMIT_EDITMSG
-rw-r--r--   1 jcbach users   276 Dec 11  2024 config
-rw-r--r--   1 jcbach jcbach   73 Jun 25  2019 description
-rw-r--r--   1 jcbach jcbach  107 Aug 19 14:59 FETCH_HEAD
-rw-r--r--   1 jcbach users    21 Dec 11  2024 HEAD
drwxr-xr-x   2 jcbach jcbach 4.0K Jun 25  2019 hooks
-rw-r--r--   1 jcbach users   27K Aug 22 10:42 index
drwxr-xr-x   2 jcbach jcbach 4.0K Jun 25  2019 info
drwxr-xr-x   3 jcbach jcbach 4.0K Jun 25  2019 logs
drwxr-xr-x 260 jcbach jcbach 4.0K Aug 19 14:59 objects
-rw-r--r--   1 jcbach users    41 Aug 19 14:59 ORIG_HEAD
-rw-r--r--   1 jcbach jcbach  114 Jun 25  2019 packed-refs
drwxr-xr-x   5 jcbach jcbach 4.0K Sep 23  2020 refs
```

Progress

Adopting a workflow

- One tool, many usages
- Tools alone do not solve development problems
- Need of a process that fits the team
- Many possible Git workflows (examples later)
  - centralized workflow
  - feature branch workflow
  - gitflow workflow
  - forking workflow
  - . . .

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Centralized workflow

- ▸ One central repository, one branch (main)
- ▸ Common when coming from centralized systems like Subversion
- ▸ Common for small size teams
- ▸ Easy to understand for a newcomer

Source: Atlassian

Feature branch workflow
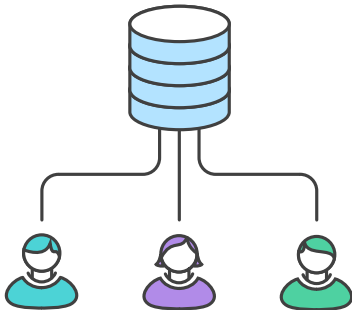
- ▶ Central repository + main branch = official project history
- ▶ One branch per feature: no direct commit on the main branch
- ▶ Feature branches are pushed to the central repository
- ▶ Branches are then merged (after pull requests, feedbacks, conflict resolutions)
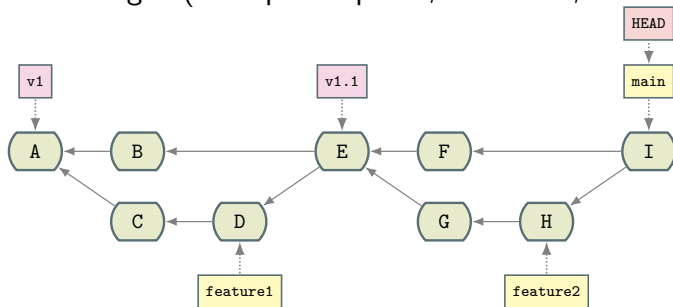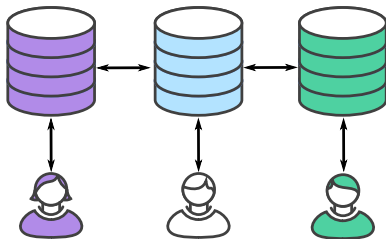
Gitflow workflow

▶ Strict branching model designed around the project release

▶ Well-suited for large projects with deadlines (releases)

▶ One branch one role, workflow defines their interactions

▶ Can be combined with feature branch workflow

▶ Project history = main (the releases) + development branch

Source: Atlassian
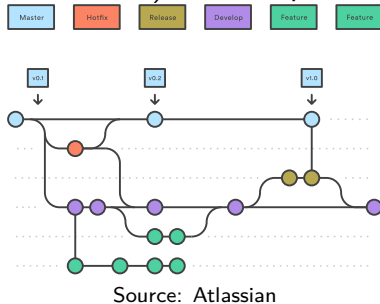
Forking workflow

- One serverside repository per developer
- Each developer manages her repository and make pull requests to the reference repository
- Typical model when contributing to a FLOSS project hosted on GitHub: "Fork us on GitHub"

Source: Atlassian

Workflows: summary

▶ Chosen workflow depends on the team's concerns and organisation
  ▶ no one-size-fits-all Git workflow
▶ Feature workflow: business domain oriented
▶ Forking and gitflow workflows: repository oriented
▶ What is a good workflow?
  ▶ enhance or limit team efficiency?
  ▶ scale with team size?
  ▶ easy to undo mistakes and errors?
  ▶ impose any new unnecessary cognitive overhead to the team?
  ▶ does it limit conflicts?

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VCS practices

▶ Git
  ▶ useful and powerful tool
  ▶ . . . but a tool alone does not solve all problems. It can also create ones
  ⇒ developers do not only need tools, but also working processes

▶ Good practices
  ▶ formalizing the process/workflow
  ▶ coordinating with co-workers
  ▶ testing before sending changes
  ▶ updating before sending a change
  ▶ committing meaningful changes
  ▶ committing often
  ▶ adding meaningful messages for commits
  ▶ not committing generated files
  ▶ short-lived branches

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VCS in practice: how to start?

- By practicing
  - ILSD TUs: back-to-school week (codecamp), FIAB, ANSYD, CAD, PROCOM, . . .
  - during every lab sessions, even in non-CS context
  - at home
- One usually needs a server to host repositories
  - . . . but it is not mandatory: you can use Git in serverless mode!
- Some questions to ask before choosing
  - do you want to make your project public?
  - is there any security, privacy or IP problems with the project?
  - is your project a cornerstone of your business?
- Your answers should drive your choices of VCS hosting
  - simple and free non-professional account on an open platform *vs* paid service
  - installation of your own VCS server

Git in practice: which platform to start with?

- IMTA infrastructure for academic projects and for learning:
  - Gitlab: `https://gitlab-df.imt-atlantique.fr/`
- Many platforms can be used without any fee:
  - Assembla: `https://www.assembla.com/`
  - Bitbucket: `https://bitbucket.org/`
  - Codeberg: `ihttps://codeberg.org/`
  - Gitea: `https://about.gitea.com/`
  - Gitlab: `https://about.gitlab.com/`
  - GitHub: `https://github.com/`
  - Sourcehut: `https://sourcehut.org/`
  - ... and probably many other
- You can also install your own server!

Serverless mode: a simple way to start with Git

▶ Git can also be used without any other host

1. `$> mkdir mycode`
2. `$> cd mycode`
3. `$> git init`
   initialize a new Git repository

▶ that type of Git repository can be shared
   ▶ as every folder (copy/paste on an USB key, . . .)
   ▶ or using a Git command to add a remote repository (it has to exist)
   `$> git remote add <name> <url>`

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Git integration

▶ If you use a mainstream IDE, Git is probably already integrated
- Eclipse
  - ▶ Window > Perspective > Open Perspective > Other > Git
- vscode
  - ▶ Ctrl+Shift+G
  - ▶ nice and useful plugins: *Git graph* and *GitLens*
- IntelliJ
  - ▶ Alt+'
- well-configured Vim or Emacs: you don't need any help 😄
  - ▶ maybe a TUI: *tig*, *Lazygit*, *GitUI*
▶ *CI* (*Continuous Integration*)
  - ▶ VCS are the first brick of CI pipelines
  - ▶ all modern CI tools already integrate Git (GitHub actions, GitLab CI/CD, Jenkins, Travis CI, etc.)
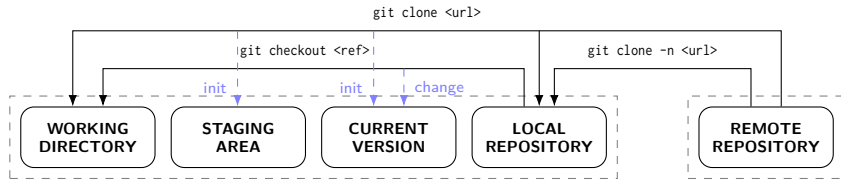
Progress

Git by the example

▶ Practical use cases in order to learn few commands
  - ▶ setting up a new repository (`init`, `remote url`)
  - ▶ retrieving a repository (`clone`)
  - ▶ making changes in the working repository (`status`)
  - ▶ updating the remote environment (`add`, `commit`, `push`)
  - ▶ checking differences after changes (`diff`)
  - ▶ updating dev environment (`fetch`, `pull`)
  - ▶ diverging/branching (`branch`, `merge`, `checkout`)
  - ▶ . . .
▶ Non-exhaustive use cases
▶ Workflows

Let's have a look at the terminal!
(I'll probably forget the slides)

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Retrieving a repository


```
                              git clone <url>
              git checkout <ref>              git clone -n <url>
         init          init      change
    ┌─────────────────────────────────────────────────┐   ┌─────────────────────┐
    │  WORKING      STAGING      CURRENT      LOCAL     │   │      REMOTE          │
    │  DIRECTORY    AREA         VERSION      REPOSITORY│   │      REPOSITORY      │
    └─────────────────────────────────────────────────┘   └─────────────────────┘
```

$> git clone -n *<url>*

  only creates the .git directory

$> git checkout *<ref>*

  retrieves files from local repository into the working directory

$> git clone *<url>*

  creates the .git directory and retrieves files into the working directory; clone =
  clone -n + checkout

Making changes in the working directory

tracked

WORKING DIRECTORY	STAGING AREA	CURRENT VERSION	LOCAL REPOSITORY

untracked
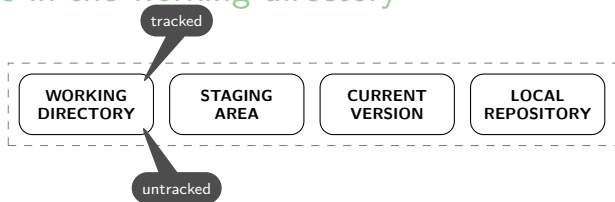
Checking the current state

$> `git status`

```
On branch main
Your branch is up to date with 'origin/main'.
Changes not staged for commit:
  (use "git add <file>..." to update what will be committed)
  (use "git checkout -- <file>..." to discard changes in working directory)
        modified:   file1
        ...
Untracked files:
  (use "git add <file>..." to include in what will be committed)
        file4
        ...
no changes added to commit (use "git add" and/or "git commit -a")
```

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Updating the remote environment
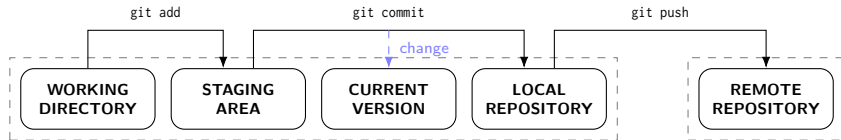
Example

```
$> git add file1 file2 file3 ...
   add in the index of the staging area
$> git commit -m ``add my super new feature''

   ...
$> git push
   push into the remote repository
```
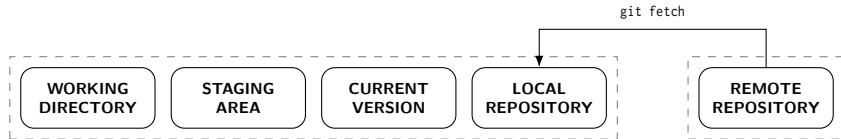
Checking differences after changes
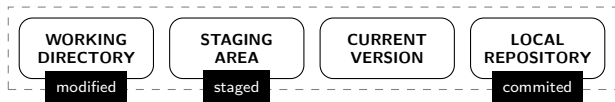
Diff commands

```
$> git diff
$> git diff --staged
$> man git-diff will help you
```
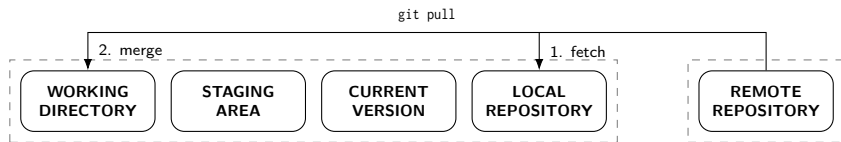
Updating dev environment (`fetch`)


```
$> git fetch
```
▶ retrieves updates from the remote repository
▶ is safe
  ▶ does not affect working directory $\Rightarrow$ cannot lose uncommited changes,
  ▶ no automated merge

Updating dev environment (pull)

git pull

2. merge			1. fetch		
WORKING DIRECTORY	**STAGING AREA**	**CURRENT VERSION**	**LOCAL REPOSITORY**		**REMOTE REPOSITORY**

`$> git pull`

retrieves updates from the remote repository and merge them with the working directory

▶ `git merge`: to be seen few slides later

Diverging: vocabulary

- ▶ a branch = a reference to a version
  - ▶ can be seen as a "local checkpoint" (another says like a bookmark)
- ▶ branching
  - ▶ creating a named reference to a version
  - ▶ the common way to work without messing with the main line

Diverging (branch)

git branch [-a]
git branch <ref>
git branch -d

```
┌─────────────────────────────────────────────────────────────────┐
│  ┌───────────┐   ┌───────────┐   ┌───────────┐   ┌───────────┐   │
│  │  WORKING  │   │  STAGING  │   │  CURRENT  │   │   LOCAL   │   │
│  │ DIRECTORY │   │   AREA    │   │  VERSION  │   │ REPOSITORY│   │
│  └───────────┘   └───────────┘   └───────────┘   └───────────┘   │
└─────────────────────────────────────────────────────────────────┘
```
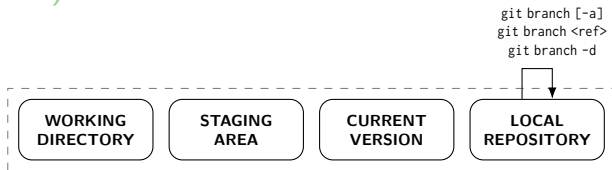
$> git branch

   list local branches

$> git branch -a

   list all (local and remote) branches

$> git branch <ref>

   creates a named branch from the current branch

$> git branch -d <ref>

   deletes a named branch

Diverging (checkout)


```
git checkout [-b] <ref>
```

| WORKING DIRECTORY | STAGING AREA | CURRENT VERSION | LOCAL REPOSITORY |
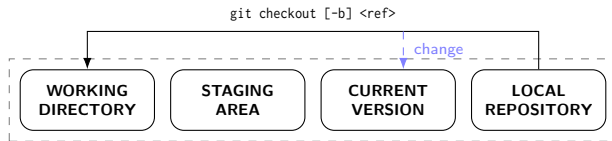
$> git checkout <ref>

   changes the current branch

$> git checkout -b <ref>

   creates a branch from the current branch and changes to it
   (= git branch + git checkout)

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Diverging (merge)

▶ Starting point: 2 branches (main + newawesomefeature), HEAD points to main

`$> git merge newawesomefeature`

integrate changes from newawesomefeature branch into main

▶ Two situations
  ▶ no conflict: changes from newawesomefeature are integrated in the main (local) line, time to push
  ▶ conflicts: resolution needed in order to be able to push

▶ Conflict resolution:
  1 fix the conflicts (edit the files, keep/remove stuff)
  2 add the changes
  3 commit

Diverging scenario
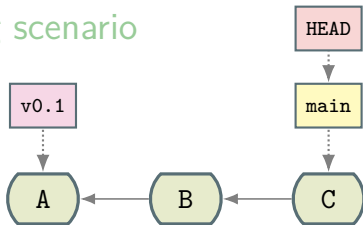
Initial situation

Diverging scenario
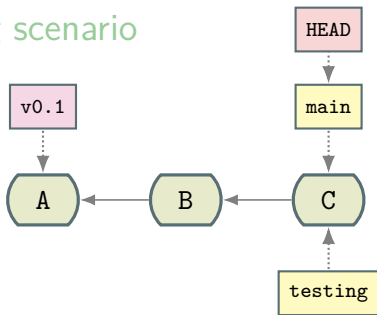

```
$> git branch testing
```

Diverging scenario
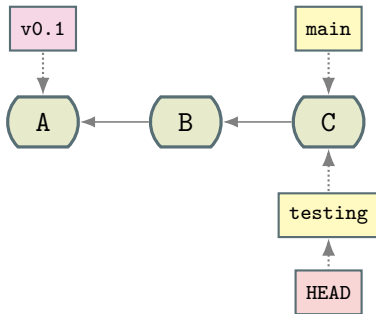

```
$> git checkout testing
```

Diverging scenario

One commit later

Diverging scenario


```
$> git checkout main
```
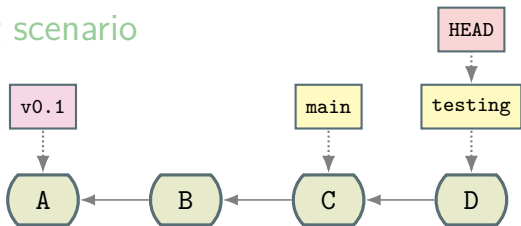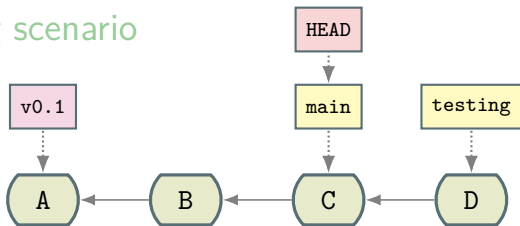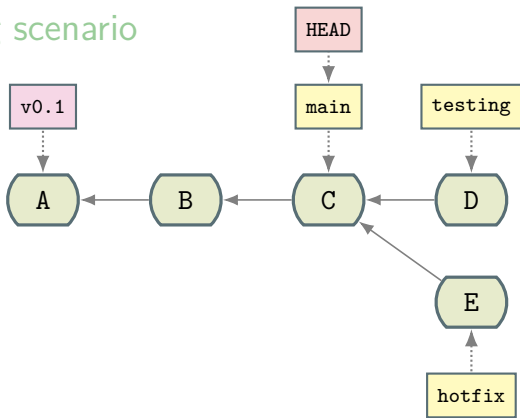
Diverging scenario
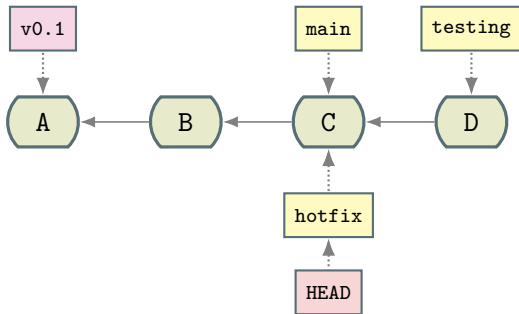

```
$> git checkout -b hotfix
```
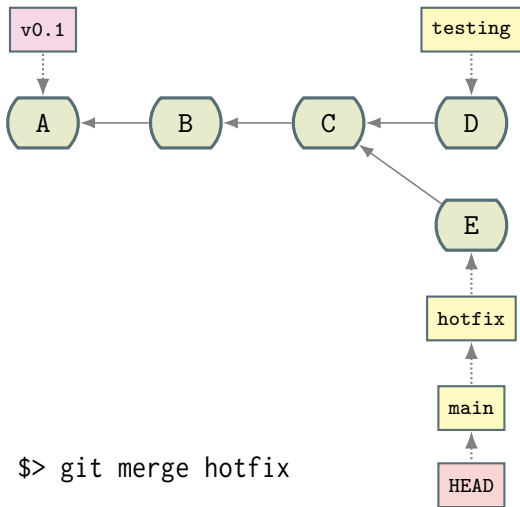
Diverging scenario

One commit later
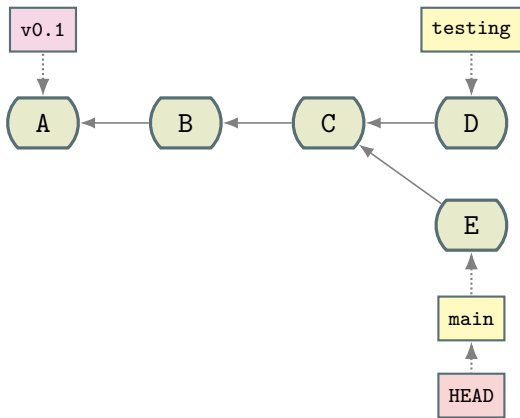
Diverging scenario

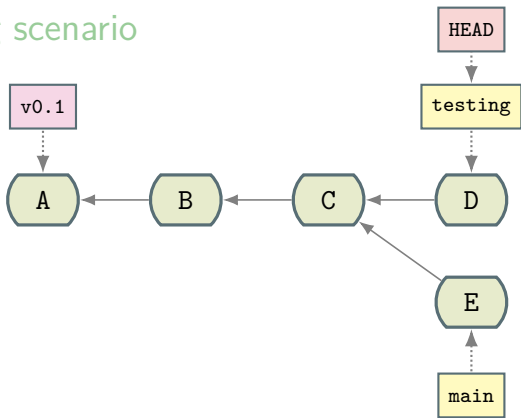
```
$> git checkout main
```
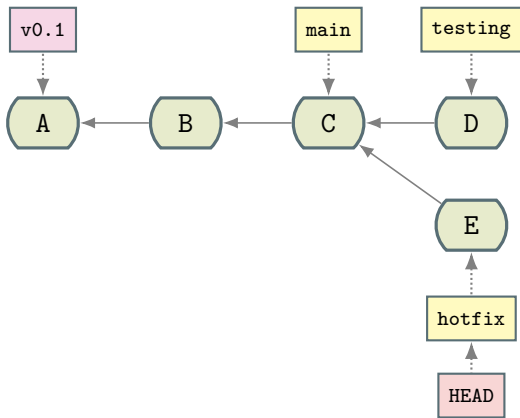
Diverging scenario


```
$> git merge hotfix
```

Diverging scenario

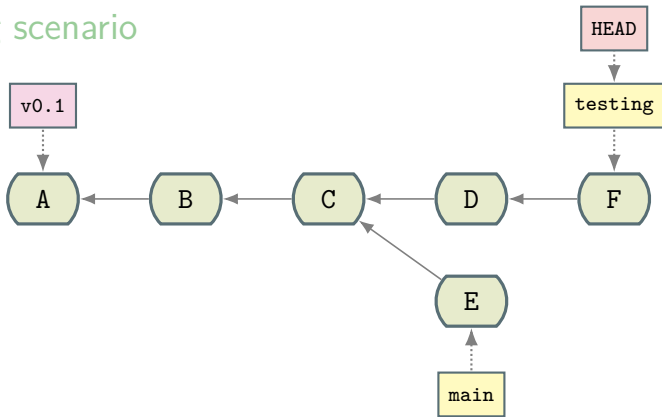

```
$> git branch -d hotfix
```

Diverging scenario
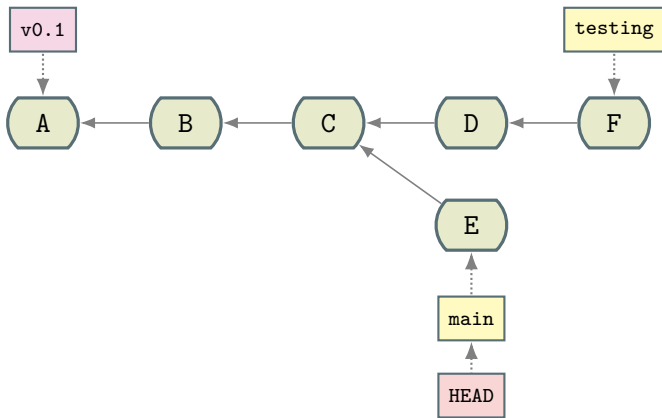
```
$> git checkout testing
```

Diverging scenario
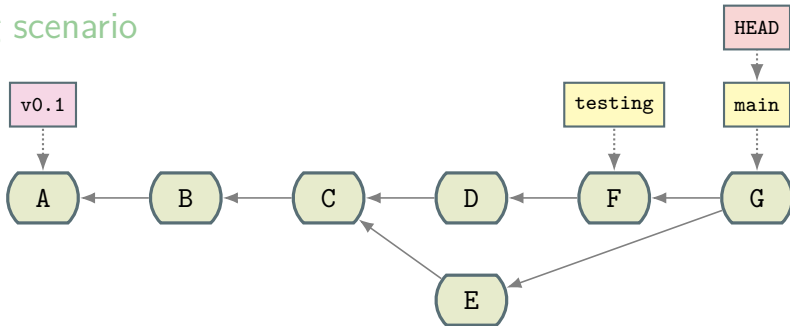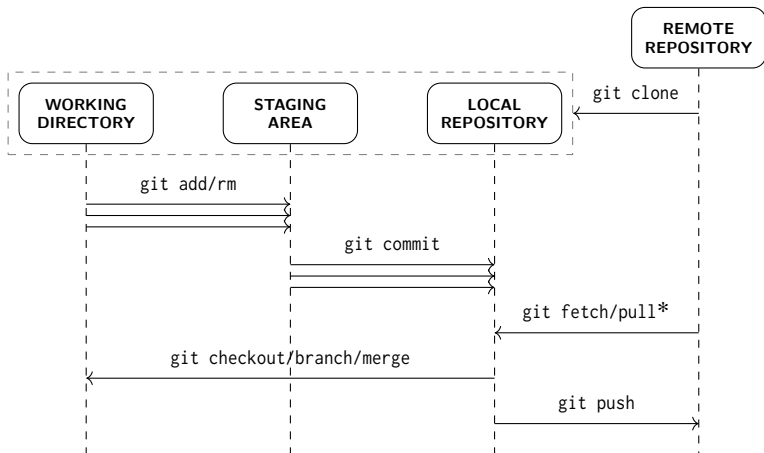

One commit later

Diverging scenario


```
$> git checkout main
```

Diverging scenario


```
$> git merge testing
```

Summary of a typical Git workflow

Conclusion

- Tendency to confuse VCS and Git
- Basic principles of VCS
  - basic principles
  - two main families: centralized vs decentralized
  - tools diversity
- Some good practices for VCS/Git usage
- Importance of a workflow
  - should be simple
  - should enhance the team productivity
  - should be oriented by business requirements
- VCS usage should be an habit, not a constraint

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Resources

- VCS
  - https://homes.cs.washington.edu/~mernst/advice/version-control.html
  - https://betterexplained.com/articles/a-visual-guide-to-version-control/
  - https://betterexplained.com/articles/intro-to-distributed-version-control-illustrated/

- Git
  - https://git-scm.com/
  - https://git-scm.com/book/en/v2/ (Pro Git book)
  - http://justinhileman.info/article/git-pretty/
  - https://betterexplained.com/articles/aha-moments-when-learning-git/
  - https://rachelcarmena.github.io/2018/12/12/how-to-teach-git.html

- Subversion: http://svnbook.red-bean.com/
- Mercurial: https://www.mercurial-scm.org/

Gentle reminder

⚠ Important notes

▶ If you do not understand something, please ask your questions. *We cannot answer the questions you do not ask*

▶ If you disagree with us, please say it (politely)

▶ People don't learn computer science by only reading few academic slides: practicing is fundamental