Laboratorio di Programmazione

Prof. Marco Bertini
marco.bertini@unifi.it
http://www.micc.unifi.it/bertini/

Code versioning: techniques and tools

Software versions

- All software has multiple versions:
  - Each time you edit a program
  - Versions within a development cycle
    - Test release with debugging code
    - Alpha, beta of final release
  - Variations for different platforms
    - Hardware and software
  - Different releases of a product

Version control

- Version control tracks multiple versions of code.
- In particular, allows:
  - old versions to be recovered
  - multiple versions to exist simultaneously
- Typically multiple users can contribute to software development and version control systems allow them to collaborate:
  - multiple versions of multiple users, merging their contribute
  - tracks who did what

Version control

- Version control tracks multiple versions of code.

In general **version control** (or **revision control**, or **source control**) is about managing multiple versions of documents, programs, web sites. It works best on text documents but can manage also binary files such as images.

development and version control systems allow them to collaborate:

- multiple versions of multiple users, merging their contribute
- tracks who did what

Why using version control?

- Because it is useful
  - You will want old/multiple versions
  - Without version control, can’t recreate project history
  - Allows to go back in history, to solve bugs introduced since the last version of the code
- Because everyone does
  - A basic software development tool.
    Beware of those who do not use it.
  - If you need to share coding responsibilities or maintenance of a codebase with another person, you need version control.

Why using version control?

- For working by yourself:
  - Gives you a “time machine” for going back to earlier versions
  - Gives you great support for different versions of the same project
- For working with others:
  - Greatly simplifies concurrent work, merging changes

Code base

- A Code Base does not just mean code!
  It also includes:
  - Documentation
  - Build Tools (CMake files, Makefiles, etc.)
  - Configuration files
- All these files may change over time and older versions have to be kept.

Code base

Manage these things using a version control system (**VCS**)
A version control system is a system which allows for the management of a code base.

- Documentation
- Build Tools (CMake files, Makefiles, etc.)
- Configuration files

- All these files may change over time and older versions have to be kept.

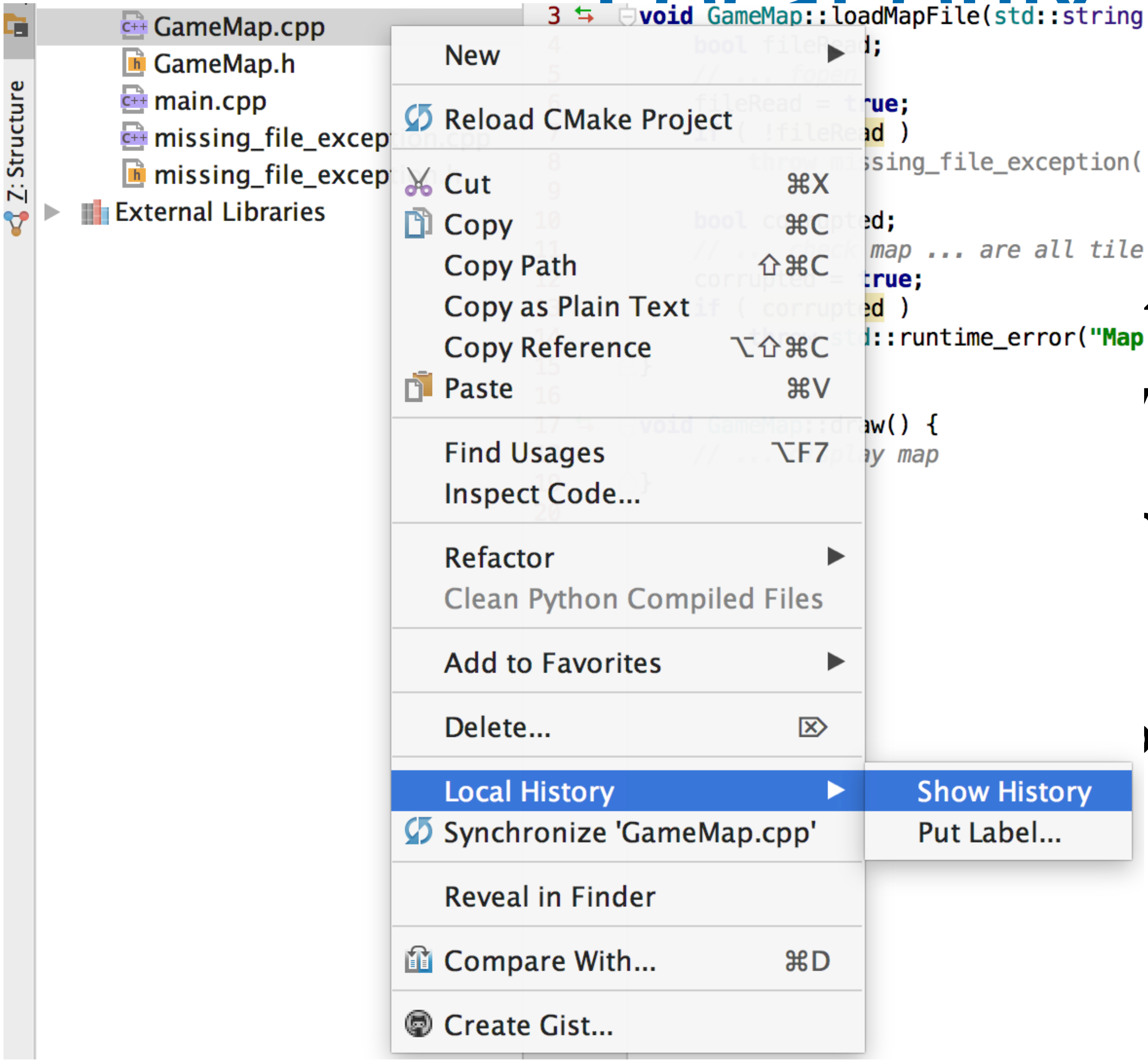
Types of Version Control Systems

- Local only - keeps a local database of changes in your local machine filesystem.
- Centralized - (Subversion, CVS), require a connection to a central server and "checkout"
- Distributed - (Git, Mercurial) allow for local systems to be "mirrors" of the central repo. You don't need to be connected to the central server to get work or commits done.

Local only

- IDE like CLion and Eclipse maintain a local history of each file developed within the IDE.
- Pros: you don't have to do anything. This versioning is automatic.
- Cons: each file has its own history. You do not know which versions of several files was used at a certain moment.

Local only



```
void GameMap::loadMapFile(std::string
    bool fileRead;
    // ... fopen
    fileRead = true;
    if ( !fileRead )
        throw missing_file_exception(

    bool corrupted;
    // ... check map ... are all tile
    corrupted = true;
    if ( corrupted )
        throw std::runtime_error("Map
    }
}

void GameMap::draw() {
    // ... display map
}
```

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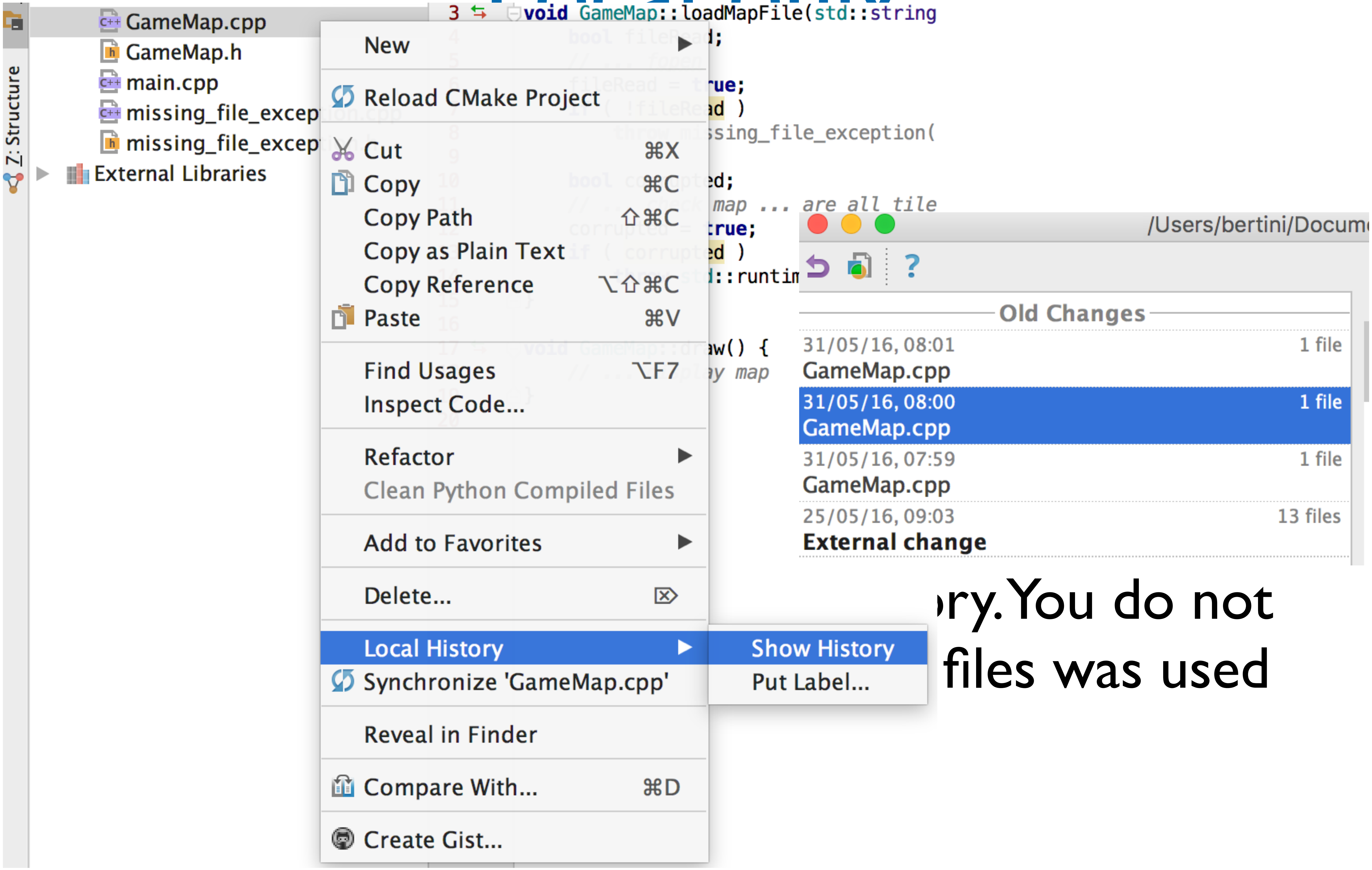
files was used

Local only



```
void GameMap::loadMapFile(std::string
```

Old Changes

31/05/16, 08:01 1 file
GameMap.cpp

31/05/16, 08:00 1 file
GameMap.cpp

31/05/16, 07:59 1 file
GameMap.cpp

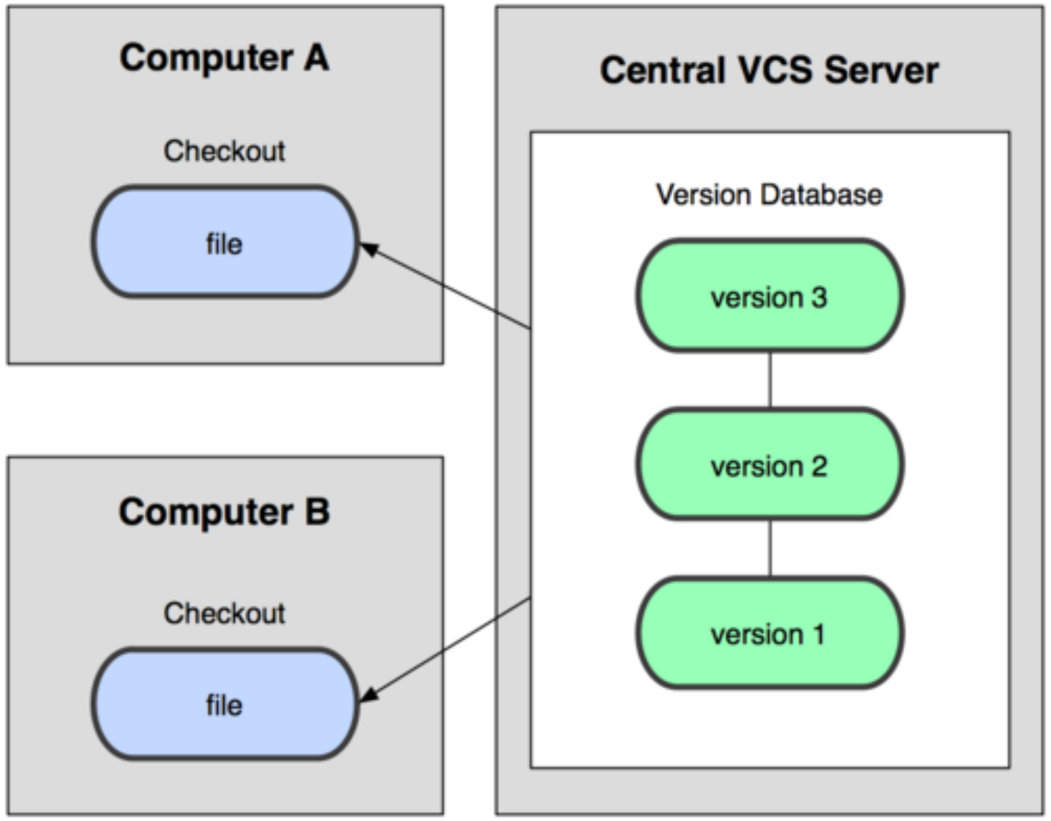
25/05/16, 09:03 13 files
External change

ry. You do not

files was used

Centralized

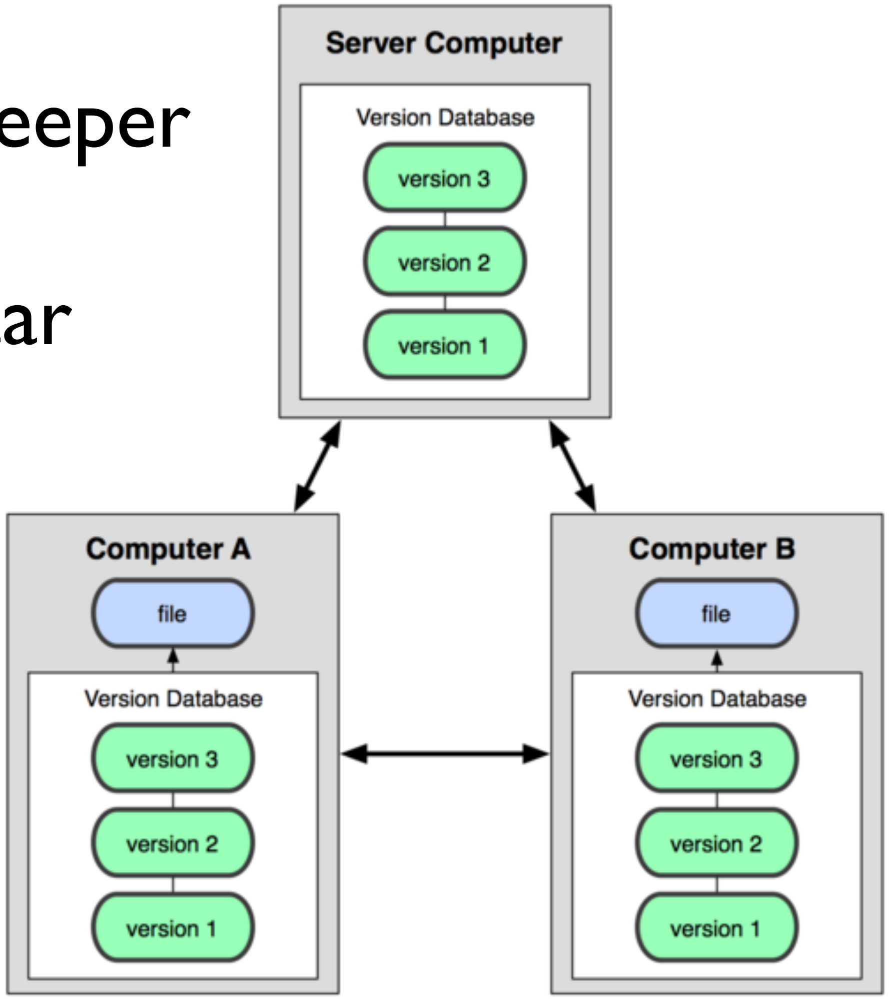
- Traditional version control system
  - Server with database
  - Clients have a working version
- Examples
  - CVS
  - Subversion
  - Visual Source Safe
- Challenges
  - Multi-developer conflicts
  - Client/server communication



Distributed

- Authoritative server by convention only
- Every working checkout is a repository
- Get version control even when detached
- Backups are trivial

- Examples
  - Git
  - Mercurial
  - BitKeeper
  - Bazaar



Overview of the process

- Files are kept in a **repository**
- Repositories can be local or remote to the user
- The user edits a copy called the **working copy**
- Changes are **committed** to the repository when the user is finished making changes
- Other people can then access the repository to get the new code
- Can also be used to manage files when working across multiple computers

Branching

- Branches allows multiple copies of the code base within a single repository.
- Different customers have different requirements
  - Customer A wants features A,B, C
  - Customer B wants features A & C but not B because his computer is old and it slows down too much.
  - Customer C wants only feature A due to costs
- Each customer has their own branch.
- Different versions can easily be maintained

Basic features of a VCS

- Check-in and check-out of items to repository
- Creation of baselines (labels/tags)
  - e.g. "Version 1.0 released!"
- Control and manipulation of branching
  - management of multiple versions
- Overview of version history
  - Allows to see who changed what

Check out / check in

- If you want to make a change the file needs to be **checked out** from the repository.
- When changes are completed the new code is **checked-in**.
- A **commit** consists of a set of checked in files and the diff between the new and parent versions of each file.
- Each check-in is accompanied by a user name and other meta data.
- Check-ins can be exported from the Version Control System the form of a **patch**.

Revision

- Consider
  - Check out a file
  - Edit it
  - Check the file back in
- This creates a new version of the file
- With each revision, system stores
  - The diffs for that version (typically for efficiency, the VCS doesn't store entire new file, but stores diff with previous version)
  - The new file version number
  - Other metadata
  - Author
  - Time of check in
  - Log file message

Merge

- There are occasions when multiple versions of a file need to be collapsed into a single version.
- E.g. a feature from one branch is required in another, or two developers worked on the same file.
- This process is known as a **merge**.

Merge

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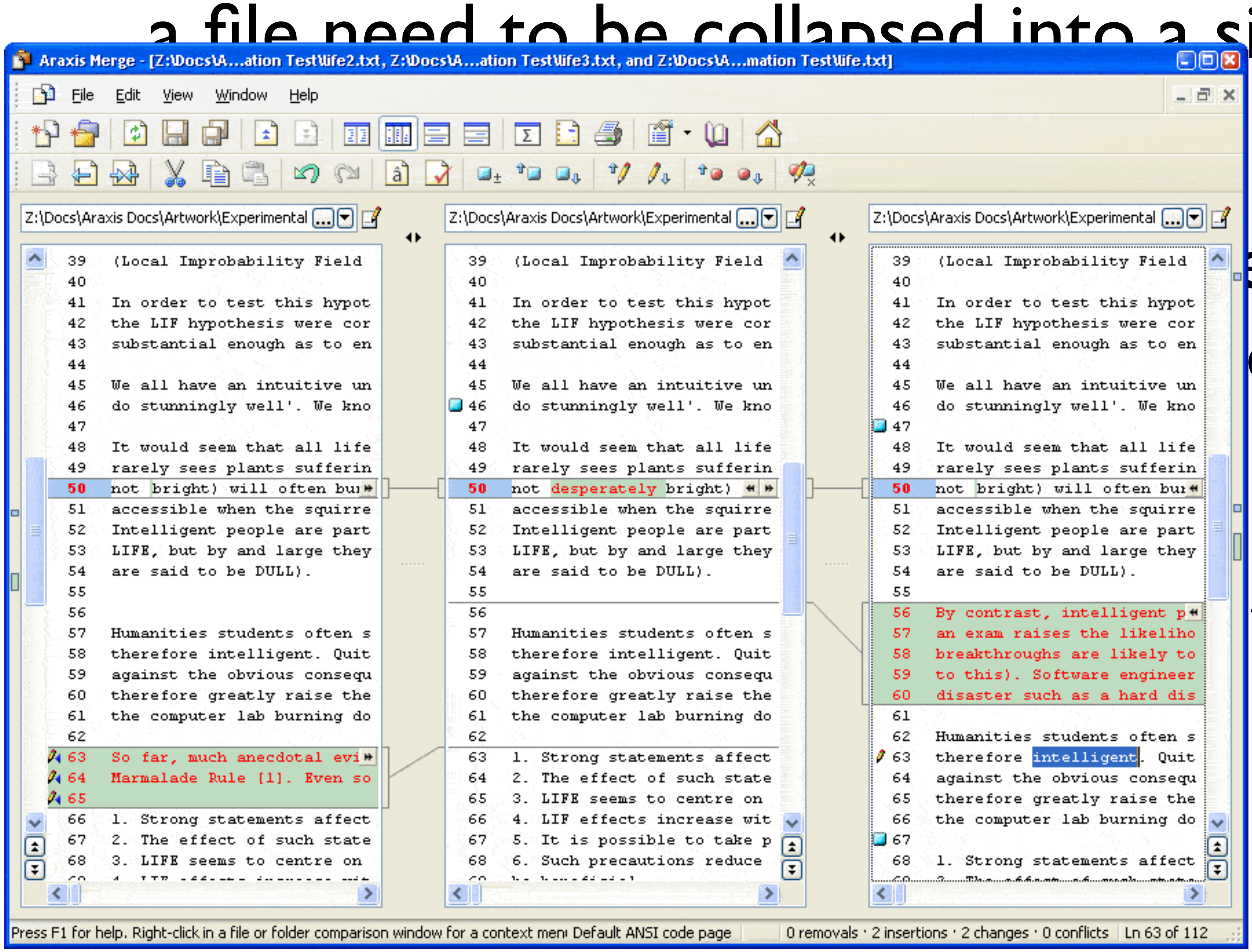

Araxis Merge - [Z:\Docs\A...ation Test\life2.txt, Z:\Docs\A...ation Test\life3.txt, and Z:\Docs\A...mation Test\life.txt]

Z:\Docs\Araxis Docs\Artwork\Experimental

```
39  (Local Improbability Field
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41  In order to test this hypot
42  the LIF hypothesis were cor
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45  We all have an intuitive un
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63  So far, much anecdotal evi
64  Marmalade Rule [1]. Even so
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66  1. Strong statements affect
67  2. The effect of such state
68  3. LIFE seems to centre on
```

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65  3. LIFE seems to centre on
66  4. LIF effects increase wit
67  5. It is possible to take p
68  6. Such precautions reduce
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61
62  Humanities students often s
63  therefore intelligent. Quit
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65  therefore greatly raise the
66  the computer lab burning do
67
68  1. Strong statements affect
```

Press F1 for help. Right-click in a file or folder comparison window for a context meni Default ANSI code page | 0 removals · 2 insertions · 2 changes · 0 conflicts | Ln 63 of 112

Merging

1. Start with a file, e.g. v.1.5
2. Bob makes changes A to v.1.5
3. Alice makes changes B to v.1.5
4. Assume Alice checks in first
5. Current revision is v.1.6 = apply(B, v.1.5)
6. Now Bob checks in
7. System notices that Bob checked out v.1.5, but current version is v.1.6
8. Bob has not made his changes in the current version!
9. The system complains
10. Bob is told to update his local copy of the code
11. Bob does an update
12. This applies Alice's changes B to Bob's code
13. Two possible outcomes of an update:
    - Success
    - Conflicts

Merge success

- Assume that:
    - apply(A, apply(B, v.1.5) = apply(B, apply(A, v.1.5))
- Then then order of changes didn’t matter
- Same result whether Bob or Alice checks in first
- The version control system is happy with this
- Bob can now check in his changes
    - Because apply(B, apply(A, v.1.6)) = apply(B, v.1.6)

Merge conflict

- Assume
- apply(A,apply(B,1.5) ≠ apply(B,apply(A,1.6))
- There is a conflict
  - The order of the changes matters
  - Version control will complain
- Arise when two programmers edit the same piece of code
  - One change overwrites another

Merge conflict

- System cannot apply changes when there are conflicts:
  - Final result is not unique
  - Depends on order in which changes are applied
- Version control shows conflicts on update
- Conflicts must be **resolved by hand**

Conflicts

- Conflict detection is based on “nearness” of changes
    - Changes to the same line will conflict
    - Changes to different lines will likely not conflict
- Note: Lack of conflicts does not mean Alice’s and Bob’s changes work together

Merging conflicts

- Merging is syntactic
- Semantic errors may not create conflicts
  - But the code is still wrong
- You are lucky if the code doesn’t compile
  - Worse if it does . . .

Problem example

- The Linux kernel runs on different processors (ARM, x86, MIPS). These can require significant differences in low level parts of the code base
- Many different modules
- Old versions are required for legacy systems
- Because it is open source, any one can download and suggest changes.

Git

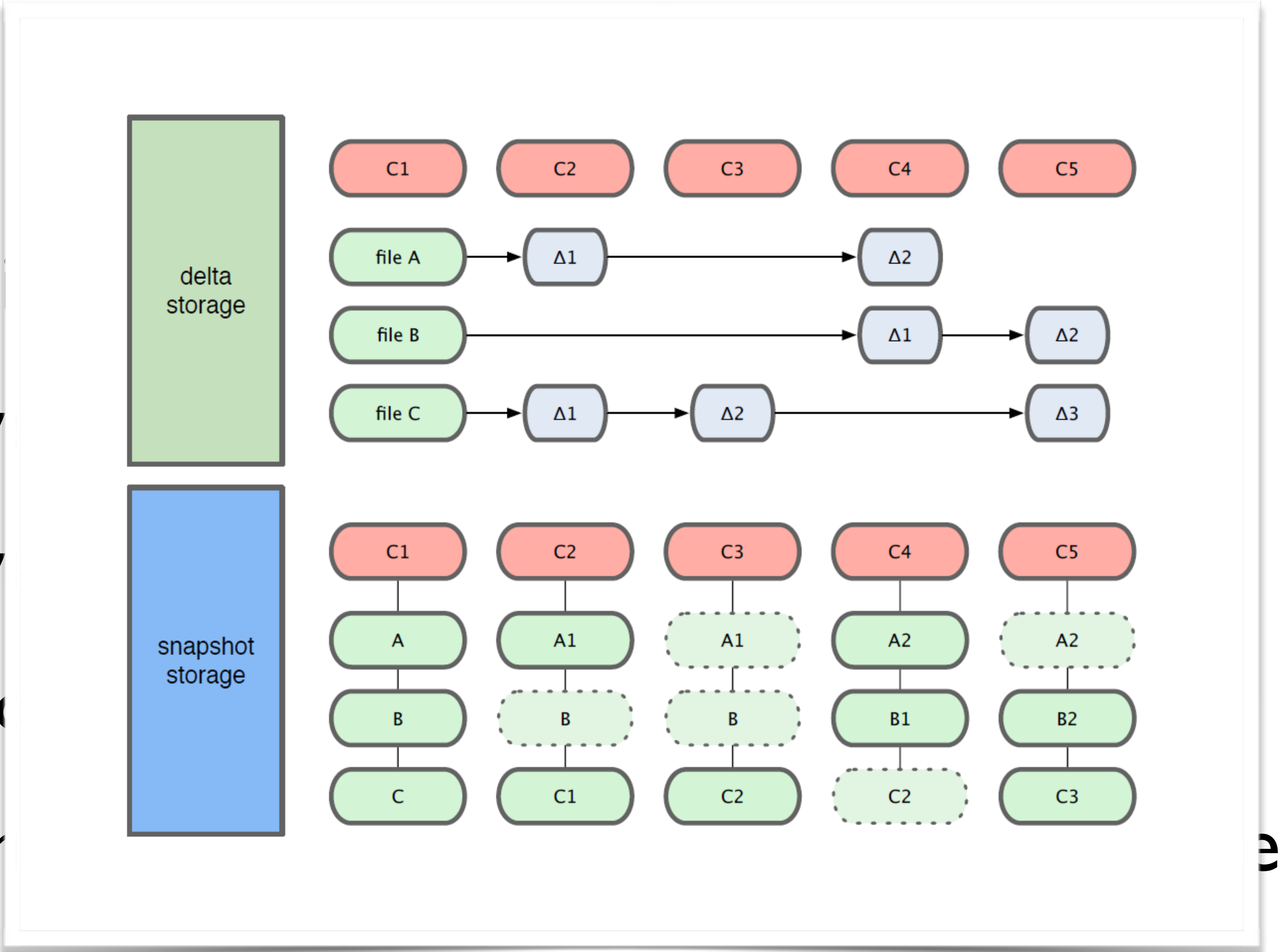
History

- Came out of Linux development community
- Linus Torvalds, 2005
- Initial goals:
  - Speed
  - Support for non-linear development (thousands of parallel branches)
  - Fully distributed
  - Able to handle large projects like Linux efficiently

Features

- It is distributed
- Everyone has the complete history
- Everything is done offline
- No central authority
- Changes can be shared even without a server
- Snapshot storage instead of diff

Features



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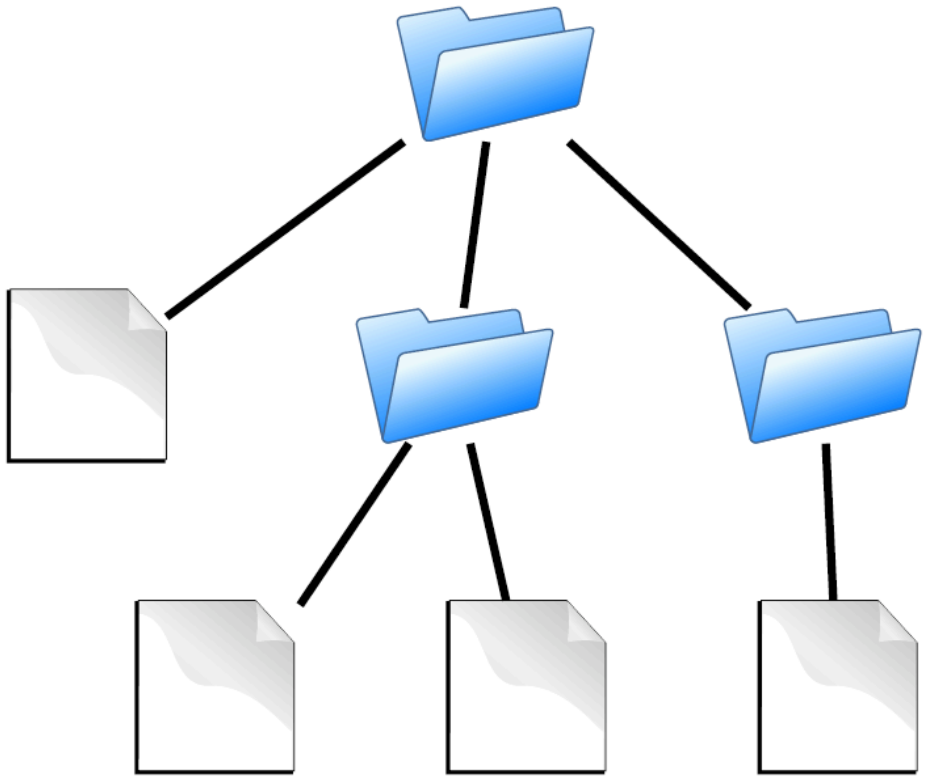
Code base

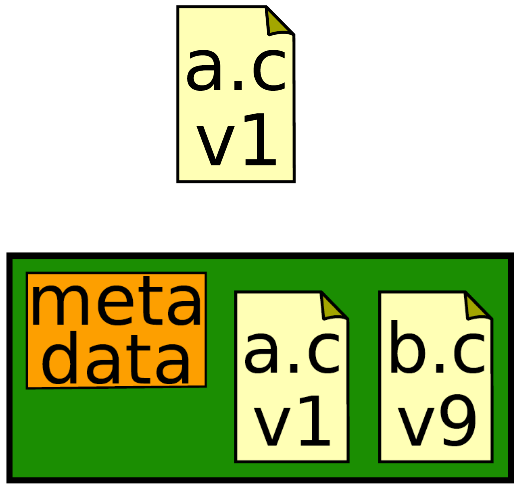


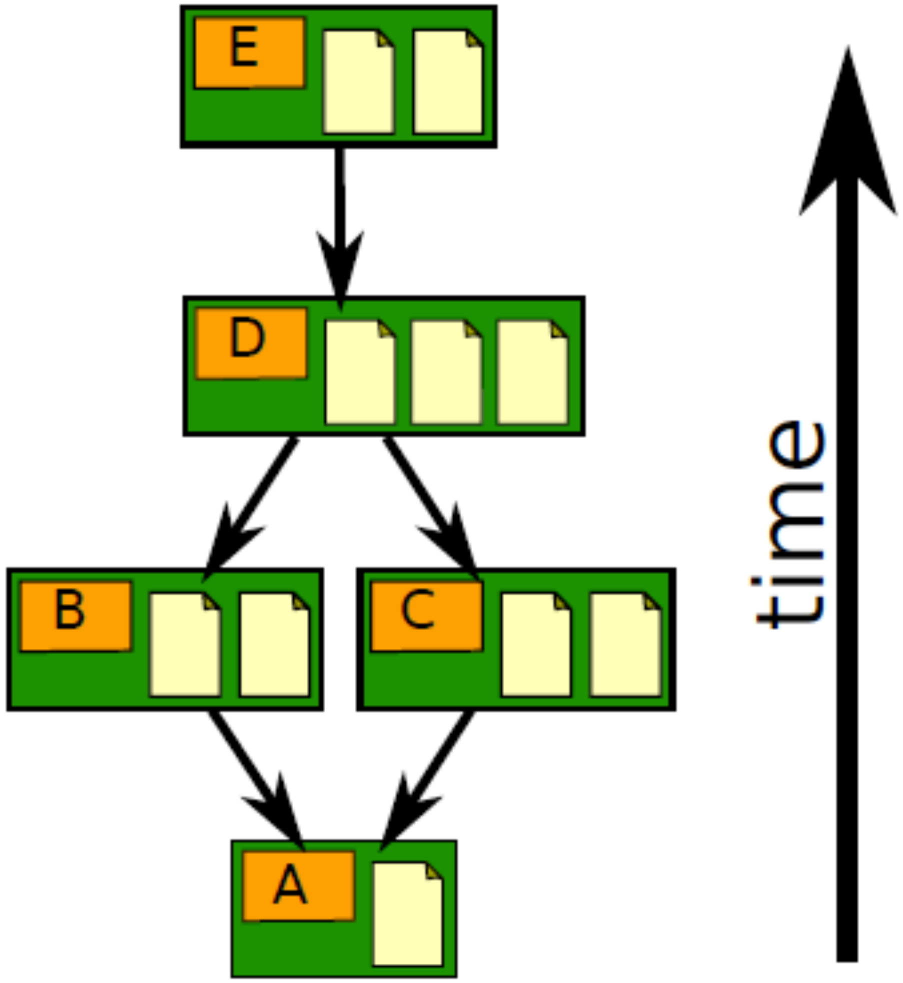
Contains:

- directories
- files

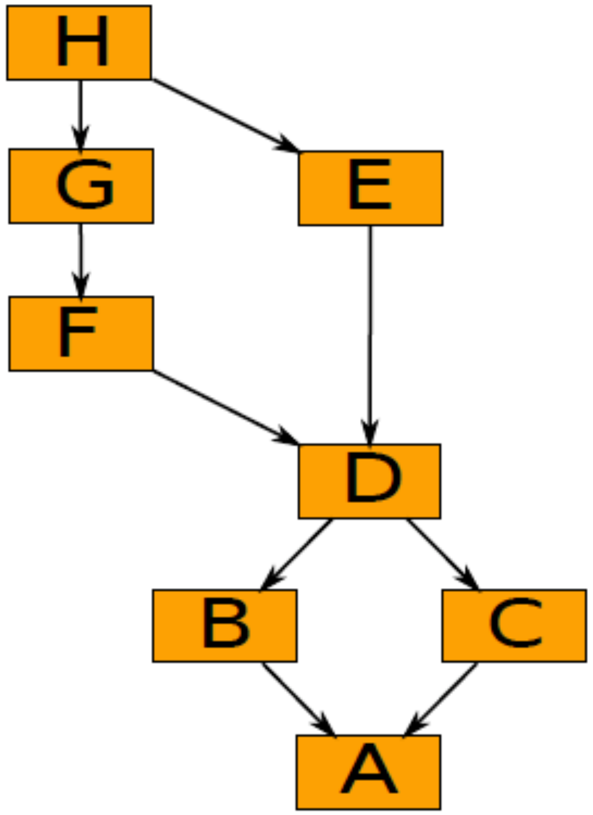
Repository

- Contains
  - files
  - commits
  - ancestry relationships
- records history of changes



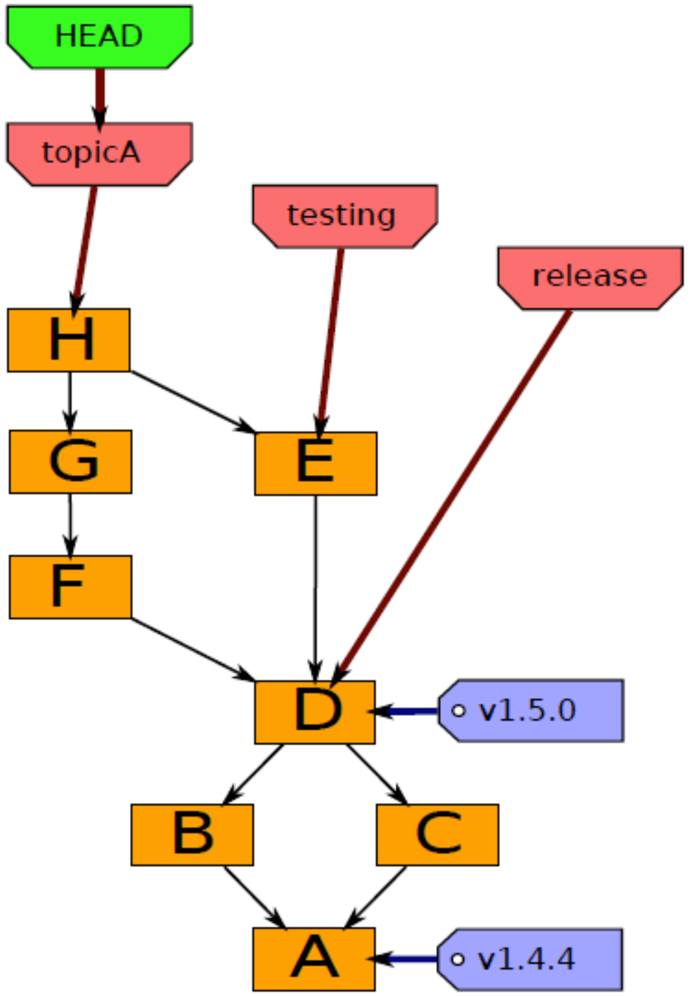


Ancestry relationships



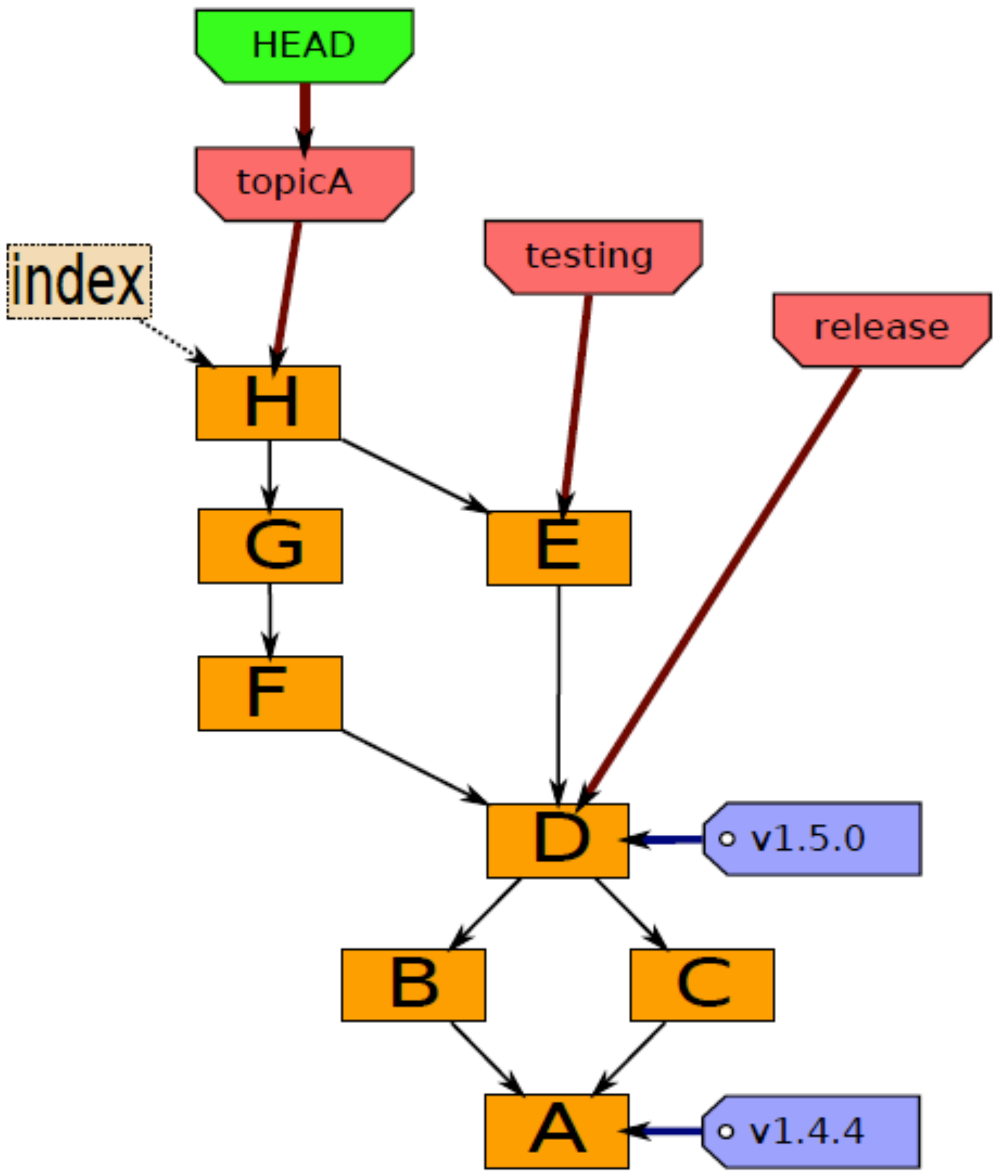
- form a directed acyclic graph (DAG)

Ancestry graph features



- HEAD
  - is current checkout
  - usually points to a branch

Git component

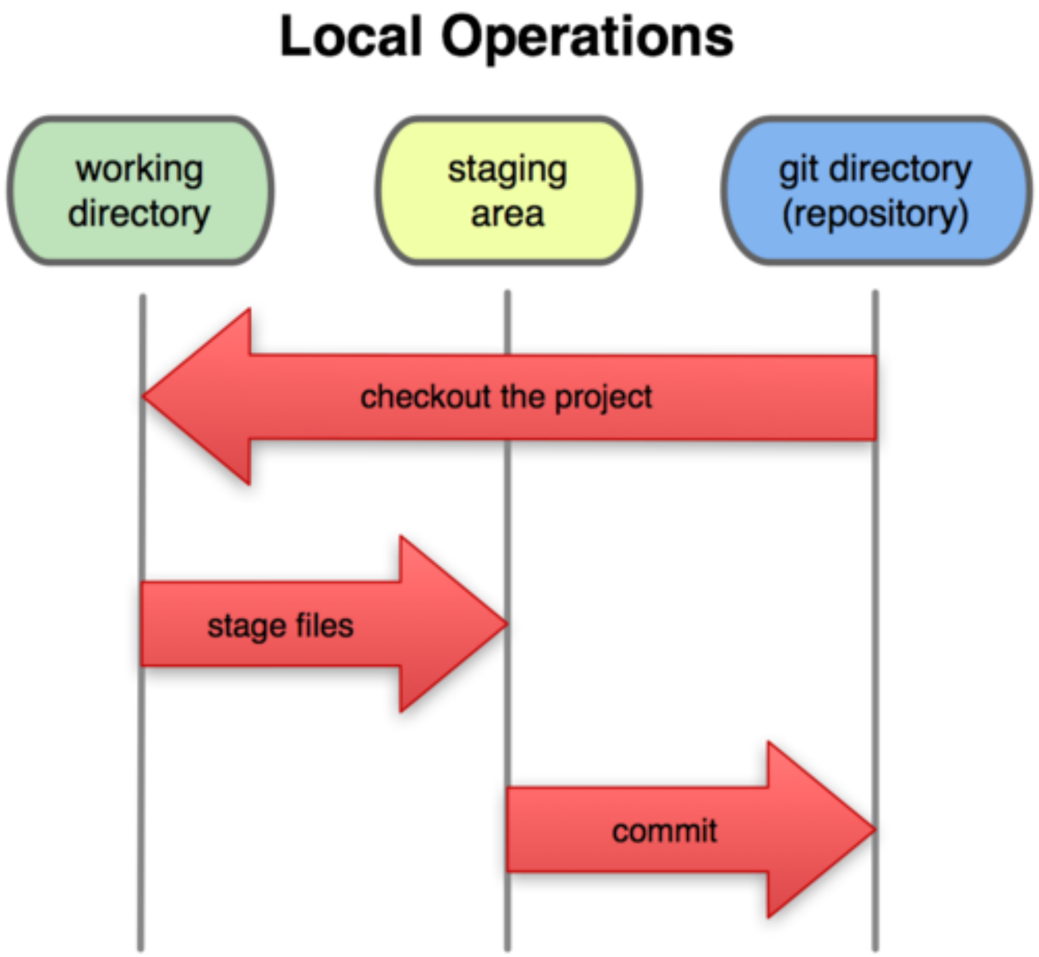


- Index
  - “staging area”
  - what is to be committed

Getting started

- Three areas of Git
- The HEAD
    - last commit snapshot, next parent
- Index
    - Proposed next commit snapshot
- Working directory
    - Sandbox

Index HEAD



Unmodified/modified Files

Staged Files

Committed Files

Basic workflow

- Init a repo(sitory): init to start a new project or clone an existing project
  - will create a “.git” directory.
    This is your local repo.
- Edit files
- Stage the changes (add files to repo)
- Review your changes
- Commit the changes

You can work as much as you like in your working directory, but the repository isn't updated until you commit something

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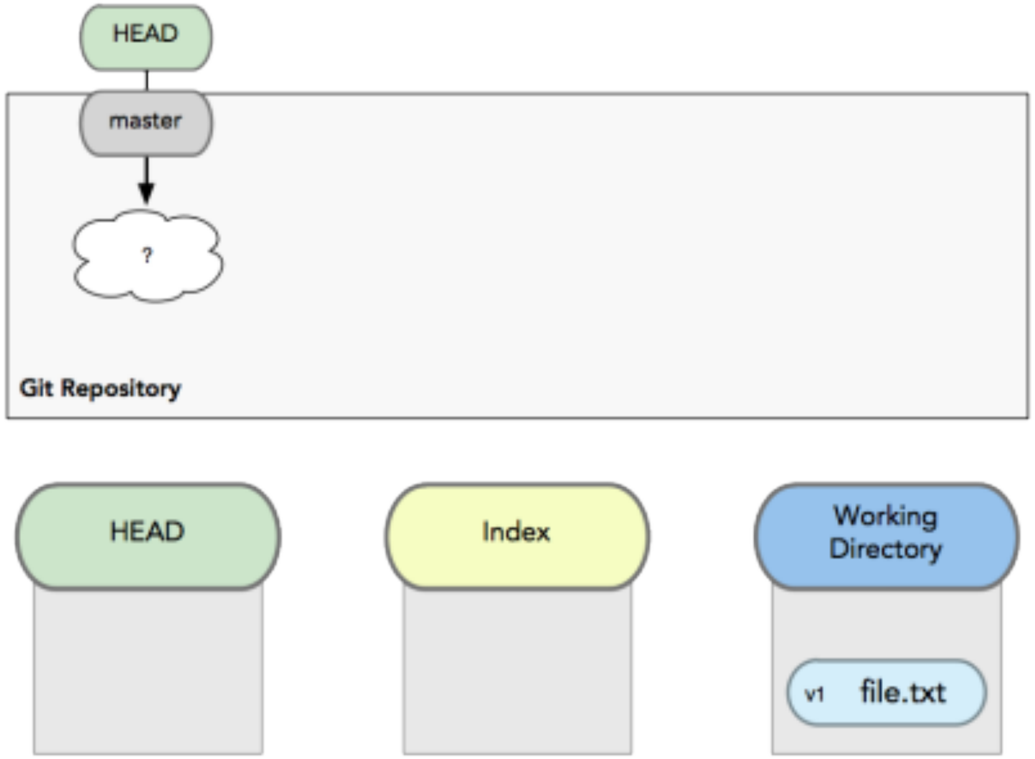
What not to track

- It’s important to tell Git what files you do not want to track
- Temp files, executable files, etc. do not need version control (and can cause major issues when merging!)
- We add the filenames to the special file .gitignore. We store this file in the repository

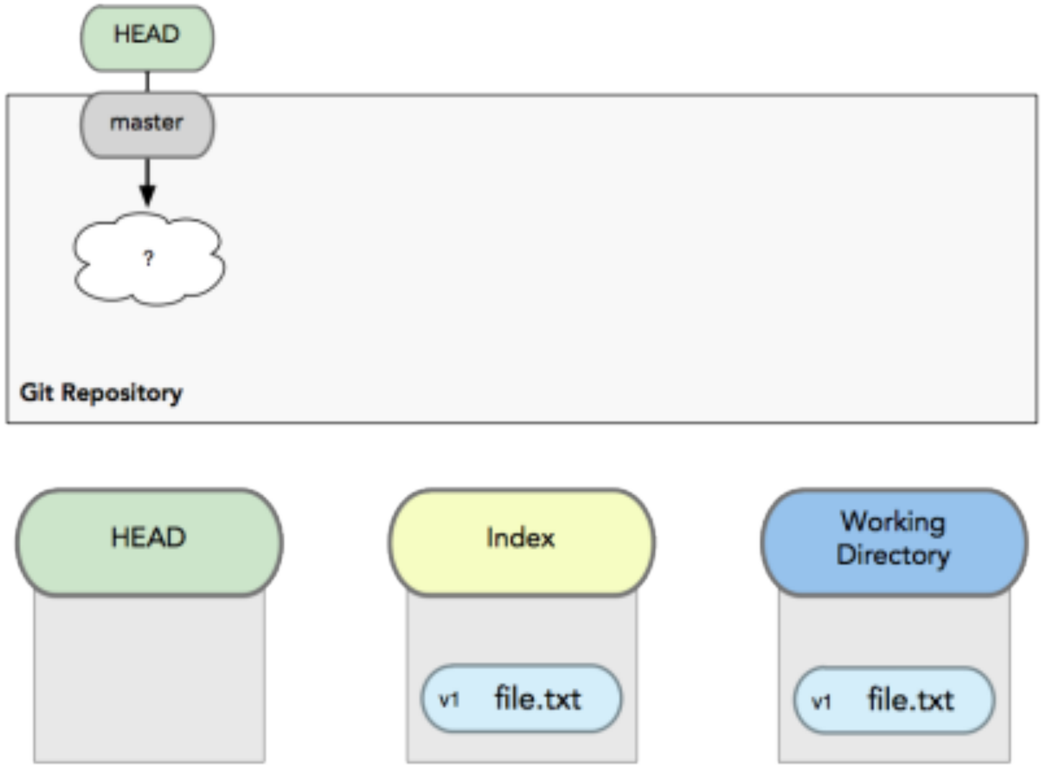
Getting started: edit file

- A basic workflow
  - **Edit files**
  - Stage the changes
  - Review your changes
  - Commit the changes



Getting started: stage

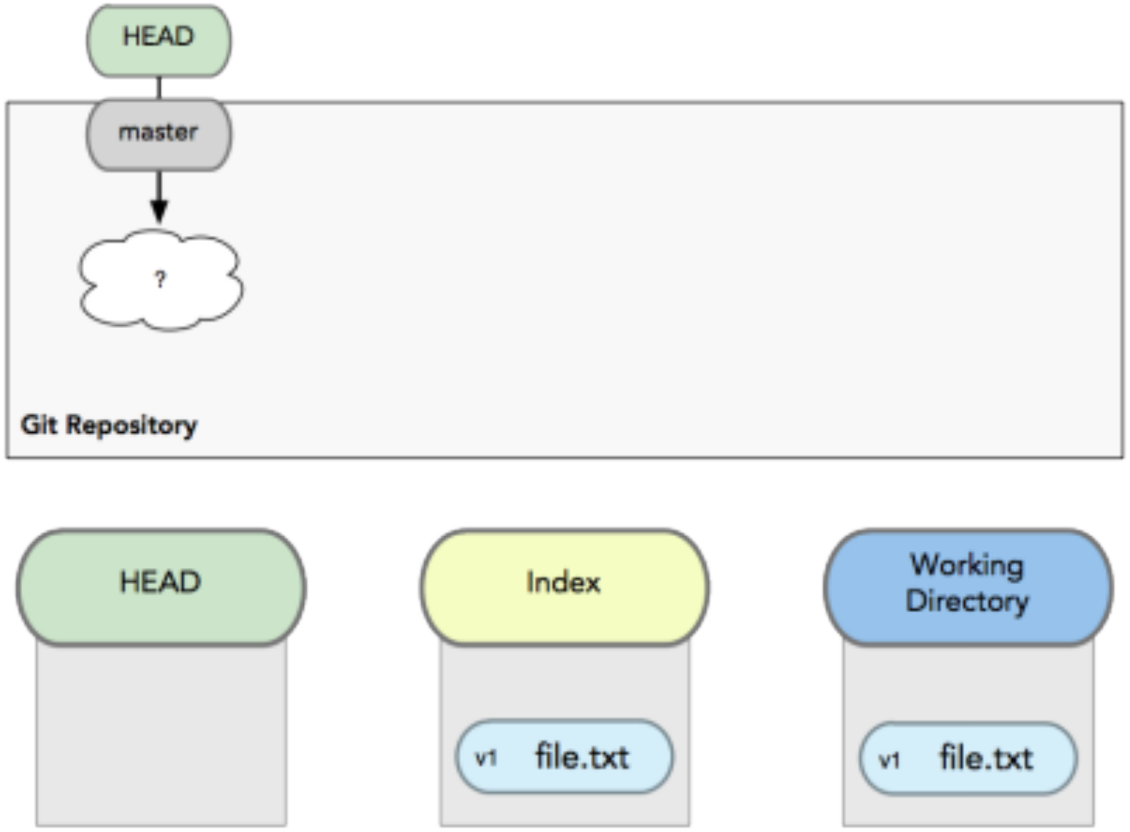
- A basic workflow
  - Edit files
  - **Stage the changes**
  - Review your changes
  - Commit the changes



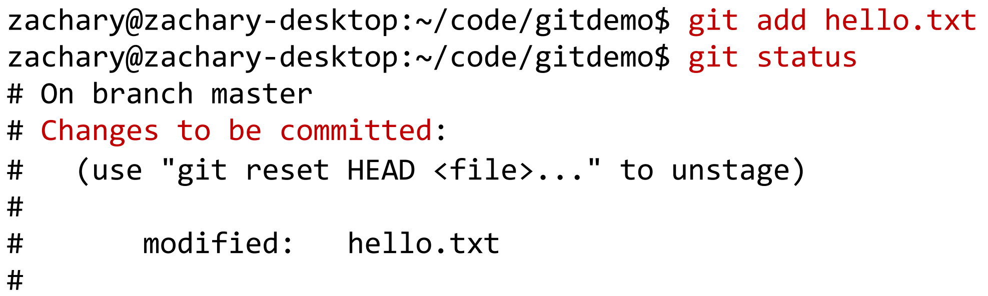
git add

Getting started: review

- A basic workflow
  - Edit files
  - Stage the changes
  - **Review your changes**
  - Commit the changes



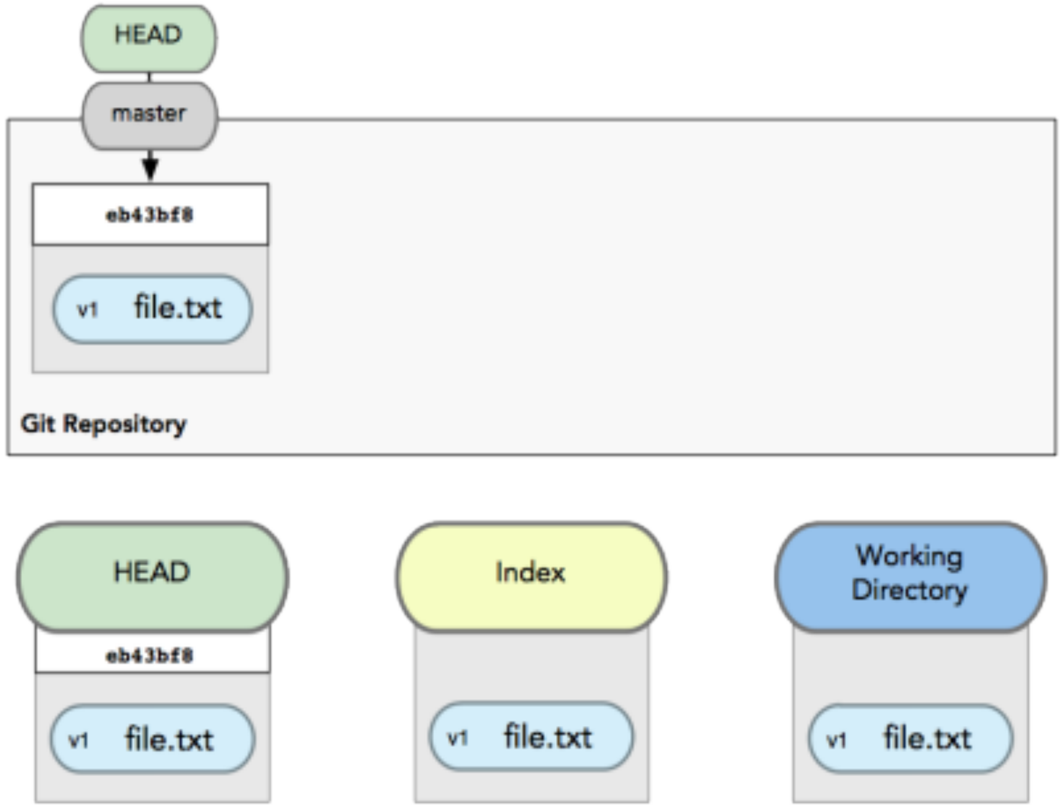
git status



```
zachary@zachary-desktop:~/code/gitdemo$ git add hello.txt
zachary@zachary-desktop:~/code/gitdemo$ git status
# On branch master
# Changes to be committed:
#   (use "git reset HEAD <file>..." to unstage)
#
#       modified:   hello.txt
#
```

Getting started: commit

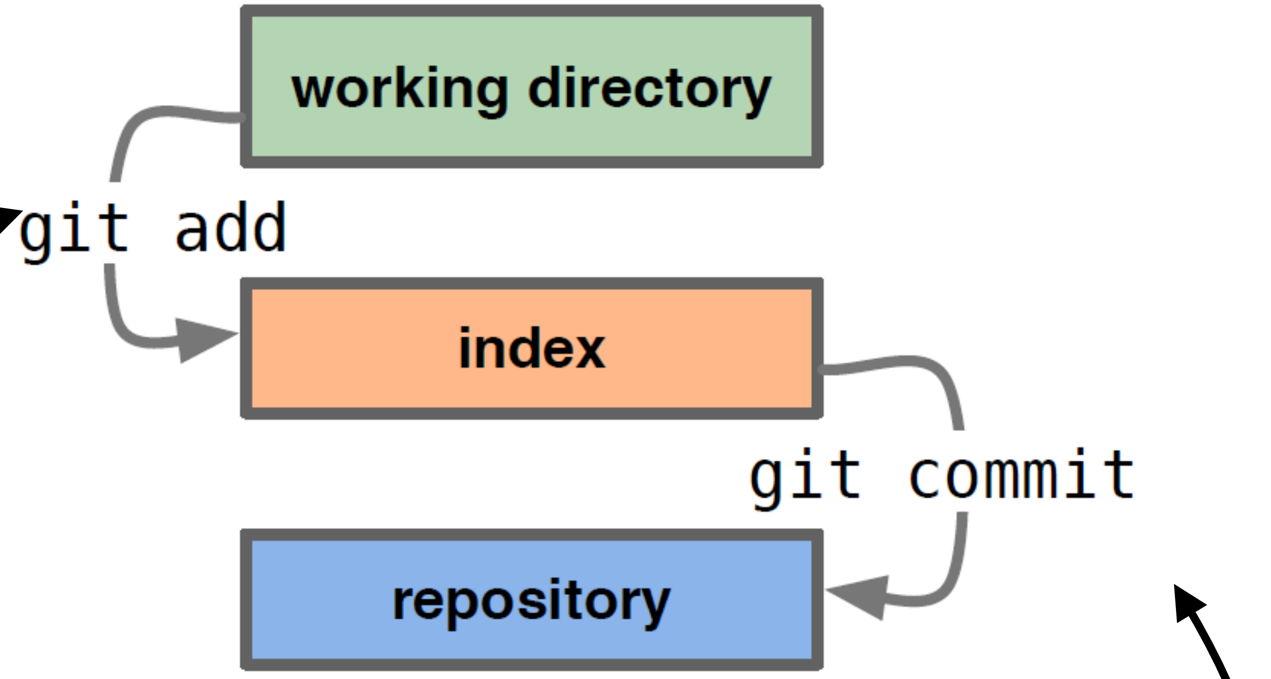
- A basic workflow
  - Edit files
  - Stage the changes
  - Review your changes
  - **Commit the changes**



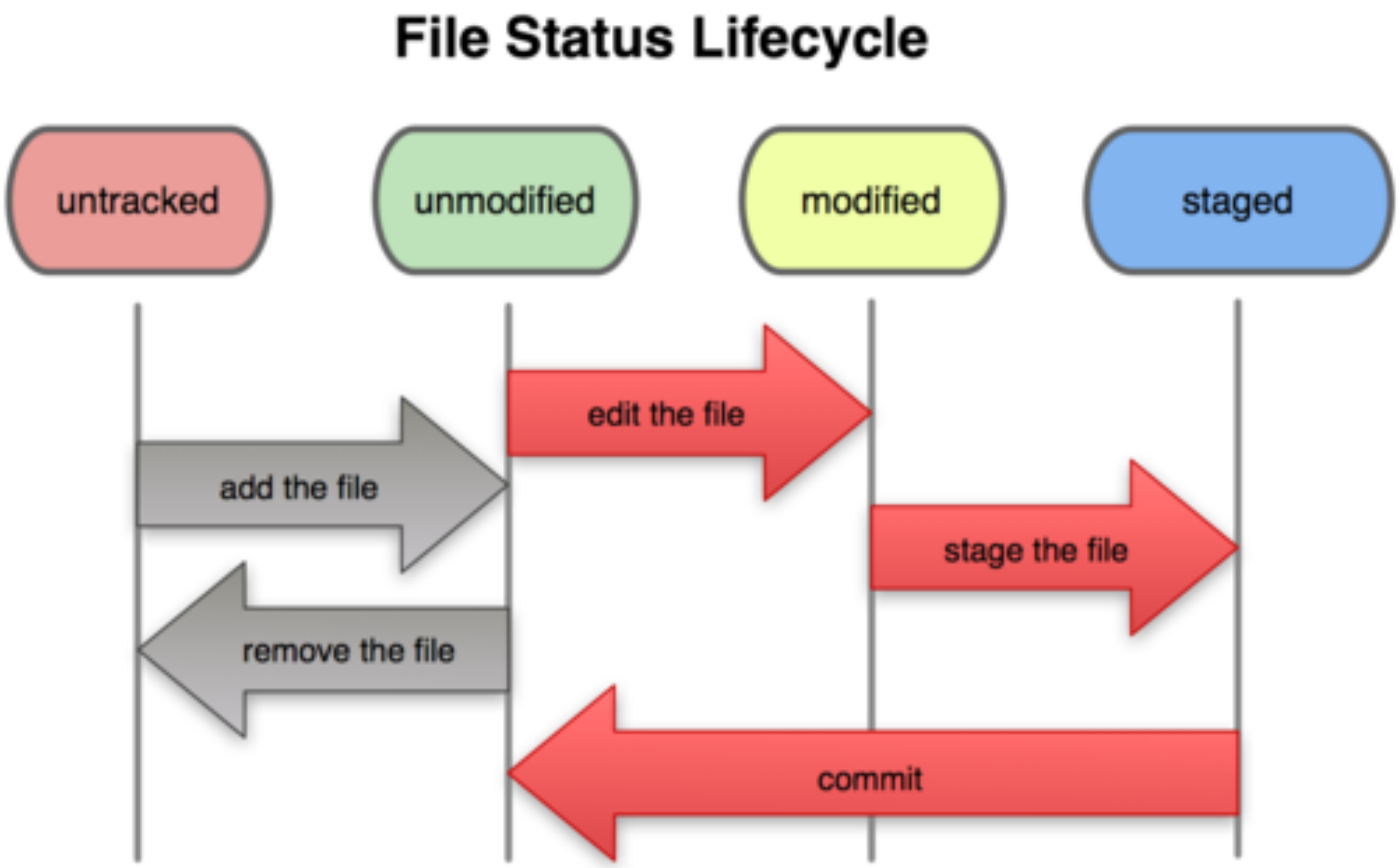
git commit

Getting started

- A basic workflow
  - Edit files
  - Stage the changes
  - Review your changes
  - Commit the changes



File life lifecycle



Files outside Git

Commits and graphs

- A commit is when you tell git that a change (or addition) you have made is ready to be included in the project
- When you commit your change to git, it creates a commit object, that represents the complete state of the project, including all the files in the project
- The very first commit object has no “parents”
- Usually, you take some commit object, make some changes, and create a new commit object; the original commit object is the parent of the new commit object
  - Hence, most commit objects have a single parent
  - You can also merge two commit objects to form a new one, in this case the new commit object has two parents
  - Hence, commit objects form a directed graph
- Git is all about using and manipulating this graph

Commits and graphs

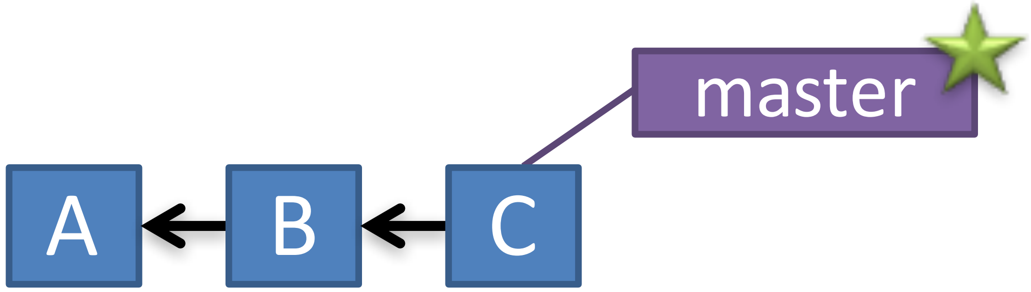
- A head is a reference to a commit object
- The "current head" is called HEAD (all caps)
- Usually, you will take HEAD (the current commit object), make some changes to it, and commit the changes, creating a new current commit object
- This results in a linear graph: A → B → C → … → HEAD

Good practice

- In git, "Commits are cheap." Do them often.
- When you commit, you must provide a one-line message stating what you have done
    - Terrible message: "Fixed a bunch of things"
    - Better message: "Corrected the calculation of median scores"
- Commit messages can be very helpful, to yourself as well as to your team members

Branching and merging

- Branch annotates which commit we are working on
- E.g. we can work on development, create a new branch to handle a bug, write code in the branch and then merge to the master branch



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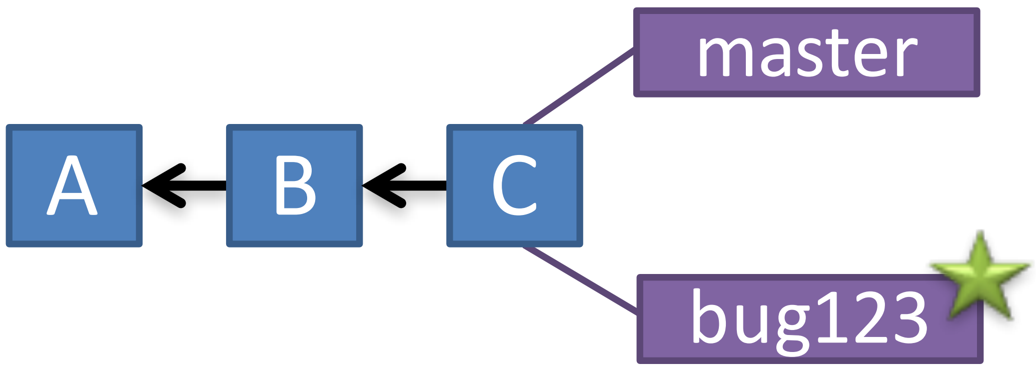

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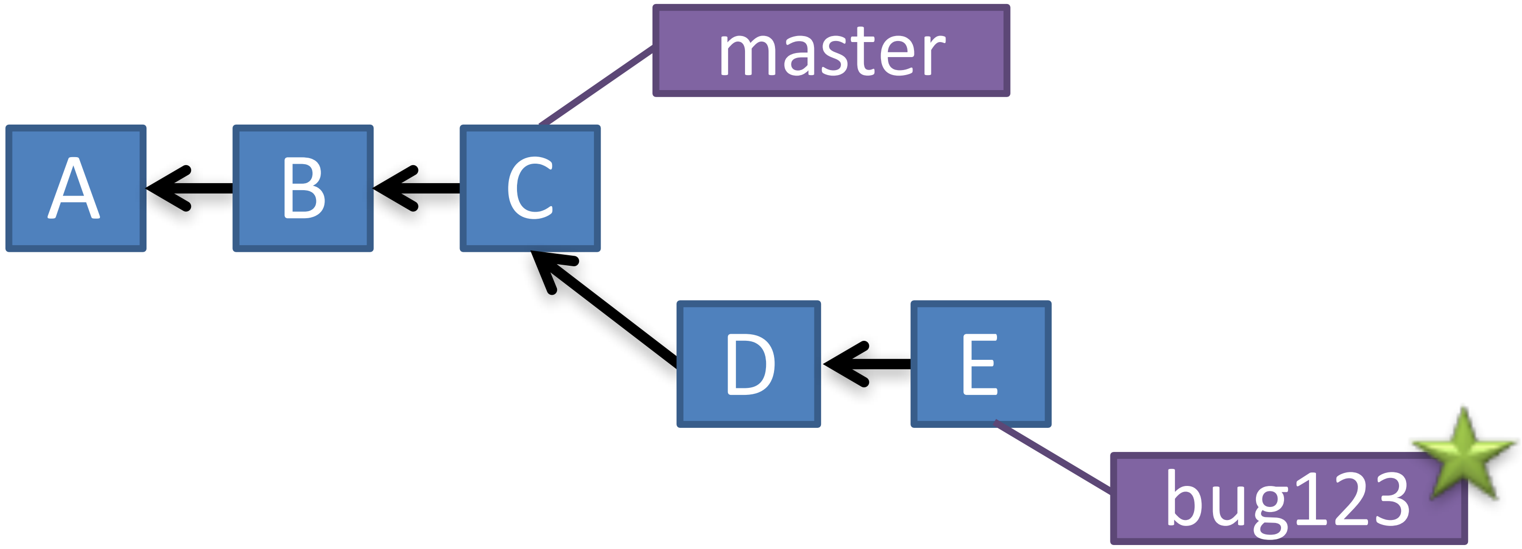

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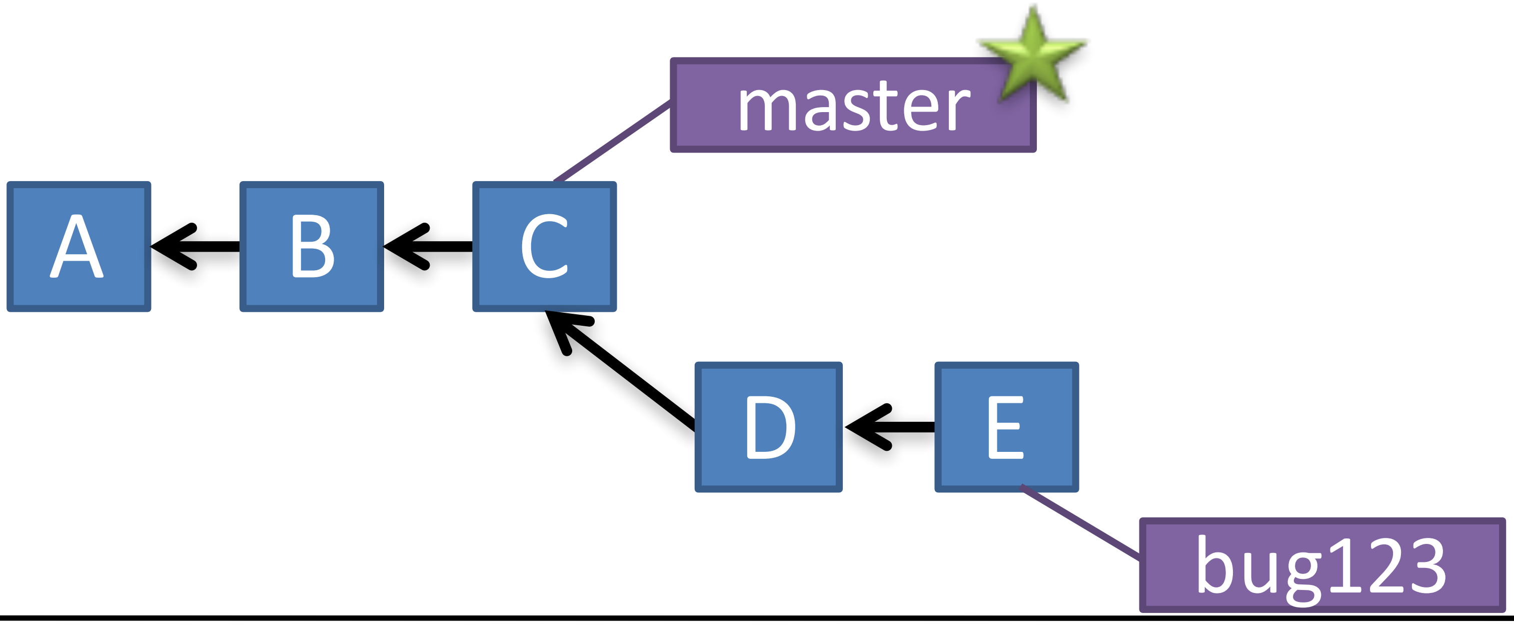

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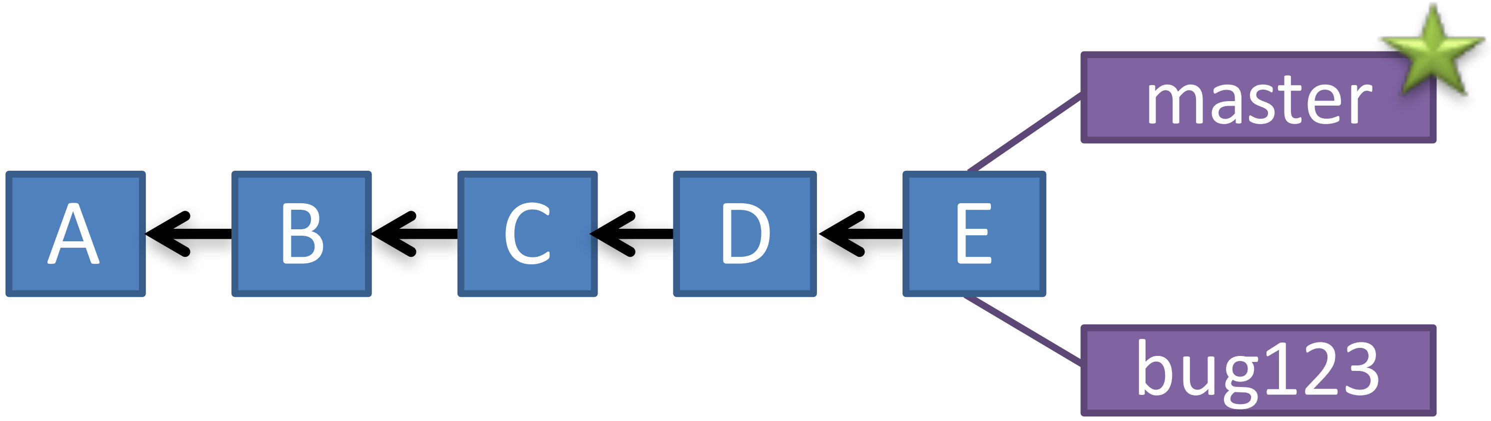


Retrieve old commit

- Use **checkout** to select a committed version of the project or to branches
  - allows to go back in time, e.g. to see when a bug was introduced
  - we can also just evaluate the difference between current ad older versions of code base

Working with remote

- **Add** and **Commit** your changes to your **local** repo
- **Pull from remote** repo to get most recent changes (fix conflicts if necessary, add and commit them to your local repo)
- **Push** your changes **to** the **remote** repo
- **Fetch** to retrieve **from remote** without merging with current code.

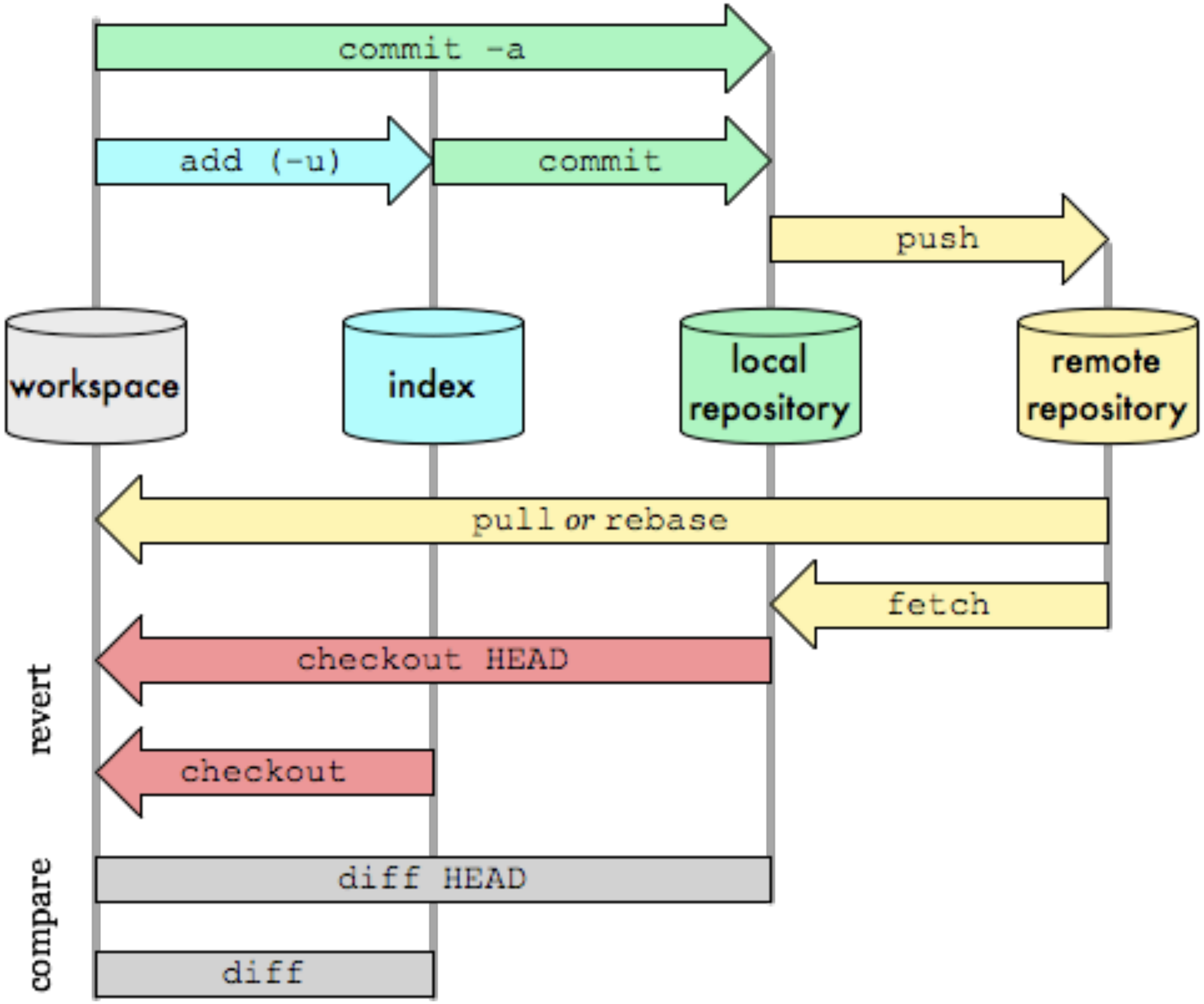
Working with remote

- **Add** and **Commit** your changes to your **local** repo
- **Pull from remote** repo to get most recent changes (fix conflicts if necessary, add and commit them to your local repo)
- **Push** your changes **to** the **remote** repo

Good practice: Pull then Push

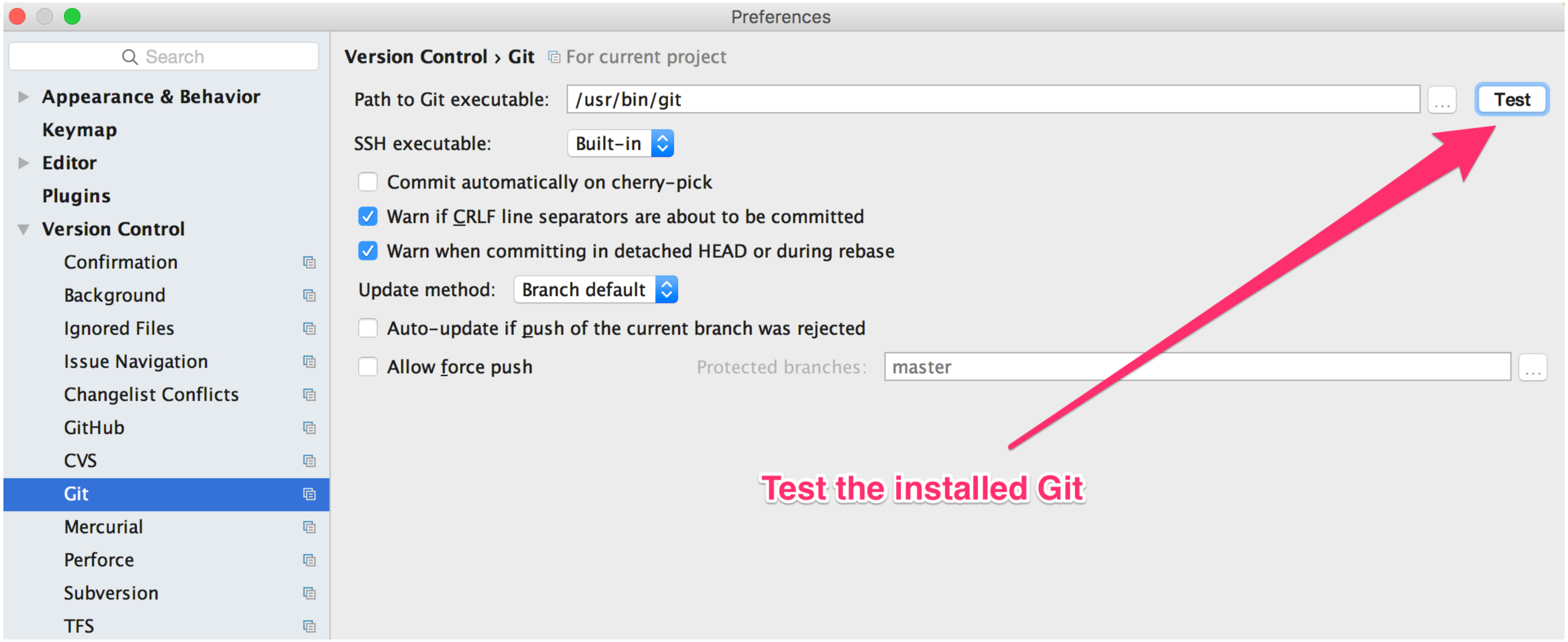
Push will update the remote server.
If you are out of date, Git will reject that push.

Git at a glance



Git and CLion

Check git install



Preferences

Version Control › Git For current project

Path to Git executable: /usr/bin/git

SSH executable: Built-in

□ Commit automatically on cherry-pick

☑ Warn if CRLF line separators are about to be committed

☑ Warn when committing in detached HEAD or during rebase

Update method: Branch default

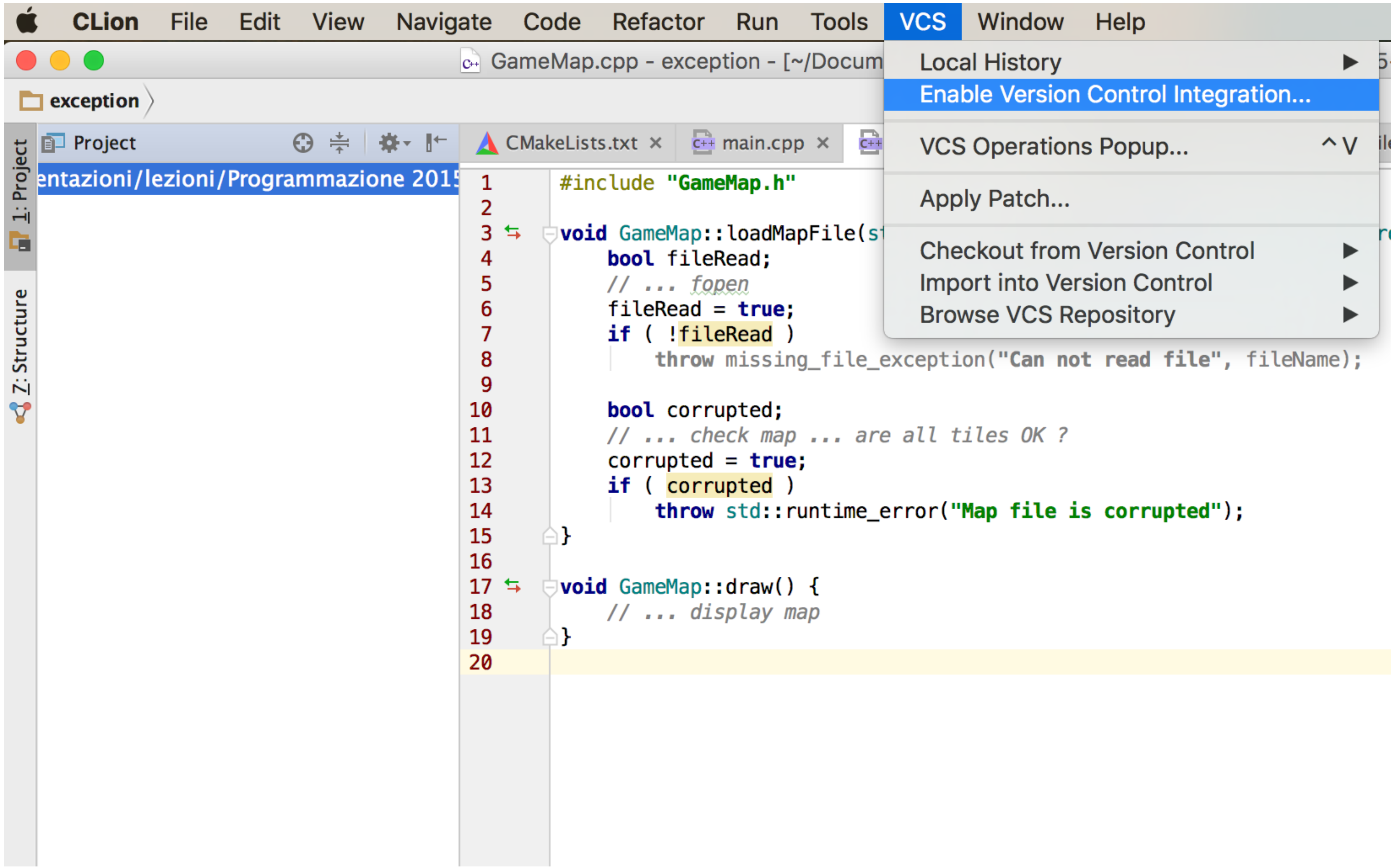
□ Auto-update if push of the current branch was rejected

□ Allow force push Protected branches: master

Test the installed Git

- OSX command line development tools include git. Linux and Windows require to install it.

Start using git on a project



CLion
File
Edit
View
Navigate
Code
Refactor
Run
Tools
VCS
Window
Help
GameMap.cpp - exception - [~/Docum
exception
Project
entazioni/lezioni/Programmazione 2015
CMakeLists.txt
main.cpp
1: Project
7: Structure
Local History
Enable Version Control Integration...
VCS Operations Popup... ^V
Apply Patch...
Checkout from Version Control
Import into Version Control
Browse VCS Repository

```
#include "GameMap.h"

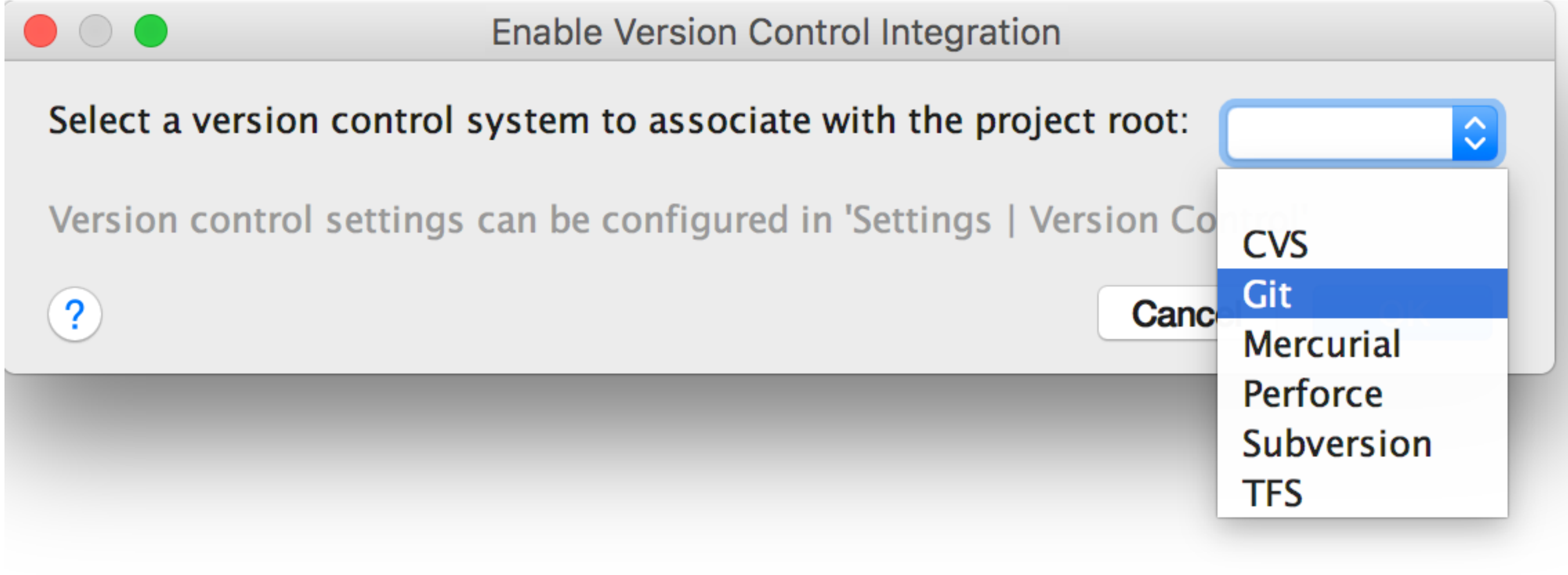
void GameMap::loadMapFile(st
    bool fileRead;
    // ... fopen
    fileRead = true;
    if ( !fileRead )
        throw missing_file_exception("Can not read file", fileName);

    bool corrupted;
    // ... check map ... are all tiles OK ?
    corrupted = true;
    if ( corrupted )
        throw std::runtime_error("Map file is corrupted");
}

void GameMap::draw() {
    // ... display map
}
```

- Enable VCS integration

Start using git on a project



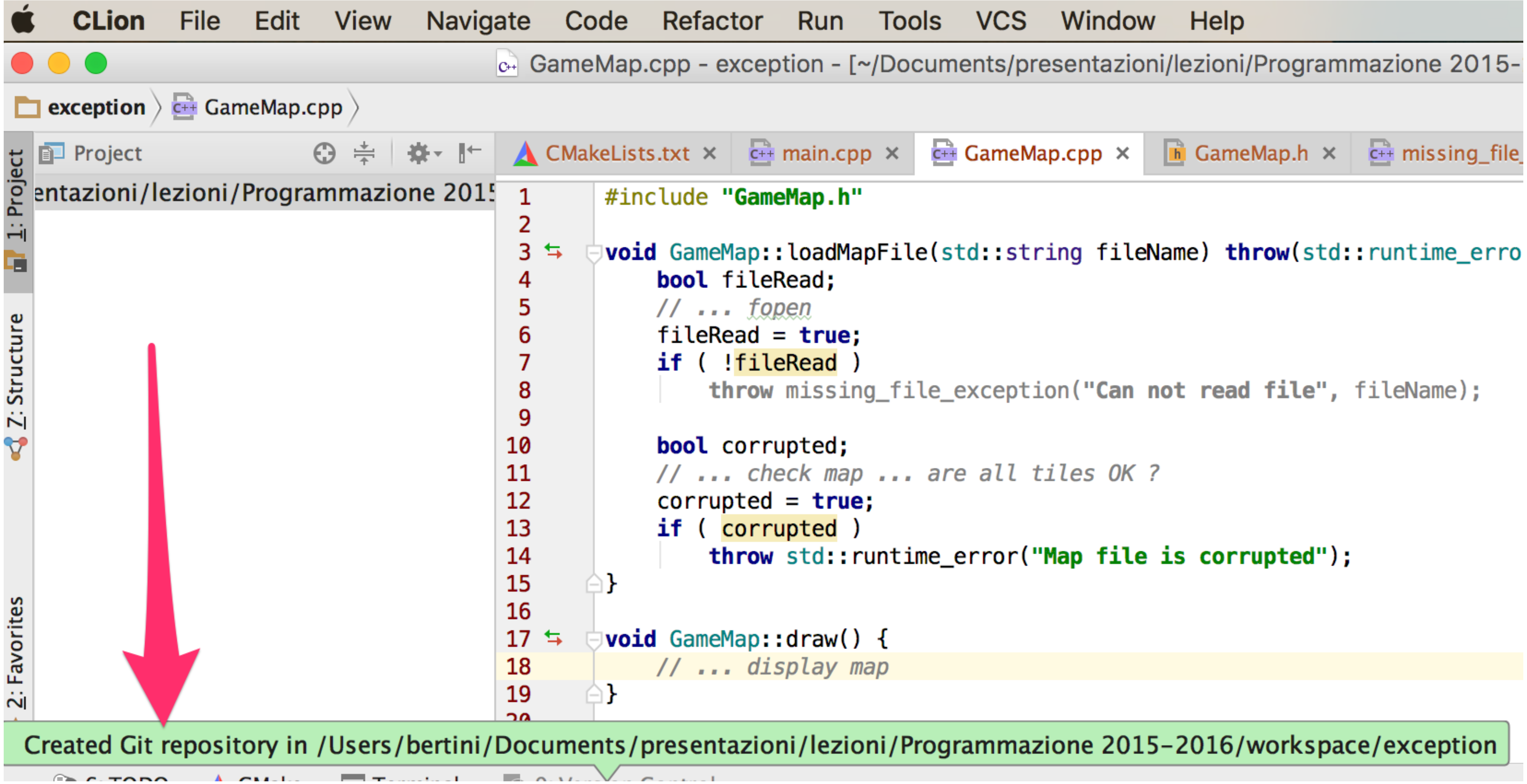
Enable Version Control Integration

Select a version control system to associate with the project root:

Version control settings can be configured in 'Settings | Version Co

- Enable VCS integration

Start using git on a project



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#include "GameMap.h"

void GameMap::loadMapFile(std::string fileName) throw(std::runtime_erro
    bool fileRead;
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    if ( !fileRead )
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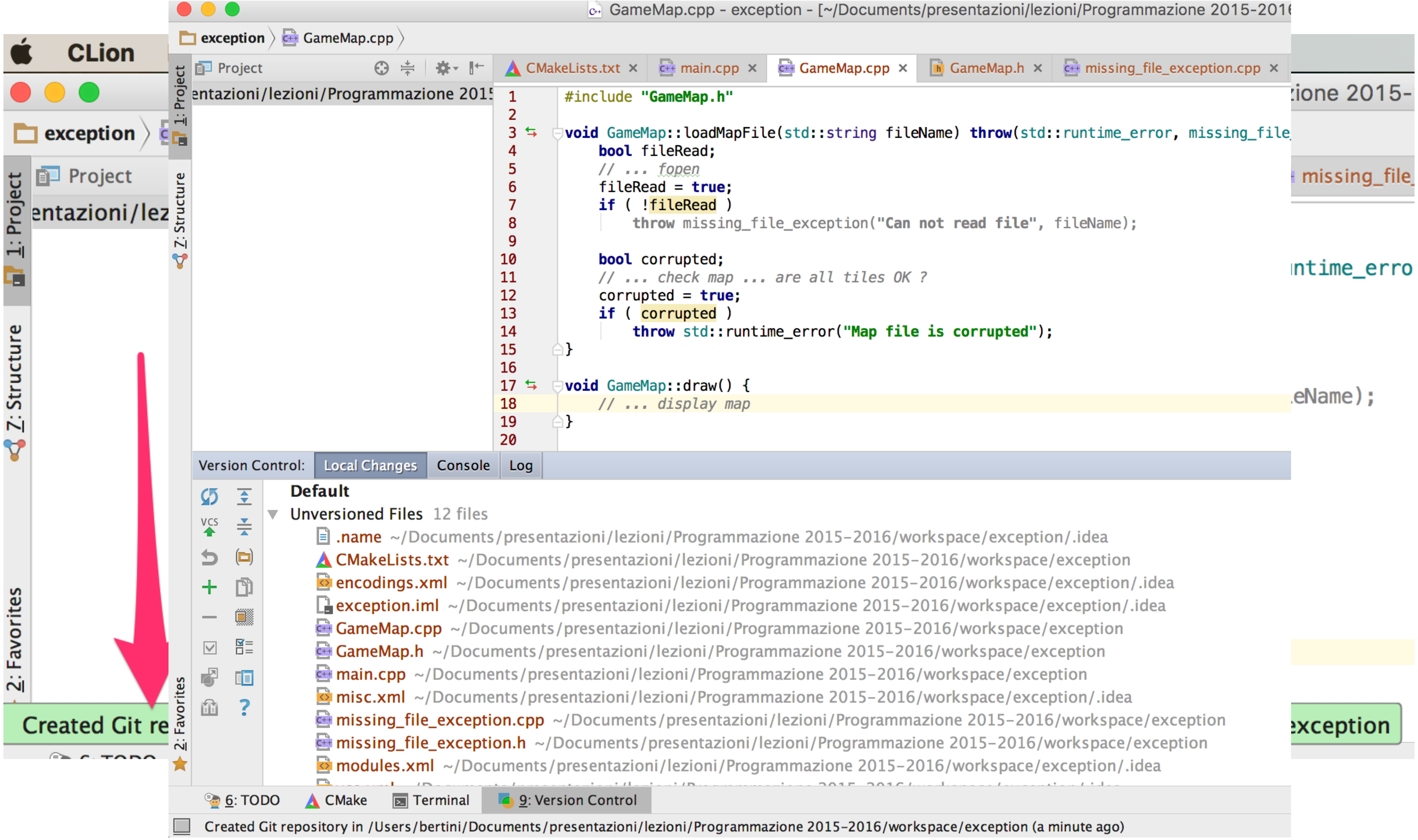
```

Created Git repository in /Users/bertini/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception

- Enable VCS integration

Start using git on a project



GameMap.cpp - exception - [~/Documents/presentazioni/lezioni/Programmazione 2015-201

entazioni/lezioni/Programmazione 2015

```
#include "GameMap.h"

void GameMap::loadMapFile(std::string fileName) throw(std::runtime_error, missing_file
    bool fileRead;
    // ... fopen
    fileRead = true;
    if ( !fileRead )
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}

void GameMap::draw() {
    // ... display map
}
```

Default

Unversioned Files 12 files

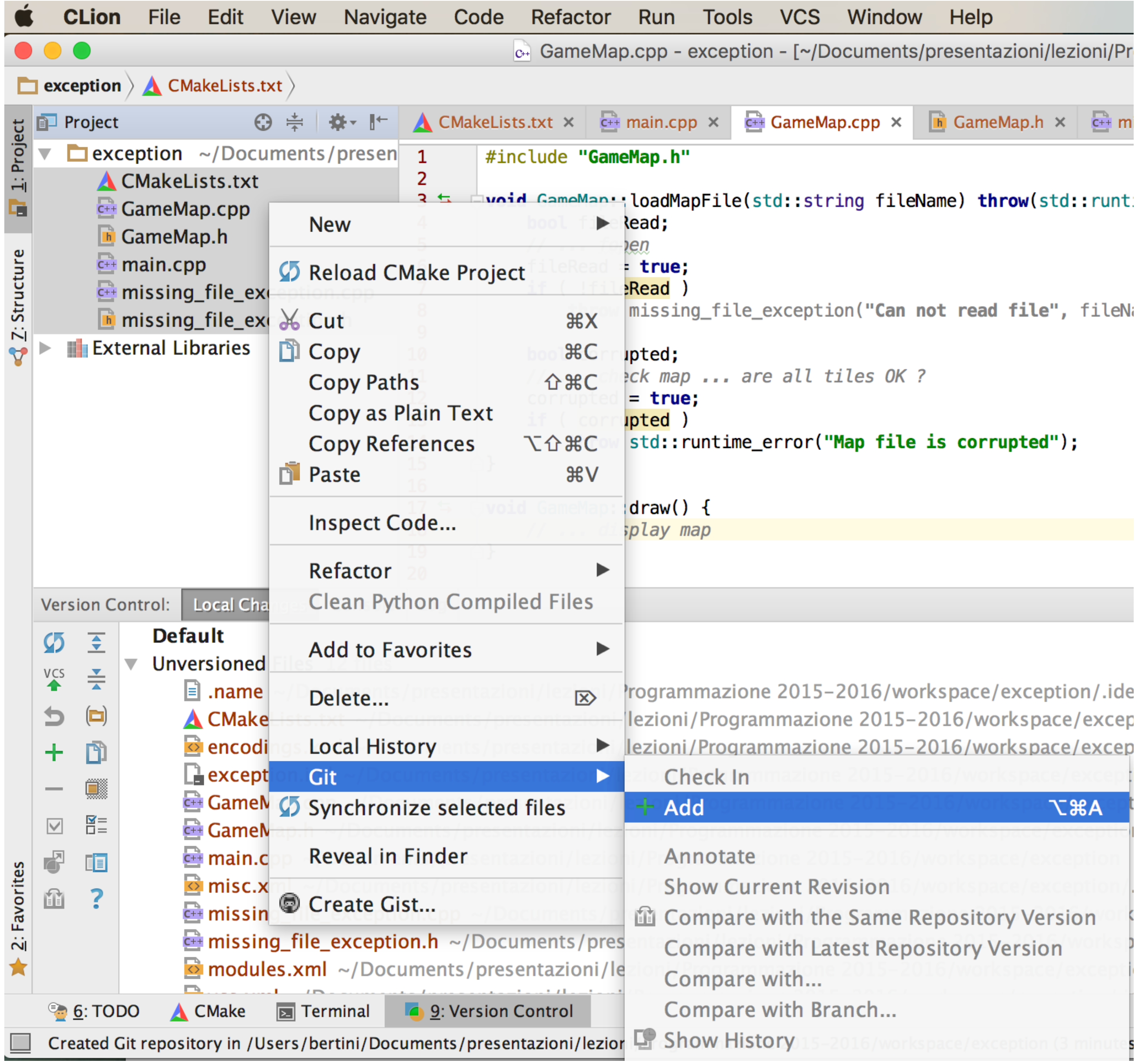
```
.name ~/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception/.idea
CMakeLists.txt ~/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception
encodings.xml ~/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception/.idea
exception.iml ~/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception/.idea
GameMap.cpp ~/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception
GameMap.h ~/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception
main.cpp ~/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception
misc.xml ~/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception/.idea
missing_file_exception.cpp ~/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception
missing_file_exception.h ~/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception
modules.xml ~/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception/.idea
```

Created Git repository in /Users/bertini/Documents/presentazioni/lezioni/Programmazione 2015-2016/workspace/exception (a minute ago)

Created Git re … xception

- Enable VCS integration

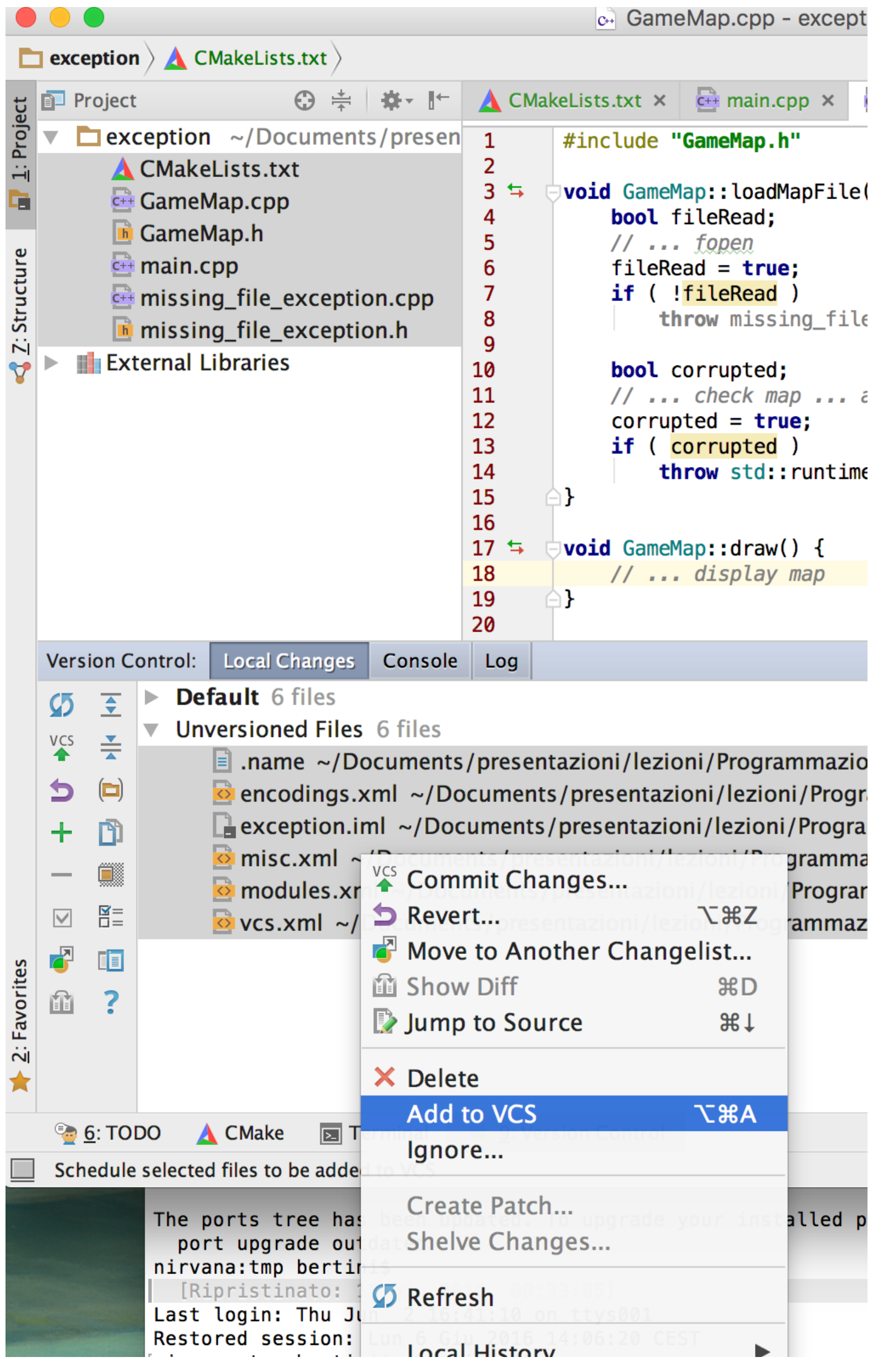
Add files



```
#include "GameMap.h"

void GameMap::loadMapFile(std::string fileName) throw(std::runt
```

Created Git repository in /Users/bertini/Documents/presentazioni/lezior



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#include "GameMap.h"

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    if ( corrupted )
        throw std::runtime
}

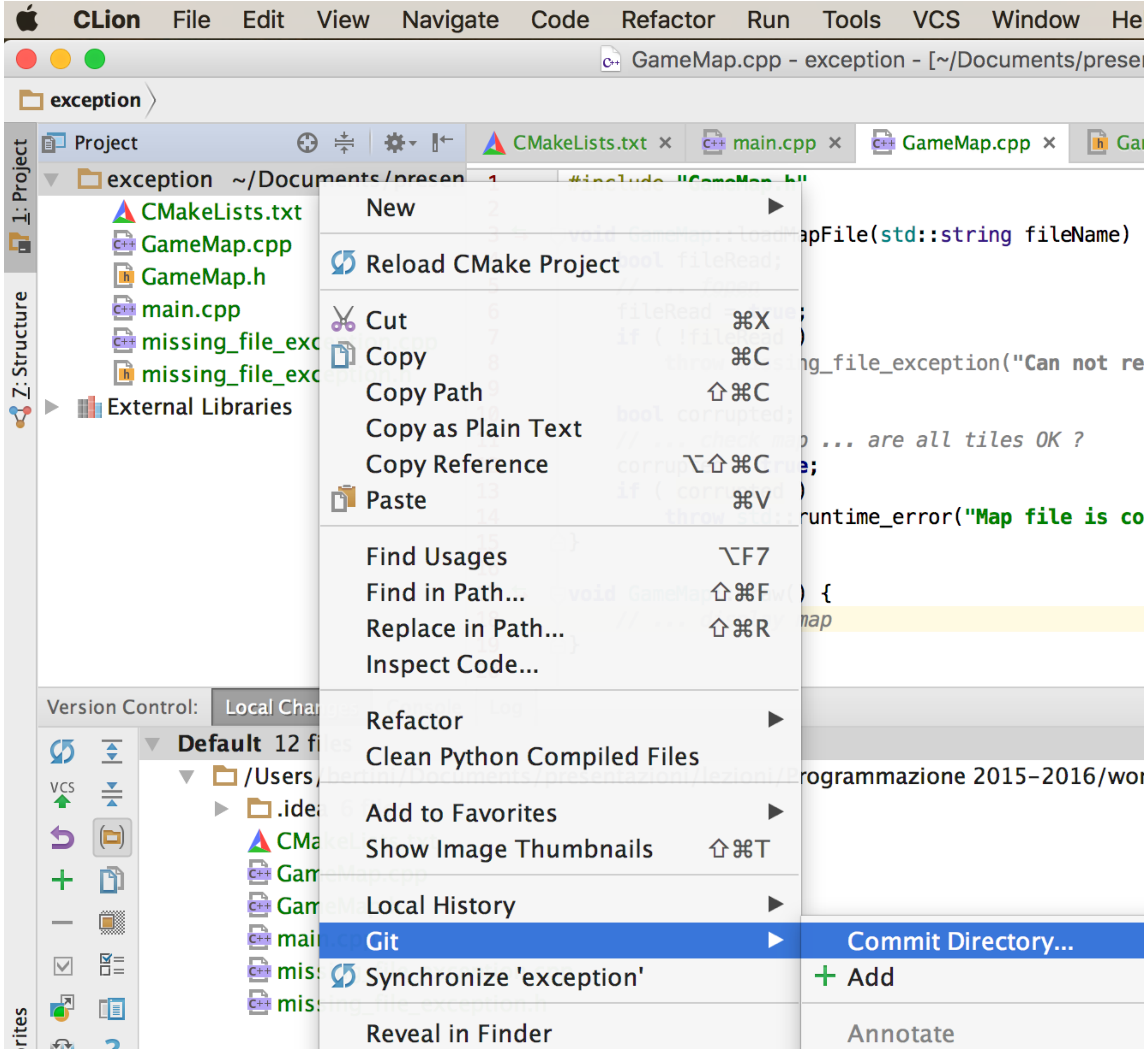
void GameMap::draw() {
    // ... display map
}
```

Schedule selected files to be adde

```
The ports tree has                                   alled p
  port upgrade out
nirvana:tmp bertir
  [Ripristinato:
Last login: Thu Ju
Restored session:
```

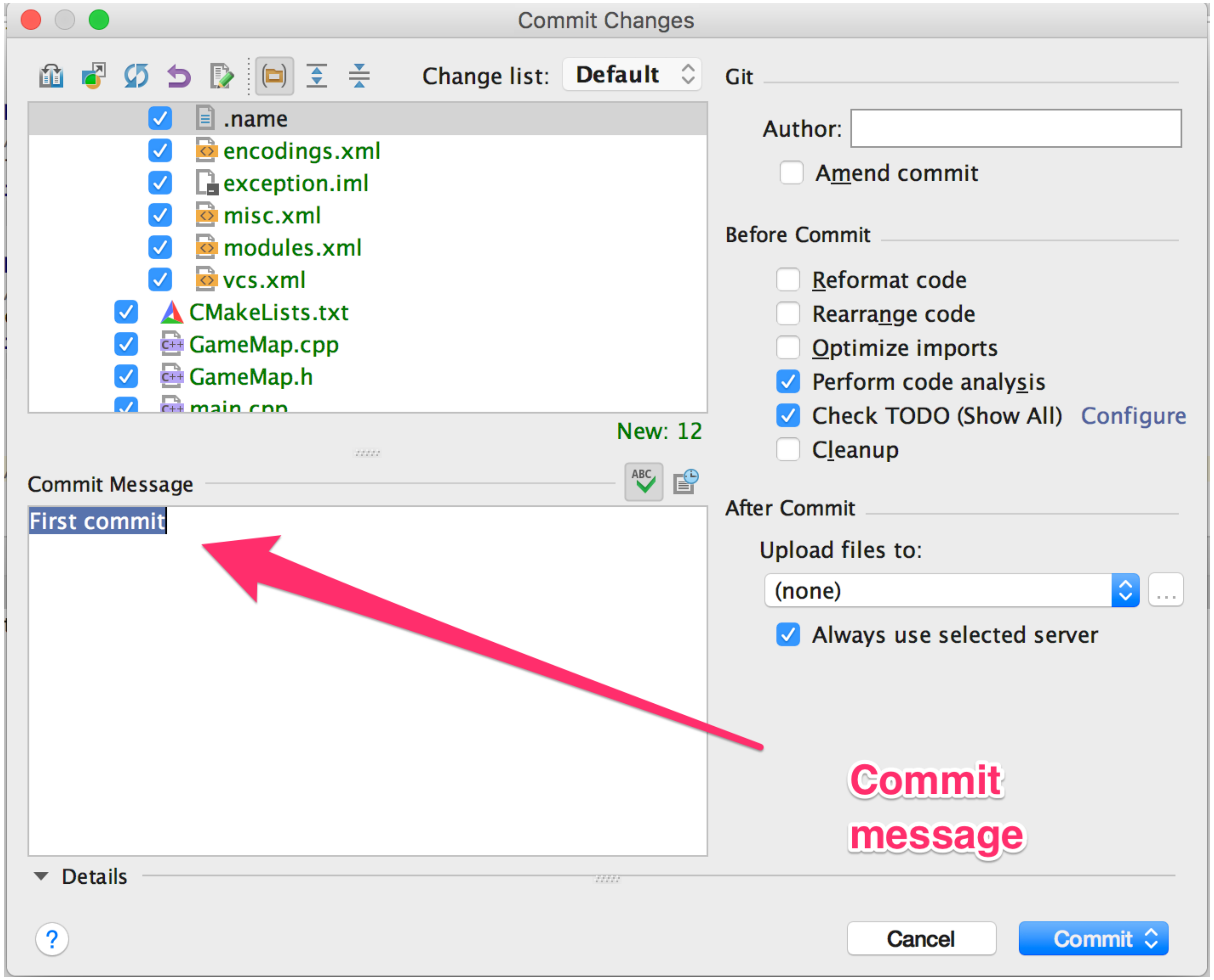
- Stage files adding them to git versioning. Use project view or Version Control tab that shows also invisible files like those of the CLion project.

Commit



- Commit whole directory or single files

Commit



Commit Changes

Change list: Default

- ☑ .name
- ☑ encodings.xml
- ☑ exception.iml
- ☑ misc.xml
- ☑ modules.xml
- ☑ vcs.xml
- ☑ CMakeLists.txt
- ☑ GameMap.cpp
- ☑ GameMap.h
- ☑ main.cpp

New: 12

Commit Message

First commit

Git

Author:

□ Amend commit

Before Commit

- □ Reformat code
- □ Rearrange code
- □ Optimize imports
- ☑ Perform code analysis
- ☑ Check TODO (Show All) Configure
- □ Cleanup

After Commit

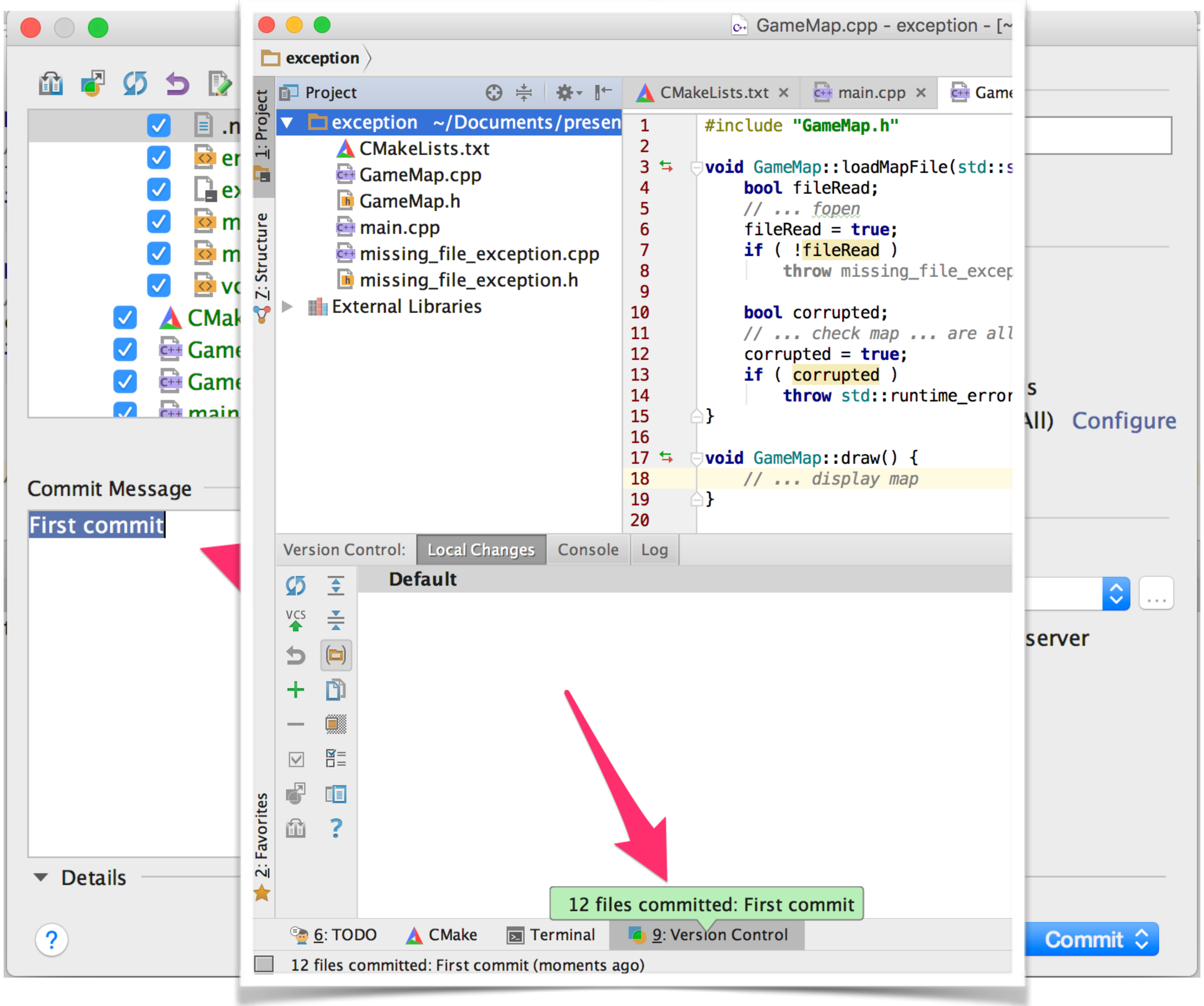
Upload files to: (none)

☑ Always use selected server

Commit message

- Commit whole directory or single files

Commit



GameMap.cpp - exception - [~

```
#include "GameMap.h"

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    if ( corrupted )
        throw std::runtime_error
}

void GameMap::draw() {
    // ... display map
}
```

Commit Message

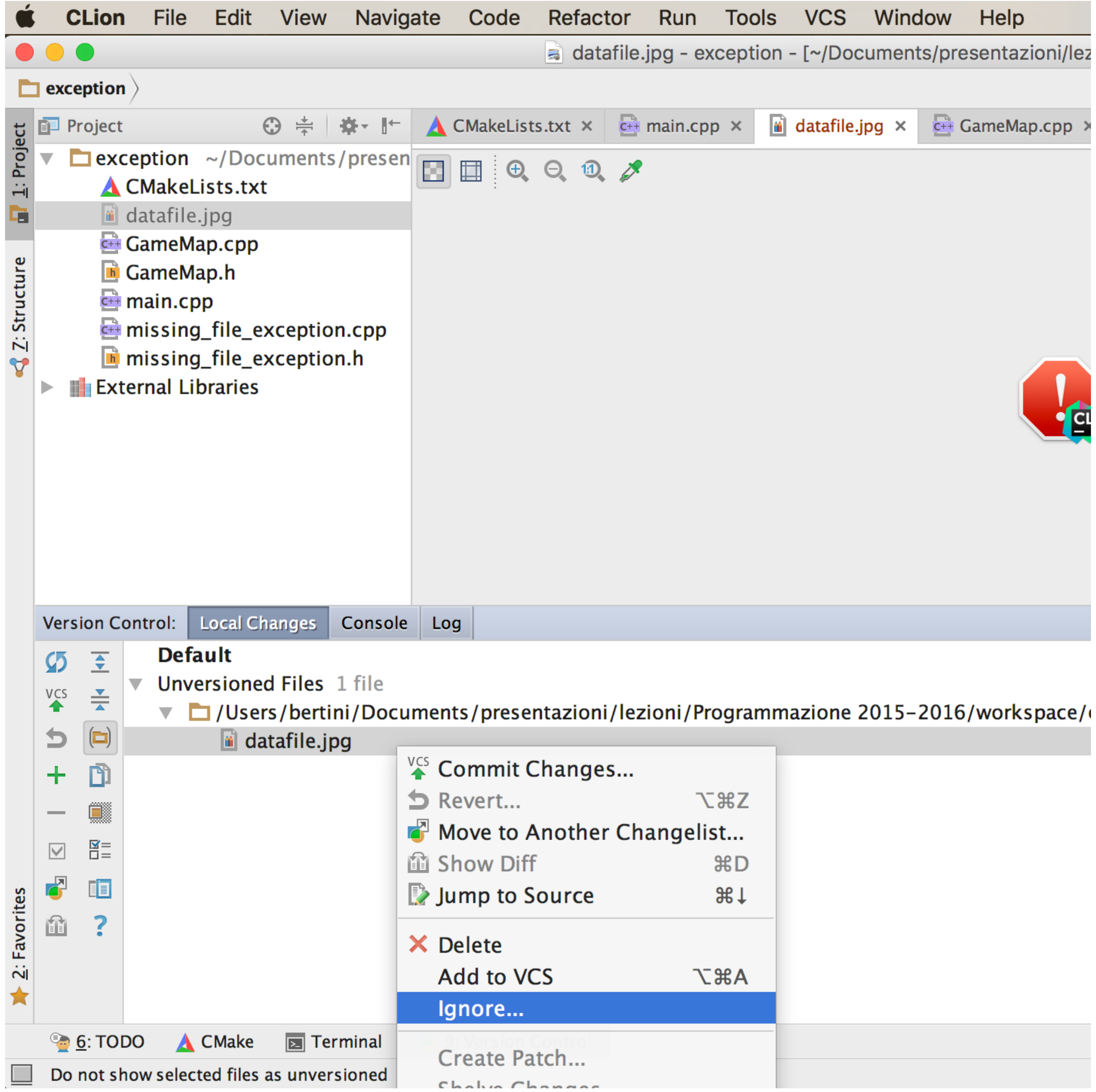
First commit

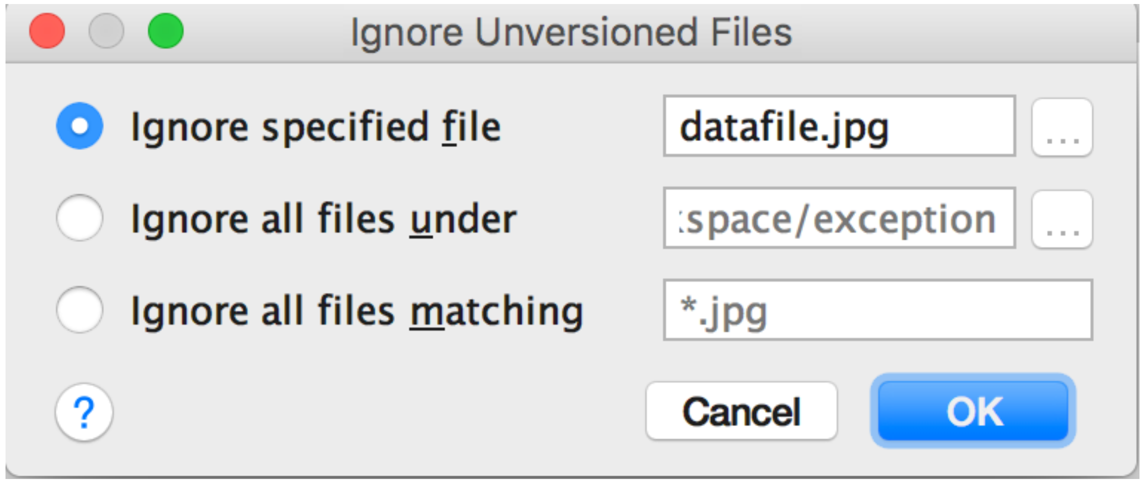
12 files committed: First commit

12 files committed: First commit (moments ago)

- Commit whole directory or single files

Ignore files





● Ignore specified file: datafile.jpg

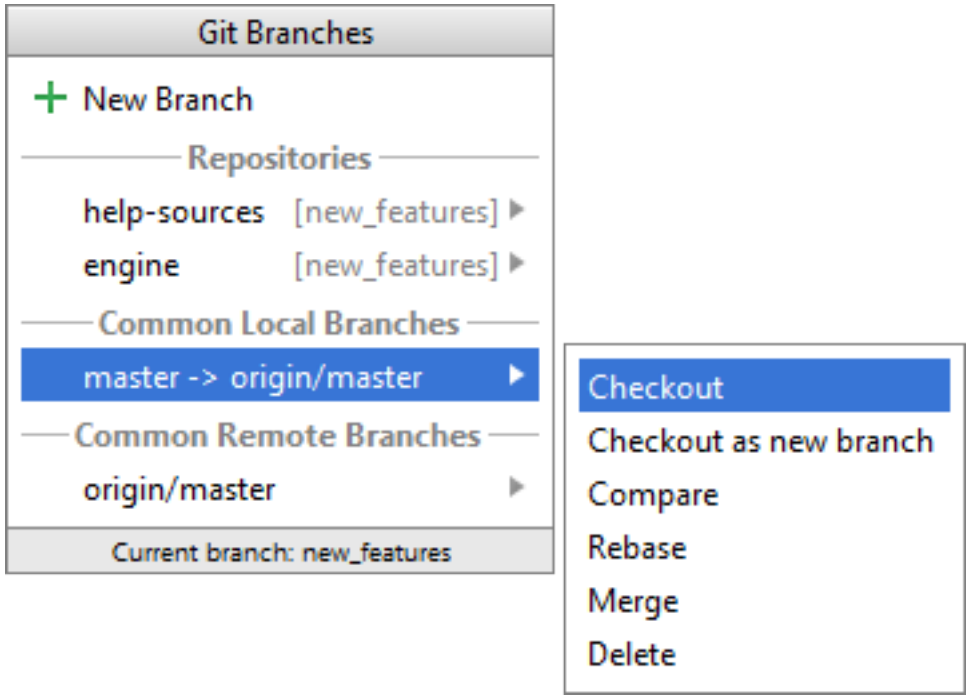
○ Ignore all files under: :space/exception

○ Ignore all files matching: *.jpg

- Add to .gitignore with Ignore

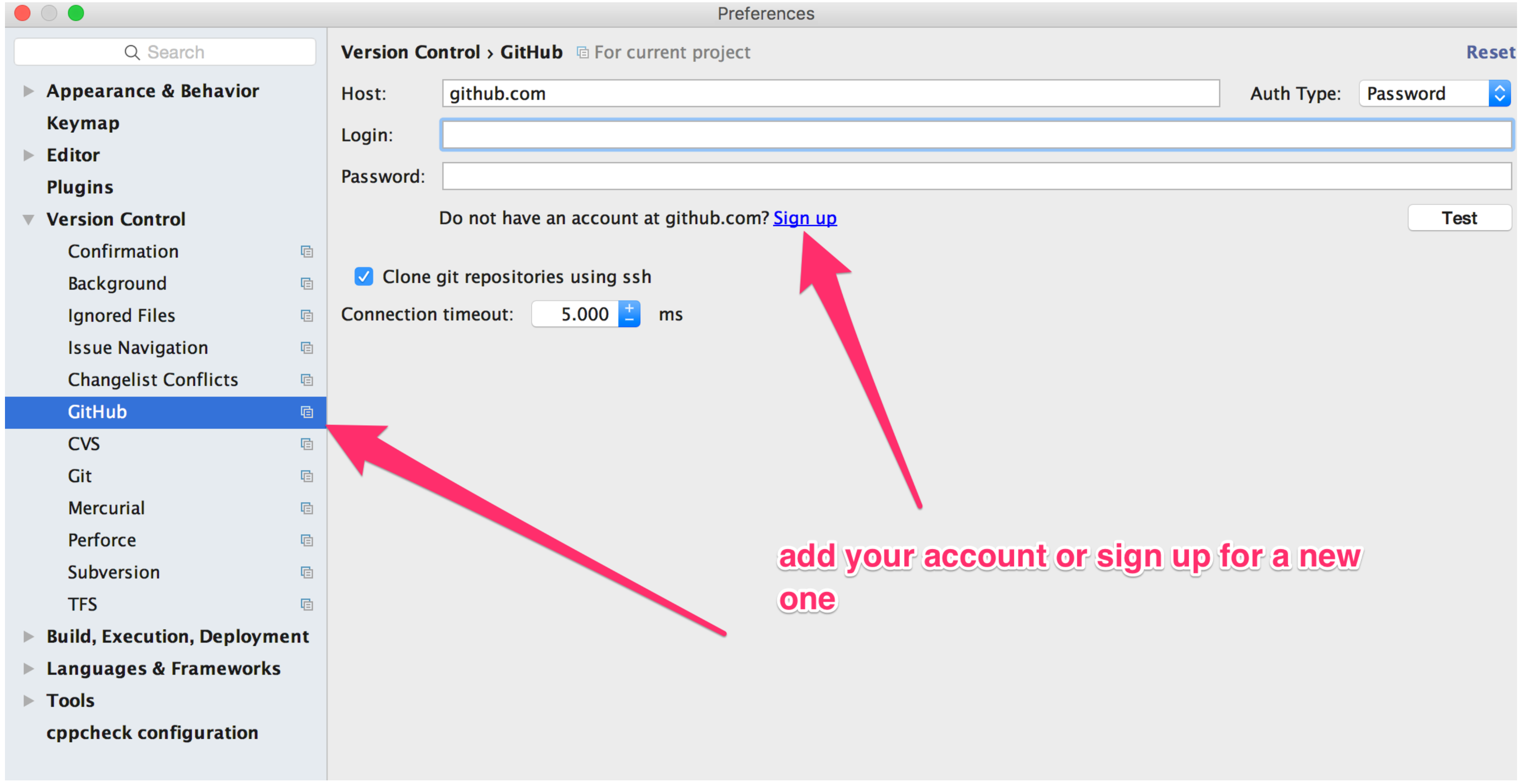
Branch

- Use the contextual menu to add new branches, or to checkout them.
- The same menu can be used to merge the current branch with one of the list. The same applies for comparison.



Github

- CLion can use Github as remote server, and allows also to create an account from the options



Version Control › GitHub   For current project

Host: github.com   Auth Type: Password

Login:

Password:

Do not have an account at github.com? Sign up

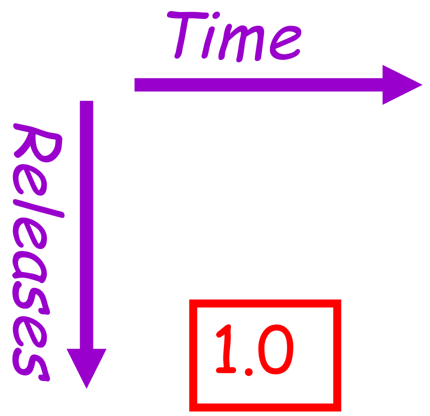
☑ Clone git repositories using ssh

Connection timeout: 5.000 ms

add your account or sign up for a new one

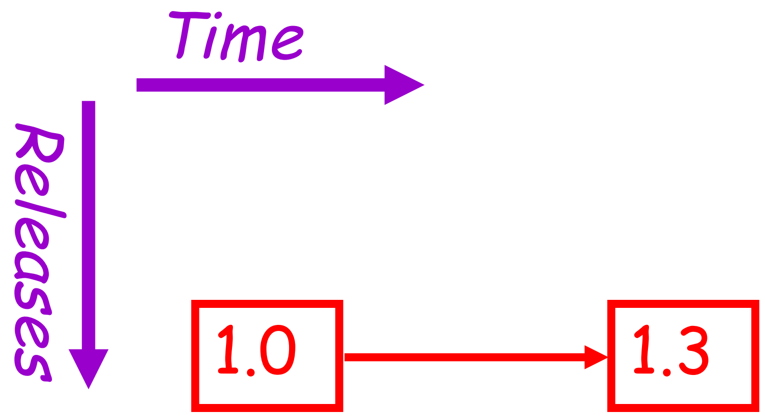
Use scenarios

Scenario 1: bug fix



First public release of the hot new product

Scenario 1: bug fix



First public release of the hot new product

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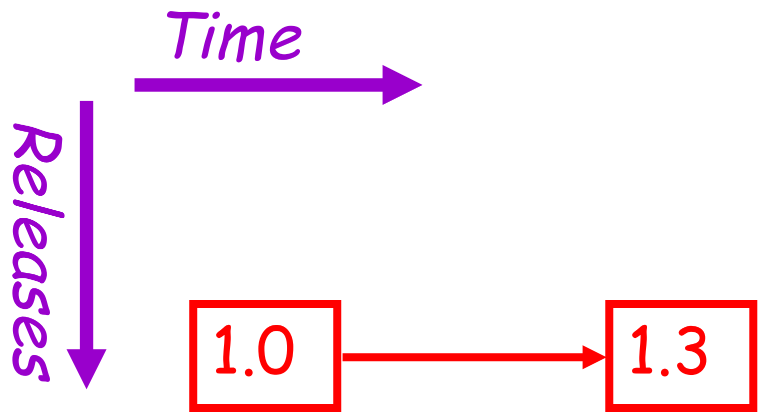

First public release of the hot new product

Internal development continues, progressing to version 1.3

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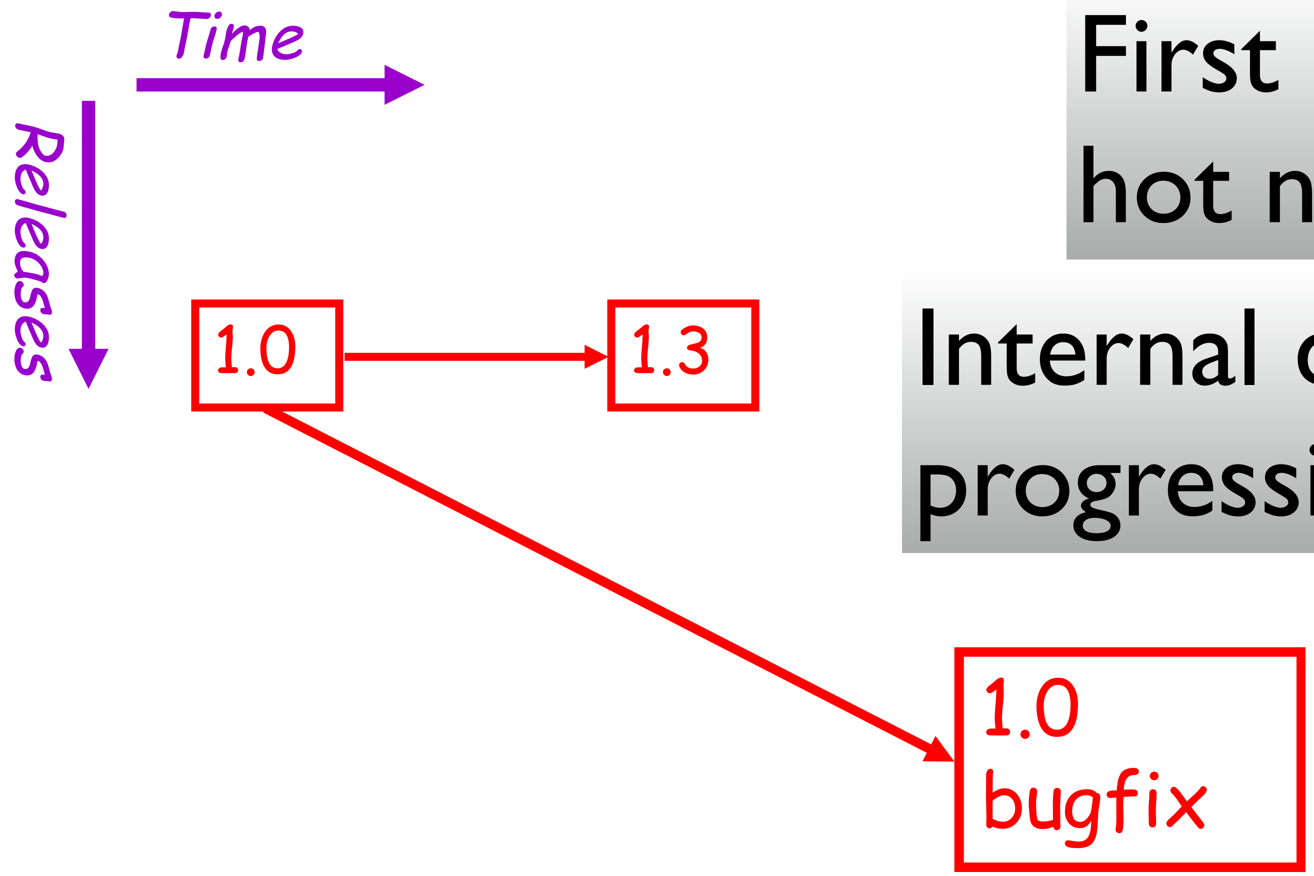
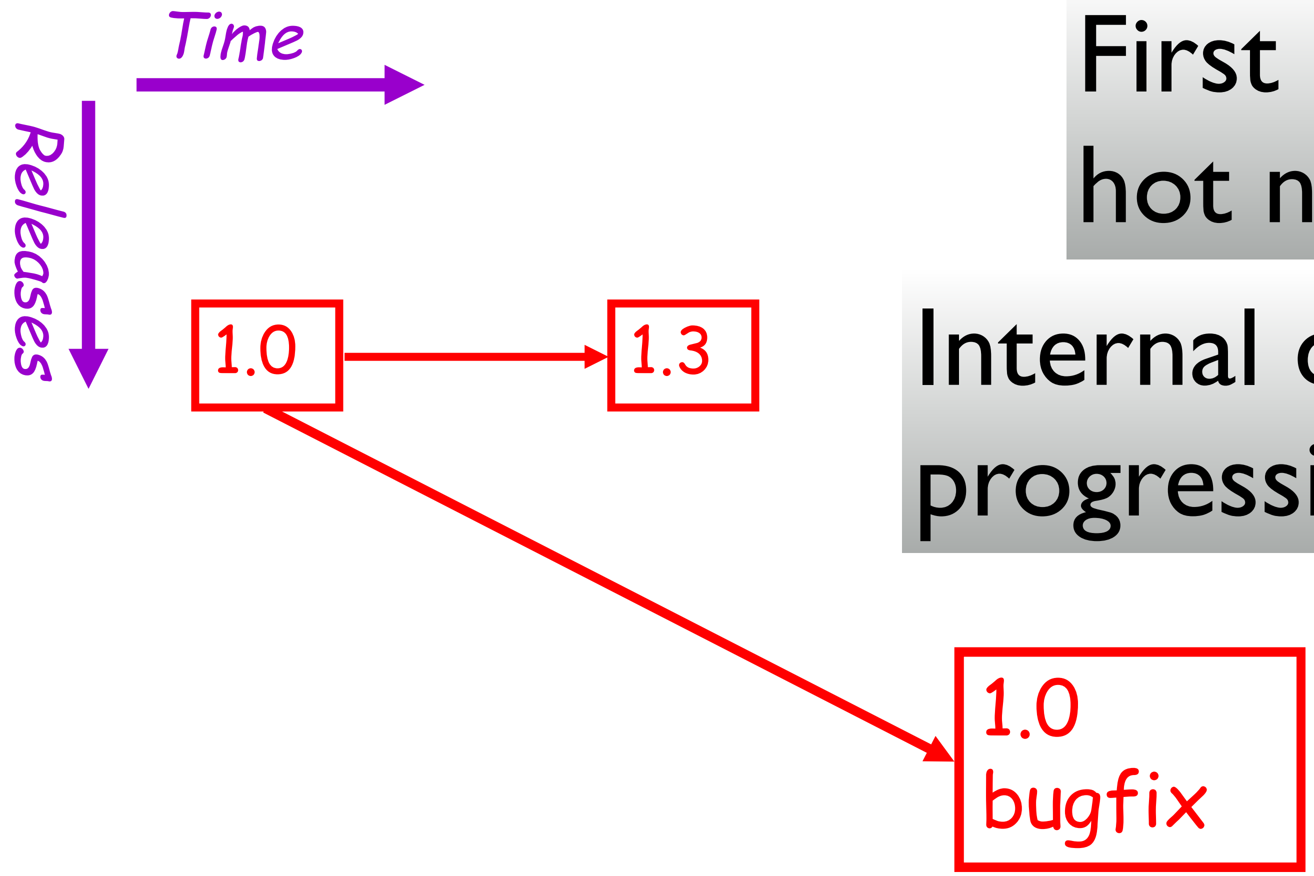


First public release of the hot new product

Internal development continues, progressing to version 1.3

A fatal bug is discovered in the product (1.0), but 1.3 is not stable enough to release. Solution: Create a version based on 1.0 with the bug fix.

Note that there are now two lines of development beginning at 1.0.
This is branching.



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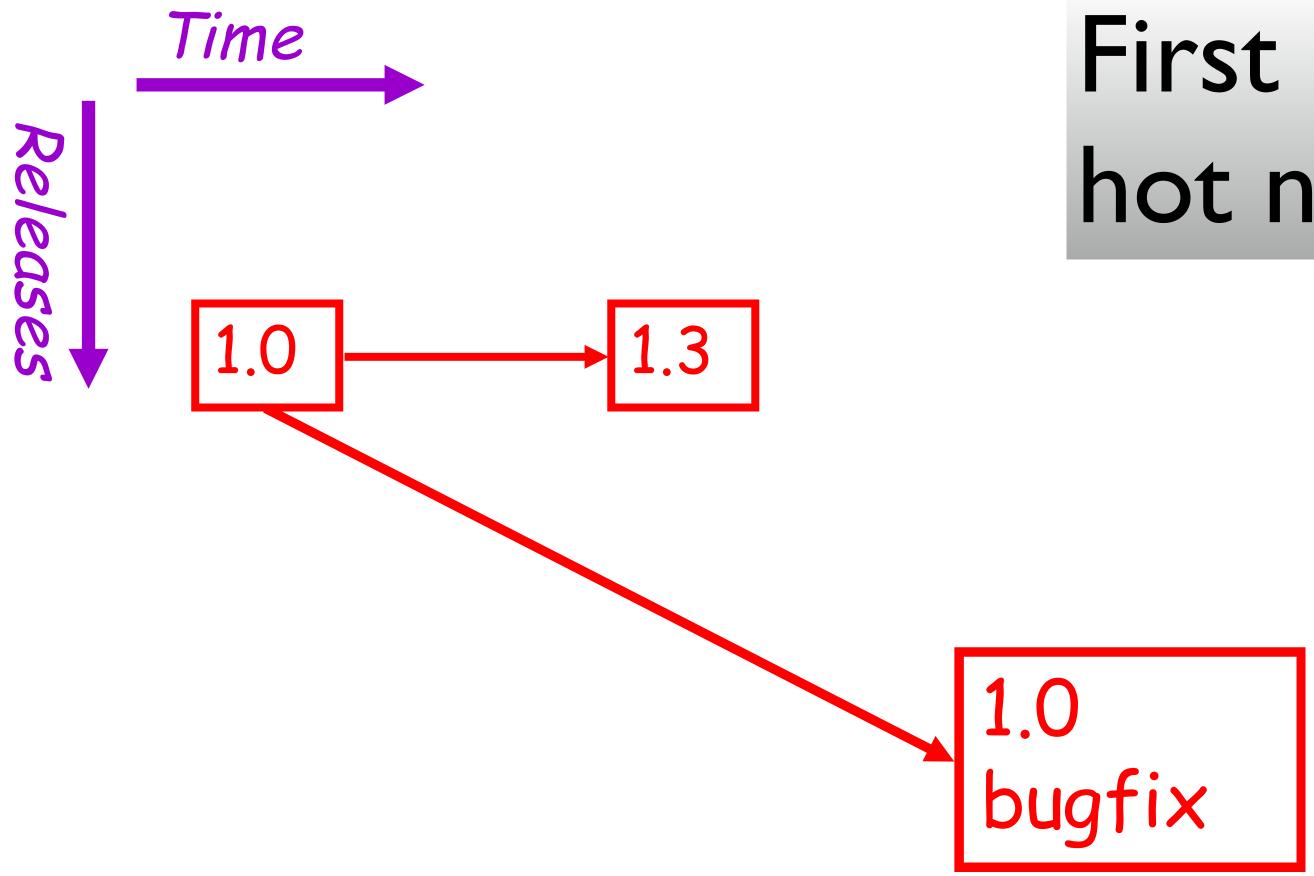

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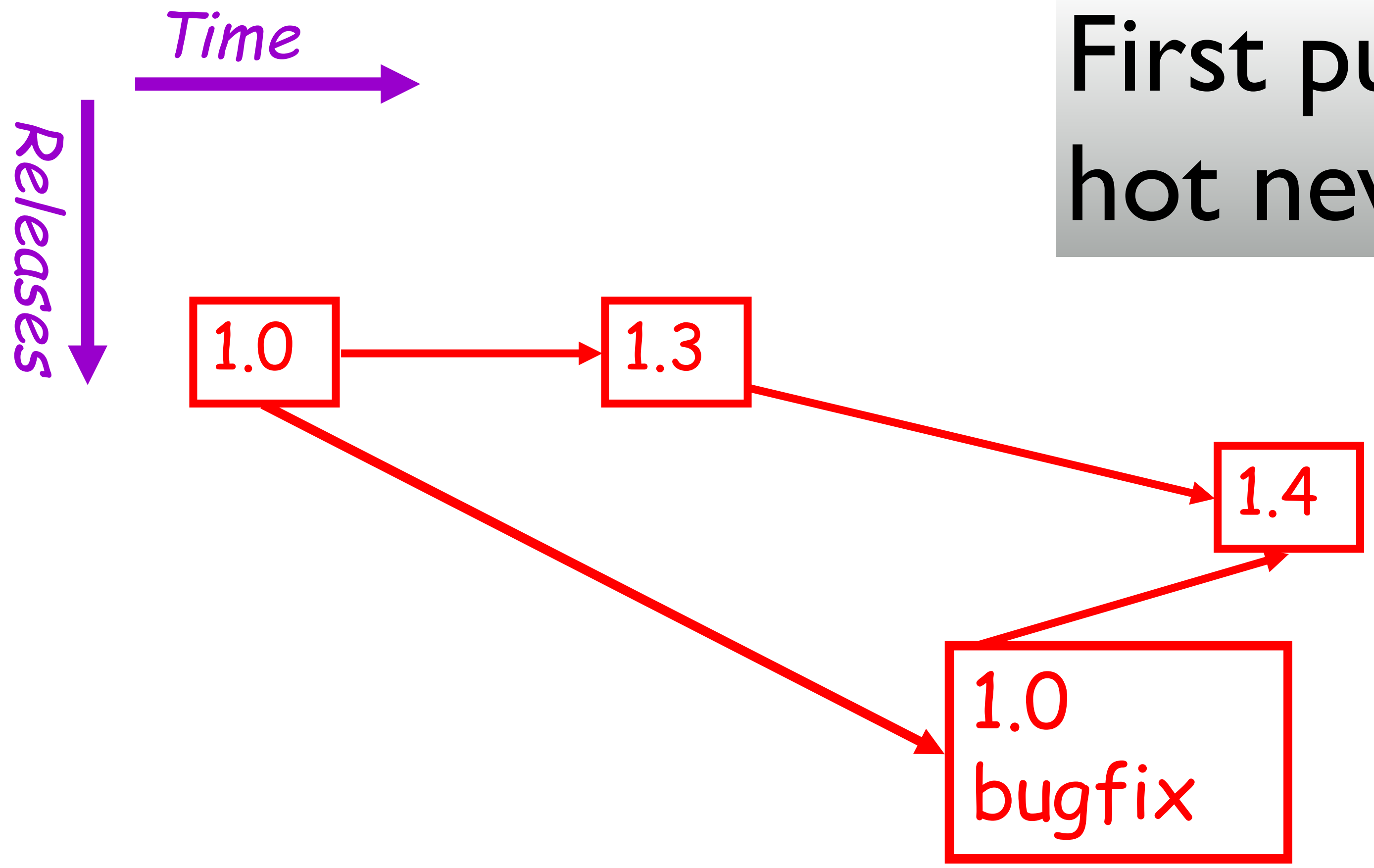

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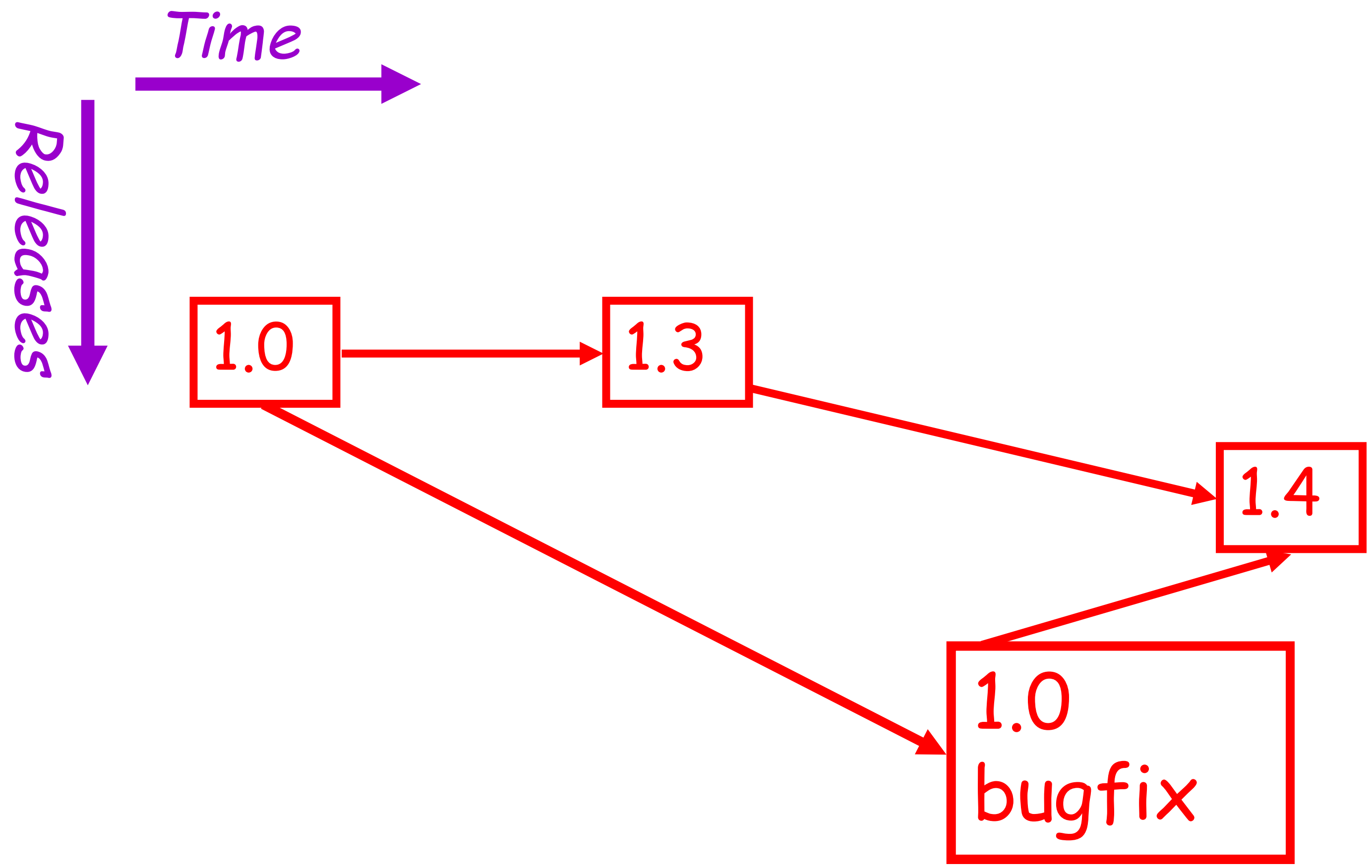

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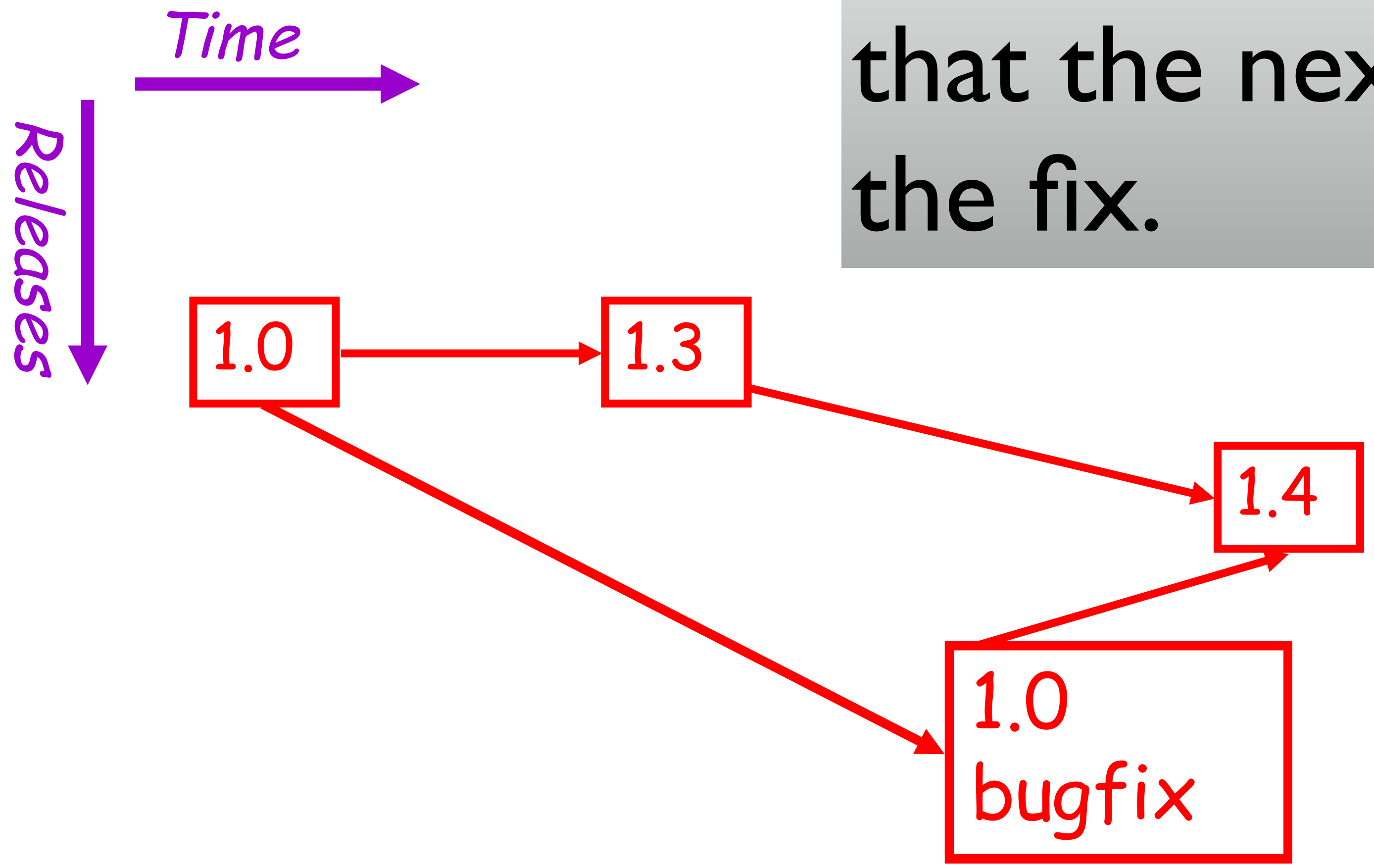
Note that there are now two lines of development beginning at 1.0.
This is branching.

The bug fix should also be applied to the main code line so that the next product release has the fix.



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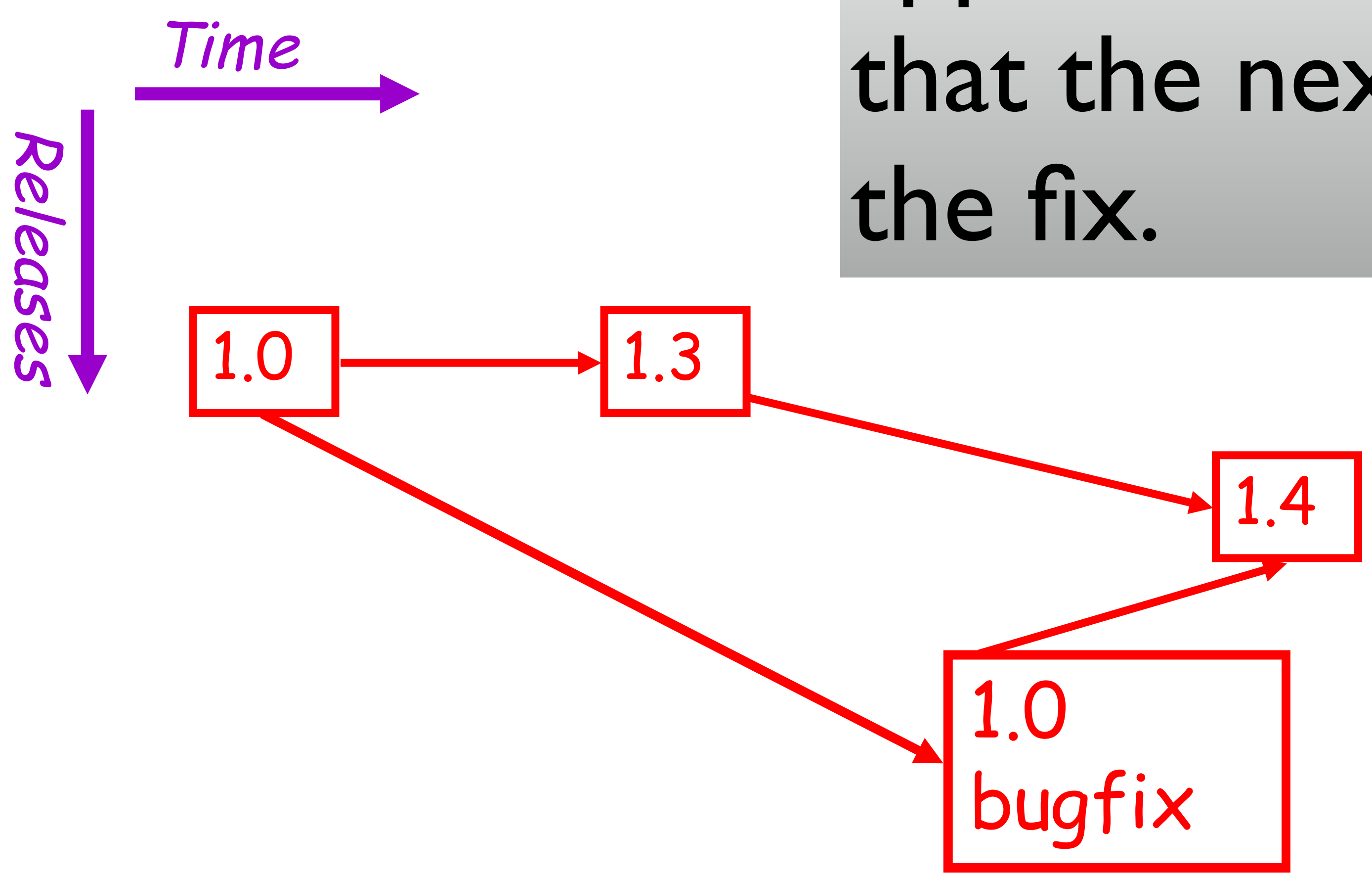
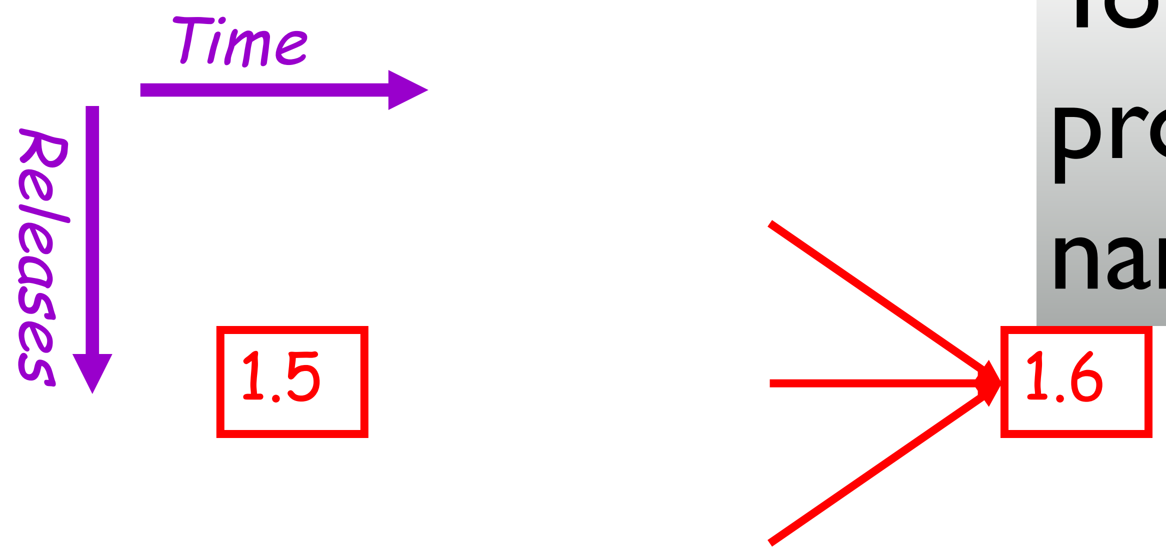


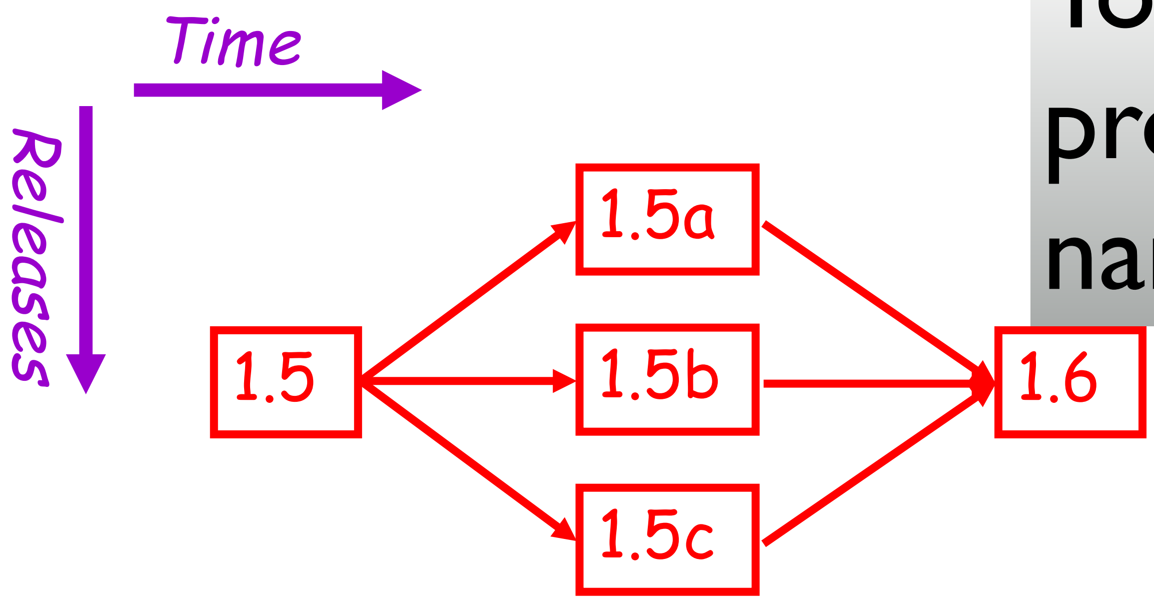
Note that two separate lines of development come back together in 1.4.
This is merging.

Scenario 2: normal dev.



You are in the middle of a project with three developers named a, b, and c.

Scenario 2: normal dev.



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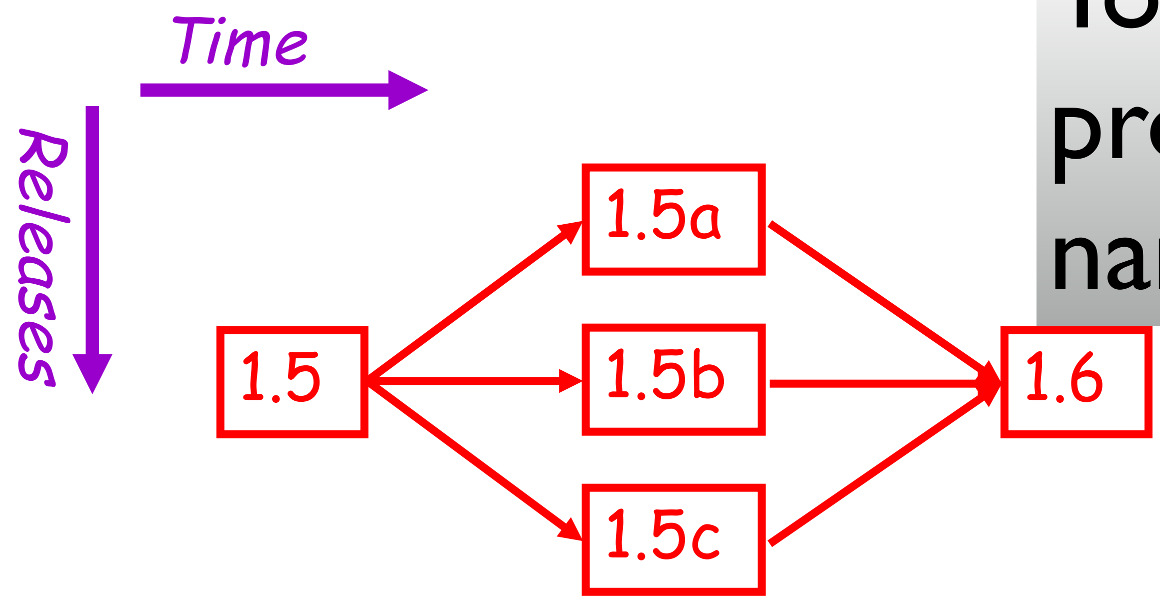
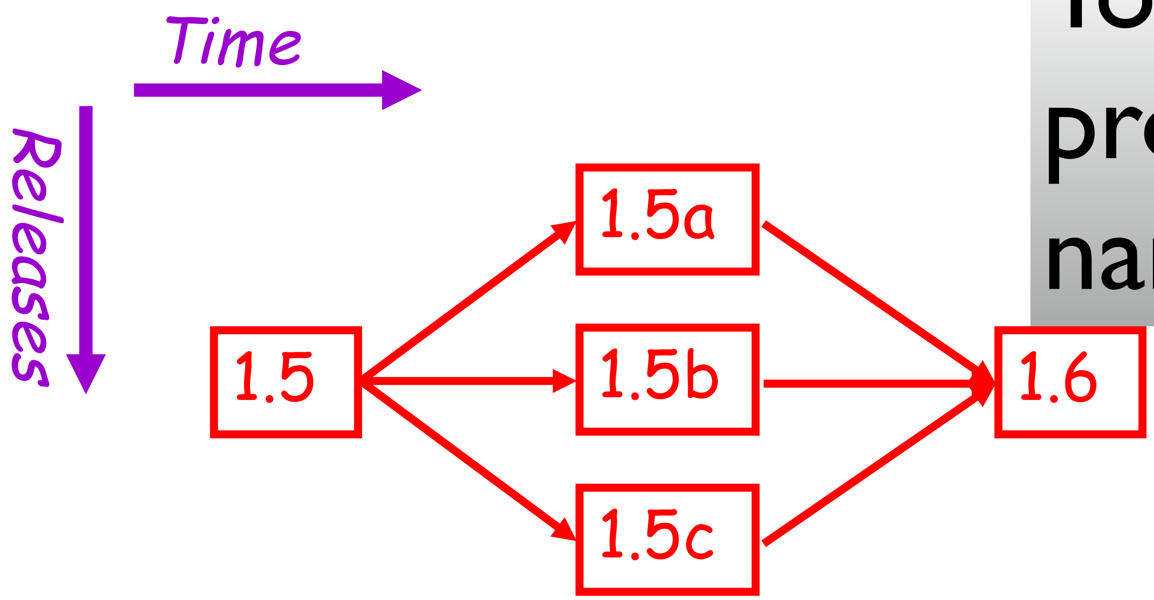


You are in the middle of a project with three developers named a, b, and c.

At the beginning of the day everyone checks out a copy of the code.
A check out is a local working copy of a project, outside of the version control system. Logically it is a (special kind of) branch.

Scenario 2: normal dev.

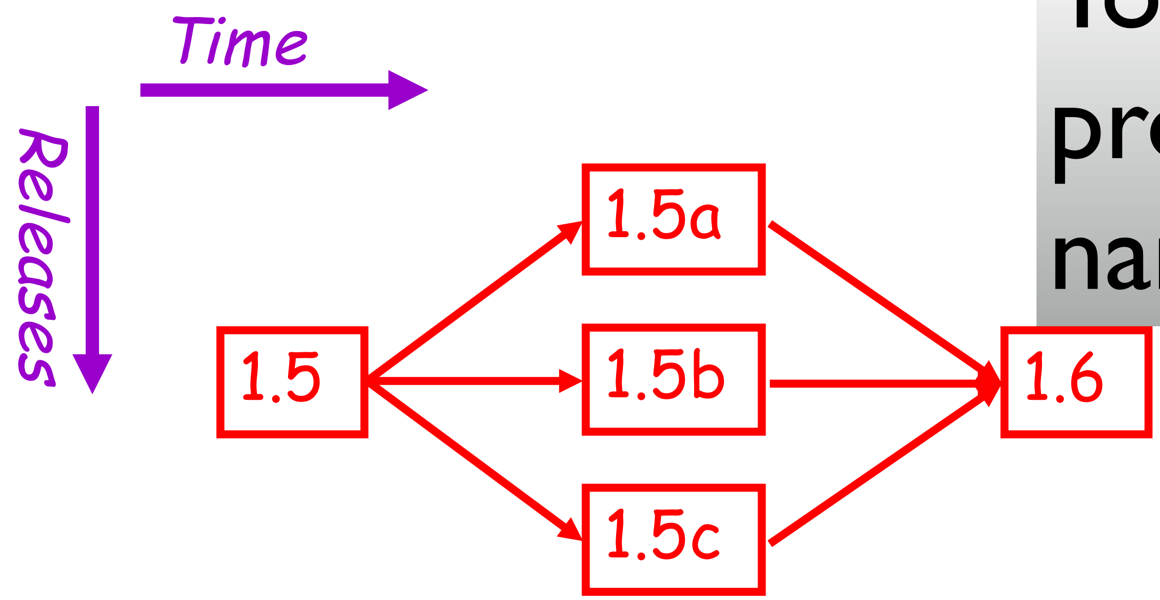


You are in the middle of a project with three developers named a, b, and c.

The local versions isolate the developers from each other's possibly unstable changes. Each builds on 1.5, the most recent stable version.

A check out is a local working copy of a project, outside of the version control system. Logically it is a (special kind of) branch.

Scenario 2: normal dev.

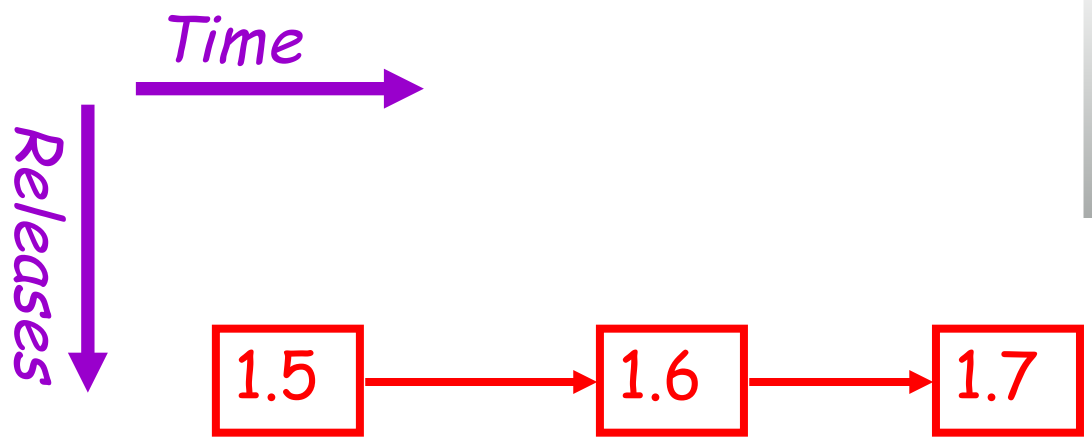


You are in the middle of a project with three developers named a, b, and c.

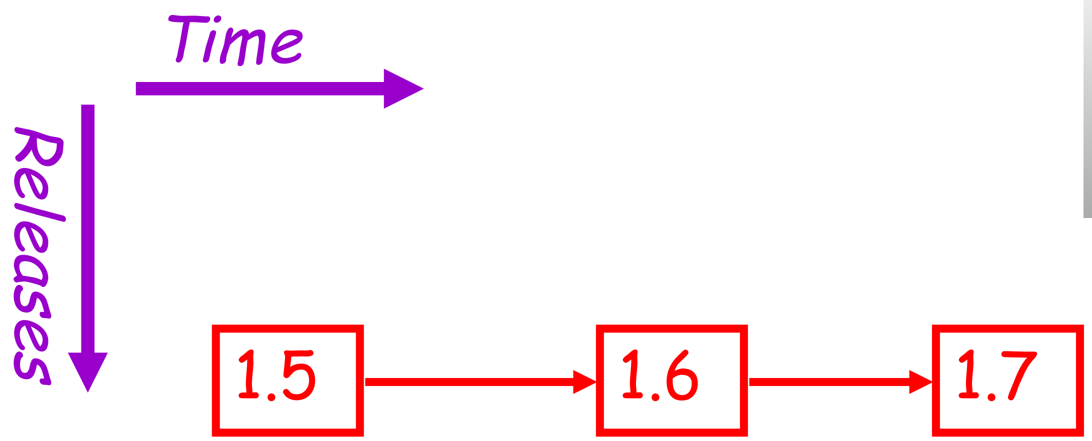
At the end of the day everyone checks in their tested modifications. A check in is a kind of merge where local versions are copied back into the version control system.

Scenario 3: debugging

A software system is developed through several revisions.



Scenario 3: debugging

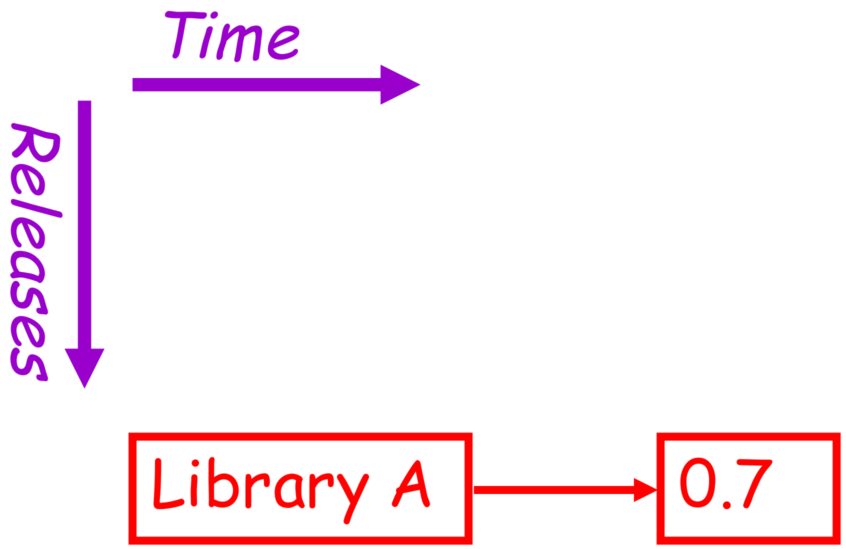


A software system is developed through several revisions.

In 1.7 you suddenly discover a bug has crept into the system. When was it introduced?

With version control you can check out old versions of the system and see which revision introduced the bug.

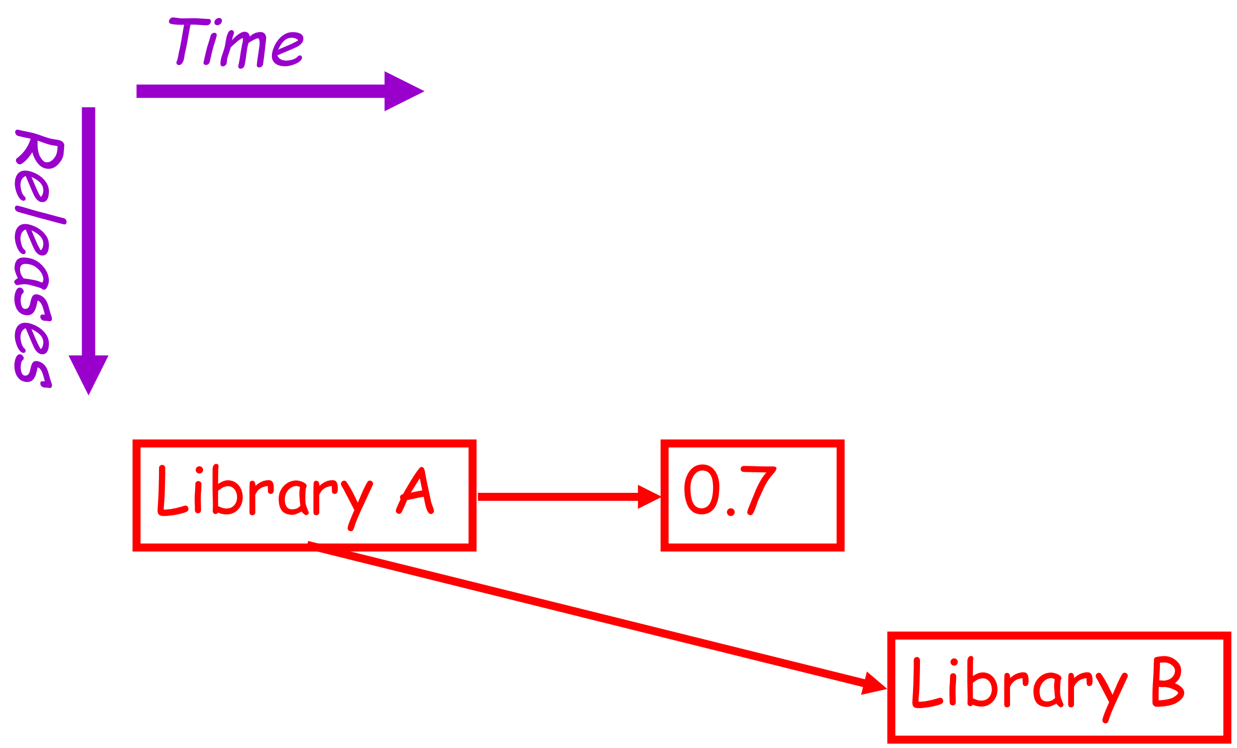
Scenario 4: external libraries



You are building software on top of a third-party library, for which you have source.

You begin implementation of your software, including modifications to the library.

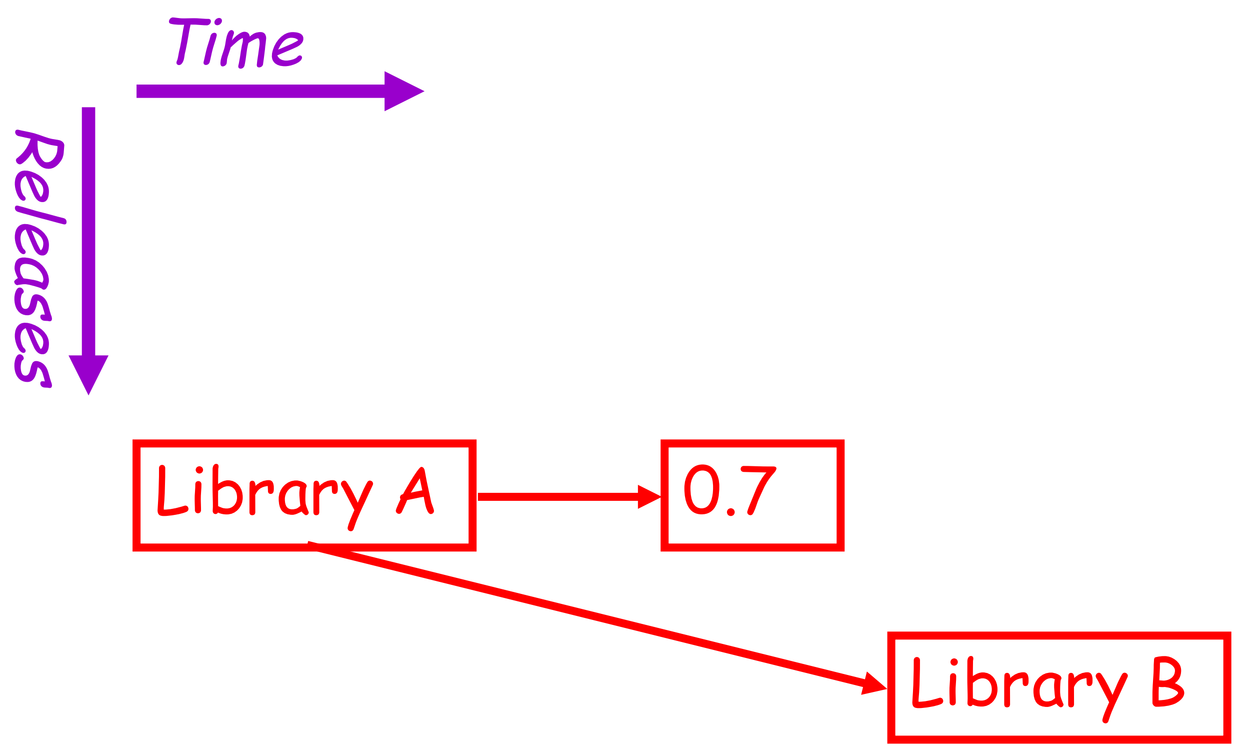
Scenario 4: external libraries



You are building software on top of a third-party library, for which you have source.

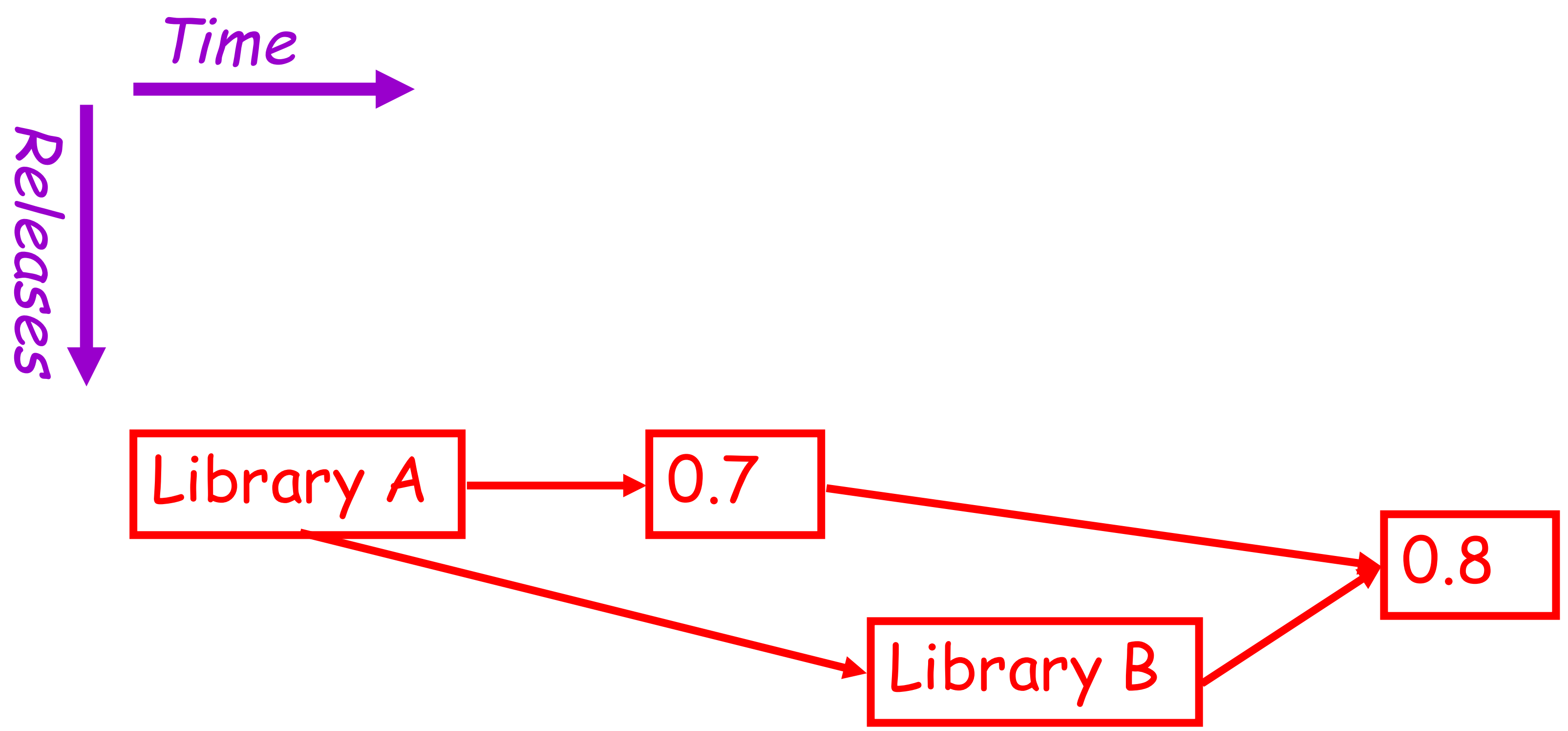
You begin implementation of your software, including modifications to the library.

Scenario 4: external libraries



A new version of the library is released. Logically this is a branch: library development has proceeded independently of your own development.

Scenario 4: external libraries



You merge the new library into the main code line, thereby applying your modifications to the new library version.

Reading material

- E. Sink, “Version Control by Example” - cap. 2, 4, 8

Credits

- These slides are based on the material of:
  - Prof. Aiken,
  - Dr. N. Benatar,
  - Prof. R. Anderson, Univ. Washington
  - P. Chen, Stanford