Understanding Git

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2020

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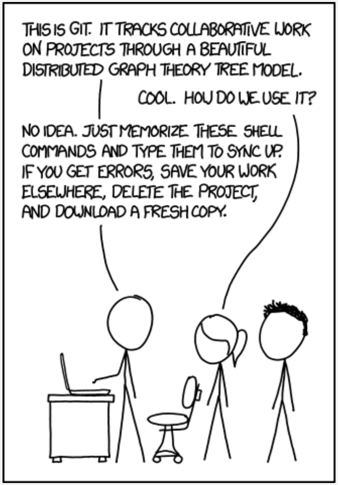
`http://recherche.noiraudes.net/resources/git/Slides/understanding-git-slides.pdf`

Goals of the presentation

- Presenting the data model behind Git
- Showing how Git stores data and history
- Understanding how to navigate between the commits of a repository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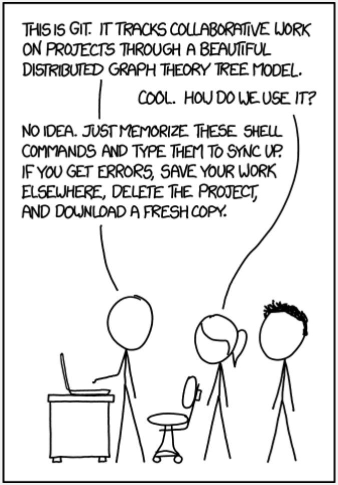
COOL. HOW DO WE USE IT?
NO IDEA. JUST MEMORIZE THESE SHELL COMMANDS AND TYPE THEM TO SYNC UP. IF YOU GET ERRORS, SAVE YOUR WORK ELSEWHERE, DELETE THE PROJECT, AND DOWNLOAD A FRESH COPY.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If that doesn't fix it, git.txt contains the phone number of a friend of mine who understands git. Just wait through a few minutes of "It's really pretty simple, just think of branches as..." and eventually you'll learn the commands that will fix everything.

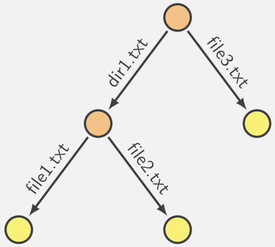
Why do I need to learn about Git's internal?

- Beauty of Git: very simple data model
  (The tool is clever, the repository format is simple&stupid)
- Understand the model, and the 150+ commands will become simple!

Objects, sha1

Content of a Git repository: Git objects

🟡	blob	Any sequence of bytes, represents file content
🟠	tree	Associates object to pathnames, represents a directory



Content of a Git repository: Git objects

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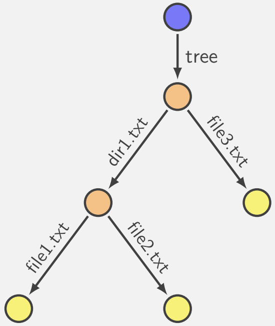
🔵	commit	Metadata + pointer to tree + pointer to parents



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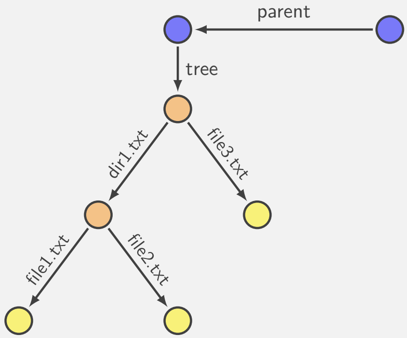

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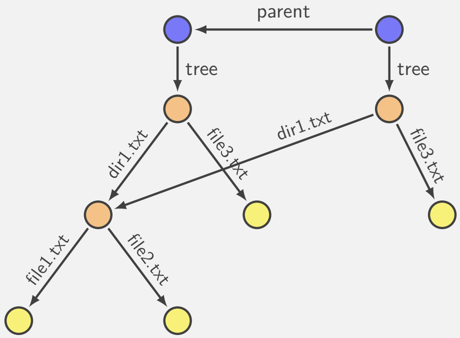

Content of a Git repository: Git objects

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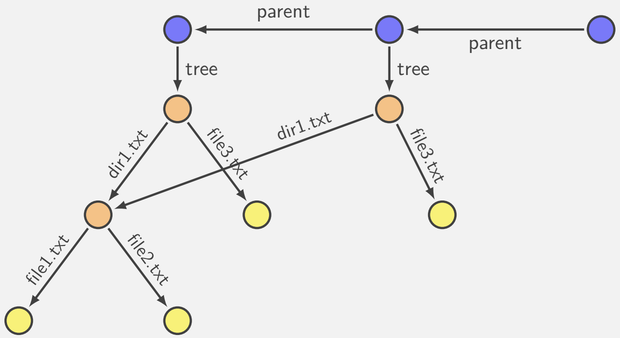
● tree Associates object to pathnames, represents a directory

● commit Metadata + pointer to tree + pointer to parents



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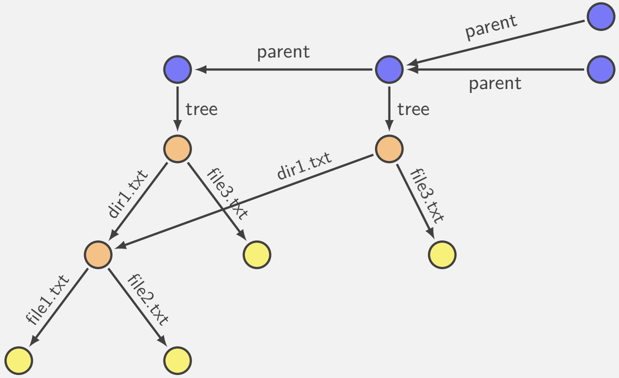

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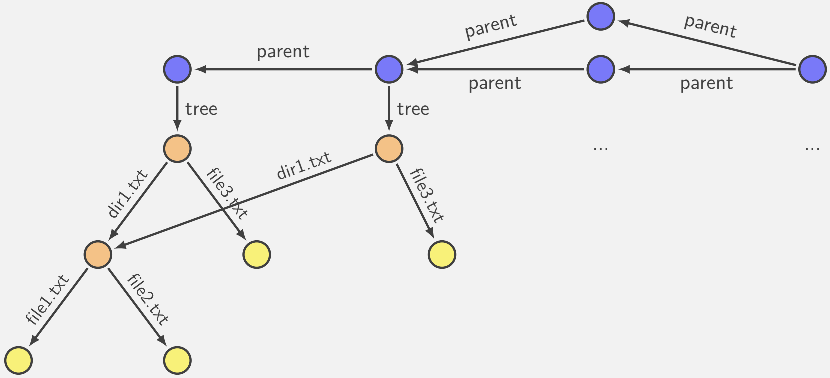


Git objects: On-disk format

```
$ git log
commit 7a7fb77be431c284f1b6d036ab9aebf646060271
Author: Matthieu Moy <Matthieu.Moy@imag.fr>
Date:   Wed Jul 2 20:13:49 2014 +0200

    Initial commit
$ find .git/objects/
.git/objects/
.git/objects/fc
.git/objects/fc/264b697de62952c9ff763b54b5b11930c9cfec
.git/objects/7a
.git/objects/7a/7fb77be431c284f1b6d036ab9aebf646060271
.git/objects/50
.git/objects/50/a345788a8df75e0f869103a8b49cecdf95a416
.git/objects/26
.git/objects/26/27a0555f9b58632be848fee8a4602a1d61a05f
```

Git objects: On-disk format

```
$ echo foo > README.txt; git add README.txt
$ git commit -m "add README.txt"
[master 5454e3b] add README.txt
 1 file changed, 1 insertion(+)
 create mode 100644 README.txt
$ find .git/objects/
.git/objects/
.git/objects/fc
.git/objects/fc/264b697de62952c9ff763b54b5b11930c9cfec
.git/objects/7a
.git/objects/7a/7fb77be431c284f1b6d036ab9aebf646060271
.git/objects/25
.git/objects/25/7cc5642cb1a054f08cc83f2d943e56fd3ebe99
.git/objects/54
.git/objects/54/54e3b51e81d8d9b7e807f1fc21e618880c1ac9
...
```

Git objects: On-disk format

- By default, 1 object = 1 file
- Name of the file = object unique identifier content
- Content-addressed database:
  - Identifier computed as a hash of its content
  - Content accessible from the identifier
- Consequences:
  - Objects are immutable
  - Objects with the same content have the same identity (deduplication for free)
  - Previously, no known collision in SHA1, no moving to SHA-256
  - Acyclic (DAG = Directed Acyclic Graph)

On-disk format: Pack files

```
$ du -sh .git/objects/
68K     .git/objects/
$ git gc
...
$ du -sh .git/objects/
24K     .git/objects/
$ find .git/objects/
.git/objects/
.git/objects/pack
.git/objects/pack/pack-f9cbdc53005a4b500934625d...a3.idx
.git/objects/pack/pack-f9cbdc53005a4b500934625d...a3.pack
.git/objects/info
.git/objects/info/packs
$
```

$\rightsquigarrow$ More efficient format, no conceptual change (objects are still there)

Exploring the object database

- **`git cat-file -p`** : pretty-print the content of an object

```
$ git log --oneline
5454e3b add README.txt
7a7fb77 Initial commit
$ git cat-file -p 5454e3b
tree 59802e9b115bc606b88df4e2a83958423661d8c4
parent 7a7fb77be431c284f1b6d036ab9aebf646060271
author Matthieu Moy <Matthieu.Moy@imag.fr> 1404388746 +0200
committer Matthieu Moy <Matthieu.Moy@imag.fr> 1404388746 +0200

add README.txt
```

Exploring the object database

- **`git cat-file -p`** : pretty-print the content of an object

```
$ git cat-file -p 59802e9b115bc606b88df4e2a83958423661d8c4
100644 blob 257cc5642cb1a054f08cc83f2d943e56fd3ebe99  README.txt
040000 tree 2627a0555f9b58632be848fee8a4602a1d61a05f  sandbox
$ git cat-file -p 257cc5642cb1a054f08cc83f2d943e56fd3ebe99
foo
$ printf 'blob 4\0foo\n' | sha1sum
257cc5642cb1a054f08cc83f2d943e56fd3ebe99  -
```

Merge commits in the object database

```
$ git checkout -b branch HEAD^
Switched to a new branch 'branch'
$ echo foo > file.txt; git add file.txt
$ git commit -m "add file.txt"
[branch f44e9ab] add file.txt
 1 file changed, 1 insertion(+)
 create mode 100644 file.txt
$ git merge master
Merge made by the 'recursive' strategy.
 README.txt | 1 +
 1 file changed, 1 insertion(+)
 create mode 100644 README.txt
```

Merge commits in the object database

```
$ git checkout -b branch HEAD^
$ echo foo > file.txt; git add file.txt
$ git commit -m "add file.txt"
$ git merge master
$ git log --oneline --graph
*   1a7f9ae (HEAD, branch) Merge branch 'master' into branch
|\
| * 5454e3b (master) add README.txt
* | f44e9ab add file.txt
|/
* 7a7fb77 Initial commit
$ git cat-file -p 1a7f9ae
tree 896dbd61ffc617b89eb2380cdcaffcd7c7b3e183
parent f44e9abff8918f08e91c2a8fefe328dd9006e242
parent 5454e3b51e81d8d9b7e807f1fc21e618880c1ac9
author Matthieu Moy <Matthieu.Moy@imag.fr> 1404390461 +0200
committer Matthieu Moy <Matthieu.Moy@imag.fr> 1404390461 +0200

Merge branch 'master' into branch
```

Snapshot-oriented storage

- A commit represents exactly the state of the project
- A tree represents only the state of the project (where we are, not how we got there)
- Renames are not tracked, but re-detected on demand
- Diffs are computed on demand (e.g. `git diff HEAD HEAD^`)
- Physical storage still efficient

References

Branches, tags: references

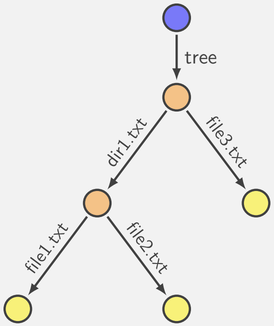
- In Java:

```java
String s; // Reference named s
s = new String("foo"); // Object pointed to by s
String s2 = s; // Two refs for the same object
```

- In Git: likewise!

```
$ git log -oneline
5454e3b add README.txt
7a7fb77 Initial commit
$ cat .git/HEAD
ref: refs/heads/master
$ cat .git/refs/heads/master
5454e3b51e81d8d9b7e807f1fc21e618880c1ac9
$ git symbolic-ref HEAD
refs/heads/master
$ git rev-parse refs/heads/master
5454e3b51e81d8d9b7e807f1fc21e618880c1ac9
```

References (refs) and objects



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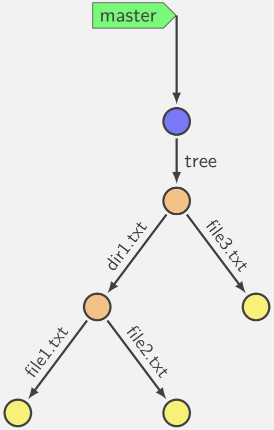

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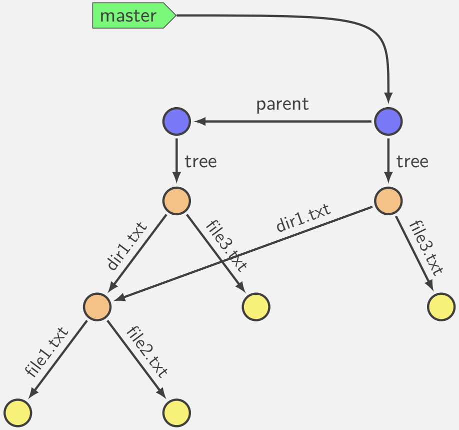

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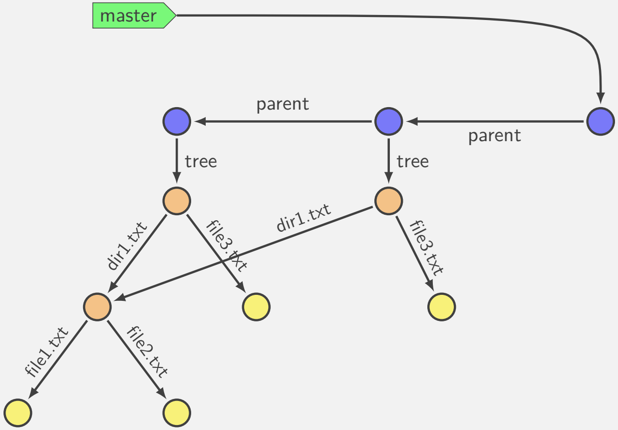

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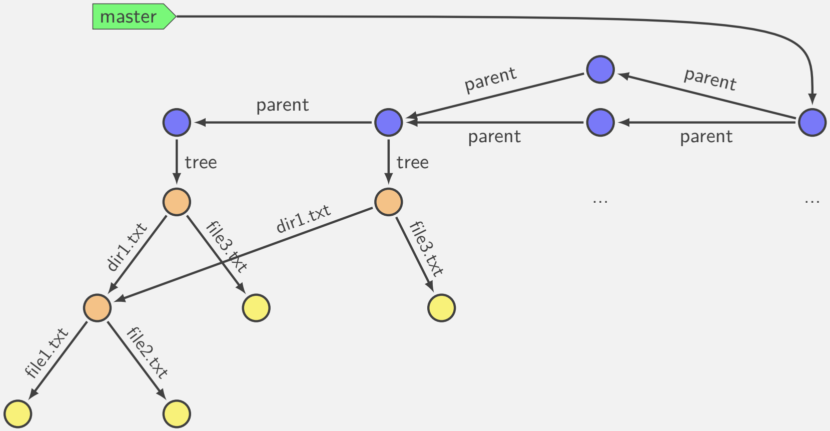

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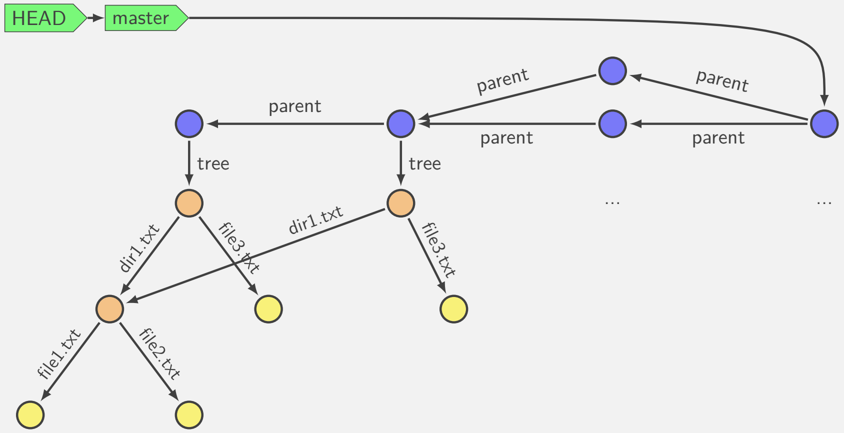
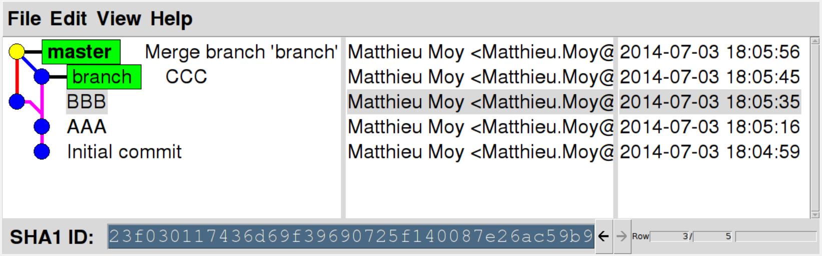


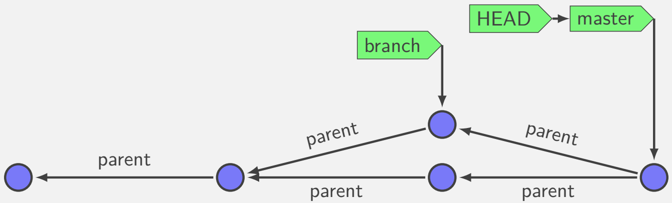
Sounds Familiar?



```
Merge branch 'branch'   Matthieu Moy <Matthieu.Moy@   2014-07-03 18:05:56
CCC                     Matthieu Moy <Matthieu.Moy@   2014-07-03 18:05:45
BBB                     Matthieu Moy <Matthieu.Moy@   2014-07-03 18:05:35
AAA                     Matthieu Moy <Matthieu.Moy@   2014-07-03 18:05:16
Initial commit          Matthieu Moy <Matthieu.Moy@   2014-07-03 18:04:59
```

SHA1 ID: 23f030117436d69f39690725f140087e26ac59b9

$\approx$



Branches, HEAD, tags

- A branch is a ref to a commit
- A lightweight tag is a ref (usually to a commit) (like a branch, but doesn't move)
- Annotated tags are objects containing a ref + a (signed) message
- HEAD is "where we currently are"
  - If HEAD points to a branch, the next commit will move the branch
  - If HEAD points directly to a commit (detached HEAD), the next commit creates a commit not in any branch (warning!)

Branches and tags in practice

Branches and Tags in Practice

- Create a local branch and check it out:
  `git checkout -b` *`branch-name`*
- List local branches:
  `git branch`
- List all branches (including remote-tracking):
  `git branch -a`
- Create a tag:
  `git tag` *`tag-name`*
- Switch to a branch, a tag, or a commit:
  `git checkout` *`branch-name/tag-name/commit`*