Understanding Git

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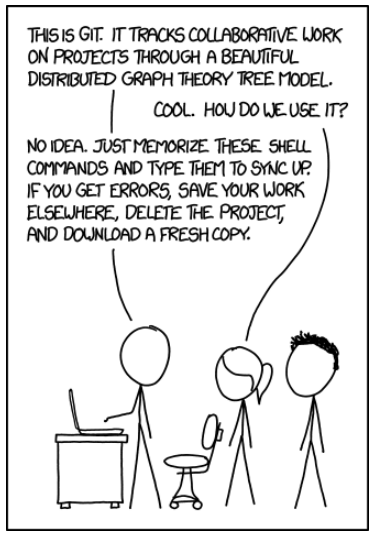
https://git.pages.ensimag.fr/formation-git/slides/understanding-git-handout.pdf

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



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.

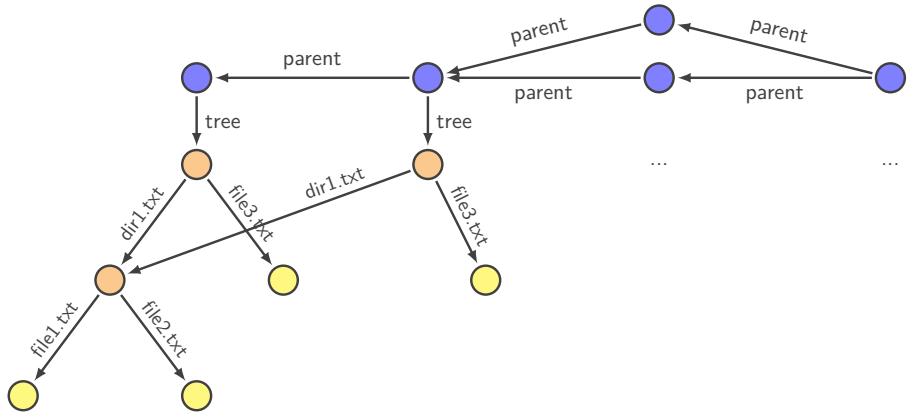
Why do I need to learn about Git's internal?

- 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
- **commit** Metadata + pointer to tree + pointer to parents



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, now 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
$
```

⇝ 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

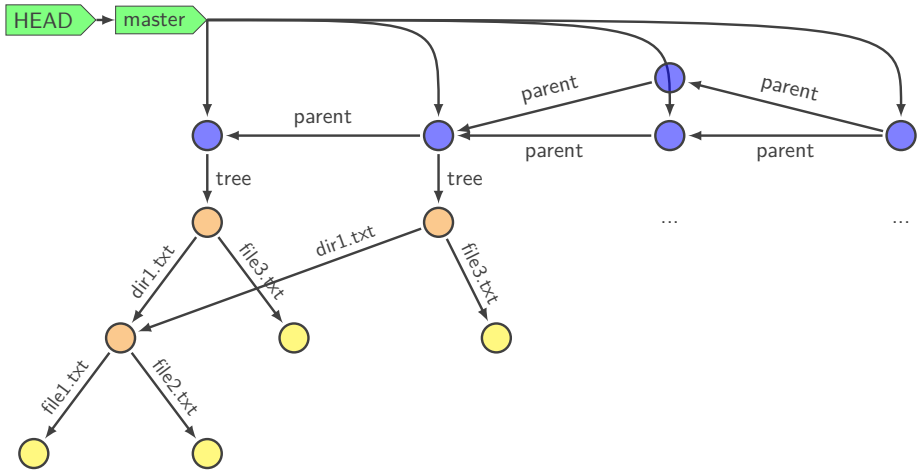
- In Java:

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

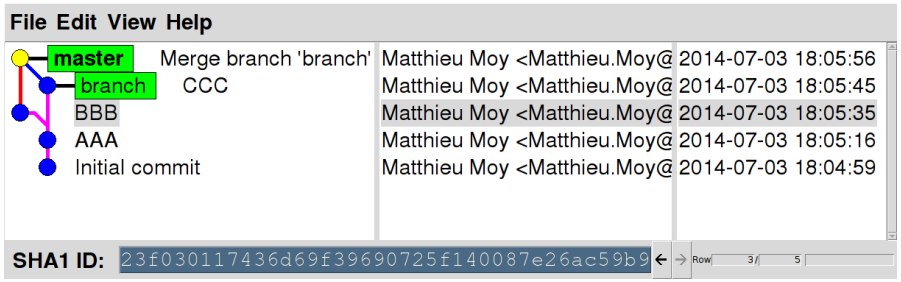
- In Git: likewise!

```
$ 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



Sounds Familiar?



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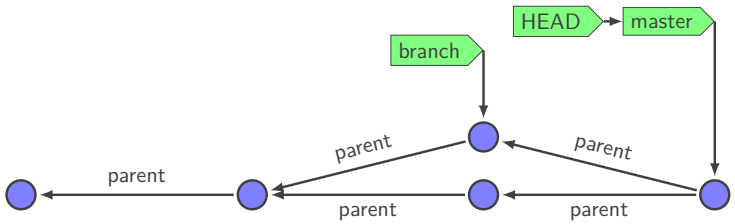

Branches, HEAD, tags

- 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

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- 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]
```