Understanding Git with Alloy

Milestone 3

Cláudio Lourenço Renato Neves

University of Minho
Formal Methods in Software Engineering

July 11, 2012

Table of contents

Git as VCS

Git is one of many Version Control Systems

- Fast
- Efficient
- Oriented to snapshots - Not differences
- Widely used

Project Motivation

Gap in existing Git documentation

- Lack of precise descriptions
- Contradictions between manuals
- Git users could benefit from a manual that is precise and rigorous

The dark world of Git

The common (and above average) knowledge of Git

- "if there are any uncommitted changes when you run git checkout, Git will behave very strangely." [1]
- "When you create a branch, it will contain everything committed on the branch you created it from at that given point. So if you commit more things on the master branch like you have done (after creating b), then switch to branch b, they won't appear. This is the correct behavior. Does that answer your question?" [2]

[1] "Understanding Git" Manual

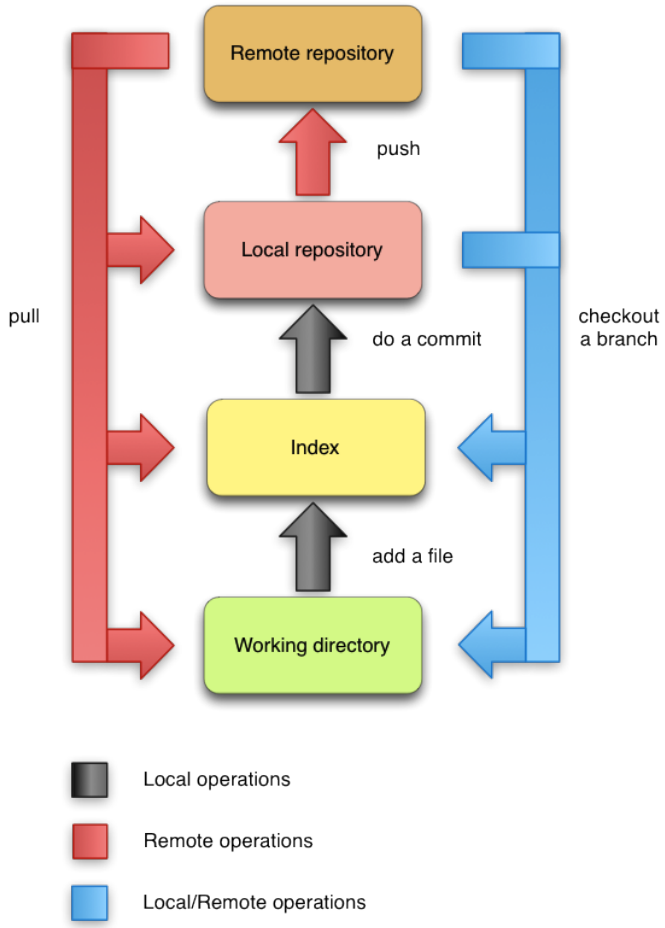
[2] An user of Git development mailing list

Objectives of this project

Shine some light into Git internals

- Build a precise model of how Git works using Alloy
- Analyze the model and verify which properties it does (not) guarantee
- Help others understanding Git, writing a new (hopefully more precise) manual

The Git Structure



Blob and Tree

Blob

- Represents the content of a file
- The identifier is an hash calculated from its content
- Files with same content will be represented by the same blob

```
sig Blob extends Object {}
```

Tree

- Contains Blobs or other Trees
- Used to represent the file system structure
- The identifier is an hash calculated in a similar way to the Blobs
- Sharing is done as in Blobs - Same content, same Tree

```
sig Tree extends Object {
   contains: Name -> lone(Tree+Blob)
}
```

Commit

- A snapshot of the project on a certain moment in time
- It has a set of parents, that are considered the previous commits
- Points to a Tree that represents the root folder in the Working Directory
- An auxiliary abstract relation was specified to simplify the commit operation

```
sig Commit extends Object {
    points : Tree,
    parent : set Commit,
    abs: Path -> Object,
    merge : set State
}

sig RootCommit extends Commit {}
```

Branch and HEAD

Branch

- It is just a pointer to a commit - Unlike other VCS, where a branch is a full copy of the repository

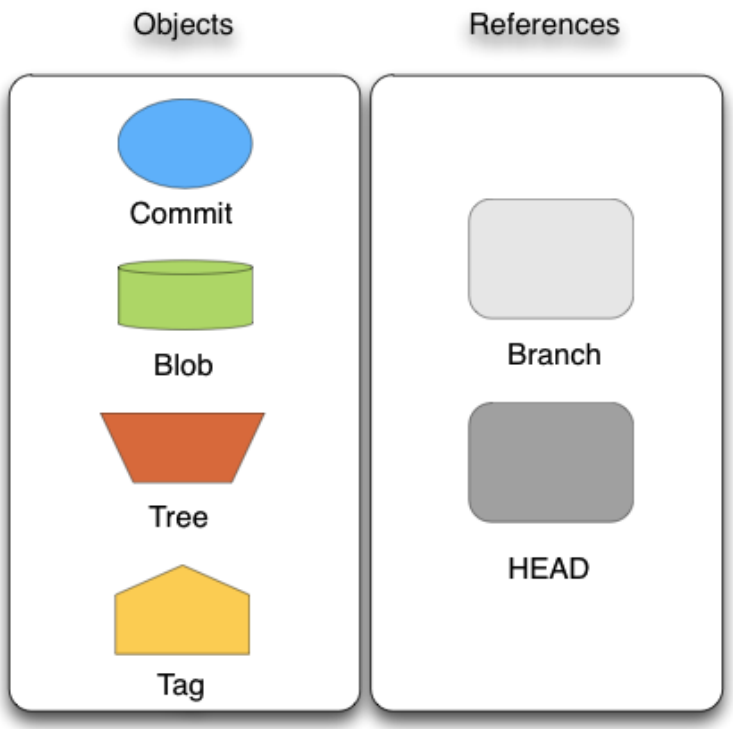
HEAD

- Special reference that identifies the current Branch

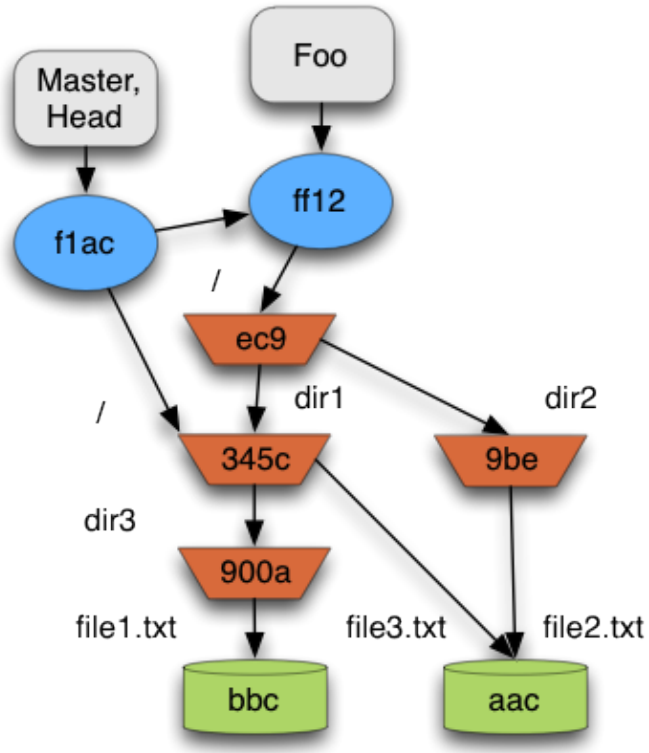
```
sig Branch{
    marks: Commit lone -> State,
    branches: set State,
    head: set State
}

lone sig Master extends Branch{}
```

Repository



Repository


Foo
Master,
Head
ff12
f1ac
/
ec9
/
dir1
dir2
345c
9be
dir3
900a
file1.txt
file3.txt
file2.txt
bbc
aac

Working Directory

- Subset of a file system that is tracked by Git
- In our model we simplify this component using the notion of path
- Our convention dictates that if a file exists in an Alloy instance, then it automatically exists in the Working Directory

```
sig Path {
   pathparent: lone Path,
   name: Name,
   unmerge: set State
}

one sig Root extends Path{}
```

Index

- Contains all files that are going to be committed on the next commit
- The index is not necessarily equal to the Working Directory
- If an user wants to commit a new file or a modified file, first he must add it to the index

```
sig File{
    path: Path,
    blob: Blob,
    index: set State
}
```

Modeled Operations

- Add and Remove
- Commit
- Branch and Branch Remove
- **Checkout**
- **Merge (2-way and fast-forward)**

Add and remove

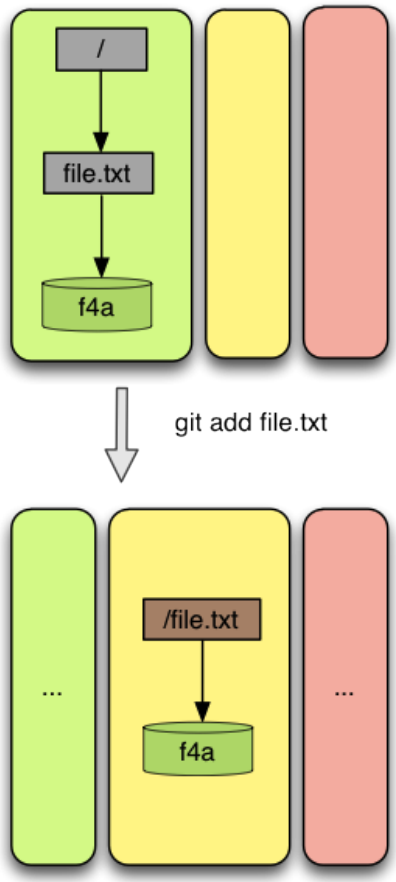
Add

- Adds a file to the index
- Updates the content of a file in the index
- Those changes will be stored in the next commit

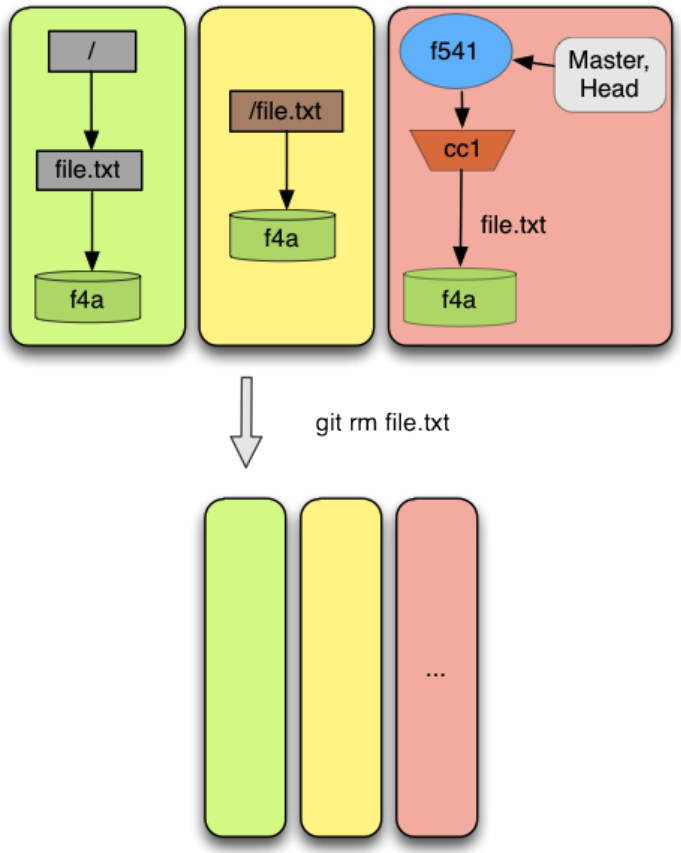
Remove

- Removes a file from index, and from the Working Directory
- The removed file will not be present in the next commit

Add



Remove

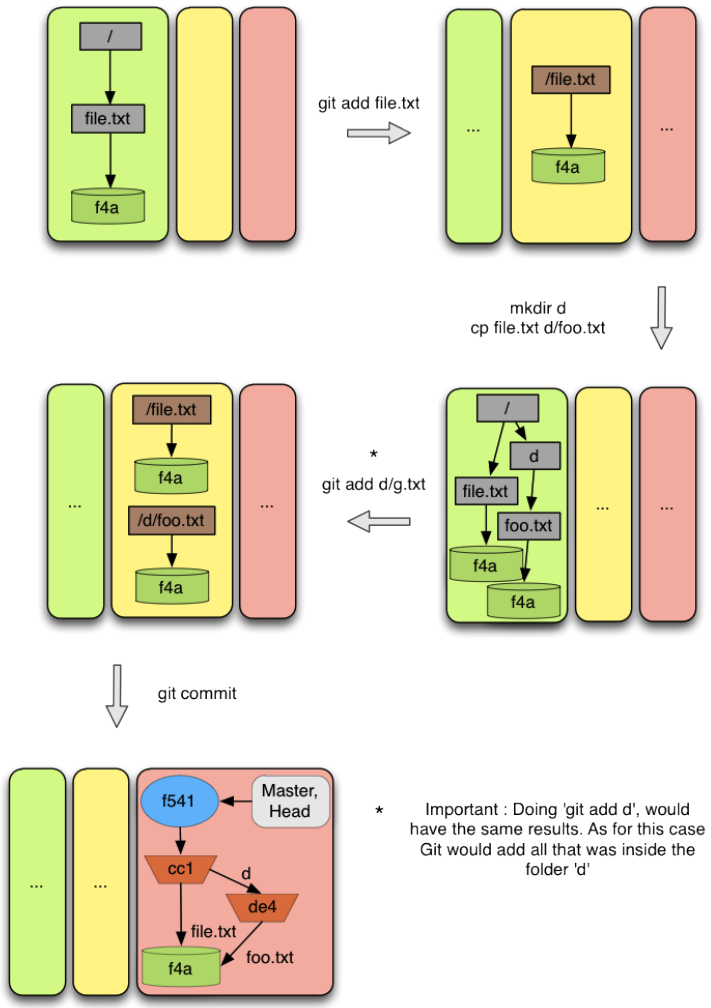

/
file.txt
f4a
/file.txt
f4a
f541
Master,
Head
cc1
file.txt
f4a
git rm file.txt
...

Commit

Commit

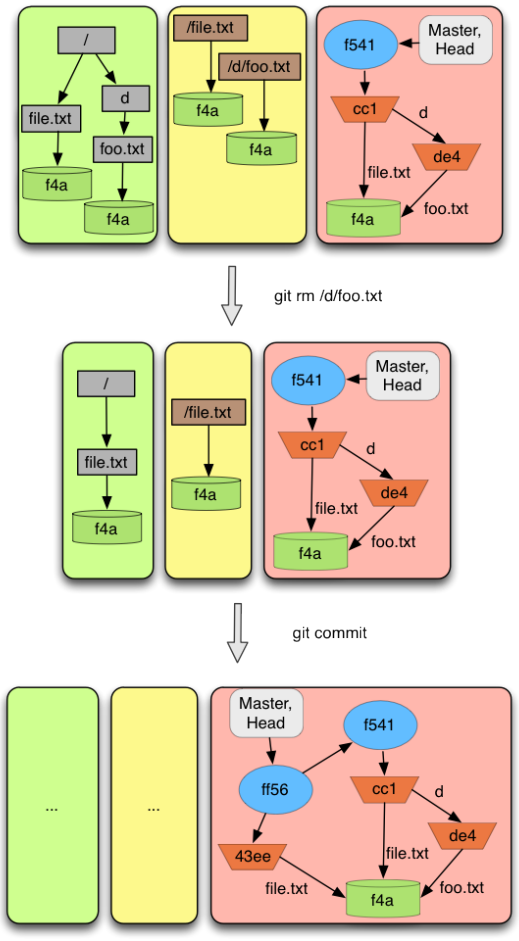
- A snapshot of a project on a certain moment in time
- In the first version of the model it was very difficult to model such operation
- An abstract relation was then modeled to map objects on a certain commit with a path

Commit



CSAIL

Commit



CSAIL

Checkout

The most difficult operation to specify

- No manual was found with a full description
- No references to the existing pre-conditions - "if there are any uncommitted changes when you run git checkout, Git will behave very strangely. The strangeness is predictable and sometimes useful, but it is best to avoid it..." [3]
- Bug was found and reported to the Git Mailing List [4]

[3] http://www.sbf5.com/ cduan/technical/git/git-2.shtml
[4] git@vger.kernel.org

Checkout pre-conditions

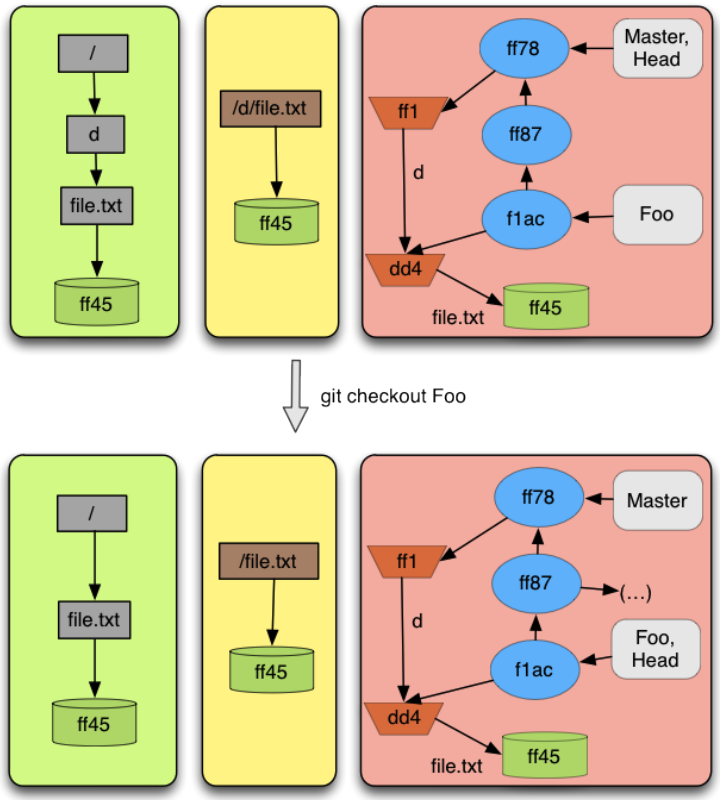
Expected pre-condition

- No uncommitted files

Real pre-condition

- Everything that is in the index has to be committed, except if
  - The content of a file is the same in the current and destination commit (warning is thrown)
  - A file in the index does not exist neither in the current nor in the destination commit (warning is thrown)
  - Content of a file in the index is the same as in the destination commit (no warning is thrown)

Checkout


/
d
file.txt
ff45
/d/file.txt
ff45
ff78
Master, Head
ff1
ff87
d
f1ac
Foo
dd4
file.txt
ff45
git checkout Foo
/
file.txt
ff45
/file.txt
ff45
ff78
Master
ff1
ff87
(...)
d
Foo, Head
f1ac
dd4
file.txt
ff45

Merge

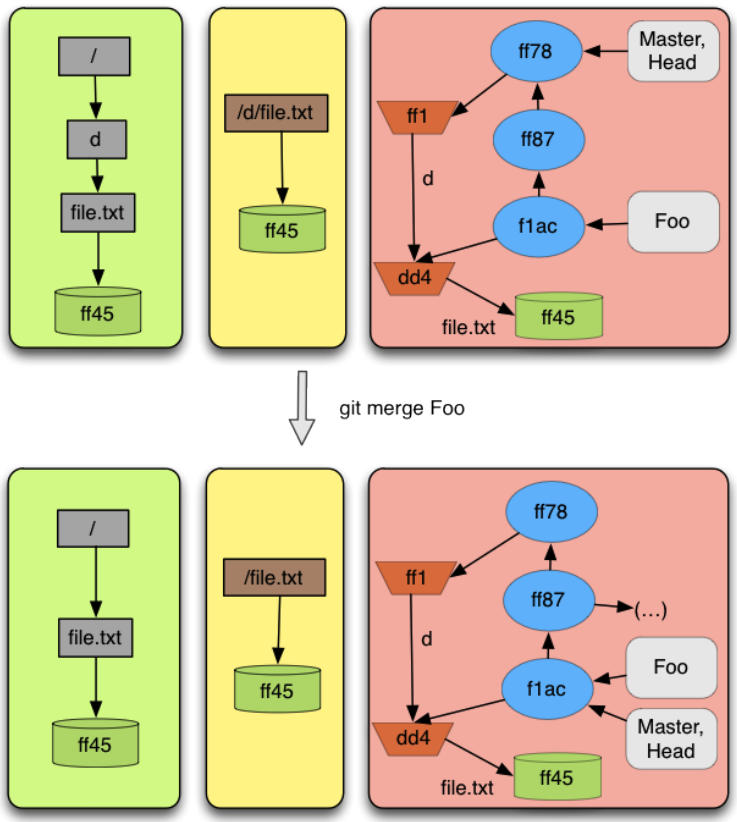
Merge

- The current commit and the commit pointed by the specified branch will be merged into a possible new commit

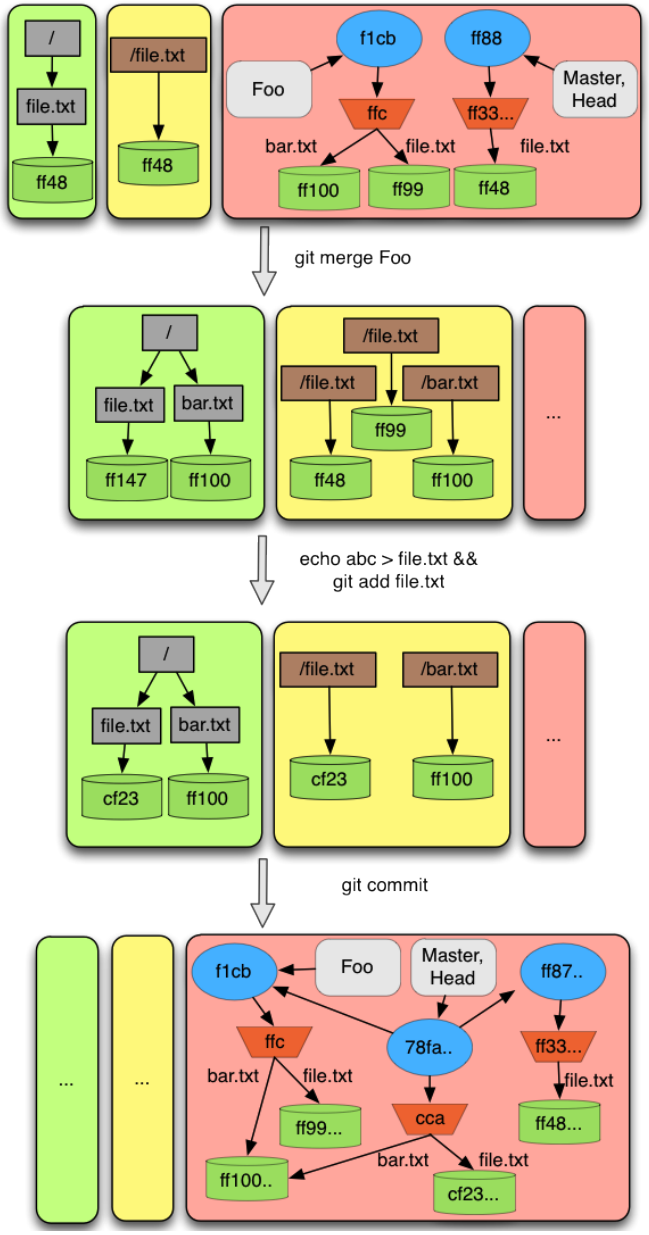
Merge variants

- The commit being merged is more recent than the current commit - A new commit is not created because the commit being merged takes precedence - **Fast-Forward Merge**
- The typical **2-way merge** will create a new commit resulting from both commits
- The **3-way merge** will also create a new commit, however it uses the most recent common ancestor to solve automatically some conflicts that cannot be solved with 2-way merge

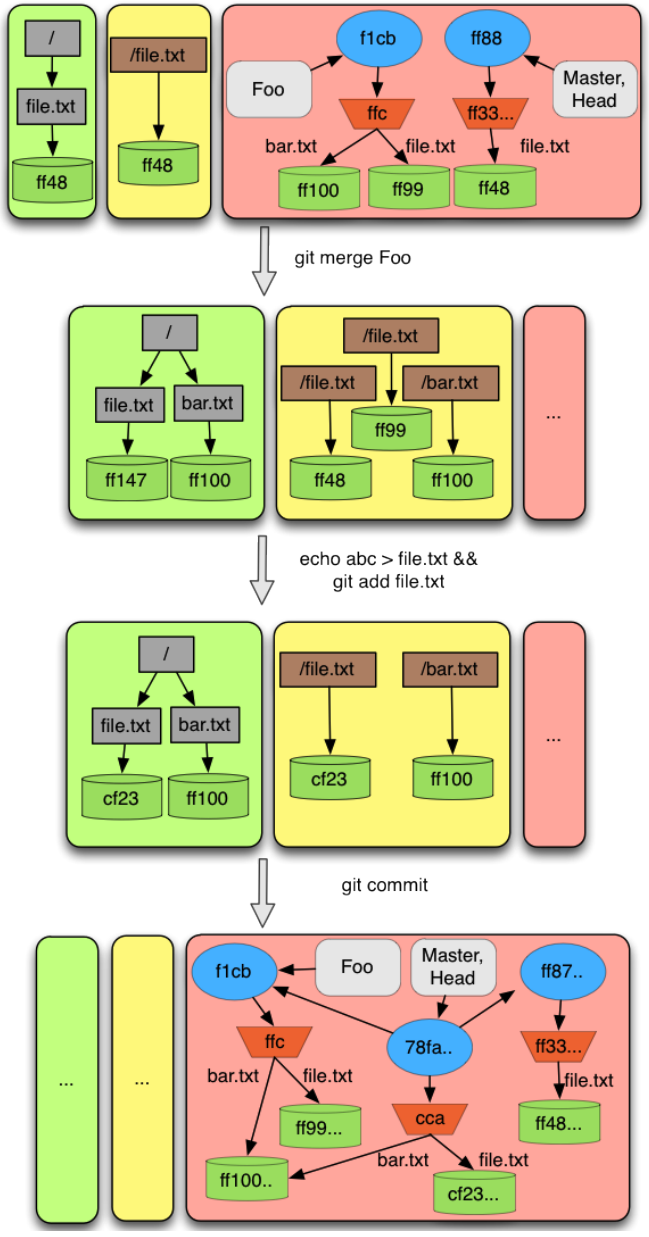
A fast-forward Merge



A 2-way Merge


/
file.txt
ff48
/file.txt
ff48
f1cb
ff88
Foo
Master, Head
ffc
ff33...
bar.txt
file.txt
file.txt
ff100
ff99
ff48
git merge Foo
/
file.txt
bar.txt
ff147
ff100
/file.txt
/file.txt
/bar.txt
ff99
ff48
ff100
...
echo abc > file.txt &&
git add file.txt
/
file.txt
bar.txt
cf23
ff100
/file.txt
/bar.txt
cf23
ff100
...
git commit
...
...
f1cb
Foo
Master, Head
ff87..
ffc
78fa..
ff33...
bar.txt
file.txt
file.txt
ff99...
cca
ff48...
bar.txt
file.txt
ff100..
cf23...

A 3-way Merge


/
file.txt
ff48
/file.txt
ff48
f1cb
ff88
Foo
Master, Head
ffc
ff33...
bar.txt
file.txt
file.txt
ff100
ff99
ff48
git merge Foo
/
file.txt
bar.txt
ff147
ff100
/file.txt
/file.txt
/bar.txt
ff99
ff48
ff100
...
echo abc > file.txt &&
git add file.txt
/
file.txt
bar.txt
cf23
ff100
/file.txt
/bar.txt
cf23
ff100
...
git commit
...
...
f1cb
Foo
Master, Head
ff87..
ffc
78fa..
ff33...
bar.txt
file.txt
file.txt
ff99...
cca
ff48...
bar.txt
file.txt
ff100..
cf23...

Merge specification

- Fast-Forward Merge and 2-way Merge are modeled
- 3-way Merge partially modeled
- Two relations had to be created for the case a manual merge takes place:
  - Unmerged Files
  - A relation to identify the branch being merged

Merge specification

Most important pre-conditions specified

- The current commit cannot be more recent than the commit being merged
- There cannot be an unfinished merge
- When the fast-forward variant is applied, the index cannot have uncommitted files that would conflict with files from the resulting merge
- When a 2-way or 3-way merge is applied, it is not possible to have uncommitted files in the index

Website

- A manual was created using the knowledge obtained
- Website was created based on the manual
- Project documentation is also available
- `http://nevrenato.github.com/CSAIL_Git`

Future Work

- Model some more operations: 3-way merge, rebase, fetch, etc.
- Check for some more properties that the model does (not) guarantee
- Build interactive diagrams of concrete examples of operations

Conclusions

- Not enough time (not even close) to specify the whole Git
- It would be nice to check the properties in a theorem prover, in order to have completeness
- Model is stable and documented enough to be extended with other operations by outsiders