Modelling the Git core system with Alloy

Cláudio Lourenço, Renato Neves
Universidade do Minho

June 28, 2012

Contents

1 Introduction

1.1 What is a VCS system?

A Version control system is a tool that records changes on your files over time. The main idea is to keep track of the changes on your files and to retrieve them later. There are mainly three kinds of Version control system, local, centralized and distributed. On a local VCS it is not possible to collaborate with other users and the structure that keeps track of the files is kept only locally. The need for collaborations with other users brought the centralized VCS. On the centralized version control systems exists a server that keeps track of the changes on the files and each user pulls and checks out files from this server. This approach has mainly two problems. The first is to have a single point of failure, if a server goes down during a certain time, nobody can check out or pull updates. The second problem is when you are not connected to the network, you cannot pull or commit your changes. To solve this problems, the distributed VCS appear. Here each user keeps a mirror of the repository and there is not a central server. An user can always commit, and when connected, can pull/checkout the changes.

1.2 What is Git?

Git is a distributed VCS. It was created in 2005 by Linus Torvalds, for the Linux kernel development. The main difference when comparing to others distributed VCS is that git keeps snapshots of how your system looks likes on a certain moment in time, instead of keeping track of changes.

1.3 Our motivation for this manual

Nowadays git is having great success, it is efficient, fast and very easy to use. The problem here is that, most of the users do not dive into the git internals,

they are just happy that it works. The ones that actually try to go deep into git to see how it works and why git behaves in a specific way, are fronted with the lack of formal or even informal specifications. So, the purpose of this project is to formally model the git core using a tool called Alloy, analyse and model some git operations with that tool, and then check which properties the model does (not) guarantee. This manual presents to the reader a formal description of git internals, the description of some operations and it ends with some properties that the model guarantee.

Alloy is a declarative specification language, used for describing structures in a formal way. After modeling the structures, it is possible to visualize instances of them.

1.4 How this manual is structured

This reports starts by explaining the organization of git, how git is structured. Then we cover each component of git. We begin with the object model, following the index and working directory. For matters of time and complexity we focus our model on the index and object model. After the presentation of the structure we give the formal specification of some operations. We finish the report with the analysis of some properties.

2 The Git structure

The git is divided mainly in three components. The working directory, the index and the repository. The connection between these components can be seen in figure 1.

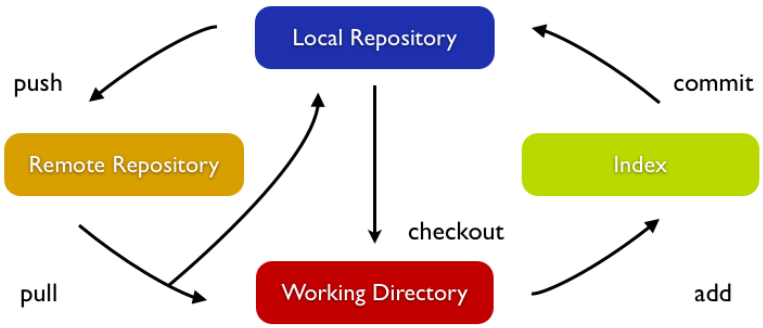


Figure 1: Git WorkFlow

2.1 Working Directory

The working directory is a subset of a file system that contains the files of the project that you are currently working on. When retrieving an older snapshot

of the project, the working directory is updated to reflect the project in that state.

2.2 Index

The index is a component that contains all the files that will be committed on the next commit (the next snapshot).

2.3 Repository

As said, Git is a distributed VCS. So we can work not just with a local repository, or remote repository, but we can work with both types at the same time. One of the advantages of Git is that we can work off-line and then at the end of day, we update the remote repository with our work.

In fact, the definition of local/remote depends only on the perspective of the user, as there are no structural differences between local and remote repositories. Imagining two users, where each one has his local repository, one will see the other as the remote repository and vice-versa.

A repository contains all the information needed to store, and stores all snapshots taken.

3 What lives in the repository?

As we have presented before git keeps snapshoots of how your system looked like on a certain moment in time. This moment in time is represented in git by a commit. A commit points to a tree, that represents the structure of your system on that moment. So a tree contains others trees and/or blobs. In git the files are not kept. What git keeps is a blob that represents the content of files. The relation between the path of a file and the content of that path is kept on the trees corresponding to that path.

We will show the specification of the git object model, using as basis two manuals, [1] and [2].

Only the key parts of the model will be presented.

3.1 Identification of Objects

All objects are identified by a sha defined by their contents.

"All the information needed to represent the history of a project is stored in files referenced by a 40-digit **"object name"**..." (page 7)

We don't need to specify this, as Alloy already can uniquely identify atoms, so we can reutilize that functionality.

3.1.1 The four types of Objects

The objects are defined as in [1] (page 7) wich says: "...and there are four different types of objects: blob, tree, commit, and tag." Also: "A blob is used to store file data - it is generally a file" [1] (page 8).

For trees: "A tree is basically like a directory - **it references a bunch of other trees and/or blobs**..." (page 8)

The tag will be discarded, as it doesn't affect the main operations of git.

Now for the commit: "As you can see,a commit is defined by : parent(s):**The SHA1 name of some number of commits which represent the immediately previous step(s) in the history of the project**..." "...merge commits may have more than one. A commit with no parents is called a root commit, and represents the initial revision of a project. **Each project must have at least one root. A project can also have multiple roots, though that isn't common (or necessarily a good idea)**". [1] (page12) A commit also points to a certain tree that represents the state of the repository at a given state.

4 Git operations

4.1 Add and Remove

4.1.1 What they do?

When you use the 'git add <file>' command, a file will be added to the index. The file added can be a new file, or a file already existing in the index. When the latter is true, git just updates the content of that file.

When you add a file, it will be marked to be committed in the next commit.

'git rm <file>' can be seen as the inverse operation of the 'git add <file>'. In this case Git, will remove a file from the index, so it won't appear in the next commit. Besides being removed from index, it will also be removed from the working directory (if it's still there).

4.1.2 Pre requisites

There are a few cases where Git prevents you from removing a file :

- The file must exist in the index.
- Removing a file, when the file with it's current content doesn't exist in some commit object.

The last restriction exists, to avoid the accidental deletion of files. Imagine the case where you have a file 'x' with 10k lines of code. You add it

to the index, but, before committing you accidentally use 'git rm x'. Because Git erases from the index and the working directory you would lose it permanently.

4.1.3 Properties

- Adding a file after adding the same file, has no effect
- Adding a file, committing, removing the same file and committing brings to a commit equal to before of adding the file
- Removing a file and then adding the same file brings to an index equal to the one before removing the file

4.1.4 Examples

In these figures, it is shown the process of adding a file to the index. In fact, both files showing represent the same file, but with different content at a given time. So imagine that, after adding "File1", "File0" is added. "File1" would be removed from the index (because there cannot be a file with different contents in the index at any given state) and "File0" would be added. What was described was the representation of the update of the content of a file in the index.

Figure 2: Before the add

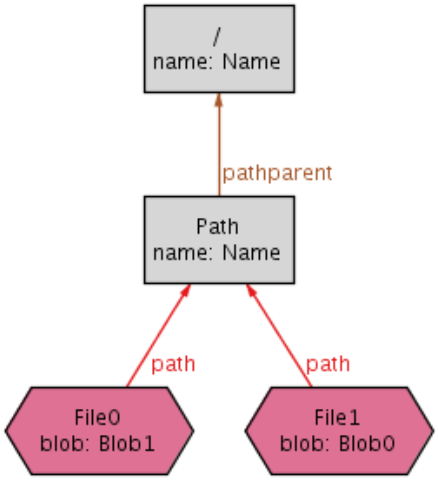
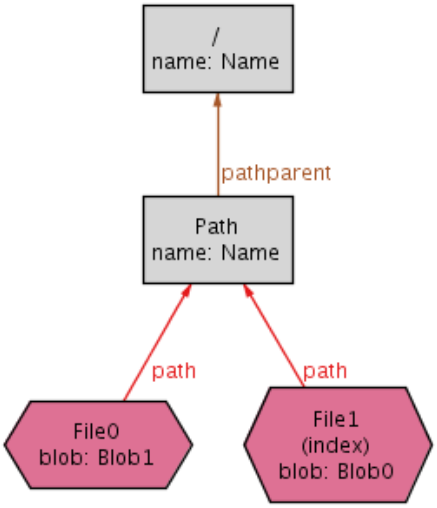


Figure 3: After the add



4.2 Commit

4.2.1 What it does?

The 'git commit' operation, stores the current content of the index in a new commit.

When the first commit is created, a branch called "Master" will be created and will be marked as the current branch. Also, the first commit of a repository is called a RootCommit.

4.2.2 Pre requisites

The only restriction that Git has about this operation it's that your new commit must have something different from the previous commit, or, if it's the first commit, then there must exist some content in current index.

4.2.3 Properties

4.2.4 Examples

The figure 4 is a typical example of a RootCommit. There is a file with the path Name/Name, and a content Blob. It is currently on the index. The current branch is Master, and it is pointing to a commit, which represents the index at current state.

The figure 5 represents the case of a normal commit, where the newest commit comes after the RootCommit. The line of thought is the same as in the last image. We can see that the difference between these two commits, it that the only file was moved to a folder named "Name".

Figure 4: A first commit

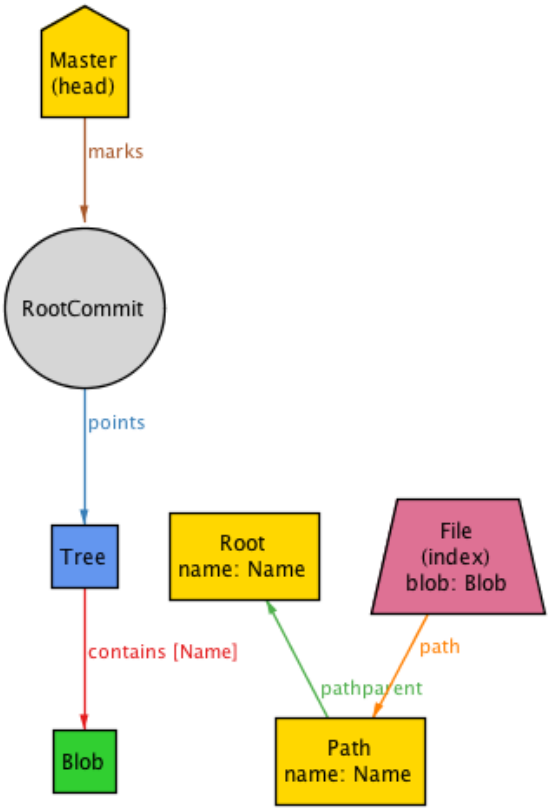
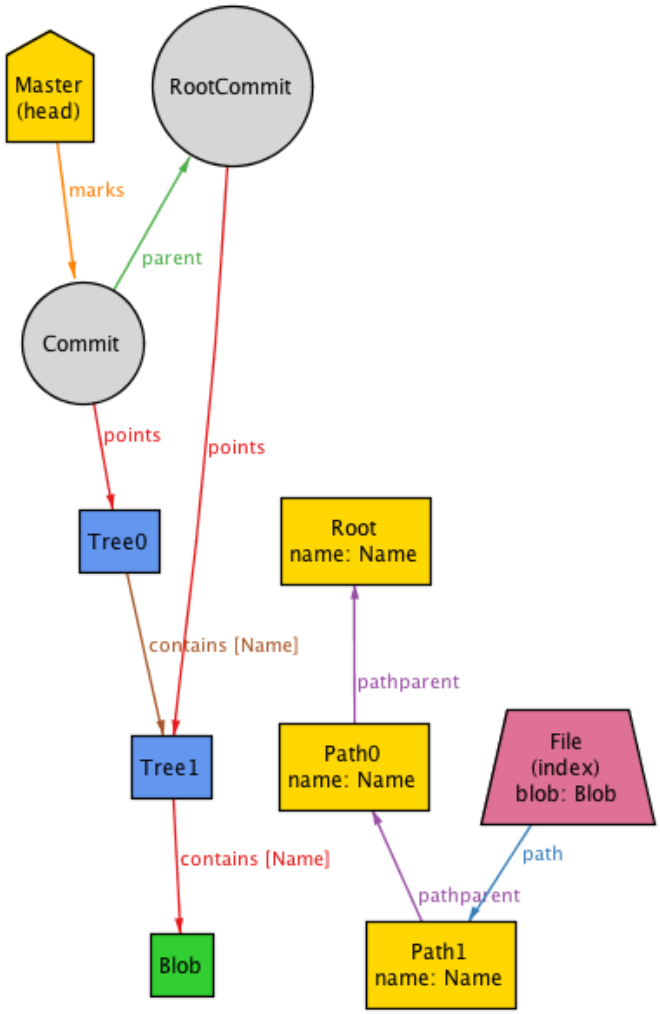


Figure 5: A Commit



We can also see the efficiency of Git, about the sharing property of objects in the commits, thus minimizing the space occupied in the repository.

4.3 Branch

4.3.1 What it does?

4.3.2 Pre requisites

4.3.3 Properties

4.3.4 Examples

Git branch operation has several forms, that to different things on git. The ones which we care are the forms that create and delete branches.

When a new branch is created it will point to the current HEAD by default.

The man git-branch says that when deleting a branch, it must be fully merged in its upstream branch, or in HEAD if no upstream was set.

4.4 Checkout

4.4.1 What it does?

4.4.2 Pre requisites

4.4.3 Properties

4.4.4 Examples

From man git-checkout : "Switches branches by updating the index, working tree, and HEAD to reflect the specified branch or commit".

4.5 Merge

4.5.1 What it does?

When you do a 'git merge <branch>', a merge will happen between the current branch and the branch selected on the command. The result will be a new merge commit, or a partially merged index.

Git knows three types of merge :

- A fast-forward merge, that will happen when the current commit from the other branch, is more recent than the current commit from the current branch.

  This type is not a true merge, in the sense that the only thing that changes it's the pointer of the current branch is moved to the newest commit.

- A 2-way merge, that happens when the conditions for a fast-forward don't exist, and there isn't a common ancestor for both commits.
- A 3-way merge, happens when the conditions for a fast-forward don't exist, but, there is a common ancestor for both commits.

  The difference between these two last types, is that the last is much more automatic having much less conflicts than the previous type.

Knowing these 3 types of merge, it's important to know that Git tries to make the merge process as automatic as possible. However conflicts do exist, and when they happen it leaves to the user the process of resolving those conflicts.

When the Git/user, finishes the merging of files in the index, he can commit the resulting merge, in a merge commit.

Note that while there are unmerged files in the index, a commit cannot be made.

4.5.2 Pre requisites

- A merge can't be made, if the current commit is more recent then the other commit.
- A merge can't be made, while there are unmerged files.
- In the case of a fast-forward merge, the index can't have uncommitted files that can be changed by the merge operation.
- In the case of a 2-way or 3-way merge operation there can not be uncommitted files.

4.5.3 Properties

4.5.4 Examples

References

[1] *Git Community Book*.

[2] Scott Chacon. *Pro Git*. Apress, Berkely, CA, USA, 1st edition, 2009.