Modelling the Git core system with Alloy

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1 Abstract

2 Introduction

This project aims to build a precise model of how the git works.

The purpose of this model is to check some properties that the model does (not) guarantees.

In this report, we will try to give a specification of the git core system.

After the specification process, we will make the model dynamic, in order to specify git most important operations.

Following this, some assertions on the model will be introduced, in order to verify the git robustness and safety.

Finally some conclusions will be presented to the readers.

2.1 A brief explanation of git

Git is just one of many Version control system available. They are distinguished by two main types: Centralized and Distributed. Git it's in the later. The major difference between git and any other VCS, is that while others save differences between files, git saves snapshots.

A Git project usually has three main sections: Repository, Index and Working Directory. Where the later it's just a subset of the filesystem.

Git was created in 2005 by the Linux community, with the purpose of replacing BitKeeper. Some of it's goals are [2]:

1. Speed
2. Simple design
3. Strong support for non-linear development
4. Fully distributed
5. Able to handle large projects like the Linux Kernel efficently (speed and data size)

2.2 Why the verification of git is important

Nowadays, the software projects are getting bigger, and in most cases it is needed a version control system. Thus, git is being more and more used. However, can we trust in git to manage projects of big value ? We don't know the answer, but it's true that we can be more confident in git if we make some kind of verification on it. Because there are no known formal/semiformal verifications of git, we try to fill part of that hole with this project.

3 Git Static Object Model

In this section we will show the specification in Alloy of the git static object model. It will be mostly based on the textual specification present in [1] and [2].

3.1 The 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)

However Alloy has a mechanism to uniquely identify atoms, so we can use it instead of the sha.

The objects are defined as in [1] (page 7) "...and there are four different types of objects: "blob", "tree", "commit", and "tag". "


```
abstract sig Object {
}
sig Blob extends Object{}
sig Tree extends Object {}
sig Commit extends Object{}
sig Tag extends Object{}
```

"A "blob" is used to store file data - it is generally a file" [1] (page 8). We can abstract from it.

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

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

Again from [1].

"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**. The example above has one parent; 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)**". (page 12)

```
sig Commit extends Object{
  points : Tree,
  parent : set Commit
}

sig RootCommit extends Commit{}
```

```
fact {
  no ^parent & iden
  no RootCommit.parent
  all c : Commit - RootCommit | some c.parent
}
```

One of the advantages of git compared to others VCS is the operation of creating a new branch. While in others VCS, a copy of the hole project is done each time we create new branch, in git, only a new pointer is created.

"A branch in Git is **simply a lightweight movable pointer to one of these commits**."

[2] (pag 39) "The special pointer called **Header points to the branch we are working on**". [2] (pag 40)

```
sig Branch {
        mark : Commit,
        head : lone Branch
}{
        some Commit <=> one head
}
```

3.2 Implicit specifications

As the book [1] says, a "tree" acts like a directory, so we know that it or its descendants cannot point to themselves.

Also, git only deals with files and their paths. Thus, git cannot have folders without descendants.

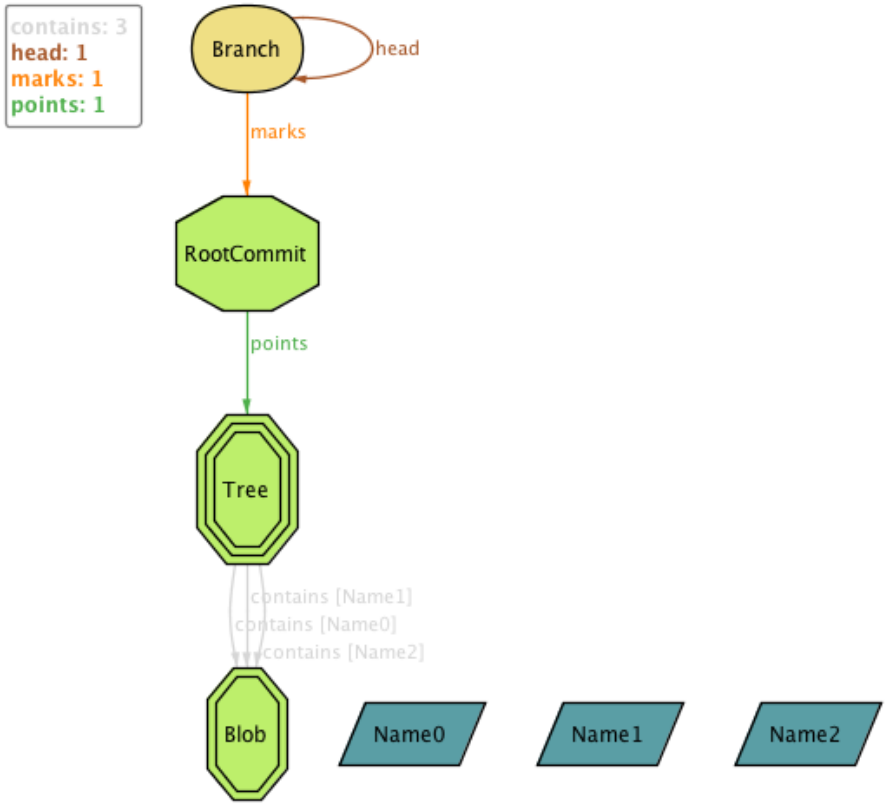
```
let r = {x :Tree, y : Tree+Blob |
                some n : Name | x->n->y in contains} {
        no ^r & iden
        all t : Tree | some t.r
}
```

A tree needs to have at most one parent. Because it is part of a file's path.

```
all t:Tree | lone contains.t
```

Only with this specifications we can already see some interesting examples, like the next one.

Figure 1: A simple commit



4 Index

4.1 The notion of path

A path here is defined as part of a filesystem path. Each file on git has a blob and a path associated. The later and it's parents define a filesystem path.

```
sig Path {
        pathparent : lone Path,
        name : Name,
        blob : lone Blob,
}
```

With this new information we introduce some new invariants. We can't have cycles and two paths with the same name, as in unix filesytem. Only the leafs of a path can have a file (blob) associated.

```
fact {
         no ^pathparent & iden
         all disj p,p' : Path | p.pathparent = p'.pathparent
         implies p.name != p'.name
         no Path.pathparent & blob.Blob
}
```


4.2 The notion of Index

The definition of Index: "...staging area between your working directory and your repository. You can use the index to **build up a set of changes that you want to commit together**. When you create a commit, **what is committed is what is currently in the index, not what is in your working directory.**" [1] (page 17).

"The index is a binary file (generally kept in .git/index) **containing a sorted list of path names**, each with permissions and the SHA1 of a blob object" [1] (pag 120).

```
sig Path {
        ...
        index: lone Path
}
fact{
        no Path.parent & index.Path
}
```

The index relation will define which files are in the index. And we know that only files can be in the index.

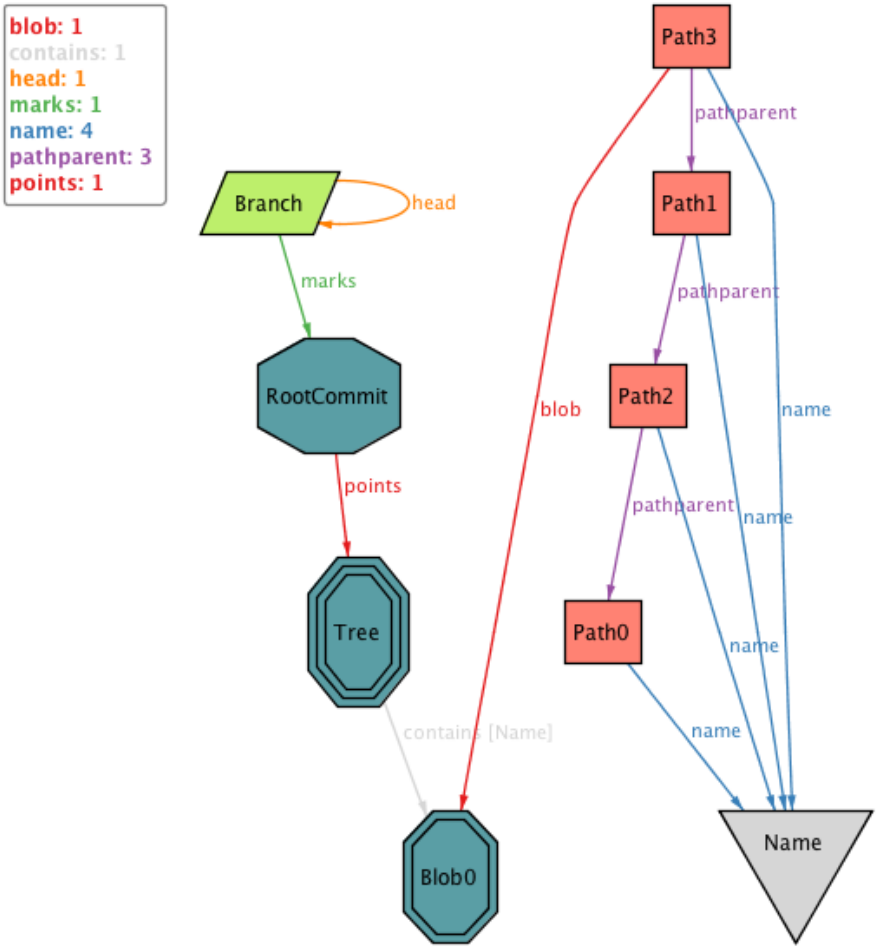
Also : "The index **contains all the information necessary to generate a single (uniquely determined) tree object**" [1] (pag 121).

This description tells us that the index saves a snapshot of the system, not the differences !

What is the practical difference between the Index and the Working Directory? The Working Directory is just the root folder of a repository, that we work on. When we want to save something in a commit, we have to explicitly tell git to add that to the Index. Once added, it will be saved in the git database at the next commit. If we don't want to save something in a commit, we simply don't add it to the Index.

Now we can see a more complete model of git.

Figure 2: A simple commit and a file



5 Modelling Git Dynamic Object Model

The static object model, only by itself, is not very useful. And so the model would be much more interesting if we specify the some git operations. In order to do that, we need to specify on the model, what can change over time.

5.1 The notion of state

From now on, all relations with potential to change must have a state associated. So, a relation that has some information before an operation, can have other contents after it.

For example :

```
sig Commit extends Object {
        ...
        parent : Commit set -> State
}
```

We can see that a commit can have a determined set of parents, but, after some operation it can have another set of parents. Thus, the state will define the relation contents in a certain "instant".

The model, now, needs some adaptations to support the notion of state.

5.2 Git operations

5.2.1 add

This command is one of the most used in git. [1] (page 26) tells us that "git add is **used both for new and newly modified files**, and in both cases it takes a snapshot of the given files and **stages that content in the index, ready for inclusion in the next commit**."

Thus, we can see the add operation, only as the adition of a file to the index, and nothing else can change between the two states.

```
        //path needs to be a file
        no pathparent.p

        // a path is added to the index
        objects.s' = objects.s + p.blob
        index.s' = index.s + p

        //all other things are kept
        parent.s' = parent.s
        marks.s' = marks.s
        branches.s' = branches.s
        head.s' = head.s
```

5.2.2 rm

The usefullness of rm can be seen in the following [2] (page 21) "To remove a file from Git, you have to remove it from your tracked files (more accurately, **remove it from your staging area with git rm**) and then commit. An important restriction that git imposes when using git rm is used, it that the content of the file to remove must be equal to the last commit.

So, we can see the rm operation as a removal operation of a file that is in the index, and it cannot have changed since the last commit.

5.2.3 commit

The commit operation is simply explained. "A commit is usually created by git commit, which creates a **commit whose parent is normally the current HEAD**, and whose **tree is taken from the content currently stored in the index**" [1] (page 13). But hard to model. The culprit is the transformation of the index into a tree that is pointed by the new commit.

5.2.4 push

5.2.5 pull

6 Conclusions

References

[1] *Git Community Book*.

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

Glossary

version control system Management of changes to documents, computer programs, large web sites, and other collections of information. 1