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Git as I understand (3): diff and merge

For traditional delta-based SCM, diff/delta is the first class citizen which is stored as a native object in software model. Git is snapshot based, and it stores "content" directly instead of delta. Even though git use diff/delta to pack object files into "pack file", the delta interface/structure does not aims to provide open API for end users and only aims at providing storage space efficiency and network IO bandwidth saving on the background. Whenever a diff view of different commit/snapshot tree is needed, git will compute it on the fly. Per my understanding, git employs the design philosophy of "disk is cheap and trade cpu power for a simpler software model" in regard to diff/delta.

The more important reason for Git to exclude patch/diff out of basic object model, per my personal experience, is that "patch/diff" theory is far from perfect. diff based on text line can not provide any syntactical or semantic diff. Two source files with different text content might be identical in syntax. Two developer might have drastically different source code to implement the same algorithm/processing. When we diff/merge different software artifacts, current diff/patch implementation can not guarantee the merged results are correct in semantic sense, although it is an "automatic" merge. The correctness of merge will always depends on human judgement. diff/merge implementation could only be used as a productivity tool but not a correctness verification tool. By excluding diff/patch out of basic object model, Git has great flexibility to employ any progress in diff/patch algorithm at will, without introducing any compatibility issues for stored objects.

Additionally, traditional SCM focus on tracking individual file/directory's history. On the contrary, git only tracks the history of root snapshot tree as a whole, instead of individual file/directory.

Git is distinguished for its encourage to use branch. The usage of branch will sure lead to merge. Git touts its merge feature with saying like "merge just works automatically most of time". Such saying at best is misleading. Merging of source code always mandates human intervention, be it "merged automatically" or "merged with conflict resolution". If Git is said to be "more branch and merge friendly" comparing to other SCMs, it is just because Git does not make it harder.

Many of Git's advanced features mandate your thorough understanding on how diff and merge work. We will introduce many git work flow embedded within "porcelain" commands. Only after you know how diff/merge play roles in these commands you can use these commands with confidence and let Git help you to achieve your goal.

Git is a snapshot based version control system. When you need the difference between two snapshots, git will calculate the difference for us

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```
            default, myers
                The basic greedy diff algorithm. Currently, this is the default.

            minimal
                   Spend extra time to make sure the smallest possible diff is
produced.

            patience
                Use "patience diff" algorithm when generating patches.

            histogram
                 This algorithm extends the patience algorithm to "support low-
occurrence common elements".
```

To gain some solid understanding on how diff algorithm works, I recommend a classical paper:

http://xmailserver.org/diff2.pdf [http://xmailserver.org/diff2.pdf]
http://simplygenius.net/Article/DiffTutorial1
[http://simplygenius.net/Article/DiffTutorial1]
http://simplygenius.net/Article/DiffTutorial2
[http://simplygenius.net/Article/DiffTutorial2]

If you want to know more about gnu diff/merge tools, you can refer to documentation of package "diffutils":

```
[luke@rmbp project]$ info diffutils
```

1.tree diff

Under many git work flow, a diff on snapshot directory tree is the first step. Here is an example:

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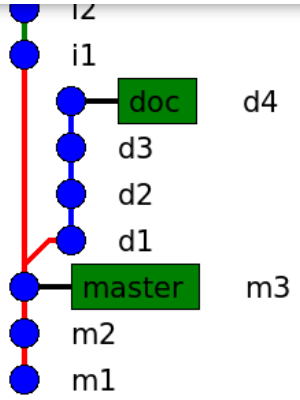

[http://3.bp.blogspot.com/-YChDkmURPRM/U4m2JmQ4vpI/AAAAAAAABms/VDbNXs99-Ww/s1600/gitk5.png]

We have three branches, "master","doc" and "info". We can list the directory tree of branch tip via "git ls-tree":

```
[luke@rmbp project]$ git ls-tree doc
100644 blob 6f1852975b9306ae5d8dfdf0d4cb1f5cb36ac229 d1.txt
100644 blob fd3671590780b645e1bef030d550191f6cdf1c95 d2.txt
100644 blob 69c77a9ea746edd27b46107142fc2c5288c1daf5 d3.txt
100644 blob 3c69f010b48e8e008a43bf7f6c495b325d8af96e m1.txt
100644 blob 08bb2331e777f431177c40df6841c0034f89fb58 m2.txt
100644 blob e5c9ce9248c688a566f3d03be31d0097edb96443 m3.txt
[luke@rmbp project]$ git ls-tree info
100644 blob ca49db8a781513484f01251ca2ae2bb92d46aafe i1.txt
100644 blob 928f40b2d212da87857cfe0ffb2c90ea5c1b4f7b i2.txt
100644 blob 04ad29f02f6bc9aff95c6d07aedee83a808865f9 i3.txt
100644 blob 835ceee2b2bb6d6167c59441d01b62cd849b7e1e m1.txt
100644 blob 08bb2331e777f431177c40df6841c0034f89fb58 m2-rename.txt
100644 blob e5c9ce9248c688a566f3d03be31d0097edb96443 m3.txt
```

The output of "git ls-tree" is actually a text representation of a directory tree. To diff these two directory, we can diff these two text representation. But Git provides more sensible diff algorithm to show directory diff.

a. sort directory tree according to path names; the diff is based on path names first;

b. For every path name, do:

. if it exists in both directory, then

. if the whole dir entry (mode, content hash, type" is identical to the one on another directory, then we say we have same entry;

. if the whole dir entry is not identical, then we have "modified" entry (marked as "M");

. If it exists only in one directory tree, then we have "added" or "deleted" entry, marked as "A" or "D".

```
[luke@rmbp project]$ git diff-tree doc info
```

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```
:000000              100644              0000000000000000000000000000000000000000
ca49db8a781513484f01251ca2ae2bb92d46aafe A i1.txt
:000000              100644              0000000000000000000000000000000000000000
928f40b2d212da87857cfe0ffb2c90ea5c1b4f7b A i2.txt
:000000              100644              0000000000000000000000000000000000000000
04ad29f02f6bc9aff95c6d07aedee83a808865f9 A i3.txt
:100644              100644              3c69f010b48e8e008a43bf7f6c495b325d8af96e
835ceee2b2bb6d6167c59441d01b62cd849b7e1e M m1.txt
:000000              100644              0000000000000000000000000000000000000000
08bb2331e777f431177c40df6841c0034f89fb58 A m2-rename.txt
:100644              000000              08bb2331e777f431177c40df6841c0034f89fb58
0000000000000000000000000000000000000000 D m2.txt
```

From the diff output, we can see:
a. "m2.txt" and "m3.txt" are identical entries;
b. "m1.txt" is "modified/M"
c. "d1.txt/d2.txt/d3.txt" does not exist in "info" branch, so they are marked as "deleted/D".
d. "i1.txt/i2.txt/i3.txt" does not exist in "doc" branch, so they are marked as "Added/A".
e. we rename "m2.txt" to "m2-rename.txt". In diff output, it is displayed as a "delete" and an "add".

Such a diff output format is called "raw format" in Git. We can also use "git diff -raw " to produce such output:
[luke@rmbp project]$ git diff --raw doc info

```
:100644 000000 6f18529... 0000000... D  d1.txt
:100644 000000 fd36715... 0000000... D  d2.txt
:100644 000000 69c77a9... 0000000... D  d3.txt
:000000 100644 0000000... ca49db8... A  i1.txt
:000000 100644 0000000... 928f40b... A  i2.txt
:000000 100644 0000000... 04ad29f... A  i3.txt
:100644 100644 3c69f01... 835ceee... M  m1.txt
:000000 100644 0000000... 08bb233... A  m2-rename.txt
:100644 000000 08bb233... 0000000... D  m2.txt
```

2. file diff
After we have identified the different entries between directory trees, we can use "git diff" to find out the difference among files. The default diff output format for "git diff" is very similar to gnu diff "unified format". For example:

```
[luke@rmbp project]$ git diff doc:m1.txt info:m1.txt
diff --git a/doc:m1.txt b/info:m1.txt
index 3c69f01..835ceee 100644
--- a/doc:m1.txt
+++ b/info:m1.txt
@@ -1 +1 @@
```

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```
[luke@rmbp project]$ git diff doc info
diff --git a/d1.txt b/d1.txt
deleted file mode 100644
index 6f18529..0000000
--- a/d1.txt
+++ /dev/null
@@ -1 +0,0 @@
-d1
diff --git a/d2.txt b/d2.txt
deleted file mode 100644
index fd36715..0000000
--- a/d2.txt
+++ /dev/null
@@ -1 +0,0 @@
-d2
.......
```

3. Typical trees diff usage

In Git, the most used directory snapshot trees are :
a. working directory
This is where we are working on
b. the git index
this the tree we are going to commit
c. most recent commit
this is the snapshot we base our current work on.

Since the difference between these three snapshot tree are so common, "git diff" provide specific options to select two of them to compare:
. git diff
index<---->working directory
.git diff --cached
most recent commit<--->index
.git diff HEAD
most recent commit<--->working directory

The untracked files in working directory are not used for diff. You need to "git add" them first so they will be display in "git diff" results. "git status" is a high level command which outputs difference among above three snapshot trees.

the most general format to select two tree is :

```
git diff tree-ish1 tree-ish2
```

Both tree-ish could be a reference (head or tag), a commit SHA1, a tree SHA1.

```
[luke@rmbp project1]$ git log --pretty=oneline
```

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```
[luke@rmbp project1]$ git diff d2f5de55ee3aa1dc90aec01a4e450f61285fece0
100e22641983cc82656b1202588d8a3dc9a22622
diff --git a/hello.txt b/hello.txt
index 3b18e51..fc9dda4 100644
--- a/hello.txt
+++ b/hello.txt
@@ -1 +1,2 @@
 hello world
+anohter
diff --git a/me b/me
new file mode 100644
index 0000000..78925fb
--- /dev/null
+++ b/me
@@ -0,0 +1 @@
+me
[luke@rmbp project1]$ git diff master^ master
diff --git a/hello.txt b/hello.txt
index 3b18e51..fc9dda4 100644
--- a/hello.txt
+++ b/hello.txt
@@ -1 +1,2 @@
 hello world
+anohter
diff --git a/me b/me
new file mode 100644
index 0000000..78925fb
--- /dev/null
+++ b/me
@@ -0,0 +1 @@
+me
[luke@rmbp project1]$ git cat-file -p master
tree c668aae69ca999df6648ea196c3f5af226e2262d
parent d2f5de55ee3aa1dc90aec01a4e450f61285fece0
author Luke Luo <luke.jf.luo@gmail.com> 1400592712 +0800
committer Luke Luo <luke.jf.luo@gmail.com> 1400592712 +0800

second commit
[luke@rmbp project1]$ git cat-file -p master^
tree 68aba62e560c0ebc3396e8ae9335232cd93a3f60
author Luke Luo <luke.jf.luo@gmail.com> 1400570856 +0800
committer Luke Luo <luke.jf.luo@gmail.com> 1400570856 +0800

initial commit
[luke@rmbp project1]$ git diff 68aba62e560c0ebc3396e8ae9335232cd93a3f60
c668aae69ca999df6648ea196c3f5af226e2262d
diff --git a/hello.txt b/hello.txt
```

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```
diff --git a/me b/me
new file mode 100644
index 0000000..78925fb
--- /dev/null
+++ b/me
@@ -0,0 +1 @@
+me
```

We can diff only two blobs instead of two tree. For example:
git diff blob1 blob2
or:

```
[luke@rmbp project1]$ git diff master^ master -- hello.txt
diff --git a/hello.txt b/hello.txt
index 3b18e51..fc9dda4 100644
--- a/hello.txt
+++ b/hello.txt
@@ -1 +1,2 @@
 hello world
+anohter
```

4. git merge

Git employs the classical 3-way merge algorithms. You can get some feeling of 3 way merge via unix command "diff3". A classical paper help me to gain a solid understanding on 3 way merge:

A **Formal** Investigation of **Diff3** [http://www.cis.upenn.edu/~bcpierce/…

A 3 way merge involves 3 nodes, "Base","Local (ours)", "Remote(Theirs)". In Git, the most typical merge scenario is the merge of two branch tip, with the base of nearest common ancestor of both branch tips. For example:

```
[luke@rmbp project]$ git branch
* doc
  info
  master
[luke@rmbp project]$ git log --graph --all --decorate --oneline
* 678ecb9 (info) i5
* cda4be2 i4
* 1be45a3 i3
* 291b851 i2
* cdc35be i1
| * 0b765c2 (HEAD, doc) d4
| * c09b225 d3
| * 5eb037a d2
| * 8f5300c d1
|/
* 34c21d1 (master) m3
```

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```
committer Luke Luo <luke.jf.luo@gmail.com> 1401532415 +0800



m3


[luke@rmbp project]$ git merge info
Auto-merging m1.txt
CONFLICT (content): Merge conflict in m1.txt
Automatic merge failed; fix conflicts and then commit the result.
```

Here, we are in branch "doc", so the doc tip is the "Local" node; We merge branch "info" into branch "doc", so the "Remote" node is the "info" tip. The base node "m3" could be found via "git merge_base". Since we have conflict, let us look at the index:

```
[luke@rmbp project]$ git ls-files -s
100644 6f1852975b9306ae5d8dfdf0d4cb1f5cb36ac229 0 d1.txt
100644 fd3671590780b645e1bef030d550191f6cdf1c95 0 d2.txt
100644 69c77a9ea746edd27b46107142fc2c5288c1daf5 0 d3.txt
100644 ca49db8a781513484f01251ca2ae2bb92d46aafe 0 i1.txt
100644 928f40b2d212da87857cfe0ffb2c90ea5c1b4f7b 0 i2.txt
100644 04ad29f02f6bc9aff95c6d07aedee83a808865f9 0 i3.txt
100644 63a911f26fe84ea7fd8a863a636cfac908895ec9 1 m1.txt
100644 3c69f010b48e8e008a43bf7f6c495b325d8af96e 2 m1.txt
100644 835ceee2b2bb6d6167c59441d01b62cd849b7e1e 3 m1.txt
100644 08bb2331e777f431177c40df6841c0034f89fb58 0 m2-rename.txt
100644 e5c9ce9248c688a566f3d03be31d0097edb96443 0 m3.txt
[luke@rmbp project]$ git cat-file -p 63a911f26fe84ea7fd8a863a636cfac908895ec9
m1
[luke@rmbp project]$ git cat-file -p 3c69f010b48e8e008a43bf7f6c495b325d8af96e
m1 doc
[luke@rmbp project]$ git cat-file -p 835ceee2b2bb6d6167c59441d01b62cd849b7e1e
m1 info


[luke@rmbp project]$ cat m1.txt


<<<<<<< HEAD


m1 doc


=======


m1 info
>>>>>>> info
```

So "1/2/3" version of "m1.txt" in index corresponds to versions in "Base/Local/Remote" nodes. and "m1.txt" in work tree is the merged version. After we merge "m1.txt" manually, we commit the change:

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```
*   79f4756 (HEAD, doc) merged of doc and info
|\
| * 678ecb9 (info) i5
| * cda4be2 i4
| * 1be45a3 i3
| * 291b851 i2
| * cdc35be i1
* | 0b765c2 d4
* | c09b225 d3
* | 5eb037a d2
* | 8f5300c d1
|/
* 34c21d1 (master) m3
* 323bccf m2
* af3f4db m1
```

5. subtree merge

git merge provide a merge strategy called "subtree". You can do it via "git merge -s subtree" or "git merge -s recursive -X subtree=[xxx]". Since the second form is more flexible, I will stick to the second form in this section. Suppose we have two branch "master" and "test":

```
[luke@rmbp subtree]$ git checkout master
Switched to branch 'master'
[luke@rmbp subtree]$ tree
.
├── common
│   └── cm.txt
├── master1
│   └── m1.txt
├── master2
│   └── m2.txt
└── master.txt

3 directories, 4 files
[luke@rmbp subtree]$ git checkout test
Switched to branch 'test'
[luke@rmbp subtree]$ tree
.
├── common
│   └── ct.txt
├── test1
│   └── t1.txt
├── test2
│   └── t2.txt
└── test.txt

3 directories, 4 files
```

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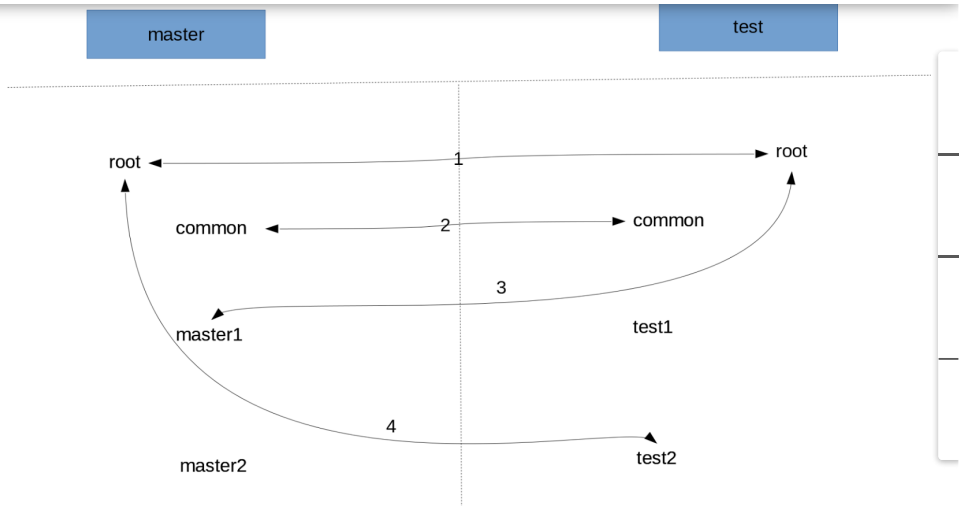

[http://1.bp.blogspot.com/--WX60Bd4Y5k/U6LqXaTA_kI/AAAAAAAABr4/2NNMcGn7TTU/s1600/gitk18.png]

We can specify "subtree=[a sub dir]". If this sub dir only exist in one branch, then the merge will happen between this sub dir in this branch and the root dir of another branch. If this sub-dir exists in both branches, then only these two sub dirs' contents will be merged between this two branches. Other directories in original branch are deleted as if we use "-s theirs"; other directories in other branch will be accepted as if "-s theirs";

Here are some example outputs:

```
[luke@rmbp subtree]$ git branch
  master
* test
[luke@rmbp subtree]$ git merge -s recursive -X subtree=common --no-commit --squash master
Removing test2/t2.txt
Removing test1/t1.txt
Removing test.txt
Squash commit -- not updating HEAD
Automatic merge went well; stopped before committing as requested
[luke@rmbp subtree]$ tree
.
├── common
│   ├── cm.txt
│   └── ct.txt
├── master1
│   └── m1.txt
├── master2
│   └── m2.txt
└── master.txt

[luke@rmbp subtree]$ git status -s
```

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```
D  test2/t2.txt
```

In this example, we merge master branch into test branch. Since "common" exists in both root tree, in this merge, only two "common" sub dirs are merged . Other dirs in test are deleted, and other dirs in masters are added into test.

```
[luke@rmbp subtree]$ git merge -s recursive -X subtree=master1  --no-commit --
squash master


Squash commit -- not updating HEAD
Automatic merge went well; stopped before committing as requested
[luke@rmbp subtree]$ tree
.
├── common
│   └── ct.txt
├── m1.txt
├── test1
│   └── t1.txt
├── test2
│   └── t2.txt
└── test.txt

3 directories, 5 files
[luke@rmbp subtree]$ git status -s
A  m1.txt
```

In this example, the "master1" dir in mater branch is merged into root dir of test branch.

6. gitdiffcore

"man gitdiffcore" will provide some in-depth details on how git do diff, especially on how "copy/rename" are detected, and how "pickaxe" is implemented. Take a look at it if you love deep hacking on git.

Posted 31st May 2014 by Luke Luo

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