Git Community Book

The open Git resource pulled together by the whole community

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Chapter 1

Introduction

WELCOME TO GIT

Welcome to Git - the fast, distributed version control system.

This book is meant to be a starting point for people new to Git to learn it as quickly and easily as possible.

This book will start out by introducing you to the way Git stores data, to give you the context for why it is different than other VCS tools. This is meant to take you about 20 minutes.

Next we will cover **Basic Git Usage** - the commands you will be using 90% of the time. These should give you a good basis to use Git comfortably for most of what you're going to use it for. This section should take you about 30 minutes to read through.

Next we will go over **Intermediate Git Usage** - things that are slightly more complex, but may replace some of the basic commands you learned in the first section. This will mostly be tricks and commands that will feel more comfortable after you know the basic commands.

After you have all of that mastered, we will cover **Advanced Git** - commands that most people probably don't use very often, but can be very helpful in certain situations. Learning these commands should round out your day-to-day git knowledge; you will be a master of the Git!

Now that you know Git, we will then cover **Working with Git**. Here we will go over how to use Git in scripts, with deployment tools, with editors and more. These sections are meant to help you integrate Git into your environment.

Lastly, we will have a series of articles on **low-level documentation** that may help the Git hackers who want to learn how the actual internals and protocols work in Git.

Feedback and Contributing

At any point, if you see a mistake or want to contribute to the book, you can send me an email at schacon@gmail.com, or you can clone the source of this book at http://github.com/schacon/gitscm and send me a patch or a pull-request.

References

Much of this book is pulled together from different sources and then added to.
If you would like to read some of the original articles or resources, please visit them and thank the authors:

- Git User Manual
- The Git Tutorial
- The Git Tutorial pt 2

- "My Git Workflow" blog post

THE GIT OBJECT MODEL

The SHA

All the information needed to represent the history of a project is stored in files referenced by a 40-digit "object name" that looks something like this:

```
6ff87c4664981e4397625791c8ea3bbb5f2279a3
```

You will see these 40-character strings all over the place in Git. In each case the name is calculated by taking the SHA1 hash of the contents of the object. The SHA1 hash is a cryptographic hash function. What that means to us is that it is virtually impossible to find two different objects with the same name. This has a number of advantages; among others:

- Git can quickly determine whether two objects are identical or not, just by comparing names.
- Since object names are computed the same way in every repository, the same content stored in two repositories will always be stored under the same name.
- Git can detect errors when it reads an object, by checking that the object's name is still the SHA1 hash of its contents.

The Objects

Every object consists of three things - a **type**, a **size** and **content**. The *size* is simply the size of the contents, the contents depend on what type of object it is, and there are four different types of objects: "blob", "tree", "commit", and "tag".

- A **"blob"** is used to store file data - it is generally a file.
- A **"tree"** is basically like a directory - it references a bunch of other trees and/or blobs (i.e. files and sub-directories)
- A **"commit"** points to a single tree, marking it as what the project looked like at a certain point in time. It contains meta-information about that point in time, such as a timestamp, the author of the changes since the last commit, a pointer to the previous commit(s), etc.
- A **"tag"** is a way to mark a specific commit as special in some way. It is normally used to tag certain commits as specific releases or something along those lines.

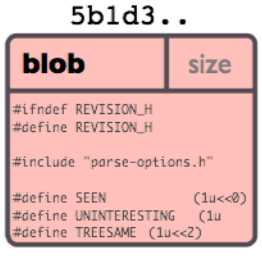
Almost all of Git is built around manipulating this simple structure of four different object types. It is sort of its own little filesystem that sits on top of your machine's filesystem.

Different from SVN

It is important to note that this is very different from most SCM systems that you may be familiar with. Subversion, CVS, Perforce, Mercurial and the like all use *Delta Storage* systems - they store the differences between one commit and the next. Git does not do this - it stores a snapshot of what all the files in your project look like in this tree structure each time you commit. This is a very important concept to understand when using Git.

Blob Object

A blob generally stores the contents of a file.



You can use git show to examine the contents of any blob. Assuming we have the SHA for a blob, we can examine its contents like this:

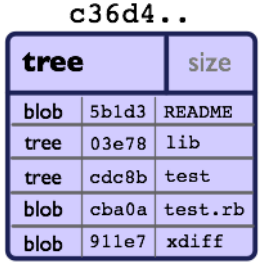
```
$ git show 6ff87c4664

 Note that the only valid version of the GPL as far as this project
 is concerned is _this_ particular version of the license (ie v2, not
 v2.2 or v3.x or whatever), unless explicitly otherwise stated.
...
```

A "blob" object is nothing but a chunk of binary data. It doesn't refer to anything else or have attributes of any kind, not even a file name.

Since the blob is entirely defined by its data, if two files in a directory tree (or in multiple different versions of the repository) have the same contents, they will share the same blob object. The object is totally independent of its location in the directory tree, and renaming a file does not change the object that file is associated with.

Tree Object

A tree is a simple object that has a bunch of pointers to blobs and other trees - it generally represents the contents of a directory or subdirectory.



The ever-versatile git show command can also be used to examine tree objects, but git ls-tree will give you more details. Assuming we have the SHA for a tree, we can examine it like this:

```
$ git ls-tree fb3a8bdd0ce
100644 blob 63c918c667fa005ff12ad89437f2fdc80926e21c    .gitignore
100644 blob 5529b198e8d14decbe4ad99db3f7fb632de0439d    .mailmap
100644 blob 6ff87c4664981e4397625791c8ea3bbb5f2279a3    COPYING
040000 tree 2fb783e477100ce076f6bf57e4a6f026013dc745    Documentation
100755 blob 3c0032cec592a765692234f1cba47dfdcc3a9200    GIT-VERSION-GEN
100644 blob 289b046a443c0647624607d471289b2c7dcd470b    INSTALL
100644 blob 4eb463797adc693dc168b926b6932ff53f17d0b1    Makefile
100644 blob 548142c327a6790ff8821d67c2ee1eff7a656b52    README
...
```

As you can see, a tree object contains a list of entries, each with a mode, object type, SHA1 name, and name, sorted by name. It represents the contents of a single directory tree.

An object referenced by a tree may be blob, representing the contents of a file, or another tree, representing the contents of a subdirectory. Since trees and blobs, like all other objects, are named by the SHA1 hash of their contents, two trees have the same SHA1 name if and only if their contents (including, recursively, the contents of all subdirectories) are identical. This allows git to quickly determine the differences between two related tree objects, since it can ignore any entries with identical object names.

(Note: in the presence of submodules, trees may also have commits as entries. See the **Submodules** section.)

Note that the files all have mode 644 or 755: git actually only pays attention to the executable bit.

Commit Object

The "commit" object links a physical state of a tree with a description of how we got there and why.

You can use the --pretty=raw option to git show or git log to examine your favorite commit:

```
$ git show -s --pretty=raw 2be7fcb476
commit 2be7fcb4764f2dbcee52635b91fedb1b3dcf7ab4
```

```
tree fb3a8bdd0ceddd019615af4d57a53f43d8cee2bf
parent 257a84d9d02e90447b149af58b271c19405edb6a
author Dave Watson <dwatson@mimvista.com> 1187576872 -0400
committer Junio C Hamano <gitster@pobox.com> 1187591163 -0700

    Fix misspelling of 'suppress' in docs

    Signed-off-by: Junio C Hamano <gitster@pobox.com>
```

As you can see, a commit is defined by:

- a **tree**: The SHA1 name of a tree object (as defined below), representing the contents of a directory at a certain point in time.
- **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).
- an **author**: The name of the person responsible for this change, together with its date.
- a **committer**: The name of the person who actually created the commit, with the date it was done. This may be different from the author; for example, if the author wrote a patch and emailed it to another person who used the patch to create the commit.
- a **comment** describing this commit.

Note that a commit does not itself contain any information about what actually changed; all changes are calculated by comparing the contents of the tree referred to by this commit with the trees associated with its parents. In particular, git does not attempt to record file renames explicitly, though it can identify cases where the existence of the same file data at changing paths suggests a rename. (See, for example, the -M option to git diff).

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.

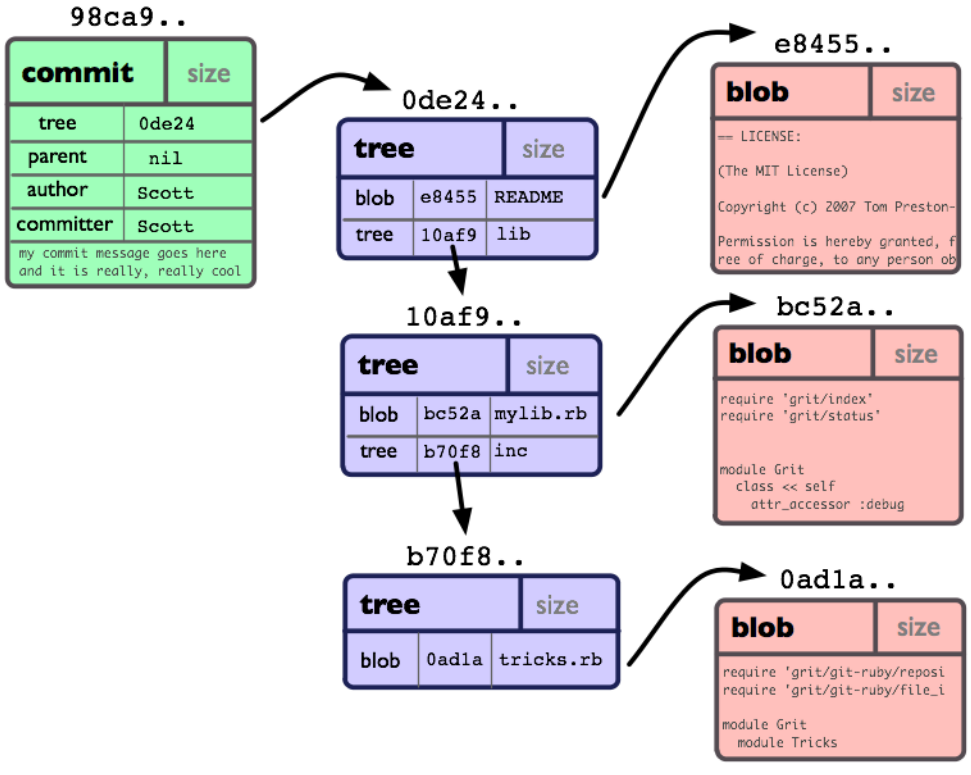
The Object Model

So, now that we've looked at the 3 main object types (blob, tree and commit), let's take a quick look at how they all fit together.

If we had a simple project with the following directory structure:

```
$>tree
.
|-- README
`-- lib
    |-- inc
    |   `-- tricks.rb
    `-- mylib.rb

2 directories, 3 files
```

And we committed this to a Git repository, it would be represented like this:



You can see that we have created a **tree** object for each directory (including the root) and a **blob** object for each file. Then we have a **commit** object to point to the root, so we can track what our project looked like when it was committed.

Tag Object

A tag object contains an object name (called simply 'object'), object type, tag name, the name of the person ("tagger") who created the tag, and a message, which may contain a signature, as can be seen using git cat-file:

```
$ git cat-file tag v1.5.0
object 437b1b20df4b356c9342dac8d38849f24ef44f27
type commit
tag v1.5.0
tagger Junio C Hamano <junkio@cox.net> 1171411200 +0000

GIT 1.5.0
-----BEGIN PGP SIGNATURE-----
Version: GnuPG v1.4.6 (GNU/Linux)

iD8DBQBF0lGqwMbZpPMRm5oRAuRiAJ9ohBLd7s2kqjkKlq1qqC57SbnmzQCdG4ui
nLE/L9aUXdWeTFPron96DLA=
=2E+0
-----END PGP SIGNATURE-----
```

See the git tag command to learn how to create and verify tag objects. (Note that git tag can also be used to create "lightweight tags", which are not tag objects at all, but just simple references whose names begin with "refs/tags/").

GIT DIRECTORY AND WORKING DIRECTORY

The Git Directory

The 'git directory' is the directory that stores all Git's history and meta information for your project - including all of the objects (commits, trees, blobs, tags), all of the pointers to where different branches are and more.

There is only one Git Directory per project (as opposed to one per subdirectory like with SVN or CVS), and that directory is (by default, though not necessarily) '.git' in the root of your project. If you look at the contents of that directory, you can see all of your important files:

```
$>tree -L 1
.
|-- HEAD         # pointer to your current branch
|-- config       # your configuration preferences
|-- description  # description of your project
|-- hooks/       # pre/post action hooks
|-- index        # index file (see next section)
|-- logs/        # a history of where your branches have been
|-- objects/     # your objects (commits, trees, blobs, tags)
`-- refs/        # pointers to your branches
```

(there may be some other files/directories in there as well, but they are not important for now)

The Working Directory

The Git 'working directory' is the directory that holds the current checkout of the files you are working on. Files in this directory are often removed or replaced by Git as you switch branches - this is normal. All your history is stored in the Git Directory; the working directory is simply a temporary checkout place where you can modify the files until your next commit.

THE GIT INDEX

The Git index is used as a 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.

Looking at the Index

The easiest way to see what is in the index is with the git status command. When you run git status, you can see which files are staged (currently in your index), which are modified but not yet staged, and which are completely untracked.

```
$>git status
# On branch master
# Your branch is behind 'origin/master' by 11 commits, and can be fast-forwarded.
#
# Changes to be committed:
#   (use "git reset HEAD <file>..." to unstage)
#
#   modified:   daemon.c
#
# Changed but not updated:
```

```
#   (use "git add <file>..." to update what will be committed)
#
#   modified:   grep.c
#   modified:   grep.h
#
# Untracked files:
#   (use "git add <file>..." to include in what will be committed)
#
#   blametree
#   blametree-init
#   git-gui/git-citool
```

If you blow the index away entirely, you generally haven't lost any information as long as you have the name of the tree that it described.

And with that, you should have a pretty good understanding of the basics of what Git is doing behind the scenes, and why it is a bit different than most other SCM systems. Don't worry if you don't totally understand it all right now; we'll revisit all of these topics in the next sections. Now we're ready to move on to installing, configuring and using Git.

Chapter 2

First Time

INSTALLING GIT

Installing from Source

In short, on a Unix-based system, you can download the Git source code from the Git Download Page, and then run something along the lines of :

```
$ make prefix=/usr all ;# as yourself
$ make prefix=/usr install ;# as root
```

You will need the expat, curl, zlib, and openssl libraries installed - though with the possible exception of *expat*, these will normally already be there.

Linux

If you are running Linux, you can likely install Git easily via your native package management system:

```
$ yum install git-core
```

```
$ apt-get install git-core
```

If that doesn't work, you can download the .deb or .rpm packages from here:

RPM Packages

Stable Debs

If you prefer to install from source on a Linux system, this article may be helpful:

Article: Installing Git on Ubuntu

Mac 10.4

In both Mac 10.4 and 10.5, you can install Git via MacPorts, if you have that installed. If not, you can install it from here.

Once MacPorts is installed, all you should have to do is:

```
$ sudo port install git-core
```

If you prefer to install from source, these articles may be helpful:

Article: Installing Git on Tiger

Article: Installing Git and git-svn on Tiger from source

Mac 10.5

With Leopard, you can also install via MacPorts, but here you have the additional option of using a nice installer, which you can download from here: Git OSX Installer

If you prefer to install it from source, these guides may be particularly helpful to you :

Article: Installing Git on OSX Leopard

Article: Installing Git on OS 10.5

Windows

On Windows, installing Git is pretty easy. Simply download and install the msysGit package.

See the *Git on Windows* chapter for a screencast demonstrating installing and using Git on Windows.

SETUP AND INITIALIZATION

Git Config

The first thing you're going to want to do is set up your name and email address for Git to use to sign your commits.

```
$ git config --global user.name "Scott Chacon"
$ git config --global user.email "schacon@gmail.com"
```

That will set up a file in your home directory which may be used by any of your projects. By default that file is *~/.gitconfig* and the contents will look like this:

```
[user]
        name = Scott Chacon
        email = schacon@gmail.com
```

If you want to override those values for a specific project (to use a work email address, for example), you can run the *git config* command without the *–global* option while in that project. This will add a [user] section like the one shown above to the *.git/config* file in your project's root directory.

Chapter 3

Basic Usage

GETTING A GIT REPOSITORY

So now that we're all set up, we need a Git repository. We can do this one of two ways - we can *clone* one that already exists, or we can *initialize* one either from existing files that aren't in source control yet, or from an empty directory.

Cloning a Repository

In order to get a copy of a project, you will need to know the project's Git URL - the location of the repository. Git can operate over many different protocols, so it may begin with ssh://, http(s)://, git://, or just a username (in which case git will assume ssh). Some repositories may be accessed over more than one protocol. For example, the source code to Git itself can be cloned either over the git:// protocol:

```
git clone git://git.kernel.org/pub/scm/git/git.git
```

or over http:

```
git clone http://www.kernel.org/pub/scm/git/git.git
```

The git:// protocol is faster and more efficient, but sometimes it is necessary to use http when behind corporate firewalls or what have you. In either case you should then have a new directory named 'git' that contains all the Git source code and history - it is basically a complete copy of what was on the server.

By default, Git will name the new directory it has checked out your cloned code into after whatever comes directly before the '.git' in the path of the cloned project. (ie. *git clone http://git.kernel.org/linux/kernel/git/torvalds/linux-2.6.git* will result in a new directory named 'linux-2.6')

Initializing a New Repository

Assume you have a tarball named project.tar.gz with your initial work. You can place it under git revision control as follows.

```
$ tar xzf project.tar.gz
$ cd project
$ git init
```

Git will reply

```
Initialized empty Git repository in .git/
```

You've now initialized the working directory--you may notice a new directory created, named ".git".

NORMAL WORKFLOW

Modify some files, then add their updated contents to the index:

```
$ git add file1 file2 file3
```

You are now ready to commit. You can see what is about to be committed using git diff with the --cached option:

```
$ git diff --cached
```

(Without --cached, git diff will show you any changes that you've made but not yet added to the index.) You can also get a brief summary of the situation with git status:

```
$ git status
# On branch master
# Changes to be committed:
#   (use "git reset HEAD <file>..." to unstage)
#
#   modified:   file1
#   modified:   file2
#   modified:   file3
#
```

If you need to make any further adjustments, do so now, and then add any newly modified content to the index. Finally, commit your changes with:

```
$ git commit
```

This will again prompt you for a message describing the change, and then record a new version of the project.

Alternatively, instead of running `git add` beforehand, you can use

```
$ git commit -a
```

which will automatically notice any modified (but not new) files, add them to the index, and commit, all in one step.

A note on commit messages: Though not required, it's a good idea to begin the commit message with a single short (less than 50 character) line summarizing the change, followed by a blank line and then a more thorough description. Tools that turn commits into email, for example, use the first line on the Subject: line and the rest of the commit message in the body.

Git tracks content not files

Many revision control systems provide an "add" command that tells the system to start tracking changes to a new file. Git's "add" command does something simpler and more powerful: `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.

BASIC BRANCHING AND MERGING

A single git repository can maintain multiple branches of development. To create a new branch named "experimental", use

```
$ git branch experimental
```

If you now run

```
$ git branch
```

you'll get a list of all existing branches:

```
  experimental
* master
```

The "experimental" branch is the one you just created, and the "master" branch is a default branch that was created for you automatically. The asterisk marks the branch you are currently on; type

```
$ git checkout experimental
```

to switch to the experimental branch. Now edit a file, commit the change, and switch back to the master branch:

```
(edit file)
$ git commit -a
$ git checkout master
```

Check that the change you made is no longer visible, since it was made on the experimental branch and you're back on the master branch.

You can make a different change on the master branch:

```
(edit file)
$ git commit -a
```

at this point the two branches have diverged, with different changes made in each. To merge the changes made in experimental into master, run

```
$ git merge experimental
```

If the changes don't conflict, you're done. If there are conflicts, markers will be left in the problematic files showing the conflict;

```
$ git diff
```

will show this. Once you've edited the files to resolve the conflicts,

```
$ git commit -a
```

will commit the result of the merge. Finally,

```
$ gitk
```

will show a nice graphical representation of the resulting history.

At this point you could delete the experimental branch with

```
$ git branch -d experimental
```

This command ensures that the changes in the experimental branch are already in the current branch.

If you develop on a branch crazy-idea, then regret it, you can always delete the branch with

```
$ git branch -D crazy-idea
```

Branches are cheap and easy, so this is a good way to try something out.

How to merge

You can rejoin two diverging branches of development using git merge:

```
$ git merge branchname
```

merges the changes made in the branch "branchname" into the current branch. If there are conflicts--for example, if the same file is modified in two different ways in the remote branch and the local branch--then you are warned; the output may look something like this:

```
$ git merge next
 100% (4/4) done
Auto-merged file.txt
CONFLICT (content): Merge conflict in file.txt
Automatic merge failed; fix conflicts and then commit the result.
```

Conflict markers are left in the problematic files, and after you resolve the conflicts manually, you can update the index with the contents and run git commit, as you normally would when modifying a file.

If you examine the resulting commit using gitk, you will see that it has two parents: one pointing to the top of the current branch, and one to the top of the other branch.

Resolving a merge

When a merge isn't resolved automatically, git leaves the index and the working tree in a special state that gives you all the information you need to help resolve the merge.

Files with conflicts are marked specially in the index, so until you resolve the problem and update the index, git commit will fail:

```
$ git commit
file.txt: needs merge
```

Also, git status will list those files as "unmerged", and the files with conflicts will have conflict markers added, like this:

```
<<<<<<< HEAD:file.txt
Hello world
=======
Goodbye
>>>>>>> 77976da35a11db4580b80ae27e8d65caf5208086:file.txt
```

All you need to do is edit the files to resolve the conflicts, and then

```
$ git add file.txt
$ git commit
```

Note that the commit message will already be filled in for you with some information about the merge. Normally you can just use this default message unchanged, but you may add additional commentary of your own if desired.

The above is all you need to know to resolve a simple merge. But git also provides more information to help resolve conflicts:

Undoing a merge

If you get stuck and decide to just give up and throw the whole mess away, you can always return to the pre-merge state with

```
$ git reset --hard HEAD
```

Or, if you've already committed the merge that you want to throw away,

```
$ git reset --hard ORIG_HEAD
```

However, this last command can be dangerous in some cases--never throw away a commit if that commit may itself have been merged into another branch, as doing so may confuse further merges.

Fast-forward merges

There is one special case not mentioned above, which is treated differently. Normally, a merge results in a merge commit with two parents, one for each of the two lines of development that were merged.

However, if the current branch has not diverged from the other--so every commit present in the current branch is already contained in the other--then git just performs a "fast forward"; the head of the current branch is moved forward to point at the head of the merged-in branch, without any new commits being created.

REVIEWING HISTORY - GIT LOG

The git log command can show lists of commits. On its own, it shows all commits reachable from the parent commit; but you can also make more specific requests:

```
$ git log v2.5..        # commits since (not reachable from) v2.5
$ git log test..master  # commits reachable from master but not test
$ git log master..test  # commits reachable from test but not master
$ git log master...test # commits reachable from either test or
                        #    master, but not both
$ git log --since="2 weeks ago" # commits from the last 2 weeks
$ git log Makefile      # commits that modify Makefile
$ git log fs/           # commits that modify any file under fs/
$ git log -S'foo()'     # commits that add or remove any file data
                        # matching the string 'foo()'
$ git log --no-merges   # dont show merge commits
```

And of course you can combine all of these; the following finds commits since v2.5 which touch the Makefile or any file under fs:

```
$ git log v2.5.. Makefile fs/
```

Git log will show a listing of each commit, with the most recent commits first, that match the arguments given to the log command.

```
commit f491239170cb1463c7c3cd970862d6de636ba787
Author: Matt McCutchen <matt@mattmccutchen.net>
Date:   Thu Aug 14 13:37:41 2008 -0400

    git format-patch documentation: clarify what --cover-letter does

commit 7950659dc9ef7f2b50b18010622299c508bfdfc3
Author: Eric Raible <raible@gmail.com>
Date:   Thu Aug 14 10:12:54 2008 -0700

    bash completion: 'git apply' should use 'fix' not 'strip'
    Bring completion up to date with the man page.
```

You can also ask git log to show patches:

```
$ git log -p

commit da9973c6f9600d90e64aac647f3ed22dfd692f70
Author: Robert Schiele <rschiele@gmail.com>
Date:   Mon Aug 18 16:17:04 2008 +0200

    adapt git-cvsserver manpage to dash-free syntax

diff --git a/Documentation/git-cvsserver.txt b/Documentation/git-cvsserver.txt
index c2d3c90..785779e 100644
--- a/Documentation/git-cvsserver.txt
+++ b/Documentation/git-cvsserver.txt
@@ -11,7 +11,7 @@ SYNOPSIS
```

```
 SSH:

 [verse]
-export CVS_SERVER=git-cvsserver
+export CVS_SERVER="git cvsserver"
 'cvs' -d :ext:user@server/path/repo.git co <HEAD_name>

 pserver (/etc/inetd.conf):
```

Log Stats

If you pass the `--stat` option to 'git log', it will show you which files have changed in that commit and how many lines were added and removed from each.

```
$ git log --stat

commit dba9194a49452b5f093b96872e19c91b50e526aa
Author: Junio C Hamano <gitster@pobox.com>
Date:   Sun Aug 17 15:44:11 2008 -0700

    Start 1.6.0.X maintenance series

 Documentation/RelNotes-1.6.0.1.txt |   15 +++++++++++++++
 RelNotes                           |    2 +-
 2 files changed, 16 insertions(+), 1 deletions(-)
```

Formatting the Log

You can also format the log output almost however you want. The '--pretty' option can take a number of preset formats, such as 'oneline':

```
$ git log --pretty=oneline
a6b444f570558a5f31ab508dc2a24dc34773825f dammit, this is the second time this has reverted
49d77f72783e4e9f12d1bbcacc45e7a15c800240 modified index to create refs/heads if it is not
9764edd90cf9a423c9698a2f1e814f16f0111238 Add diff-lcs dependency
e1ba1e3ca83d53a2f16b39c453fad33380f8d1cc Add dependency for Open4
0f87b4d9020fff756c18323106b3fd4e2f422135 merged recent changes: * accepts relative alt pat
f0ce7d5979dfb0f415799d086e14a8d2f9653300 updated the Manifest file
```

or you can do 'short' format:

```
$ git log --pretty=short
commit a6b444f570558a5f31ab508dc2a24dc34773825f
Author: Scott Chacon <schacon@gmail.com>

    dammit, this is the second time this has reverted

commit 49d77f72783e4e9f12d1bbcacc45e7a15c800240
Author: Scott Chacon <schacon@gmail.com>

    modified index to create refs/heads if it is not there

commit 9764edd90cf9a423c9698a2f1e814f16f0111238
Author: Hans Engel <engel@engel.uk.to>

    Add diff-lcs dependency
```

You can also use 'medium', 'full', 'fuller', 'email' or 'raw'. If those formats aren't exactly what you need, you can also create your own format with the '--pretty=format' option (see the git log docs for all the formatting options).

```
$ git log --pretty=format:'%h was %an, %ar, message: %s'
a6b444f was Scott Chacon, 5 days ago, message: dammit, this is the second time this has re
49d77f7 was Scott Chacon, 8 days ago, message: modified index to create refs/heads if it i
9764edd was Hans Engel, 11 days ago, message: Add diff-lcs dependency
```

```
e1ba1e3 was Hans Engel, 11 days ago, message: Add dependency for Open4
0f87b4d was Scott Chacon, 12 days ago, message: merged recent changes:
```

Another interesting thing you can do is visualize the commit graph with the '--graph' option, like so:

```
$ git log --pretty=format:'%h : %s' --graph
* 2d3acf9 : ignore errors from SIGCHLD on trap
*   5e3ee11 : Merge branch 'master' of git://github.com/dustin/grit
|\
| * 420eac9 : Added a method for getting the current branch.
* | 30e367c : timeout code and tests
* | 5a09431 : add timeout protection to grit
* | e1193f8 : support for heads with slashes in them
|/
* d6016bc : require time for xmlschema
```

It will give a pretty nice ASCII representation of the commit history lines.

Ordering the Log

You can also view the log entries in a few different orders. Note that git log starts with the most recent commit and works backwards through the parents; however, since git history can contain multiple independent lines of development, the particular order that commits are listed in may be somewhat arbitrary.

If you want to specify a certain order, you can add an ordering option to the git log command.

By default, the commits are shown in reverse chronological order.

However, you can also specify '--topo-order', which makes the commits appear in topological order (i.e. descendant commits are shown before their parents). If we view the git log for the Grit repo in topo-order, you can see that the development lines are all grouped together.

```
$ git log --pretty=format:'%h : %s' --topo-order --graph
*   4a904d7 : Merge branch 'idx2'
|\
| *   dfeffce : merged in bryces changes and fixed some testing issues
| |\
| | * 23f4ecf : Clarify how to get a full count out of Repo#commits
| | *   9d6d250 : Appropriate time-zone test fix from halorgium
| | |\
| | | * cec36f7 : Fix the to_hash test to run in US/Pacific time
| | * | decfe7b : fixed manifest and grit.rb to make correct gemspec
| | * | cd27d57 : added lib/grit/commit_stats.rb to the big list o' files
| | * | 823a9d9 : cleared out errors by adding in Grit::Git#run method
| | * |   4eb3bf0 : resolved merge conflicts, hopefully amicably
| | |\ \
| | | * | d065e76 : empty commit to push project to runcoderun
| | | * | 3fa3284 : whitespace
| | | * | d01cffd : whitespace
| | | * | 7c74272 : oops, update version here too
| | | * | 13f8cc3 : push 0.8.3
| | | * | 06bae5a : capture stderr and log it if debug is true when running commands
| | | * | 0b5bedf : update history
| | | * | d40e1f0 : some docs
| | | * | ef8a23c : update gemspec to include the newly added files to manifest
| | | * | 15dd347 : add missing files to manifest; add grit test
| | | * | 3dabb6a : allow sending debug messages to a user defined logger if provided; tes
| | | * | eac1c37 : pull out the date in this assertion and compare as xmlschemaw, to avoi
| | | * | 0a7d387 : Removed debug print.
| | | * | 4d6b69c : Fixed to close opened file description.
```

You can also use '--date-order', which orders the commits primarily by commit date. This option is similar to --topo-order in the sense that no parent comes before all of its children, but otherwise things are still ordered in the commit timestamp order. You can see that development lines are not grouped together here, that they jump around as parallel development occurred:

```
$ git log --pretty=format:'%h : %s' --date-order --graph
*   4a904d7 : Merge branch 'idx2'
|\
* | 81a3e0d : updated packfile code to recognize index v2
| *   dfeffce : merged in bryces changes and fixed some testing issues
| |\
| * | c615d80 : fixed a log issue
|/ /
| * 23f4ecf : Clarify how to get a full count out of Repo#commits
| *   9d6d250 : Appropriate time-zone test fix from halorgium
| |\
| * | decfe7b : fixed manifest and grit.rb to make correct gemspec
| * | cd27d57 : added lib/grit/commit_stats.rb to the big list o' file
| * | 823a9d9 : cleared out errors by adding in Grit::Git#run method
| * |   4eb3bf0 : resolved merge conflicts, hopefully amicably
| |\ \
| * | | ba23640 : Fix CommitDb errors in test (was this the right fix?
| * | | 4d8873e : test_commit no longer fails if you're not in PDT
| * | | b3285ad : Use the appropriate method to find a first occurrenc
| * | | 44dda6c : more cleanly accept separate options for initializin
| * | | 839ba9f : needed to be able to ask Repo.new to work with a bar
| | * | d065e76 : empty commit to push project to runcoderun
* | | | 791ec6b : updated grit gemspec
* | | | 756a947 : including code from github updates
| | * | 3fa3284 : whitespace
| | * | d01cffd : whitespace
| * | | a0e4a3d : updated grit gemspec
| * | | 7569d0d : including code from github updates
```

Lastly, you can reverse the order of the log with the '--reverse' option.

COMPARING COMMITS - GIT DIFF

You can generate diffs between any two versions of your project using git diff:

```
$ git diff master..test
```

That will produce the diff between the tips of the two branches. If you'd prefer to find the diff from their common ancestor to test, you can use three dots instead of two:

```
$ git diff master...test
```

git diff is an incredibly useful tool for figuring out what has changed between any two points in your project's history, or to see what people are trying to introduce in new branches, etc.

What you will commit

You will commonly use git diff for figuring out differences between your last commit, your index, and your current working directory. A common use is to simply run

```
$ git diff
```

which will show you changes in the working directory that are not yet staged for the next commit. If you want to see what *is* staged for the next commit, you can run

```
$ git diff --cached
```

which will show you the difference between the index and your last commit; what you would be committing if you run "git commit" without the "-a" option. Lastly, you can run

```
$ git diff HEAD
```

which shows changes in the working directory since your last commit; what you would be committing if you run "git commit -a".

More Diff Options

If you want to see how your current working directory differs from the state of the project in another branch, you can run something like

```
$ git diff test
```

This will show you what is different between your current working directory and the snapshot on the 'test' branch. You can also limit the comparison to a specific file or subdirectory by adding a *path limiter*:

```
$ git diff HEAD -- ./lib
```

That command will show the changes between your current working directory and the last commit (or, more accurately, the tip of the current branch), limiting the comparison to files in the 'lib' subdirectory.

If you don't want to see the whole patch, you can add the '--stat' option, which will limit the output to the files that have changed along with a little text graph depicting how many lines changed in each file.

```
$>git diff --stat
 layout/book_index_template.html                    |    8 ++-
 text/05_Installing_Git/0_Source.markdown           |   14 ++++++
```

```
 text/05_Installing_Git/1_Linux.markdown            |   17 +++++++
 text/05_Installing_Git/2_Mac_104.markdown          |   11 +++++
 text/05_Installing_Git/3_Mac_105.markdown          |    8 ++++
 text/05_Installing_Git/4_Windows.markdown          |    7 +++
 .../1_Getting_a_Git_Repo.markdown                  |    7 +++-
 .../0_ Comparing_Commits_Git_Diff.markdown         |   45 ++++++++++++++++++++
 .../0_ Hosting_Git_gitweb_repoorcz_github.markdown |    4 +-
 9 files changed, 115 insertions(+), 6 deletions(-)
```

Sometimes that makes it easier to see overall what has changed, to jog your memory.

DISTRIBUTED WORKFLOWS

Suppose that Alice has started a new project with a git repository in /home/alice/project, and that Bob, who has a home directory on the same machine, wants to contribute.

Bob begins with:

```
$ git clone /home/alice/project myrepo
```

This creates a new directory "myrepo" containing a clone of Alice's repository. The clone is on an equal footing with the original project, possessing its own copy of the original project's history.

Bob then makes some changes and commits them:

```
(edit files)
$ git commit -a
(repeat as necessary)
```

When he's ready, he tells Alice to pull changes from the repository at /home/bob/myrepo. She does this with:

```
$ cd /home/alice/project
$ git pull /home/bob/myrepo master
```

This merges the changes from Bob's "master" branch into Alice's current branch. If Alice has made her own changes in the meantime, then she may need to manually fix any conflicts. (Note that the "master" argument in the above command is actually unnecessary, as it is the default.)

The "pull" command thus performs two operations: it fetches changes from a remote branch, then merges them into the current branch.

When you are working in a small closely knit group, it is not unusual to interact with the same repository over and over again. By defining 'remote' repository shorthand, you can make it easier:

```
$ git remote add bob /home/bob/myrepo
```

With this, Alice can perform the first operation alone using the "git fetch" command without merging them with her own branch, using:

```
$ git fetch bob
```

Unlike the longhand form, when Alice fetches from Bob using a remote repository shorthand set up with `git remote`, what was fetched is stored in a remote tracking branch, in this case `bob/master`. So after this:

```
$ git log -p master..bob/master
```

shows a list of all the changes that Bob made since he branched from Alice's master branch.

After examining those changes, Alice could merge the changes into her master branch:

```
$ git merge bob/master
```

This `merge` can also be done by 'pulling from her own remote tracking branch', like this:

```
$ git pull . remotes/bob/master
```

Note that git pull always merges into the current branch, regardless of what else is given on the command line.

Later, Bob can update his repo with Alice's latest changes using

```
$ git pull
```

Note that he doesn't need to give the path to Alice's repository; when Bob cloned Alice's repository, git stored the location of her repository in the repository configuration, and that location is used for pulls:

```
$ git config --get remote.origin.url
/home/alice/project
```

(The complete configuration created by git-clone is visible using "git config -l", and the git config man page explains the meaning of each option.)

Git also keeps a pristine copy of Alice's master branch under the name "origin/master":

```
$ git branch -r
  origin/master
```

If Bob later decides to work from a different host, he can still perform clones and pulls using the ssh protocol:

```
$ git clone alice.org:/home/alice/project myrepo
```

Alternatively, git has a native protocol, or can use rsync or http; see git pull for details.

Git can also be used in a CVS-like mode, with a central repository that various users push changes to; see git push and link:cvs-migration.html[git for CVS users].

Public git repositories

Another way to submit changes to a project is to tell the maintainer of that project to pull the changes from your repository using git pull. In the section "<<getting-updates-with-git-pull, Getting updates with git-pull>>" we described this as a way to get updates from the "main" repository, but it works just as well in the other direction.

If you and the maintainer both have accounts on the same machine, then you can just pull changes from each other's repositories directly; commands that accept repository URLs as arguments will also accept a local directory name:

```
$ git clone /path/to/repository
$ git pull /path/to/other/repository
```

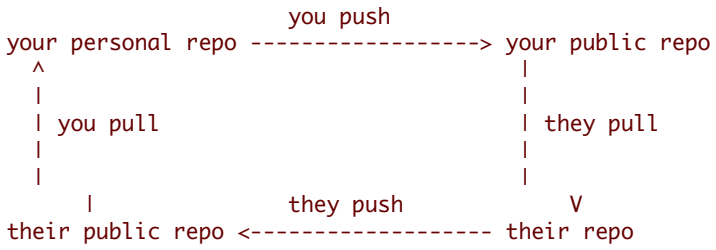
or an ssh URL:

```
$ git clone ssh://yourhost/~you/repository
```

For projects with few developers, or for synchronizing a few private repositories, this may be all you need.

However, the more common way to do this is to maintain a separate public repository (usually on a different host) for others to pull changes from. This is usually more convenient, and allows you to cleanly separate private work in progress from publicly visible work.

You will continue to do your day-to-day work in your personal repository, but periodically "push" changes from your personal repository into your public repository, allowing other developers to pull from that repository. So the flow of changes, in a situation where there is one other developer with a public repository, looks like this:



Pushing changes to a public repository

Note that the two techniques outlined above (exporting via <<exporting-via-http,http>> or <<exporting-via-git,git>>) allow other maintainers to fetch your latest changes, but they do not allow write access, which you will need to update the public repository with the latest changes created in your private repository.

The simplest way to do this is using git push and ssh; to update the remote branch named "master" with the latest state of your branch named "master", run

```
$ git push ssh://yourserver.com/~you/proj.git master:master
```

or just

```
$ git push ssh://yourserver.com/~you/proj.git master
```

As with git-fetch, git-push will complain if this does not result in a <<fast-forwards,fast forward>>; see the following section for details on handling this case.

Note that the target of a "push" is normally a <<def*bare*repository,bare>> repository. You can also push to a repository that has a checked-out working tree, but the working tree will not be updated by the push. This may lead to unexpected results if the branch you push to is the currently checked-out branch!

As with git-fetch, you may also set up configuration options to save typing; so, for example, after

```
$ cat >>.git/config <<EOF
[remote "public-repo"]
    url = ssh://yourserver.com/~you/proj.git
EOF
```

you should be able to perform the above push with just

```
$ git push public-repo master
```

See the explanations of the remote..url, branch..remote, and remote..push options in git config for details.

What to do when a push fails

If a push would not result in a <<fast-forwards,fast forward>> of the remote branch, then it will fail with an error like:

```
error: remote 'refs/heads/master' is not an ancestor of
local  'refs/heads/master'.
Maybe you are not up-to-date and need to pull first?
error: failed to push to 'ssh://yourserver.com/~you/proj.git'
```

This can happen, for example, if you:

```
- use `git-reset --hard` to remove already-published commits, or
- use `git-commit --amend` to replace already-published commits
```

```
    (as in <<fixing-a-mistake-by-rewriting-history>>), or
  - use `git-rebase` to rebase any already-published commits (as
    in <<using-git-rebase>>).
```

You may force git-push to perform the update anyway by preceding the branch name with a plus sign:

```
  $ git push ssh://yourserver.com/~you/proj.git +master
```

Normally whenever a branch head in a public repository is modified, it is modified to point to a descendant of the commit that it pointed to before. By forcing a push in this situation, you break that convention. (See <<problems-with-rewriting-history>>.)

Nevertheless, this is a common practice for people that need a simple way to publish a work-in-progress patch series, and it is an acceptable compromise as long as you warn other developers that this is how you intend to manage the branch.

It's also possible for a push to fail in this way when other people have the right to push to the same repository. In that case, the correct solution is to retry the push after first updating your work: either by a pull, or by a fetch followed by a rebase; see the <<setting-up-a-shared-repository,next section>> and gitcvs-migration for more.

GIT TAG

Lightweight Tags

We can create a tag to refer to a particular commit by running git tag with no arguments.

```
  $ git tag stable-1 1b2e1d63ff
```

After that, we can use stable-1 to refer to the commit 1b2e1d63ff.

This creates a "lightweight" tag, basically a branch that never moves. If you would also like to include a comment with the tag, and possibly sign it cryptographically, then we can create a *tag object* instead.

Tag Objects

If one of **-a**, **-s**, or **-u <key-id>** is passed, the command creates a tag object, and requires the tag message. Unless -m or -F is given, an editor is started for the user to type in the tag message.

When this happens, a new object is added to the Git object database and the tag ref points to that *tag object*, rather than the commit itself. The strength of this is that you can sign the tag, so you can verify that it is the correct commit later. You can create a tag object like this:

```
$ git tag -a stable-1 1b2e1d63ff
```

It is actually possible to tag any object, but tagging commit objects is the most common. (In the Linux kernel source, the first tag object references a tree, rather than a commit)

Signed Tags

If you have a GPG key setup, you can create signed tags fairly easily. First, you will probably want to setup your key id in your *.git/config* or *~.gitconfig* file.

```
[user]
    signingkey = <gpg-key-id>
```

You can also set that with

```
$ git config (--global) user.signingkey <gpg-key-id>
```

Now you can create a signed tag simply by replacing the **-a** with a **-s**.

```
$ git tag -s stable-1 1b2e1d63ff
```

If you don't have your GPG key in your config file, you can accomplish the same thing this way:

```
$ git tag -u <gpg-key-id> stable-1 1b2e1d63ff
```

Chapter 4

Intermediate Usage

IGNORING FILES

A project will often generate files that you do 'not' want to track with git. This typically includes files generated by a build process or temporary backup files made by your editor. Of course, 'not' tracking files with git is just a matter of 'not' calling "`git-add`" on them. But it quickly becomes annoying to have these untracked files lying around; e.g. they make "`git add .`" and "`git commit -a`" practically useless, and they keep showing up in the output of "`git status`".

You can tell git to ignore certain files by creating a file called .gitignore in the top level of your working directory, with contents such as:

```
# Lines starting with '#' are considered comments.
# Ignore any file named foo.txt.
foo.txt
# Ignore (generated) html files,
```

```
*.html
# except foo.html which is maintained by hand.
!foo.html
# Ignore objects and archives.
*.[oa]
```

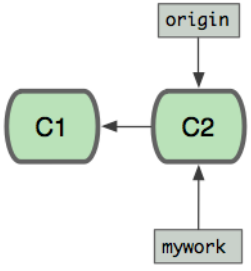
See gitignore for a detailed explanation of the syntax. You can also place .gitignore files in other directories in your working tree, and they will apply to those directories and their subdirectories. The `.gitignore` files can be added to your repository like any other files (just run `git add .gitignore` and `git commit`, as usual), which is convenient when the exclude patterns (such as patterns matching build output files) would also make sense for other users who clone your repository.

If you wish the exclude patterns to affect only certain repositories (instead of every repository for a given project), you may instead put them in a file in your repository named .git/info/exclude, or in any file specified by the `core.excludesfile` configuration variable. Some git commands can also take exclude patterns directly on the command line. See gitignore for the details.

REBASING

Suppose that you create a branch "mywork" on a remote-tracking branch "origin".

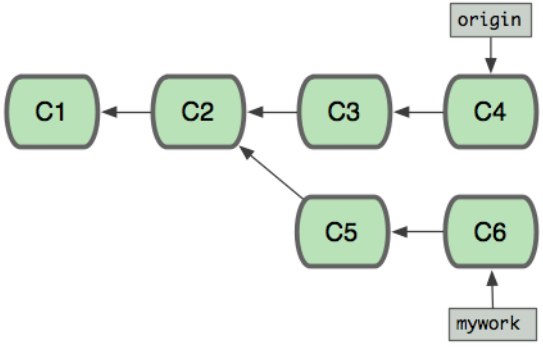
```
$ git checkout -b mywork origin
```



Now you do some work, creating two new commits.

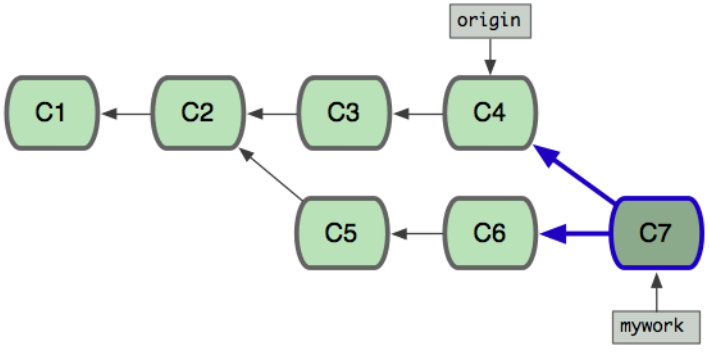
```
$ vi file.txt
$ git commit
$ vi otherfile.txt
$ git commit
...
```

Meanwhile, someone else does some work creating two new commits on the origin branch too. This means both 'origin' and 'mywork' has advanced, which means the work has diverged.



At this point, you could use "pull" to merge your changes back in; the result would create a new merge commit, like this:

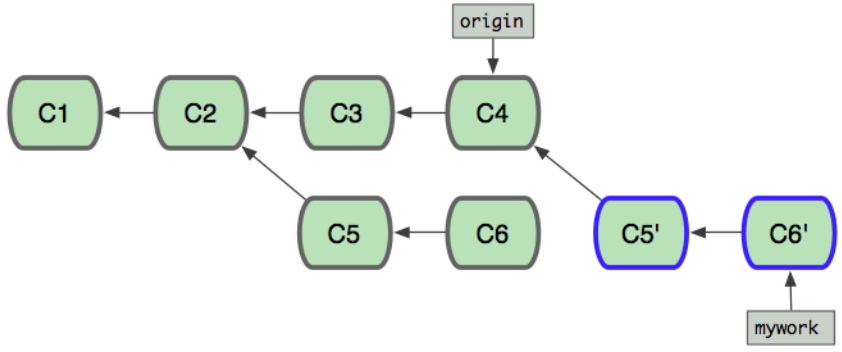
git merge



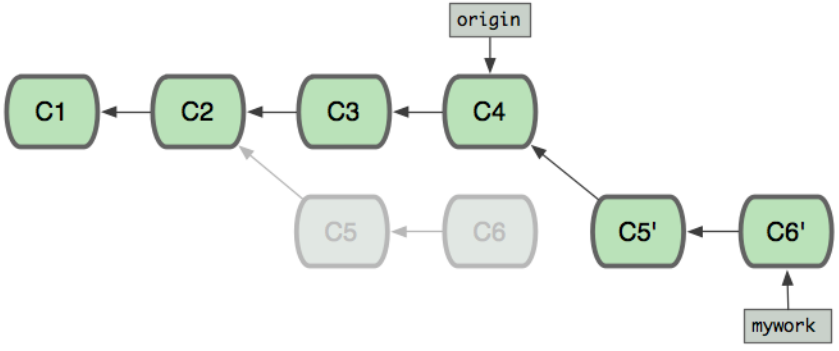
However, if you prefer to keep the history in mywork a simple series of commits without any merges, you may instead choose to use git rebase:

```
$ git checkout mywork
$ git rebase origin
```

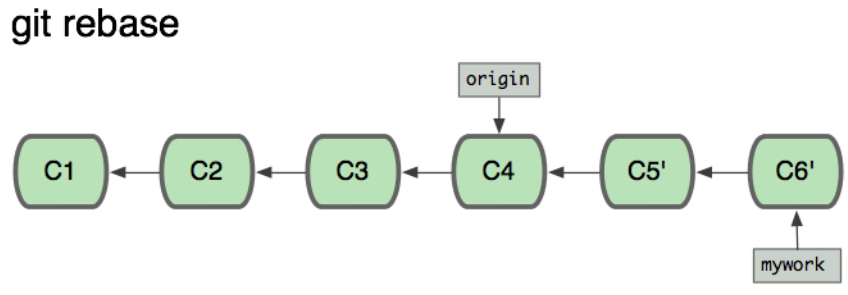
This will remove each of your commits from mywork, temporarily saving them as patches (in a directory named ".git/rebase"), update mywork to point at the latest version of origin, then apply each of the saved patches to the new mywork.

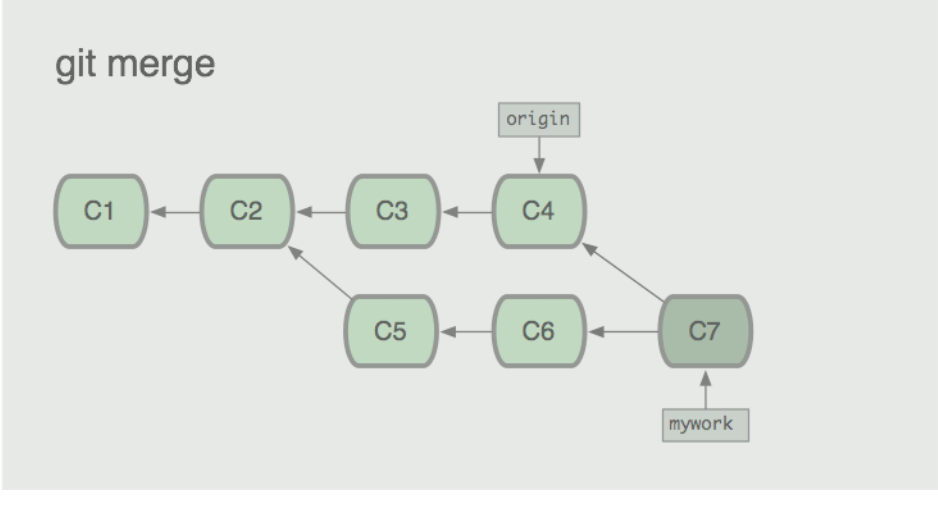


Once the ref ('mywork') is updated to point to the newly created commit objects, your older commits will be abandoned. They will likely be removed if you run a pruning garbage collection. (see git gc)



So now we can look at the difference in our history between running a merge and running a rebase:





In the process of the rebase, it may discover conflicts. In that case it will stop and allow you to fix the conflicts; after fixing conflicts, use "git-add" to update the index with those contents, and then, instead of running git-commit, just run

```
$ git rebase --continue
```

and git will continue applying the rest of the patches.

At any point you may use the `--abort` option to abort this process and return mywork to the state it had before you started the rebase:

```
$ git rebase --abort
```

INTERACTIVE REBASING

You can also rebase interactively. This is often used to re-write your own commit objects before pusing them somewhere. It is an easy way to split, merge or re-order commits before sharing them with others. You can also use it to clean up commits you've pulled from someone when applying them locally.

If you have a number of commits that you would like to somehow modify during the rebase, you can invoke interactive mode by passing a '-i' or '--interactive' to the 'git rebase' command.

```
$ git rebase -i origin/master
```

This will invoke interactive rebase mode on all the commits you have made since the last time you have pushed (or merged from the origin repository).

To see what commits those are beforehand, you can run log this way:

```
$ git log github/master..
```

Once you run the 'rebase -i' command, you will be thrown into your editor of choice with something that looks like this:

```
pick fc62e55 added file_size
pick 9824bf4 fixed little thing
pick 21d80a5 added number to log
pick 76b9da6 added the apply command
pick c264051 Revert "added file_size" - not implemented correctly

# Rebase f408319..b04dc3d onto f408319
#
# Commands:
#  p, pick = use commit
#  e, edit = use commit, but stop for amending
#  s, squash = use commit, but meld into previous commit
#
# If you remove a line here THAT COMMIT WILL BE LOST.
# However, if you remove everything, the rebase will be aborted.
#
```

This means that there are 5 commits since you last pushed and it gives you one line per commit with the following format:

```
(action) (partial-sha) (short commit message)
```

Now, you can change the action (which is by default 'pick') to either 'edit' or 'squash', or just leave it as 'pick'. You can also reorder the commits just by moving the lines around however you want. Then, when you exit the editor, git will try to apply the commits however they are now arranged and do the action specified.

If 'pick' is specified, it will simply try to apply the patch and save the commit with the same message as before.

If 'squash' is specified, it will combine that commit with the previous one to create a new commit. This will drop you into your editor again to merge the commit messages of the two commits it is now squashing together. So, if you exit the editor with this:

```
pick   fc62e55 added file_size
squash 9824bf4 fixed little thing
squash 21d80a5 added number to log
squash 76b9da6 added the apply command
squash c264051 Revert "added file_size" - not implemented correctly
```

Then you will have to create a single commit message from this:

```
# This is a combination of 5 commits.
# The first commit's message is:
added file_size

# This is the 2nd commit message:

fixed little thing

# This is the 3rd commit message:

added number to log

# This is the 4th commit message:

added the apply command

# This is the 5th commit message:

Revert "added file_size" - not implemented correctly

This reverts commit fc62e5543b195f18391886b9f663d5a7eca38e84.
```

Once you have edited that down into once commit message and exit the editor, the commit will be saved with your new message.

If 'edit' is specified, it will do the same thing, but then pause before moving on to the next one and drop you into the command line so you can amend the commit, or change the commit contents somehow.

If you wanted to split a commit, for instance, you would specify 'edit' for that commit:

```
pick   fc62e55 added file_size
pick   9824bf4 fixed little thing
edit   21d80a5 added number to log
pick   76b9da6 added the apply command
pick   c264051 Revert "added file_size" - not implemented correctly
```

And then when you get to the command line, you revert that commit and create two (or more) new ones. Lets say 21d80a5 modified two files, file1 and file2, and you wanted to split them into seperate commits. You could do this after the rebase dropped you to the command line :

```
$ git reset HEAD^
$ git add file1
$ git commit 'first part of split commit'
$ git add file2
$ git commit 'second part of split commit'
$ git rebase --continue
```

And now instead of 5 commits, you would have 6.

The last useful thing that interactive rebase can do is drop commits for you. If instead of choosing 'pick', 'squash' or 'edit' for the commit line, you simply remove the line, it will remove the commit from the history.

INTERACTIVE ADDING

Interactive Adding is a really nice way of working with and visualizing the Git index. To start it up, simply type 'git add -i'. Git will show you all the modified files you have and their status.

```
$>git add -i
           staged     unstaged path
  1:    unchanged        +4/-0 assets/stylesheets/style.css
  2:    unchanged      +23/-11 layout/book_index_template.html
  3:    unchanged        +7/-7 layout/chapter_template.html
  4:    unchanged        +3/-3 script/pdf.rb
  5:    unchanged      +121/-0 text/14_Interactive_Rebasing/0_ Interactive_Rebasing.markdown

*** Commands ***
  1: status   2: update   3: revert   4: add untracked
  5: patch    6: diff     7: quit     8: help
What now>
```

In this case, we can see that there are 5 modified files that have not been added to our index yet (unstaged), and even how many lines have been added to or removed from each. It then shows us an interactive menu of what we can do in this mode.

If we want to stage the files, we can type '2' or 'u' for the update mode. Then I can specify which files I want to stage (add to the index) by typing in the numbers of the files (in this case, 1-4)

```
What now> 2
           staged     unstaged path
  1:    unchanged        +4/-0 assets/stylesheets/style.css
  2:    unchanged      +23/-11 layout/book_index_template.html
  3:    unchanged        +7/-7 layout/chapter_template.html
  4:    unchanged        +3/-3 script/pdf.rb
  5:    unchanged      +121/-0 text/14_Interactive_Rebasing/0_ Interactive_Rebasing.markdown
```

```
Update>> 1-4
           staged     unstaged path
* 1:    unchanged        +4/-0 assets/stylesheets/style.css
* 2:    unchanged      +23/-11 layout/book_index_template.html
* 3:    unchanged        +7/-7 layout/chapter_template.html
* 4:    unchanged        +3/-3 script/pdf.rb
  5:    unchanged      +121/-0 text/14_Interactive_Rebasing/0_ Interactive_Rebasing.markdown
Update>>
```

If I hit enter, I will be taken back to the main menu where I can see that the file status has changed:

```
What now> status
           staged     unstaged path
  1:        +4/-0      nothing assets/stylesheets/style.css
  2:      +23/-11      nothing layout/book_index_template.html
  3:        +7/-7      nothing layout/chapter_template.html
  4:        +3/-3      nothing script/pdf.rb
  5:    unchanged      +121/-0 text/14_Interactive_Rebasing/0_ Interactive_Rebasing.markdown
```

Now we can see the first four files are staged and the last one is still not. This is basically a compressed way to see the same information we see when we run 'git status' from the command line:

```
$ git status
# On branch master
# Changes to be committed:
#   (use "git reset HEAD <file>..." to unstage)
#
#   modified:   assets/stylesheets/style.css
#   modified:   layout/book_index_template.html
#   modified:   layout/chapter_template.html
#   modified:   script/pdf.rb
#
# Changed but not updated:
```

```
#   (use "git add <file>..." to update what will be committed)
#
#   modified:   text/14_Interactive_Rebasing/0_ Interactive_Rebasing.markdown
#
```

There are a number of useful things we can do, including unstaging files (3: revert), adding untracked files (4: add untracked), and viewing diffs (6: diff). Those are all pretty straightforward. However, there is one command that is pretty cool here, which is staging patches (5: patch).

If you type '5' or 'p' in the menu, git will show you your diff patch by patch (or hunk by hunk) and ask if you want to stage each one. That way you can actually stage for a commit a part of a file edit. If you've edited a file and want to only commit part of it and not an unfinished part, or commit documentation or whitespace changes seperate from substantive changes, you can use 'git add -i' to do so relatively easily.

Here I've staged some changes to the book*index*template.html file, but not all of them:

```
          staged     unstaged path
1:        +4/-0      nothing assets/stylesheets/style.css
2:       +20/-7        +3/-4 layout/book_index_template.html
3:        +7/-7      nothing layout/chapter_template.html
4:        +3/-3      nothing script/pdf.rb
5:    unchanged      +121/-0 text/14_Interactive_Rebasing/0_ Interactive_Rebasing.markdown
6:    unchanged       +85/-0 text/15_Interactive_Adding/0_ Interactive_Adding.markdown
```

When you are done making changes to your index through 'git add -i', you simply quit (7: quit) and then run 'git commit' to commit the staged changes. Remember **not** to run 'git commit -a', which will blow away all the careful changes you've just made and simply commit everything.

STASHING

While you are in the middle of working on something complicated, you find an unrelated but obvious and trivial bug. You would like to fix it before continuing. You can use git stash to save the current state of your work, and after fixing the bug (or, optionally after doing so on a different branch and then coming back), unstash the work-in-progress changes.

```
$ git stash "work in progress for foo feature"
```

This command will save your changes away to the `stash`, and reset your working tree and the index to match the tip of your current branch. Then you can make your fix as usual.

```
... edit and test ...
$ git commit -a -m "blorpl: typofix"
```

After that, you can go back to what you were working on with `git stash apply`:

```
$ git stash apply
```

Stash Queue

You can also use stashing to queue up stashed changes.
If you run 'git stash list' you can see which stashes you have saved:

```
$>git stash list
stash@{0}: WIP on book: 51bea1d... fixed images
stash@{1}: WIP on master: 9705ae6... changed the browse code to the official repo
```

Then you can apply them individually with 'git stash apply stash@{1}'. You can clear out the list with 'git stash clear'.

GIT TREEISHES

There are a number of ways to refer to a particular commit or tree other than spelling out the entire 40-character sha. In Git, these are referred to as a 'treeish'.

Partial Sha

If your commit sha is '`980e3ccdaac54a0d4de358f3fe5d718027d96aae`', git will recognize any of the following identically:

```
980e3ccdaac54a0d4de358f3fe5d718027d96aae
980e3ccdaac54a0d4
980e3cc
```

As long as the partial sha is unique - it can't be confused with another (which is incredibly unlikely if you use at least 5 characters), git will expand a partial sha for you.

Branch, Remote or Tag Name

You can always use a branch, remote or tag name instead of a sha, since they are simply pointers anyhow. If your master branch is on the 980e3 commit and you've pushed it to origin and have tagged it 'v1.0', then all of the following are equivalent:

```
980e3ccdaac54a0d4de358f3fe5d718027d96aae
origin/master
refs/remotes/origin/master
master
refs/heads/master
v1.0
refs/tags/v1.0
```

Which means the following will give you identical output:

```
$ git log master
$ git log refs/tags/v1.0
```

Date Spec

The Ref Log that git keeps will allow you to do some relative stuff locally, such as:

```
master@{yesterday}
master@{1 month ago}
```

Which is shorthand for 'where the master branch head was yesterday', etc. Note that this format can result in different shas on different computers, even if the master branch is currently pointing to the same place.

Ordinal Spec

This format will give you the Nth previous value of a particular reference. For example:

```
master@{5}
```

will give you the 5th prior value of the master head ref.

Carrot Parent

This will give you the Nth parent of a particular commit. This format is only useful on merge commits - commit objects that have more than one direct parent.

```
master^2
```

Tilde Spec

The tilde spec will give you the Nth grandparent of a commit object. For example,

```
master~2
```

will give us the first parent of the first parent of the commit that master points to. It is equivalent to:

```
master^^
```

You can keep doing this, too. The following specs will point to the same commit:

```
master^^^^^^
master~3^~2
master~6
```

Tree Pointer

This disambiguates a commit from the tree that it points to. If you want the sha that a commit points to, you can add the '^{tree}' spec to the end of it.

```
master^{tree}
```

Blob Spec

If you want the sha of a particular blob, you can add the blob path at the end of the treeish, like so:

```
master:/path/to/file
```

Range

Finally, you can specify a range of commits with the range spec. This will give you all the commits between 7b593b5 and 51bea1 (where 51bea1 is most recent), excluding 7b593b5 but including 51bea1:

```
7b593b5..51bea1
```

This will include every commit *since* 7b593b:

```
7b593b..
```

TRACKING BRANCHES

A 'tracking branch' in Git is a local branch that is connected to a remote branch. When you push and pull on that branch, it automatically pushes and pulls to the remote branch that it is connected with.

Use this if you always pull from the same upstream branch into the new branch, and if you don't want to use "git pull " explicitly.

The 'git clone' command automatically sets up a 'master' branch that is a tracking branch for 'origin/master' - the master branch on the cloned repository.

You can create a tracking branch manually by adding the '--track' option to the 'branch' command in Git.

```
git branch --track experimental origin/experimental
```

Then when you run:

```
$ git pull experimental
```

It will automatically fetch from 'origin' and merge 'origin/experimental' into your local 'experimental' branch.

Likewise, when you push to origin, it will push what your 'experimental' points to to origins 'experimental', without having to specify it.

FINDING WITH GIT GREP

Finding files with words or phrases in Git is really easy with the git grep command. It is possible to do this with the normal unix 'grep' command, but with 'git grep' you can also search through previous versions of the project without having to check them out.

For example, if I wanted to see every place that used the 'xmmap' call in my git.git repository, I could run this:

```
$ git grep xmmap
config.c:               contents = xmmap(NULL, contents_sz, PROT_READ,
diff.c:         s->data = xmmap(NULL, s->size, PROT_READ, MAP_PRIVATE, fd, 0);
git-compat-util.h:extern void *xmmap(void *start, size_t length, int prot, int fla
read-cache.c:   mmap = xmmap(NULL, mmap_size, PROT_READ | PROT_WRITE, MAP_PRIVATE,
refs.c: log_mapped = xmmap(NULL, mapsz, PROT_READ, MAP_PRIVATE, logfd, 0);
sha1_file.c:    map = xmmap(NULL, mapsz, PROT_READ, MAP_PRIVATE, fd, 0);
sha1_file.c:    idx_map = xmmap(NULL, idx_size, PROT_READ, MAP_PRIVATE, fd, 0);
```

```
sha1_file.c:                    win->base = xmmap(NULL, win->len,
sha1_file.c:                    map = xmmap(NULL, *size, PROT_READ, MAP_PRIVATE, f
sha1_file.c:            buf = xmmap(NULL, size, PROT_READ, MAP_PRIVATE, fd, 0);
wrapper.c:void *xmmap(void *start, size_t length,
```

If I wanted to see the line number of each match as well, I can add the '-n' option:

```
$>git grep -n xmmap
config.c:1016:          contents = xmmap(NULL, contents_sz, PROT_READ,
diff.c:1833:            s->data = xmmap(NULL, s->size, PROT_READ, MAP_PRIVATE, fd,
git-compat-util.h:291:extern void *xmmap(void *start, size_t length, int prot, int
read-cache.c:1178:      mmap = xmmap(NULL, mmap_size, PROT_READ | PROT_WRITE, MAP_
refs.c:1345:    log_mapped = xmmap(NULL, mapsz, PROT_READ, MAP_PRIVATE, logfd, 0);
sha1_file.c:377:        map = xmmap(NULL, mapsz, PROT_READ, MAP_PRIVATE, fd, 0);
sha1_file.c:479:        idx_map = xmmap(NULL, idx_size, PROT_READ, MAP_PRIVATE, fd
sha1_file.c:780:                        win->base = xmmap(NULL, win->len,
sha1_file.c:1076:                       map = xmmap(NULL, *size, PROT_READ, MAP_PR
sha1_file.c:2393:               buf = xmmap(NULL, size, PROT_READ, MAP_PRIVATE, fd
wrapper.c:89:void *xmmap(void *start, size_t length,
```

If we're only interested in the filename, we can pass the '--name-only' option:

```
$>git grep --name-only xmmap
config.c
diff.c
git-compat-util.h
read-cache.c
refs.c
sha1_file.c
wrapper.c
```

We could also see how many line matches we have in each file with the '-c' option:

```
$>git grep -c xmmap
config.c:1
diff.c:1
git-compat-util.h:1
read-cache.c:1
refs.c:1
sha1_file.c:5
wrapper.c:1
```

Now, if I wanted to see where that was used in a specific version of git, I could add the tag reference to the end, like this:

```
$ git grep xmmap v1.5.0
v1.5.0:config.c:                contents = xmmap(NULL, st.st_size, PROT_READ,
v1.5.0:diff.c:          s->data = xmmap(NULL, s->size, PROT_READ, MAP_PRIVATE, fd,
v1.5.0:git-compat-util.h:static inline void *xmmap(void *start, size_t length,
v1.5.0:read-cache.c:                    cache_mmap = xmmap(NULL, cache_mmap_size,
v1.5.0:refs.c:  log_mapped = xmmap(NULL, st.st_size, PROT_READ, MAP_PRIVATE, logfd
v1.5.0:sha1_file.c:     map = xmmap(NULL, st.st_size, PROT_READ, MAP_PRIVATE, fd,
v1.5.0:sha1_file.c:     idx_map = xmmap(NULL, idx_size, PROT_READ, MAP_PRIVATE, fd
v1.5.0:sha1_file.c:                     win->base = xmmap(NULL, win->len,
v1.5.0:sha1_file.c:     map = xmmap(NULL, st.st_size, PROT_READ, MAP_PRIVATE, fd,
v1.5.0:sha1_file.c:             buf = xmmap(NULL, size, PROT_READ, MAP_PRIVATE, fd
```

We can see that there are some differences between the current lines and these lines in version 1.5.0, one of which is that xmmap is now used in wrapper.c where it was not back in v1.5.0.

We can also combine search terms in grep. Say we wanted to search for where SORT_DIRENT is defined in our repository:

```
$ git grep -e '#define' --and -e SORT_DIRENT
builtin-fsck.c:#define SORT_DIRENT 0
builtin-fsck.c:#define SORT_DIRENT 1
```

We can also search for every file that has *both* search terms, but display each line that has *either* of the terms in those files:

```
$ git grep --all-match -e '#define' -e SORT_DIRENT
builtin-fsck.c:#define REACHABLE 0x0001
builtin-fsck.c:#define SEEN      0x0002
builtin-fsck.c:#define ERROR_OBJECT 01
builtin-fsck.c:#define ERROR_REACHABLE 02
builtin-fsck.c:#define SORT_DIRENT 0
builtin-fsck.c:#define DIRENT_SORT_HINT(de) 0
builtin-fsck.c:#define SORT_DIRENT 1
builtin-fsck.c:#define DIRENT_SORT_HINT(de) ((de)->d_ino)
builtin-fsck.c:#define MAX_SHA1_ENTRIES (1024)
builtin-fsck.c: if (SORT_DIRENT)
```

We can also search for lines that have one term and either of two other terms, for example, if we wanted to see where we defined constants that had either PATH or MAX in the name:

```
$ git grep -e '#define' --and \( -e PATH -e MAX \)
abspath.c:#define MAXDEPTH 5
builtin-blame.c:#define MORE_THAN_ONE_PATH      (1u<<13)
builtin-blame.c:#define MAXSG 16
builtin-describe.c:#define MAX_TAGS     (FLAG_BITS - 1)
builtin-fetch-pack.c:#define MAX_IN_VAIN 256
builtin-fsck.c:#define MAX_SHA1_ENTRIES (1024)
...
```

UNDOING IN GIT - RESET, CHECKOUT AND REVERT

Git provides multiple methods for fixing up mistakes as you are developing. Selecting an appropriate method depends on whether or not you have committed the mistake, and if you have committed the mistake, whether you have shared the erroneous commit with anyone else.

Fixing un-committed mistakes

If you've messed up the working tree, but haven't yet committed your mistake, you can return the entire working tree to the last committed state with

```
$ git reset --hard HEAD
```

This will throw away any changes you may have added to the git index and as well as any outstanding changes you have in your working tree. In other words, it causes the results of "git diff" and "git diff --cached" to both be empty.

If you just want to restore just one file, say your hello.rb, use git checkout instead

```
$ git checkout -- hello.rb
$ git checkout HEAD hello.rb
```

The first command restores hello.rb to the version in the index, so that "git diff hello.rb" returns no differences. The second command will restore hello.rb to the version in the HEAD revision, so that both "git diff hello.rb" and "git diff --cached hello.rb" return no differences.

Fixing committed mistakes

If you make a commit that you later wish you hadn't, there are two fundamentally different ways to fix the problem:

1. You can create a new commit that undoes whatever was done by the old commit. This is the correct thing if your mistake has already been made public.

2. You can go back and modify the old commit. You should never do this if you have already made the history public; git does not normally expect the "history" of a project to change, and cannot correctly perform repeated merges from a branch that has had its history changed.

Fixing a mistake with a new commit

Creating a new commit that reverts an earlier change is very easy; just pass the git revert command a reference to the bad commit; for example, to revert the most recent commit:

```
$ git revert HEAD
```

This will create a new commit which undoes the change in HEAD. You will be given a chance to edit the commit message for the new commit.

You can also revert an earlier change, for example, the next-to-last:

```
$ git revert HEAD^
```

In this case git will attempt to undo the old change while leaving intact any changes made since then. If more recent changes overlap with the changes to be reverted, then you will be asked to fix conflicts manually, just as in the case of resolving a merge.

Fixing a mistake by modifying a commit

If you have just committed something but realize you need to fix up that commit, recent versions of git commit support an **--amend** flag which instructs git to replace the HEAD commit with a new one, based on the current contents of the index. This gives you an opportunity to add files that you forgot to add or correct typos in a commit message, prior to pushing the change out for the world to see.

If you find a mistake in an older commit, but still one that you have not yet published to the world, you use git rebase in interactive mode, with "git rebase -i" marking the change that requires correction with **edit**. This will allow you to amend the commit during the rebasing process.

MAINTAINING GIT

Ensuring good performance

On large repositories, git depends on compression to keep the history information from taking up too much space on disk or in memory.

This compression is not performed automatically. Therefore you should occasionally run git gc:

```
$ git gc
```

to recompress the archive. This can be very time-consuming, so you may prefer to run git-gc when you are not doing other work.

Ensuring reliability

The git fsck command runs a number of self-consistency checks on the repository, and reports on any problems. This may take some time. The most common warning by far is about "dangling" objects:

```
$ git fsck
dangling commit 7281251ddd2a61e38657c827739c57015671a6b3
dangling commit 2706a059f258c6b245f298dc4ff2ccd30ec21a63
dangling commit 13472b7c4b80851a1bc551779171dcb03655e9b5
dangling blob 218761f9d90712d37a9c5e36f406f92202db07eb
dangling commit bf093535a34a4d35731aa2bd90fe6b176302f14f
dangling commit 8e4bec7f2ddaa268bef999853c25755452100f8e
dangling tree d50bb86186bf27b681d25af89d3b5b68382e4085
dangling tree b24c2473f1fd3d91352a624795be026d64c8841f
...
```

Dangling objects are not a problem. At worst they may take up a little extra disk space. They can sometimes provide a last-resort method for recovering lost work.

SETTING UP A PUBLIC REPOSITORY

Assume your personal repository is in the directory ~/proj. We first create a new clone of the repository and tell git-daemon that it is meant to be public:

```
$ git clone --bare ~/proj proj.git
$ touch proj.git/git-daemon-export-ok
```

The resulting directory proj.git contains a "bare" git repository--it is just the contents of the ".git" directory, without any files checked out around it.

Next, copy proj.git to the server where you plan to host the public repository. You can use scp, rsync, or whatever is most convenient.

Exporting a git repository via the git protocol

This is the preferred method.

If someone else administers the server, they should tell you what directory to put the repository in, and what git:// URL it will appear at.

Otherwise, all you need to do is start git daemon; it will listen on port 9418. By default, it will allow access to any directory that looks like a git directory and contains the magic file git-daemon-export-ok. Passing some directory paths as git-daemon arguments will further restrict the exports to those paths.

You can also run git-daemon as an inetd service; see the git daemon man page for details. (See especially the examples section.)

Exporting a git repository via http

The git protocol gives better performance and reliability, but on a host with a web server set up, http exports may be simpler to set up.

All you need to do is place the newly created bare git repository in a directory that is exported by the web server, and make some adjustments to give web clients some extra information they need:

```
$ mv proj.git /home/you/public_html/proj.git
$ cd proj.git
```

```
$ git --bare update-server-info
$ chmod a+x hooks/post-update
```

(For an explanation of the last two lines, see git update-server-info and githooks.)

Advertise the URL of proj.git. Anybody else should then be able to clone or pull from that URL, for example with a command line like:

```
$ git clone http://yourserver.com/~you/proj.git
```

SETTING UP A PRIVATE REPOSITORY

If you need to setup a private repository and want to do so locally, rather than using a hosted solution, you have a number of options.

Repo Access over SSH

Generally, the easiest solution is to simply use Git over SSH. If users already have ssh accounts on a machine, you can put the git repository anywhere on the box that they have access to and let them access it over normal ssh logins. For example, say you have a repository you want to host. You can export it as a bare repo and then scp it onto your server like so:

```
$ git clone --bare /home/user/myrepo/.git /tmp/myrepo.git
$ scp -r /tmp/myrepo.git myserver.com:/opt/git/myrepo.git
```

Then someone else with an ssh account on myserver.com can clone via:

```
$ git clone myserver.com:/opt/git/myrepo.git
```

Which will simply prompt them for thier ssh password or use thier public key, however they have ssh authentication setup.

Multiple User Access using Gitosis

If you don't want to setup seperate accounts for every user, you can use a tool called Gitosis. In gitosis, there is an authorized_keys file that contains the public keys of everyone authorized to access the repository, and then everyone uses the 'git' user to do pushes and pulls.

Installing and Setting up Gitosis

Chapter 5

Advanced Git

CREATING NEW EMPTY BRANCHES

Ocasionally, you may want to keep branches in your repository that do not share an ancestor with your normal code. Some examples of this might be generated documentation or something along those lines. If you want to create a new branch head that does not use your current codebase as a parent, you can create an empty branch like this:

```
git symbolic-ref HEAD refs/heads/newbranch
rm .git/index
git clean -fdx
<do work>
git add your files
git commit -m 'Initial commit'
```

MODIFYING YOUR HISTORY

Interactive rebasing is a good way to modify individual commits.

git filter-branch is a good way to edit commits en masse.

ADVANCED BRANCHING AND MERGING

Getting conflict-resolution help during a merge

All of the changes that git was able to merge automatically are already added to the index file, so git diff shows only the conflicts. It uses an unusual syntax:

```
$ git diff
diff --cc file.txt
index 802992c,2b60207..0000000
--- a/file.txt
+++ b/file.txt
@@@ -1,1 -1,1 +1,5 @@@
++<<<<<<< HEAD:file.txt
 +Hello world
++=======
+ Goodbye
++>>>>>>> 77976da35a11db4580b80ae27e8d65caf5208086:file.txt
```

Recall that the commit which will be committed after we resolve this conflict will have two parents instead of the usual one: one parent will be HEAD, the tip of the current branch; the other will be the tip of the other branch, which is stored temporarily in MERGE_HEAD.

During the merge, the index holds three versions of each file. Each of these three "file stages" represents a different version of the file:

```
$ git show :1:file.txt  # the file in a common ancestor of both branches
$ git show :2:file.txt  # the version from HEAD.
$ git show :3:file.txt  # the version from MERGE_HEAD.
```

When you ask git diff to show the conflicts, it runs a three-way diff between the conflicted merge results in the work tree with stages 2 and 3 to show only hunks whose contents come from both sides, mixed (in other words, when a hunk's merge results come only from stage 2, that part is not conflicting and is not shown. Same for stage 3).

The diff above shows the differences between the working-tree version of file.txt and the stage 2 and stage 3 versions. So instead of preceding each line by a single "+" or "-", it now uses two columns: the first column is used for differences between the first parent and the working directory copy, and the second for differences between the second parent and the working directory copy. (See the "COMBINED DIFF FORMAT" section of git diff-files for a details of the format.)

After resolving the conflict in the obvious way (but before updating the index), the diff will look like:

```
$ git diff
diff --cc file.txt
index 802992c,2b60207..0000000
--- a/file.txt
+++ b/file.txt
@@@ -1,1 -1,1 +1,1 @@@
- Hello world
-Goodbye
++Goodbye world
```

This shows that our resolved version deleted "Hello world" from the first parent, deleted "Goodbye" from the second parent, and added "Goodbye world", which was previously absent from both.

Some special diff options allow diffing the working directory against any of these stages:

```
$ git diff -1 file.txt      # diff against stage 1
$ git diff --base file.txt  # same as the above
$ git diff -2 file.txt      # diff against stage 2
$ git diff --ours file.txt  # same as the above
$ git diff -3 file.txt      # diff against stage 3
$ git diff --theirs file.txt    # same as the above.
```

The git log and gitk commands also provide special help for merges:

```
$ git log --merge
$ gitk --merge
```

These will display all commits which exist only on HEAD or on MERGE_HEAD, and which touch an unmerged file.

You may also use git mergetool, which lets you merge the unmerged files using external tools such as emacs or kdiff3.

Each time you resolve the conflicts in a file and update the index:

```
$ git add file.txt
```

the different stages of that file will be "collapsed", after which git-diff will (by default) no longer show diffs for that file.

Multiway Merge

You can merge several heads at one time by simply listing them on the same git merge command. For instance,

```
$ git merge scott/master rick/master tom/master
```

is the equivalent of:

```
$ git merge scott/master
$ git merge rick/master
$ git merge tom/master
```

Subtree

There are situations where you want to include contents in your project from an independently developed project. You can just pull from the other project as long as there are no conflicting paths.

The problematic case is when there are conflicting files. Potential candidates are Makefiles and other standard filenames. You could merge these files but probably you do not want to. A better solution for this problem can be to merge the project as its own subdirectory. This is not supported by the recursive merge strategy, so just pulling won't work.

What you want is the subtree merge strategy, which helps you in such a situation.

In this example, let's say you have the repository at /path/to/B (but it can be an URL as well, if you want). You want to merge the master branch of that repository to the dir-B subdirectory in your current branch.

Here is the command sequence you need:

```
$ git remote add -f Bproject /path/to/B (1)
$ git merge -s ours --no-commit Bproject/master (2)
$ git read-tree --prefix=dir-B/ -u Bproject/master (3)
$ git commit -m "Merge B project as our subdirectory" (4)
$ git pull -s subtree Bproject master (5)
```

The benefit of using subtree merge is that it requires less administrative burden from the users of your repository. It works with older (before Git v1.5.2) clients and you have the code right after clone.

However if you use submodules then you can choose not to transfer the submodule objects. This may be a problem with the subtree merge.

Also, in case you make changes to the other project, it is easier to submit changes if you just use submodules.

(from Using Subtree Merge)

FINDING ISSUES - GIT BISECT

Suppose version 2.6.18 of your project worked, but the version at "master" crashes. Sometimes the best way to find the cause of such a regression is to perform a brute-force search through the project's history to find the particular commit that caused the problem. The git bisect command can help you do this:

```
$ git bisect start
$ git bisect good v2.6.18
$ git bisect bad master
Bisecting: 3537 revisions left to test after this
[65934a9a028b88e83e2b0f8b36618fe503349f8e] BLOCK: Make USB storage depend on SCSI rather than selecting it [try
```

If you run "git branch" at this point, you'll see that git has temporarily moved you to a new branch named "bisect". This branch points to a commit (with commit id 65934...) that is reachable from "master" but not from v2.6.18. Compile and test it, and see whether it crashes. Assume it does crash. Then:

```
$ git bisect bad
Bisecting: 1769 revisions left to test after this
[7eff82c8b1511017ae605f0c99ac275a7e21b867] i2c-core: Drop useless bitmaskings
```

checks out an older version. Continue like this, telling git at each stage whether the version it gives you is good or bad, and notice that the number of revisions left to test is cut approximately in half each time.

After about 13 tests (in this case), it will output the commit id of the guilty commit. You can then examine the commit with git show, find out who wrote it, and mail them your bug report with the commit id. Finally, run

```
$ git bisect reset
```

to return you to the branch you were on before and delete the temporary "bisect" branch.

Note that the version which git-bisect checks out for you at each point is just a suggestion, and you're free to try a different version if you think it would be a good idea. For example, occasionally you may land on a commit that broke something unrelated; run

```
$ git bisect visualize
```

which will run gitk and label the commit it chose with a marker that says "bisect". Choose a safe-looking commit nearby, note its commit id, and check it out with:

```
$ git reset --hard fb47ddb2db...
```

then test, run "bisect good" or "bisect bad" as appropriate, and continue.

FINDING ISSUES - GIT BLAME

The linkto:git-blame[1] command is really helpful for figuring out who changed which sections of a file. If you simple run 'git blame [filename]' you'll get an output of the entire file with the last commit sha, date and author for every line in the file.

```
$ git blame sha1_file.c
...
0fcfd160 (Linus Torvalds  2005-04-18 13:04:43 -0700    8)  */
0fcfd160 (Linus Torvalds  2005-04-18 13:04:43 -0700    9) #include "cache.h"
1f688557 (Junio C Hamano  2005-06-27 03:35:33 -0700   10) #include "delta.h"
a733cb60 (Linus Torvalds  2005-06-28 14:21:02 -0700   11) #include "pack.h"
8e440259 (Peter Eriksen   2006-04-02 14:44:09 +0200   12) #include "blob.h"
8e440259 (Peter Eriksen   2006-04-02 14:44:09 +0200   13) #include "commit.h"
8e440259 (Peter Eriksen   2006-04-02 14:44:09 +0200   14) #include "tag.h"
8e440259 (Peter Eriksen   2006-04-02 14:44:09 +0200   15) #include "tree.h"
f35a6d3b (Linus Torvalds  2007-04-09 21:20:29 -0700   16) #include "refs.h"
70f5d5d3 (Nicolas Pitre   2008-02-28 00:25:19 -0500   17) #include "pack-revindex.h"628522ec (Junio C Hamano
...
```

This is often helpful if a file had a line reverted or a mistake that broke the build to help you see who changed that line last.

You can also specify a start and end line for the blame:

```
$>git blame -L 160,+10 sha1_file.c
ace1534d (Junio C Hamano 2005-05-07 00:38:04 -0700       160)}
ace1534d (Junio C Hamano 2005-05-07 00:38:04 -0700       161)
0fcfd160 (Linus Torvalds 2005-04-18 13:04:43 -0700       162)/*
0fcfd160 (Linus Torvalds 2005-04-18 13:04:43 -0700       163) * NOTE! This returns a statically allocate
790296fd (Jim Meyering   2008-01-03 15:18:07 +0100       164) * careful about using it. Do an "xstrdup()
0fcfd160 (Linus Torvalds 2005-04-18 13:04:43 -0700       165) * filename.
ace1534d (Junio C Hamano 2005-05-07 00:38:04 -0700       166) *
ace1534d (Junio C Hamano 2005-05-07 00:38:04 -0700       167) * Also note that this returns the location
ace1534d (Junio C Hamano 2005-05-07 00:38:04 -0700       168) * SHA1 file can happen from any alternate
d19938ab (Junio C Hamano 2005-05-09 17:57:56 -0700       169) * DB_ENVIRONMENT environment variable if i
```

GIT AND EMAIL

Submitting patches to a project

If you just have a few changes, the simplest way to submit them may just be to send them as patches in email:

First, use git format-patch; for example:

```
$ git format-patch origin
```

will produce a numbered series of files in the current directory, one for each patch in the current branch but not in origin/HEAD.

You can then import these into your mail client and send them by hand. However, if you have a lot to send at once, you may prefer to use the git send-email script to automate the process. Consult the mailing list for your project first to determine how they prefer such patches be handled.

Importing patches to a project

Git also provides a tool called git am (am stands for "apply mailbox"), for importing such an emailed series of patches. Just save all of the patch-containing messages, in order, into a single mailbox file, say "patches.mbox", then run

```
$ git am -3 patches.mbox
```

Git will apply each patch in order; if any conflicts are found, it will stop, and you can fix the conflicts as described in "<<resolving-a-merge,Resolving a merge>>". (The "-3" option tells git to perform a merge; if you would prefer it just to abort and leave your tree and index untouched, you may omit that option.)

Once the index is updated with the results of the conflict resolution, instead of creating a new commit, just run

```
$ git am --resolved
```

and git will create the commit for you and continue applying the remaining patches from the mailbox.

The final result will be a series of commits, one for each patch in the original mailbox, with authorship and commit log message each taken from the message containing each patch.

CUSTOMIZING GIT

git config

Changing your Editor

```
$ git config --global core.editor emacs
```

Adding Aliases

```
$ git config --global alias.last 'cat-file commit HEAD'

$ git last
tree c85fbd1996b8e7e5eda1288b56042c0cdb91836b
parent cdc9a0a28173b6ba4aca00eb34f5aabb39980735
author Scott Chacon <schacon@gmail.com> 1220473867 -0700
committer Scott Chacon <schacon@gmail.com> 1220473867 -0700

fixed a weird formatting problem
```

```
$ git cat-file commit HEAD
tree c85fbd1996b8e7e5eda1288b56042c0cdb91836b
parent cdc9a0a28173b6ba4aca00eb34f5aabb39980735
author Scott Chacon <schacon@gmail.com> 1220473867 -0700
committer Scott Chacon <schacon@gmail.com> 1220473867 -0700

fixed a weird formatting problem
```

Adding Color

See all color.* options in the git config docs

```
$ git config color.branch auto
$ git config color.diff auto
$ git config color.interactive auto
$ git config color.status auto
```

Or, you can set all of them on with the color.ui option:

```
$ git config color.ui true
```

Commit Template

```
$ git config commit.template '/etc/git-commit-template'
```

Log Format

```
$ git config format.pretty oneline
```

Other Config Options

There are also a number of interesting options for packing, gc-ing, merging, remotes, branches, http transport, diffs, paging, whitespace and more. If you want to tweak these, check out the git config docs.

GIT HOOKS

Git Hooks

Server Side Hooks

Post Receive

```
GIT_DIR/hooks/post-receive
```

If you wrote it in Ruby, you might get the args this way:

```
rev_old, rev_new, ref = STDIN.read.split(" ")
```

Or in a bash script, something like this would work:

```
#!/bin/sh
# <oldrev> <newrev> <refname>
# update a blame tree
while read oldrev newrev ref
do
    echo "STARTING [$oldrev $newrev $ref]"
```

```
    for path in `git diff-tree -r $oldrev..$newrev | awk '{print $6}'`
    do
      echo "git update-ref refs/blametree/$ref/$path $newrev"
      `git update-ref refs/blametree/$ref/$path $newrev`
    done
done
```

Client Side Hooks

Pre Commit

Running your tests automatically before you commit

```
GIT_DIR/hooks/pre-commit
```

Here is an example of a Ruby script that runs RSpec tests before allowing a commit.

```
html_path = "spec_results.html"
`spec -f h:#{html_path} -f p spec` # run the spec. send progress to screen. save html results to

# find out how many errors were found
html = open(html_path).read
examples = html.match(/(\d+) examples/)[0].to_i rescue 0
failures = html.match(/(\d+) failures/)[0].to_i rescue 0
pending = html.match(/(\d+) pending/)[0].to_i rescue 0

if failures.zero?
  puts "0 failures! #{examples} run, #{pending} pending"
else
  puts "\aDID NOT COMMIT YOUR FILES!"
```

```
    puts "View spec results at #{File.expand_path(html_path)}"
    puts
    puts "#{failures} failures! #{examples} run, #{pending} pending"
    exit 1
  end
```

- http://probablycorey.wordpress.com/2008/03/07/git-hooks-make-me-giddy/

RECOVERING CORRUPTED OBJECTS

Recovering Lost Commits Blog Post

Recovering Corrupted Blobs by Linus

SUBMODULES

Large projects are often composed of smaller, self-contained modules. For example, an embedded Linux distribution's source tree would include every piece of software in the distribution with some local modifications; a movie player might need to build against a specific, known-working version of a decompression library; several independent programs might all share the same build scripts.

With centralized revision control systems this is often accomplished by including every module in one single repository. Developers can check out all modules or only the modules they need to work with. They can even modify files across several modules in a single commit while moving things around or updating APIs and translations.

Git does not allow partial checkouts, so duplicating this approach in Git would force developers to keep a local copy of modules they are not interested in touching. Commits in an enormous checkout would be slower than you'd expect as Git would have to scan every directory for changes. If modules have a lot of local history, clones would take forever.

On the plus side, distributed revision control systems can much better integrate with external sources. In a centralized model, a single arbitrary snapshot of the external project is exported from its own revision control and then imported into the local revision control on a vendor branch. All the history is hidden. With distributed revision control you can clone the entire external history and much more easily follow development and re-merge local changes.

Git's submodule support allows a repository to contain, as a subdirectory, a checkout of an external project. Submodules maintain their own identity; the submodule support just stores the submodule repository location and commit ID, so other developers who clone the containing project ("superproject") can easily clone all the submodules at the same revision. Partial checkouts of the superproject are possible: you can tell Git to clone none, some or all of the submodules.

The git submodule command is available since Git 1.5.3. Users with Git 1.5.2 can look up the submodule commits in the repository and manually check them out; earlier versions won't recognize the submodules at all.

To see how submodule support works, create (for example) four example repositories that can be used later as a submodule:

```
$ mkdir ~/git
$ cd ~/git
$ for i in a b c d
do
    mkdir $i
    cd $i
    git init
    echo "module $i" > $i.txt
    git add $i.txt
    git commit -m "Initial commit, submodule $i"
```

```
    cd ..
done
```

Now create the superproject and add all the submodules:

```
$ mkdir super
$ cd super
$ git init
$ for i in a b c d
do
    git submodule add ~/git/$i
done
```

NOTE: Do not use local URLs here if you plan to publish your superproject!

See what files `git-submodule` created:

```
$ ls -a
.  ..  .git  .gitmodules  a  b  c  d
```

The `git-submodule add` command does a couple of things:

- It clones the submodule under the current directory and by default checks out the master branch.
- It adds the submodule's clone path to the gitmodules file and adds this file to the index, ready to be committed.
- It adds the submodule's current commit ID to the index, ready to be committed.

Commit the superproject:

```
$ git commit -m "Add submodules a, b, c and d."
```

Now clone the superproject:

```
$ cd ..
$ git clone super cloned
$ cd cloned
```

The submodule directories are there, but they're empty:

```
$ ls -a a
.  ..
$ git submodule status
-d266b9873ad50488163457f025db7cdd9683d88b a
-e81d457da15309b4fef4249aba9b50187999670d b
-c1536a972b9affea0f16e0680ba87332dc059146 c
-d96249ff5d57de5de093e6baff9e0aafa5276a74 d
```

NOTE: The commit object names shown above would be different for you, but they should match the HEAD commit object names of your repositories. You can check it by running `git ls-remote ../a`.

Pulling down the submodules is a two-step process. First run `git submodule init` to add the submodule repository URLs to `.git/config`:

```
$ git submodule init
```

Now use `git-submodule update` to clone the repositories and check out the commits specified in the superproject:

```
$ git submodule update
$ cd a
$ ls -a
.  ..  .git  a.txt
```

One major difference between `git-submodule update` and `git-submodule add` is that `git-submodule update` checks out a specific commit, rather than the tip of a branch. It's like checking out a tag: the head is detached, so you're not working on a branch.

```
$ git branch
* (no branch)
master
```

If you want to make a change within a submodule and you have a detached head, then you should create or checkout a branch, make your changes, publish the change within the submodule, and then update the superproject to reference the new commit:

```
$ git checkout master
```

or

```
$ git checkout -b fix-up
```

then

```
$ echo "adding a line again" >> a.txt
$ git commit -a -m "Updated the submodule from within the superproject."
$ git push
$ cd ..
$ git diff
diff --git a/a b/a
index d266b98..261dfac 160000
--- a/a
+++ b/a
@@ -1 +1 @@
-Subproject commit d266b9873ad50488163457f025db7cdd9683d88b
+Subproject commit 261dfac35cb99d380eb966e102c1197139f7fa24
```

```
$ git add a
$ git commit -m "Updated submodule a."
$ git push
```

You have to run `git submodule update` after `git pull` if you want to update submodules, too.

Pitfalls with submodules

Always publish the submodule change before publishing the change to the superproject that references it. If you forget to publish the submodule change, others won't be able to clone the repository:

```
$ cd ~/git/super/a
$ echo i added another line to this file >> a.txt
$ git commit -a -m "doing it wrong this time"
$ cd ..
$ git add a
$ git commit -m "Updated submodule a again."
$ git push
$ cd ~/git/cloned
$ git pull
$ git submodule update
error: pathspec '261dfac35cb99d380eb966e102c1197139f7fa24' did not match any file(s) known to git.
Did you forget to 'git add'?
Unable to checkout '261dfac35cb99d380eb966e102c1197139f7fa24' in submodule path 'a'
```

You also should not rewind branches in a submodule beyond commits that were ever recorded in any superproject.

It's not safe to run `git submodule update` if you've made and committed changes within a submodule without checking out a branch first. They will be silently overwritten:

```
$ cat a.txt
module a
$ echo line added from private2 >> a.txt
$ git commit -a -m "line added inside private2"
$ cd ..
$ git submodule update
Submodule path 'a': checked out 'd266b9873ad50488163457f025db7cdd9683d88b'
$ cd a
$ cat a.txt
module a
```

NOTE: The changes are still visible in the submodule's reflog.

This is not the case if you did not commit your changes.

Chapter 6

Working with Git

GIT ON WINDOWS

(mSysGit)

DEPLOYING WITH GIT

Capistrano and Git

GitHub Guide on Deploying with Cap

Git and Capistrano Screencast

SUBVERSION INTEGRATION

SCM MIGRATION

So you've made the decision to move away from your existing system and convert your whole project to Git. How can you do that easily?

Importing Subversion

Git comes with a script called git-svn that has a clone command that will import a subversion repository into a new git repository. There is also a free tool on the GitHub service that will do this for you.

```
$ git-svn clone http://my-project.googlecode.com/svn/trunk new-project
```

This will give you a new Git repository with all the history of the original Subversion repo. This takes a pretty good amount of time, generally, since it starts with version 1 and checks out and commits locally every single revision one by one.

Importing Perforce

In contrib/fast-import you will find the git-p4 script, which is a Python script that will import a Perforce repository for you.

```
$ ~/git.git/contrib/fast-import/git-p4 clone //depot/project/main@all myproject
```

Importing Others

These are other SCMs that listed high on the Git Survey, should find import docs for them. !!TODO!!

- CVS
- Mercurial (hg)
- Bazaar-NG
- Darcs
- ClearCase

GRAPHICAL GIT

Git has a couple of fairly popular Graphial User Interfaces that can read and/or maniplulate Git repositories.

Bundled GUIs

Git comes with two major GUI programs written in Tcl/Tk. Gitk is a repository browser and commit history visualization tool.

gitk

git gui is a tool that helps you visualize the index operations, like add, remove and commit. It won't do everything you can do on the command line, but for many of the basic operations, it's pretty good.

git gui

Third Party Projects

For Mac users, there is GitNub

For Linux or other Qt users, there is QGit

HOSTED GIT

github

repoorcz

ALTERNATIVE USES

ContentDistribution

TicGit

SCRIPTING AND GIT

Ruby and Git

grit

jgit + jruby

PHP and Git

Python and Git

pygit

Perl and Git

perlgit

GIT AND EDITORS

textmate

eclipse

netbeans

Chapter 7

Internals and Plumbing

HOW GIT STORES OBJECTS

This chapter goes into detail about how Git physically stores objects.

All objects are stored as compressed contents by their sha values. They contain the object type, size and contents in a gzipped format.

There are two formats that Git keeps objects in - loose objects and packed objects.

Loose Objects

Loose objects are the simpler format. It is simply the compressed data stored in a single file on disk. Every object written to a seperate file.

If the sha of your object is `ab04d884140f7b0cf8bbf86d6883869f16a46f65`, then the file will be stored in the following path:

```
GIT_DIR/objects/ab/04d884140f7b0cf8bbf86d6883869f16a46f65
```

It pulls the first two characters off and uses that as the subdirectory, so that there are never too many objects in one directory. The actual file name is the remaining 38 characters.

The easiest way to describe exactly how the object data is stored is this Ruby implementation of object storage:

```
def put_raw_object(content, type)
  size = content.length.to_s

  header = "#{type} #{size}#body"
  store = header + content

  sha1 = Digest::SHA1.hexdigest(store)
  path = @git_dir + '/' + sha1[0...2] + '/' + sha1[2..40]

  if !File.exists?(path)
    content = Zlib::Deflate.deflate(store)

    FileUtils.mkdir_p(@directory+'/'+sha1[0...2])
    File.open(path, 'w') do |f|
      f.write content
    end
  end
  return sha1
end
```

Packed Objects

The other format for object storage is the packfile. Since Git stores each version of each file as a seperate object, it can get pretty inefficient. Imagine having a file several thousand lines long and changing a single line. Git will store the second file in it's entirety, which is a great big waste of space.

In order to save that space, Git utilizes the packfile. This is a format where Git will only save the part that has changed in the second file, with a pointer to the file it is similar to.

When objects are written to disk, it is often in the loose format, since that format is less expensive to access. However, eventually you'll want to save the space by packing up the objects - this is done with the git gc command. It will use a rather complicated heuristic to determine which files are likely most similar and base the deltas off that analysis. There can be multiple packfiles, they can be repacked if neccesary (git repack) or unpacked back into loose files (git unpack-objects) relatively easily.

Git will also write out an index file for each packfile that is much smaller and contains offsets into the packfile to more quickly find specific objects by sha.

The actual details of the packfile implementation are found in the Packfile chapter a little later on.

BROWSING GIT OBJECTS

We can ask git about particular objects with the cat-file command. Note that you can shorten the shas to only a few characters to save yourself typing all 40 hex digits:

```
$ git-cat-file -t 54196cc2
commit
$ git-cat-file commit 54196cc2
```

```
tree 92b8b694ffb1675e5975148e1121810081dbdffe
author J. Bruce Fields <bfields@puzzle.fieldses.org> 1143414668 -0500
committer J. Bruce Fields <bfields@puzzle.fieldses.org> 1143414668 -0500

initial commit
```

A tree can refer to one or more "blob" objects, each corresponding to a file. In addition, a tree can also refer to other tree objects, thus creating a directory hierarchy. You can examine the contents of any tree using ls-tree (remember that a long enough initial portion of the SHA1 will also work):

```
$ git ls-tree 92b8b694
100644 blob 3b18e512dba79e4c8300dd08aeb37f8e728b8dad    file.txt
```

Thus we see that this tree has one file in it. The SHA1 hash is a reference to that file's data:

```
$ git cat-file -t 3b18e512
blob
```

A "blob" is just file data, which we can also examine with cat-file:

```
$ git cat-file blob 3b18e512
hello world
```

Note that this is the old file data; so the object that git named in its response to the initial tree was a tree with a snapshot of the directory state that was recorded by the first commit.

All of these objects are stored under their SHA1 names inside the git directory:

```
$ find .git/objects/
.git/objects/
.git/objects/pack
```

```
.git/objects/info
.git/objects/3b
.git/objects/3b/18e512dba79e4c8300dd08aeb37f8e728b8dad
.git/objects/92
.git/objects/92/b8b694ffb1675e5975148e1121810081dbdffe
.git/objects/54
.git/objects/54/196cc2703dc165cbd373a65a4dcf22d50ae7f7
.git/objects/a0
.git/objects/a0/423896973644771497bdc03eb99d5281615b51
.git/objects/d0
.git/objects/d0/492b368b66bdabf2ac1fd8c92b39d3db916e59
.git/objects/c4
.git/objects/c4/d59f390b9cfd4318117afde11d601c1085f241
```

and the contents of these files is just the compressed data plus a header identifying their length and their type. The type is either a blob, a tree, a commit, or a tag.

The simplest commit to find is the HEAD commit, which we can find from .git/HEAD:

```
$ cat .git/HEAD
ref: refs/heads/master
```

As you can see, this tells us which branch we're currently on, and it tells us this by naming a file under the .git directory, which itself contains a SHA1 name referring to a commit object, which we can examine with cat-file:

```
$ cat .git/refs/heads/master
c4d59f390b9cfd4318117afde11d601c1085f241
$ git cat-file -t c4d59f39
commit
$ git cat-file commit c4d59f39
tree d0492b368b66bdabf2ac1fd8c92b39d3db916e59
parent 54196cc2703dc165cbd373a65a4dcf22d50ae7f7
author J. Bruce Fields <bfields@puzzle.fieldses.org> 1143418702 -0500
```

```
committer J. Bruce Fields <bfields@puzzle.fieldses.org> 1143418702 -0500

add emphasis
```

The "tree" object here refers to the new state of the tree:

```
$ git ls-tree d0492b36
100644 blob a0423896973644771497bdc03eb99d5281615b51    file.txt
$ git cat-file blob a0423896
hello world!
```

and the "parent" object refers to the previous commit:

```
$ git-cat-file commit 54196cc2
tree 92b8b694ffb1675e5975148e1121810081dbdffe
author J. Bruce Fields <bfields@puzzle.fieldses.org> 1143414668 -0500
committer J. Bruce Fields <bfields@puzzle.fieldses.org> 1143414668 -0500
```

GIT REFERENCES

Branches, remote-tracking branches, and tags are all references to commits. All references are named with a slash-separated path name starting with "refs"; the names we've been using so far are actually shorthand:

```
- The branch "test" is short for "refs/heads/test".
- The tag "v2.6.18" is short for "refs/tags/v2.6.18".
- "origin/master" is short for "refs/remotes/origin/master".
```

The full name is occasionally useful if, for example, there ever exists a tag and a branch with the same name.

(Newly created refs are actually stored in the .git/refs directory, under the path given by their name. However, for efficiency reasons they may also be packed together in a single file; see git pack-refs).

As another useful shortcut, the "HEAD" of a repository can be referred to just using the name of that repository. So, for example, "origin" is usually a shortcut for the HEAD branch in the repository "origin".

For the complete list of paths which git checks for references, and the order it uses to decide which to choose when there are multiple references with the same shorthand name, see the "SPECIFYING REVISIONS" section of git rev-parse.

Showing commits unique to a given branch

Suppose you would like to see all the commits reachable from the branch head named "master" but not from any other head in your repository.

We can list all the heads in this repository with git show-ref:

```
$ git show-ref --heads
bf62196b5e363d73353a9dcf094c59595f3153b7 refs/heads/core-tutorial
db768d5504c1bb46f63ee9d6e1772bd047e05bf9 refs/heads/maint
a07157ac624b2524a059a3414e99f6f44bebc1e7 refs/heads/master
24dbc180ea14dc1aebe09f14c8ecf32010690627 refs/heads/tutorial-2
1e87486ae06626c2f31eaa63d26fc0fd646c8af2 refs/heads/tutorial-fixes
```

We can get just the branch-head names, and remove "master", with the help of the standard utilities cut and grep:

```
$ git show-ref --heads | cut -d' ' -f2 | grep -v '^refs/heads/master'
refs/heads/core-tutorial
refs/heads/maint
refs/heads/tutorial-2
refs/heads/tutorial-fixes
```

And then we can ask to see all the commits reachable from master but not from these other heads:

```
$ gitk master --not $( git show-ref --heads | cut -d' ' -f2 |
                grep -v '^refs/heads/master' )
```

Obviously, endless variations are possible; for example, to see all commits reachable from some head but not from any tag in the repository:

```
$ gitk $( git show-ref --heads ) --not  $( git show-ref --tags )
```

(See git rev-parse for explanations of commit-selecting syntax such as `--not`.)

(!!update-ref!!)

THE GIT INDEX

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; git ls-files can show you the contents of the index:

```
$ git ls-files --stage
100644 63c918c667fa005ff12ad89437f2fdc80926e21c 0   .gitignore
100644 5529b198e8d14decbe4ad99db3f7fb632de0439d 0   .mailmap
100644 6ff87c4664981e4397625791c8ea3bbb5f2279a3 0   COPYING
100644 a37b2152bd26be2c2289e1f57a292534a51a93c7 0   Documentation/.gitignore
100644 fbefe9a45b00a54b58d94d06eca48b03d40a50e0 0   Documentation/Makefile
...
100644 2511aef8d89ab52be5ec6a5e46236b4b6bcd07ea 0   xdiff/xtypes.h
100644 2ade97b2574a9f77e7ae4002a4e07a6a38e46d07 0   xdiff/xutils.c
100644 d5de8292e05e7c36c4b68857c1cf9855e3d2f70a 0   xdiff/xutils.h
```

Note that in older documentation you may see the index called the "current directory cache" or just the "cache". It has three important properties:

1. The index contains all the information necessary to generate a single (uniquely determined) tree object.

   For example, running git commit generates this tree object from the index, stores it in the object database, and uses it as the tree object associated with the new commit.

2. The index enables fast comparisons between the tree object it defines and the working tree.

   It does this by storing some additional data for each entry (such as the last modified time). This data is not displayed above, and is not stored in the created tree object, but it can be used to determine quickly which files in the working directory differ from what was stored in the index, and thus save git from having to read all of the data from such files to look for changes.

3. It can efficiently represent information about merge conflicts between different tree objects, allowing each pathname to be associated with sufficient information about the trees involved that you can create a three-way merge between them.

   We saw in <<conflict-resolution>> that during a merge the index can store multiple versions of a single file (called "stages"). The third column in the git ls-files output above is the stage number, and will take on values other than 0 for files with merge conflicts.

The index is thus a sort of temporary staging area, which is filled with a tree which you are in the process of working on.

THE PACKFILE

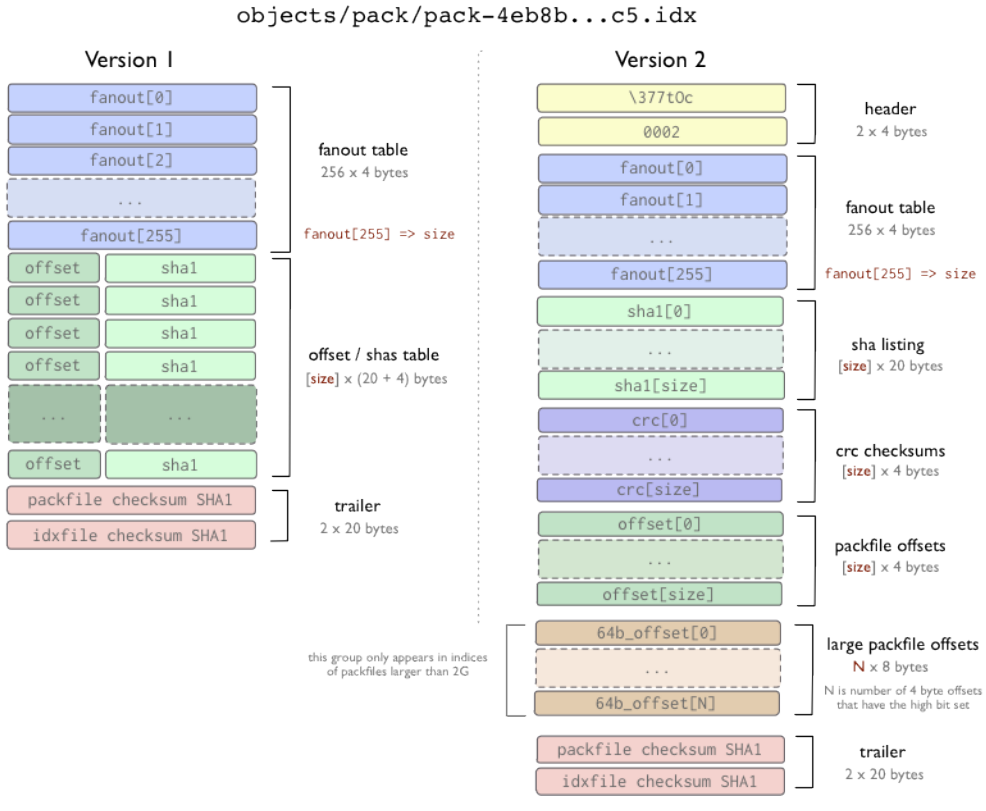
This chapter explains in detail, down to the bits, how the packfile and pack index files are formatted.

The Packfile Index

First off, we have the packfile index, which is basically just a series of bookmarks into a packfile.

There are two versions of the packfile index - version one, which is the default in versions of Git earlier than 1.6, and version two, which is the default from 1.6 forward, but which can be read by Git versions going back to 1.5.2, and has been further backported to 1.4.4.5 if you are still on the 1.4 series.

Version 2 also includes a CRC checksum of each object so compressed data can be copied directly from pack to pack during repacking without undetected data corruption. Version 2 indexes can also handle packfiles larger than 4 Gb.



In both formats, the fanout table is simply a way to find the offset of a particular sha faster within the index file. The offset/sha1[] tables are sorted by sha1[] values (this is to allow binary search of this table), and fanout[] table points at the offset/

sha1[] table in a specific way (so that part of the latter table that covers all hashes that start with a given byte can be found to avoid 8 iterations of the binary search).

In version 1, the offsets and shas are in the same space, where in version two, there are seperate tables for the shas, crc checksums and offsets. At the end of both files are checksum shas for both the index file and the packfile it references.

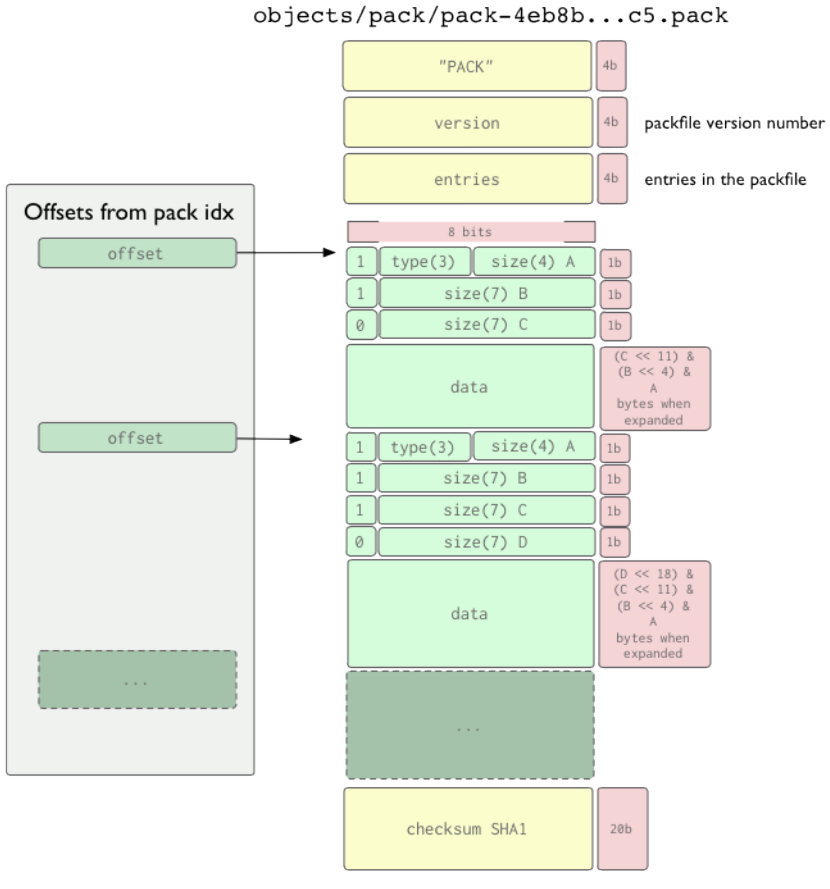
Importantly, packfile indexes are *not* neccesary to extract objects from a packfile, they are simply used to *quickly* retrieve individual objects from a pack. The packfile format is used in upload-pack and receieve-pack programs (push and fetch protocols) to transfer objects and there is no index used then - it can be built after the fact by scanning the packfile.

The Packfile Format

The packfile itself is a very simple format. There is a header, a series of packed objects (each with it's own header and body) and then a checksum trailer. The first four bytes is the string 'PACK', which is sort of used to make sure you're getting the start of the packfile correctly. This is followed by a 4-byte packfile version number and then a 4-byte number of entries in that file. In Ruby, you might read the header data like this:

```
def read_pack_header
  sig = @session.recv(4)
  ver = @session.recv(4).unpack("N")[0]
  entries = @session.recv(4).unpack("N")[0]
  [sig, ver, entries]
end
```

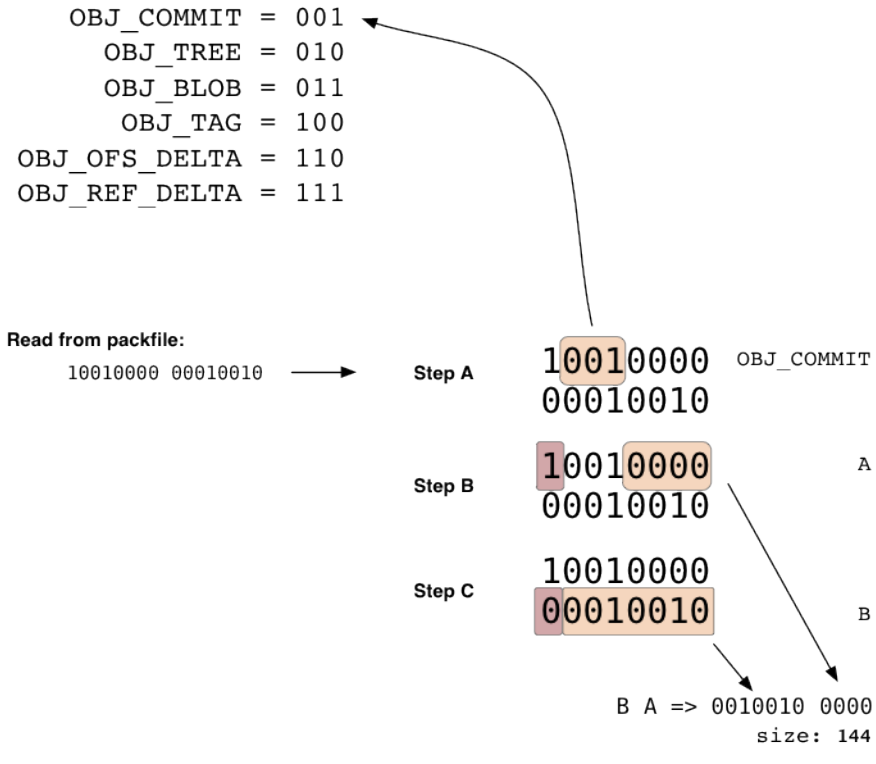
After that, you get a series of packed objects, in order of thier SHAs which each consist of an object header and object contents. At the end of the packfile is a 20-byte SHA1 sum of all the shas (in sorted order) in that packfile.


objects/pack/pack-4eb8b...c5.pack
"PACK"
4b
version
4b
packfile version number
entries
4b
entries in the packfile
Offsets from pack idx
offset
offset
...
8 bits
1
type(3)
size(4) A
1b
1
size(7) B
1b
0
size(7) C
1b
data
(C << 11) &
(B << 4) &
A
bytes when
expanded
1
type(3)
size(4) A
1b
1
size(7) B
1b
1
size(7) C
1b
0
size(7) D
1b
data
(D << 18) &
(C << 11) &
(B << 4) &
A
bytes when
expanded
...
checksum SHA1
20b

The object header is a series of one or more 1 byte (8 bit) hunks that specify the type of object the following data is, and the size of the data when expanded. Each byte is really 7 bits of data, with the first bit being used to say if that hunk is the last one or not before the data starts. If the first bit is a 1, you will read another byte, otherwise the data starts next. The first 3 bits in the first byte specifies the type of data, according to the table below.

(Currently, of the 8 values that can be expressed with 3 bits (0-7), 0 (000) is 'undefined' and 5 (101) is not yet used.)

Here, we can see an example of a header of two bytes, where the first specifies that the following data is a commit, and the remainder of the first and the last 7 bits of the second specifies that the data will be 144 bytes when expanded.



It is important to note that the size specified in the header data is not the size of the data that actually follows, but the size of that data *when expanded*. This is why the offsets in the packfile index are so useful, otherwise you have to expand every object just to tell when the next header starts.

The data part is just zlib stream for non-delta object types; for the two delta object representations, the data portion contains something that identifies which base object this delta representation depends on, and the delta to apply on the base object to resurrect this object. `ref-delta` uses 20-byte hash of the base object at the beginning of data, while `ofs-delta` stores an offset within the same packfile to identify the base object. In either case, two important constraints a reimplementor must adhere to are:

- delta representation must be based on some other object within the same packfile;
- the base object must be of the same underlying type (blob, tree, commit or tag);

RAW GIT

Here we will take a look at how to manipulate git at a more raw level, in case you would like to write a tool that generates new blobs, trees or commits in a more artificial way. If you want to write a script that uses more low-level git plumbing to do something new, here are some of the tools you'll need.

Creating Blobs

Creating a blob in your Git repository and getting a SHA back is pretty easy. The git hash-object command is all you'll need. To create a blob object from an existing file, just run it with the '-w' option (which tells it to write the blob, not just compute the SHA).

```
$ git hash-object -w myfile.txt
6ff87c4664981e4397625791c8ea3bbb5f2279a3

$ git hash-object -w myfile2.txt
3bb0e8592a41ae3185ee32266c860714980dbed7
```

The STDOUT output of the command will the the SHA of the blob that was created.

Creating Trees

Now lets say you want to create a tree from your new objects. The git mktree command makes it pretty simple to generate new tree objects from git ls-tree formatted output. For example, if you write the following to a file named '/tmp/tree.txt' :

```
100644 blob 6ff87c4664981e4397625791c8ea3bbb5f2279a3    file1
100644 blob 3bb0e8592a41ae3185ee32266c860714980dbed7    file2
```

and then piped that through the git mktree command, Git will write a new tree to the object database and give you back the new sha of that tree.

```
$ cat /tmp/tree.txt | git mk-tree
f66a66ab6a7bfe86d52a66516ace212efa00fe1f
```

Then, we can take that and make it a subdirectory of yet another tree, and so on. If we wanted to create a new tree with that one as a subtree, we just create a new file (/tmp/newtree.txt) with our new SHA as a tree in it:

```
100644 blob 6ff87c4664981e4397625791c8ea3bbb5f2279a3    file1-copy
040000 tree f66a66ab6a7bfe86d52a66516ace212efa00fe1f    our_files
```

and then use git mk-tree again:

```
$ cat /tmp/newtree.txt | git mk-tree
5bac6559179bd543a024d6d187692343e2d8ae83
```

And we now have an artificial directory structure in Git that looks like this:

```
.
|-- file1-copy
`-- our_files
    |-- file1
    `-- file2

1 directory, 3 files
```

without that structure ever having actually existed on disk. Plus, we have a SHA (5bac6559) that points to it.

Rearranging Trees

We can also do tree manipulation by combining trees into new structures using the index file. As a simple example, let's take the tree we just created and make a new tree that has two copies of our 5bac6559 tree in it using a temporary index file. (You can do this by resetting the GIT*INDEX*FILE environment variable or on the command line)

First, we read the tree into our index file under a new prefix using the git read-tree command, and then write the index contents as a tree using the git write-tree command:

```
$ export GIT_INDEX_FILE=/tmp/index
$ git read-tree --prefix=copy1/  5bac6559
$ git read-tree --prefix=copy2/  5bac6559
$ git write-tree
bb2fa6de7625322322382215d9ea78cfe76508c1

$>git ls-tree bb2fa
040000 tree 5bac6559179bd543a024d6d187692343e2d8ae83    copy1
040000 tree 5bac6559179bd543a024d6d187692343e2d8ae83    copy2
```

So now we can see that we've created a new tree just from index manipulation. You can also do interesting merge operations and such in a temporary index this way - see the git read-tree docs for more information.

Creating Commits

Now that we have a tree SHA, we can create a commit object that points to it. We can do this using the git commit-tree command. Most of the data that goes into the commit has to be set as environment variables, so you'll want to set the following:

```
GIT_AUTHOR_NAME
GIT_AUTHOR_EMAIL
GIT_AUTHOR_DATE
GIT_COMMITTER_NAME
GIT_COMMITTER_EMAIL
GIT_COMMITTER_DATE
```

Then you will need to write your commit message to a file or somehow pipe it into the command through STDIN. Then, you can create your commit object based on the tree sha we have.

```
$ git commit-tree bb2fa < /tmp/message
a5f85ba5875917319471dfd98dfc636c1dc65650
```

If you want to specify one or more parent commits, simply add the shas on the command line with a '-p' option before each. The SHA of the new commit object will be returned via STDOUT.

Updating a Branch Ref

Now that we have a new commit object SHA, we can update a branch to point to it if we want to. Lets say we want to update our 'master' branch to point to the new commit we just created - we would use the git update-ref command. Technically, you can just do something like this:

```
$ echo 'a5f85ba5875917319471dfd98dfc636c1dc65650' > .git/refs/heads/master
```

But a safer way of doing that is to use the update-ref command:

```
$ git update-ref refs/heads/master a5f85ba5875917319471dfd98dfc636c1dc65650
```

TRANSFER PROTOCOLS

Here we will go over how clients and servers talk to each other to transfer Git data around.

Fetching Data over HTTP

Fetching over an http/s URL will make Git use a slightly dumber protocol. In this case, all of the logic is entirely on the client side. The server requires no special setup - any static webserver will work fine if the git directory you are fetching from is in the webserver path.

In order for this to work, you do need to run a single command on the server repo everytime anything is updated, though - git update-server-info, which updates the objects/info/packs and info/refs files to list which refs and packfiles are available, since you can't do a listing over http. When that command is run, the objects/info/packs file looks something like this:

```
P pack-ce2bd34abc3d8ebc5922dc81b2e1f30bf17c10cc.pack
P pack-7ad5f5d05f5e20025898c95296fe4b9c861246d8.pack
```

So that if the fetch can't find a loose file, it can try these packfiles. The info/refs file will look something like this:

```
184063c9b594f8968d61a686b2f6052779551613    refs/heads/development
32aae7aef7a412d62192f710f2130302997ec883    refs/heads/master
```

Then when you fetch from this repo, it will start with these refs and walk the commit objects until the client has all the objects that it needs.

For instance, if you ask to fetch the master branch, it will see that master is pointing to 32aae7ae and that your master is pointing to ab04d88, so you need 32aae7ae. You fetch that object

```
CONNECT http://myserver.com
GET /git/myproject.git/objects/32/aae7aef7a412d62192f710f2130302997ec883 - 200
```

and it looks like this:

```
tree aa176fb83a47d00386be237b450fb9dfb5be251a
parent bd71cad2d597d0f1827d4a3f67bb96a646f02889
author Scott Chacon <schacon@gmail.com> 1220463037 -0700
committer Scott Chacon <schacon@gmail.com> 1220463037 -0700

added chapters on private repo setup, scm migration, raw git
```

So now it fetches the tree aa176fb8:

```
GET /git/myproject.git/objects/aa/176fb83a47d00386be237b450fb9dfb5be251a - 200
```

which looks like this:

```
100644 blob 6ff87c4664981e4397625791c8ea3bbb5f2279a3    COPYING
100644 blob 97b51a6d3685b093cfb345c9e79516e5099a13fb    README
100644 blob 9d1b23b8660817e4a74006f15fae86e2a508c573    Rakefile
```

So then it fetches those objects:

```
GET /git/myproject.git/objects/6f/f87c4664981e4397625791c8ea3bbb5f2279a3 - 200
GET /git/myproject.git/objects/97/b51a6d3685b093cfb345c9e79516e5099a13fb - 200
GET /git/myproject.git/objects/9d/1b23b8660817e4a74006f15fae86e2a508c573 - 200
```

It actually does this with Curl, and can open up multiple parallel threads to speed up this process. When it's done recursing the tree pointed to by the commit, it fetches the next parent.

```
GET /git/myproject.git/objects/bd/71cad2d597d0f1827d4a3f67bb96a646f02889 - 200
```

Now in this case, the commit that comes back looks like this:

```
tree b4cc00cf8546edd4fcf29defc3aec14de53e6cf8
parent ab04d884140f7b0cf8bbf86d6883869f16a46f65
author Scott Chacon <schacon@gmail.com> 1220421161 -0700
committer Scott Chacon <schacon@gmail.com> 1220421161 -0700

added chapters on the packfile and how git stores objects
```

and we can see that the parent, `ab04d88` is where our master branch is currently pointing. So, we recursively fetch this tree and then stop, since we know we have everything before this point. You can force Git to double check that we have everything with the '--recover' option. See git http-fetch for more information.

If one of the loose object fetches fails, Git will download the packfile indexes looking for the sha that it needs, then download that packfile.

It is important if you are running a git server that serves repos this way to implement a post-receive hook that runs the 'git update-server-info' command each time or there will be confusion.

Fetching Data with Upload Pack

For the smarter protocols, fetching objects is much more efficient. A socket is opened, either over ssh or over port 9418 (in the case of the git:// protocol), and the git fetch-pack command on the client begins communicating with a forked git upload-pack process on the server.

Then the server will tell the client which SHAs it has for each ref, and the client figures out what it needs and responds with a list of SHAs it wants and already has.

At this point, the server will generate a packfile with all the objects that the client needs and begin streaming it down to the client.

Let's look at an example.

The client connects and sends the request header. The clone command

```
$ git clone git://myserver.com/project.git
```

produces the following request:

```
0032git-upload-pack /project.git\000host=myserver.com\000
```

The first four bytes contain the hex length of the line (including 4 byte line length and trailing newline if present). Following are the command and arguments. This is followed by a null byte and then the host information. The request is terminated by a null byte.

The request is processed and turned into a call to git-upload-pack:

```
$ git-upload-pack /path/to/repos/project.git
```

This immediately returns information of the repo:

```
007c74730d410fcb6603ace96f1dc55ea6196122532d HEAD\000multi_ack thin-pack side-band side-band-64k ofs-delta shall
003e7d1665144a3a975c05f1f43902ddaf084e784dbe refs/heads/debug
003d5a3f6be755bbb7deae50065988cbfa1ffa9ab68a refs/heads/dist
003e7e47fe2bd8d01d481f44d7af0531bd93d3b21c01 refs/heads/local
```

```
003f74730d410fcb6603ace96f1dc55ea6196122532d refs/heads/master
0000
```

Each line starts with a four byte line length declaration in hex. The section is terminated by a line length declaration of 0000.

This is sent back to the client verbatim. The client responds with another request:

```
0054want 74730d410fcb6603ace96f1dc55ea6196122532d multi_ack side-band-64k ofs-delta
0032want 7d1665144a3a975c05f1f43902ddaf084e784dbe
0032want 5a3f6be755bbb7deae50065988cbfa1ffa9ab68a
0032want 7e47fe2bd8d01d481f44d7af0531bd93d3b21c01
0032want 74730d410fcb6603ace96f1dc55ea6196122532d
00000009done
```

The is sent to the open git-upload-pack process which then streams out the final response:

```
"0008NAK\n"
"0023\002Counting objects: 2797, done.\n"
"002b\002Compressing objects:   0% (1/1177)   \r"
"002c\002Compressing objects:   1% (12/1177)   \r"
"002c\002Compressing objects:   2% (24/1177)   \r"
"002c\002Compressing objects:   3% (36/1177)   \r"
"002c\002Compressing objects:   4% (48/1177)   \r"
"002c\002Compressing objects:   5% (59/1177)   \r"
"002c\002Compressing objects:   6% (71/1177)   \r"
"0053\002Compressing objects:   7% (83/1177)   \rCompressing objects:   8% (95/1177)   \r"
...
"005b\002Compressing objects: 100% (1177/1177)   \rCompressing objects: 100% (1177/1177), done.\n"
"2004\001PACK\000\000\000\002\000\000\n\355\225\017x\234\235\216K\n\302"...
"2005\001\360\204{\225\376\330\345]z2673"...
...
"0037\002Total 2797 (delta 1799), reused 2360 (delta 1529)\n"
```

```
...
"<\276\255L\273s\005\001w0006\001[0000"
```

See the Packfile chapter previously for the actual format of the packfile data in the response.

Pushing Data

Pushing data over the git and ssh protocols is similar, but simpler. Basically what happens is the client requests a receive-pack instance, which is started up if the client has access, then the server returns all the ref head shas it has again and the client generates a packfile of everything the server needs (generally only if what is on the server is a direct ancestor of what it is pushing) and sends that packfile upstream, where the server either stores it on disk and builds an index for it, or unpacks it (if there aren't many objects in it)

This entire process is accomplished through the git send-pack command on the client, which is invoked by git push and the git receive-pack command on the server side, which is invoked by the ssh connect process or git daemon (if it's an open push server).