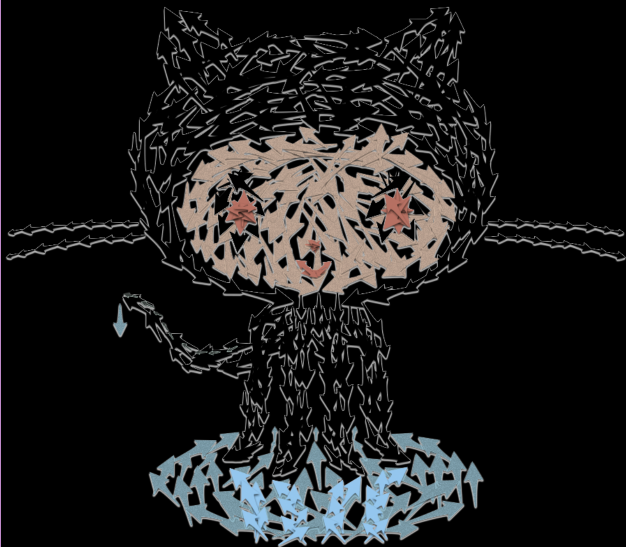
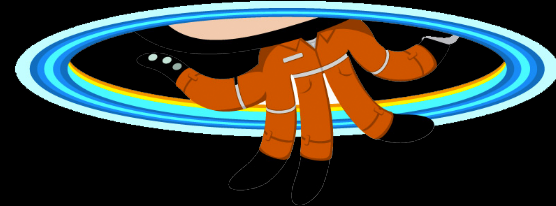




Git Internals

by Jonathan Miedel and Alvin Wang

Last Week on Git

- Midterm Review
- Cherry Picking
- Reflog

What is Git internals and why?

- We will look at how Git works at a lower level.
- How Git manages your files and how it creates commits.

- This information will give you a higher level of understanding of Git
- “Your ability to fix problems that arise in git will greatly increase” -- Alvin Wang

Historically Low Level

- Early in its history it had a much more complex interface
- Closer to toolkit for VCS's rather than a full fledged VCS in its own right
- Git at its base is a content addressable filesystem

Content Addressable Filesystem

- Retrieve files based on content instead of location/path
- Retrieves data using hash keys
- High-speed storage
- Great for storing files that will not change

Hashing

- Take some data and shorten it to a key
  - The key is a hopefully unique identifier
- Produce random looking key even with small changes
- Can use key to lookup data later
- Should minimize collisions
- Easy to generate
- Hard to invert

SHA-1

- Cryptographic Hash Function
  - cryptographic implies extremely hard to invert
  - Essentially means 1 way
- Most widely used SHA hash function
  - used in SSL and SSH
- Published in 1995

SHA-1 Features

- 20 byte key size
- Key size affects security
  - Being deprecated in very secure applications
  - Wikipedia says you only need 2^69 to build a collision (far less than ideal)
- Merkle-Damgård Construction

“If all 6.5 billion humans on Earth were programming, and every second, each one was producing code that was the equivalent of the entire Linux kernel history (3.6 million Git objects) and pushing it into one enormous Git repository, it would take roughly 2 years until that repository contained enough objects to have a 50% probability of a single SHA-1 object collision.” - Scott Chacon

Hashing Demo

http://www.sha1-online.com/

Hashing in Git

- git uses SHA-1
- git uses hashing to identify and organize blobs
  - Blobs are chunks of files with information regarding chunk size
- Also used to identify commits
  - It is hash of the entire commit object
- Used for consistency not for security
  - Consistency indirectly ensures security

Plumbing vs. Porcelain

- Commands can be grouped into two groups
- Plumbing commands are lower level
    - intended to be used programmatically
    - git cat-file, git hash-object, git update-ref
- Porcelain are higher level
    - intended to be used by normal everyday users
    - git pull, git add, git branch, git bisect

.git Overview

- HEAD
- FETCH_HEAD
- ORIG_HEAD
- config
- description
- hooks/
- index
- info/
- logs
- objects/
- packedrefs/
- refs/

git ls-files

- `git ls-files`
- shows the index in human readable format

Lets look at the folder

Git Objects

- Git stores pretty much everything in objects
- Objects consist of a type, a size and content
  - types:
    - blob - chunks of binary data
    - tree - similar to directory, references other trees and blobs
    - commit - pointer to a single tree
    - tag - special marking on a commit
- `find .git/objects/` to look at all the objects
  - first two letters become the folder name and the remaining 38 characters are the filename of the object

git show

- `git show -s --pretty=raw <commit hash>`
- allows you to look at detailed commit information

git ls-tree

- git ls-tree <object>
- Displays the tree of the object
  - displays mode type hash path
- Only works on tree objects

git cat-file

git cat-file <object hash>

will show contents of the file

Objects Demo

git show and git ls-tree

Object Types: part 1

Blob Object

5b1d3..

blob	size

```
#ifndef REVISION_H
#define REVISION_H

#include "parse-options.h"

#define SEEN            (1u<<0)
#define UNINTERESTING   (1u
#define TREESAME  (1u<<2)
```

Tree Object

c36d4..

tree		size
blob	5b1d3	README
tree	03e78	lib
tree	cdc8b	test
blob	cba0a	test.rb
blob	911e7	xdiff

Object Types: part 2

Commit Object

ae668..

commit	size
tree	c4ec5
parent	a149e
author	Scott
committer	Scott

my commit message goes here and it is really, really cool

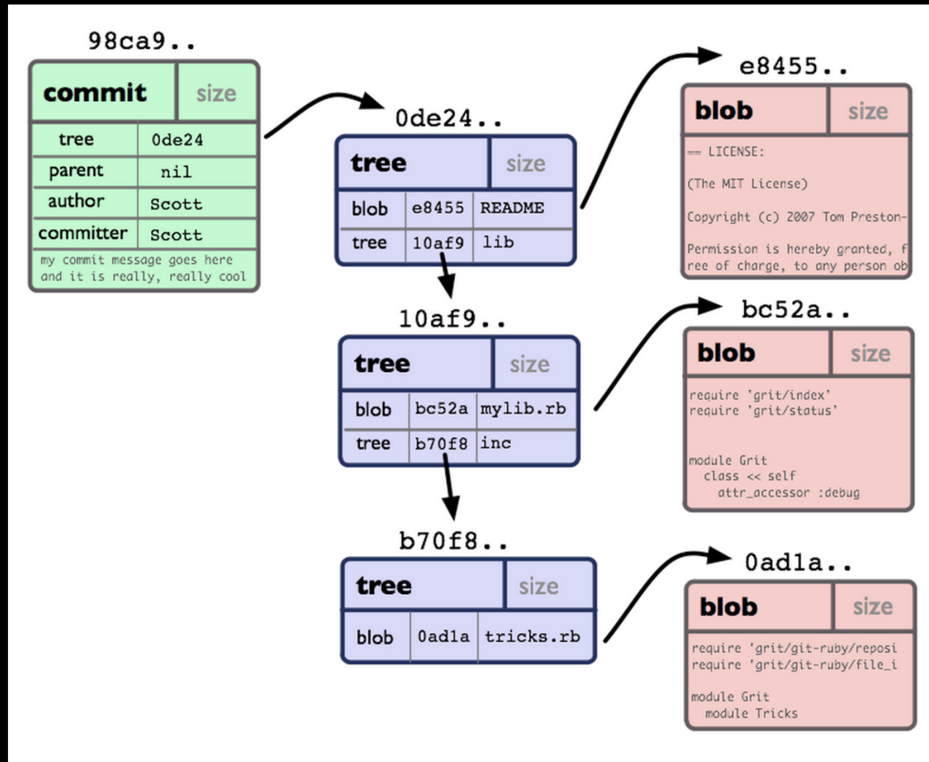
Tag Object

49e11..

tag	size
object	ae668
type	commit
tagger	Scott

my tag message that explains this tag

Git Object Illustration



http://git-scm.com/book/en/Git-Internals-Git-Objects

Ruby implementation of git file storage

```
def put_raw_object(content, type)
  size = content.length.to_s
```
<-- Size is one of the 3 components of an object

```
  header = "#{type} #{size}\0" # type(space)size(null byte)
  store = header + content
```
<-- type is the object type

```
  sha1 = Digest::SHA1.hexdigest(store)
```
<-- hash the header+content

```
  path = @git_dir + '/' + sha1[0...2] + '/' + sha1[2..40]
```
<-- creates the path by taking the first two characters as the folder and the last 38 as the file name

```
  if !File.exists?(path)
    content = Zlib::Deflate.deflate(store)
```
<-- if file does not exist, compress it using ZLib

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

```
    end
  end
  return sha1
```
<-- return SHA-1 hash

```
end
```

Example The Commit Object

- All parent object ids
- Author name, email and date
- Committer name and email and the commit time
- Hash of the above

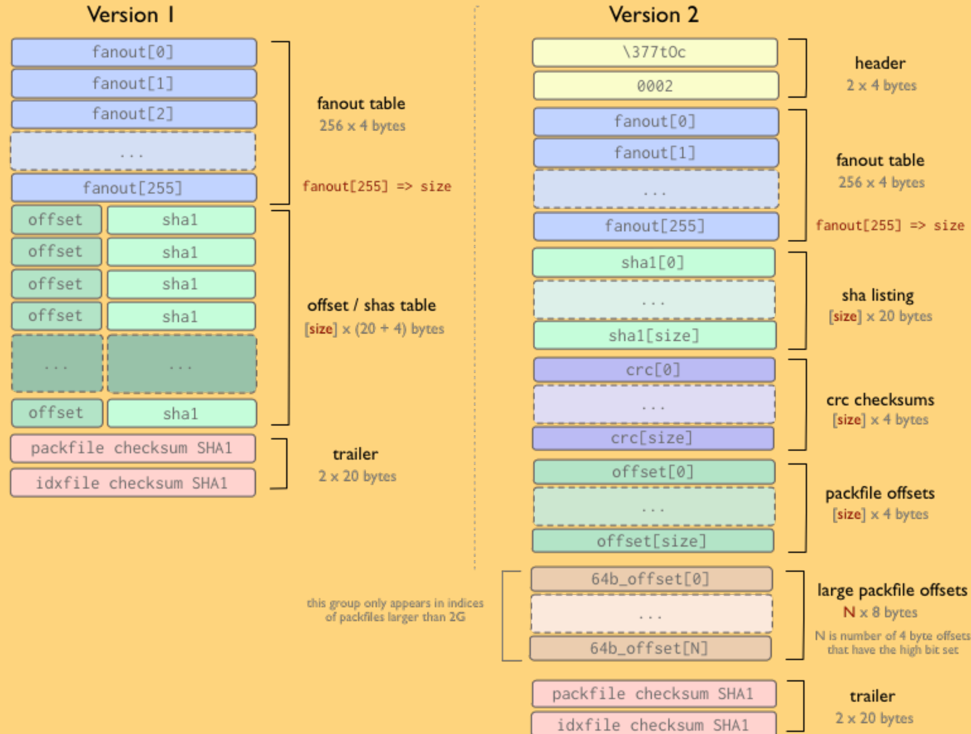
Cool Plumbing Commands

- plumbing command:
  - `git hash-object`
    - takes your data gives you back the hash of it
    - -w stores it into .git as an object
  - git cat-file <hash>
    - takes hash and outputs original information

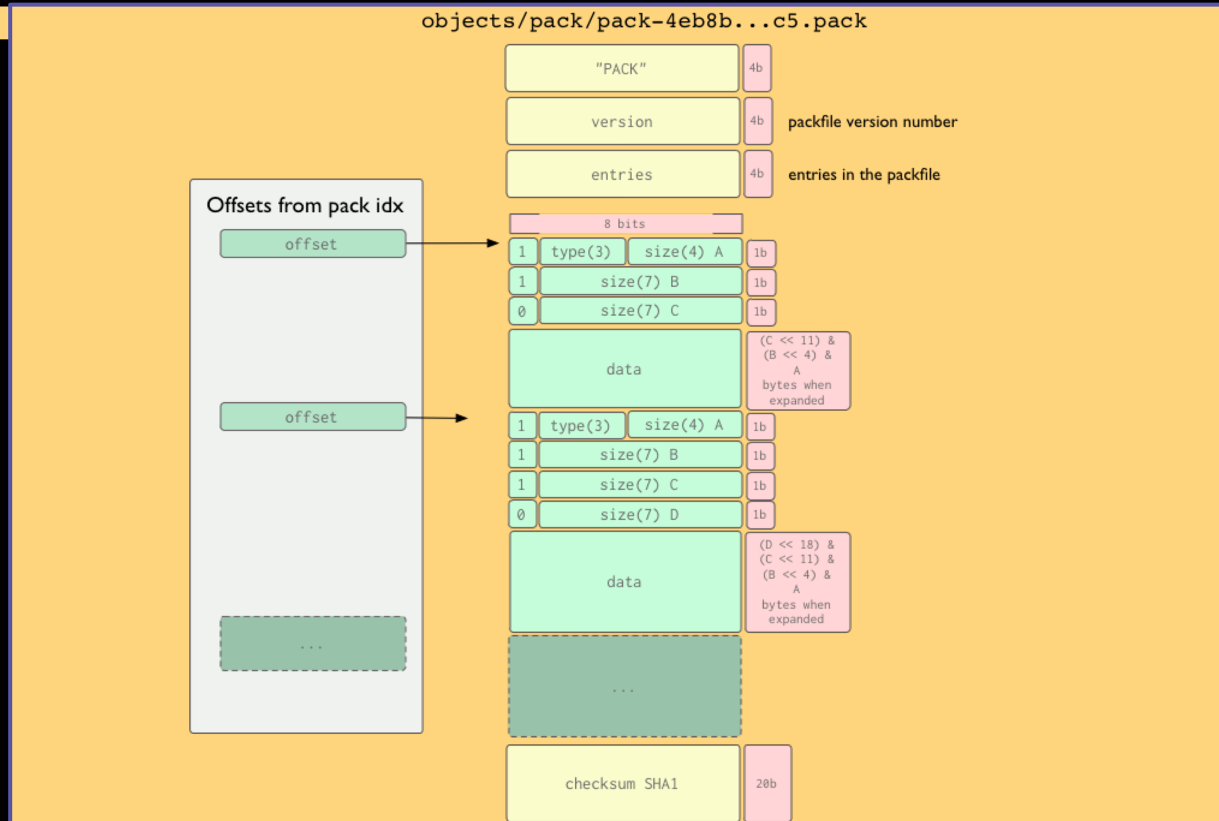
Loose objects + packed objects

- both types are compressed
- loose objects are compressed blobs
- easier and faster to access
- `git gc` - packs the files into packs
- packing algorithm analyzes loose objects to figure out deltas to prevent storing duplicate data

The Packfile Index (idx)



The Packfile



High level Description

- Starts with header
  - Version information, entry number
- List of compressed objects
- Ends in checksum

Compressed Objects

- Header
  - Size, Type
- Data
  - for non-delta objects
    - simply data
  - for delta objects it is the base object
    - base object
    - deltas needed to reconstruct

Packfile Demo

HW 5

- Review this week's slides
- Short quiz (counts as a HW grade) at the beginning of the next class to reinforce some of these complex topics

Next Week in Git Stuco

- Git Internals (Part 2)