Software Heritage

Technical challenges when archiving the entire Software Commons

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Inria, Software Heritage

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Inria Rocquencourt

Software Heritage
THE GREAT LIBRARY OF SOURCE CODE

Outline

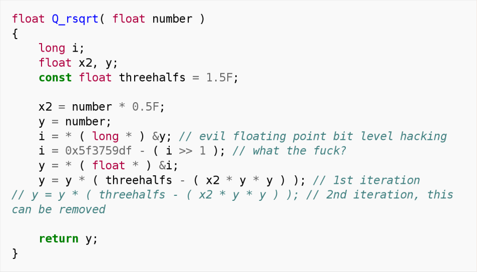
1. The Software Commons
2. Software Heritage
3. Architecture
4. Technical challenges
5. Community

Software source code is *special*

Harold Abelson, Structure and Interpretation of Computer Programs

“Programs must be written for people to read, and only incidentally for machines to execute.”

Quake 2 source code (excerpt)

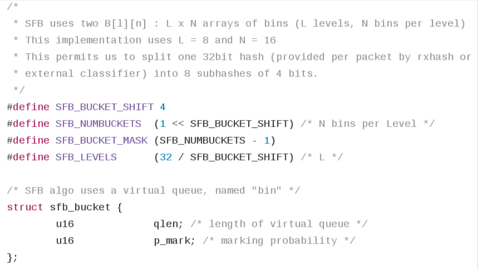


```
float Q_rsqrt( float number )
{
    long i;
    float x2, y;
    const float threehalfs = 1.5F;

    x2 = number * 0.5F;
    y = number;
    i = * ( long * ) &y; // evil floating point bit level hacking
    i = 0x5f3759df - ( i >> 1 ); // what the fuck?
    y = * ( float * ) &i;
    y = y * ( threehalfs - ( x2 * y * y ) ); // 1st iteration
// y = y * ( threehalfs - ( x2 * y * y ) ); // 2nd iteration, this
can be removed

    return y;
}
```

Net. queue in Linux (excerpt)



```
/*
 * SFB uses two B[l][n] : L x N arrays of bins (L levels, N bins per level)
 * This implementation uses L = 8 and N = 16
 * This permits us to split one 32bit hash (provided per packet by rxhash or
 * external classifier) into 8 subhashes of 4 bits.
 */
#define SFB_BUCKET_SHIFT 4
#define SFB_NUMBUCKETS  (1 << SFB_BUCKET_SHIFT) /* N bins per Level */
#define SFB_BUCKET_MASK (SFB_NUMBUCKETS - 1)
#define SFB_LEVELS      (32 / SFB_BUCKET_SHIFT) /* L */

/* SFB algo uses a virtual queue, named "bin" */
struct sfb_bucket {
        u16             qlen; /* length of virtual queue */
        u16             p_mark; /* marking probability */
};
```

Len Shustek, Computer History Museum

“Source code provides a view into the mind of the designer.”

Our Software Commons

Definition (Commons)

The commons is the cultural and natural resources accessible to all members of a society, including natural materials such as air, water, and a habitable earth. These resources are held in common, not owned privately. https://en.wikipedia.org/wiki/Commons

Definition (Software Commons)

The software commons consists of all computer software which is available at little or no cost and which can be altered and reused with few restrictions. Thus *all open source software and all free software are part of the [software] commons.* [. . .]

https://en.wikipedia.org/wiki/Software_Commons

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Source code is *a precious part* of our commons

are we taking care of it?

Software is fragile

Like all digital information, FOSS is fragile

- inconsiderate and/or malicious code loss (e.g., Code Spaces)
- business-driven code loss (e.g., Gitorious, Google Code)
- for obsolete code: physical media decay (data rot)

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Where is the archive…

where we go if (a repository on) GitHub or GitLab.com goes away?

Software lacks its own research infrastructure

A wealth of software research on crucial issues...

- safety, security, test, verification, proof
- software engineering, software evolution
- big data, machine learning, empirical studies

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If you study the stars, you go to Atacama...

... where is the *very large telescope* of source code?

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The Software Heritage Project

Software Heritage

THE GREAT LIBRARY OF SOURCE CODE

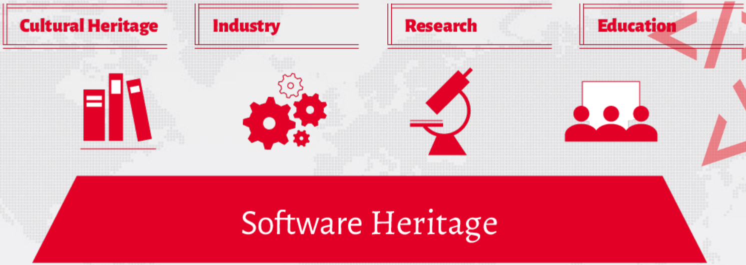
Our mission

Collect, preserve and share the *source code* of *all the software* that is publicly available.

Past, present and future

Preserving the past, *enhancing* the present, *preparing* the future.

Our principles



Cultural Heritage

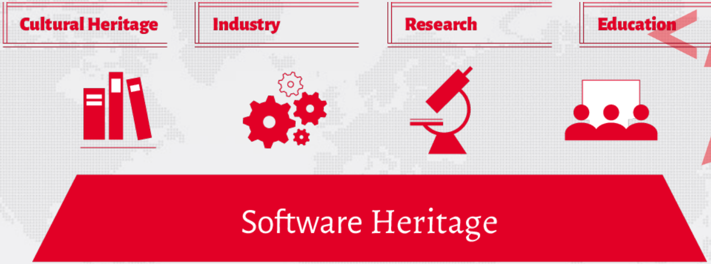
Industry

Research

Education

Software Heritage

Our principles



Open approach

- open source
- transparency

In for the long haul

- non profit
- replication

Collaboration

- minimalism
- interfaces

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Archiving goals

Targets: VCS repositories & source code releases (e.g., tarballs)

We DO archive

- file content (= blobs)
- revisions (= commits), with full metadata
- releases (= tags), ditto
- where (origin) & when (visit) we found any of the above

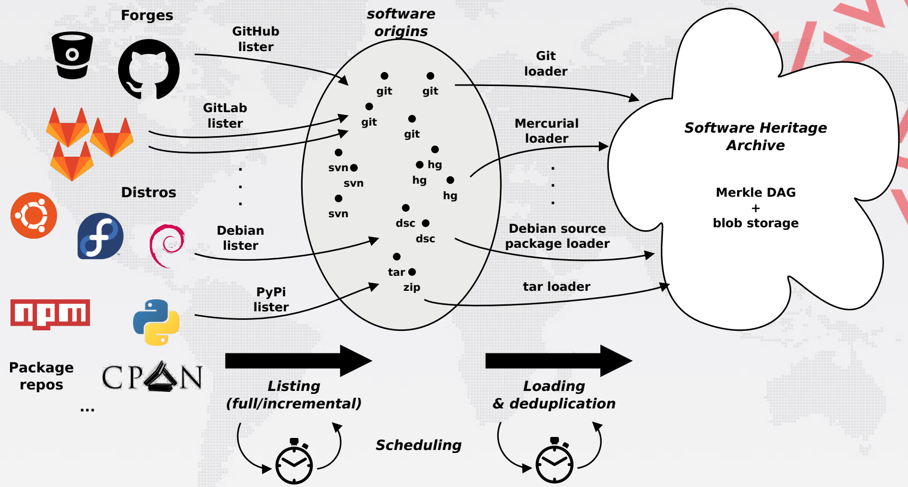
… in a VCS-/archive-agnostic canonical data model

We DON'T archive

- homepages, wikis
- BTS/issues/code reviews/etc.
- mailing lists

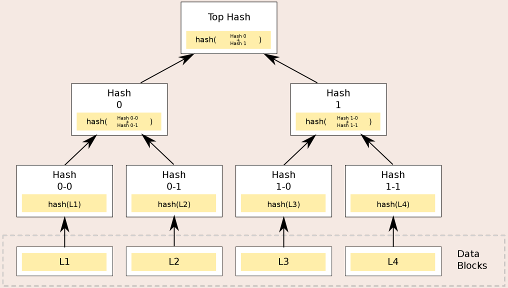
Long term vision: play our part in a *"semantic wikipedia of software"*

Data flow


Forges
GitHub lister
GitLab lister
Distros
Debian lister
PyPi lister
Package repos
...
software origins
git
git
git
git
svn
svn
svn
hg
hg
hg
dsc
dsc
tar
zip
Git loader
Mercurial loader
Debian source package loader
tar loader
Software Heritage Archive
Merkle DAG
+
blob storage
Listing (full/incremental)
Loading & deduplication
Scheduling

Merkle trees

Merkle tree (R. C. Merkle, Crypto 1979)



Combination of

- tree
- hash function

Merkle trees

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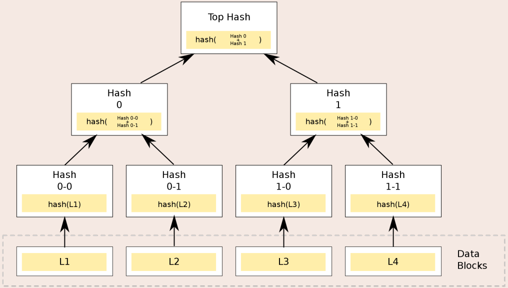


Combination of

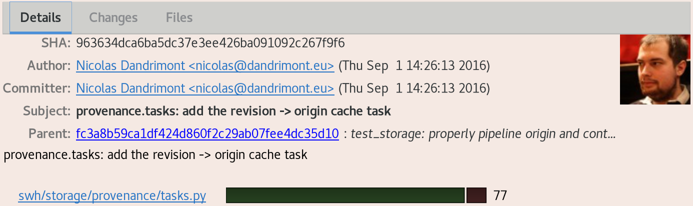
- tree
- hash function

Classical cryptographic construction

- fast, parallel signature of large data structures
- widely used (e.g., Git, blockchains, IPFS, ...)
- built-in deduplication

Example: a Software Heritage revision

Revisions



SHA: 963634dca6ba5dc37e3ee426ba091092c267f9f6

Author: Nicolas Dandrimont <nicolas@dandrimont.eu> (Thu Sep 1 14:26:13 2016)

Committer: Nicolas Dandrimont <nicolas@dandrimont.eu> (Thu Sep 1 14:26:13 2016)

Subject: **provenance.tasks: add the revision -> origin cache task**

Parent: fc3a8b59ca1df424d860f2c29ab07fee4dc35d10 : *test_storage: properly pipeline origin and cont...*

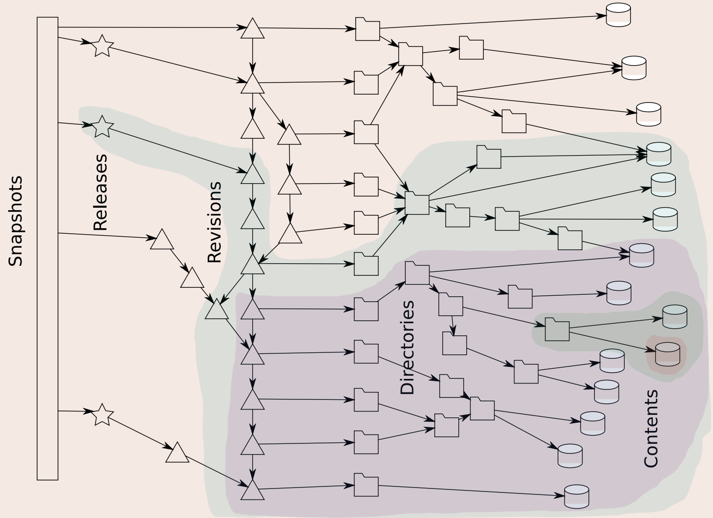
provenance.tasks: add the revision -> origin cache task

swh/storage/provenance/tasks.py 77

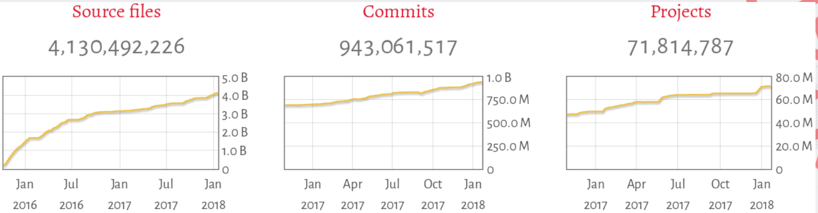
```
tree 515f00d44e92c65322aaa9bf3fa097c00ddb9c7d
parent fc3a8b59ca1df424d860f2c29ab07fee4dc35d10
author Nicolas Dandrimont <nicolas@dandrimont.eu> 1472732773 +0200
committer Nicolas Dandrimont <nicolas@dandrimont.eu> 1472732773 +0200

provenance.tasks: add the revision -> origin cache task
```

id: 963634dca6ba5dc37e3ee426ba091092c267f9f6

The archive: a (giant) Merkle DAG



Archive coverage



Current sources

- live: GitHub, Debian
- one-off: Gitorious, Google Code
- WIP: Bitbucket

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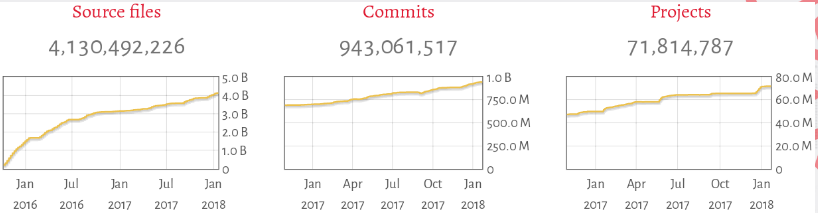

Source files

4,130,492,226

Commits

943,061,517

Projects

71,814,787

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150 TB blobs, 5 TB database (as a graph: 7 B nodes + 60 B edges)

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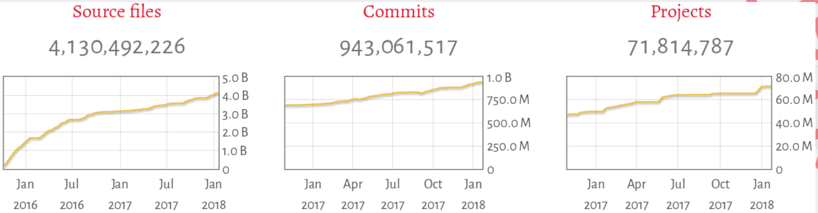

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The *richest* public source code archive, ... and growing daily!

Web API

First public version of our Web API (Feb 2017)
`https://archive.softwareheritage.org/api/`

Features

- pointwise browsing of the Software Heritage archive
  - … releases ⟶ revisions ⟶ directories ⟶ contents …
- full access to the metadata of archived objects
- crawling information
  - *when have you last visited this Git repository I care about?*
  - *where were its branches/tags pointing to at the time?*

Complete endpoint index

`https://archive.softwareheritage.org/api/1/`

Roadmap

Features...

- (done) lookup by content hash
- browsing: "wayback machine" for archived code
  - (done) via Web API
  - (stay tuned) via Web UI
- (stay tuned) download: `wget` / `git clone` from the archive
- (stay tuned) deposit of source code bundles directly to the archive
- (todo) provenance lookup for all archived content
- (todo) full-text search on all archived source code files

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… and much more than one could possibly imagine

all the world's software development history in a single graph!

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Technology: how do you store the SWH DAG?

Problem statement

- How would you store and query a graph with 10 billion nodes and 60 billion edges?
- How would you store the contents of more than 3 billion files, 300TB of raw data?
- … on a limited budget (100 000 € of hardware overall)

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Our hardware stack

- two hypervisors with 512GB RAM, 20TB SSD each, sharing access to a storage array (60 x 6TB spinning rust)
- one backup server with 48GB RAM and another storage array

Our software stack

- A RDBMS (PostgreSQL, what else?), for storage of the graph nodes and edges
- filesystems for storing the actual file contents

Technology: archive storage components

Metadata storage

- Python module swh.storage
- thin Python API over a pile of PostgreSQL functions
- motivation: keeping relational integrity at the lowest layer

Content ("object") storage

- Python module swh.objstorage
- very thin object storage abstraction layer (PUT, APPEND and GET) over regular storage technologies
- separate layer for asynchronous replication and integrity management (swh.archiver)
- motivation: stay as technology neutral as possible for future mirrors

Technology: object storage

Primary deployment

- Storage on 16 sharded XFS filesystems; key = *sha1* (content), value = *gzip* (content)
- if sha1 = abcdef01234..., file path = / srv / storage / a / ab / cd / ef / abcdef01234...
- 3 directory levels deep, each level 256-wide = 16 777 216 directories (1 048 576 per partition)

Secondary deployment

- Storage on Azure blob storage
- 16 storage containers, objects stored in a flat structure there

Technology: object storage review

Generic model is fine

The abstraction layer is fairly simple and generic, and the implementation of the upper layers (replication, integrity checking) was a breeze.

Filesystem implementation is bad

Slow spinning storage + little RAM (48GB) + 16 million dentries = (very) bad performance

Technology: metadata storage

Current deployment

- PostgreSQL deployed in primary/replica mode, using pg_logical for replication: different indexes on primary (tuned for writes) and replicas (tuned for reads).
- most logic done in SQL
- thin Pythonic API over the SQL functions

End goals

- proper handling of relations between objects at the lowest level
- doing fast recursive queries on the graph (e.g., find the provenance info for a content, walking up the whole graph, with a single query)

Technology: metadata storage review

Limited resources

PostgreSQL works really well

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Massive deduplication = efficient storage

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Reality check

Referential integrity?

Technology: metadata storage review

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Reality check

Referential integrity? Real repositories downloaded from the internet are all kinds of broken.

Technology: outlook

Object storage

Our Azure prototype shows that using a scale-out "cloudy" technology for our object storage works really well. Plain filesystems on spinning rust, not so much.

Technology: outlook

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Our initial assumption that we wanted referential integrity and built-in recursive queries was wrong.

Technology: outlook

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Metadata storage

Our initial assumption that we wanted referential integrity and built-in recursive queries was wrong. We could probably migrate to "dumb" object storages for each type of object, with another layer to check metadata integrity regularly.

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Sponsors

Inria
INVENTEURS DU MONDE NUMÉRIQUE

Microsoft
intel
SOCIETE GENERALE
HUAWEI
DANS Data Archiving and Networked Services
NOKIA Bell Labs
ALMA MATER STUDIORUM UNIVERSITÀ DI BOLOGNA DIPARTIMENTO DI INFORMATICA - SCIENZA E INGEGNERIA
GitHub

Testimonials

IEEE Software
GitLab
ENGINEERING
eclipse
OW2
fsfe
nlnet FOUNDATION
SIGSOFT SPECIAL INTEREST GROUP ON SOFTWARE ENGINEERING
Liberté • Égalité • Fraternité RÉPUBLIQUE FRANÇAISE
INAPI
THE LINUX FOUNDATION
ADULLACT
INFORMATICS EUROPE
Computer History Museum
software freedom conservancy
Software Freedom Law Center
AdaCore The GNAT Pro Company
gandi.net
TDF
FREE SOFTWARE FOUNDATION
creative commons
SIF Société Informatique de France
open source initiative
openinventionnetwork

UNESCO/Inria agreement (April 3rd, 2017)

UNESCO

You can help!

Coding

- `www.softwareheritage.org/community/developers/`
- `forge.softwareheritage.org` — our own code

Current development priorities

★★★	listers for unsupported forges, distros, pkg. managers
★★★	loaders for unsupported VCS, source package formats
★★	Web UI: eye candy wrapper around the Web API
★	content indexing and search

… *all* contributions equally welcome!

Conclusion

- It is urgent to preserve software source code; Software Heritage has took a systematic approach at it and has already assembled the largest archive to date.
- Software Heritage responds to cultural, research, and industry needs; it is a shared infrastructure that can benefit us all.
- We should collaborate and pool resources to make it so.

References

Roberto Di Cosmo, Stefano Zacchiroli. *Software Heritage: Why and How to Preserve Software Source Code.* iPRES 2017. Preprint: `http://deb.li/swhipres17`

Come in, we're open!

`www.softwareheritage.org` — *sponsoring, job openings*
`wiki.softwareheritage.org` — *internships, leads*
`forge.softwareheritage.org` — *our own code*