What would you do with **billions** of source code files?

Challenges and opportunities in software archival

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Software Heritage
THE GREAT LIBRARY OF SOURCE CODE

Ten years of research on open source software

Di Cosmo, Leroy, Treinen, Vouillon et al

Managing the complexity of large free and open source package-based software distributions *ASE 2006*

Abate, Boender, Di Cosmo, Zacchiroli

Strong Dependencies between Software Components, *ESEM 2009*

Di Cosmo and J. Vouillon.

On software component co-installability, *ESEC/FSE 2011*

Abate, Di Cosmo, Treinen, Zacchiroli

Learning from the Future of Component Repositories, CBSE 2012

Vouillon, Dogguy, Di Cosmo.

Easing software component repository evolution. *ICSE 2014*

Abate, Di Cosmo, Gesbert, Le Fessant, Treinen, and Zacchiroli.

Mining component repositories for installability issues, *MSR 2015*

Claes, Mens, Di Cosmo, and Vouillon.

A historical analysis of debian package incompatibilities, *MSR 2015*

Tools

- Cudf library: `http://gforge.inria.fr/projects/cudf/`,
- Coinst suite: `http://coinst.irill.org`,

Dose library: `http://gforge.inria.fr/projects/dose/`

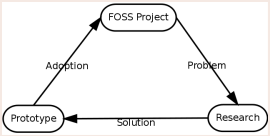
Debian QA: `http://qa.debian.org/dose`

Ten years of research on open source software

A recurring pattern

- identify a real world problem whose solution requires a research effort
- work hard to find a solution
- implement a tool, validate it on real world cases
- publish a research article
- foster adoption (the hardest part!)

In a picture



Under the hood

Question:

What were the
technical prerequisites
that made this work possible?

Technical and legal enablers

Availability

- all the (history of) Debian packages (since 2005)
- no *technical* restrictions
- no *legal* restrictions on content or metadata

Traceability

Debian packages have

- *unique identifier*
- *reference central repository*

Uniformity

Debian packages: a reference catalog

- *uniform metadata structure*
- *uniform naming and versioning schema*

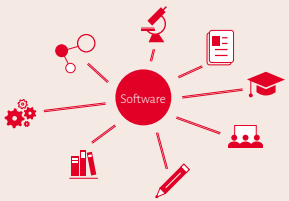
These are all essential features

for *reproducibility* and for *preservation*...

... we need them for *all* software!

Software is everywhere

At the heart of our society



- communication, entertainment
- administration, finance
- health, energy, transportation
- education, research, politics
- …

Knowledge enabler

- *Key mediator* for accessing *all* information
- *Essential component* of modern scientific research

Software embodies

our collective Knowledge and Cultural Heritage

Software is spread all around

Fashion victims

- many disparate development platforms
- a myriad places where distribution may happen
- projects tend to migrate from one place to another over time

Wehere is the place …

where we can find, track and search *all* source code?

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)

Where is the archive…

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

Software is missing its own Research Infrastructure

Photo: ALMA(ESO/NAOJ/NRAO), R. Hills

A wealth of software research on crucial issues…

- safety, security; test, verification, proof;
- software engineering, software evolution;
- empirical and big data studies;

If you study the stars, you go to Atacama…

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

Software Heritage

THE GREAT LIBRARY OF SOURCE CODE

Our mission

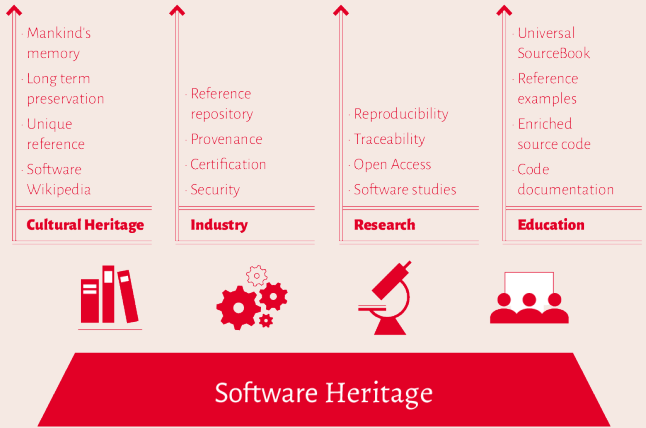
Collect, preserve and share the *source code* of *all the software* that lies at the heart of our culture and our society.

Past, present and future

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

We are working on the foundations

one infrastructure to build them all

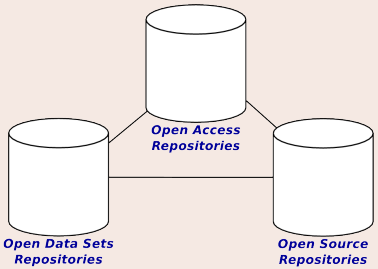


Supporting more accessible and reproducible science

A global library referencing all software used in all research fields

- completes the infrastructure for Open Access in science
- provides intrinsic persistent identifiers needed for scientific reproducibility
- enables large scale, verifiable software studies

The Knowledge Conservancy Magic Triangle



Legenda (links are important!)

- articles: ArXiv, HAL, ...
- data: Zenodo, ...
- software: *Software Heritage* to the rescue

Archive coverage

Our sources

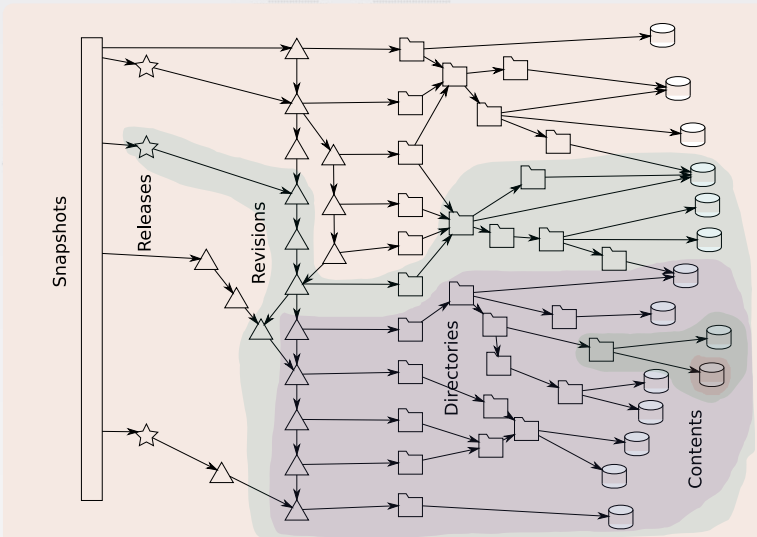
- GitHub — full, up-to-date mirror
- Debian — daily snapshots of all suites since 2005–2015
- GNU — all releases as of August 2015
- Gitorious, Google Code — local copy (Archive Team & Google)

Some numbers

150 TB blobs, 6 TB database (as a graph: 5 B nodes + 50 B edges)

The *richest* source code archive already, … and growing daily!

The archive: a (giant) Merkle DAG



Metadata alignment

Many concepts related to source code

- project, archive, source, language, licence, bts, mailing list, …
- developer, committer, author, architect, …

Many existing ontologies

DOAP, FOAF, Appstream, schema.org, ADMS.SW, …

Many disparate catalogs

Freecode (40.000+), Plume (400+), Debian (25.000+), OpenHub (670.000+), …

Challenge : scale up metadata to millions of projects

- *reconcile* existing ontologies
- *link* and *check* existing catalogs with Software Heritage
- handle *inconsistent data* and *provenance information*

Software phylogenetics

The Software Diaspora

- Code often *migrates* across projects : forks, copy-paste
- Code gets *cloned* : reuse, language limitations, code smells
- Projects *migrate* across forges : fashion, functionality
- Projects get *cloned* : mirrors, packages

Challenge: tracing software evolution across billions of files

- rebuild the history of software artefacts
- identify code origins
- spot code clones
- build project impact graphs

Distributed infrastructure

The software graph

- files
- directories
- commits
- projects

all de-duplicated in Software Heritage

Challenge: design efficient architectures and algorithms

- replication and availability (CAP?)
- navigation
- query
- path analysis

Code search: an old problem

A natural need

- Find the definition of a function/class/procedure/type/structure
- Search examples of code usage in an archive of source code
- you name it…

A natural approach

- Regular expressions

We have all used *grep* since the 1970's!

where is the challenge?

Finding a needle in a haystack: size matters!

How do we search in *millions* of source code files?

Google code search (open 2006, closed 2011)

see `https://swtch.com/~rsc/regexp/regexp4.html` reborn in 2013 for Debian `http://sources.debian.net/`

how

- build an inverted index of *trigrams* from all source files
- *map* regexps to trigrams
- *filter* files that may match
- run *grep* on each file (using the cloud)

performance

scaled reasonably well up to *1 billion lines of codes*

Challenge: scaling up code search

What about *all the source code* in the world?

Software Heritage is *two orders of magnitude* bigger already

- over *two billion* unique source files
- *hundreds* of billions of LOCs

We need new insight for handling this.

Beyond regular expressions?

Advanced code search requires

- language specific *patterns*
- working on *abstract syntax trees*

Regular expressions are a nice *swiss-army knife* approximation, can we build a specific tool that scales?

Software as Big Data

Remember the numbers

- 50+ million repositories ingested
- 700+ million commits
- 3+ billion unique source files / 200 TB of raw source code

and growing by the day!

Challenge: what can machines learn here?

- programming patterns / trends
- developer skills
- vulnerabilities
- bugs and fixes

Web API (FOSDEM'17 release)

Fresh from the oven: first public version of our Web API

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/

A tour of the Web API — origins & visits

```
GET https://archive.softwareheritage.org/api/1/origin/ \
      git/url/https://github.com/hylang/hy
{ "id": 1,
  "origin_visits_url": "/api/1/origin/1/visits/",
  "type": "git",
  "url": "https://github.com/hylang/hy"
}
```

```
GET https://archive.softwareheritage.org/api/1/origin/ \
      1/visits/
[ ...,
  { "date": 1473851066.769266,
    "origin": 1,
    "origin_visit_url": "/api/1/origin/1/visit/13/",
    "status": "full",
    "visit": 13
  }, ...
]
```

A tour of the Web API — snapshots

```
GET https://archive.softwareheritage.org/api/1/origin/ \
      1/visit/13/
{ ...,
  "occurrences": { ...,
    "refs/heads/master": {
      "target": "b94211251...",
      "target_type": "revision",
      "target_url": "/api/1/revision/b94211251.../"
    },
    "refs/tags/0.10.0": {
      "target": "7045404f3...",
      "target_type": "release",
      "target_url": "/api/1/release/7045404f3.../"
    }, ...
  },
  "origin": 1,
  "origin_url": "/api/1/origin/1/",
  "status": "full",
  "visit": 13
}
```

A tour of the Web API — revisions

```
GET https://archive.softwareheritage.org/api/1/revision/ \
      6072557b6c10cd9a21145781e26ad1f978ed14b9/
{
  "author": {
    "email": "tag@pault.ag",
    "fullname": "Paul Tagliamonte <tag@pault.ag>",
    "id": 96,
    "name": "Paul Tagliamonte"
  },
  "committer": { ... },
  "date": "2014-04-10T23:01:11-04:00",
  "committer_date": "2014-04-10T23:01:11-04:00",
  "directory": "2df4cd84e...",
  "directory_url": "/api/1/directory/2df4cd84e.../",
  "history_url": "/api/1/revision/6072557b6.../log/",
  "merge": false,
  "message": "0.10: The Oh f*ck it's PyCon release",
  "parent_urls": [ "/api/1/revision/10149f66e.../" ],
  "parents": [ "10149f66e..." ],
```

A tour of the Web API — contents

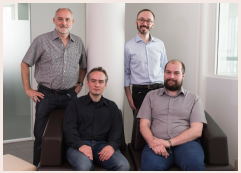
```
GET https://archive.softwareheritage.org/api/1/content/ \
      adc83b19e793491b1c6ea0fd8b46cd9f32e592fc/
{
  "data_url": "/api/1/content/sha1:adc83b19e.../raw/",
  "filetype_url": "/api/1/content/sha1:.../filetype/",
  "language_url": "/api/1/content/sha1:.../language/",
  "length": 1,
  "license_url": "/api/1/content/sha1:.../license/",
  "sha1": "adc83b19e...",
  "sha1_git": "8b1378917...",
  "sha256": "01ba4719c...",
  "status": "visible"
}
```

- rate limits apply throughout the API
- blob download not available yet

The Software Heritage community

The core team

- Roberto Di Cosmo
- Stefano Zacchiroli
- Nicolas Dandrimont (Engineer)
- Antoine Dumont (Engineer)



Inria as initiator

Inria INVENTEURS DU MONDE NUMÉRIQUE *the* .fr CS research institution, strong FOSS culture, W3C founding partner

Early Partners and Supporters

Société Générale, Microsoft, Huawei, Nokia Bell Labs, DANS, ACM, Adullact, Creative Commons, Eclipse, Free Software Foundation, Gandi, Open Source Initiative, GitHub, IEEE, OIN, OW2, Software Freedom Conservancy, SFLC, The Document Foundation, The Linux Foundation, …

Come in, we're open

Software Heritage is

- a *reference archive* of *all* FOSS ever written
- a fantastic new tool for *research* software
- a unique *complement* for *development platforms*
- an international, open, nonprofit, *mutualized infrastructure*
- at the service of our community, at the service of society

Learn more

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

Questions ?