Software Heritage

Building the Universal Software Archive for Open Science

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May 14th, 2018

Software Heritage

THE GREAT LIBRARY OF SOURCE CODE

Outline

Software is Pervasive

At the heart of *our society*

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

At the heart of *technology*

- house appliances ≈ 10M SLOC
- phones ≈ 20M SLOC, *cars* ≈ 100M SLOC
- Internet of things, …

Software is Knowledge

Key mediator for accessing *all* information (c) Banski

Information is a main pillar of our modern societies.

> *Absent an ability to correctly interpret digital information, we are left with [...] "rotting bits" [...] of no value.*
>
> *Vinton G. Cerf IEEE 2011*

Software is *an essential component* of modern scientific research

> *[...] the vast majority describe experimental methods or software that have become essential in their fields.*
>
> Top 100 papers (Nature, October 2014)

Sofware embodies our *Knowledge* and *Cultural Heritage*

Source code matters!

"The source code for a work means the preferred form of the work for making modifications to it."

— GPL Licence

Hello World

Program (excerpt of binary)

```
4004e6: 55
4004e7: 48 89 e5
4004ea: bf 84 05 40 00
4004ef: b8 00 00 00 00
4004f4: e8 c7 fe ff ff
4004f9: 90
4004fa: 5d
4004fb: c3
```

Program (source code)

```
/* Hello World program */

#include<stdio.h>

void main()
{
    printf("Hello World");
}
```

Software Source Code is *special*

Harold Abelson, Structure and Interpretation of Computer Programs (1st ed.) 1985

"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."

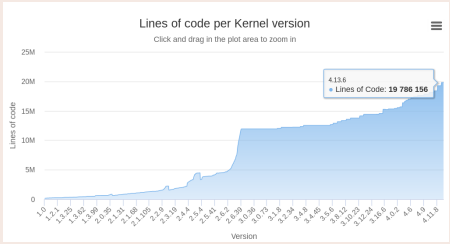
~ 50 years, a lightning fast growth

Apollo 11 Guidance Computer (~60.000 lines), 1969

"When I first got into it, nobody knew what it was that we were doing. It was like the Wild West."

Margaret Hamilton

Linux Kernel



… now in your pockets!

are we taking care of all this?

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

Where 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)

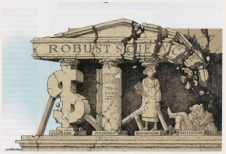
Where is the archive…

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

Outline

We face a science crisis

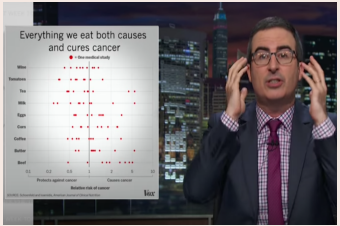
"Sub-prime science"? (Nicholas Humprey)



- inconsistencies
- data corruption, fraud
- non reproducible findings… (picture from Nature, Sep. 2015)

The world starts noticing

October 2013



John Oliver, *Science* May 2016

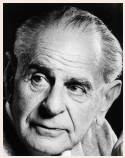
How we built our scientific knowledge

The experimental method

- make an *observation*
- formulate an *hypothesis*
- set up an experiment
- formulate a *theory*

And then we reproduce and verify.

Reproducibility is the key



non-reproducible single occurrences are of no significance to science

Karl Popper, The Logic of Scientific Discovery, 1934

Reproducibility in the digital age

For an experiment involving software, we need

- open access to the scientific article describing it
- open data sets used in the experiment
- source code of all the components
- environment of execution
- stable references between all this

Remark

The first two items are already widely discussed!

… what about *software*?

Collberg's report from the trenches

Analysis of 613 papers

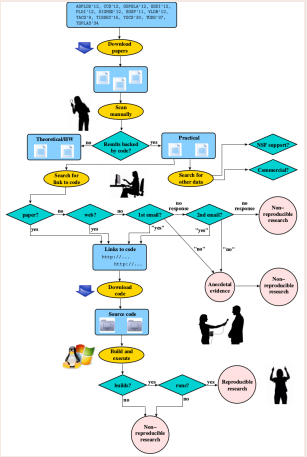
- 8 ACM conferences: ASPLOS'12, CCS'12, OOPSLA'12, OSDI'12, PLDI'12, SIGMOD'12, SOSP'11, VLDB'12
- 5 journals: TACO'9, TISSEC'15, TOCS'30, TODS'37, TOPLAS'34

all very practical oriented

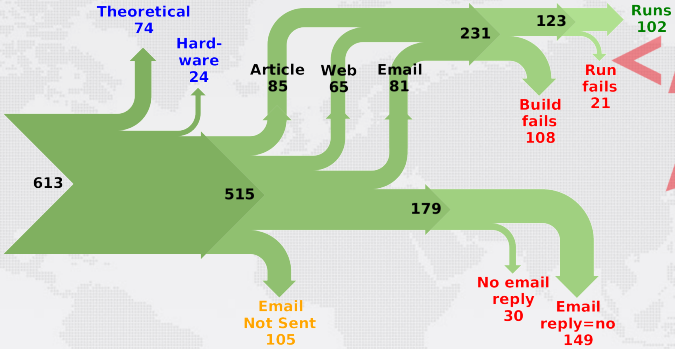
The basic question

can we get the code to build and run?

The workflow



The result



This can be debated (see `http://cs.brown.edu/~sk/Memos/Examining-Reproducibility/`), but...

... that's a whopping 81% of non reproducible works!

URL decay disrupts the *web of reference*

Web links *are not* permanent (even *permalinks*)

there is no general guarantee that a URL… which at one time points to a given object continues to do so
T. Berners-Lee et al. Uniform Resource Locators. RFC 1738.

URLs used in articles *decay*!

Analysis of *IEEE Computer* (Computer), and the *Communications of the ACM* (CACM): 1995-1999

- the *half-life* of a referenced URL *is approximately 4 years* from its publication date
  D. Spinellis. The Decay and Failures of URL References.
  Communications of the ACM, 46(1):71-77, January 2003.

Similar findings in Lawrence, S. et al. *Persistence of Web References in Scientific Research*, IEEE Computer, 34(2), pp. 26–31, 2001.

Scholar roster of broken links

An example from Astronomy

Domain	links (broken)	.html	.txt	.dat	.gz	.tar	.fits	tilde
cxc.harvard.edu	802 (110)	336 (70)	0	0	4 (2)	5 (4)	1	0
heasarc.gsfc.nasa.gov	640 (33)	423 (27)	1	0	0	0	0	0
www.stsci.edu	498 (61)	205 (29)	3	0	0	0	0	15 (10)
asc.harvard.edu	471 (152)	212 (99)	0	0	0	0	0	1 (1)
ssc.spitzer.caltech.edu	427 (194)	125 (76)	3 (3)	0	0	0	0	0
cfa-www.harvard.edu	352 (68)	277 (52)	1	0	0	0	0	54 (17)
archive.stsci.edu	308 (58)	57 (9)	2	1 (0)	0	0	0	0
www.ipac.caltech.edu	285 (14)	209 (12)	0	0	0	0	0	0
www.atnf.csiro.au	211 (21)	12 (6)	0	0	0	0	0	7 (5)
space.mit.edu	193 (10)	58 (5)	1	0	0	0	0	2 (1)
www.astro.psu.edu	186 (4)	103 (1)	1	10	1	1	0	2
www.eso.org	186 (58)	54 (22)	1 (1)	0	0	0	0	4 (1)
irsa.ipac.caltech.edu	163 (5)	38	0	0	1	0	0	0
www.sdss.org	156 (2)	106 (1)	0	0	0	0	0	0
hea-www.harvard.edu	125 (37)	42 (17)	1	0	0	1	0	26 (16)
physics.nist.gov	125 (3)	63 (2)	0	0	0	0	0	0
www.noao.edu	120 (3)	50 (2)	0	0	0	0	0	0
xmm.vilspa.esa.es	118 (35)	23 (19)	0	0	8 (1)	0	0	1 (1)
www.astro.princeton.edu	115 (31)	43 (14)	0	0	0	0	0	53 (12)
ad.usno.navy.mil	110 (27)	98 (22)	3 (3)	0	0	0	0	1 (1)

This table lists total number of links and broken links (HTTP status codes 3xx, 4xx, and 5xx) to top domains (domains with over 100 links) found within articles published in the four main astronomy journals between 1997 and 2008. The table also shows, for each domain, the portion of links to common filename extensions, as well as links that contain the tilde character.
doi:10.1371/journal.pone.0104798.t001

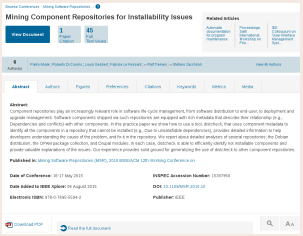
How Do Astronomers Share Data?
Pepe, Goodman, Muench, Crosas, Erdmann
dx.doi.org/10.1371/journal.pone.0104798

PLOS August 28, 2014

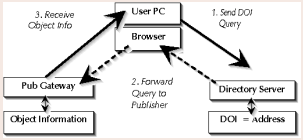
DOI limitations

Example: doi:10.1109/MSR.2015.10

- to find what 10.1109/MSR.2015.10 is, go to a *resolver* (e.g. doi.org)
- this returns `http://ieeexplore.ieee.org/document/7180064/`
- at this URL we find …



Architecture of the DOI infrastructure



- DOI resolution *can change*
- content at URL *can change*
- no *intrinsic* way of noticing
- persistence based on *good will* of *multiple parties*

No catalog, no archive, no references, … and we are at a turning point

Looking at the past

- a lot of old software misplaced, lost, or behind barriers, but…
- most founding fathers are still here, and willing to share
- urgent to collect their knowledge

Only a few years left.

Looking at the future

- software development and use skyrockets: more programmers, and more code!
- essential to provide a universal platform for all the future software source code

Every year that goes by makes the problem worse.

it is urgent to take action!

Outline

Software Heritage

Our mission

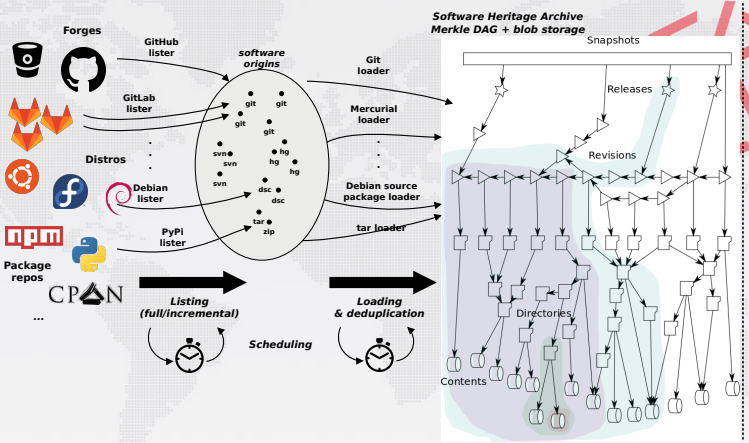
Collect, preserve and share the *source code* of *all the software* that is available

Past, present and future

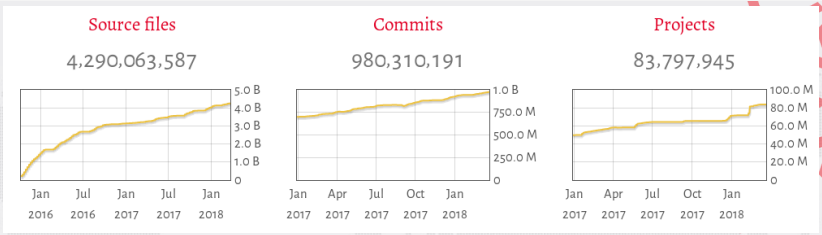
Preserving the past, *enhancing* the present, *preparing* the future

Outline

Architecture (simplified)



Archive coverage



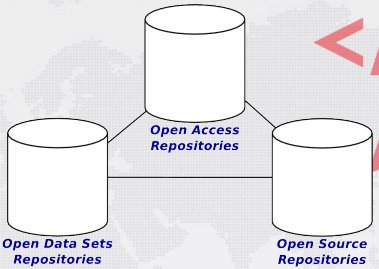
Current sources

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

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

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

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

Demo time (breaking news!)

Browsing the archive contents

- archive.softwareheritage.org (fosdem/2018)

Archiving scientific software via HAL

- open on the Inria instance, see the deposit guide at `http://bit.ly/swhdepositHALen`

Outline

Growing Support

Landmark Inria Unesco agreement, April 3rd, 2017

Inria — INVENTEURS DU MONDE NUMÉRIQUE

UNESCO

Sharing the vision

The Software Gitlab ENGINEERING eclipse OW2 fsfe nlnet SIGSOFT Liberté • Égalité • Fraternité RÉPUBLIQUE FRANÇAISE INRIA 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 open source initiative openinventionnetwork

Contributing to the mission

Inria — INVENTEURS DU MONDE NUMÉRIQUE

>= 100Ke/year	Microsoft, intel, SOCIETE GENERALE
>= 50Ke/year	HUAWEI
>= 25Ke/year	
>= 10Ke/year	DANS (Data Archiving and Networked Services), NOKIA Bell Labs, GitHub

The next steps

The Software Heritage Foundation

- independent
- long term mission
- multistakeholder

The community

- academia: Open Access, research
- industry: better software
- cultural heritage: the software history

The mirror network

- resilience
- biodiversity

> *"Let us save what remains: not by vaults and locks which fence them from the public eye and use in consigning them to the waste of time, but by such a multiplication of copies, as shall place them beyond the reach of accident."*
>
> *Thomas Jefferson*

An unique opportunity

Library of Alexandria of code

Take *urgent* action to

- recover the past
  - founding fathers still here
- structure the future
  - programming skyrockets

A CERN for Software

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

Build a *common infrastructure*

- supporting industry needs
- enabling software research
- fostering better science
- for society as a whole

Come in, we're open, and you can help!

Software Heritage

www.softwareheritage.org

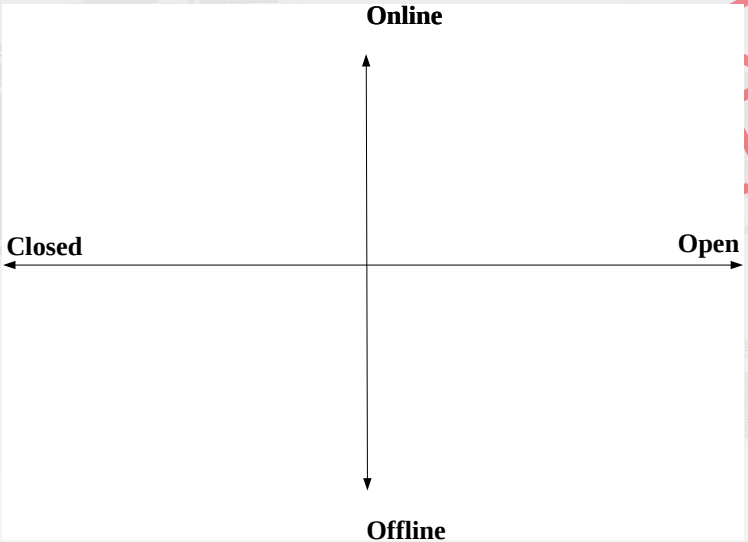
@swheritage

Support the effort, get involved!

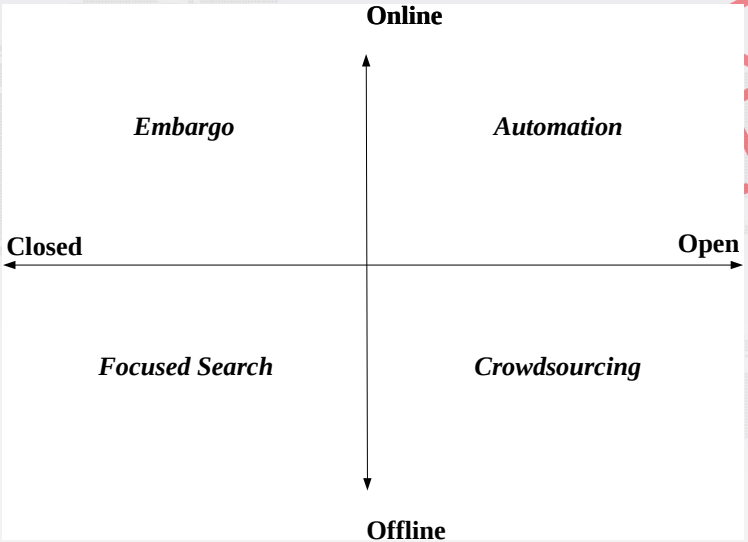
partnerships, mirrors	mailto:roberto@dicosmo.org
sponsoring	sponsorship.softwareheritage.org
donations	www.softwareheritage.org/donate
our own code	forge.softwareheritage.org

Outline

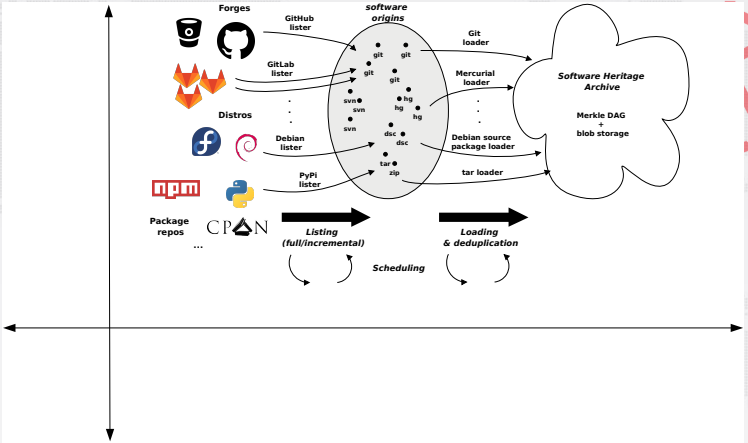
All the source code



All the source code, strategies



Online, open source code: automation overview



Outline

Data compression

Deduplication is performed at the file level *across all projects in the world*

Pros

- very efficient to cope with file clones
- quite resilient to technology changes

Cons

- a minor edit creates two different files

Challenge: exploit file similarities

- adapt / improve variable size checksums
- compression rates of up to 100 to 1 may arise

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

Outline

Software as Big Data

Remember the numbers

- 70+ million repositories ingested
- 900+ million unique commits
- 4+ 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

Efficient data representation

Remember the numbers

- 70+ million repositories ingested
- 900+ million unique commits
- 4+ billion unique source files / 200 TB of raw source code

and growing by the day!

Challenge: can we make this fit in memory?

- efficient graph representation
- fast non-local queries
- mitigate the size/speed tradeoff