Open Science Best Practices for Source Code Preservation

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Software Heritage
Télécom Paris, Polytechnic Institute of Paris

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CERN
Geneva, Switzerland

Software Heritage
THE GREAT LIBRARY OF SOURCE CODE

Outline

1. Introduction
2. The software commons: an endangered knowledge
3. Avoiding the tragedy of an unattended software commons
4. Source code in open science
5. Archive and reference
6. Describe, cite, credit
7. Policy framework
8. Call to actions

About the speaker

- Professor of Computer Science, Télécom Paris, Institut Polytechnique de Paris
  - Research: digital commons, open source software engineereing, computer security, software supply chain.
  - 70+ papers in these fields: upsilon.cc/zack/research/publications
- Free/Open Source Software activist (20+ years)
- Debian Developer & Former 3x Debian Project Leader
- Former Open Source Initiative (OSI) director
- Software Heritage co-founder & CTO

Software is everywhere (and a key mediator) in society

Free/Open Source Software (FOSS) is everywhere as well

Definition (Free Software (1986))

A program is free software if the program's users have the four *essential freedoms*:

- Freedom #0, to run the program, for any purpose
- Freedom #1, to study how the program works, and change it
- Freedom #2, to redistribute copies
- Freedom #3, to improve the program, and release improvements

Current estimates: 99% of software products on the market contains at least *some* free software parts (Synopsis 2020).

The Commons and FOSS

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.

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.* [...]

Kranich and Schement (2008); Schweik and English (2012).

Software is dual-form knowledge

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

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

```
Hello World
```

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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
```

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```

Program (source code)

```
/* Hello World program */

#include<stdio.h>

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

Software *source code* is precious human knowledge

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."

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Apollo 11 source code (excerpt)

```
P63SPOT3        CA      BIT6            # IS THE LR ANTENNA IN POSITION 1 YET
                EXTEND
                RAND    CHAN33
                EXTEND
                BZF     P63SPOT4        # BRANCH IF ANTENNA ALREADY IN POSITION 1

                CAF     CODE500         # ASTRONAUT:    PLEASE CRANK THE
                TC      BANKCALL        #               SILLY THING AROUND
                CADR    GOPERF1
                TCF     GOTOPOOH        # TERMINATE
                TCF     P63SPOT3        # PROCEED       SEE IF HE'S LYING

P63SPOT4        TC      BANKCALL        # ENTER         INITIALIZE LANDING RADAR
                CADR    SETPOS1

                TC      POSTJUMP        # OFF TO SEE THE WIZARD ...
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Quake III 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;
}
```

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Len Shustek, Computer History Museum 2006

"Source code provides a view into the mind of the designer."

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But *where* is this commons?

- many disparate development platforms, with a few dominant players (e.g., GitHub)
- a myriad places where distribution may happen
- most of them operated by for-profit companies

Software source code is fragile

Like all digital information, FOSS is fragile

- link rot: projects are created, moved around, removed
- business-driven code loss (e.g., Gitorious, Google Code, Bitbucket)
- data rot: physical media with legacy software decay

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If a website disappears you go to the Internet Archive…

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

Calling for preservation: UNESCO

Experts call for greater recognition of software source code as heritage for sustainable development

.6 November 2018

UNESCO, Inria, Software Heritage invite

40 international experts meet in Paris …

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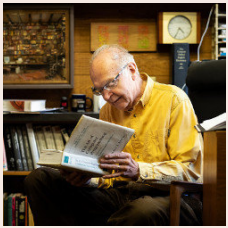
"[We call to] support efforts to gather and preserve the artifacts and narratives of the history of computing, while the earlier creators are still alive"

https://en.unesco.org/foss/paris-call-software-source-code

Calling for preservation: Donald Knuth and Len Shustek

Communications of the ACM, February 2021



"Telling historical stories is the best way to teach. It's much easier to understand something if you know the threads it is connected to."

Let's Not Dumb Down the History of Computer Science
Donald E. Knuth, Len Shustek
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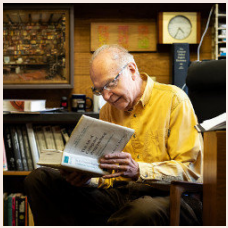

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A unique opportunity

most of the creators are still here: we can talk to them!

but the clock is ticking…

Why Open Science?

Open Science (Second National Plan for Open Science, France, 2021)

Unhindered dissemination of results, methods and products from scientific research.
It draws on *the opportunity provided by recent digital progress* to develop *open access* to *publications* and – as much as possible – *data*, *source code* and *research methods*.

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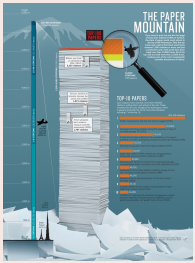
Yuval Noah Harari (on COVID 19)

"The real antidote [to epidemic] is scientific knowledge *and* global cooperation."

Software is a pillar of Open Science

Software powers modern research



[…] software […] essential in their fields.
Top 100 papers (Nature, 2014)

Sometimes, if you dont have the software, you dont have the data
Christine Borgman, Paris, 2018

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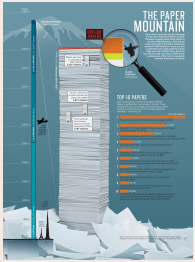

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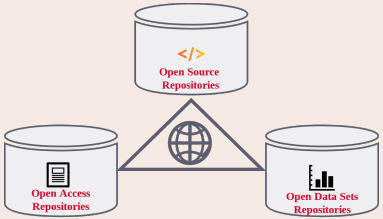

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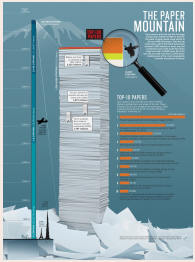

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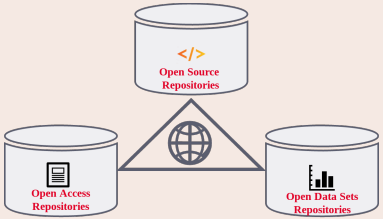

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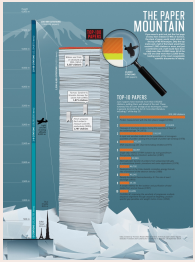

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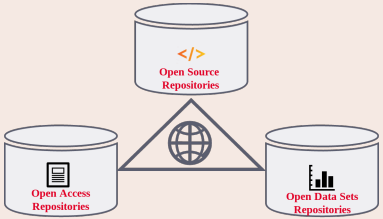

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Nota Bene

software may be a *tool*, a *research outcome* and a *research object*

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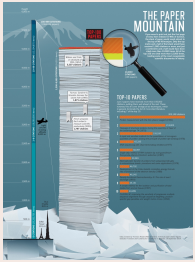

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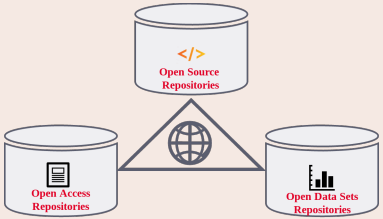

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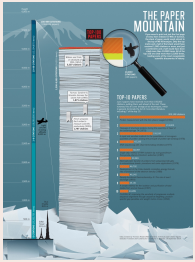

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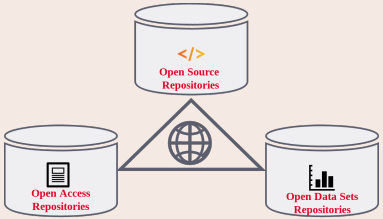

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Preserving the history of source code is important for *reproducibility*

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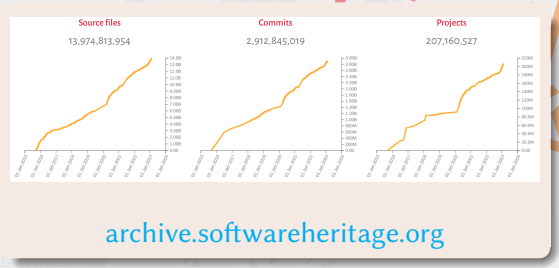
Research infrastructure

enable analysis of all software source code

The largest public source code archive, principled

bit.ly/swhpaper



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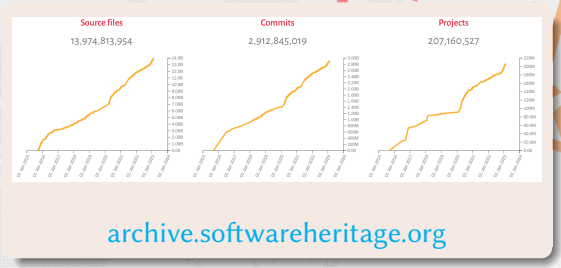


Technology

- transparency and FOSS
- replicas all the way down

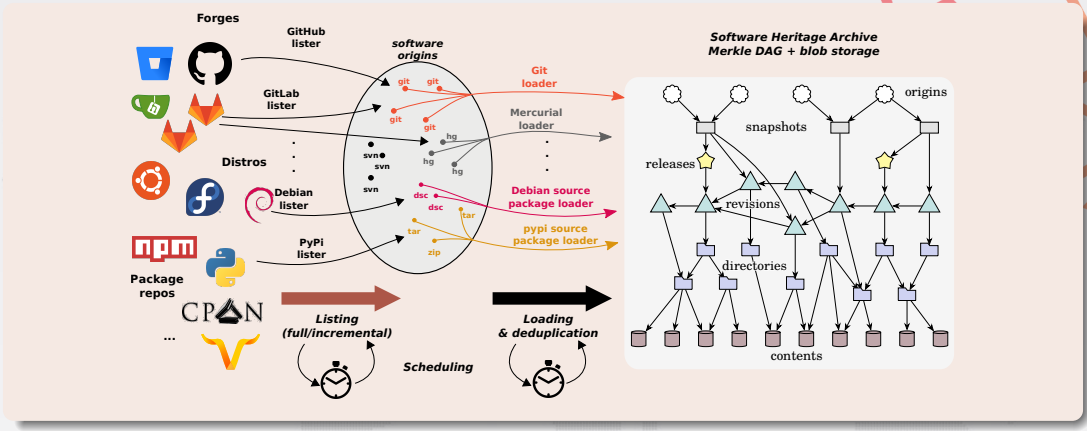
Content (billions!)

- intrinsic identifiers
- facts and provenance

Organization

- non-profit
- multi-stakeholder

A peek under the hood: a global view on the software commons



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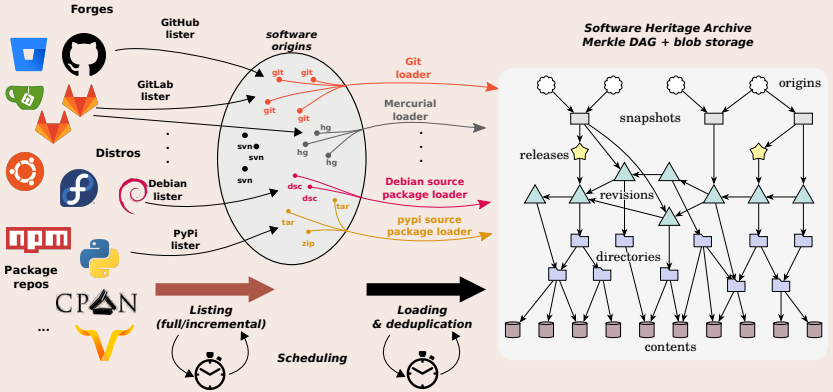
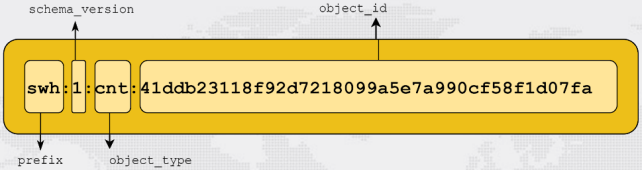


A global graph linking together fully deduplicated source code artifact (files, commits, directories, releases, etc.) to the places that distribute them (e.g., Git repositories), providing a unified view on the entire *Software Commons*.
(Size: ~30 B nodes, ~300 B edges, ~1 PiB blobs)

Software Heritage *intrinsic* Identifiers (SWHID) (full spec)



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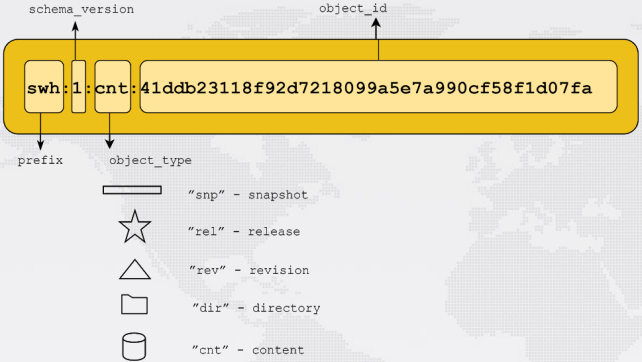

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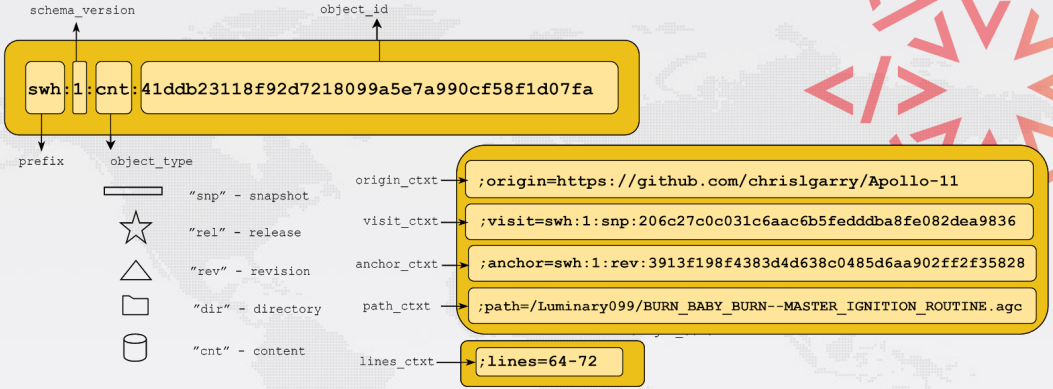

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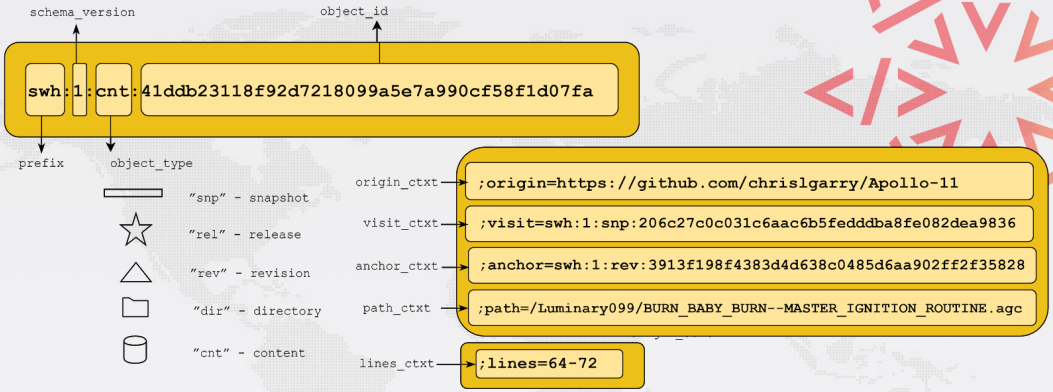

An emerging standard

- in Linux Foundation's SPDX 2.2
- IANA registered, WikiData property P6138

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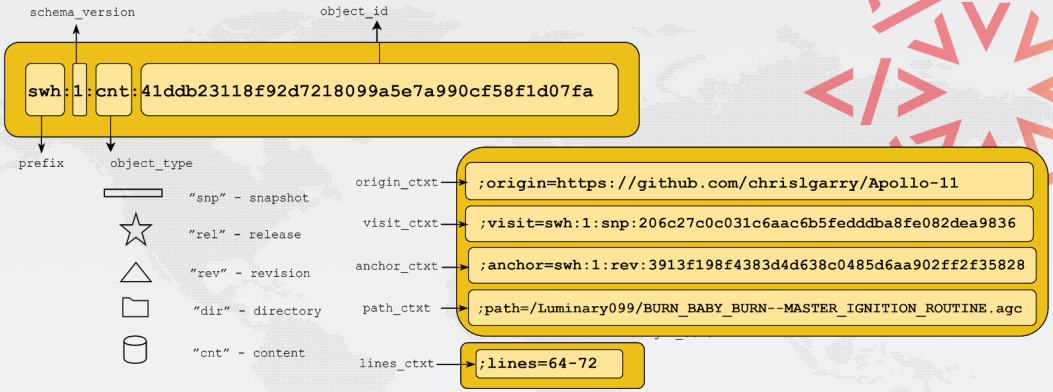

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Examples:

- Apollo 11 AGC excerpt
- Quake III rsqrt

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- archive and reference software used in articles
- find useful software
- get credit for developed software
- verify, reproduce, improve results

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Research Organizations and/or Funders

know its software assets

- technology transfer
- impact metrics
- funding strategy
- career evaluation

Archive, Reference, Describe, Cite and Credit

Archive

Research software artifacts must be properly archived

make sure we can *retrieve* them (*reproducibility*)

Archive, Reference, Describe, Cite and Credit

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to give *credit* to authors (*evaluation*!)

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2. The software commons: an endangered knowledge
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Some old popular approaches

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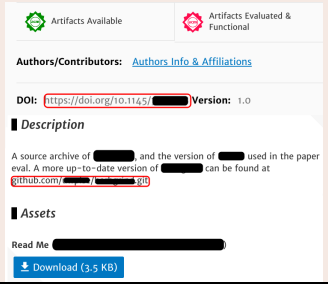

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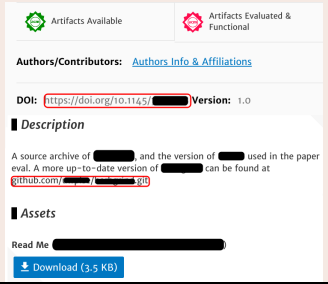

Can get no satisfaction…

A *Poor user experience*

B *No preservation guarantee*

C Can do *so much* better

Forges are *not* archives!

2015: the first big bad news

Google Code and Gitorious.org shutdown: ~1M endangered repositories

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Software Heritage is *radically different*

A quick tour as a user

- designed for source code: Browse (e.g. Apollo 11 excerpt, see also Apollo 11 blog post) like on a developer platform, not a document archive!

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- reference source code: all granularities, using SWHIDs (full specification available online)
  - compare Fig. 1 and conclusions in the 2012 version and the updated version
  - SWHID in a replication experiment
  - guidelines and a full article
  - SWHIDs *guarantee integrity* like in *blockchains*
    demo if time left:
    1. download a version of a project for a given SWHID
    2. compute locally the SWHID with swh-identify
    3. check that the computed id match the given one

Software Heritage is *radically different* (cont.)

Getting software archived

- automated harvesting: over 200 million software origins, your researchers' work may already be there (actually, here)!

Software Heritage is *radically different* (cont.)

Getting software archived

- automated harvesting: over 200 million software origins, your researchers' work may already be there (actually, here)!
- universal archive: *all* source code from *all* platforms (BitBucket, GitHub, GitLab, your own forge, etc.)
  - trigger archival of *any code* in one click with the updateswh browser extension
  - use webhooks to automatically archive *your code* (a GitHub action is available too)
  - journals, libraries, open access portals may *deposit sourcecode and metadata*
    - Example article from IPOL
    - Example article from eLife

A look at some adoption indicators

From Melissa Harrison's OSEC 2022 talk

What are they "referencing"?

source	n	percentage
Not available	2868	46.22
GitHub	1151	18.55
software heritage	387	6.24
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r package	70	1.13
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HAL+SWH in the Open Science software booklet

Funding agencies recommendations ANR 2023 guidelines (p. 17)

Enfin, conformément au 2ème Plan national pour la science ouverte, L'ANR recommande que les logiciels développés durant le projet soient mis à disposition sous une licence libre[30] et que les codes sources soient stockés dans l'archive Software Heritage[31] en indiquant la référence au financement ANR.

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- example from Parmap, created using the Codemeta generator

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- export of citation information for biblatex-software
- examples: LinBox, SLALOM, Givaro, NS2DDV, SumGra, Coq proof, …
- generation of reports, cv, web pages: for Inria, for CNRS, for CNES, for LIRMM or for Rémi Gribonval using HalTools

Bottomline

Software Heritage + a *curated* metadata repository allows to address all needs …

- *researcher, engineer*: archival, reference, credit, CV etc. *with a little effort from them*
- *labs, organizations*: track and report software production in a simple way
- *technology transfer offices*: view the software production
- *national level*: a *curated* catalog of the software production

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French National plan for Open Science, 2021-2024

MINISTÈRE
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SECOND FRENCH PLAN FOR OPEN SCIENCE

Generalising open science in France 2021-2024

1

Launch on 6 July 2021 by Frédérique Vidal, Minister for Higher Education, Research and Innovation

- Multiplying the **levers for change** in order to **generalise open science practices**
- Structuring the **policy for opening up or sharing research data**
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Path Three :

Opening up and promoting source code produced by research

7 **Recognize and support the dissemination under an open source license of software** produced by publicly funded research programmes

8 **Highlight the production of source code** from higher education, research and innovation

9 Define and promote an **open source software policy**

« The opening of software source code is a major challenge for the **reproducibility** of scientific results. »

« Distribution of software products under **open source licence** will be preferred. »

3

Define and promote an open source software policy

- Produce a **National Charter for Open Source Software** coming from higher education, research and innovation
- Develop the **link between data and software** through a network of **Chief Data Officers** in the various universities and research performing organisations.
- Develop the **economic models of open source software** and make them known within commercialization services
- **Support Software Heritage** and recommend it for the archiving and referencing of source code

Recognise source code as a contribution to research

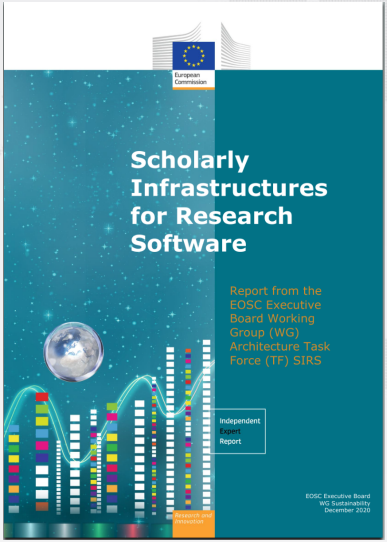
- Create an **open source research software prize**
- **Provide greater recognition** for software production in the career of researchers, research support staff

Build an ecosystem that connects code, data and publications

- Develop **proper coordination** between software forges, open publication archives, data repositories and the scientific publishing sector.

4

The EOSC SIRS report: Software Source Code and Open Science, 2020



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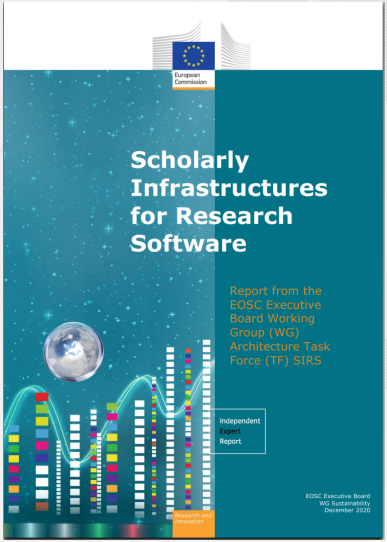


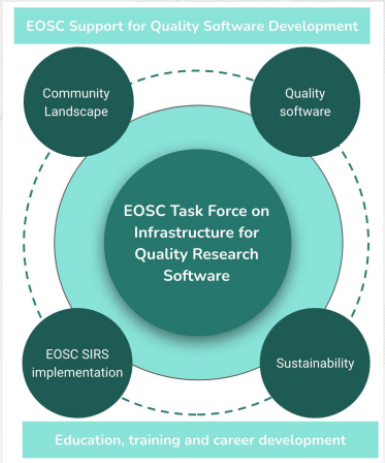
Important *policy tool* in Open Science (Dec 2020)

- 9 infrastructures
  - 3 archives
  - 3 open access publishers
  - 3 aggregators
- recommendations
  - archive in Software Heritage, use SWHID
  - open non profit
  - default to open source for research software

"all research software should be made available under an Open Source license by default, and all deviations from this default practice should be properly motivated"

See https://doi.org/10.2777/28598

Software in the EOSC



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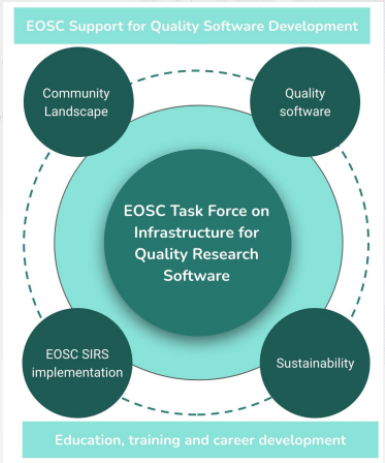


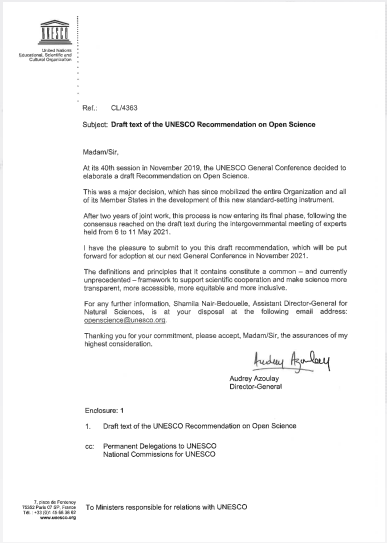
Ongoing action in the EOSC

Task force on infrastructures for quality research software

- Foster the development and deployment of tools and services that allow researchers to properly archive, reference, describe with proper metadata, share and reuse research software.
- Improve the quality of research software, both from the technical and organizational point of view …
- Increase recognition to software developers and maintainers of research software …

See the charter of the task force.

The UNESCO recommendations for Open Science (2021)



United Nations
Educational, Scientific and
Cultural Organization

Ref.: CL/4363

Subject: **Draft text of the UNESCO Recommendation on Open Science**

Madam/Sir,

At its 40th session in November 2019, the UNESCO General Conference decided to elaborate a draft Recommendation on Open Science.

This was a major decision, which has since mobilized the entire Organization and all of its Member States in the development of this new standard-setting instrument.

After two years of joint work, this process is now entering its final phase, following the consensus reached on the draft text during the intergovernmental meeting of experts held from 6 to 11 May 2021.

I have the pleasure to submit to you this draft recommendation, which will be put forward for adoption at our next General Conference in November 2021.

The definitions and principles that it contains constitute a common – and currently unprecedented – framework to support scientific cooperation and make science more transparent, more accessible, more equitable and more inclusive.

For any further information, Shamila Nair-Bedouelle, Assistant Director-General for Natural Sciences, is at your disposal at the following email address: openscience@unesco.org.

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Tél. : +33 (0)1 45 68 38 62
www.unesco.org

To Ministers responsible for relations with UNESCO

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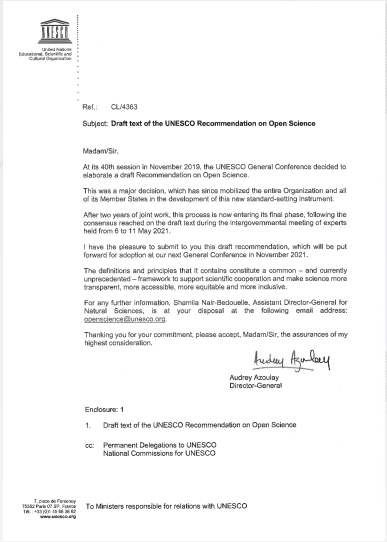

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Selection from the recommendations

- Open Source for Open Science

  "The source code must be included in the software release and made available on openly accessible repositories and the chosen license must allow modifications, derivative works and sharing under equal or compatible open terms and conditions"

- Infrastructures

  "Open science infrastructures should be organized and financed upon an essentially not-for-profit and long-term vision, which enhance open science practices and guarantee permanent and unrestricted access to all, to the largest extent possible."

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Call to action: best practices for ARDC are available… today!

Archiving and referencing

For all source code used in research (*yes, even small scripts!*)

- ensure it is archived in Software Heritage (see save code now)
- get the proper SWHID for your software (see detailed HOWTO)
- add it to research articles for reproducibility (see detailed HOWTO)

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Describing and Citing/Crediting

For software you want to put forward (*mention in your CV, reports, etc., get citations and credit for it*), do the following extra steps:

- add codemeta.json with description (see the codemeta generator)
- reference in the HAL portal (french partners, see online HAL documentation)
- cite software using the biblatex-software package (in CTAN and TeXLive)

Call to action: policy making

A working agenda

- avoid proprietarisation: set the default to open
  - *publicly funded research software should be open source*, exceptions must be justified
- avoid balkanisation
  - build on common, shared, open, non profit infrastructures, like Software Heritage
- support mutualised common infrastructures
  - acknowledge the predominant human component of digital infrastructures
    - recurrent funding of their cost
    - proper evaluation of their service
- establish intelligent incentives
  - count quality software contributions in careers, avoid purely numerical indicators, keep the human in the loop

Appendix

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9 Under the hood

10 HAL and Software Heritage

11 Software Heritage vs. other approaches

12 FAIR software

13 All the source code

14 More on the data model

Under the hood

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Metadata access and software citation will be next

GraphQL API (thanks Jayesh), and citation generation widget

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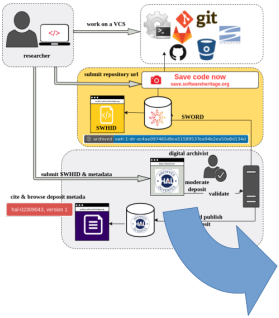
Overview of the Software Heritage / HAL synergy

https://hal.archives-ouvertes.fr/hal-02130801



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Zenodo

- compare the Parmap library on Zenodo and on Software Heritage
- connector with InvenioRDM under development as part of FAIRCORE4EOSC

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- let's focus on more actionable issues: ARDC a good starting point

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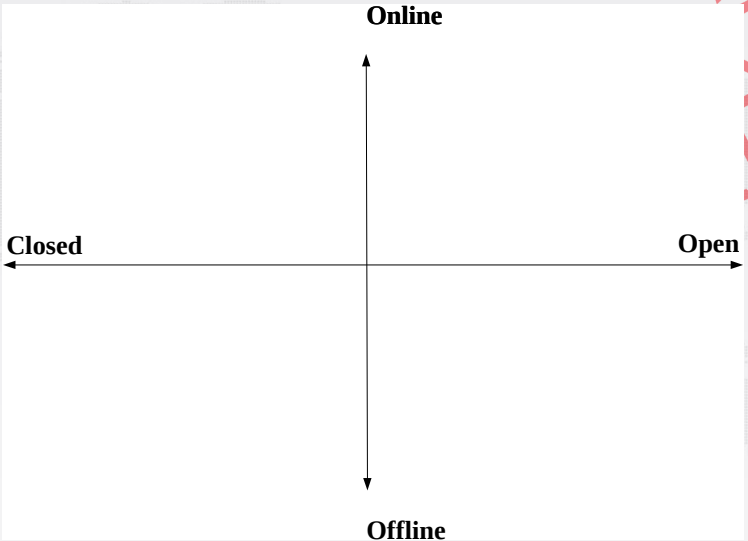
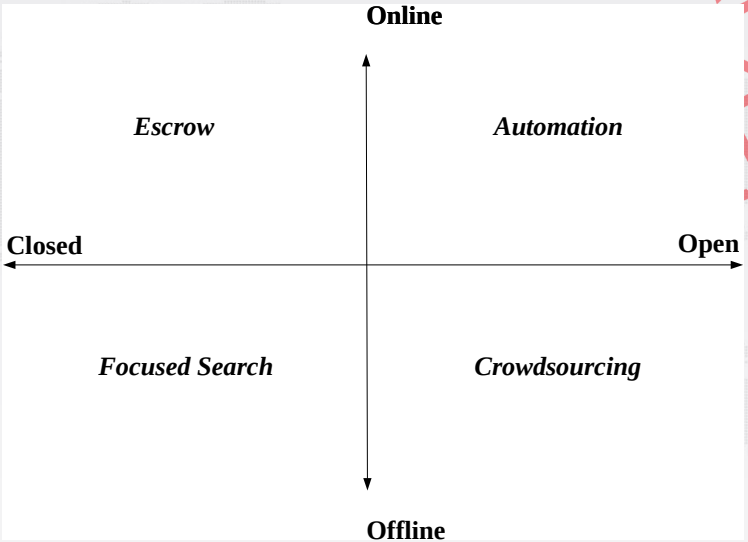


All the source: strategies



Outline

9 Under the hood

10 HAL and Software Heritage

11 Software Heritage vs. other approaches

12 FAIR software

13 All the source code

14 More on the data model

Archiving goals

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

We DO archive

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

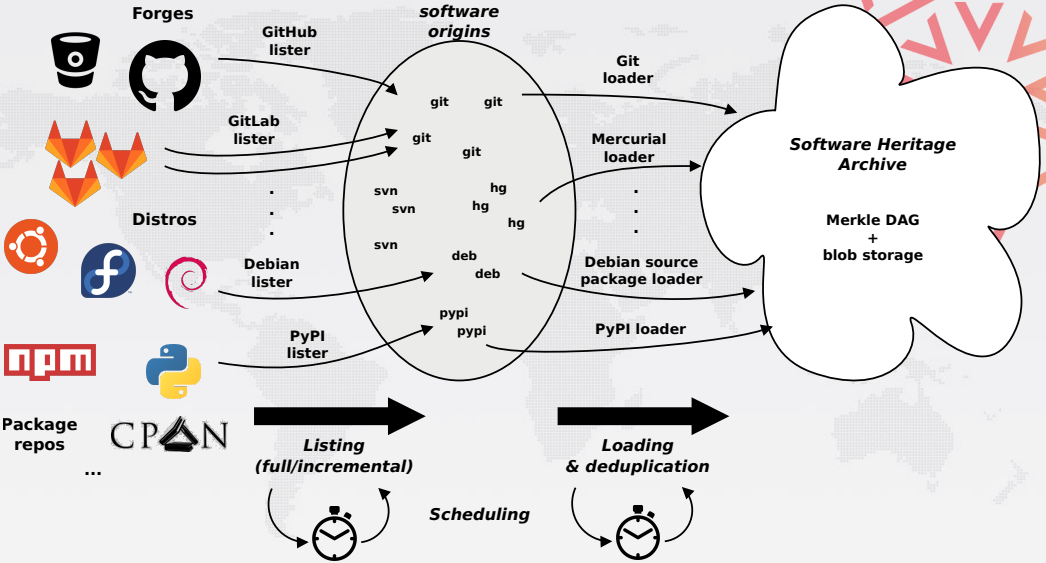
… in a VCS-/archive-agnostic canonical data model

We DON'T archive (yet)

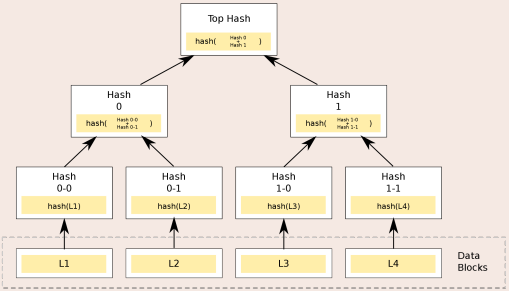
- homepages, wikis
- BTS/issues/code reviews/etc.
- mailing lists

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
deb
deb
pypi
pypi
Git loader
Mercurial loader
Debian source package loader
PyPI loader
Software Heritage Archive
Merkle DAG
+
blob storage
Listing (full/incremental)
Scheduling
Loading & deduplication

Merkle tree (R. C. Merkle, CRYPTO 1987)

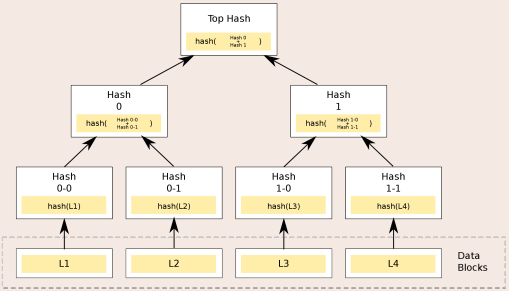


Combination of

- tree
- hash function

Merkle trees

Merkle tree (R. C. Merkle, CRYPTO 1987)



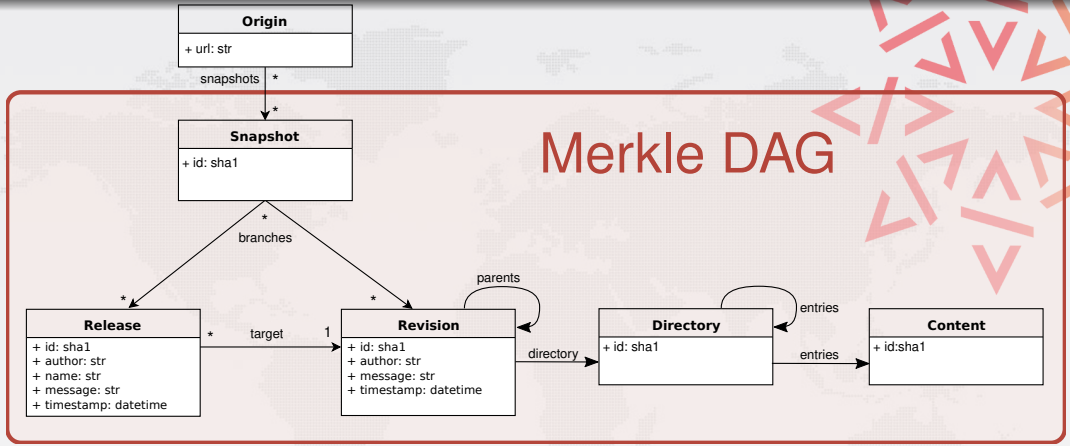
Combination of

- tree
- hash function

Classical cryptographic construction

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

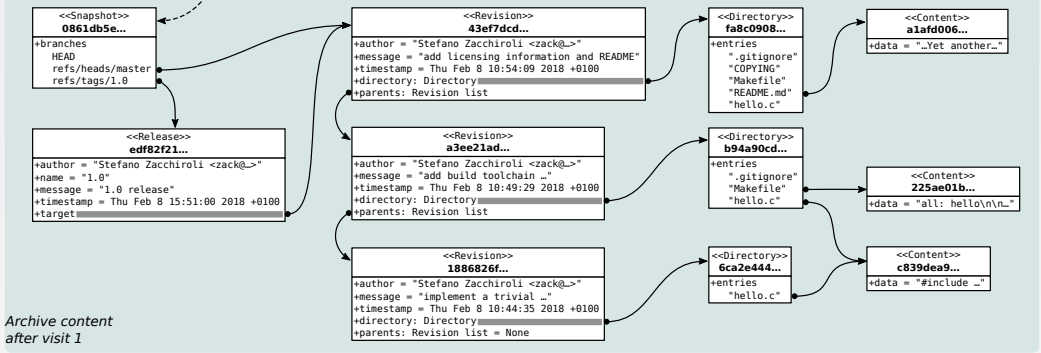
Data model



A global graph linking together fully deduplicated source code artifact (files, commits, directories, releases, etc.) to the places that distribute them (e.g., Git repositories), providing a unified view on the entire *Software Commons*.

The archive: a (giant) Merkle DAG

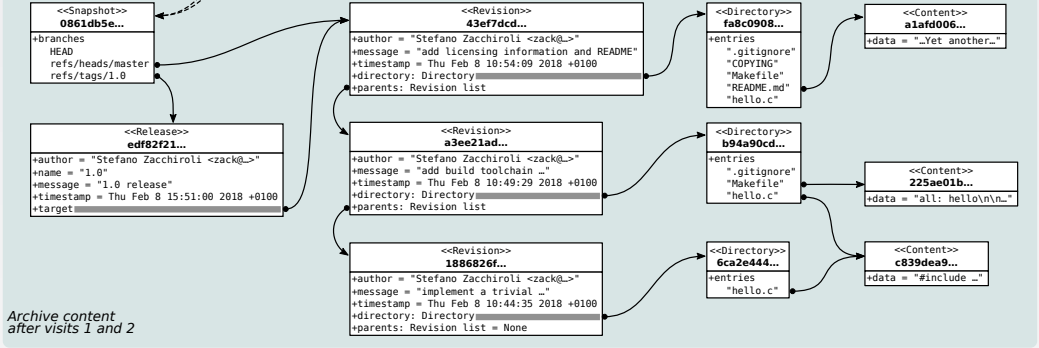
origin	visit	snapshot	timestamp
https://forge.softwareheritage.org/source/helloworld.git	1	0861db5e…	Fri Feb 9 12:38:45 2018 +0100



Archive content after visit 1

The archive: a (giant) Merkle DAG

origin	visit	snapshot	timestamp
https://forge.softwareheritage.org/source/helloworld.git	1	0861db5e...	Fri Feb 9 12:38:45 2018 +0100
https://forge.softwareheritage.org/source/helloworld.git	2	0861db5e...	Fri Feb 9 13:29:00 2018 +0100



The archive: a (giant) Merkle DAG