Software Pillar of Open Science

challenges and opportunities

Roberto Di Cosmo

Director, Software Heritage
Inria and Université de Paris Cité

April 2025

Software Heritage

THE GREAT LIBRARY OF SOURCE CODE

Outline

Short Bio: Roberto Di Cosmo

Computer Science professor in Paris, now working at INRIA

- *35+ years* of research (Theor. CS, Programming, Software Engineering, Erdos #: 3)
- *25+ years* of Free and Open Source Software
- *15+ years* building and directing structures for the common good

1999 *DemoLinux* – first live GNU/Linux distro

2007 *Free Software Thematic Group*
150 members 40 projects 200Me

2008 *Mancoosi project* www.mancoosi.org

2010 *IRILL* www.irill.org

2015 *Software Heritage* at INRIA

2018 *National Committee for Open Science*, France

2021 *EOSC Task Force on Infrastructures for Software*, European Union

Outline

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*.

Jean-Eric Paquet (EU DGRI, on the objective of Open Science)

"Increase *scientific quality*, the *pace of discovery and technological development*, as well as *societal trust in science*."

Mariya Gabriel (EU Commissionneer for Research)

The COVID-19 crisis has also shown that cooperation at international level in research and innovation is more important than ever, including through *open access to data and results. No nation, no country can tackle any of these global challenges alone.*

Yuval Noah Harari (on COVID 19)

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

Software *Source Code* is Precious 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."

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 ...
                CADR    BURNBABY
```

Quake III source code (excerpt)

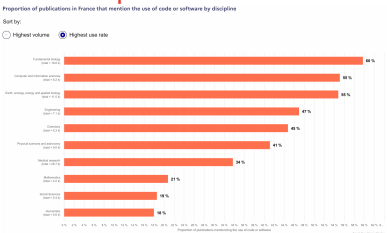
```
float Q_rsqrt( float number )
{
    long i;
    float x2, y;
    const float threehalfs = 1.5F;

    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;
}
```

Len Shustek, Computer History Museum 2006

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

Software is a pillar of Open Science

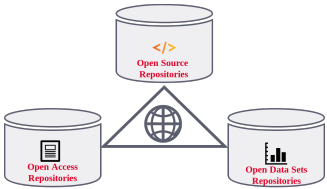
Software powers modern research



Over 20% of articles using software across all disciplines share it

2024 French Open Science Monitor

Key pillar: software



Links are important

Nota Bene

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

access to the *source code* is essential!

Preserving (the history of) source code is necessary for *reproducibility*

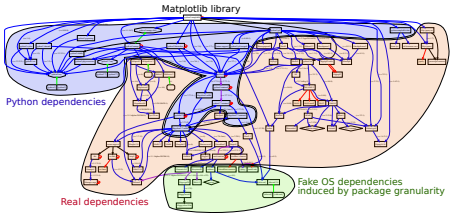
Source code is *special* (software is *not* data)

Software *evolves* over time

- projects may last decades
- the *development history* is key to its *understanding*

Complexity

- *millions* of lines of code
- large *web of dependencies*
  - easy to break, difficult to maintain
  - *research software* a thin top layer
- sophisticated *developer communities*



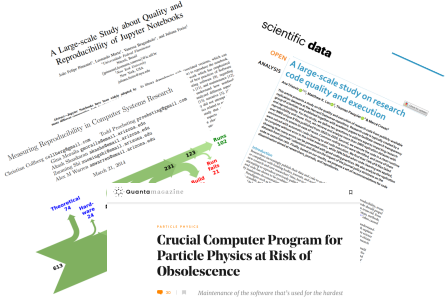
The human side

design, algorithm, code, test, documentation, community, funding

and so many more facets …

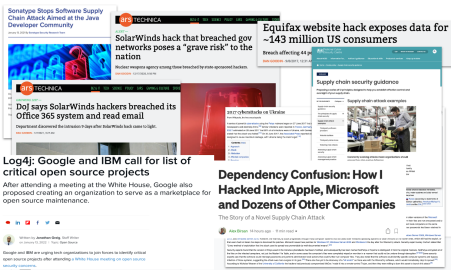
How are we managing our software ?

Reproducibility, maintenance in Academia



(articles: here, here, here and here)

Security, integrity, traceability in Industry



Can they track the software that they

- ship, use, acquire
- has that bug or vulnerability

awareness is raising at the level of public policy

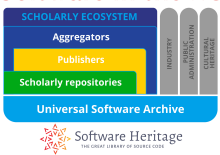
International highlights

Paris Call on Software Source code (2019, UNESCO)

40 international experts call to *"promote software development as a valuable research activity, and research software as a key enabler for Open Science/Open Research, [...] recognising in the careers of academics their contributions to high quality software development, in all their forms"*

☞ Open Source in UNESCO recommendations for Open Science, 2021

Software in the EOSC



2020 EOSC SIRS connect scholarly ecosystem via Software Heritage
2021 EOSC Task Force on Infrastructures for Research Software
2022 FAIRCORE4EOSC project WP6 implements SIRS report

And much more

Software track in OSEC 2022, Software working group launched in Science Europe, DFG adds software to model CV (9/22), NASA unveils Open Science policy (12/22), ...

What is at stake

ARDC

- Archive for retrieval (*reproducibility*)
- Reference for identification (*reproducibility*)
- Describe for discovery and reuse
- Cite/Credit for credit and evaluation

Before ARDC

- Development practices and tools (VCS, build system, test suites, CI, code quality, …)
- Opening up towards a community (documentation, organization, communication)

Need training, tooling, infrastructures, best practices

Beyond ARDC

- Policies (dissemination, reuse, careers, …)
- Sustainability (legal, financial, etc.)
- Technology transfer
- Advanced technologies and tools (quality, traceability, etc.)

a humbling challenge, and a complex one (we are not in a vacuum)

Outline

French National plan for Open Science, 2021-2024

MINISTÈRE
DE L'ENSEIGNEMENT
SUPÉRIEUR,
DE LA RECHERCHE
ET DE L'INNOVATION

Liberté
Égalité
Fraternité

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**
- New commitments to the **opening of source code** produced by research
- **European and international inclusion** in the context of the French Presidency of the European Union
- **Disciplinary and thematic variations**: open science policies must be adapted to disciplinary specificities

2

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 **reproductibility** 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

Software College in the CoSO

Five action lines (see details online)

- Identifying and highlighting research software production
- Technical and social tools and best practices
- Valorization and sustainability
- Liaison and animation at national, European, and international levels
- Recognition and careers

Source Code primer

key concepts

- for students
- for teachers
- for researchers

Report on software forges

in academia (FR):

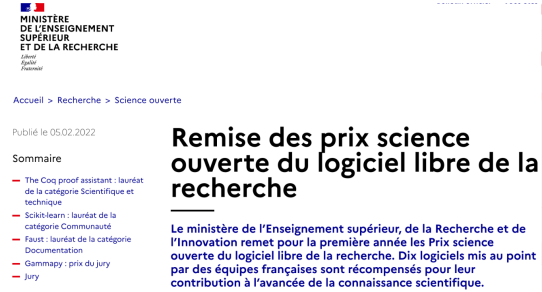
- needs
- options
- limitations

Annual award

Establishing a national research software award. Open Research Europe 2023

National Open Science awards for FOSS in France: 2022 and 2023

First edition, 2022 prize



- 129 projects
- 4 awards
- 6 accessit
- first edition

- Coq proof assistant
- Scikit-Learn ML/AI
- Faust music
- Gammapy astronomy

Second edition, 2023 prize

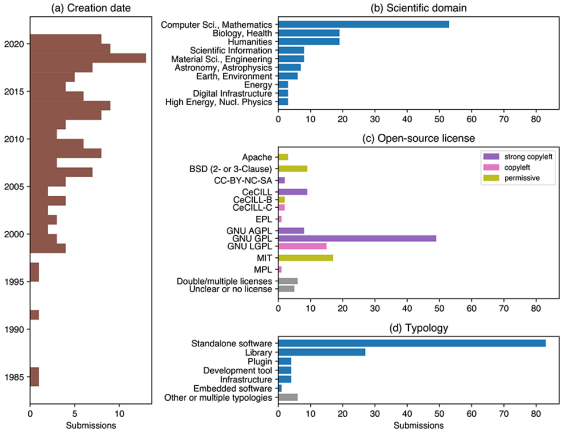
- 66 projects
- 4 awards
- 4 "espoirs"
- now runs annually

Blueprint and data from the first edition (2021-2022)

Blueprints and analysis available

- goals, design decisions
- challenges and solutions
- lessons learned
- detailed data

A look at the data



Emulation is working

Australia: here and here; Germany: Helmholtz; European Commission: a CSA; …

National survey of research software (2023)

Context

Article 163 of Law No. 2022-217 of February 21, 2022 required a report on the production and impact of software resulting from research performed in publicly funded entities (universities, research organisations, etc.)

Process and selected results

Open survey (1331 detailed answers), and in depth exchanges with tech transfer offices

- 50% of software is older than 9 years
- 36% has more than 100 users
- 62% impact outside academia
- majority is FOSS, 10% proprietary
- 23% undergoes tech transfer

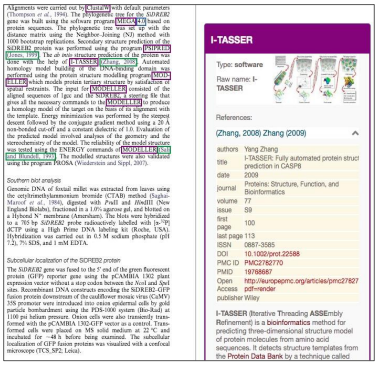
all details (in french) at

A LITTLE BIT OF CONTEXT IN FRANCE…

Credits: Laetitia Bracco and the BSO team

MINING FULL-TEXTS TO DETECT MENTIONS TO DATASETS AND SOFTWARE

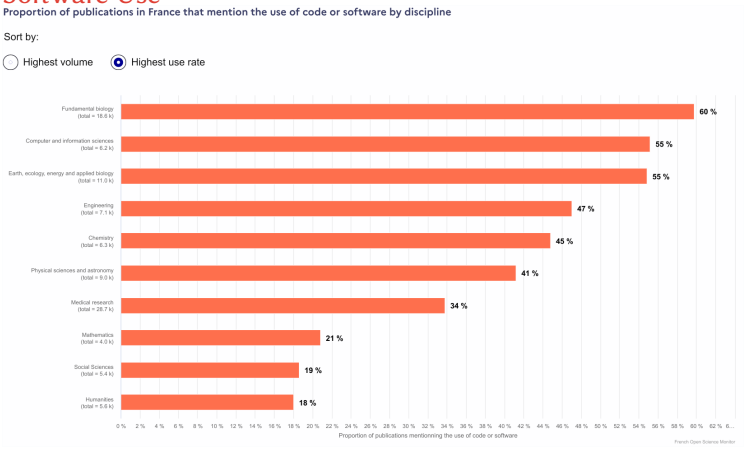
- **Innovative approach** based upon the use and development of machine learning tools
  - GROBID: full-text structuring
  - Softcite: **software mention detection**
  - DataStet: **data set mention detection**
- Automatic characterisation of mentions: **usage / production or creation / sharing**
- Another challenge: **downloading massive amounts of full-texts**



science-miner

Credits: Laetitia Bracco and the BSO team
Uses improved version of SoftCite w.r.t. the CZI 2022 study in biomedicine

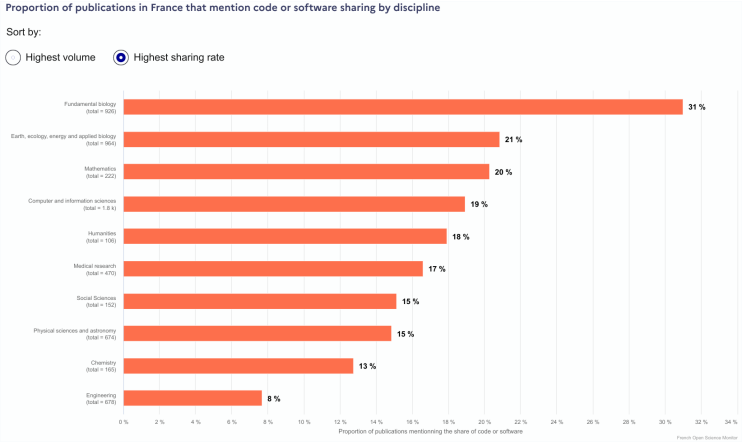
… gives a precious view, per discipline



Software is used massively across all disciplines/

… gives a precious view, per discipline, cont'd

Software Sharing



Over 20% of articles mentioning software creation actually share it

Outline

What is at stake

Archive

Research software artifacts must be properly archived

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

Reference

Research software artifacts must be properly referenced

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

Describe

Research software artifacts must be properly described

make it easy to *discover* and *reuse* them (*visibility*)

Cite/Credit

Research software artifacts must be properly cited *(not the same as referenced!)*

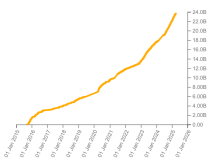
to give *credit* to authors (*evaluation*!)

Software Heritage: *one* software archive, a *shared infrastructure* ...

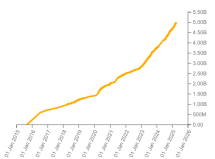
One infrastructure
open and shared

The largest archive ever built

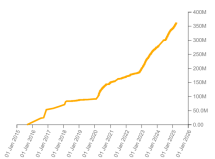
Source files
23,828,196,855



Commits
5,006,891,310



Projects
362,987,832



Directories
18,809,563,175

Authors
90,221,599

Releases
106,890,095

Diamond sponsors

Platinum sponsors

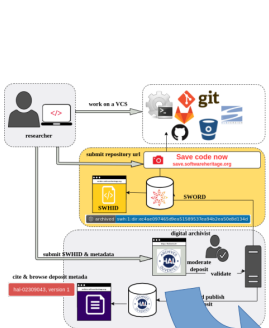
Gold sponsors

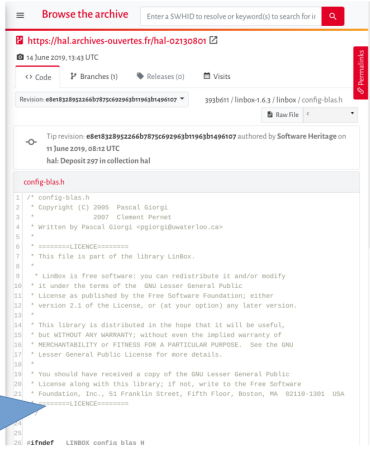
Silver sponsors

Bronze sponsors

… best experience for researchers, worldwide

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



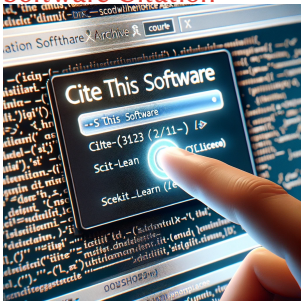


swh:1:dir:393b611a1424f032e83569bf6762502371cfcf65

Learn more at https://softwareheritage.org/ demo time!

Breaking news: seamless software citation

Software Citation



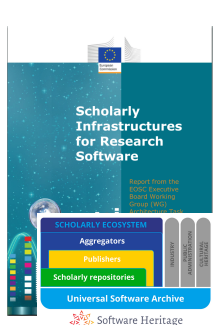
DALL-E's view of software citation

- SWH is uniquely positioned:
  - platform agnostic: works with all forges, not just GitHub!
  - *only place* to provide the right SWHID for a visited (version of a) project
- in production since January 2025

Outline

A few adoption indicators

Policy



- Recommendations in ANR 2023 guidelines (p. 17)
- HAL+SWH in the Open Science software booklet

Projects

eosc | FAIRCORE4EOSC
Core Components Supporting a FAIR EOSC

The CodeMeta Project

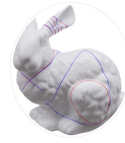
eosc | FAIR-IMPACT
Expanding FAIR solutions across EOSC

Users and collaborations

What are they "referencing"?

source	n	percentage
Not available	2868	46.22
GitHub	1151	18.55
software heritage	387	6.24
zenodo	142	2.29
r package	70	1.13
cran	56	0.90
r package version	54	0.87
gitlab	35	0.56

Graphics Replicability Stamp Initiative



b/Surf: Interactive Bézier Splines on Surface Meshes

Claudio Mancinelli, Giacomo Nazzaro, Fabio Pellacini, Enrico Puppo
IEEE Transactions on Visualization and Computer Graphics (TVCG)

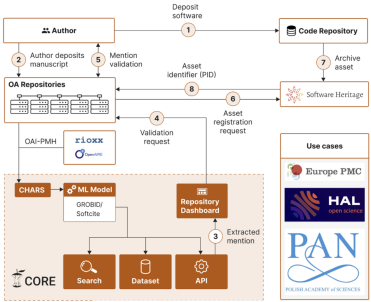
doi | Repository

We are going global

Institutional: OSMF

Effort under UNESCO and France impulse to build an "open science monitor framework" compatible monitors across countries

Infrastructure: SOFair



Effort to identify software mentions in all the open access literature, and add links to the Software Heritage archive

Call to action: push adoption of best practices for ARDC

Archive and reference

All source code used in research (*yes, even small scripts!*) *for reproducibility*

- save in Software Heritage
- add SWHID in articles

See detailed HOWTO online

Describe and Cite/Credit

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

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

train students and colleagues

engage journals, conferences, learned societies

libraries join the ALIG interest group

Call to action: policy making

A working agenda

- support open source research software
  - clear policy and institutional home (see OSPOs in the US)
  - common knowledge base for technology transfer
  - technical and financial sustainability
  - modern, efficient, scalable, maintained collaboration infrastructures
- establish *intelligent and effective* incentives (mind Goodhart's law)
  - count *quality software contributions* in careers
  - avoid *purely numerical indicators*, keep the human in the loop
  - respect software complexity, *dont treat it as data*
- avoid balkanisation, support mutualised common infrastructures
  - build on common, shared, open, non profit infrastructures, like Software Heritage
  - acknowledge the predominant human component of digital infrastructures
    - *recurrent funding* of the cost, for proper *evaluation of the service*
- lead, dont follow the international conversation

The floor is yours

let's work together to drive the wave

References


UNESCO, *Draft recommendations on Open Science*
2021, (online)


French Ministry of Research, *Second National Plan for Open Science*
2021, (online)


EOSC SIRS Task Force, *Scholarly Infrastructures for Research Software*
2020, Publications office of the European Commission, (10.2777/28598)


R. Di Cosmo, *Archiving and Referencing Source Code with Software Heritage*
International Conference on Mathematical Software 2020 (10.1007/978-3-030-52200-1_36)


J.F. Abramatic, R. Di Cosmo, S. Zacchiroli, *Building the Universal Archive of Source Code*
CACM, October 2018 (10.1145/3183558)