CODE beyond FAIR: towards sustainable research software

Roberto Di Cosmo, Sabrina Granger, Nicolas Jullien, Konrad Hinsen, Daniel Le Berre, Violaine Louvet, Camille Maumet, Clémentine Maurice, Raphaël Monat & Nicolas P. Rougier

`rmonat.fr`

SWH Ambassadors Meeting
2025-12-16

Research software

What is research software (RS)?

"Research Software includes source code files [...] created during the research process [...]. Software components [...] that [...] were not created [...] with a clear research intent should be considered software in research [...]."

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Research software as a pillar of research

- RS mentions: 33% in 2013 to 48% in 2021 Bassinet et al. [Bas+23]
  large scale study of 908,000 articles with French authors

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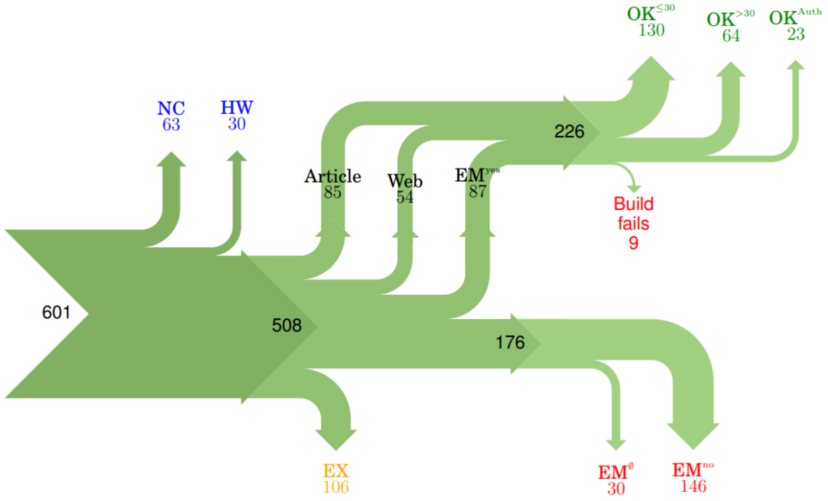
  large scale study of 908,000 articles with French authors
- 10% of French RS uses proprietary licensing [Cat+24]

Reproducibility crisis – Collberg and Proebsting [CP16] – CS publications in 2013



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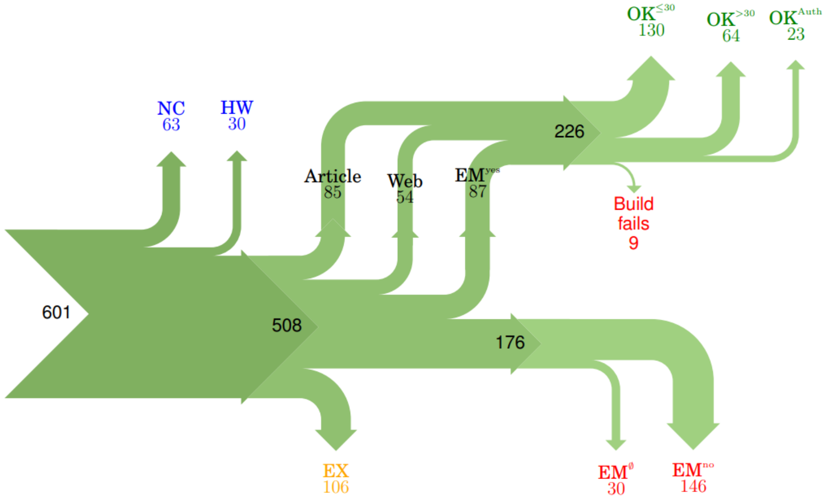
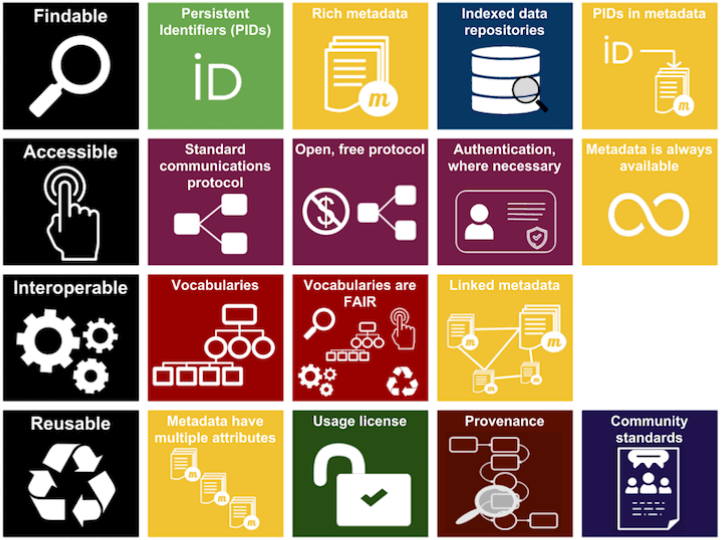


$\Longrightarrow$ Guidelines & principles to improve the state of research software

FLOSS: Free/Libre Open-Source Software

- FLOSS exists since the 80s
- Academia is a small part of it since the beginning
- Successes: Linux, Firefox, VLC, ...

FAIR principles for data [Wil+16]



FAIR principles for research software (FAIR4RS) – Barker et al. [Bar+22]

- **F** — Software, and its associated metadata, is easy for both humans and machines to find. (F1, F1.1, F1.2, F2, F3, F4)

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- **R** — Software is both usable (can be executed) and reusable (can be understood, modified, built upon, or incorporated into other software). (R1, R1.1, R1.2, R2, R3)

CODE beyond FAIR

Beyond current principles

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- Do not deter engagement: mandatory, recommended, optional guidelines

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- Accommodate disparities among disciplines

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A call to action for all stakeholders

- Ensure means to set these new practices in stone

A roadmap for research software developers

Open

Publish your source code on a public forge **Mandatory**

- ~~Code available upon request~~ does not work empirically [CP16]
- Forges provide tailored development and collaboration tools

Open

Publish your source code on a public forge — **Mandatory**

Save your repository on dedicated archive — **Mandatory**

⚠ Repositories and forges can close (Google Code, 2016)

▶ UNESCO-backed Software Heritage as a long-term, dedicated software archive

Open

Publish your source code on a public forge — **Mandatory**

Save your repository on dedicated archive — **Mandatory**

License your code with an open license — **Strongly recommended**

- No license = no rights distributed
- See Choose a License and institutional policies

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Declare authorship and rightholders	Recommended

- Legal aspects
- For citing software

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Especially important in RS, defining state-of-the-art, specialized methods

Choose meaningful names **Recommended**

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Execute

Goal: avoid dependency hell and ensure computational reproducibility.

List software and hardware dependencies **Recommended**

- Version of dependencies (including operating system)
- Improper use can create crashes or even incorrect results [Bha+19]

Execute

Goal: avoid dependency hell and ensure computational reproducibility.

List software and hardware dependencies — **Recommended**

Provide a computational environment — **Optional**

- Guix, Nix, or at least containers (Docker, VMs)

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List software and hardware dependencies — **Recommended**

Provide a computational environment — **Optional**

Implement a test suite — **Optional**

- Can also help you as a developer to detect regressions!

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Implement a test suite	Optional
Show real-life usage example with expected results	Optional

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Institutions

Support development **Mandatory**

- Hiring research software engineers
- Actionable legal frameworks for distributing FLOSS research software

Institutions

Support development — **Mandatory**

Promote software — **Recommended**

- Software as scientific contributions for hiring/promotion [Can+21; Ver+25]
- Awards to create visibility and raise awareness [Cat+23]

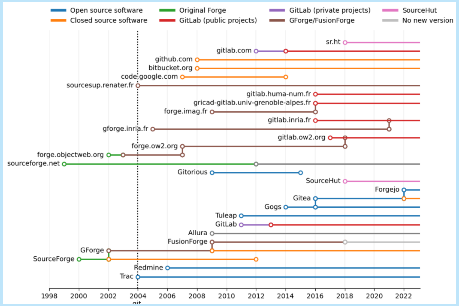
Institutions

Support development Mandatory

Promote software Recommended

Build and maintain institutional forges Optional

- 81 different forges in French higher education [Le +23]



- Key issue: international interoperability

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Funders

Provide grants for long-term support — **Mandatory**

- Long-term sustainability cannot be the sole responsibility of scientists.
- Recent initiatives by the Software Sustainability Institute or the German Research Foundation.

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Promote reproducibility — **Recommended**

Natural follow-up of important funders (ERC) promoting open science.

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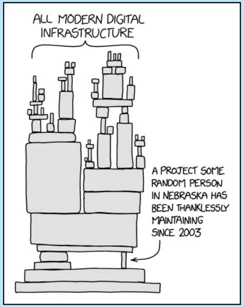
Facilitate collaborations — **Optional**

- subset of a grant could be dedicated to the support of a core library
- RS equivalent of the publicly-funded German Sovereign Tech Fund?


ALL MODERN DIGITAL INFRASTRUCTURE
A PROJECT SOME RANDOM PERSON IN NEBRASKA HAS BEEN THANKLESSLY MAINTAINING SINCE 2003

XKCD #2347

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Libraries can accompany the turn into research software and bring their expertise to ensure proper metadata definition and archival.

Prepare software archival plans	**Mandatory**

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Create and curate software metadata — **Mandatory**

Examples: SWHID, CodeMeta, Bioschemas ComputationalTool or Automated Software Metadata Publication.

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Catalog software **Recommended**

- Institutional: NASA's Software Catalog, French Catalog for Research Software
- Specific communities: swMATH, bio.tools

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Publishers

Enforce open source **Mandatory**

- Code should be published alongside papers
- ~~Availability upon request~~

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Link publications and codes **Recommended**

Examples: Dagstuhl Artifact Series (DARTS) [Dag] and IACR’s Artifact Archive [IAC]

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Link publications and codes — **Recommended**

Review software — **Optional**

artefact evaluation processes since 2011 [Di +20; Inf+25]

- ▶ Artifact = computational environment + software
- ▶ Goal: reproducibility of software-related experimental claims

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  - Preprint (under revision) `hal.science/hal-04930405` [Di +25a]

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- Comments? Other examples in mind?

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