Logiciels et Science Ouverte: enjeux et opportunités

Roberto Di Cosmo

November 19th, 2019
Short Bio: Roberto Di Cosmo

Computer Science professor in Paris, now working at INRIA

- 30 years of research (Theor. CS, Programming, Software Engineering, Erdos #: 3)
- 20 years of Free and Open Source Software
- 10 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
2015 Software Heritage at INRIA
2018 National Committee for Open Science, France
Source code is *special*. 

Executable and *human readable* knowledge

> “Programs must be written for people to read, and only incidentally for machines to execute.”
>
> Harold Abelson

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
- sophisticated *developer communities*
Software is everywhere in modern research

[…] software […] essential in their fields.

*Top 100 papers (Nature, 2014)*

_Sometimes, if you don’t have the software, you don’t have the data_

Christine Borgman, Paris, 2018

Open Science: three pillars

Nota bene

The links in the picture are essential
Where we stand

A wealth of initiatives!

- Policies: ACM Artifact Review and Badging, …
- Working groups: FORCE11, RDA, SPSO, …
- Metrics: Open Science Monitor (Elsevier!), …
- Repositories: FigShare, Zenodo, …

but …

Lack of recognition

not (yet) a first class citizen
- in the EOSC plan
- in the scholarly works

Lack of proper guidance on how to

- archive and reference software
- choose a license
- cite a software project
What is at stake

Archival
Research software artifacts must be properly **archived**
make it sure we can **retrieve** them (**reproducibility**)

Identification
Research software artifacts must be properly **referenced**
make it sure we can **identify** them (**reproducibility**)

Metadata
Research software artifacts must be properly **described**
make it easy to **discover** them (**visibility**)

Citation
Research software artifacts must be properly **cited** (*not the same as referenced!*)
to give **credit** to authors (**evaluation!**)
Sustainability
Organisational schemas, legal tools, economic models, processes and policies to ensure research software can be maintained and sustained over time

Technology transfer and industry collaboration
Approaches, support, methods, processes to establish connections with industry in order to foster uptake and transfer of research software
1. Introduction

2. Archival and reference: use Software Heritage!

3. The road ahead
Collect, preserve and share the source code of all the software

Preserving our heritage, enabling better software and better science for all

Reference catalog
find and reference all the source code

Universal archive
preserve all the source code

Research infrastructure
enable analysis of all the source code
The largest software source code archive ever

20 billions intrinsic identifiers for reproducibility

See DIO vs IDO in bit.ly/swhpiddpaper

Reference archive

See the work done at swmath.org

SWH IDs now a standard for Wikidata

See https://www.wikidata.org/wiki/Property:P6138

Policy

Now part of the French National Plan for Open Science
Archive and reference

Guidelines
https://www.softwareheritage.org/save-and-reference-research-software/

Save code now
... just a few clicks!

Demo
live...
Describe and cite

How it works, what is special

Generic mechanism:
- SWORD based
- review process
- versioning
- **today**: deposit .zip or .tar.gz file ([guide](https://hal.archives-ouvertes.fr/hal-01872189))
- **tomorrow**:
  - just provide SWH id, metadata extraction

Deposit/describe research software in HAL

- **author**: [https://hal.archives-ouvertes.fr/hal-01872189](https://hal.archives-ouvertes.fr/hal-01872189)
- **moderator**: [https://hal.archives-ouvertes.fr/hal-01876705](https://hal.archives-ouvertes.fr/hal-01876705)
Many articles/guidelines

- reproducibility
- archival
- credit and evaluation

Most common limitations

- software is 'just data'
- citation = reference = DOIs
- citation produced by automated tools

A few remarkable exceptions

- **ASCL (since 1999):** metadata only, carefully curated
- **geodynamics.org:** source, documentation, metadata
- **swmath.org:** software catalog via articles

Software Citation WG at Inria (since 10/2018)

- leverage a 50 year experience, make recommendations
- read more [https://hal.archives-ouvertes.fr/hal-02135891](https://hal.archives-ouvertes.fr/hal-02135891)
### Why it is not simple

**Software is complex**

<table>
<thead>
<tr>
<th>Structure</th>
<th>monolithic/composite; self-contained/external dependencies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lifetime</td>
<td>one-shot/long term</td>
</tr>
<tr>
<td>Community</td>
<td>one man/one team/distributed community</td>
</tr>
<tr>
<td>Authorship</td>
<td>complex set of roles <em>(more later)</em></td>
</tr>
<tr>
<td>Authority</td>
<td>institutions/organizations/communities/single person</td>
</tr>
</tbody>
</table>

**Various granularities**

- **Exact status of the source code** for reproducibility, e.g.
  
  “you can find at `swh:1:cnt:cdf19c4487c43c76f3612557d4dc61f9131790a4;lines=146-187` the core algorithm used in this article”

- **(Major) release** “This functionality is available in OCaml version 4”

- **Project** “Inria has created OCaml and Scikit-Learn”.  

Roberto Di Cosmo

(CC-BY 4.0) Logiciels et Science Ouverte November 19th, 2019
Proposals for the scholarly world

Refined ontology for contributors
- Design, Architecture,
- Coding, Testing, Debugging,
- Documentation, Maintenance, Support,
- Management

see also CRediT, Geodynamics

Reference is distinct from citation
- **Reference** is for *reproducibility*
- **Citation** is for *credit*

They must not be conflated

Beware of the numbers game:

… do we really want an *s-index*?

Keep the human in the loop

When *credit* is at stake, automation/crowdsourcing is not enough!

Humans *are needed* to get *quality information*
Outline

1. Introduction
2. Archival and reference: use Software Heritage!
3. The road ahead
Conclusion

Research software

- pillar of open science
- finally in the limelight

Doing it right is not easy

- simplistic approaches, "just data", ...
- soon part of research evaluation

You can help make a change

- leverage Software Heritage in conferences and journals for archival and reference
- join the conversation on software citation and software evaluation criteria
- join the SPSO GPLO: https://www.ouvrirlasscience.fr/logiciels-libres-et-open-source/

Thank you!

Jean-François Abramatic, Roberto Di Cosmo, Stefano Zacchirolı
Building the Universal Archive of Source Code
Communications of the ACM, October 2018

Roberto Di Cosmo, Morane Gruenpeter, Stefano Zacchirolı
Identifiers for Digital Objects: the Case of Software Source Code Preservation
Appendix
Outline

4 Under the hood

5 Identifiers are not easy

6 Looking for the right identifiers
full development history **permanently archived!**
Outline

4 Under the hood

5 Identifiers are not easy

6 Looking for the right identifiers
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*


*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.*


## An example from Astronomy

<table>
<thead>
<tr>
<th>Domain</th>
<th>links (broken)</th>
<th>.html</th>
<th>.txt</th>
<th>.dat</th>
<th>.gz</th>
<th>.tar</th>
<th>.fits</th>
<th>tilde</th>
</tr>
</thead>
<tbody>
<tr>
<td>cec.harvard.edu</td>
<td>802 (110)</td>
<td>336 (70)</td>
<td>0</td>
<td>0</td>
<td>4 (2)</td>
<td>5 (4)</td>
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<td>0</td>
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<td>640 (33)</td>
<td>423 (27)</td>
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<td>0</td>
<td>0</td>
<td>0</td>
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<td>0</td>
</tr>
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<td>0</td>
<td>0</td>
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<td>0</td>
<td>7 (5)</td>
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<td>1</td>
<td>0</td>
<td>2</td>
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<td>0</td>
<td>4 (1)</td>
</tr>
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<td>0</td>
</tr>
<tr>
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<td>0</td>
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<td>1</td>
<td>0</td>
<td>1 (1)</td>
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<tr>
<td><a href="http://www.astroph.princeton.edu">www.astroph.princeton.edu</a></td>
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<td>0</td>
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<td>astro.navy.mil</td>
<td>110 (27)</td>
<td>98 (22)</td>
<td>3 (3)</td>
<td>0</td>
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<td>0</td>
<td>0</td>
<td>1 (1)</td>
</tr>
</tbody>
</table>

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

---

**How Do Astronomers Share Data?**

Pepe, Goodman, Muench, Crosas, Erdmann

dx.doi.org/10.1371/journal.pone.0104798

---

PLOS August 28, 2014
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*
Outline

4 Under the hood

5 Identifiers are not easy

6 Looking for the right identifiers
A system of identifiers is

- a set of labels (the identifiers)
- mechanisms to perform:

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation (minting)</td>
<td>create a new label</td>
</tr>
<tr>
<td>Assignment</td>
<td>associate label to object</td>
</tr>
<tr>
<td>Retrieval</td>
<td>get object from a label</td>
</tr>
</tbody>
</table>

- optionally, mechanisms to perform:

<table>
<thead>
<tr>
<th>Mechanism</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Verification</td>
<td>check label and object</td>
</tr>
<tr>
<td>Reverse Lookup</td>
<td>get label from an object</td>
</tr>
<tr>
<td>Description</td>
<td>get metadata of an object</td>
</tr>
</tbody>
</table>
Mechanisms offered in some systems of identifiers

<table>
<thead>
<tr>
<th>Mech. / System</th>
<th>Handle</th>
<th>DOI</th>
<th>Ark</th>
<th>PURL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Assignment</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Retrieval</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Verification</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>Reverse Lookup</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
<td>N.A.</td>
</tr>
<tr>
<td>Description</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>N.A.</td>
</tr>
</tbody>
</table>
Our challenges in the PID landscape

Typical properties of systems of identifiers
- uniqueness, non ambiguity, persistence, abstraction (opacity)

Key needed properties from our use cases
- gratis: identifiers are free (billions of objects)
- integrity: the associated object cannot be changed (sw dev, reproducibility)
- no middle man: no central authority is needed (sw dev, reproducibility)

we could not find systems with both integrity and no middle man!
An important distinction: DIOs vs. IDOs

The term “Digital Object Identifier” is construed as “digital identifier of an object,” rather than “identifier of a digital object”  
Norman Paskin, 2010

<table>
<thead>
<tr>
<th><strong>DIO (Digital Identifier of an Object)</strong></th>
<th><strong>IDO (Identifier of a Digital Object)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>digital identifiers for (potentially) non digital objects</td>
<td>digital identifiers (only) for digital objects</td>
</tr>
<tr>
<td>epistemic complexity (manifestations, versions, locations, etc.)</td>
<td>can provide both integrity and no middle man</td>
</tr>
<tr>
<td>need an authority to ensure persistence and uniqueness</td>
<td>broadly used in modern software development (git, etc.)</td>
</tr>
</tbody>
</table>

for the core Software Heritage archive, IDOs are enough
Merkle tree (R. C. Merkle, Crypto 1979)

Combination of
- tree
- hash function

Classical cryptographic construction

fast, parallel signature of large data structures, built-in deduplication
- satisfies all three criteria: gratis, integrity, no middle man!
- widely used in industry (e.g., Git, nix, blockchains, IPFS, …)
Contents

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Version 3, 29 June 2007

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developer are protected.

sha1: 8624bcdae55baeef...
sha256: 8ceb4b9ee5aded...
sha1_git: 94a9ed024d385...
length: 35147
IDIos in Software Heritage: a worked example
IDOs in Software Heritage: a worked example

Directories

```
100644 blob c5baade4c44766042186ef858c0fd63d587ebf09 .gitignore
100644 blob 2d6a34af6f52cf3cf6b6c27bd6048ffbd255e77f AUTHORS
100644 blob 94a9ed824d3859793618152ea559a168bbcb5e2 LICENSE
100644 blob d9b2665a435a43f8a79a84e0867751dfb895c7bb MANIFEST.in
100644 blob 524175c2bad0b35b975f79284c2f6a6d8ef2eb4 Makefile
100644 blob 5c7e3a5bbdb083862ba7793f440492ed9678bb3 Makefile.local
100644 blob 8617980629cd24e8080404099a749b885e3e67b README.db_testing
100644 blob 76b29f94cf815e0869c414d38d7877ce08ec51e4 README.dev
040000 tree e1e10eeef948af0b93ad8372af9812e92618a bin
040000 tree 83e56d8beaf7793c7a45a435c080fcb8af503013 debian
040000 tree a34c9c4ba213f8cedc67f9816348d27955577af5 docs
100644 blob f2a6d32c6139a7287bd76167b01df2ae4f1539 requirements.txt
100755 blob eee147c36caflbbc2cd820d8adc026cb568180bc setup.py
040000 tree 224bb4c1f4c67fca1d160bfff2d260947e1a63f sql
040000 tree 8631c9cd77bba99318107a85baf51f40e6306be swh
040000 tree 8fb90b56ba8ed692f1209b273b474c61d66c1 utils
```

id: 515f00d44e92c65322aaa9bf3fa097c00ddb9c7d
IDOs in Software Heritage: a worked example
Revisions

<table>
<thead>
<tr>
<th>Details</th>
<th>Changes</th>
<th>Files</th>
</tr>
</thead>
<tbody>
<tr>
<td>SHA: 963634dca6ba5dc37e3ee426ba091092c267f9f6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Author: Nicolas Dandrimont <a href="mailto:nicolas@dandrimont.eu">nicolas@dandrimont.eu</a> (Thu Sep 14 26:13 2018)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Committer: Nicolas Dandrimont <a href="mailto:nicolas@dandrimont.eu">nicolas@dandrimont.eu</a> (Thu Sep 14 26:13 2018)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subject: provenance.tasks: add the revision -&gt; origin cache task</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Parent: fc3a8b59ca1df424d860f2c29ab07ee4dc35d10 : test...storage: properly pipeline origin and cont...provenance.tasks: add the revision -&gt; origin cache task</td>
<td>swh/storage/provenance/tasks.py</td>
<td>77</td>
</tr>
</tbody>
</table>

```
tree 515f00d44e92c65322aaa9bf3fa097c00d9db9c7d
parent fc3a8b59ca1df424d860f2c29ab07ee4dc35d10
author Nicolas Dandrimont <nicolas@dandrimont.eu> 1472732773 +0200
committer Nicolas Dandrimont <nicolas@dandrimont.eu> 1472732773 +0200
provenance.tasks: add the revision -> origin cache task

id: 963634dca6ba5dc37e3ee426ba091092c267f9f6```
Releases

object: c0c9f16b1e134f593e7567570a1761b1566e6b1

type: commit

tag: v0.0.51

tagger: Nicolas Dandrimont <nicolas@dandrimont.eu>

date: Wed Aug 24 14:36:03 2026 +0200

Release sw/h.storage v0.0.51

- Add new metadata column to origin_visit
- Update sw/h-add-directory script for updated API

----BEGIN PGP SIGNATURE-----

IQJzB9A8CAAdBO4xZTFNuxxWNVgQGFQGRbm/RyaW1vbQiuZUACgqiQ7AWLmo2+
neqropriw/ao65b0sDjzEa+KWNl3kQV5=+k12EhVh3Wkw8k7aX2kE5L957u
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=K0hP

----END PGP SIGNATURE-----

id: 85083a5cc14a441c89dea73f5bdf67c3f9c6afdb
IDOs in Software Heritage: a worked example
Snapshots

commit 00ffe2b577010952e3b3c21691466c531d9158 refs/heads/atime
commit ba5443a24e39f9e32e3b46c92cc4fe0e61c67eb refs/heads/directory.listing-arrays
commit d69e07c683285f569b92f1e1c05f723889c5 refs/heads/foo
commit c7f7f9e6ba9e22b78946909750a86160f67edee46b80f88 refs/heads/master
commit 7ca197f2e5d62824047e54b1ed9e8b44361a1f6c2 refs/heads/tag-dir
commit 642a285f7a685685a56d427b3556eeef472522e82e refs/heads/tag-merge
commit 2910f3b1378c7f69266597790f6d907c757f755 refs/tags/v0.1
commit 0499ebae86908786a783761765f2a38b8f04f7f5c8c refs/tags/v0.10
commit 33378427a433b5a59a7777b68cd6674f4c556e refs/tags/v0.11
commit 86f7465275b327cf5903112bfa0936cf3b03d5 refs/tags/v0.12
commit 5a63525fe8b68b46b8e6d4286d92e31e327f3bd refs/tags/v0.13
commit 58eb88c46ac95b45f9a0b5f55937643c3b1a9c7f refs/tags/v0.14
commit 86c8888f4f9b8f3631777b2d82df8560f5eb51c refs/tags/v0.15
commit a542444e339f8be83b3efb287feee65b09ab63c7d6 refs/tags/v0.16
commit 22baf37f559d12222e55555f462e1e06fc4993d9 refs/tags/v0.17
commit 6969794ac85d4977fc8d024a0dd9dce82536e4f47c refs/tags/v0.18
commit 32bf5a59f2ca2f3b0aed51f56a0sd3279c275a67 refs/tags/v0.19
commit 314fc3d3eac46cf64927f801e9e0b1237ebdf7c7 refs/tags/v0.20
commit 215ea50daab118e82e6b2e766b4b670f83a87908 refs/tags/v0.21
commit 3fb168c2872a5d8b252124257a1a5d5c85f1a1df refs/tags/v0.22
commit 8cbbe8d4a743c5a262789e4e0b16ac3c72aba4 refs/tags/v0.23

...
The Software Heritage IDO schema (see http://bit.ly/swhpids)

- **swh:1:cnt:** 94a9ed024d3859793618152ea559a168bbcbbb5e2 - full text of the GPL3 license
- **swh:1:dir:** d198bc9d7a6bcf6db04f476d29314f157507d505 - Darktable source code
- **swh:1:rev:** 309cf2674ee7a0749978cf8265ab91a60ae0f7d - a revision in the development history of Darktable
- **swh:1:rel:** 22ece559cc7cc2364edc5e5593d63ae8bd229f9f - release 2.3.0 of Darktable, dated 24 December 2016
- **swh:1:snp:** c7c108084bc0bf3d81436bf980b46e98bd338453 - a snapshot of the entire Darktable repository (4 May 2017, GitHub)

Current resolvers: archive.softwareheritage.org and n2t.org