Software Heritage for Open Science and Open Source

a revolutionary infrastructure

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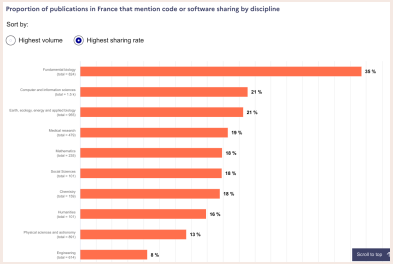
Software Heritage

THE GREAT LIBRARY OF SOURCE CODE

Outline

Software: a pillar of Open Science

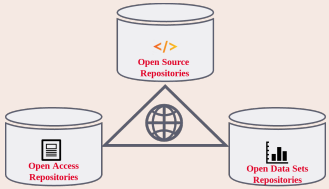
Software powers modern research



Over 20% of articles across all disciplines share software

2023 French Open Science Monitor

Key pillar: software



Links are important

Nota Bene

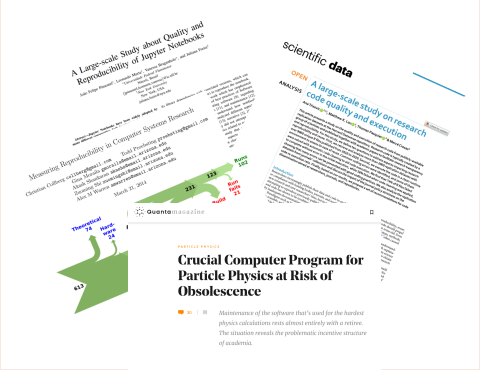
software may be a *tool*, a *research outcome* and a *research object*

access to the *source code* is essential!

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

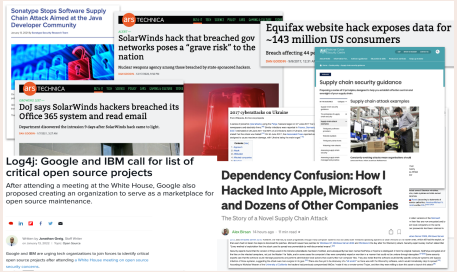
How are we managing our software ?

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

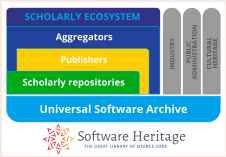
International highlights

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
2023 INFRAEOSC call on quality of scientific software

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), …

French National plan for Open Science, 2021-2024

2nd National Plan for Open Science (6/7/2021)

Open and promote research software source code

- actions (selection)
  - charter for research software policy
  - recognize software development (see 2022 prize and 2023 call)
  - coordinate communities of practice
  - connected ecosystem of research outputs
- recommendations (selection)
  - archive in Software Heritage
  - standardise and use SWHID
  - build a national catalog of research software
  - leverage ADAC network

See official announcement

Outline

A plurality of needs

Researchers

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

Laboratories/teams

- track software contributions
- produce reports
- maintain web page

Research Organizations and/or Funders

know its software assets

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

Basic needs

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*!)

Some popular approaches, and why they do not fit the bill

A - Since the ~~1970's~~ 1990's

.zip or .tar file on:

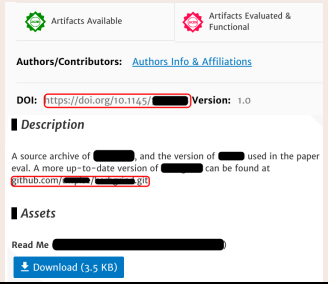
- ~~ftp server~~ (e.g. gnu)
- web page (example)
- document archive (+ DOI sample)

B - Since the 2000's

Rely on *software forges*

- institutional/project (e.g. example)
- free commercial ones: BitBucket, GitHub, GitLab, … (e.g. parmap)

C: a mix of the two



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

- broken links in the web of knowledge (my papers too)

Big bad news keep coming in

- summer 2019: BitBucket announces Mercurial VCS sunset
- july 2020: BitBucket erases *250.000+* repositories (including research software)
- summer 2022: GitLab.com considers erasing all projects that are inactive for a year

In Academia too!

- 2021: Inria's old gforge is unplugged… breaks the Opam build chain for OCaml

We need a universal archive of software source code: now we have one!

Outline

Software Heritage

THE GREAT LIBRARY OF SOURCE CODE

Collect, preserve and share *all* software source code

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

Reference catalog

find and reference all software source code

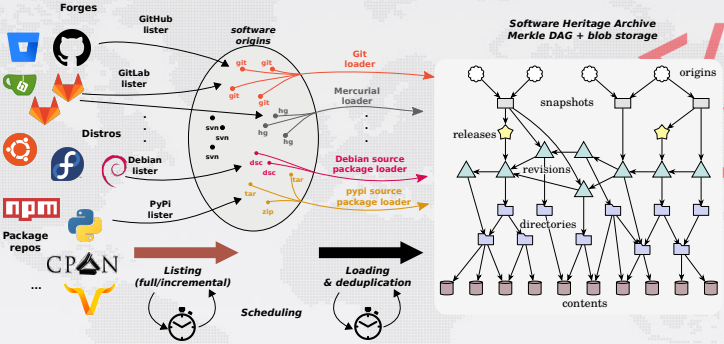
Universal archive

preserve and share all software source code

Research infrastructure

enable analysis of all software source code

A peek under the hood: a universal archive



Global development history permanently archived in a uniform data model

- over 14 billion unique source files from over 210 million software projects
- ~1PB (compressed) blobs, ~30 B nodes, ~400 B edges

A walkthrough

- Browse and Reference (e.g. Apollo 11, and your work may be already there !)
- Trigger archival, use the updateswh browser extension, configure the webhooks
- Cite with biblatex-software (CTAN, Overleaf ACMART template)
- Describe with Codemeta (use codemeta generator)
- Curated deposit in SWH via HAL, see for example: LinBox, SLALOM, Givaro, NS2DDV, SumGra, Coq proof, ...
- Extracting all the software products for Inria, for CNRS, for CNES, for LIRMM or for Rémi Gribonval using HalTools
- Example with Parmap: devel on Github, archive in SWH, curated deposit in HAL
- Example research articles:
  - compare Fig. 1 and conclusions in the 2012 version and the updated version
  - SWHID in a replication experiment

Adoption indicators

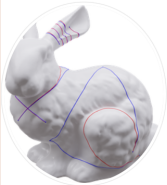
From Melissa Harrison's OSEC 2022 talk

What are they "referencing"?

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

- 6205 "software" references identified
- Top 8 listed, then long tail of 1055 other sites – 932 are unique "source"

Use on replicabilitystamp.org



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

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.

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

Archiving and referencing

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

- archive and reference in Software Heritage (see detailed HOWTO)

Describing and Citing/Crediting

For software one wants to put forward, add these extra steps:

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

We can (and must)

- train students and colleagues
- engage journals, conferences, learned societies

Outline

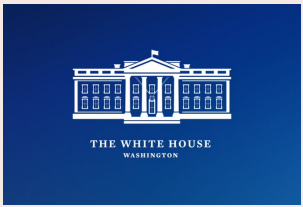
Improving Security and Transparency for Open Source

Where does reused software come from?

Do *you* know where it comes from?

- the software you ship
- the software you use
- the software you acquire
- the software that
  - has that bug
  - has that vulnerability

KYSW: Know Your SoftWare



Like KYC in banking, KYSW is now essential all over IT…

Sec. 4. Enhancing Software Supply Chain Security

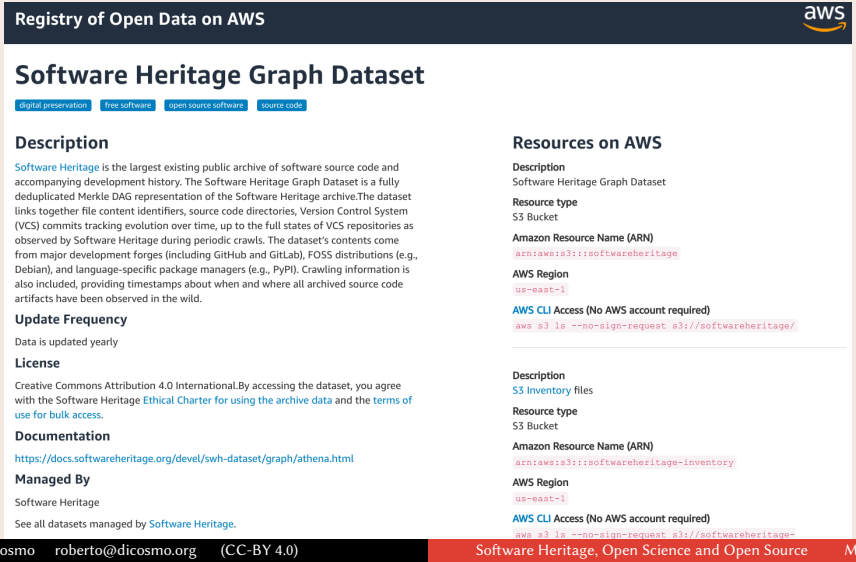
ensuring and attesting, to the extent practicable, to the integrity and provenance of open source software

May 2021 POTUS Executive Order

Outline

The full graph in the AWS Open Data collection

https://registry.opendata.aws/software-heritage/



Registry of Open Data on AWS

aws

Software Heritage Graph Dataset

digital preservation | free software | open source software | source code

Description

Software Heritage is the largest existing public archive of software source code and accompanying development history. The Software Heritage Graph Dataset is a fully deduplicated Merkle DAG representation of the Software Heritage archive.The dataset links together file content identifiers, source code directories, Version Control System (VCS) commits tracking evolution over time, up to the full states of VCS repositories as observed by Software Heritage during periodic crawls. The dataset's contents come from major development forges (including GitHub and GitLab), FOSS distributions (e.g., Debian), and language-specific package managers (e.g., PyPI). Crawling information is also included, providing timestamps about when and where all archived source code artifacts have been observed in the wild.

Update Frequency

Data is updated yearly

License

Creative Commons Attribution 4.0 International.By accessing the dataset, you agree with the Software Heritage Ethical Charter for using the archive data and the terms of use for bulk access.

Documentation

https://docs.softwareheritage.org/devel/swh-dataset/graph/athena.html

Managed By

Software Heritage

See all datasets managed by Software Heritage.

Resources on AWS

Description
Software Heritage Graph Dataset

Resource type
S3 Bucket

Amazon Resource Name (ARN)
`arn:aws:s3:::softwareheritage`

AWS Region
`us-east-1`

AWS CLI Access (No AWS account required)
`aws s3 ls --no-sign-request s3://softwareheritage/`

Description
S3 Inventory files

Resource type
S3 Bucket

Amazon Resource Name (ARN)
`arn:aws:s3:::softwareheritage-inventory`

AWS Region
`us-east-1`

AWS CLI Access (No AWS account required)
`aws s3 ls --no-sign-request s3://softwareheritage-`

A peek at the dataset

Accessing graph leaves (a.k.a. contents)

```
$ aws s3 ls --no-sign-request s3://softwareheritage/
       PRE content/
       PRE graph/
```

File contents can be accessed using their SHA1 checksum

```
$ aws s3 cp --no-sign-request \
  s3://softwareheritage/content/8624bcdae55baeef00cd11d5dfcfa60f68710a02 .
```

Notice that file contents are compressed:

```
$ zcat 8624bcdae55baeef00cd11d5dfcfa60f68710a02 | head
  GNU GENERAL PUBLIC LICENSE
     Version 3, 29 June 2007

Copyright (C) 2007 Free Software Foundation, Inc. <http://fsf.org/>
Everyone is permitted to copy and distribute verbatim copies
of this license document, but changing it is not allowed.
```

A peek at the dataset, cont'd

Annual dumps of (inner nodes of) the full graph

```
$ aws s3 ls --no-sign-request s3://softwareheritage/graph/

   2018-09-25/                                2021-03-23-cpython-3-5/
   2019-01-28-popular-3k-python/              2021-03-23-popular-3k-python/
   2019-01-28-popular-4k/                     2021-03-23/
   2020-05-20/                                2022-04-25/
   2020-12-15/
```

How to use

- online full documentation
- Antoine Pietri's PhD Thesis

How to cite

Antoine Pietri, Diomidis Spinellis, Stefano Zacchiroli. *The Software Heritage Graph Dataset: Public software development under one roof.* MSR 2019. (bibtex)

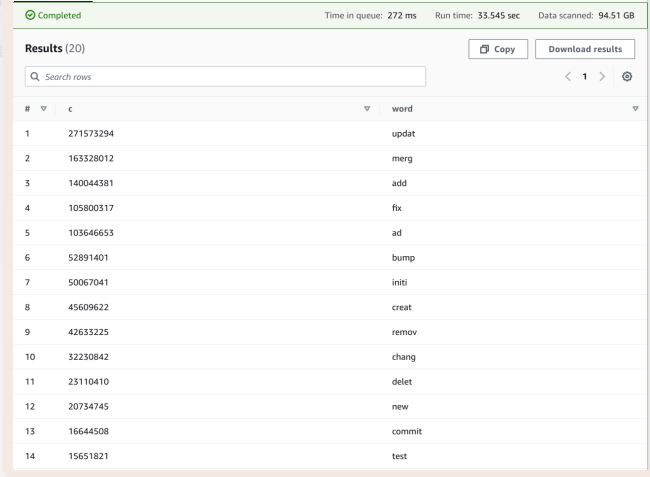
Example: most popular commit verbs (stemmed)

Query using Amazon Athena

```
SELECT COUNT(*) AS C, word FROM (
   SELECT word_stem(lower(split_part(
    trim(from_utf8(message)),' ', 1)))
   AS word FROM revision
   WHERE length(message) < 1000000)
WHERE word != ''
GROUP BY word
ORDER BY C
DESC LIMIT 20;
```

Total cost: approximately .5 euros

Results



Completed — Time in queue: 272 ms — Run time: 33.545 sec — Data scanned: 94.51 GB

Results (20) — Copy — Download results

Search rows — 1

#	c	word
1	271573294	updat
2	163328012	merg
3	140044381	add
4	105800317	fix
5	103646653	ad
6	52891401	bump
7	50067041	initi
8	45609622	creat
9	42633225	remov
10	32230842	chang
11	23110410	delet
12	20734745	new
13	16644508	commit
14	15651821	test

Outline

Going beyond SQL

State-of-the-art graph compression from social networks

Paolo Boldi, Antoine Pietri, Sebastiano Vigna, Stefano Zacchiroli

Ultra-Large-Scale Repository Analysis via Graph Compression

SANER 2020, 27th Intl. Conf. on Software Analysis, Evolution and Reengineering. IEEE

Results

Full graph structure (25 B nodes, 350 B edges) in 200 GiB RAM

- traversal time is tens of ns per edge
- bidirectional traversals implemented
- beware: metadata access is still *off RAM*

Java and gRPC APIs available

docs.softwareheritage.org/devel/swh-graph/grpc-api.html

Find all origins containing a given content

```
grpc_cli call localhost:50091 swh.graph.TraversalService.Traverse "\
src: 'swh:1:cnt:8722d84d658e5e11519b807abb5c05bfbfc531f0', direction: BACKWARD, \
mask: {paths: ['swhid','ori.url']}, return_nodes: {types: 'ori'}"
```

Gives a list of origins including "https://github.com/rdicosmo/parmap", encoded as "swh:1:ori:8903a90cff8f07159be7aed69f19d66d33db3f86" (beware: this is not a SWHID!)

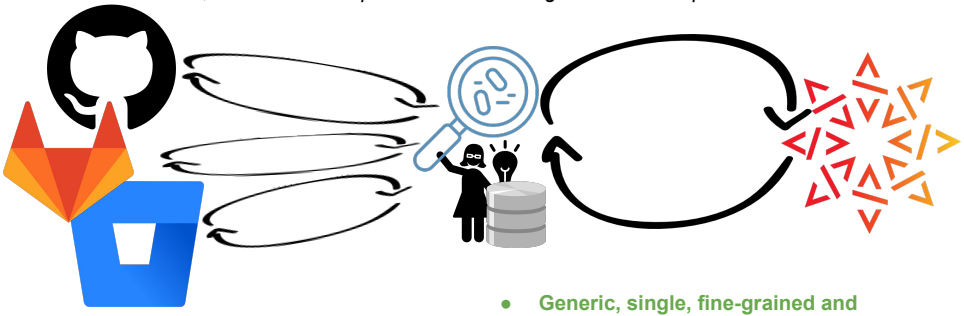
Shortest provenance path of a content in a given origin

```
grpc_cli call localhost:50091 swh.graph.TraversalService.FindPathBetween "\
src: 'swh:1:ori:8903a90cff8f07159be7aed69f19d66d33db3f86', \
dst: 'swh:1:cnt:8722d84d658e5e11519b807abb5c05bfbfc531f0', \
mask: {paths: ['swhid']}" | egrep 'swhid'
connecting to localhost:50091
  swhid: "swh:1:ori:8903a90cff8f07159be7aed69f19d66d33db3f86"
  swhid: "swh:1:snp:1527a93b039d70f6a781b05d76b77c6209912887"
  swhid: "swh:1:rev:82df563aecf86b9164eee7d10d40f2d8cbd1c78d"
  swhid: "swh:1:dir:484db39bb2825886191837bb0960b7450f9099bb"
  swhid: "swh:1:dir:4d15e44b378fe39dd23817abee756cd47ad14575"
  swhid: "swh:1:cnt:8722d84d658e5e11519b807abb5c05bfbfc531f0"
Rpc succeeded with OK status
```

Outline

Mining Android Applications on Software Heritage

RQ: how to build a specific dataset for a given research question?



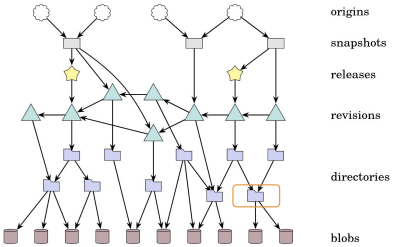
- **Specific and limited API**
- **Hardly reproducible**

- **Generic, single, fine-grained and unlimited API**
- **Growing number of source codes**
- **Easy to update the dataset**

(from the Inria/IRISA DiverSE team)

Using the SWH merkle dag to identify android repositories

Identify android application repositories = Find the AndroidManifest.xml among the sources

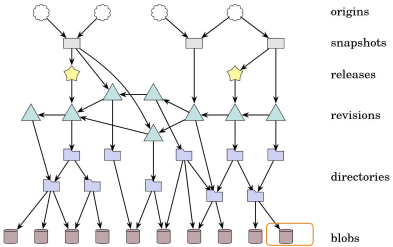


SWH Merkle DAG, Antoine Pietri

1) Iterate over the graph nodes until you find a directory node containing a file named "AndroidManifest.xml".

Using the SWH merkle dag to identify android repositories

Identify android application repositories = Find the AndroidManifest.xml among the sources

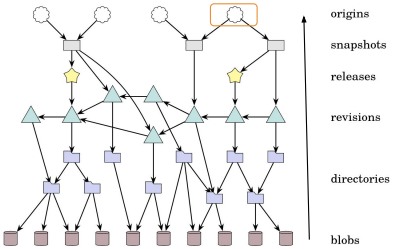


SWH Merkle DAG, Antoine Pietri

2) Extract the SWH identifier of the blob corresponding to the AndroidManifest.xml and download the corresponding file through the SWH Web API

Using the SWH merkle dag to identify android repositories

Identify android application repositories = Find the AndroidManifest.xml among the sources



SWH Merkle DAG, Antoine Pietri

3) Traverse the graph in backward direction to the origin node and get the repository url

Bottomline

Broad variety of sources in *one open dataset*

reduces usual GH bias

Reference simple *standard data format*

VCS and forge details are abstracted away

Simplifies reproducibility packages

no need to create a full copy, *just list the SWHIDs!*

Software Heritage does the heavy lifting for you

no need to scrape/download repositories all over again

Outline

Research projects

Open science (EOSC framework)

- FAIR-IMPACT : recommendations for research software
- FAIRCORE4EOSC
  - connect SWH with Zenodo (InvenioRDM), Dataverse, Dagstuhl, episcience, OpenAire, swMath, …)
  - SWH mirror for the EOSC

Cybersecurity

SWHSec (PTCC): IMT, CEA, SU, Inria approved, starting now infra for research

Big Code

CINECA, ENEA, Unibo, UniPi around Leonardo and the Bologna mirror submitted

… and much more!

please come onboard

Outline

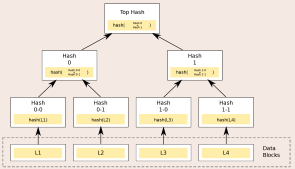
A revolutionary infrastructure

The *graph* of public software development

All software development in a single graph …

- enable traceability

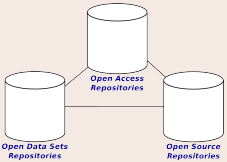
The *global ledger* of public code



… a Merkle graph

- ensure integrity

A *pillar* of Open Science



Reference archive of Research Software

- reproducibility
- reference

Reference platform for *Big Code*

uniform data structure

- large scale studies
- machine learning, AI, …

A rally flag for a grand vision

Bring together academia, industry, governments, communities

"to build a reference, global infrastructure for open and better software"

Software Heritage is the first brick ...

- vendor neutral
- open source
- a worldwide initiative
- a long term initiative

... that will enable

- archival, reference, integrity
- qualification, sharing and reuse
- a global software knowledge base
- test and deploy world class tooling

A lot more is needed

Software Heritage can be the *catalyser* of a way bigger undertaking

You can help!

help maintain and improve the infrastructure, adapt research tools to work with it, ...

Let's work together!

Questions?

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)