Software citation today and tomorrow

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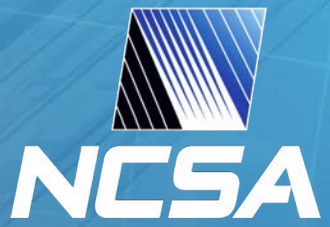

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Software in research

- Claim: software (including services) essential for the bulk of research

- Evidence from surveys
  - UK academics at Russell Group Universities (2014)
  - Members of (US) National Postdoctoral Research Association (2017)
  - My research would not be possible without software: 67% / 63% (UK/US)
  - My research would be possible but harder: 21% / 31%
  - It would make no difference: 10% / 6%

S. Hettrick, "It's impossible to conduct research without software, say 7 out of 10 UK researchers," Software Sustainaiblity Institute, 2014. Available at: https://www.software.ac.uk/blog/2016-09-12-its-impossible-conduct-research-without-software-say-7-out-10-uk-researchers

S.J. Hettrick, M. Antonioletti, L. Carr, N. Chue Hong, S. Crouch, D. De Roure, et al, "UK Research Software Survey 2014", Zenodo, 2014. doi: 10.5281/zenodo.14809.

U. Nangia and D. S. Katz, "Track 1 Paper: Surveying the U.S. National Postdoctoral Association Regarding Software Use and Training in Research," WSSSPE5.1, 2017. doi: 10.6084/m9.figshare.5328442.v1

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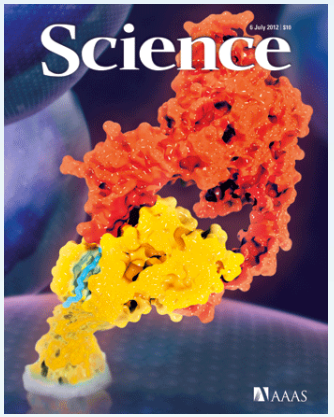
Software in scholarship



- Claim: software (including services) essential for the bulk of research

- Evidence from journals:
  - About half the papers in recent issues of Science were software-intensive projects
  - In Nature Jan–Mar 2017, software mentioned in 32 of 40 research articles
    - Average of 6.5 software packages mentioned per article

U. Nangia and D. S. Katz, "Understanding Software in Research: Initial Results from Examining Nature and a Call for Collaboration," WSSSPE5.2, 2017. https://arxiv.org/abs/1706.06527

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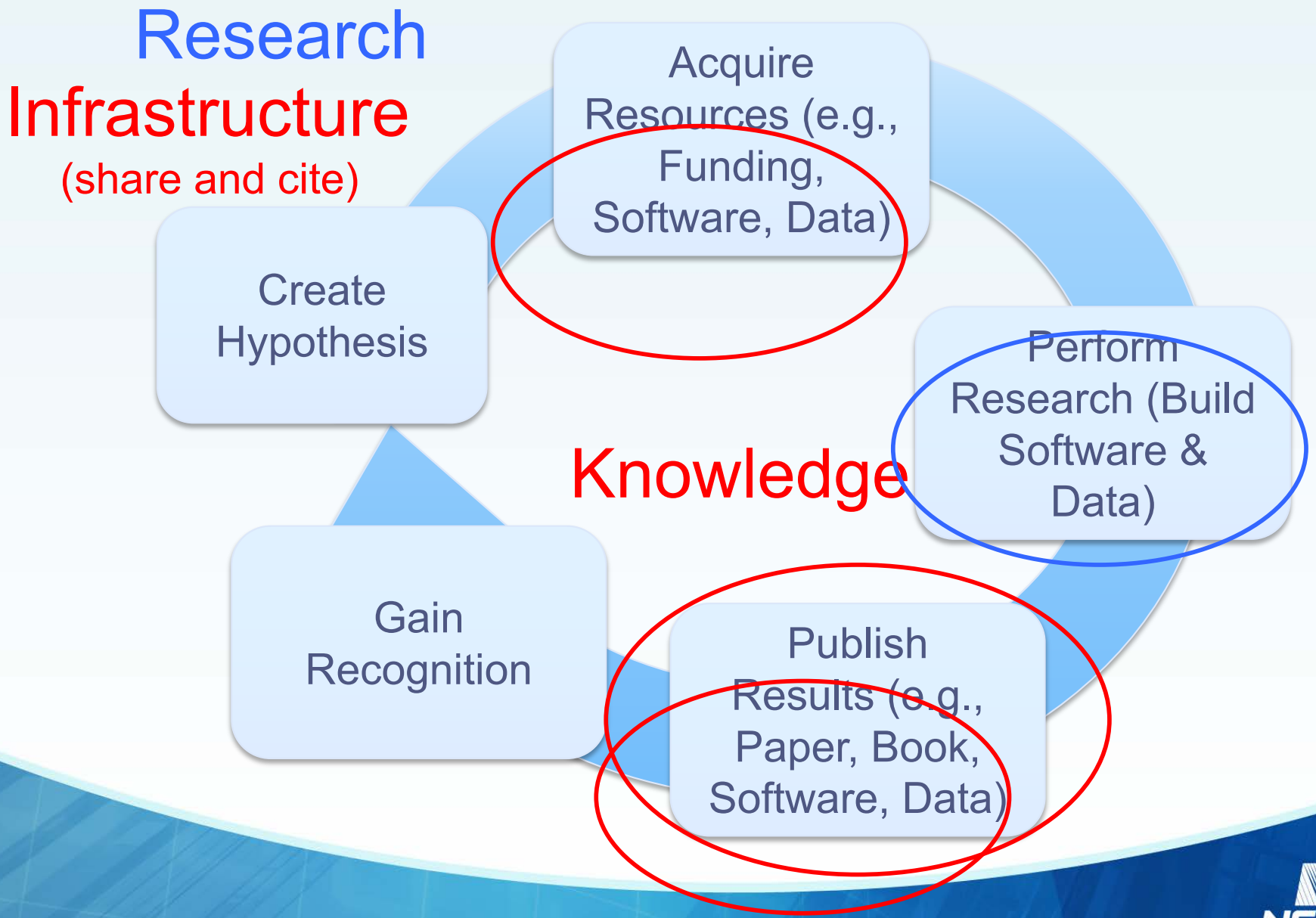
Software in research cycle



Software Citation Motivation

- Scientific research is becoming:
  - More open – scientists want to collaborate; want/need to share
  - More digital – outputs such as software and data; easier to share
- Significant time spent developing software & data
- Efforts not recognized or rewarded
- Citations for papers systematically collected, metrics built
  - But not for software & data
- Hypothesis:

  Better measurement of contributions (citations, impact, metrics)

  —> Rewards (incentives)

  —> Career paths, willingness to join communities

  —> More sustainable software

To better measure software contributions

- Citation system was created for papers/books
- We need to either/both
  1. Jam software into current citation system
  2. Rework citation system
     - Focus on 1 as possible; 2 is very hard.
- Challenge: not just how to identify software in a paper
  - **How to identify software used within research process**

Software citation today

- Software and other digital resources currently appear in publications in very inconsistent ways
- Howison: random sample of 90 articles in the biology literature -> 7 different ways that software was mentioned

Mention Type	Count (n=286)	Percentage
Cite to publication	105	37%
Cite to users manual	6	2%
Cite to name or website	15	5%
Instrument-like	53	19%
URL in text	13	5%
In-text name only	90	31%
Not even name	4	1%

- Studies on data and facility citation -> similar results

J. Howison and J. Bullard. Software in the scientific literature: Problems with seeing, finding, and using software mentioned in the biology literature. Journal of the Association for Information Science and Technology, 2015. In press. http://dx.doi.org/10.1002/asi.23538.

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Software citation principles: people & process

- FORCE11 Software Citation group started July 2015
- WSSSPE3 Credit & Citation working group joined September 2015
- ~55 members (researchers, developers, publishers, repositories, librarians)
- Working on GitHub https://github.com/force11/force11-scwg & FORCE11 https://www.force11.org/group/software-citation-working-group
- Reviewed existing community practices & developed use cases
- Drafted software citation principles document
  - Started with data citation principles, updated based on software use cases and related work, updated based working group discussions, community feedback and review of draft, workshop at FORCE2016
  - Discussion via GitHub issues, changes tracked
  - Contents: 6 principles, discussion, use cases, …
- Submitted, reviewed and modified (many times), published
  - Smith AM, Katz DS, Niemeyer KE, FORCE11 Software Citation Working Group.(2016) Software Citation Principles. *PeerJ Computer Science* 2:e86. DOI: 10.7717/peerj-cs.86 and https://www.force11.org/software-citation-principles
  - Also includes reviews and responses

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Principle 1. Importance

- **Software should be considered a legitimate and citable product of research**. Software citations should be **accorded the same importance** in the scholarly record **as citations of other research products**, such as publications and data; they should be included in the metadata of the citing work, for example in the reference list of a journal article, and should not be omitted or separated. Software should be cited on the same basis as any other research product such as a paper or a book, that is, authors should cite the appropriate set of software products just as they cite the appropriate set of papers.

Principle 2. Credit and attribution

- **Software citations should facilitate giving** scholarly **credit and** normative, legal **attribution to all contributors** to the software, recognizing that a single style or mechanism of attribution may not be applicable to all software.

Principle 3. Unique identification

- **A software citation should include a method for identification that is machine actionable, globally unique, interoperable, and recognized** by at least a community of the corresponding domain experts, and preferably by general public researchers.

Principle 4. Persistence

- **Unique identifiers and metadata describing the software and its disposition should persist** – even beyond the lifespan of the software they describe.

Principle 5. Accessibility

- **Software citations should facilitate access to the software itself and to its associated** metadata, documentation, data, and other **materials necessary** for both humans and machines **to make informed use of the referenced software**.

Principle 6. Specificity

- **Software citations should facilitate identification of, and access to, the specific version of software that was used**. Software identification should be as specific as necessary, such as using version numbers, revision numbers, or variants such as platforms.

Discussion: What to cite

- Importance principle: "…**authors should cite the appropriate set of software products just as they cite the appropriate set of papers**"
- What software to cite decided by author(s) of product, in context of community norms and practices

- POWL: "Do not cite standard office software (e.g. Word, Excel) or programming languages. Provide references only for specialized software."
- i.e., if using different software could produce different data or results, then the software used should be cited

Purdue Online Writing Lab. Reference List: Electronic Sources (Web Publications). https://owl.english.purdue.edu/owl/resource/560/10/, 2015.

Discussion: What to cite (citation vs provenance & reproducibility)

- Provenance/reproducibility requirements > citation requirements
- Citation: software important to research outcome
- Provenance: all steps (including software) in research
- Software citation principles cover minimal needs for software citation for software identification
- Provenance & reproducibility may need more metadata

Discussion: Software papers

- Goal: Software should be cited
- Practice: Papers about software ("software papers") are published and cited
- Importance principle (1) and other discussion: **The software itself should be cited on the same basis as any other research product; authors should cite the appropriate set of software products**
- Ok to cite software paper too, if it contains results (performance, validation, etc.) that are important to the work
- If the software authors ask users to cite software paper, can do so, *in addition to citing to the software*

Discussion: Derived software

- Imagine Code A is derived from Code B, and a paper uses and cites Code A
- Should the paper also cite Code B?
- No, any research builds on other research
- Each research product just cites those products that it directly builds on
- Together, this give credit and knowledge chains
- Science historians study these chains
- More automated analyses may also develop, such as transitive credit

Discussion: Software peer review

- Important issue for software in science
- Probably out-of-scope in citation discussion
- Goal of software citation is to identify software that has been used in a scholarly product
  - Whether or not that software has been peer-reviewed is irrelevant
- Possible exception: if peer-review status of software is part of software metadata
- Working group opinion: not part of the minimal metadata needed to identify the software

Discussion: Citations in text

- Each publisher/publication has a style it prefers
  - e.g., AMS, APA, Chicago, MLA
- Examples for software using these styles published by Lipson
- Citations typically sent to publishers as text formatted in that citation style, not as structured metadata
- Recommendation: **text citation styles should support:**
  - **a) a label indicating that this is software, e.g. [Computer program]**
  - **b) support for version information, e.g. Version 1.8.7**

C. Lipson. Cite Right, Second Edition: A Quick Guide to Citation Styles–MLA, APA, Chicago, the Sciences, Professions, and More. Chicago Guides to Writing, Editing, and Publishing. University of Chicago Press, 2011.

Discussion: Citation limits

- Software citation principles
- –> more software citations in scholarly products
- –> more overall citations
- Some journals have strict limits on
  - Number of citations
  - Number of pages (including references)
- Recommendations to publishers:
  - **Add specific instructions regarding software citations to author guidelines to not disincentivize software citation**
  - **Don’t include references in content counted against page limits**

Discussion: Unique identification

- **Recommend DOIs for identification of published software**
- However, identifier can point to
  1. a specific version of a piece of software
  2. the piece of software (all versions of the software)
  3. the latest version of a piece of software
- One piece of software may have identifiers of all 3 types
- And maybe 1+ software papers, each with identifiers
- Use cases:
  - Cite a specific version
  - Cite the software in general
  - Link multiple releases together, to understand all citations

Discussion: Unique identification (cont.)

- Principles intended to apply at all levels
- To all identifiers types, e.g., DOIs, RRIDs, ARKS, etc.
- Though again: **recommend when possible use DOIs that identify specific versions of source code**

Discussion: Types of software

- Principles and discussion generally focus on software as source code
- But some software is only available as an executable, a container, or a service
- Principles intended to apply to all these forms of software
- Implementation of principles will differ by software type
- **When software exists as both source code and another type, cite the source code**

Discussion: Access to software

- Accessibility principle: “software citations should permit and facilitate access to the software itself”
- Metadata should provide access information
- Free software: metadata includes UID that resolves to URL to specific version of software
- Commercial software: metadata provides information on how to access the specific software
  - E.g., company’s product number, URL to buy the software
- If software isn’t available now, it still should be cited along with information about how it was accessed
- Metadata should persist, even when software doesn’t

Discussion: Identifier resolves to …

- Identifier that points directly to software (e.g., GitHub repo) satisfies Unique Identification (3), Accessibility (5), and Specificity (6), but not Persistence (4)
- Recommend that **identifier should resolve to persistent landing page that contains metadata and link to the software itself, rather than directly to source code**
- Ensures longevity of software metadata, even beyond software lifespan
- Point to figshare, Zenodo, etc., not GitHub

Example 1: Make your software citable

- Publish it – if it's on GitHub, follow steps in https://guides.github.com/activities/citable-code/
- Otherwise, submit it to zenodo or figshare, with appropriate metadata (including authors, title, …, citations of … & software that you use)
- Get a DOI
- Create a CITATION file, update your README, tell people how to cite
- Also, can write a software paper and ask people to cite that (but this is secondary, just since our current system doesn't work well)

Example 2: Cite someone else's software

- Check for a CITATION file or README; if this says how to cite the software itself, do that
- If not, do your best following the principles
  - Try to include all contributors to the software (maybe by just naming the project)
  - Try to include a method for identification that is machine actionable, globally unique, interoperable – perhaps a URL to a release, a company product number
  - If there's a landing page that includes metadata, point to that, not directly to the software (e.g. the GitHub repo URL)
  - Include specific version/release information
- If there's a software paper, can cite this too, but not in place of citing the software

Problem: software citation vs paper citation

- Three relevant steps for paper citation
  1. Creator (aka author) submits paper to “publisher”
  2. [review+], then publisher publishes paper & assigns identifier, often DOI
  3. To refer to paper within another work, cite paper metadata, often including DOI
- Fixed order, discrete steps
- For software today
  - Creator develops software on GitHub, released at different stages (versions) during its development
  - Someone who uses that software will likely not cite it, but if they do, they will cite the repository
  - No step 2
  - Partial step 3, because there is no clear metadata or identifier for the software that was used
- Software citation principles inserts step 2

Software citation vs paper citation (cont.)

- Software citation principles guidance may not work
  - Adds a step to the software developer's workflow
  - They may not care enough to implement it
- Even if we do get to a future time in which developers routinely published their software releases, what happens until then, or for existing software?
- Real problem:
  - Steps (create, publish, cite) don't match how open source is developed and used
    - Software is more fine-grained and iterative
  - Open source development mostly occurs in the open
    - No natural need for publish step, other than marketing and credit, which are not primary concerns in all projects

Software citation vs paper citation (cont.)

- Back to papers: what happens if the citer wants to refer to something that has not been published?
  - Students initially taught to avoid this situation, later taught to cite as “personal communication”
  - APA Publication Manual distinguishes between recoverable and unrecoverable data.
  - Recoverable data (that which can be accessed by the reader via the citation information) should be cited as a formal citation
  - Unrecoverable data should be referred to within the text as “(*author*, personal communication, *date*)”
- This distinction between recoverable (published & available) and unrecoverable (not published & not available) doesn’t work for software
- All versions of software on GitHub, even if never published, are recoverable by default
  - Unless project is deleted from GitHub; could still be recovered from a local copy
- Regarding credit, Software Citation Principles paper: “It is not that academic software needs a separate credit system from that of academic papers, but that the need for credit for research software underscores the need to overhaul the system of credit for all research products.”
- The fact that the three-step model of distinct creator, publisher, and citer doesn’t really fit modern open source practices is another argument for that overhaul

APA Publication Manual: http://www.apastyle.org/manual/index.aspx

Software Heritage **as a partial solution?**

- Mission: to collect, preserve, and share **all** software that is publicly available in source code form
- Source code stored in a Merkle tree, with hashed pointers
- To cite unpublished software, need to find hash to version used
  - Tool to go from GitHub commit to SH hash could be developed
- Need ID for SH hash
  - Maybe https://softwareheritage/id
- What about metadata?

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Software metadata

- Two types of metadata:
  - *Software creation metadata*: describe properties of software itself as source code, such as: authors, language, license, version number, location, etc.
  - *Software usage metadata*: describe how the code is being used, possibly including how it is built, such as: compiler version, operating system, parallel computing platform, command-line options, etc.
- Software Citation Principles
  - Software creation metadata needed for citation; software usage metadata needed for provenance and reproducibility
  - Metadata for provenance > metadata for citation
- For code, software user can determine software usage metadata, but not software creation metadata
- Software Heritage cannot provide the metadata needed for software citation
- Software creation metadata can only be determined by software creators

Software creation metadata & CodeMeta

- If authors of software want to be cited, they can fill this gap fairly easily: just need to create single metadata file in repo root
- As suggested by Martin Fenner, based on work done in CodeMeta (which has goal to create minimal metadata schema for science software and code, in JSON and XML)
  - Example: codemeta.json in https://github.com/datacite/maremma repo
  - DataCite can generate DOI and citation from this
- Code developers create codemeta.json in their repo when they start a project, then keep it up to data, like README or CONTRIBUTORS
- Software Heritage keeps all versions of codemeta.json with corresponding versions of software code
- Can use this to retrospectively build proper citation metadata for any version of the software

But this is not quite enough

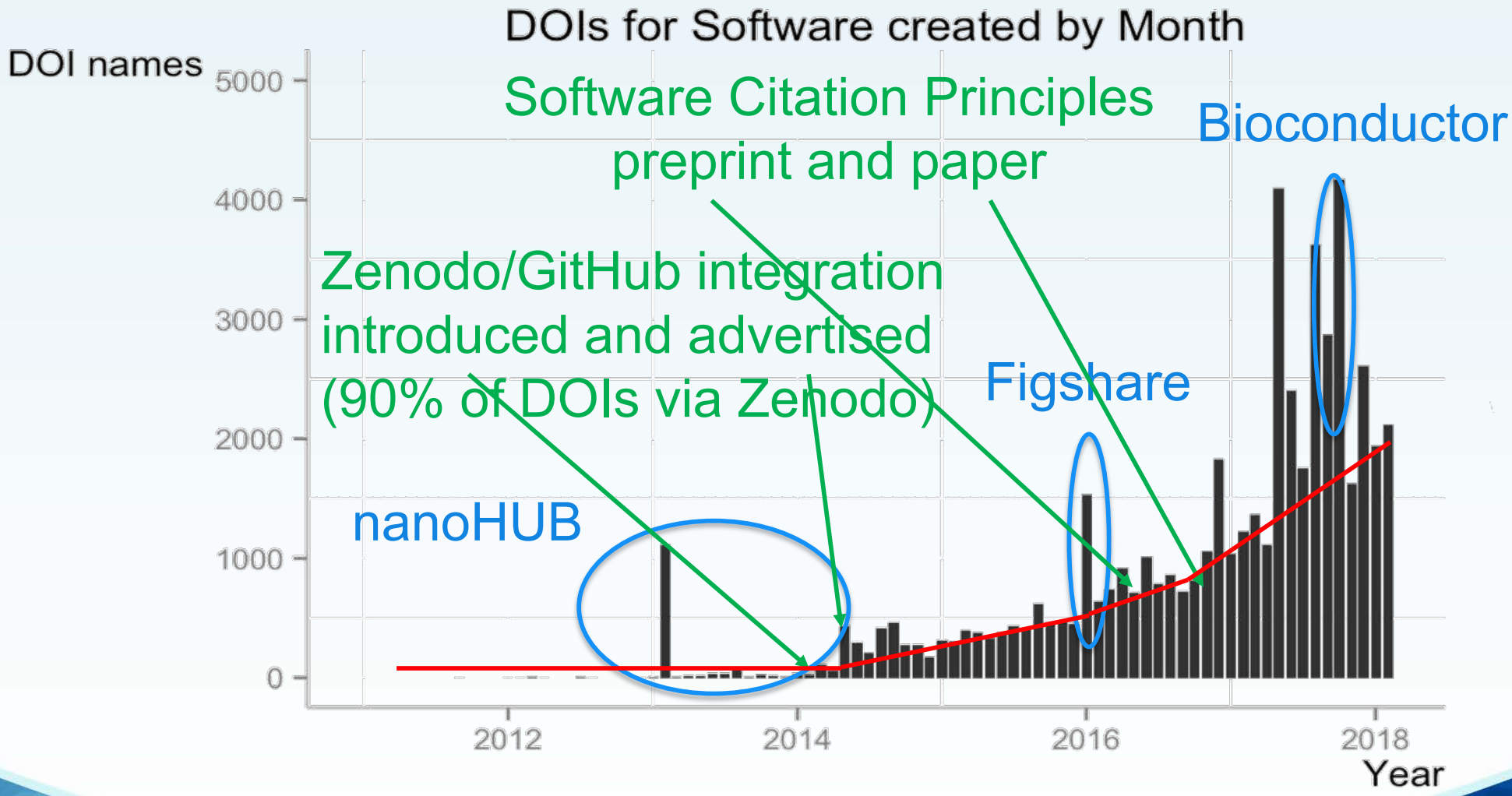
- How to build a software citation when authors don't care about credit or have not provided codemeta.json file?
- And, how to cite older software?
- Most software creation metadata can be extracted from a repo directly
- Except authors
- Authors ≠ contributors to repo
- Some project contributors do not contribute to the repo
- Some contributors to the repo should not be authors
- Best thing: identify the project as the authors
  - e.g., authors = "CodeMeta Project"

Compact identifiers to the rescue?

- A method for referring to a stored object in a registered repository
  - pdb:2gc4 is compact identifier for Protein Data Bank accession (item) number 2gc4
  - Compact identifier metaresolvers (identifiers.org & N2T.net) can resolve a compact identifier, for example: http://identifiers.org/pdb:2gc4.
- Compact identifier metaresolvers could work with Software Heritage to define compact identifiers for all the repositories that Software Heritage works with,
- And a means to resolve them to a pointer in the Software Heritage archive. For example, github:repo_name/commithash

- With Software Heritage, CodeMeta, and compact identifiers working together, users could easily and effectively cite any archived software

Software DOIs registered at DataCite



Data and early analysis via https://github.com/datacite/metadata-reports/blob/master/software/index.md

Journal of Open Source Software (JOSS)

- In the meantime, there's JOSS
- A developer friendly journal for research software packages
- "If you've already licensed your code and have good documentation then we expect that it should take **less than an hour** to prepare and submit your paper to JOSS"
- Everything is open:
  - Submitted/published paper: http://joss.theoj.org
  - Code itself: where is up to the author(s)
  - Reviews & process: https://github.com/openjournals/joss-reviews
  - Code for the journal itself: https://github.com/openjournals/joss
- JOSS papers are issued Crossref DOIs
- First paper submitted 4 May 2016
  - 31 May 2017: 111 accepted papers, 41 under review, ~15 pre-review
  - 5 Apr 2018: 258 accepted papers, 42 under review, ~15 pre-review

Working group status

- Principles document published in PeerJ CS
- Software Citation Working Group ended
- Software Citation Implementation group now in progress
  - Goal is implementing software citation
  - Working with institutions, publishers, funders, researchers, etc.
  - Planning subgroups in to study use cases with different roles
    - Find and advertise gaps
    - Suggest and try solutions
  - Some discussion of joining with Research Data Alliance (RDA) sw group
  - Want to join? Sign up on FORCE11 group page
    - https://www.force11.org/group/software-citation-implementation-working-group
- Examples …

DataCite Schema Extensions

- DataCite Metadata Schema v4.1
  - http://schema.datacite.org/meta/kernel-4.1/
  - https://blog.datacite.org/metadata-schema-4-1/
- Support for software citation
  - Facilitate software discovery, sharing and citation
  - Two new relation types
    - (HasVersion, IsVersionOf) – relate versions of the same software e.g. relate an un-versioned code repository to one of its specific software versions
    - (IsRequiredBy, Requires) – software dependencies
  - Additions and modifications to documentation to clarify use for software citation

Community-specific implementation

- High Energy Physics
  - Work with conferences (ACAT & CHEP) so that proceedings authors cite software; software developers make their software citable
  - https://indico.cern.ch/event/567550/papers/2696191/files/6046-Katz_Citation.pdf
  - Could generalize for other conferences, and other communities
- Astronomy: handling software citations between publisher (AAS), indexer (ADS), software repository (Zenodo)
  - Trying to implement this with ADS in the next couple of months
  - Model is generic
- Geosciences (AGU): related effort focused on data; also starting to consider software
  - Enabling FAIR Data: https://osf.io/jy4d9/

Better Scientific Software (BSSw)

https://bssw.io

So your code will see the future.

- BSSw is supporting my work via a fellowship
- My goal: make scientific software more sustainable by providing credit to its developers via software citation
- I'm working with disciplinary communities
- More information
  - https://danielskatzblog.wordpress.com/2018/02/08/better-scientific-software-fellowship/

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Using codemeta.json

- CaltechDATA software preservation
  - GitHub software repositories automatically preserved, with DOI
  - Extended to use codemeta.json file to incorporate full author list, keywords and license metadata in CaltechDATA landing page and associated with DOI
  - https://www.library.caltech.edu/news/enhanced- software-preservation-now-available-caltechdata
- DataCite support in new DOI registration web service
  - DOI for repo, not for specific version
  - Provide GitHub URL to service to register DOI with metadata automatically populated
  - If there's a codemeta.json file in root of repo
  - Will also give error if required metadata missing
- Need to coordinate with Citation File Format
  - "Human and machine readable citations"
    - https://citation-file-format.github.io/

Conclusions

- Software
  - Important today, essential tomorrow
- Credit
  - A known problem for papers, worse for software
- Citation
  - We know what to do (mostly), now need to do it
  - Explained in https://cite.research-software.org/
  - Need to build support for use codemeta.json in repos
  - Need to build up tools around Software Heritage
- What you can do
  - Cite the software you use, make it easy for others to cite the software you write (and see the “I solemnly pledge” manifesto – http://ceur-ws.org/Vol-1686/WSSSPE4_paper_15.pdf)
  - Organize/edit/review taking software citation into account

Credits

- Thanks to Arfon Smith and Kyle Neimeyer for co-leadership in FORCE11 Software Citation WG
- And to Neil Chue Hong & Martin Fenner for co-leadership in FORCE11 Software Citation Implementation WG
- And to the BSSw project (http://bssw.io) for the fellowship to pursue some parts of this
- More of my thinking
  - Blog: http://danielskatzblog.wordpress.com
  - Tweets: @danielskatz