Development Efforts towards Reproducible Research: Feedback and Perspectives

Miguel Colom\textsuperscript{1}, José Armando Hernández\textsuperscript{1}, Bertrand Kerautret \textsuperscript{2}, Benjamin Perret \textsuperscript{3}

RRPR 2022
Montreal, 21 August 2022

\textsuperscript{1}Centre Borelli, École Normale Supérieure Paris-Saclay, France
\textsuperscript{2}Univ Lyon, Univ Lyon 2, CNRS, INSA Lyon, UCBL, LIRIS, UMR5205, F-69676 Bron, France
\textsuperscript{3}ESIEE - LIGM, Université de Paris Est, France
Overview

1. Introduction
   1.1 Definitions of RR
   1.2 Motivation
   1.3 Implementation of RR, Why RR

2. Efforts on Software Useful for Reproducible Research
   2.1 Updated Preview of Reproducible Research Platforms
   2.2 Library Development for RR

3. Advanced Editorial Efforts
   3.1 IPOL publications
   3.2 New initiative with OVD-SaaS
   3.3 Reviewing process for RR

4. Conclusion
1. Introduction
1. Introduction: some definitions

**Repeatability and replicability**

Capacity to perform the same experiment as many times as needed.

→ **Repeatability**: Same team, same experimental setup

→ **Replicability**: Different team, same experimental setup

**Example**: is distilled water electrically conductive? Is salt water conductive? We can perform the experiment many times and get results (https://www.dailymotion.com/video/x21cg6a).

---

1There are different terminologies, see ACM Artifact Review and Badging, we use the version 1.0
1. Introduction: some definitions

Repeatability and replicability
Capacity to perform the same experiment as many times as needed.
→ **Repeatability**: Same team, same experimental setup
→ **Replicability**: Different team, same experimental setup

**Example**: is distilled water electrically conductive? Is salt water conductive? We can perform the experiment many times and get results ([https://www.dailymotion.com/video/x2lcg6a](https://www.dailymotion.com/video/x2lcg6a)).

Reproducibility
Capacity to obtain the same results when repeating an experiment by following a detailed procedure
→ Different team, different experimental setup

In computational sciences (deterministic code, digital data): results obtained by following a detailed and correct pseudo-code description must coincide if the same input data is provided.

---

1 There are different terminologies, see ACM Artifact Review and Badging, we use the version 1.0
1.1 Definition: Repeatability Examples

<table>
<thead>
<tr>
<th>Repeatable</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Obtaining the classification results with a neural network. We can repeat the experiment as many times as we want. We just need the weights of the network and the input data.</td>
<td></td>
</tr>
</tbody>
</table>
1.1 Definition: Repeatability Examples

**Repeatable**

Obtaining the classification results with a neural network. We can repeat the experiment as many times as we want. We just need the weights of the network and the input data.

**Not repeatable:**

Detection of the merger of two black holes from gravitational waves. We can’t repeat the experiment as needed.
1.1 Definition: Reproducibility Examples

Reproducible:

Given:
- a detailed pseudo-code (or the source code itself),
- any associated learning or initialization data,
- the input data,

we should obtain exactly the same results each time we run the algorithm.

⇒ Exactly the same denoised image, classification results, etc.
1.1 Definition: Reproducibility Examples

**Reproducible:**

Given:
- a detailed pseudo-code (or the source code itself),
- any associated learning or initialization data,
- the input data,

we should obtain exactly the same results each time we run the algorithm.

⇒ *Exactly the same* denoised image, classification results, etc.

**Not reproducible**

In a paper that shows
- a pseudo-code without *all the details*, or its initialization,
- the source code is not available,
- neither the learning data,

other researchers *can’t compare* with the proposed method.

⇒ We can’t be sure about anything on the method, nor test it with *their own data.*
1.2 Motivation: Example on Biomedical Research

Main Keys Points

- 2009: David Donoho points out a credibility crisis in scientific research
1.2 Motivation: Example on Biomedical Research

Main Keys Points

- 2009: David Donoho points out a credibility crisis in scientific research
- 2012: the director of the oncology division at Amgen: tried to reproduce 53 of the most important papers on oncology. He failed to reproduce 47 of them.

Sources:

https://www.nature.com/articles/nature.2016.19269

https://www.nature.com/articles/483531a
1.2 Motivation: Example on Biomedical Research

Main Keys Points

- 2009: David Donoho points out a credibility crisis in scientific research
- 2012: the director of the oncology division at Amgen: tried to reproduce 53 of the most important papers on oncology. He failed to reproduce 47 of them.
  
  Sources:
  
  https://www.nature.com/articles/nature.2016.19269
  
  https://www.nature.com/articles/483531a

- Bayer HealthCare Germany confirmed: only 25% of cancer research is reproducible.
  
  Source: https://www.nature.com/articles/nrd3439-c1
1.3 Implementation of Reproducible Research

- Non-exact sciences (biology, medicine, ...): difficult (but desirable). Hard to have exactly the same conditions along experiments.
1.3 Implementation of Reproducible Research

- Non-exact sciences (biology, medicine, . . .): difficult (but desirable). Hard to have exactly the same conditions along experiments.
- Computational sciences: no excuse!
Why are not we all doing reproducible research?

Several reasons in general:

• Some researchers don’t want to make public working code
• Doesn’t correspond to any version of the pseudo-codes,
• Low software quality,
• Quality software takes more time to produce: testing, documentation, objective quality metrics, . . .
• Results of a method do not generalize . . . (For the discussion later!)
• Not really considered for career advance
• Classic metrics: “number of high impact-factor classic publications”
• Software is considered as a 2nd class citizen
Why are not we all doing reproducible research?

Several reasons in general:

- Some researchers don’t want to make public working code
  - doesn’t correspond to any version of the pseudo-codes,
  - low software quality,
  - quality software takes more time to produce: testing, documentation, objective quality metrics, . . .

- Results of a method do not generalize

- . . . (For the discussion later!)
Why are not we all doing reproducible research?

**Several reasons in general:**

- Some researchers don’t want to make public working code
  - doesn’t correspond to any version of the pseudo-codes,
  - low software quality,
  - quality software takes more time to produce: testing, documentation, objective quality metrics, . . .
- Results of a method do not generalize
- . . . (For the discussion later!)

**Not really considered for career advance**

- Classic metrics: ”number of high impact-factor classic publications”
- Software is considered as a 2nd class citizen
Good news:

The French government is promoting a Plan for Open Science

- [https://www.ouvrirlascience.fr/second-national-plan-for-open-scienc](https://www.ouvrirlascience.fr/second-national-plan-for-open-scienc)
- "Path three: opening up and promoting source code produced by research"
- Not directly on reproducible research, but certainly fosters it
- → Let’s share in the discussion later other initiatives or experiences you know
Good news:

The French government is promoting a Plan for Open Science

- [link](https://www.ouvrirlascience.fr/second-national-plan-for-open-scienc)
- "Path three: opening up and promoting source code produced by research"
- Not directly on reproducible research, but certainly fosters it
- Let’s share in the discussion later other initiatives or experiences you know

Initiatives at European level

- European Open Science Cloud (EOSC): recommendations to the European Commission
  - [link](https://www.eosc.eu)
- Publication: "Scholarly infrastructures for research software"
2. Efforts on Software Useful for Reproducible Research
2. Efforts on software useful for reproducible research

2.1 Updated Preview of Reproducible Research Platforms

- Synthetic recall of main platforms [CKK19].
- Updates with news elements from last publication.
## 2. Efforts on software useful for reproducible research

### 2.1 Updated Preview of Reproducible Research Platforms

- Synthetic recall of main platforms [CKK19].
- Updates with news elements from last publication.

### 2.2 Library development

- Another ways to help for RR.
- Examples of library efforts from image domains.
2.1 Updated Preview of Reproducible Research Platforms

Different types of platforms [CKK19]

- **Online execution platforms.**
- **Dissemination platforms.**
- **Peer-reviewed journals.**

- **Galaxy** - [https://galaxyproject.org](https://galaxyproject.org)
- **IPython** - [https://ipython.org](https://ipython.org)
- **Jupyter** - [http://jupyter.org](http://jupyter.org)
- **Code Ocean** - [https://codeocean.com](https://codeocean.com)
- **DAE** - [http://dae.cse.lehigh.edu/DAE](http://dae.cse.lehigh.edu/DAE)
- **IPOL** - [https://www.ipol.im](https://www.ipol.im)
- **Research Compendia** - [ResearchCompendia.org](http://www.researchcompendia.org)
- **MLOSS** - [https://mloss.org/software](https://mloss.org/software)
- **DataHub** - [https://datahub.io/](https://datahub.io/)
- **PaperWithCode** - [https://paperswithcode.com](https://paperswithcode.com)
- **ReScience Journal** - [http://rescience.github.io](http://rescience.github.io)
- **JOSS Journal** - [https://joss.theoj.org](https://joss.theoj.org)
- **Insight J Journal** - [https://insight-journal.org](https://insight-journal.org)
2.1 Updated Preview of Reproducible Research Platforms

**Different types of platforms [CKK19]**

- Online execution platforms.
- **Dissemination platforms.**
- Peer-reviewed journals.

- **Galaxy** - https://galaxyproject.org
- **IPython** - https://ipython.org
- **Jupyter** - http://jupyter.org
- **Code Ocean** - https://codeocean.com
- **DAE** - http://dae.cse.lehigh.edu/DAE
- **IPOL** - https://www.ipol.im
- **Research Compendia** - ResearchCompendia.org
- **MLOSS** - https://mloss.org/software
- **DataHub** - https://datahub.io/
- **PaperWithCode** - https://paperswithcode.com

- **JOSS Journal** - https://joss.theoj.org
- **Insight J Journal** - https://insight-journal.org
2.1 Updated Preview of Reproducible Research Platforms

Different types of platforms [CKK19]

- Online execution platforms.
- Dissemination platforms.
- Peer-reviewed journals.

- **Galaxy** - [https://galaxyproject.org](https://galaxyproject.org)
- **IPython** - [https://ipython.org](https://ipython.org)
- **Jupyter** - [http://jupyter.org](http://jupyter.org)
- **Code Ocean** - [https://codeocean.com](https://codeocean.com)
- **DAE** - [http://dae.cse.lehigh.edu/DAE](http://dae.cse.lehigh.edu/DAE)
- **IPOL** - [https://www.ipol.im](https://www.ipol.im)
- **Research Compendia** - [ResearchCompendia.org](http://rescience.github.io)
- **MLOSS** - [https://mloss.org/software](https://mloss.org/software)
- **DataHub** - [https://datahub.io/](https://datahub.io/)
- **PaperWithCode** - [https://paperswithcode.com](https://paperswithcode.com)

- **ReScience Journal** - [http://rescience.github.io](http://rescience.github.io)
- **JOSS Journal** - [https://joss.theoj.org](https://joss.theoj.org)
- **Insight J Journal** - [https://insight-journal.org](https://insight-journal.org)
New Reproducible Research Platform (1)

Platform [https://reproducedpapers.org](https://reproducedpapers.org) [Dissemination platforms]

- Presented during previous edition of RRPR 2020 [YHK$^+$21].
- Oriented machine learning reproducibility (in teaching context - master degree -).
New Reproducible Research Platform (1)

<table>
<thead>
<tr>
<th>Platform</th>
<th>[Dissemination platforms]</th>
</tr>
</thead>
<tbody>
<tr>
<td><a href="https://reproducedpapers.org">https://reproducedpapers.org</a></td>
<td></td>
</tr>
</tbody>
</table>

- Presented during previous edition of RRPR 2020 \([YHK^+21]\).  
- Oriented machine learning reproducibility (in teaching context - master degree -).  
- Main ideas:  
  - Suggest a paper to be reproduced.  
  - Propose a reproduction/replication/new variant/new data.  
  - A paper/web page describing reproduction.
New Reproducible Research Platform (1)

Platform https://reproducedpapers.org

[Dissemination platforms]

- Presented during previous edition of RRPR 2020 \([\text{YHK}^+21]\).
- Oriented machine learning reproducibility (in teaching context - master degree -).
- Main ideas:
  - Suggest a paper to be reproduced.
  - Propose a reproduction/replication/new variant/new data.
  - A paper/web page describing reproduction.
New Reproducible Research Platform (2)

Platform [https://replicability.graphics](https://replicability.graphics)  

<table>
<thead>
<tr>
<th>[Dissemination platforms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Platform</td>
</tr>
<tr>
<td><strong><a href="https://replicability.graphics">https://replicability.graphics</a></strong></td>
</tr>
</tbody>
</table>

- Invited in previous edition of RRPR [BCDM20].
- Oriented from the computer graphic topic.
- Replicate and evaluate difficulty to reproduce SIGGRAPH papers.
- Light formatted review rating the success of replication.
New Reproducible Research Platform (2)

Platform [https://replicability.graphics](https://replicability.graphics) [Dissemination platforms]

- Invited in previous edition of RRPR [BCDM20].
- Oriented from the computer graphic topic.
- Replicate and evaluate difficulty to reproduce SIGGRAPH papers.
- Light formatted review rating the success of replication.
New Reproducible Research Platform (2)

Platform [https://replicability.graphics](https://replicability.graphics) [Dissemination platforms]

- Invited in previous edition of RRPR [BCDM20].
- Oriented from the computer graphic topic.
- Replicate and evaluate difficulty to reproduce SIGGRAPH papers.
- Light formatted review rating the success of replication.
# New Reproducible Research Platform (3)

**ReproZip:** [https://server.reprozip.org](https://server.reprozip.org)  
[Online execution platforms]

- Open source tool to bundle everything necessary to reproduce your work.
- Way to share reproducible work from the ReproServer.
- Actually allows to reproduce ReproZip packages online (work in progress).
New Reproducible Research Platform (3)

ReproZip: [https://server.reprozip.org](https://server.reprozip.org)  [Online execution platforms]

- Open source tool to bundle everything necessary to reproduce your work.
- Way to share reproducible work from the ReproServer.
- Actually allows to reproduce ReproZip packages online (work in progress).
ReproZip: https://server.reprozip.org

- Open source tool to bundle everything necessary to reproduce your work.
- Way to share reproducible work from the ReproServer.
- Actually allows to reproduce ReproZip packages online (work in progress).
Platform **REANA**: [https://reanahub.io](https://reanahub.io)

- Reproducible research data analysis platform.

[Online execution platforms]
Platform **REANA**: [https://reanahub.io](https://reanahub.io)

- Reproducible research data analysis platform.
- Allow to launch workflows from external sources (GitHub, GitLab).

![REANA Platform Interface](image-url)
Platform **REANA**: [https://reanahub.io](https://reanahub.io)

- Reproducible research data analysis platform.
- Allow to launch workflows from external sources (GitHub, GitLab).
- Reserved to CERN members only.

⇒ limited impact
## New Reproducible Research Platform (5)

<table>
<thead>
<tr>
<th>Platform</th>
<th><a href="https://replicate.com">https://replicate.com</a></th>
<th>[Online execution platforms]</th>
</tr>
</thead>
<tbody>
<tr>
<td>● Machine learning code replication.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>● Applying ML from real-world problem without complex code installation.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| ● Propose model, run online, run with API or from your computer.  
  ⇒ base on COG (open source tool to package a production ready container)  
  https://github.com/replicate/cog |
New Reproducible Research Platform (5)

<table>
<thead>
<tr>
<th>Platform</th>
<th><a href="https://replicate.com">https://replicate.com</a></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Online execution platforms</strong></td>
<td></td>
</tr>
<tr>
<td>● Machine learning code replication.</td>
<td></td>
</tr>
<tr>
<td>● Applying ML from real-world problem without complex code installation.</td>
<td></td>
</tr>
<tr>
<td>● Propose model, run online, run with API or from your computer. ⇒ base on COG (open source tool to package a production ready container)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><a href="https://github.com/replicate/cog">https://github.com/replicate/cog</a></td>
</tr>
</tbody>
</table>
### New Reproducible Research Platform (5)

<table>
<thead>
<tr>
<th>Platform</th>
<th><a href="https://replicate.com">https://replicate.com</a></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[Online execution platforms]</td>
</tr>
<tr>
<td></td>
<td><img src="image.png" alt="Platform Image" /></td>
</tr>
</tbody>
</table>

- Machine learning code replication.
- Applying ML from real-world problem without complex code installation.
- Propose model, run online, run with API or from your computer.
  - base on COG (open source tool to package a production ready container)
    - [https://github.com/replicate/cog](https://github.com/replicate/cog)
1. Introduction
2. Efforts on Software Useful for Reproducible Research
3. Advanced Editorial Efforts
4. Conclusion

New Reproducible Research Platform (5)

Platform [https://replicate.com](https://replicate.com) [Online execution platforms]

- Machine learning code replication.
- Applying ML from real-world problem without complex code installation.
- Propose model, run online, run with API or from your computer.
  ⇒ base on COG (open source tool to package a production ready container)
  [https://github.com/replicate/cog](https://github.com/replicate/cog)
## 2.2 Library Development for RR

### Contribution to RR from library development

- Way to diffuse research results to larger use.
- Documented and referenced algorithms easy to be used from new Phd student.
- Extend the classic academic results to real applications.
- Gather algorithms and make easier comparisons and use in other context.
- Make easier software demonstrator or online demonstrations.
2.2 Library Development for RR

**Contribution to RR from library development**

- Way to diffuse research results to larger use.
- Documented and referenced algorithms easy to be used from new Phd student.
- Extend the classic academic results to real applications.
- Gather algorithms and make easier comparisons and use in other context.
- Make easier software demonstrator or online demonstrations.

**Attentive key point towards reproducibility**

- **Compatibility problems**: libraries evolve rapidly (compilation issues).
- **Implementation change**: can change numerical results from a version to another.
- Implies the use of container solution like *Docker* to ensure longer terms reproducibility.
### 2.2 Library Development for RR: examples (1)

#### Example of library of vision/image/geometry domains

<table>
<thead>
<tr>
<th>Library</th>
<th>ref</th>
<th>domain</th>
<th>language</th>
<th>version</th>
<th>#auth.</th>
<th>date</th>
<th>funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>OpenCV</td>
<td>[Bra00]</td>
<td>Comp. Vision</td>
<td>C++</td>
<td>4.5.5</td>
<td>1,383</td>
<td>1999</td>
<td>Willow Garage</td>
</tr>
<tr>
<td>ITK</td>
<td>[MLJ+14]</td>
<td>Image Processing</td>
<td>C++/Pyt.</td>
<td>5.2.1</td>
<td>265</td>
<td>2000</td>
<td>Kitware</td>
</tr>
<tr>
<td>PCL</td>
<td>[RC11]</td>
<td>Point clouds</td>
<td>C++</td>
<td>1.12.1</td>
<td>464</td>
<td>2010</td>
<td>Willow Garage</td>
</tr>
<tr>
<td>Clmg</td>
<td>[Tsc12]</td>
<td>Image processing</td>
<td>C++</td>
<td>3.1.2</td>
<td>72</td>
<td>1999</td>
<td>Acad.</td>
</tr>
<tr>
<td>Geogram</td>
<td>[Geo]</td>
<td>Geometric algorithm</td>
<td>C++</td>
<td>1.7.8</td>
<td>7</td>
<td>1998</td>
<td>Acad./INRIA/ERC</td>
</tr>
<tr>
<td>Olena</td>
<td>[RCG18]</td>
<td>Image processing</td>
<td>C++/Pyt.</td>
<td>2.1</td>
<td>50</td>
<td>2001</td>
<td>Acad. / Project</td>
</tr>
<tr>
<td>Tulip</td>
<td>[Aub04]</td>
<td>huge graph visualiz</td>
<td>C++/Pyt.</td>
<td>5.6.2</td>
<td>9</td>
<td>2001</td>
<td>Acad./private</td>
</tr>
<tr>
<td>Vigra</td>
<td>[Vig]</td>
<td>Comp. Vision</td>
<td>C++</td>
<td>1.11</td>
<td>50</td>
<td>2008</td>
<td>Acad.</td>
</tr>
<tr>
<td>DGtal</td>
<td>[DGt]</td>
<td>Digital geometry</td>
<td>C++/Pyt.</td>
<td>1.2</td>
<td>27</td>
<td>2011</td>
<td>Acad. / Project</td>
</tr>
<tr>
<td>TTK</td>
<td>[TFL+17]</td>
<td>Topology ToolKit</td>
<td>C++</td>
<td>1.0</td>
<td>36</td>
<td>2017</td>
<td>Acad. / Project</td>
</tr>
<tr>
<td>Higra</td>
<td>[HIG]</td>
<td>Graph analysis</td>
<td>C++/Pyt.</td>
<td>0.6.5</td>
<td>4</td>
<td>2018</td>
<td>Acad. / Project</td>
</tr>
</tbody>
</table>
### 2.2 Library Development for RR: examples (1)

**Example of library of vision/image/geometry domains**

- Some libraries were initiated/funded by private company.

<table>
<thead>
<tr>
<th>Library</th>
<th>ref</th>
<th>domain</th>
<th>language</th>
<th>version</th>
<th>#auth.</th>
<th>date</th>
<th>funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>OpenCV</td>
<td>[Bra00]</td>
<td>Comp. Vision</td>
<td>C++</td>
<td>4.5.5</td>
<td>1,383</td>
<td>1999</td>
<td>Willow Garage</td>
</tr>
<tr>
<td>ITK</td>
<td>[MLJ+14]</td>
<td>Image Processing</td>
<td>C++/Pyt.</td>
<td>5.2.1</td>
<td>265</td>
<td>2000</td>
<td>Kitware</td>
</tr>
<tr>
<td>PCL</td>
<td>[RC11]</td>
<td>Point clouds</td>
<td>C++</td>
<td>1.12.1</td>
<td>464</td>
<td>2010</td>
<td>Willow Garage</td>
</tr>
<tr>
<td>Geogram</td>
<td>[Geo]</td>
<td>Geometric algorith.</td>
<td>C++</td>
<td>1.7.8</td>
<td>7</td>
<td>1998</td>
<td>Acad./INRIA/ERC</td>
</tr>
<tr>
<td>Olена</td>
<td>[RCG18]</td>
<td>Image processing</td>
<td>C++/Pyt.</td>
<td>2.1</td>
<td>50</td>
<td>2001</td>
<td>Acad. / Project</td>
</tr>
<tr>
<td>Tulip</td>
<td>[Aub04]</td>
<td>huge graph visualiz.</td>
<td>C++/Pyt.</td>
<td>5.6.2</td>
<td>9</td>
<td>2001</td>
<td>Acad./private</td>
</tr>
<tr>
<td>Vircra</td>
<td>[Vig]</td>
<td>Comp. Vision</td>
<td>C++</td>
<td>1.11</td>
<td>50</td>
<td>2008</td>
<td>Acad.</td>
</tr>
<tr>
<td>DGtal</td>
<td>[DGt]</td>
<td>Digital geometry</td>
<td>C++/Pyt.</td>
<td>1.2</td>
<td>27</td>
<td>2011</td>
<td>Acad. / Project</td>
</tr>
<tr>
<td>TTK</td>
<td>[TFL+17]</td>
<td>Topology ToolKit</td>
<td>C++</td>
<td>1.0</td>
<td>36</td>
<td>2017</td>
<td>Acad. / Project</td>
</tr>
<tr>
<td>Higra</td>
<td>[HIG]</td>
<td>Graph analysis</td>
<td>C++/Pyt.</td>
<td>0.6.5</td>
<td>4</td>
<td>2018</td>
<td>Acad. / Project</td>
</tr>
</tbody>
</table>
### 2.2 Library Development for RR: examples (1)

**Example of library of vision/image/geometry domains**

- Some **libraries** were initiated/funded by private company.
- The others come mainly from university initiatives.

<table>
<thead>
<tr>
<th>Library</th>
<th>ref</th>
<th>domain</th>
<th>langage</th>
<th>version</th>
<th>#auth.</th>
<th>date</th>
<th>funding</th>
</tr>
</thead>
<tbody>
<tr>
<td>OpenCV</td>
<td>[Bra00]</td>
<td>Comp. Vision</td>
<td>C++</td>
<td>4.5.5</td>
<td>1,383</td>
<td>1999</td>
<td>Willow Garage</td>
</tr>
<tr>
<td>ITK</td>
<td>[MLJ+14]</td>
<td>Image Processing</td>
<td>C++/Pyt.</td>
<td>5.2.1</td>
<td>265</td>
<td>2000</td>
<td>Kitware</td>
</tr>
<tr>
<td>PCL</td>
<td>[RC11]</td>
<td>Point clouds</td>
<td>C++</td>
<td>1.12.1</td>
<td>464</td>
<td>2010</td>
<td>Willow Garage</td>
</tr>
<tr>
<td>CImg</td>
<td>[Tsc12]</td>
<td>Image processing</td>
<td>C++</td>
<td>3.1.2</td>
<td>72</td>
<td>1999</td>
<td>Acad.</td>
</tr>
<tr>
<td>Geogram</td>
<td>[Geo]</td>
<td>Geometric algorith.</td>
<td>C++</td>
<td>1.7.8</td>
<td>7</td>
<td>1998</td>
<td>Acad./INRIA/ERC</td>
</tr>
<tr>
<td>Olena</td>
<td>[RCG18]</td>
<td>Image processing</td>
<td>C++/Pyt.</td>
<td>2.1</td>
<td>50</td>
<td>2001</td>
<td>Acad. / Project</td>
</tr>
<tr>
<td>Tulip</td>
<td>[Aub04]</td>
<td>huge graph visualiz</td>
<td>C++/Pyt.</td>
<td>5.6.2</td>
<td>9</td>
<td>2001</td>
<td>Acad./private</td>
</tr>
<tr>
<td>Vegra</td>
<td>[Vig]</td>
<td>Comp. Vision</td>
<td>C++</td>
<td>1.11</td>
<td>50</td>
<td>2008</td>
<td>Acad.</td>
</tr>
<tr>
<td>DGtal</td>
<td>[DGt]</td>
<td>Digital geometry</td>
<td>C++/Pyt.</td>
<td>1.2</td>
<td>27</td>
<td>2011</td>
<td>Acad. / Project</td>
</tr>
<tr>
<td>TTK</td>
<td>[TFL+17]</td>
<td>Topology ToolKit</td>
<td>C++</td>
<td>1.0</td>
<td>36</td>
<td>2017</td>
<td>Acad. / Project</td>
</tr>
<tr>
<td>Higra</td>
<td>[HIG]</td>
<td>Graph analysis</td>
<td>C++/Pyt.</td>
<td>0.6.5</td>
<td>4</td>
<td>2018</td>
<td>Acad. / Project</td>
</tr>
</tbody>
</table>
2.2 Library Development for RR: examples (2)

Long time efforts

- Commit evolution over 25 years from the CGal library [The22].

![CGal commits evolution from Github data](image)
### 2.2 Library Development for RR: examples (2)

#### Long time efforts

- Commit evolution over 25 years from the CGal library [The22].
- Commit evolution over 10 years from the OpenMVG [MMPM17].

---

**CGal commits evolution from Github data**

**OpenMVG commits evolution from Github data**
2.2 Library Development for RR: examples (2)

**Long time efforts**

- Commit evolution over 25 years from the CGal library [The22].
- Commit evolution over 10 years from the OpenMVG [MMPM17].
  \(\Rightarrow\) no more funding from 2016 (open source only)
2.2 Library Development for RR: examples (2)

**Long time efforts**

- Commit evolution over 25 years from the CGal library [The22].
- Commit evolution over 10 years from the OpenMVG [MMPM17].
  ⇒ no more funding from 2016 (open source only)

**Example of impact measure**

- Geogram library [Geo] (7 authors).
- Estimated from the authors declaring using the library in projects/publications.
2.2 Library Development for RR

**Elements to increase reproducibility across libraries**

- Limit dependencies to other libraries or include them inside the library itself.
- Orient to an header only library (if C++ like CImg or CGal since version 5).
- From a user use, extract all dependent header files.
2.2 Library Development for RR

**Elements to increase reproducibility across libraries**

- Limit dependancies to other libraries or include them inside the library itself.
- Orient to an header only library (if C++ like CImg or CGal since version 5).
- From a user use, extract all dependent header files.

Examples in C++:

It is possible to use a **special option** in order to list all header files:

```
g++ hello.c -o hello -I/specialHeaderLibPath -MD
```

Then command will generate a **hello.d** file containing all header files that are really used by the compilator to produce the executable.
2.2 Library Development for RR

Elements to increase reproducibility across libraries

- Limit dependencies to other libraries or include them inside the library itself.
- Orient to an header only library (if C++ like CImg or CGal since version 5).
- From a user use, extract all dependent header files.

Examples in C++:

It is possible to use a special option in order to list all header files:

```sh
g++ hello.c -o hello -I/specialHeaderLibPath  -MD
```

Then command will generate a `hello.d` file containing all header files that are really used by the compiler to produce the executable.

⇒ then an archive can be constructed including only needed files and independently of library or system header file.
3. Advanced Editorial Efforts
3. Advanced Editorial Investment: IPOL Publications

Peer-reviewed

- Both the article (PDF) and the source code.
- Reproducibility: the reviewers check carefully that the source code matches the pseudo-code.
3. Advanced Editorial Investment: IPOL Publications

**Peer-reviewed**

- Both the *article* (PDF) and the *source code*.
- Reproducibility: the reviewers check carefully that the source code matches the pseudo-code.

**Each publication:**

- A text describing the method in detail, including pseudo-codes.
- The source code, under an open-source software license.
- An online demo which allows users to test the method with their own data.
- An archive of experiments.
### 3. Advanced Editorial Investment: IPOL Publications

#### Peer-reviewed
- Both the article (PDF) and the source code.
- Reproducibility: the reviewers check carefully that the source code matches the pseudo-code.

#### Each publication:
- A text describing the method in detail, including pseudo-codes.
- The source code, under an open-source software license.
- An online demo which allows users to test the method with their own data.
- An archive of experiments.

- **No need to be an original work.** We’re interested in the math details, reproducibility, and understanding.
- ISSN, DOI, indexed by SCOPUS. Not yet an "Impact Factor".
3. Advanced Editorial Investment: IPOL Publications

Peer-reviewed

- Both the article (PDF) and the source code.
- Reproducibility: the reviewers check carefully that the source code matches the pseudo-code.

Each publication:

- A text describing the method in detail, including pseudo-codes.
- The source code, under an open-source software license.
- An online demo which allows users to test the method with their own data.
- An archive of experiments.

No need to be an original work. We’re interested in the math details, reproducibility, and understanding.

ISSN, DOI, indexed by SCOPUS. Not yet an "Impact Factor".

Let’s have a look! ⇒ http://www.ipol.im/pub/art/2017/201/
## 3.1 IPOL publications: Benefits of RR, from our experience

### If a method is worth it, the impact is large

- Users worldwide can test the algorithm with their **own data**.
- Increase in the number of citations: other researchers can now **compare** to you.
### 3.1 IPOL publications: Benefits of RR, from our experience

**If a method is worth it, the impact is large**

- Users worldwide can test the algorithm with their *own data*.
- Increase in the number of citations: other researchers can now *compare* to you.

#### Scientific acceleration:

⇒ other researchers can reuse text, source code, data
3.1 IPOL publications: Benefits of RR, from our experience

If a method is worth it, the impact is large

- Users worldwide can test the algorithm with their own data.
- Increase in the number of citations: other researchers can now compare to you.

**Scientific acceleration:**

⇒ other researchers can reuse text, source code, data

Useful for Centre Borelli to show a landscape of our scientific activity

A way of working!
3.2 New initiative with OVD-SaaS

Main idea of the project

- **New long-term project** at Centre Borelli
- Inspired on the experience of IPOL
- Opening industrial **software as a service (SaaS)** to final users
- Needless to say: based on **reproducible research and sharing data**
- Do not focus on technical details of low-level services, but solving a concrete and final **industrial need**
3.2 New initiative with OVD-SaaS

Main idea of the project

- **New long-term project** at Centre Borelli
- Inspired on the experience of IPOL
- Opening industrial **software as a service (SaaS)** to final users
- Needless to say: based on **reproducible research** and **sharing data**
- Do not focus on technical details of low-level services, but solving a concrete and final **industrial need**
- Examples of application domains:
  - Security, quality management, health and biometry, predictive maintenance, ...
3.2 New initiative with OVD-SaaS

Main idea of the project

- New long-term project at Centre Borelli
- Inspired on the experience of IPOL
- Opening industrial software as a service (SaaS) to final users
- Needless to say: based on reproducible research and sharing data
- Do not focus on technical details of low-level services, but solving a concrete and final industrial need
- Examples of application domains:
  ⇒ Security, quality management, health and biometry, predictive maintenance, . . .

Even more!

SaclAI-School, MVA track on reproducible research, . . .
3.2 New initiative with OVD-SaaS: feedback

<table>
<thead>
<tr>
<th>Preliminary feedback</th>
</tr>
</thead>
<tbody>
<tr>
<td>● First &quot;ML-Briefs&quot; in April 2022. Second in October 2022.</td>
</tr>
<tr>
<td>● Publication of short ML papers.</td>
</tr>
</tbody>
</table>
### Preliminary feedback

- First "ML-Briefs" in April 2022. Second in October 2022.
- Publication of short ML papers.
- Some challenges:
  - **Evaluation** of neural networks. They’re not “classic” code. Evaluate type of architecture, how the training was conducted (initialization, which datasets, etc). Black-box model to check same outputs.
  - **Instability** of libraries. Use of Python’s *venv* not enough. Other dependencies at OS and hardware levels. Using Docker *containers*.
### 3.3 Reviewing Reproducible Research: How?

**Main attention points:**

- Consider **source code** as **part of the publication**, not supplementary material.
- Different **levels of evaluation**:
  - **Lowest**: black box (same inputs $\rightarrow$ same outputs)
  - ...  
  - **Highest**: deep understanding of the method and checking that the source code matches exactly the implementation.
3.3 Reviewing Reproducible Research: How?

Main attention points:

- Consider **source code** as **part of the publication**, not supplementary material
- **Different levels of evaluation:**
  - **Lowest**: black box (same inputs \(\rightarrow\) same outputs)
  - ... 
  - **Highest**: deep understanding of the method and checking that the source code matches exactly the implementation.

Difficulty

- **Software** is **not easy to review**.
- Not all researchers are software engineers!

\[\Rightarrow\] A possible solution (IPOL): use **at least two reviewers**, one of them being an expert reading source code.
3.3 Reviewing Reproducible Research: How?

Main attention points:

- Consider source code as part of the publication, not supplementary material
- Different levels of evaluation:
  - Lowest: black box (same inputs → same outputs)
  - ... 
  - Highest: deep understanding of the method and checking that the source code matches exactly the implementation.

Difficulty

- Software is not easy to review.
- Not all researchers are software engineers!

⇒ A possible solution (IPOL): use at least two reviewers, one of them being an expert reading source code.

Special case of neural networks

Focus on the architecture, training, understanding, and generalization.
3.3 Reviewing Reproducible Research: How? (2)

**Important point**

- **Versioning** is important!
  - Research source code *changes* constantly
  - A publication is steady
- Much of the code is publicly available on platforms such as Gitlab, Github, and others

[DOI is not enough]: the pointed object might change (or even disappear!). It's just a pointer.

[Persistent and universal archive]:

- A good candidate: UNESCO's Software Heritage project [DCGZ18]
- SWHID: SoftWare Heritage persistent IDentifiers [DCGZ19]

[Perpetual objects]:

- At different levels: contents, directories, revisions, releases, snapshots
- Points to perpetual objects in an universal archive
3.3 Reviewing Reproducible Research: How? (2)

**Important point**

- **Versioning** is important!
  - Research source code **changes** constantly
  - A publication is steady
- Much of the code is publicly available on platforms such as Gitlab, Github, and others

**Need to identify software artifacts at different levels**

- **DOI is not enough**: the pointed object might change (or even disappear!). It’s just a **pointer**.
- Need of a **persistent** and **universal archive**
- A good candidate: UNESCO’s **Software Heritage** project [DCGZ18]
- **SWHID**: SoftWare Heritage persistent IDentifiers [DCGZ19]
  - At **different levels**: contents, directories, revisions, releases, snapshots
  - Points to **perpetual objects** in an universal archive
A quick review of software and platforms for RR (1)

Scientific Workflows management systems [CBBC\textsuperscript{+}17, Hat17]

- **Taverna**: open source scientific workflow management system that provides a workbench for designing workflows, used in biology, chemistry, meteorology, social sciences.

- **Galaxy**: is very popular workflow system in the bioinformatics community and life sciences.

- **OpenAlea** is an open source scientific workflow system with a visual programming environment that enables users to design, execute and interact with workflows.

- **Nextflow**: is a command-line based workflow system implemented in Groovy (a scripting language for the Java Virtual Machine), developed to simplify the design of complex parallel scientific workflows.

- **Chimera** system: originated in support of data-intensive physics computations as a means to capture and automate a complex pipeline of transformations on the data by external software.
## Project/Experiment management systems [Jen22]

- **Neptune**: is a *metadata store* for any **MLOps workflow**. It was built for both research and production teams that run a lot of experiments.
- **Weights & Biases**: is a machine learning platform built for **experiment tracking**, **dataset versioning**, and **model management**.
- **Comet**: ML platform that helps data scientists **track, compare, explain** and **optimize experiments** and **models** across the model’s entire lifecycle.
- **Sacred + Omniboard**: **open-source** software that allows machine learning researchers to **configure, organize, log**, and **replicate** experiments.
A quick review of software and platforms for RR (3)

**Project/Experiment management systems**

- **Tensorboard**: visualization toolkit for TensorFlow
- **Polyaxon**: platform for *reproducible and scalable machine learning* and deep learning applications
- **ClearML**: is an open-source platform, a suite of tools to streamline your ML workflow
- **Pachyderm**: enterprise-grade, open-source data science platform that makes it possible for its users to control an end-to-end machine learning cycle
- **MLflow**: open-source platform that helps manage the whole machine learning lifecycle. This includes experimentation, but also model storage, reproducibility, and deployment
4. Conclusion
4. Conclusions

- **Reproducible research** is needed for the **advancement of science**
- The **article**, the **software**, and **data** must be all part of the same publication
- It has a **larger impact**, but it requires a **larger effort** too
- Researchers need to be rewarded
4. Conclusions

- **Reproducible research** is needed for the advancement of science
- The *article*, the *software*, and *data* must be all part of the same publication
- It has a **larger impact**, but it requires a **larger effort** too
- Researchers need to be rewarded

**Many initiatives on this direction:**

- **European**: European Open Science Cloud (EOSC)
- **National**: French *Plan for Open Science*. **Discussion**: others?
- **Centre Borelli**: IPOL, OVD-SaaS, MVA track on reproducibility, ... **Discussion**: what about your research centers?
Thank you for your attention
References


References


*Higra: Hierarchical graph analysis.*


References


References
