Integration of Research software into the EOSC infrastructure

Lessons learned from Computer science
/whoami

Mohammad Reza Saleh Sedghpour
Dpt. Computing science, Umeå University
msaleh@cs.umu.se
Twitter: @sedghpour

Sanna Isabel Ulfsparré
Umeå University Library
sanna.isabel.ulfsparré@umu.se
www.umu.se/personal/sanna-isabel-ulfsparré/
Research software (RS) in EOSC

EOSC infrastructure need to:

- include RS to fulfill the FAIR and the FAIR4RS principles
- support sharing, collaborating, evaluating, reproducing, re-using and preserving software
- have a research domain neutral core of standards.
Transparency in research and research-related practices
Rigor, credibility and validity

For qualitative research, it is important to have transparency to:

• show that conclusions and analysis are justifiable
• make it possible to discuss unconscious biases and ethical issues
• show a clear relationship between data, theory and method, as well as rigour in the execution.
How do you define "Reproducibility"?

www.menti.com
Code: 67 80 83 6
Reproducibility

*Reproducibility* is the procedure of independent *confirmation* of a scientific *hypothesis* by another *team*.

(Vitek and Kalibera 2011)
How do you define "Repeatability"?

www.menti.com
Code: 67 80 83 6
The ability to re-run the exact same experiment with the same procedure on the same or comparable system and receive the same or very similar result is referred to as repeatability.

(Vitek and Kalibera 2011)
Distributed Systems Research

Research Questions → Develop the Tools → Experiments/Data Collection → Data Analysis/Answers to RQs

Repeatability

Reproducibility
Is the current research repeatable and reproducible?

www.menti.com
Code: 67 80 83 6
Reproducibility crisis

In a survey published 2016, 90% of researchers answered that there was a slight or a significant reproducibility crisis.

(Baker, Science 2016)

"[...] the scientific community was shaken by reports that a troubling proportion of peer-reviewed preclinical studies are not reproducible."

(McNutt, Nature 2014)
Conclusion:

EOSC need to support RS in order to support reproducibility, repeatability and validation of qualitative processes.
Questions during the presentation

www.menti.com
Code: 67 80 83 6
EOSC for RS

- Share
- Collaborate
- Evaluate
- Reproduce, repeat and validate
- Re-use
- Preserve
EOSC for RS

- Share
- Collaborate
- Evaluate
- Reproduce, repeat and validate
- Re-use
- Preserve
EOSC for RS

- Share
- Collaborate
- Evaluate
- Reproduce, repeat and validate
- Re-use
- Preserve

Funders and HEI:s
Evaluate, using the metadata generated in the process
Integration of Computer science practices

Generalisation of existing practices for:

• Open source communities
• Infrastructures and features
• Evaluation and quality control
• Scholarly communication practices
The badging system

2011
The Artifact Evaluation process started by ACM*.

2015
8 Submitted Artifacts

2021
614 Submitted Artifacts

* Association for Computing Machinery
Timeline for artifact evaluation in distributed systems

(Saleh Sedghpour, M.R; Klein, C.; Papadopoulos, A.V. et al. Est. 2023.)
The study

- ACM Digital Library
- IEEE Xplore
- WikiCFP
- Researchr

<table>
<thead>
<tr>
<th>No</th>
<th>Keyword</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Distributed Systems</td>
</tr>
<tr>
<td>2</td>
<td>Cloud Computing</td>
</tr>
<tr>
<td>3</td>
<td>Edge Computing</td>
</tr>
<tr>
<td>4</td>
<td>Fog Computing</td>
</tr>
<tr>
<td>5</td>
<td>Serverless Computing</td>
</tr>
<tr>
<td>6</td>
<td>Service-Oriented Architectures</td>
</tr>
<tr>
<td>7</td>
<td>Microservices</td>
</tr>
</tbody>
</table>
# The study: Process

<table>
<thead>
<tr>
<th>Conference Name</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASPLOS</td>
<td>2022, 2021, 2020</td>
</tr>
<tr>
<td>CF</td>
<td>2020</td>
</tr>
<tr>
<td>CoNEXT</td>
<td>2022, 2021, 2020</td>
</tr>
<tr>
<td>ESEC/FSE</td>
<td>2021, 2020</td>
</tr>
<tr>
<td>EuroSys</td>
<td>2022, 2021</td>
</tr>
<tr>
<td>ICPE</td>
<td>2022, 2021, 2020</td>
</tr>
<tr>
<td>ICSE</td>
<td>2022, 2021, 2020</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conference Name</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>MICRO</td>
<td>2021</td>
</tr>
<tr>
<td>Middleware</td>
<td>2022, 2021, 2020</td>
</tr>
<tr>
<td>SC</td>
<td>2022, 2021, 2020</td>
</tr>
<tr>
<td>SOSP</td>
<td>2021</td>
</tr>
<tr>
<td>PPoPP</td>
<td>2022, 2021, 2020</td>
</tr>
<tr>
<td>UCC</td>
<td>2021</td>
</tr>
</tbody>
</table>
Extracting best practices

- Extract conferences employing Artifact Evaluation process
- Extract best practices for:
  - Researchers
  - Reviewers
  - Community
  - Funding agencies, repositories, policy makers, and publishers
  - HEIs
  - Training and research support
- Extract conferences in Distributed Systems research
- Extract guidelines from conferences public website
Introduction

Best practices: Researchers
Best practices: Researchers

| Introduction | Archival Repository (DOI) |
# Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
</tr>
</thead>
</table>

**Introduction**

**Archival Repository (DOI)**

**Algorithms**
# Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
</tr>
</thead>
</table>

This table outlines the key sections of the document focusing on best practices for researchers.
Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Introduction</td>
<td>Archival Repository (DOI)</td>
<td>Algorithms</td>
<td>Required Resources</td>
</tr>
<tr>
<td>--------------</td>
<td>---------------------------</td>
<td>------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td></td>
</tr>
</tbody>
</table>
# Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td>Metrics</td>
</tr>
</tbody>
</table>


# Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td>Metrics</td>
</tr>
<tr>
<td>Planning</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td>Metrics</td>
</tr>
<tr>
<td>Planning</td>
<td>Expected Outputs</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td>Metrics</td>
</tr>
<tr>
<td>Planning</td>
<td>Expected Outputs</td>
<td>Sample Data</td>
<td></td>
</tr>
</tbody>
</table>
## Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td>Metrics</td>
</tr>
<tr>
<td>Planning</td>
<td>Expected Outputs</td>
<td>Sample Data</td>
<td>Licenses</td>
</tr>
</tbody>
</table>

- **Introduction**
- **Archival Repository (DOI)**
- **Algorithms**
- **Required Resources**
- **Inputs**
  - Run-Time States
  - Problem Dimensions
  - Metrics
- **Planning**
  - Expected Outputs
  - Sample Data
  - Licenses
# Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
<th>Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td>Metrics</td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td>Expected Outputs</td>
<td>Sample Data</td>
<td>Licenses</td>
<td></td>
</tr>
</tbody>
</table>
**Best practices: Researchers**

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
<th>Programs</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td>Metrics</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td>Expected Outputs</td>
<td>Sample Data</td>
<td>Licenses</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
<th>Programs</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td>Metrics</td>
<td>Source Control</td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td>Expected Outputs</td>
<td>Sample Data</td>
<td>Licenses</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
<th>Programs</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td>Metrics</td>
<td>Source Control</td>
<td>Automation</td>
</tr>
<tr>
<td>Planning</td>
<td>Expected Outputs</td>
<td>Sample Data</td>
<td>Licenses</td>
<td>Programs</td>
<td>Experiment</td>
</tr>
</tbody>
</table>

- **Inputs**
  - Run-Time States
  - Problem Dimensions
  - Metrics

- **Planning**
  - Expected Outputs
  - Sample Data
  - Licenses

- **Programs**
  - Source Control

- **Experiment**
  - Automation
# Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
<th>Programs</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td>Metrics</td>
<td>Source Control</td>
<td>Automation</td>
</tr>
<tr>
<td>Planning</td>
<td>Expected Outputs</td>
<td>Sample Data</td>
<td>Licenses</td>
<td>Test Driven Developing</td>
<td></td>
</tr>
</tbody>
</table>
## Best practices: Researchers

<table>
<thead>
<tr>
<th>Introduction</th>
<th>Archival Repository (DOI)</th>
<th>Algorithms</th>
<th>Required Resources</th>
<th>Programs</th>
<th>Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>Run-Time States</td>
<td>Problem Dimensions</td>
<td>Planning</td>
<td>Source Control</td>
<td>Automation</td>
</tr>
<tr>
<td>Metrics</td>
<td>Expected Outputs</td>
<td>Sample Data</td>
<td>Licenses</td>
<td>Test Driven Developing</td>
<td>Public Cloud</td>
</tr>
</tbody>
</table>
# Best practices: Researchers

<table>
<thead>
<tr>
<th>Metadata describing software</th>
<th>Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>Programs, Experiment</td>
</tr>
<tr>
<td>Archival Repository (DOI)</td>
<td></td>
</tr>
<tr>
<td>Algorithms</td>
<td></td>
</tr>
<tr>
<td>Required Resources</td>
<td></td>
</tr>
<tr>
<td>Inputs</td>
<td>Source Control, Automation</td>
</tr>
<tr>
<td>Run-Time States</td>
<td></td>
</tr>
<tr>
<td>Problem Dimensions</td>
<td></td>
</tr>
<tr>
<td>Metrics</td>
<td></td>
</tr>
<tr>
<td>Planning</td>
<td>Test Driven Developing, Public Cloud</td>
</tr>
<tr>
<td>Expected Outputs</td>
<td></td>
</tr>
<tr>
<td>Sample Data</td>
<td></td>
</tr>
<tr>
<td>Licenses</td>
<td></td>
</tr>
</tbody>
</table>
Best practices: Reviewers

Multi-stage reviewing
Best practices: Reviewers

- Multi-stage reviewing
- Providing guidelines and checklists
Best practices: Reviewers

- Multi-stage reviewing
- Providing guidelines and checklists
- Communications between reviewers should be facilitated and encouraged
## Best practices: Reviewers

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-stage reviewing</td>
<td></td>
</tr>
<tr>
<td>Providing guidelines and checklists</td>
<td></td>
</tr>
<tr>
<td>Communications between reviewers should be facilitated and encouraged</td>
<td></td>
</tr>
<tr>
<td>Access to a public cloud, such as EOSC</td>
<td></td>
</tr>
</tbody>
</table>
Best practices:
Research communities

Research and discussions on best practices
Best practices:
Research communities

- Research and discussions on best practices
- Encouragement of and engagement in research software reviews
### Best practices:
#### Research communities

- Research and discussions on best practices
- Encouragement of and engagement in research software reviews
- Evaluation of new ideas and methods, such as crowd-sourcing and citizen science
## Best practices:
### Research communities

<table>
<thead>
<tr>
<th>Icon</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>✏️</td>
<td>Research and discussions on best practices</td>
</tr>
<tr>
<td>🔍</td>
<td>Encouragement of and engagement in research software reviews</td>
</tr>
<tr>
<td>👥</td>
<td>Evaluation of new ideas and methods, such as crowd-sourcing and citizen science</td>
</tr>
<tr>
<td>👥</td>
<td>Inter-disciplinary working groups for research software practices</td>
</tr>
</tbody>
</table>
Best practices: Research communities

- Research and discussions on best practices
- Encouragement of and engagement in research software reviews
- Evaluation of new ideas and methods, such as crowd-sourcing and citizen science
- Inter-disciplinary working groups for research software practices
- Support and exploration of practices that follow the FAIR principles
Our recommendation: Policy makers, publishers and funding agencies

✓ FAIR research software practices should be embedded in policy and funding requirements.
Our recommendation: Policy makers, publishers and funding agencies

✓ FAIR research software practices should be embedded in policy and funding requirements.
✓ Generous metadata describing software should be expected.
Our recommendation: Policy makers, publishers and funding agencies

✓ FAIR research software practices should be embedded in policy and funding requirements.
✓ Generous metadata describing software should be expected.
✓ Access to research software should be encouraged "as openly as possible, as restricted as necessary".
Our recommendation: Policy makers, publishers and funding agencies

✓ FAIR research software practices should be embedded in policy and funding requirements.

✓ Generous metadata describing software should be expected.

✓ Access to research software should be encouraged "as openly as possible, as restricted as necessary".

✓ Research on open science and practices for reproducibility should be supported and funded.
Our recommendation: Policy makers, publishers and funding agencies

✓ FAIR research software practices should be embedded in policy and funding requirements.

✓ Generous metadata describing software should be expected.

✓ Access to research software should be encouraged "as openly as possible, as restricted as necessary".

✓ Research on open science and practices for reproducibility should be supported and funded.

✓ There should be badging system for software quality that is controlled centrally by an entity such as EOSC.
Our recommendation: Training and researcher support

- Basic programming and "Clean code"
Our recommendation: Training and researcher support

- Basic programming and "Clean code"
- Development methods:
  - Design patterns
  - Automation
  - Test driven development
Our recommendation: Training and researcher support

• Basic programming and "Clean code"
• Development methods:
  o Design patterns
  o Automation
  o Test driven development
• Iterative thinking
Our recommendation: Training and researcher support

- Basic programming and "Clean code"
- Development methods:
  - Design patterns
  - Automation
  - Test driven development
- Iterative thinking
- Use of infrastructures
Our recommendation: Training and researcher support

- Basic programming and "Clean code"
- Development methods:
  - Design patterns
  - Automation
  - Test driven development
- Iterative thinking
- Use of infrastructures
- Research software in Open science and Scholarly communication
Our recommendation: Training and researcher support

- Basic programming and "Clean code"
- Development methods:
  - Design patterns
  - Automation
  - Test driven development
- Iterative thinking
- Use of infrastructures
- Research software in Open science and Scholarly communication
- Legal training and support
References


Baker, M. 2016. 1,500 scientists lift the lid on reproducibility. *Nature* 533: 452–454. DOI: 10.1038/533452a

Saleh Sedghpour, M.R; Klein, C.; Papadopoulos, A.V. et al. Estimated publishing 2023. Title TBD.
Thank you!

Mohammad Reza Saleh Sedghhpour
Sanna Isabel Ulfsparr