Reproducibility in Parallel and Distributed Computing: Challenges, State of the Practice, Limitations, and Opportunities

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The Question of Reproducibility

Researchers perform computations on parallel & distributed computing systems.

High performance ☺
Distributed ☺
Shared ☺

Difficult to control ☹

⇓

Is Reproducibility Achievable?

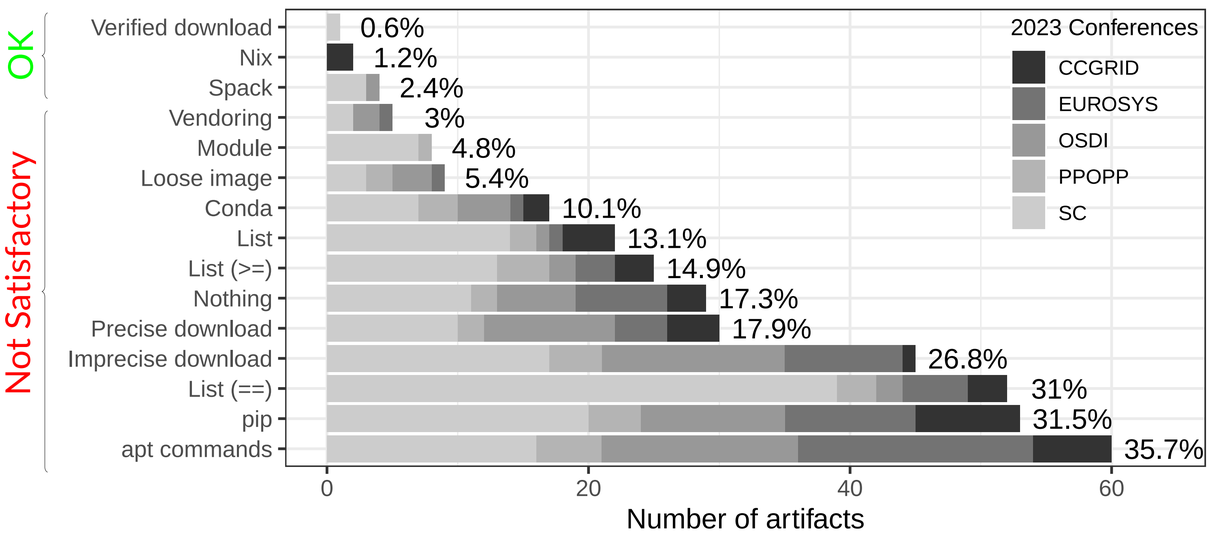
↪ What can researchers control? **The software environments.**

Community's Answer: Artifact Evaluation

Upon article's acceptance, authors submit **code** and other **artifacts** to be **evaluated and reproduced** by reviewers. Reproducible artifacts are then rewarded with **badges** [1]. ⇝

Current State of the Practice

We surveyed 296 papers of top conferences in parallel and distributed computing from 2023 and recorded how their software environments were described [2]:



↪ **Finding:** 17% of the artifacts did not describe their software environments!

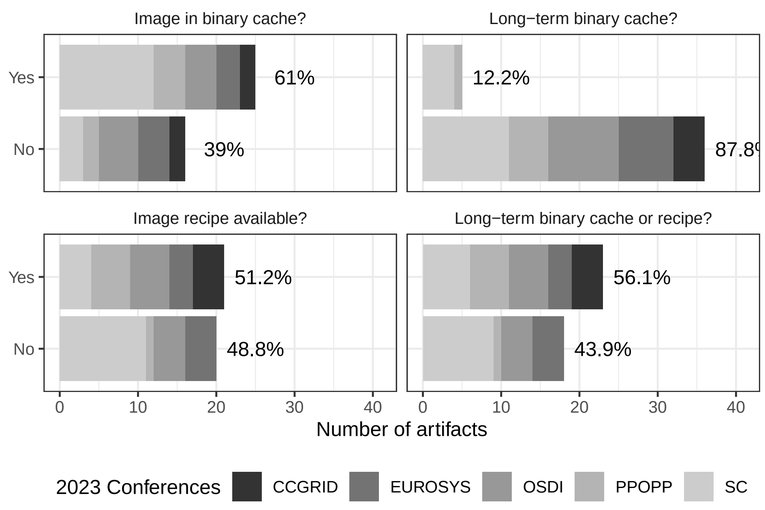
↪ **Finding:** Most research artifacts **are not shared in reproducible software environments**.

Common Tools: Environment Modules

- Managed by system administrators ⇝ can **disappear** at any time ☹
- System-specific ⇝ **not portable** across computing platforms ☹
- Side effects ⇝ unloading may not reset environment to previous state ☹

Common Tools: Containers

Finding: The software environments of 12% of artifacts use containers.



Full paper [2] available:

↪ Half of these artifacts **do not share the container recipe**.

⇝ How can then the *same* container image be rebuilt?

Typical container recipe:

Can you find all **reproducibility issues** with this `Dockerfile`?

```
FROM ubuntu
RUN apt-get update -y && apt-get install -y packageA ...
RUN git clone https://github.com/me/my-repo.git
WORKDIR my-repo
RUN curl -L https://tinyurl.com/patchrepo -o fix.patch
RUN git apply fix.patch
RUN make
ENTRYPOINT ["./my_bin"]
```

docker

↪ Container recipes are based on **non-reproducible** tools and practices.

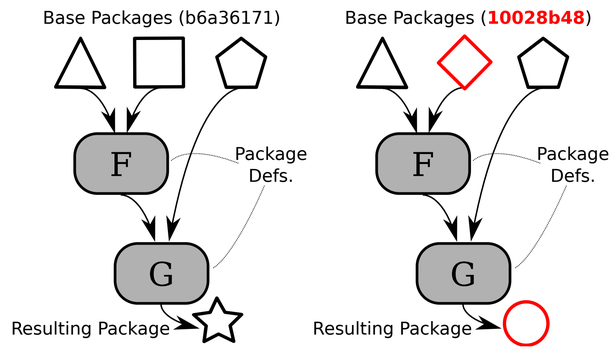
⇝ Most containers are not reproducible ☹

Limitations in the State of the Practice

Limited reproducibility and nearly impossible to extend existing work, to introduce a specific variation (*e.g.*, different compiler version) ⇝ ☹

A Solution: Functional Package Managers (FPMs)

- Nix [3], Guix [4]
- Capture the **entire** software stack
- packages ▸ functions
  - inputs ▸ dependencies
  - body ▸ commands to execute
- Base packages available on Git
- **Precise introduction of variations**



Storing packages: the FPMs way

```
/nix/store
├── yaz7pyf0ah88g2v505l38n0f3wg2vzdj-glibc-2.37
│   └── lib
│       └── libc.so
├── y9zg6ryffgc5c9y67fcmfdkyyiivjzpj-glibc-2.27
│   └── lib
│       └── libc.so
└── nc5qbagm3wqfg2lv1gwj3r3bn88dpqr8-mypkg-0.1.0
    ├── bin
    │   └── myprogram
    └── lib
        └── libmylib.so
```

- Immutable, read-only directory
- Packages stored as `hash(inputs)-pkgname`
- Can store **several versions** of the same package
- **Precise** definition of the software environment

↪ FPMs solve most reproducibility issues but require a **change of practice** and incur a **steep learning curve** due to their new concepts in package management.

A Proposal: the *Artifacts Longevity* Badge

Proposed in [2], takes into account:

- How is the artifact shared (source code, data)
- How is the software environment captured & described
- Where & how have the experiments been executed

Artifacts Longevous acm [a]

[a] In discussion with ACM

↪ **Aim:** Reward work that can be reused in the **future** (by authors or others).

Next Steps

- Longitudinal study of the state of the practice
- Awarding longevity badges to artifacts that meet the requirements
- Future testing of artifacts receiving the longevity badge
- **Survey** how parallel and distributed computing systems are used in different research fields →

Take our survey!

Bibliography

[1] https://www.acm.org/publications/policies/artifact-review-and-badging-current

[2] Guilloteau Quentin, Ciorba Florina M., Poquet Millian, Goepp Dorian, and Richard Olivier. "Longevity of Artifacts in Leading Parallel and Distributed Systems Conferences: a Review of the State of the Practice in 2023." ACM Conference on Reproducibility and Replicability (REP 2024), 2024.

[3] Dolstra Eelco, Merijn De Jonge, and Eelco Visser. "Nix: A Safe and Policy-Free System for Software Deployment." LISA. Vol. 4., 2004.

[4] Courtès Ludovic and Ricardo Wurmus. "Reproducible and user-controlled software environments in HPC with Guix." Euro-Par 2015: Parallel Processing Workshops: Euro-Par 2015 International Workshops, Vienna, Austria, August 24-25, 2015.

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