Carsten Knoll, Robert Heedt
Faculty of Electrical and Computer Engineering, Institute of Control Theory

“Automatic Control Knowledge Repository” – A Computational Approach for Simpler and More Robust Reproducibility of Results in Control Theory

ICSTCC, Sinaia, Romania (remote participation), 2020-10-08

Motivation

Reproduction of Scientific Results (1)

- Scientific communication: traditionally based on natural language (+ mathematics + diagrams)
- Growing importance of computational methods
  - Simulations
  - Numerical linear algebra
  - Symbolic calculations with CAS

Proceedings in Applied Mathematics and Mechanics, 6/10/2020

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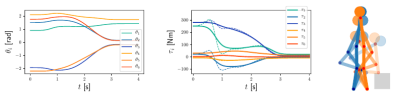
Physical interaction of humans can be a challenging. For some practically relevant situations a reasonable model is given by a closed kinematic chain of a planar rigid body mechanism. From a control perspective a cooperative motion, e. g. assisted standing-up, can be seen as an optimal control problem (OCP) with input and state restrictions. Due to the algebraic constraints and the comparably high number of joints involved, proper formulation of such a problem is not trivial. In this contribution we compare two different modeling approaches: discretization of the full dynamical problem and iterative solution of consecutive stationary problems. The latter turns out to be significantly faster while still providing – in some sense – optimal solutions.

1 Introduction: Modelling of Cooperative Standing-Up Motion

Motivated e. g. by [1] and references therein we consider the basic mechanical aspects of cooperative standing-up motion, which takes place e. g. in geriatric care. The goal of this contribution is not to provide realistic numbers but rather a methodology to simplify further research. Following [1] we model each of the two persons (care giver and receiver) as chains of $\bar{n}_L = 3$ links (rigid bodies) connected by $\bar{n}_J$ actuated revolute joints and assume that both chains are fixed to the same basis (i. e. the ground) and the motion is entirely planar. We further assume that the torque which can be applied to each joint is bounded. The connection of the two kinematic chains (i. e. persons) is also modeled as an (unactuated) revolute joint. The resulting mechanism thus has $n_L = 2\bar{n}_L = 6$ links and $n_J = 2\bar{n}_J + 1 = 7$ joints. We denote the configuration coordinates (actuated joint angles) with $(\theta_1, ..., \theta_{2\bar{n}_J})^T =: \boldsymbol{\theta}$ and the respective torques with $(\tau_1, ..., \tau_{2\bar{n}_J})^T =: \boldsymbol{\tau}$. The degree of freedom of this single closed loop is $F = n_J - 3 = 4$, cf. [2, Section 1.2.1]. The closing condition of the loop – enforcing that both independent link sequences have the connection joint as common point – introduces a constraint expressable as two scalar algebraic equations.



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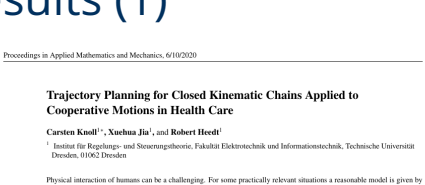

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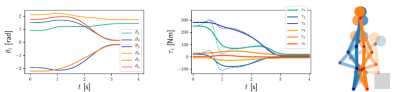

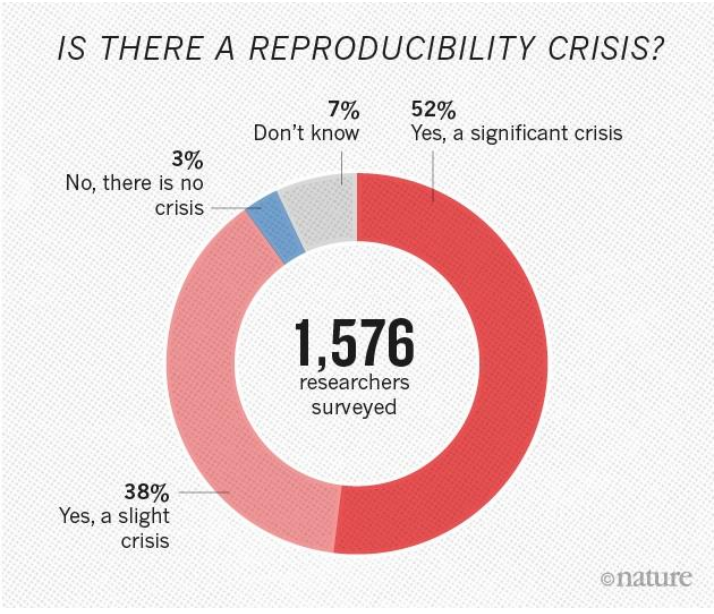

source: https://www.nature.com/news/1-500-scientists-lift-the-lid-on-reproducibility-1.19970 (2016)

source: https://www.nature.com/articles/467775a/box/2 (2010)

Outline

✓ **Motivation: Reproducibility Challenge**
☐ Existing Approaches
☐ Our Approach
☐ Implementation Status & Demo
☐ Conclusion & Outlook

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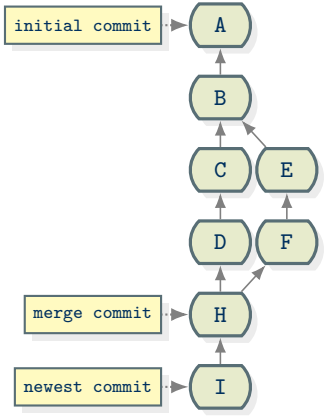

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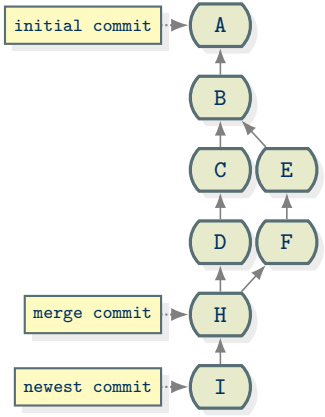

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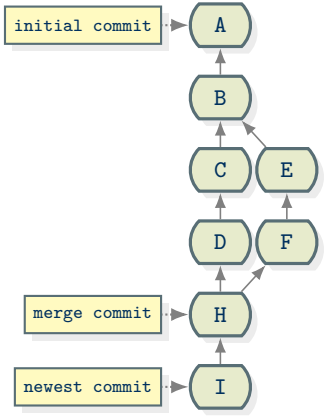

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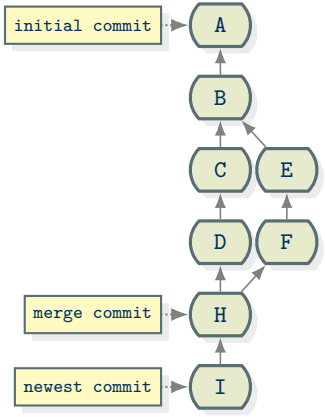
- $\exists$ platforms for public repository-hosting
  (github, gitlab, codeberg, ...)



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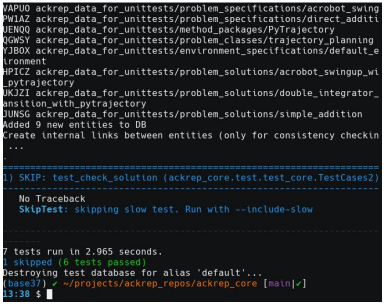

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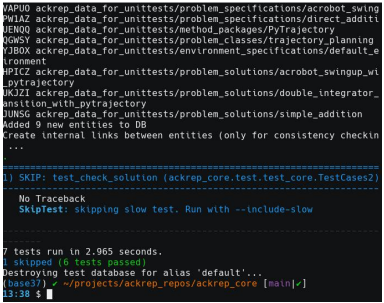

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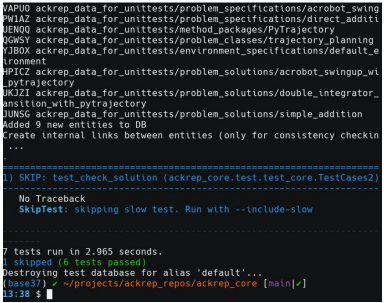

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- **Continuous Integration**:
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- Triggered e. g. by a new commit to the main branch of a repo

Insufficiencies of Existing Approaches

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Research question:

What kind of science specific structure and functionality is suited to mitigate the reproducibility crisis?

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Integration Concept: “Automatic Control Knowledge Repository”

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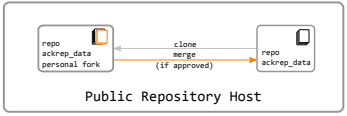

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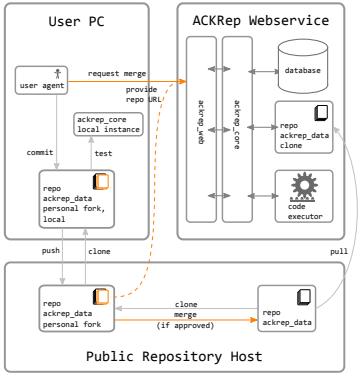

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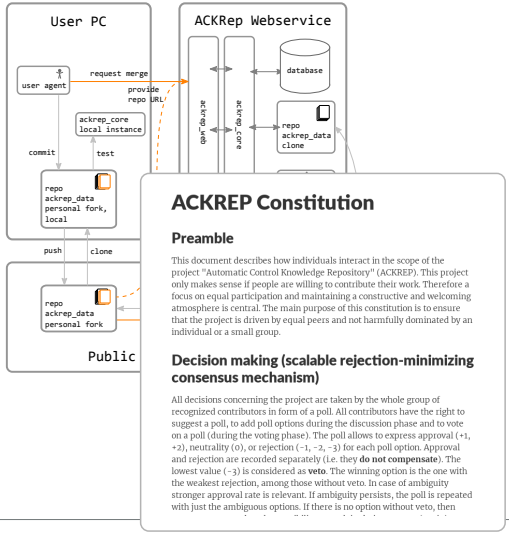

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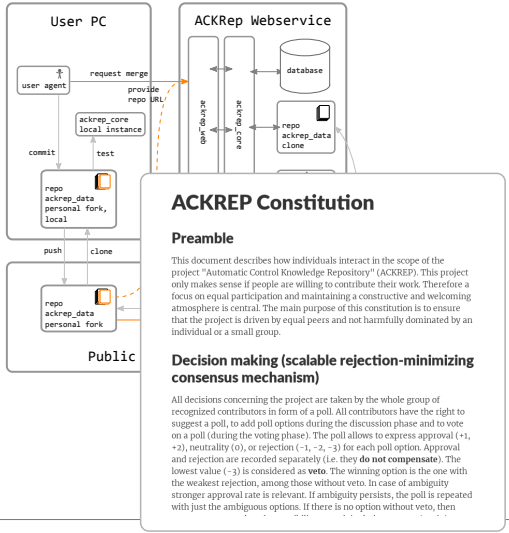

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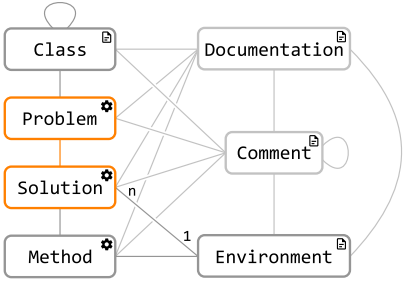
Reproducibility → entity types:



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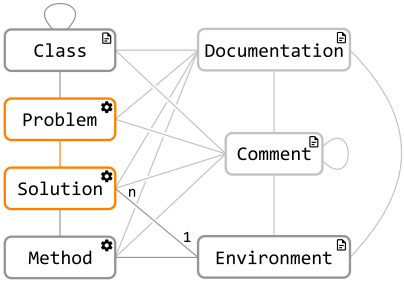

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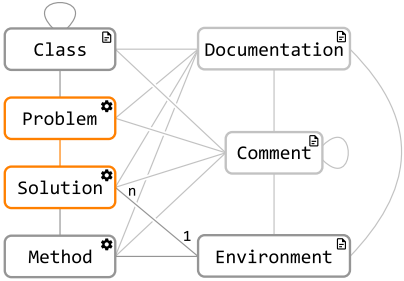

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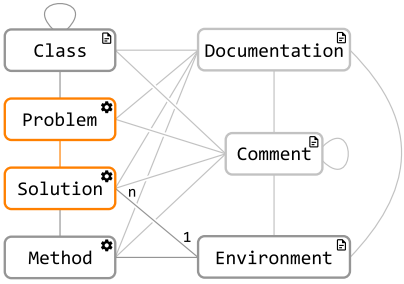

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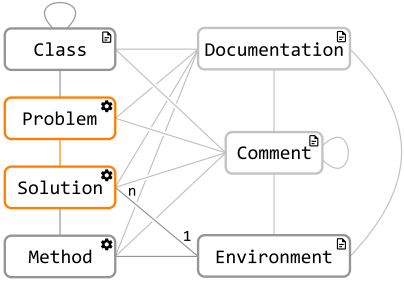

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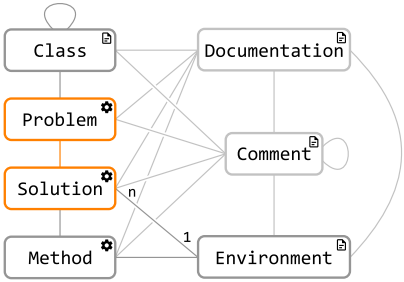

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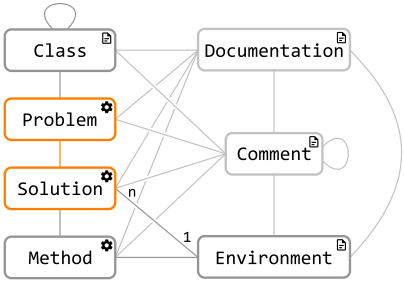

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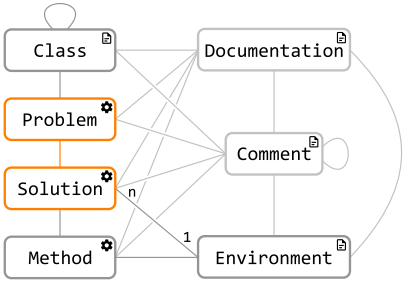
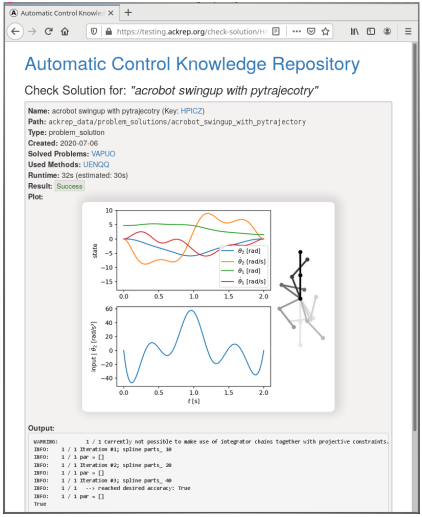


Entities:

- Identified via unique keys
- Stored in (text-based) files
- Managed via DVCS (git)
- Publicly hosted

Supportive Webservice and Tools

- Webservice:
  - Execute `Solutions` against `Problems` (≙ Continuous Integration)
  - Present results
  - Make available knowledge accessible



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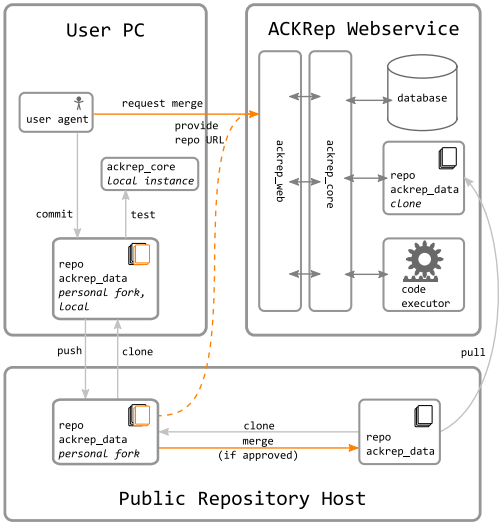
- Tools:
  - Locally check entities
  - Support debugging process



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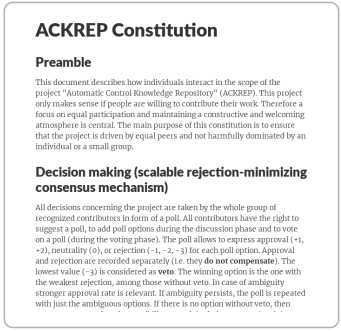
- Solution approach: **peer-based decision making**



ACKREP Constitution

Preamble

This document describes how individuals interact in the scope of the project "Automatic Control Knowledge Repository" (ACKREP). This project only makes sense if people are willing to contribute their work. Therefore a focus on equal participation and maintaining a constructive and welcoming atmosphere is central. The main purpose of this constitution is to ensure that the project is driven by equal peers and not harmfully dominated by an individual or a small group.

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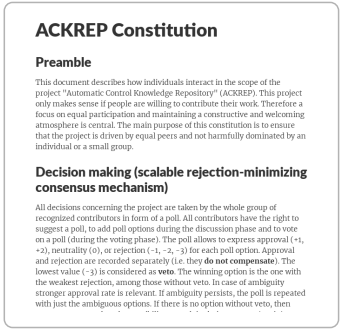
Self-Governance Rules

Canonical repository + webservice $\rightarrow$ central infrastructure

- Desirable: makes results/implementations easily findable
- Problems: single point of failure
  - Technical: public repo or webservice could vanish
    $\rightsquigarrow$ uncritical due to DVCS (open sources of data and software)
  - Personal: bad management (rejected merge-request etc.)
- Solution approach: **peer-based decision making**
  - … about contributions (merge-requests)
  - … about the rules themselves



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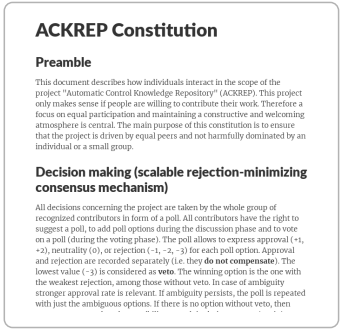

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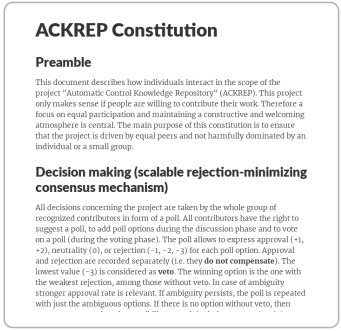

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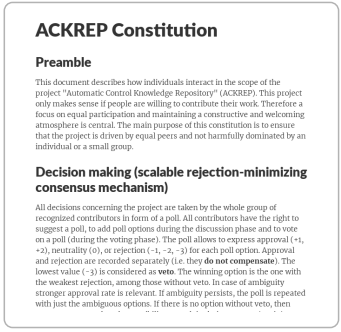

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✓ Motivation: Reproducibility Challenge
✓ Existing Approaches
✓ Our Approach
☐ **Implementation Status & Demo**
☐ Conclusion & Outlook

Current Implementation Status

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- ∃ `ackrep_web` (GPLv3)
- ∃ `ackrep_data`
  - Default license GPLv3
  - Demonstration examples only
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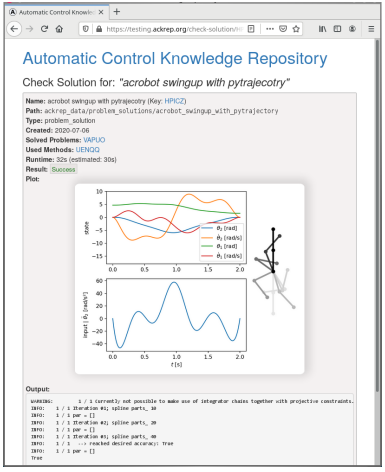
⇒ Early prototype, proof of concept

Live Demonstration



https://testing.ackrep.org

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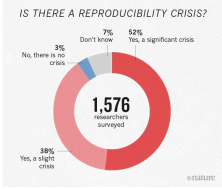
Summary:

- Reproducibility of computational results is still an unsolved challenge



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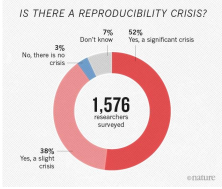

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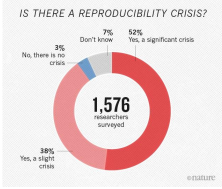

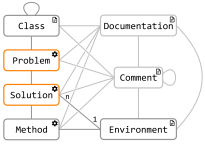

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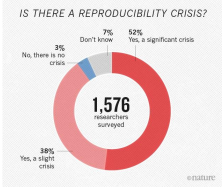

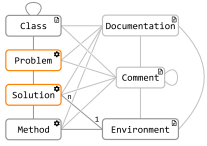

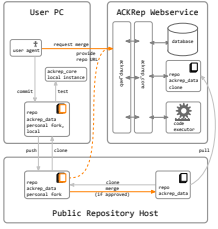

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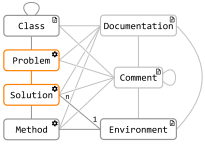

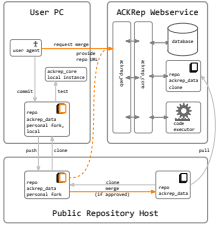

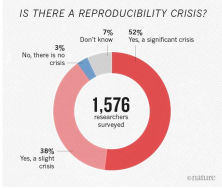

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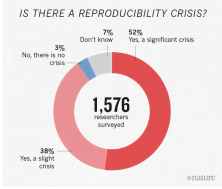

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- Incorporate feedback from potential users/contributors

→ https://testing.ackrep.org repository: https://github.com/cknoll/ackrep_data

→ Corresponding author: carsten.knoll@tu-dresden.de