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CHANGES

CULTURAL HERITAGE ACTIVE INNOVATION FOR NEXT-GEN SUSTAINABLE SOCIETY
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ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

Reproducibility: does one definition fit all?

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Reproducibility and Open Science

Considering that more open, transparent, collaborative and inclusive scientific practices is a more efficient enterprise that improves the quality, **reproducibility** and impact of science

Open science sets a new paradigm that integrates into the scientific enterprise practices for **reproducibility**, transparency, sharing and collaboration resulting from the increased opening of scientific contents, tools and processes

The following guiding principles for open science provide a framework for enabling conditions and practices within which the above values are upheld: transparency, scrutiny, critique and **reproducibility**

Promoting open science from the outset of the research process and extending the principles of openness in all stages of the scientific process to improve quality and **reproducibility**

UNESCO. (2021). UNESCO Recommendation on Open Science (Programme and Meeting Document SC-PCB-SPP/2021/OS/UROS; p. 36). <https://unesdoc.unesco.org/ark:/48223/pf0000379949>



What is reproducibility according to... Wikipedia

For the findings of a study to be reproducible means that **results** obtained by an experiment or an observational study or in a statistical analysis of a data set **should be achieved again** with a high degree of reliability when the study is replicated

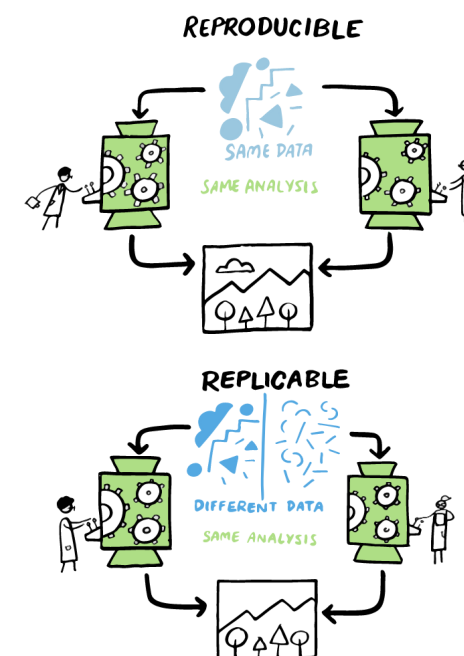
From <https://en.wikipedia.org/wiki/Reproducibility>, as of 16 April 2024



What is reproducibility according to... the European Commission

We consider reproducibility as a continuum based on three main research processes: reproduction, replication, and re-use

- **Reproduction:** the re-enactment of the **results** of a study by a third party, using the original set-up, data and methodology of analysis
- **Replication:** for more general re-enactment of the **results**, using the same analytical method, but on different datasets
- **Re-use:** for the more loose possibility to re-use the **results** beyond the original research context, both inside and outside the original scientific discipline



European Commission, Directorate General for Research and Innovation, Baker, L., Cristea, I. A., Errington, T. M., Jaško, K., Lusoli, W., MacCallum, C. J., Parry, V., Pérignon, C., Šimko, T., & Winchester, C. (2020). Reproducibility of scientific results in the EU: Scoping report (W. Lusoli, Ed.). Publications Office. <https://doi.org/10.2777/341654>



Why reproducibility is needed

Enabling reproducibility allows checking the soundness of analysis and it is one of the key factors (but not the only one) to **build trust**

Example

- Potti et al.'s article “Genomic signatures to guide the use of chemotherapeutics” published in Nature Medicine in 2006 (<https://doi.org/10.1038/nm1491>) – the authors claimed to have built an algorithm using genomic microarray data that predicted which cancer patients would respond to chemotherapy
- Keith Baggerly and Kevin Coombes (<https://doi.org/10.1214/09-AOAS291>) obtained the data and attempted to apply such an algorithm, and found that the **data analysis conducted in the original study contained several errors** that **invalidated the results** of the study

Peng, R. (2015). The reproducibility crisis in science: A statistical counterattack. *Significance*, 12(3), 30–32.
<https://doi.org/10.1111/j.1740-9713.2015.00827.x>



Is reproducibility the same in any discipline?

In contrast with natural sciences, humanistic research often involves **objects with meaning and value**: paintings, texts, statues, buildings, etc. However, the normative nature of these humanistic objects does not make reproduction and/or replication impossible, but we need to address them from the right angle.

Peels, R. (2019). Replicability and replication in the humanities. *Research Integrity and Peer Review*, 4(1), 2. <https://doi.org/10.1186/s41073-018-0060-4>

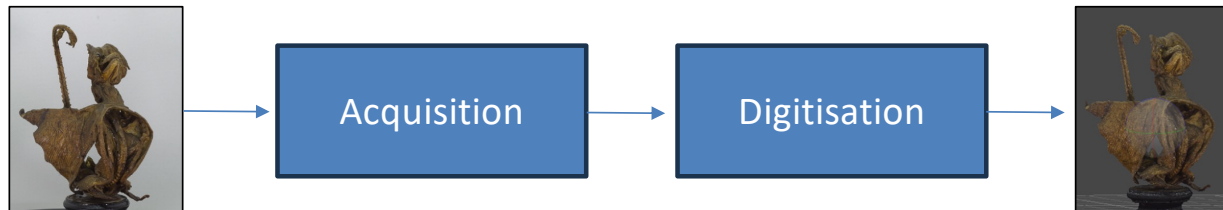
Inferential reproducibility emerges as a potential solution, a form of reproducibility that can yield qualitatively similar conclusions from either an independent replication of a study or a reanalysis of the original study. This means that scientists might draw the **same conclusions from different sets of studies and data**, or could draw **different conclusions from the same original data**, even if they agree on the analytical results.

Goodman, S. N., Fanelli, D., & Ioannidis, J. P. A. (2016). What does research reproducibility mean? *Science Translational Medicine*, 8(341). <https://doi.org/10.1126/scitranslmed.aaf5027>




An example in the Cultural Heritage domain

To obtain a digital version of the experience at the temporary exhibition (ended on May 28, 2023) "The Other Renaissance: Ulisse Aldrovandi and the wonders of the world", starting from its **digital twin**, organised and accessible online by users, using various devices (from home computers, smartphones, to tablets and VR headsets)




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Saving temporary exhibitions in virtual environments: The Digital Renaissance of Ulisse Aldrovandi – Acquisition and digitisation of cultural heritage objects

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ABSTRACT

As per the objectives of Project CHANGES, particularly its thematic sub-project on the use of virtual technologies for museums and art collections, our goal was to obtain a digital twin of the temporary exhibition on Ulisse Aldrovandi called "The Other Renaissance", and make it accessible to users online. After a preliminary study of the exhibition, focusing on acquisition constraints and related solutions, we proceeded with the digital twin creation by acquiring, processing, modelling, optimising, exporting, and metadating the exhibition. We made hybrid use of two acquisition techniques to create new digital cultural heritage objects and environments, and we used open technologies, formats, and protocols to make available the final digital product. Here, we describe the process of collecting and curating bibliographical exhibition (meta) data and the beginning of the digital twin creation to foster its findability, accessibility, interoperability, and reusability. The creation of the digital twin is currently ongoing.

1. Introduction

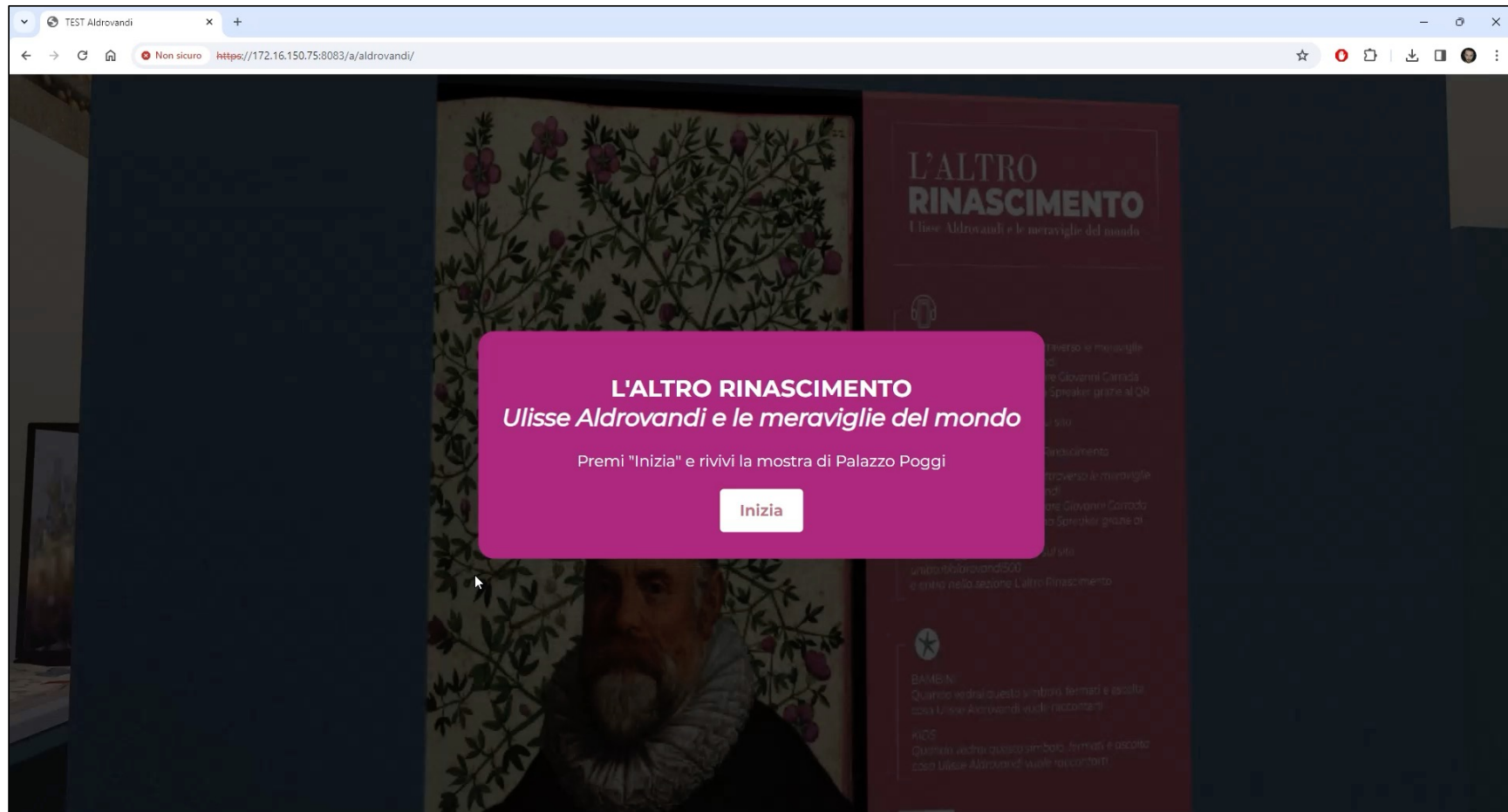
Several international policies support the focus on the universal use of digital data. Expressly, on Cultural Heritage (CH), both UNESCO and the EU have already provided clear guidelines for increasing the digitisation of heritage, considering aspects related to cataloguing systems as well as different ways for accessing cultural heritage objects and sites (e.g. *in situ* or decentralised). However, in the Italian context, expert users often perceive CH as composed of tangible and intangible artefacts. In particular, Italian legislation and established and shared practices focused primarily on using material objects. To comply with current European policies and guidelines on CH, we need to go beyond this configuration and make its digital enhancement a permanent and widespread practice in museums and art collections, aiming at (a) increasing the knowledge, curation and management of artefacts in all forms, (b) expanding the involvement of the general public and

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 2212-0568/© 2023 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY license (<http://creativecommons.org/licenses/by/4.0/>).

Balzani, R., *et al.* (2024). Saving temporary exhibitions in virtual environments: The Digital Renaissance of Ulisse Aldrovandi – Acquisition and digitisation of cultural heritage objects. *Digital Applications in Archaeology and Cultural Heritage*, 32, e00309.
<https://doi.org/10.1016/j.daach.2023.e00309>



A quick demo (video)



Is the digitisation process computationally reproducible?

CH digitisation aims to select specific elements of reality to store digitally

Such a selection process involves a **deliberate human choice** about the physical, geometric, chromatic, mechanical, and stylistic characteristics of the objects to digitise

- A digital technology survey is expected to approximate reality based on some predetermined features selected at the outset of the survey project
- The quantity and quality of the data obtained during the survey impact how accurate the digitisation will be
- The choice of the methodologies to adopt for digitisation is influenced by contextual factors (limited time, available space, etc.), objects' materials and size
- The documentation of the risks (limited object's mobility, etc.) and the solutions adopted (specific setup schemas, etc.)
- Additional documentation of processing decisions (made via software) should be a part of the scientific workflow and the (digital) cultural heritage preservation

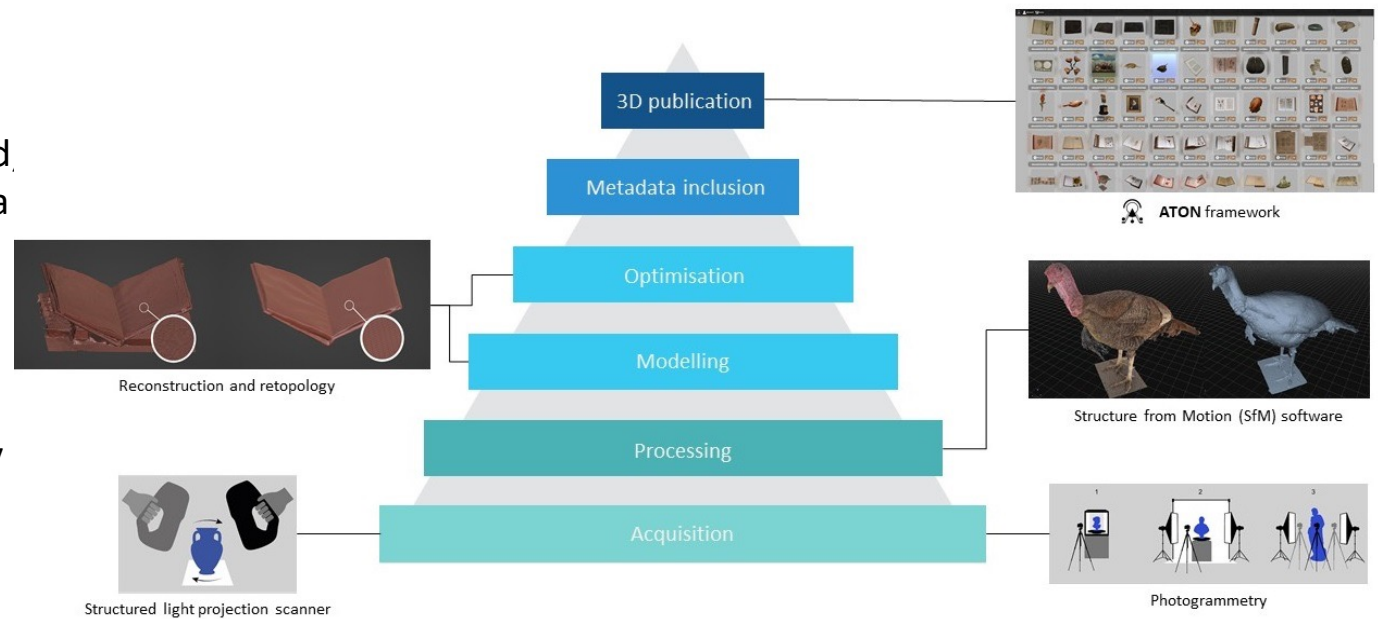


Guarantees and threats to reproducibility

Documenting all the **methodological choices and the steps of the process followed** for permitting others to retrace and repeat, at least in theory, the actions involved in a particular research effort, **producing new data**

There are issues with full computational reproducibility

- The temporary exhibition was, indeed, **temporary** – the original physical data used during the acquisition is not available anymore
- Need of specialised material for the acquisition and digitisation phases, including specific hardware (that may not be in production anymore) and software (old version used may not be maintained anymore)
- Environmental conditions may differ from those in place during the acquisition



Conclusions

We need to reach an agreement: research can be reproducible in **varying degrees**, from an “ideal” computational reproducibility to fields where **multiple interpretations** of a particular phenomenon coexist

When applicable, replication here may help to identify faulty reasoning or misguided interpretations, but it is not always possible to ascertain which interpretation is correct – indeed, the interpretation of a result and the way a study is conducted are **subjective dimensions** since they may depend on researchers’ different viewpoints, theoretical background, and previous assessments

The careful **documentation of our methodology** (study design, data collection, and analysis techniques) helps to reflect and make explicit all possible influencing factors, serving as **a fundamental tool for reliability and rigour** and for **opening research**

Barzaghi, S., Bordignon, A., Gualandi, B., & Peroni, S. (2024). Thinking Outside the Black Box: Insights from a Digital Exhibition in the Humanities. Atti Del XIII Convegno Annuale AIUCD. ME.TE. Digitali - Mediterraneo in Rete Tra Testi e Contesti. XIII Convegno Annuale AIUCD. ME.TE. Digitali - Mediterraneo in rete tra testi e contesti, Catania, Italy. <https://doi.org/10.48550/arxiv.2402.12000>



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