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Integrating the Digital Object Identifier Container (DOCiD) into the FDO Ecosystem

FAIR and CARE Indigenous Knowledge and Cultural Heritage through Integrating and Interconnecting Distributed Systems by Using FDOs

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Abstract. The preservation, accessibility and ethical care of African indigenous knowledge and cultural heritage require infrastructures. It is highly recommended, that these infrastructures comply with the FAIR principles (findable, accessible, interoperable and reusable) and the CARE principles (collective benefit, authority to control, responsibility and ethics), and follow the FAIR digital objects approach to enable data exchange across data spaces. We present the advancements made by the Africa PID Alliance, particularly with regard to DOCiD, over the past two years. Furthermore, we outline an integrative approach to connecting the DOCiD, DAMAP, and ORKG systems via FAIR Digital Objects (FDOs) within the Africa PID Alliance framework.

Keywords: FAIR Digital Objects, DOCiD, DAMAP, ORKG, CARE Principles, Indigenous Knowledge Systems (IKS)

1 Introduction

While the digital transformation of cultural heritage and research infrastructures has opened up new avenues, it has also given rise to ethical concerns, particularly with regard to Indigenous Knowledge Systems (IKS). [1] African cultural artefacts and knowledge are often scattered across fragmented digital silos with limited interoperability and provenance transparency. To counter this, the Africa PID Alliance [2] has launched DOCiD (Digital Object Identifier Container (DOCiD ecosystem) - a persistent identifier (PID) and management platform designed to provide robust digital object identifiers for African research outputs, cultural materials, and indigenous knowledge artefacts. This paper outlines the recent advancements of DOCiD and how integrating DOCiD, the machine-actionable DMP tool DAMAP [3] and the ORKG-ecosystem (Open Research Knowledge Graph) [4], [5], [6], [7] within an FDO-compliant framework can improve the FAIRness [8] and CARE-alignment [9] of digital heritage systems.

2 DOCiD: A Benchmark for African Persistent Identifiers

DOCiD serves as the technical and conceptual foundation of the Africa PID Alliance. Built on the Invenio repository platform and hosted by CORDRA, DOCiD supports integrations with Handles, ISNI, Ringgold, ARK Keys, RaID, CSTR, ROR, ORCID, DataCite, and Crossref, ensuring compatibility with globally recognised PID infrastructures [10] and PID-graph compatibility. The DOCiD key features include visible, clickable DOIs and local handles, which enable direct access to digital objects; cross-referencing and linking mechanisms for seamless navigation between related digital artefacts; API-integration with research data systems, repositories, and cultural heritage databases [11]. The DOCiD infrastructure has been shaped by extensive stakeholder engagement, with the aim of improving the user experience and enabling African researchers and heritage custodians to easily register, curate and link their digital objects [12].

3 Towards Global PID Interoperability and Indigenous Knowledge Visibility

The Africa PID Alliance's collaboration with CNRI, DataCite, Crossref, the DONA Foundation, and the DOI Foundation represents a vital step towards ensuring that African artefacts assigned with persistent identifiers can be discovered globally. By integrating these systems, the Africa PID Alliance increases the visibility and appreciation of indigenous patents, artefacts, and knowledge systems, enabling their recognition in the global scientific and cultural record. This approach ensures that African indigenous knowledge, which is often transmitted orally or contextually, is translated into digital representations that respect community governance and attribution ethics, while also ensuring interoperability across the research ecosystem.

Integrations

The DOCiD platform features extensive system integrations that enhance interoperability, data accuracy, and user convenience across the research and publication ecosystem. The system supports authentication through GitHub, Google, and ORCID, allowing users to securely access the system using their existing credentials. For publications and documents, DOCiD is integrated with DataCite, Crossref, and local APA Handle services to facilitate the automatic assignment of Persistent Identifiers (PIDs), while creators can link their works directly to their ORCID profiles. Integration with the Research Organization Registry (ROR) enables the system to automatically retrieve verified information about affiliated organizations and funders, ensuring standardized and authoritative metadata. For project-related records, DOCiD incorporates integration with the Research Activity Identifier (RAiD), allowing projects to be uniquely and persistently identified.

Translation of content to different languages

The DOCiD platform supports multi-lingual capabilities, enabling seamless translation and localization of content into more than five languages. This feature enhances global accessibility and inclusivity by ensuring that digital objects, metadata records, and related resources can be understood and utilized by diverse linguistic communities. Through the integration of language translation frameworks and standardized encoding protocols, DOCiD promotes interoperability and cultural adaptability across international research and data-sharing environments.

PID resolvability

Enhancing the interoperability and accessibility of Persistent Identifiers (PIDs) within the CORDRA environment, all PIDs generated through CORDRA are now fully resolvable. This

ensures that both document and publication object URLs now link directly to their respective digital objects.

Defining and refining parent-child object relations

Metadata records are now systematically stored alongside their respective parent-child identifiers within the CORDRA environment. Utilizing CORDRA's JSON object structure, DOCiD supports sub-objects and lists of sub-objects. These relationships ensure semantically robust representation of hierarchical relationships among digital objects

Metadata Schema

To enhance the discoverability and interoperability of research outputs across the African continent, the DOCiD has established a standardized metadata schema. This framework provides a structured model for describing a diverse range of research objects including datasets, software, and physical samples by associating them with Persistent Identifiers (PIDs). By defining a consistent set of core metadata elements, such as creator affiliations, funding information, and access rights, the schema facilitates the creation of a more integrated and machine actionable research infrastructure. Its adoption is pivotal for advancing the FAIR (Findable, Accessible, Interoperable, and Reusable) Guiding Principles within the African research ecosystem, thereby promoting greater data sharing, collaboration, and the overall visibility of scholarly contributions from the region.

Throughout 2025, the Africa PID Alliance, has conducted a series of capacity-building trainings across partner institutions, including the University of Botswana, Rhodes University, National Museum of Burkina Faso, Joseph Ki-zerbo University, Stellenbosch University, National Museums of Kenya, North-West University, National Museum of Lagos, National Museum of Namibia, Uganda community Museums, The cross cultural foundation, Kigulu Cultural museum, Bugungu Heritage and information Centre, and Africa Digital Heritage among others. The training focused on introducing and integrating the Digital Object Container Identifier (DOCiD) system to support African-led research visibility, data sovereignty, and the preservation of indigenous knowledge and cultural heritage. The primary objectives were to strengthen institutional understanding of DOCiD, improve data management practices, and align repositories with global open science infrastructure. The overarching goal was to enable institutions to independently implement DOCiD in their repositories and cultural archives, ensuring long-term traceability and recognition of African-generated knowledge. Post-training, participating institutions are expected to finalize integration workplans, work with our technical team and institution's technical teams to support ongoing adoption, and actively contribute to the broader African PID ecosystem for sustainable digital infrastructure development

4 Ensuring FDO Compliance

Significant progress has been made towards making DOCiD FDO-compliant. This involves embedding structured metadata, machine-actionable links and persistent identifiers that conform to FDO specifications. The next development phase will focus on creating user-friendly entry points and data ports with a low technical threshold. This will address a major barrier for researchers who are unfamiliar with PID and FDO-systems. Prioritising accessibility, usability and user interface design will encourage wider adoption among cultural heritage institutions, community archives and museum networks across Africa.

5 Integrating DOCiD, DAMAP and ORKG: A Distributed Joint Infrastructure

The next strategic phase involves taking a joint infrastructure approach to connect DOCiD with DAMAP and ORKG (both already fully FDO-compliant). Each system plays a distinct but complementary role.

- DOCiD is the foundation of the PID and metadata management layer.
- DAMAP provides machine-actionable data management planning and workflow automation.
- The ORKG ecosystem offers semantic structuring and machine-actionable research narratives.

These systems work together to create an interoperable, distributed infrastructure for African research and heritage data, facilitating connections between physical artefacts, research outputs and indigenous knowledge.

Future directions and Science Cluster integration

As the Africa PID Alliance progresses, the above mentioned distributed joint infrastructure envisions integration into science cluster platforms e.g., SSHOC Heritage Studies [13] to enhance interoperability within regional and international research ecosystems. Key priorities include: Developing training modules and community workshops for cultural heritage professionals; establishing metadata interoperability frameworks aligned with both FAIR and CARE; Implementing machine-actionable workflows that link Indigenous knowledge representations to global research outputs. These efforts will provide African heritage institutions with a sustainable pathway to engage with and help shape global digital research infrastructures.

6 Conclusion and Outlook

By interconnecting DOCiD, DAMAP and ORKG within the FAIR Digital Objects ecosystem and providing user-friendly services to communities with partly rudimentary RDM skills, the Africa PID Alliance is setting a precedent for inclusive, ethical and interoperable digital knowledge infrastructures. FDO integration therefore ensures that African indigenous knowledge is represented in a technically robust and culturally respectful manner. This approach bridges the gap between FAIR data science and CARE-driven cultural heritage conservation.

Data availability statement

Not applicable.

Underlying and related material

Not applicable.

Author contributions

Conceptualization (JO, CB, DB, NK, TM); Data curation (N/A); Formal Analysis (N/A); Funding acquisition (N/A); Investigation (N/A); Methodology (N/A); Project administration (N/A); Resources (N/A); Software (N/A); Supervision (N/A); Validation (N/A); Visualization (N/A); Writing – original draft (JO, CB, DB, NK, TM); Writing – review & editing (JO, CB, DB, NK, TM).

Competing interests

The authors declare that they have no competing interests.

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