ATLAS: A data model for describing FAIR Digital Humanities research outcomes

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ABSTRACT (ENGLISH)
This paper addresses the challenges of cataloguing and representing Digital Humanities (DH) research outputs within the framework of FAIR principles. Despite advancements in Semantic Web technologies and data aggregators, the scholarly community still lacks unified frameworks and domain-specific models to describe heterogeneous outputs such as digital editions, textual collections, and other scholarly resources published as Linked Open Data. The ATLAS project proposes an ontology and a knowledge graph to bridge these gaps. The methodology includes metadata modeling based on existing frameworks and novel extensions, supported by pilot studies on the Italian cultural heritage. The project, currently in its initial version, aims to enhance metadata interoperability and data accessibility, contributing to the optimization of cataloguing practices and the development of guidelines for the discovery and reuse of DH resources while providing a model applicable beyond the Italian context.
Keywords: metadata modeling; research infrastructure; scholarly outcome; linked open data; FAIR principles

ABSTRACT (ITALIANO)
ATLAS: un modello di dati per descrivere i risultati della ricerca nelle Digital Humanities secondo i principi FAIR. L'articolo discute le sfide poste dalla catalogazione e rappresentazione degli output di ricerca nel campo delle Digital Humanities (DH) in conformità ai principi FAIR. Nonostante i progressi nelle tecnologie del Web Semantico e nei sistemi di aggregazione dei dati, la comunità accademica continua a mancare di framework unificati e modelli specifici per descrivere output eterogenei come edizioni digitali, collezioni testuali e altre risorse scientifiche pubblicate come Linked Open Data. Il progetto ATLAS propone un'ontologia e un knowledge graph per colmare queste lacune. La metodologia integra modellazione dei metadati basata su framework esistenti ed estensioni innovative, supportata da studi pilota sul patrimonio culturale italiano. Il progetto, che al momento si presenta nella sua prima versione, punta a migliorare l'interoperabilità dei metadati e l'accessibilità dei dati, contribuendo a ottimizzare le pratiche di catalogazione e a sviluppare linee guida per la scoperta e il riutilizzo delle risorse DH offrendo un modello applicabile oltre il contesto italiano.
Parole chiave: modellazione di metadati; infrastruttura di ricerca; prodotto scientifico; linked open data; principi FAIR

1. INTRODUCTION[1]

The increasing adoption of World Wide Web technologies in Humanities research has, in recent years, profoundly influenced the way scholarly research is performed, particularly within the field of Digital Humanities (DH) (Tomasi, 2022). Such advancements have created new opportunities for preserving,

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sharing, and reusing research outputs, enabling unprecedented levels of collaboration and dissemination. However, the rapid increase of available scholarly data highlights the critical need for standardized models and guidelines to effectively manage, aggregate, and explore this wealth of meta-information.

In the scholarly landscape, several platforms play a pivotal role in ensuring the persistent identification, preservation, and enhanced accessibility of research data (PARTHENOS et al., 2018). Examples of key initiatives include Zenodo, OpenAIRE (Baglioni et al. 2019), and Research Infrastructures (RIs) such as CLARIN and DARIAH. Zenodo serves as a repository for documents and various research materials, while OpenAIRE offers a comprehensive range of services, including dedicated web portals for specific communities, such as the Digital Humanities and Cultural Heritage Gateway. In contrast, RIs combine both the storage of documents and research materials with the capability to access services that utilize and generate these resources. These initiatives pave the way for enhancing the sharing of research outcomes and promoting the advancement of open science practices.

Likewise, various catalogues document research in the field of DH, encompassing digital scholarly editions and projects from both national[2] and international[3] associations and research centers. However, there is still an absence of comprehensive catalogues dedicated specifically to DH projects concerning Italian Cultural Heritage, as well as a lack of structured collections for DH research outputs employing Semantic Web technologies (Tomasi, 2013).

The ATLAS[4] project aims to create a knowledge graph of DH research related to Italian Digital Cultural Heritage. By introducing the ATLAS Ontology and its knowledge graph, the project aims to create a semantic framework capable of representing the varied outputs of DH research, also beyond the Italian borders. ATLAS tackles the challenges of describing and interlinking scholarly data—including the raw text to perform full text analysis which is of primary importance for—ensuring enriched and accessible metadata to enhance both discoverability and reusability of these cultural assets. By thoroughly analyzing and mapping existing models and vocabularies, as well as surveying representative projects in the Italian DH landscape, the project introduces a reliable strategy for incorporating Italian DH resources into the global knowledge ecosystem, thereby promoting enhanced interdisciplinary collaboration and resource discovery across institutions.

2. STATE OF THE ART

In Italy, considerable advancements have been made in the digitization and aggregation of cultural heritage using Linked Open Data (LOD) collections. Prominent examples include the *dati.culturaitalia* (Di Giorgio, 2015) platform developed by the Italian Ministry of Culture and the ArCO project (Carriero et al., 2019), which has built a Knowledge Graph derived from the General Catalog of Italian Cultural Heritage. These initiatives are in line with European digitization projects such as ARIADNE (Meghini et al. 2017) and Europeana (Di Giorgio, 2016). Although these programs offer interoperable Linked Open Data, a gap still remains in 1) the construction of a catalogue of DH projects leveraging Italian Cultural Heritage, and 2) a research framework to support best practices and the enhancement of the discoverability and reusability of Italian heritage-related DH data (Carriero et al., 2019).

Existing ontologies and models fail to adequately capture the complexities of the contemporary Digital Humanities landscape. Most models address a limited range of research products types, mostly focusing on articles and publications. OpenAIRE's data model, for example, includes four categories of research products: publication, data, software and other. DH projects generate a wide range of outputs (e.g., textual archives, digital scholarly editions, digital collections, etc.), each requiring tailored descriptive strategies. Key factors, such as textual typologies and editorial criteria, are not sufficiently addressed. Moreover, current models lack effective mechanisms for linking research activities to their related Cultural Heritage objects, despite the potential provided by Linked Open Data (Daquino et al., 2024b).

3. RESEARCH QUESTIONS AND METHODOLOGY

Considering the current landscape of research product catalogues, we assessed strategies for the optimisation of cataloguing practices for DH projects based on the Italian digital cultural heritage. Our research focused on three key questions: What types of research products exist? How can we represent

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different types of research products in a way that highlights their distinctive features? Which metadata should we employ to ensure long-term preservation and improve the findability of research products?

In the first phase, we identified pilot research products related to Italian cultural heritage or developed by Italian scholars to determine the most suitable metadata for the catalogue. These pilots were selected as key references in the Italian DH landscape and span five categories, namely:

1. Text collections: ALIM (Archive of the Italian Latinity of the Middle Ages, D'Angelo & Monella, 2019); Biblioteca Italiana (Quondam, 2021); BUP - Digital Humanities (Amendola, 2021); Musisque Deoque (Venuti et al., 2023).
2. Digital Scholarly Editions: VaSto (VArchi STOria fiorentina, Brancato et al., 2021); Codice Pelavicino Digitale (Salvatori et al., 2017); Leges Langobardorum (Buzzoni & Del Turco, 2015); Digital Edition of Aldo Moro's works (Moro, 2021).
3. Linked Open Data: Zeri & LODE (Daquino et al., 2017); DanteSources (Bartalesi et al., 2015); LiLa - Linking Latin (Passarotti, 2022); Biflow - Toscana Bilingue Catalogue (Montefusco & Mancinelli, 2020).
4. Ontologies: CIDOC-CRM; SPAR (Peroni & Shotton, 2018); HiCO (Daquino & Tomasi, 2015).
5. Software tools: EVT (Edition Visualisation Technology, Del Turco et al., 2019); Voyant Tools (Sinclair & Rockwell, 2015).

For each pilot, at least one ATLAS project member was directly involved in its creation, ensuring complete and accurate information about the pilots' current state and development process.

Our analysis of the pilot research products yielded several key findings. First, we identified both common and category-specific metadata for use in the catalogue. Second, we uncovered critical issues affecting data usability and long-term preservation. Common issues across research products included: lack of data storage in "trustworthy repositories" (PARTHENOS et al., 2018) such as Zenodo, unclear dataset access points and methods, missing information about dataset status (e.g., completed, under development), unavailable data models and references to existing standards, and insufficient documentation about usage, applied methodologies, and used technologies.

Based on the identified issues and on existing guidelines for data FAIRness (Wilkinson et al., 2016; PARTHENOS et al., 2018), we developed a set of recommendations and best practices specific to each research product type.[5]

We then refined the identified metadata fields through mapping (Daquino et al., 2024a) with major existing models for describing research products, specifically: RO-Crate,[6] KNOT,[7] OpenAIRE Graph,[8] OpenAIRE Application Profile,[9] SKG-IF,[10] IRIS.[11] To translate the metadata into RDF properties, we primarily used Schema.org.[12]

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[5] Recommendations and best practices are available in the ATLAS whitebook: https://doi.org/10.5281/zenodo.14925266.

[6] RO-Crate (Research Object Crate) is a method of aggregating and describing research data with associated metadata expressed through JSON-LD using linked data. https://w3id.org/ro/crate/1.1.

[7] KNOT Ontology (KNOT-O) describes digital scholarly activity and objects as examples of the digital cultural heritage of Italian universities. http://purl.org/knot/ontology.

[8] OpenAIRE Graph is one of the largest open scholarly record collections worldwide, key in fostering Open Science and establishing its practices in the daily research activities. https://graph.openaire.eu/docs/.

[9] OpenAIRE Application Profile describes how OpenAIRE enforces specific encoding schemes for the values of some DataCite properties. https://guidelines.openaire.eu/en/latest/data/application_profile.html.

[10] SKG-IF (Scientific Knowledge Graphs Interoperability Framework) enables the exchange of data about six core entities and their relationships (Research product, Agent, Grant, Venue, Topic, Data source). https://skg-if.github.io/.

[11] IRIS (Institutional Research Information System) is a Java-based platform for managing and enhancing research outputs adopted by numerous Italian universities (Bollini et al., 2016).

[12] Schema.org describes a data model to create, maintain, and promote schemas for structured data on the Internet. https://schema.org/docs/datamodel.html.

These initial phases produced two main outcomes: a data model formalized as an OWL 2 DL ontology, i.e., the ATLAS ontology (Tomasi et al., 2024), and the first version of the knowledge graph[13] (Daquino et al., 2024a), accessible online through an extended version of the CLEF[14] software (Daquino et al., 2023). In the data model (Figure 1), research products are modeled as `schema:Dataset`. Different types of research products are implemented as subclasses of `schema:Dataset` and aligned with subclasses of `frbr:Expression` from the FaBiO ontology—for example, `fabio:ComputerProgram` for software tools. Each research product can be linked to a research project, represented by the class `schema:ResearchProject`, along with representations of people, organizations, websites, and computer programs.
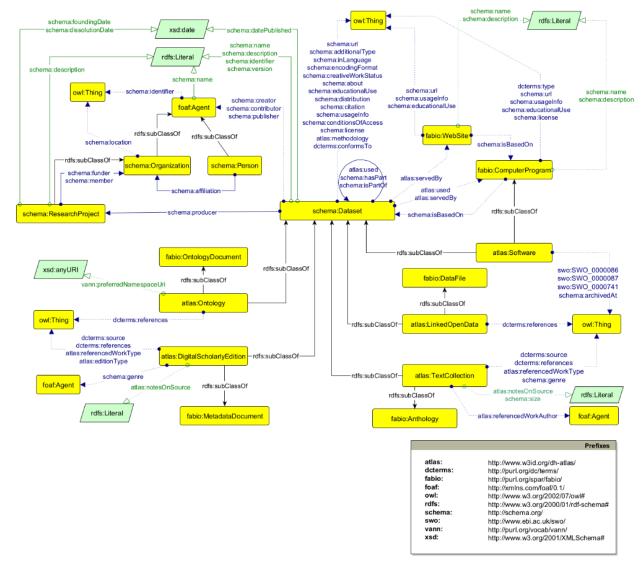

Figure 1. A visual diagram of the ATLAS ontology

The web application of ATLAS serves as a testing and evaluation platform for the ontology through an application-based validation approach. The graph currently contains the select group of research products mentioned above, together with their associated research projects, websites, people, and organizations.

4. METADATA ANALYSIS
Traditional catalogues present textual archives and (digital) scholarly editions primarily through content-focused editorial information—which remains essential and is included in our model. A novel aspect of the

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ATLAS modeling approach is that it describes digital scholarly editions and text collections primarily as datasets, while also emphasizing features and methodologies specific to the "digital paradigm" (Sahle, 2016) that distinguish these research products from their corresponding print-oriented versions.

Some metadata selected for describing research products are basic and common across most existing models. The mandatory metadata in our model include: *title* (`schema:name`), *description* (`schema:description`), *creator* (`schema:creator`), *publisher* (`schema:publisher`), *release date* (`schema:datePublished`), *landing page* (`schema:url`), *access rights* (`schema:conditionsOfAccess`), and *license* (`schema:license`). We have added two additional mandatory properties: *type* (`schema:additionalType`) to specify the research product type, and *research activities* (`schema:educationalUse`), which uses TaDiRAH vocabulary terms (Borek et al, 2020) to describe the activities enabled by the research product, such as analysis, visualization, and modeling.

Our model introduces several new properties compared to the existing models mentioned above. These include "research activities," *status* (`schema:creativeWorkStatus`) which describes the research product's current lifecycle state, and *documentation* (`schema:usageInfo`) containing the URL to the output's documentation. While many existing models include data encoding format—represented in our model as *format* (`schema:encodingFormat`)—we have added *metadata standards* (`dcterms:conformsTo`) to indicate the models and standards used for metadata modeling. The *access point* property (`atlas:servedBy`) complements the "landing page" concept by specifically presenting web addresses for dataset access, distinct from the presentation pages. We have also added *academic field* (`schema:about`) to indicate disciplinary areas, and *methodology* (`atlas:methodology`) alongside *software reuse* (`atlas:used`) to describe development processes, including specific activities and tools used.

For research products containing sub-products, such as collections within a digital archive, collections can be described separately as independent text collections and linked to the main output using the `has part` property and its inverse `is part of`.

While mandatory properties ensure basic identification and usage information, optional properties highlight specific information for research product reuse that is typically hard to find or absent in the products' documentation.

Each research product type provides additional specific metadata beyond the properties common across different types. For text collections and digital scholarly editions we have included traditional cataloguing metadata to describe content: *work* (`dcterms:source`), *author* (`atlas:referencedAuthor`), and *genre* (`schema:genre`). Beyond these "work" level properties (IFLA's Library Reference Model, Riva et al., 2020), we have added properties describing "Items" or "Manifestations"—the documents, attestations, and witnesses used by editors: *reference to the edited text* (`dcterms:references`), and *bibliographic reference of edited text*. This enables future catalogue users to filter search results to view different editions of the same textual resource. We have also created properties to specify the type of digital scholarly editions (`atlas:editionType`). Since no comprehensive vocabularies existed for edition types, we developed new values based on the *Parvum Lexicon Stemmatologicum* (Roelli & Macé, 2015) and the *Lexicon of Scholarly Editing* (Dillen, 2020). It is possible to indicate the quantity of individual texts or tokens (`schema:size`) for text collections.

To showcase model and standard reuse within the ATLAS catalogue, ontologies and linked open data can use `schema:references` to specify imported models and RDF ontologies used in data modeling. Ontologies can also indicate their *namespaces* (`vann:preferredNamespacePrefix`, Davis, 2005).

Software tools can be catalogued both as research products and as components of other research products' development and access methods. The *based on* property (`schema:isBasedOn`) specifies libraries, extensions, and components used in development. To facilitate workflow creation across tools, we include properties for *input* and *output formats* (`swo:hasSpecifiedDataInput` and `swo:hasSpecifiedDataOutput`, Lister et al., 2023). We have also added a code repository *URL* property (`schema:archivedAt`) to encourage code reuse.

5. NEXT STEPS AND FINAL REMARKS

The ATLAS ontology leverages and builds upon established models for describing digital cultural heritage, providing a comprehensive framework with carefully selected terminology and granular detail levels. This approach enables precise descriptions of the diverse and unique characteristics found across different types of research outputs within the Digital Humanities field. Additionally, the ontology facilitates detailed analysis of the methodologies employed in creating these research outputs, offering valuable insights into the research process itself.

The initial version of the ontology and the platform were recently tested through a datathon[15] during the ATLAS Workshop.[16] A group of scholars, researchers, and PhD students participated in the cataloguing process, providing valuable feedback and insights. Each participant catalogued a Research Product from international scholarly research on Italian Digital Cultural Heritage. This phase served the dual purpose of populating the database and evaluating the ATLAS platform's usability. The datathon successfully added 60 new records to the knowledge graph.

The ontology needs additional refinement in key areas to ensure its comprehensiveness, namely, 1) expanding the research product categories to address the variety of data sources, 2) enhancing the ATLAS controlled vocabularies to address identified gaps in the current state of the art, and 3) representing extracted data—such as people, places, and organizations—from source files to enable full-text searches. Once the model is consolidated we plan to test the ontology and expand the knowledge graph by including additional research projects and their diverse outputs, thus enriching the ontology in a bottom-up approach. A second datathon will help us to validate the model's final version.

To ensure long-term accessibility and preservation, the model, alongside regular snapshots of the knowledge graph and of the web application, will be deposited in the CLARIN national repository hosted at ILC-CNR. Furthermore, the knowledge graph will be integrated into the OpenAIRE Research Graph and, therefore into the European Open Science Cloud.

The model outlined above will therefore prove effective in representing not only the Italian Cultural Heritage but also research outcomes in the global Digital Humanities landscape.

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[15] A datathon is a data science or data-centric hackathon, i.e., an event where participants work together intensively on data-related tasks.

[16] https://dh-atlas.github.io/workshop.html.

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