



Making Uncertainty Explicit: The Preservation of Interpretive Complexity across Digital Humanities Project Workflows

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ABSTRACT (ENGLISH)

This contribution examines how the interpretive nature of humanities knowledge manifests and propagates through workflows in Digital Humanities projects. Focusing on three critical phases—data acquisition, knowledge representation, and web-based dissemination—we analyse selected case studies to reveal how interpretive phenomena are preserved, negotiated, simplified, or omitted at each stage. Our analysis reveals a systematic gap between the rich knowledge preserved in data models and that communicated through dissemination interfaces, where the rhetorical appeal of an "aesthetics of certainty" often overrides scholarly transparency.

Keywords: uncertainty; semantic web; data acquisition; knowledge representation; web-based dissemination

ABSTRACT (ITALIANO)

Esplicitare l'incertezza: la preservazione della complessità interpretativa nei flussi di lavoro dei progetti di Digital Humanities. Questo contributo analizza come la natura interpretativa della conoscenza umanistica si manifesti e si propaghi nel corso dello sviluppo di progetti di Digital Humanities. Concentrandoci su tre fasi critiche, ovvero la creazione dei dati, la rappresentazione della conoscenza e la disseminazione sul web, esaminiamo come i fenomeni interpretativi vengano preservati, negoziati, semplificati od omessi in una selezione di casi di studio. L'analisi mette in luce un divario tra la ricchezza di conoscenza preservata durante la modellazione dei dati e quella comunicata attraverso le interfacce di disseminazione, dove l'attrattiva retorica di un'"estetica della certezza" tende spesso a prevalere sulla trasparenza scientifica.

Parole chiave: incertezza; web semantico; acquisizione dei dati; rappresentazione della conoscenza; disseminazione web.

1. INTRODUCTION

Humanistic knowledge is often partial, evolving, or shaped by subjective perspectives. These conditions give rise to epistemic uncertainties—defined as the lack of definitive scholarly knowledge—that stand in contrast to the purely stochastic or algorithmic uncertainty of computational processes (Therón Sánchez et al., 2019). Consequently, imprecision, disagreement, credibility issues, ignorance, and data incompleteness introduce uncertainty into Digital Humanities (DH) projects at multiple stages. Depending on design decisions, uncertainty may be reduced, ignored, propagated, or even amplified (Therón Sánchez et al., 2019; Windhager, Salisu, & Mayr, 2019; Windhager, Salisu, Schreder, et al., 2019; Panagiotidou et al., 2022; Conroy et al., 2024; Windhager et al., 2024).

From the moment data are created, each stage of a DH workflow involves acts of interpretation—such as processes of selection, division, and classification—that embed particular perspectives and negotiate ambiguities, conflicts, and contradictions (Drucker, 2011; Drucker, 2014; Gitelman, 2013; D'Ignazio and Klein, 2020; Piotrowski, 2023). Modelling and communicating uncertainty have been shown to support users' trust and perceived transparency among expert users (Fisher et al., 2012; Windhager, Salisu, Schreder, et al., 2019), since this ensures methodological reliability by explicitly acknowledging the adopted perspective (Berg et al., 2018).

This contribution starts from the assumption that uncertainty is fundamental to the humanities and should therefore be treated as an asset (Piotrowski, 2023), requiring the design of appropriate

methodologies to preserve it throughout the data acquisition, knowledge representation, and dissemination phases of a DH project workflow. Despite growing theoretical recognition, the preservation of epistemic uncertainty and interpretive phenomena is often insufficiently addressed in DH practice, both in modelling and in dissemination outcomes (Barabucci et al., 2021; Battisti and Daquino, 2025a). In this contribution, we present a selection of research projects that explicitly acknowledge uncertainty as an integral component of their DH workflows, in order to extract design policies and methods that drive the phases of data acquisition, knowledge representation, and web-based dissemination. The projects exemplify different research domains on heterogeneous cultural objects and historical periods and are used to analyse how uncertainty emerges, is propagated, and is managed across the DH workflow.

2. BACKGROUND AND STATE OF THE ART

Barabucci et al. identify several recurring problems affecting the way cultural-heritage metadata are originally created, namely: **reticence**, the omission of well-known information due to haste, limited skills, or inadequate policies and tools; **flattening**, where complex, multi-layered entities are collapsed into a single, inconsistent record; **coercion**, the forcing of information into unsuitable fields when no appropriate schema elements exist; and **dumping**, where important details are relegated to free-text descriptions, making them inaccessible to computational processing (Barabucci et al., 2021). Moreover, varying reliability, inherent subjectivity, and varying degrees of confidence in scholars' claims are well-known limitations that need to be harmonised, normalised, or resolved when devising a structured dataset (e.g., a knowledge graph). Over the years, Cultural Heritage (CH) domain standards have addressed this multifaceted issue with different modelling approaches, such as the introduction of n-ary relations (e.g., the attribute assignment construct) in CIDOC CRM for museum heritage (Doerr et al., 2007), or through the definition of specific ontology extensions (e.g., CRM-inf is the CIDOC CRM Argumentation Model that formalises scholars' inferences and observations as first-class entities, distinguishing between the historical event or entity and the interpretive act that asserts its existence or properties (Doerr et al., 2023)), or by defining explicitly uncertain properties such as in RiC-O (e.g., rico:relationCertainty) (Clavaud & Wildi, 2021).

Alongside domain-specific ontologies, the Semantic Web community recognises the limitations of encoding statements as objective, universal truths, and proposes a range of ontology-independent solutions for representing assertions and their provenance in RDF. These approaches enrich RDF statements with meta-assertions—such as authorship or source—while avoiding the proliferation of specialised vocabularies. Proposed solutions include standard RDF reification, singleton properties, Named Graphs and models for organising them, alternative serialisations such as Notation3, and extensions to the graph model, including RDF-star and Conjectures (Daquino et al., 2022; Barabucci et al., 2021). In practice, large-scale collaborative platforms such as Wikidata—where disagreement, uncertainty, vagueness, and subjectivity occur across many scenarios—adopt mixed approaches combining ontology-dependent and independent solutions. Despite such modelling efforts, empirical studies show that annotators use uncertainty-related representation patterns sparingly (less than 1% of annotations on CH data in Wikidata) (Di Pasquale et al., 2024), which reveals a tendency to oversimplify the interpretive nature of humanistic knowledge for the sake of dissemination.

While interfaces for experts tend to be more inquiry-oriented, interfaces for casual users usually provide more engagement-oriented experiences that do not retain complex, potentially misleading, scholarly argumentations (Windhager, Salisu, Schreder, et al., 2019). However, interfaces shape the ways CH is perceived and interpreted by different users and communities (Dörk et al., 2011; Whitelaw, 2015; Windhager, Federico, et al., 2019; Drucker, 2013) which too often prioritise task efficiency within a “user-as-customer” paradigm rather than fostering interpretive engagement, thereby giving the illusion of certainty, completeness, and singularity of meaning (Drucker, 2013). Generous interfaces were proposed to challenge this paradigm, foregrounding exploration, interpretation, and sense-making as central activities, aligning with the epistemic characteristics of humanistic enquiry (Whitelaw, 2015). Relatedly, making the evidential status of represented information explicit—distinguishing evidence, hypotheses, and degrees of probability—is key for CH visualisations, aligning them with research practices and supporting proper user interpretation and evaluation (Denard, 2016). Such an approach can be observed, for instance, in domain-specific implementations, as in the case of bookbinding and codicological modelling (Campagnolo, 2015; Porter & Campagnolo, 2021), where structured descriptions

are transformed into uncertainty-aware diagrammatic representations recognising the complexity of humanities scholarly discourse.

In this sense, these practices resonate with broader perspectives in information visualisation and storytelling, which are argued to enhance the communication of complex information by offering an additional interpretive layer and producing memorable and engaging experiences (Gershon & Page, 2001; Kosara & Mackinlay, 2013; Shan et al., 2022; Renda et al., 2023), while promoting slower and more reflective experiences (Hinrichs et al., 2016; Elli et al., 2021)—for example, showing complexities on-demand to interested users only (Windhager, Salisu, & Mayr, 2019) was proposed to overcome the risk of cognitive overload for non-expert users due to the introduction of interpretive complexity in visualisation (Mayr et al., 2016; Windhager et al., 2018; Windhager, Salisu, Schreder, et al., 2019).

It has been argued that the scarcity of solutions and standard ways to visually communicate uncertainty with existing visualisation tools (Khulusi et al., 2020; Panagiotidou et al., 2022), and the lack of visualisation expertise, could be the reasons hindering the adoption of more critical approaches to present the interpretive nature of humanities data (Ma & Xiao, 2021). Indeed, surveys on web-based DH visualisation projects revealed that visualisation and narrative strategies often rely on generic, rarely customised, off-the-shelf solutions that oversimplify information rather than revealing its inherent complexity (Battisti & Daquino, 2025b).

While individual stages of the DH workflow (acquisition, representation and dissemination) have been studied in isolation, there is a notable lack of research tracking the continuity and propagation of uncertainty across the entire pipeline. With this work, we address this gap by analysing how uncertainty is negotiated at each stage in selected case studies, examining if and how dissemination interfaces maintain the interpretive awareness established during the data creation and representation phases.

3. CASE STUDIES

Inspired by existing conceptual frameworks that examine uncertainty propagation in humanities contexts (Therón Sánchez et al., 2019; Panagiotidou et al., 2022; Haghigatkah et al., 2022), we distinguish three key phases that characterise typical DH project structures, namely **data acquisition**, **knowledge representation**, and **web-based dissemination**. The selected cases are examples of a broader landscape rather than an attempt to create a complete survey. In fact, it is a collection of projects reflecting the evolution of the research line at hand within the Digital Humanities Advanced Research Centre (DH.arc) of the University of Bologna over the past decade. They are presented in chronological order and share epistemic uncertainty as their foundational concern across the three aforementioned phases, yet vary in their application domains (e.g., art history, digital philology) and dissemination formats (e.g., catalogues, digital editions, and data analysis projects). Selection criteria include the following aspects: 1) original data are extracted from authoritative although subjective sources (e.g. literary works, institutional catalogues), 2) data are transformed into RDF according to one or more strategies that try to preserve the interpretive nature of original data (whether this limits to preserve subjectivity or expands on other features like ambiguity, uncertainty, and disagreement), and 3) the final graph is disseminated via web interfaces for heterogeneous audiences, hence adopting diverse solutions to mitigate the complexity of data.

The "Paolo Bufalini's Notebook" digital edition¹ uses Linked Open Data (LOD) technologies to enhance a semantic scholarly edition of the notebook, in which the author collates quotations, translations and comments (his or others') which implicitly debate about the influence among literary authors (Daquino et al., 2019). Data acquisition included manual transcription, identification and disambiguation of over 250 literary quotations and their sources, and the textual encoding using XML/TEI. Knowledge representation uses the Nanopublication meta-model to explicitly represent the interpretive nature of Bufalini's assertions, specifying provenance (e.g. whether an assertion belongs to Bufalini or to a quoted author) and reusing the HiCo and CiTo ontologies (e.g., source texts, interpretive criteria). The web application shows the interpretive layers underlying the transcription and encoding phases in the form of facets, which allow users to retrieve all the occurrences of a person or work recognised in the text (even when implicit), and in the facsimile, where annotations appear on hover, revealing the (implicit) sources of a quotation. However, all information is presented as factual statements, while the subjectivity and the degree of certainty (which is not modelled) remain implicit.

¹ <https://projects.dharc.unibo.it/bufalini-notebook/>.

mythLOD² is a digital collection that semantically links museum objects depicting classical mythology subjects to the literary sources sharing common themes (Pasqual & Tomasi, 2022). Uncertainty arises from subjective interpretive acts and is explicitly modelled using the Digital Hermeneutics approach (Daquino et al., 2020), including FRBRoo as the backbone ontology, Nanopublications to preserve the provenance of individual scholarly assertions, and PROV-O and HiCo to contextualise the hermeneutic information. The platform provides a browsable catalogue with colour-coded tags and filters to visually distinguish (questionable) scholarly claims from factual data. A storytelling section with interactive visualisations conveys quantitative aspects. However, visual components are off-the-shelf data visualisations that, *per se*, cannot fully differentiate between asserted interpretations and established facts, therefore proposing a simplified view on the data.

The Iconology dataset³ is a Linked dataset that contains a selection of iconological interpretations over modern and Middle Ages artworks, manually extracted from Erwin Panofsky's works. Iconographic and iconological attributions are formally represented using the ICON ontology (Sartini et al., 2023) and n-ary relations as a reification method to represent meaning, subjects, and interpretive acts. Notably, the ontology allows to represent claims according to Panofsky's three levels of interpretation (visual recognition, iconographic interpretation and iconological interpretation). The ICON dataset supports interdisciplinary research into how meaning and interpretation are constructed and analysed within art history. The dissemination platform is intended to support data analysis tasks by combining project documentation, exploratory data analysis, visualisations, and an artwork gallery. Visualisations enable quantitative analysis of uncertainty-related features—such as the frequency of author's interpretation types or levels—treating interpretation and subjectivity as first-class citizens. The media gallery works as a filter on depicted subjects across the model's three interpretive levels while preserving the distinction between conflicting scholarly readings.

Broast⁴ leverages Heider's documentary index to collect the scholarly debate on the authenticity of damaged, tampered-with, or altered medieval documents from Upper Austria (Haider, 2022). Uncertainty arises from incomplete or ambiguous information, such as uncertain production dates, and from the coexistence of conflicting scholarly opinions about the documents' authenticity over time. To this end, the Conjectures framework (Barabucci et al. 2021), an extension of the Named Graphs syntax that expresses scholarly opinions without asserting their content, was applied to formally represent scholarly claims as undisputed, disputed, or settled, along with evidence, provenance, and bibliographic context. The web platform allows the exploration of the evolution of the scholarly debate. It presents quantitative reports where interpretive aspects are the subject (e.g., mapping the locations of authenticity-debated documents) rather than emerging as a "perspective" on data. The catalogue can be filtered by type, creator, date, and document coverage. Here, the interpretive layer is preserved through sub-filters that allow perspectives that distinguish currently disputed, debated, and settled information (Pasqual, 2025).

artresearch.net⁵ is a discovery platform that brings together the collections of the International Association of Photo Archives (PHAROS), providing access to millions of photographs of artworks. Records from seven institutions are enriched and reconciled using different approaches (manual annotation, computer vision, LOD). Uncertainty and subjectivity are preserved in the aggregated dataset, thanks to ontology-dependent methods (including application profiles of CIDOC-CRM and non-committal properties instead of equivalence assertions) to record conflicting attributions and unknown or ambiguous identities, which may entail disagreement in the reconciliation with shared authorities (Daquino et al., 2026) and Named Graphs to preserve provenance information. The platform supports cross-collection research, highlighting contrasting and multi-source information and image comparison. It provides text- and image-based search similarity capabilities with adjustable sensitivity, enabling both targeted lookup of known items and exploratory discovery through broader semantic and visual matches. Faceted filters include cascading terms to visually simplify vagueness and imprecision using a hierarchical organisation (from broader, vague terms to specialised, precise ones). Data provenance is highlighted with institutional logos, supporting comparison. So far, no information visualisation technique has been employed to address further epistemic uncertainties.

² <https://dharc-org.github.io/mythlod/>.

³ <https://iconology-dataset.streamlit.app/>.

⁴ <https://projects.dharc.unibo.it/broast/>.

⁵ <https://artresearch.net>.

4. DISCUSSION AND CONCLUSION

The case studies present some recurring patterns in the management of uncertainty.

In data acquisition, uncertainty manifests as 1) implicit knowledge nearly always manually interpreted and extracted, 2) disputed assertions, either automatically retrieved (e.g. artwork attributions) or defined via policies (e.g. for reconciliation purposes). Across cases, uncertainty is handled through explicit manual annotation of interpretive layers (e.g. Bufalini, ICON), enrichment of pre-existing sources with additional evidence and provenance (e.g. mythLOD), and harmonisation of heterogeneous and even conflicting claims within the same (e.g. Broast) or across different datasets (e.g., artresearch.net). This variety of approaches confirms the need to treat interpretive subjectivity as a first-class entity from the earliest stages of data creation in DH projects, regardless of their scale.

Knowledge representation strategies in place are still scattered. Reification approaches (n-ary in ICON and Nanopublications in mythLOD and Bufalini), hybrid strategies combining n-ary and Named Graphs (artresearch.net), or RDF vocabulary extensions (Conjectures in Broast) tend to build on top of community standards (e.g., CIDOC-CRM). However, these notable solutions significantly impact data complexity and performance, affecting their wide adoption, and implying a steeper learning curve for “re-users” who have to deal with different, non-standard solutions to perform integrated queries. We argue that the development of shared, lightweight, reusable patterns to balance high expressivity with usability is fundamental to the DH international agenda, in order to effectively lower technical barriers for humanities scholars.

The study confirms the systematic gap between the importance given to the interpretive nature of humanities data in the scholarly literature and its actual implementation in web-based environments for scholars. Epistemic uncertainties seem to be better addressed through customised interface solutions, explicitly designed to enable interaction with the content based on its interpretive aspects (e.g., artresearch.net, Broast, ICON). When available, data visualisations present interpretive phenomena as a variable of the representation (ICON) or do not represent them at all. We believe that a shift toward layered engagement modalities is needed to encode interpretation, if not as a first-class variable, as a feature on demand (Windhager, Salisu, Schreder, et al., 2019), which we see not only as a mitigation strategy but also as a way to reveal qualitative aspects emerging from the data, thereby supporting critical approaches.

Overall, the projects show a chronological, gradual shift towards a greater awareness. In early projects, uncertainty is explicitly addressed at the first two stages, but it is not explicitly reflected in the visualisation interface (e.g., only on hover annotation in Bufalini). In mythLOD, colour-coded filters in the catalogue visualisation allow this distinction, but it disappears in data visualisations. In ICON, subjectivity and interpretive layers are the subject of data visualisations. It is worth noting that earlier projects store individual, non-contradicting claims (e.g., Bufalini’s perspective, Panofsky’s perspective, or single assertions in mythLOD). In contrast, the most recent projects (Broast and artresearch.net) shift their acquisition and representation interests towards multi-perspective datasets, formalising contrasting opinions from different sources. artresearch.net shows increasing awareness across all DH workflow phases, attempting to leverage generous approaches to exploration that do not neglect transparency and interpretive plurality.

However, despite such few notable examples, we believe the “modelling-to-dissemination” bottleneck remains, since most projects share sophisticated knowledge representation patterns and minimal effort in visualising such aspects. Previous studies have confirmed this tendency (Battisti & Daquino, 2025a; Battisti & Daquino, 2025b) and have highlighted two major related challenges: the scarcity of visualisations used as critical reflective tools, and the inherent tension between the desire to adopt reusable (off-the-shelf) visual solutions and the intrinsic diversity of humanities data, which demands case-specific design. Highly reusable tools often impose rigid formats that require data to be processed to fit predefined structures, leaving little room for unanticipated interpretive specificities. It is therefore not accidental that most DH contributions propose the definition of design patterns to be used with existing software, showcase techniques to encode different uncertainty dimensions, or suggest the use of narrative strategies as a mitigating strategy (Panagiotidou et al., 2022; Windhager, Salisu, & Mayr, 2019; Battisti & Daquino, 2025a).

In conclusion, this contribution argues that within the hybrid set of technical and theoretical knowledge of a digital humanist, more attention should be paid to design processes and dissemination-oriented skills to face situations where collaboration with interface or visualisation experts is not feasible. At the same

time, we believe future work should move beyond high-level guidelines toward an operational research framework that investigates how reusability can be reconciled with interpretive complexity. While high-level approaches offer interdisciplinary application, the field must still define a threshold of standardisation: the point where a tool moves from a helpful framework to a rigid structure that flattens the very knowledge it seeks to represent.

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