

Historicising uncertainty in photo archives for semantic modelling purposes

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ABSTRACT

Cultural Heritage (CH) data are inherently ambiguous: attributions shift, authorship is debated, and titles or dates are often uncertain or contested. Cataloguing conventions vary across institutions and time, leading to inconsistencies that affect interoperability. Photo archives amplify these challenges, as early cataloguing practices developed in the absence of shared standards and often treated photographs as secondary to artworks. Linked Open Data (LOD) technologies have opened opportunities to restructure and reconcile such records. However, most models and workflows assume certainty and one-to-one matches between entities, producing overly “clean” interfaces that risk erasing interpretive diversity. Fully reassessing records to resolve uncertainty is rarely feasible, and archivists increasingly face the need to historicise metadata and embrace ambiguity as part of the record itself. This article argues that modelling uncertainty should be treated as a first-class requirement in CH infrastructures, not as a data-cleaning problem. Drawing on cases from PHAROS photo archives, it categorises recurring forms of ambiguity and proposes design principles for representing uncertainty across both data structures and catalogue interfaces, balancing scholarly accuracy with usability.

KEYWORDS

Photo archives; Semantic Web; Uncertainty; Cataloguing.

Introduction

Cultural Heritage (CH) data are intrinsically ambiguous. Attributions shift, authorship is debated, and titles or dates are often uncertain, vague, or questionable. Cataloguing conventions also vary across time and institutions, affecting the accuracy and reliability of information. Photo archives exemplify many of these challenges (Caraffa 2011). Photographic studies consolidated much later than other disciplines, e.g. art historical studies, and only recently has the photograph been recognised as a research object in its own right. As a result, early cataloguing efforts were affected by the absence of standards, terminologies, and shared conventions, which still hinder straightforward cross-institutional interoperability today.

Over the past two decades, Linked Open Data (LOD) technologies, and more recently large language models (LLMs) have offered an unprecedented opportunity to revisit these inherited idiosyncrasies and produce interoperable, shareable data. This process requires dismantling information often flattened or coerced into unsuitable metadata fields, identifying distinct entities and relationships (regardless of their degree of certainty), and reconciling key entities across authorities and institutions to harmonise different traditions, granularities, and perspectives. In fact, most data models and reconciliation workflows assume certainty and one-to-one relationships between entities (Zeng et al. 2021), enabling developers to build clean search interfaces where data appear perfectly interlinked and indexed.

However, reassessing archival records to resolve uncertainties or improve metadata quality is prohibitively costly. For example, photographs attributed simply to “Alinari” are difficult to interpret, as this label could refer to an individual, an atelier, an external photographer hired by the atelier, or other possibilities. This vagueness reflects the shifting priorities of the scholarly community. For a long time, photographers were not considered essential access points to collections, and cataloguers treated their names much like captions. Today, photo archivists must instead historicise their records, seeking a viable compromise that acknowledges uncertainty when stable, factual assertions cannot be made.

This compromise directly affects catalogue user interface design, which must balance data accuracy and usability (Grasso, Daquino, and Renda 2024). Digital infrastructures tend to favour certainty and closure, but this can lead to epistemic loss, e.g. erasing provenance or flattening interpretive diversity. On the other hand, if uncertainty is foregrounded too prominently, it may disorient both scholars and general users (Drucker 2011; Battisti and Daquino 2025). Strategies such as progressive disclosure are therefore needed to introduce complexity gradually and make uncertainty understandable. While the Digital Humanities community has discussed managing uncertainty on a case-by-case basis, there is still no concerted framework for designing catalogue interfaces that are accessible, usable, and meaningfully represent uncertain data.

This article argues that modelling uncertainty must be treated as a first-class requirement in the creation of online catalogues, not as a side effect or a data cleaning problem. Drawing on cases from the photo archives of the PHAROS association, it will categorise common forms of ambiguity in data and propose design principles for representing uncertainty in both data structures and user interfaces.

Related work

Nowadays, catalogues are characterised by some form of authority control, which ensures standardised forms of names, titles, and subjects can be used as coherent access points to collections in organisation and discovery tools (Joudrey et al. 2015). With the widespread adoption of Semantic Web technologies, such standardised names are associated with persistent identifiers like URIs that uniquely identify a real-world entity or concept. As aforementioned, a vague string like “Alinari” may make sense to catalogues’ users as an access point, but it cannot simply be mapped in a one-to-one relation with an entity. Ambiguity and vagueness in cataloguing practices is a recurring topic in the literature (Bates 1986; Brubaker 2002; Olson 2013; Joudrey et al. 2015), whose consequences are amplified and differently handled when multiple catalogues are aggregated in centralised systems. The PHAROS association of art historical archives (Caraffa et al. 2015) is currently working on the realisation of a shared platform, *artresearch.net*, which gathers catalogues of 14 photo archives and harmonises them using Semantic Web technologies. This effort faces a wide range of phenomena characterising archival records, like vagueness, ambiguity, and uncertainty, which have been analysed by data engineers and domain experts in order to define shared policies to handle edge cases and return users with user-friendly views on such complexities.

Scholars and practitioners in the Digital Humanities have also long recognised the importance of preserving ambiguity, uncertainty, and vagueness in Cultural Heritage data—not necessarily to resolve them, but to document and communicate the interpretive debates surrounding them. This has led to a variety of technical approaches spanning knowledge organisation, data reconciliation, and data visualisation. Ontologies such as CIDOC-CRM support the explicit modelling of uncertainty through constructs like *crm:E13_Attribute_Assignment* and qualifiers (Niccolucci and Hermon 2017), while specialised ontologies like the Historical Context (HiCO) Ontology (Daquino and Tomasi 2015) allow attributions and interpretations to be recorded alongside their provenance. On the representation side, techniques such as named graphs (Carroll et al. 2005), conjectural statements (Barabucci, Tomasi, and Vitali 2021), and RDF* (Hartig 2017) enable the encapsulation of contested or provisional assertions without collapsing them into definitive facts. Reconciliation workflows increasingly employ rule-based approaches, graph embeddings, and, more recently, large language models to suggest and qualify matches between certain entities (Zeng et al. 2021). However, reconciliation practices rely on the assumption that a one-to-one match is always possible (if a candidate in the matched authority list is available), which unfortunately clashes with the lack of certainty and the ambiguity that characterises attributionship and cataloguing practices in general.

In data visualisation, uncertainty-aware methods are being explored, particularly in graph-based visualisations, to render confidence levels, alternative hypotheses, and interpretive multiplicity without overwhelming users, thereby maintaining both transparency and usability (Drucker 2011; Battisti and Daquino 2025). Previous studies have also emphasised the importance of linking ontology design practices with user interface design frameworks to improve user experience (Grasso, Daquino, and Renda 2024).

However, while these works acknowledge the presence of uncertainty, they rarely address it as a systematically modelled component carried through from data content to end-user presentation. Strategies such as progressive disclosure (Springer and Whittaker 2019) and generous interfaces

(Whitelaw 2015) have been proposed to mitigate complexity in the interface, but there is still no shared set of practices for representing specific types of uncertainty in a consistent way. In particular, the field lacks empirical studies and efforts to generalise a comprehensive framework that connects the categorisation of ambiguity with corresponding reconciliation and modelling strategies, as well as with suitable visualisation approaches for cultural heritage catalogues.

Classifying ambiguity and uncertainty in photo archives

Catalogues are mirrors of shifting cultural interests and evolving knowledge organisation practices. A wide range of well-known issues affect their quality, becoming especially evident when attempting to reconcile institutional perspectives and traditions through data. The scholarly community has long recognised that archiving and cataloguing are not objective tasks, and each cataloguer inevitably introduces individual choices and idiosyncrasies that contribute further complexity—and sometimes entropy—to the ecosystem of knowledge organisation (Barabucci, Tomasi, and Vitali 2022). These subjective layers complement the inherent uncertainties already present in the knowledge being recorded. While a full inventory of such situations (e.g. homonyms, temporal fuzziness) goes beyond feasible and reasonable classificatory purposes, the classification of situations relevant to (and challenging) semantic data modelling and reconciliation efforts is a pragmatic motivation for the historicisation of photo archives, which need shared policies for expressing, rather than hiding, interpretive diversity in a landscape of digital solutions that favour factuality, flattening, and reticence. In particular, the collection of edge cases presented here exemplifies the uncertainty stemming from the identification of real world entities (people, organisations, places, materials) that affect a straightforward reconciliation between cataloguing data and authority lists.

We can draw a preliminary distinction between uncertainty that stems from gaps in knowledge, uncertainty introduced by cataloguing practices, regardless of how certain or uncertain the underlying knowledge may be at the time of the cataloguing, and uncertainty in knowledge representation with Semantic Web technologies. Specifically, the latter includes mechanisms to cope with the two former situations, which may in turn generate new idiosyncrasies in the way data is processed and interpreted by humans. For the sake of readability, cases are summarised in Table 1 with examples taken from the analysis of PHAROS archival data.¹

¹ Daquino, Mambelli and Kozlov 2026.

Table 1. Classification of uncertainties and ambiguities in photo archival records with examples

Example	Gap in Knowledge	Uncertainty introduced by cataloguers	Uncertainty in knowledge representation
“Brogi/Alinari”	Competing attributions	Reticence Varying reliability	Alternative statements Expressing without asserting
“F.lli Alinari?”	Unknown value	Varying reliability	Assumed certainty Expressing without asserting Reticence in reconciliation Ambiguous anonymous entities
“Alinari”, “Alinari, ?”	Entity ambiguity	Attributional ambiguity	Reconciliation mismatch
“Pseudo Ambrogio di Baldese”	Semantic drift		Reconciliation mismatch Reticence in reconciliation
“Anonymous Florentine, 16 th century”	Semantic drift	Vagueness	Reconciliation mismatch Reticence in reconciliation Assumed certainty
“Auction Christie’s, London 1970”	Unknown value	Coercion	Representation inconsistency Dumping
“Frick collection” vs “Frick Art Reference Library”, “Sistine Chapel” vs “Vatican museums”		Flattening Granularity mismatch Redundancy and divergence	Overlapping categories
“Broomford Manor”	Semantic ambiguity	Flattening	Overlapping categories
“Albumine”			Semantic ambiguity Granularity mismatch

Competing or evolving author attributions, such as “Brogi/Alinari”, are often recorded in catalogues without further assessment. Such a “relativist” approach may reflect cataloguers’ reticence to choose a preferred attribution in the absence of policies, or simply the lack of sufficient evidence. On the one hand, it avoids introducing subjective judgments on top of existing knowledge gaps. On the other hand, it often omits motivations, sources, or explicit acknowledgment of uncertainty, leaving readers without a sense of the reliability of the statements and without a clear explanation of the meaning (users may interpret the string as a collaboration between authors, rather than an alternative attribution). In a Linked Data context, this raises challenges for formally representing (1) alternative hypotheses and (2) the absence of endorsement by the data provider. Formal logic does not allow “either/or” statements, especially when the data do not reflect a true assertion. In practice, cataloguers are reporting hypotheses, possibly narrowed down through analysis or bibliography, but without endorsing or justifying any of them. These cannot therefore be modelled as assertions attributed to the cataloguer but instead require patterns that capture the coexistence of multiple attributions for a given object. However, existing modelling options, such as *crm:E13 Attribute Assignment*, require both an explicit agent responsible for the assignment and a declared value (not an alternative). These solutions do not easily accommodate the expression of hypotheses that fall short of an actual assertion, and do not allow the representation of alternatives. Different

ontology patterns are therefore needed to represent alternatives whose provenance is not directly linked to cataloguers, which act instead as secondary knowledge providers.

A related situation arises when cataloguers record a preferred attribution but mark it as uncertain. For instance, “F.lli Alinari?” signals an identified photographer, but with acknowledged doubt. Here, one may argue the cataloguer both endorses a candidate and encodes an epistemic stance (favoured, speculative, uncertain). In Linked Data this again requires nuance: patterns such as *crm:E13 Attribute Assignment* can be used, but the uncertainty must be captured with custom qualifiers. While this approach is workable, it risks flattening the epistemic subtlety of such cases, since it treats the attribution as a firm assignment rather than a tentative one.

The case of “Alinari” (and “Brogi”) also illustrates attributional ambiguity tied to family names. The string “Alinari” may refer to an individual, an atelier, or both. More problematically, the same string can represent different referents across records, depending on context. In Linked Data, however, URIs must unambiguously denote one entity, and cannot shift meaning depending on context. Reconciliation to external authorities (e.g. VIAF, Wikidata) therefore risks introducing false certainty, forcing ambiguous references into specific entities. Cataloguers may thus refrain from reconciliation, producing duplicate ambiguous entities in authority lists.

Other examples include strings such as “Alinari, ?”, where the family name is recognised, but the individual cannot be identified (e.g. Leopoldo, Giuseppe, or Romualdo). Such labels frame the author as an anonymous member of a family. Reconciliation to external authorities is problematic. One might map the string to a “family group” entity, but this could conflate the intended anonymous group with unrelated individuals. Again, cataloguers may opt for reticence, leading to duplication of uncertain entities in the authority.

Special cases also involve pseudonyms of anonyms. For example, “Pseudo Ambrogio di Baldese” appears as the author of an artwork in several archives. However, scholarship diverges on their identification: some identify the artist as Ventura di Moro (ULAN 500012920), others as Lippo d’Andrea (ULAN 500082343). Aligning the pseudonym with one authority would imply endorsement. When collections are merged, disagreements between institutional perspectives resurface, creating difficulties for reconciliation. In such cases, institutions may avoid external alignment, producing duplicated pseudonymous entities across authority lists.

Similarly, vague attributions such as “Anonymous Florentine, 16th century” define an author in spatio-temporal terms but not as an identifiable person. Institutions may use similar labels to describe entirely different entities. Automatic reconciliation across institutions (since anonymous are poorly represented in authorities) risks conflating them, while refusing reconciliation leads to fragmentation. Policies must therefore choose between reticence and coercion, neither of which fully resolves the ambiguity.

Comparable issues arise in provenance data. Provenance fields typically record an owner (person or institution), a place, and a date range (e.g. “Louvre Museum, 1917–1935”). But real trajectories are often incomplete, and cataloguers must coerce vague or partial evidence into rigid fields. For example, “Auction Christie’s, London, 1970” records not an owner but a sale event where the object was last seen. Such entries disrupt the sequential representation of provenance, complicating reconciliation across institutions, where descriptions may either complement or contradict one another. In practice, cataloguers may resort to dumping complex provenance narratives into text fields, which resist programmatic parsing and semantic modelling.

Granularity mismatches also appear in the identification of entities. Cataloguers sometimes record a collection rather than the holding institution (e.g. “Frick Collection” instead of “Frick Art Reference Library”), treating collections as if they were agents capable of acquisition. This is a form of flattening, where semantically distinct information is collapsed into one field, forcing interpreters to rely on common sense. Similarly, institutions may record either a specific sub-location (“Sistine Chapel”) or a broader institution (“Vatican Museums”), producing overlaps that complicate reconciliation. External authorities often exacerbate the issue. For instance, in Wikidata, the Sistine Chapel is modelled as a building, while the Vatican Museums are an organisation—making it semantically inconsistent to assert a part-whole relation.

Ambiguity also affects entities that blur the line between organisation and place, such as manors (“Broomford Manor”). These can be treated as locations, buildings, or institutions, and often give their names to collections. Here the flattening reflects the inherent semantic ambiguity of the entities themselves.

One last example, this time involving the materiality of described objects, regards a granularity mismatch introduced by semantic technologies. When cataloguers describe a photographic object as “albumine”, one would imagine that the reconciliation to authorities like Getty AAT should be a straightforward operation. Instead, the string may be interpreted (by a human as well as by a program) as the raw material itself (AAT 300411855), the photographic process employing albumine (AAT 300133274), or to the specific product “albumine print” (AAT 300127121). Archives may reconcile to different categories, introducing inconsistencies that, again, require harmonisation.

Towards a model of uncertainty

The survey of ambiguities and uncertainties in cataloguing practices reinforces the broader consensus in the Digital Humanities on the fact that uncertainty is not noise to be eliminated, but a structural feature of cultural heritage data that must be modelled explicitly. Rather than treating it as a side effect of poor cataloguing, uncertainty should be conceptualised as a relational property—linking entities, statements, and interpretations—so that data structures can reflect the interpretive debates and evolving knowledge they embody.

Authority control has historically privileged uniqueness and stability, assuming that entities can and should be reconciled to a single identifier. This bias clashes with humanistic standards, where competing hypotheses, attributions, and evolving interpretations may coexist without being ever resolved. In fact, probabilistic reconciliation approaches, common in data science, suggest one “best” match, but this statistical logic clashes with the epistemic requirements of the humanities, where acknowledging ambiguity is often more faithful to the sources than asserting certainty. Current data structures, however, frequently force premature disambiguation, leading to flattening, coercion, or duplication.

Recent developments in semantic technologies—such as named graphs, the use of `crm:E13 Attribute Assignment` in CIDOC-CRM, and extended formalisms for assertions and conjectures—point to possible ways forward. Instead of collapsing multiple attributions into a single “truth,” catalogues should represent alternative hypotheses explicitly, preserving their provenance and interpretive context.

Some concrete strategies include:

- Minting anonymous or collective entities, e.g. “Alinari family” or “Alinari (collective name),” to avoid false precision and create anchors to gather ambiguous entities under the same definition.
- Using “umbrella terms” to group heterogeneous references under a shared label without assuming identity. E.g. “Alinari” may be an instance of *crm:E33 Linguistic Object* linked to all the aforementioned ambiguous manifestations of people and organisations connected to the common-sense term. This allows one to maintain a relation between all the ambiguous entities via a shareable label, without forcing a precise semantic relation between unknown entities.
- Representing competing attributions as parallel assertions with provenance, ensuring that the origins of each statement remain visible, especially when endorsement is not given. Formalisms for representing competing statements can be found both at RDF level, e.g. using Lists, and with named graphs to separate alternatives.
- Attaching uncertainty scores or qualifiers to mark degrees of confidence or epistemic stance (favoured, tentative, speculative).
- Finally, maintaining reticence, e.g. deliberately withholding reconciliation when ambiguity is irreducible, rather than introducing false certainty.

User interfaces as sites of negotiation

The user interface is the place where ambiguity becomes visible and semantic modelling decisions shape the user experience. The challenge is to render complexity without overwhelming users, especially in the three typical main points of interaction of archives catalogues: facets, lists of results, and individual records. In many cultural heritage platforms, the research experience is reduced to a single input field (e.g. Google-like search input), rather than advanced search options, which shifts the burden of interpretation to users. This design choice requires careful strategies to make ambiguity visible while still supporting intuitive discovery.

Progressive disclosure offers one solution. Canonical or most stable names (e.g. “umbrella terms”) can be displayed by default, with alternatives, variants, and confidence levels accessible on demand, e.g. in hierarchical views or dropdowns. This allows users to navigate familiar, uncluttered interfaces while retaining access to deeper layers of interpretive nuance on demand.

Faceted navigation can also play a critical role. Uncertain or ambiguous entities, such as anonymous groups or umbrella terms, should be included in filters, but visually distinguished (for example, through typographic cues or icons) so that users can recognise their provisional nature. In this way, uncertainty becomes a navigable dimension rather than a barrier.

Finally, record-level views must reconcile clarity with transparency. Users should be able to see both the preferred form of an attribution and the alternative hypotheses, along with provenance details that justify it (e.g. logos of data providers, original non-normalised strings appearing in catalogues). Here too, the key is incremental complexity, exposing certainties and uncertainties without disorienting the reader. To do so, data modelling and interface design must be co-developed. The way uncertainty is modelled at the data level directly constrains how it can be represented in the interface, while interface requirements should inform modelling choices to ensure usability.

Discussion

What emerges from the survey is the need for a framework that balances interoperability with epistemic integrity. Cultural heritage infrastructures should not only connect data across institutions but also safeguard the ambiguities that are intrinsic to the historical record. A model of uncertainty must therefore accommodate multiple perspectives, preserve interpretive openness, and still deliver usable, navigable interfaces to end users. Only by embracing uncertainty as a first-class feature of knowledge representation can digital catalogues both support interoperability and remain faithful to the humanistic traditions they serve.

This perspective also carries implications for the long-term sustainability of cultural heritage systems. Catalogues are never definitive, since new evidence, changing scholarly consensus, and evolving descriptive practices will continue to reshape attributions, identifications, and provenance. Systems designed with rigidity or premature closure risk becoming obsolete as soon as new knowledge emerges. Conversely, infrastructures that can accommodate revision, store alternative hypotheses, and represent degrees of confidence are more resilient. They allow catalogues to evolve while maintaining provenance and interpretive transparency, ensuring that future work builds on, rather than overwrites, existing records.

Finally, modelling uncertainty situates cultural heritage practice within the wider debate on data epistemology in the humanities. Scholars have long argued that digital representations of culture must reflect the partial, contested, and situated character of knowledge rather than aspiring to an impossible neutrality. Approaches that treat uncertainty as a first-class feature align with critical traditions in archival science, historiography, and the digital humanities, which view data not as fixed facts but as interpretations embedded in social, institutional, and technological contexts. In this light, uncertainty is not a flaw but a sign of intellectual honesty, a recognition that cultural heritage is as about what we know as about what we do not know.

Conclusion

Ambiguity and uncertainty are not accidents of cataloguing but inherent features of cultural heritage data. Far from diminishing value, they enrich the record by preserving traces of scholarly debate, shifting conventions, and incomplete knowledge. Treating them as assets rather than errors requires moving beyond data-cleaning logics toward explicit modelling strategies that can capture hypotheses, alternatives, and degrees of confidence.

This study has shown that such an approach is not only possible but necessary. Infrastructures, standards, and policies must be developed with uncertainty at their core, ensuring that digital catalogues remain transparent, revisable, and faithful to the interpretive nature of the humanities. By embedding ambiguity into both data models and user interfaces, we can design systems that are not only interoperable and sustainable, but also intellectually honest.

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