Expressing Without Asserting in the Arts

Marilena Daquino[1], Valentina Pasqual[1], Francesca Tomasi[1] and Fabio Vitali[1]

[1]University of Bologna, Bologna, Italy

Abstract
Critical debate as well as uncertain or subjective claims are pivotal elements in arts scholarly analysis. Asserting such statements in RDF is hindered by the correct representation of uncertain or evolving aspects. In this article we examine and discuss the need and usefulness of expressing without asserting (EWA) arbitrary claims as RDF named graphs. We examine effectiveness of prior approaches to EWA and we propose a solution, called *conjectures*, to express and retrieve statements whose truth value is not specified.

Keywords
Conjectures, GLAM, Provenance, Uncertainty, RDF

1. Introduction

Scholars debate around claims whose certainty is not always given. A typical scenario is the scholarship in the Arts, where contradictory opinions are differently addressed. Fairly common situations include: *ignorance*, where no true answer exists (e.g. the identity of Banksy); *evolving data*, where novel arguments or new information change the perception of correctness of claims; *disagreements*, where competing claims exist, they are reciprocally inconsistent, and no overwhelming justification towards one over the other ones exists (e.g. competing artwork attributions); lastly, *challenges*, where scholars present a claim they believe to be false or unacceptable simply to discuss it, point out its flaws and discredit it. To this extent, we can identify at least three types of claim that populate cultural heritage data: **undisputed claims**, which have not been debated (yet); **disputed claims**, whose correctness is currently under discussion and no clear conclusion has been reached (yet) about their truth; and **settled claims**, that were disputed in the past but then have been decided as true by the relevant community.

Linked Open Data datasets in the Cultural Heritage domain present similar degrees of certainty of information. Many ontologies and strategies expressing provenance, context information, uncertainty and truth of statements, can be applied to cope with the problem. However, human intervention is always required to (1) understand definitions of uncertainty, which may differ from one field to another, and (2) to disambiguate statements whose truth value is not explicit.

For instance, consider the painting *Girl reading a letter at an open window*[1], which has been

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marilena.daquino2@unibo.it (M. Daquino); valentina.pasqual2@unibo.it (V. Pasqual); francesca.tomasi@unibo.it (F. Tomasi); fabio.vitali@unibo.it (F. Vitali)
0000-0002-1113-7550 (M. Daquino); 0000-0001-5931-5187 (V. Pasqual); 0000-0002-6631-8607 (F. Tomasi); 0000-0002-7562-5203 (F. Vitali)

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[1]https://en.wikipedia.org/wiki/Girl_Reading_a_Letter_at_an_Open_Window

attributed over time to Rembrandt, Hooch, and finally to Vermeer (currently, the accepted attribution). Simply presenting the attribution statements (list. 1) has obvious drawbacks:

```
:painting-pr crm:P14_carried_out_by ulan:500011051. # Rembrandt
:painting-pr crm:P14_carried_out_by ulan:500020229. # Hooch
:painting-pr crm:P14_carried_out_by ulan:500032927. # Vermeer
```

Listing 1: Competing attributions for *Girl Reading a Letter*

Given this dataset, any automatic inference engine would be prompted to allow that either the three artists collaborated to the painting or even that they were actually the same individual. A human would therefore be needed to clarify that these options are not all acceptable at the same time, that only one of these artists can be assumed, and that other claims are available for completeness but they should not be considered true. To this extent, superseded claims would rather need to be expressed without asserting (EWA), so that they can be contemplated without contributing to the truth value of the dataset. However, the lack of expressivity of datasets in conveying uncertainty leads to a great loss of information, and to an additional increase of complexity in the critical analysis that must be performed by humans. We believe these situations are the norm in the Humanities and need to be properly addressed, especially when integrating data sources which may carry a different (both informal and formal) interpretation of uncertainty.

We expect that any reasonable methodology for EWA is able to express disputed, undisputed and settled claims, and to distinguish between them with minimal complexity. Over time, several approaches have been proposed to address EWA [1, 2, 3, 4, 5], however, none of these solutions is completely satisfying, since the non-asserted status of statements is often a byproduct rather than a design issue, and the evolving status of claims is hard to represent.

The purpose of our work is therefore to be able to examine and retrieve statements whose truth is not available. We survey existing methods and we address their benefits and limitations with respect to a common scenario in the Arts, i.e. representing competing attributions. Finally, we propose another approach for expressing without asserting statements, called "conjectures". We compare our solution to prior ones and we discuss the benefits of our contribution.

2. Related works

Expressing uncertainty is considered a key issue in knowledge representation, especially when dealing with data whose truth-value is not declared [6]. Digital Humanities projects have faced the problem with both ontology-dependent and ontology-independent solutions.

Ontology-dependent solutions include OWL ontologies for describing provenance, uncertainty, and trust-related aspects. Generally N-ary Relations [2] are applied to annotate uncertain claims. In the Arts domain, CIDOC-CRM [7] is the most used data model to represent scholarly attributions. Linked Art [8] proposes an application profile of CIDOC-CRM to be shared within the museum community and integrate data from different Digital Libraries, which may include concurring claims[2]. Extensions of CIDOC-CRM [9, 10, 11] and PROV [12], were created to represent meta-knowledge. However, no agreement on a strategy has been found. Moreover,

[2] https://linked.art/model/assertion/

ontologies do not prevent limitations derived from the actual assertion of claims, e.g. in settled disagreements, where superseded statements remain asserted despite having been rejected.

To prevent the adoption of multiple vocabularies and to cope with the problem of EWA, ontology-independent solutions have been proposed. These span from the usage of reification [1] to singleton properties [13], named graphs [14], models for organising named graphs [3], serialisations like Notation3 [5], and extensions to the graph model like RDF* [4]. Projects like Vicoglossia [15] deal with a variety of text annotations reusing a customisation of the nanopublication model[3]. Likewise, projects like mythLOD or mAuth represent artwork interpretations and attributions with domain ontologies and named graphs [16]. However, the semantics of named graphs is ambiguous [17] and several interpretations of the truth value of claims included in named graphs may coexist in the same dataset.

3. Overview of methods to express without asserting

In this section we present a survey of existing technologies aimed to represent uncertainty and we classify them with respect to their effectiveness. Since a shared definition of effectiveness in EWA does not exist, we intuitively define it as the overall accuracy and thoroughness of the achieved representation. We base our analysis over the following criteria:

(1) **EWA**: does the approach allow one to express without asserting arbitrary content? (2) **Graph**: can non-assertion be associated also to graphs when appropriate? (3) **Mapping**: is it possible to map data to plain semantics of RDF? (4) **Increment**: if compatible with RDF, how many triples must be added to map individual statements to plain RDF? (5) **Independence**: is the approach independent from bespoke technologies, such as parsers, serializations, query languages? (6) **Semantics**: does it extend RDF semantics?

We selected criteria that allow us to address minimum requirements to EWA contents of named graphs (1 and 2), and focus on those approaches that can be reused from day one (3, 5 and 6) efficiently (4).

Table 1
Comparison of methods for expressing without asserting

Method	EWA	Graph	Mapping	Increment	Independence	Semantics
Reification [1]	yes	yes	yes	4	yes	no
N-ary [2]	no	no	yes	N	yes	no
Singleton [13]	no	no	yes	1	yes	yes
N. graphs [14]	depends	depends	yes	N/A	yes	yes (RDFs)
N3 [5]	yes	yes	no	N/A	no	no
RDF* [4]	yes	no	yes	6-9	no	yes

In table 1 we present methods that have been evaluated at least twice in the most recent literature on provenance or meta-knowledge research [18, 19, 20, 21, 22]. We use the aforementioned attributions for Vermeer's painting (a settled disagreement) as a running example to showcase differences between approaches.

Reification (list. 2) is part of RDF 1.1 semantics. A reified triple is not entailed, therefore complying with our minimum requirement. However, since it requires an expensive addition of triples (4+) and it does not allow inference on reified triples, it has been disregarded as a solution to describe provenance and it has been proposed for deprecation[3] [23].

N-ary relations (list. 3) are adopted in CIDOC-CRM. To represent concurring statements, instances of the class `crm:E13_Attribute_Assignment` are annotated with context information. This method shows some verbosity and redundancy of triples to add context to statements. Additionally, all statements are considered asserted, and therefore, in our example, the three attributions are equally asserted, despite the debate is settled toward only one.

```
:aa1 rdf:type rdf:Statement ;
  rdf:subject :painting-pr ;
  rdf:predicate crm:P14_carried_out_by ;
  rdf:object ulan:500011051 ; # Rembrandt
  crm:P4_has_time-span :XVIII_cent .

:aa2 rdf:type rdf:Statement ;
  rdf:subject :painting-pr ;
  rdf:predicate crm:P14_carried_out_by ;
  rdf:object ulan:500020229 ; # Hooch
  crm:P4_has_time-span :1821 .

:aa3 rdf:type rdf:Statement ;
  rdf:subject :painting-pr ;
  rdf:predicate crm:P14_carried_out_by ;
  rdf:object ulan:500032927 ; # Vermeer
  crm:P4_has_time-span :1860 ;
  crm:P14_carried_out_by ulan:500326948 . # Thore
```

Listing 2: Competing attributions with Reification

```
:aa1 a crm:E13_Attribute_Assignment ;
  crm:P177_assigned_property_of_type crm:P14_carried_out_by ;
  crm:P141_assigned ulan:500011051 ; # Rembrandt
  crm:P140_assigned_attribute_to :painting-pr ;
  crm:P4_has_time-span :XVIII_cent.

:aa2 a crm:E13_Attribute_Assignment ;
  crm:P177_assigned_property_of_type crm:P14_carried_out_by ;
  crm:P141_assigned ulan:500020229 ; # Hooch
  crm:P140_assigned_attribute_to :painting-pr ;
  crm:P4_has_time-span :1821.

:aa3 a crm:E13_Attribute_Assignment ;
  crm:P177_assigned_property_of_type crm:P14_carried_out_by ;
  crm:P141_assigned ulan:500032927 ; # Vermeer
  crm:P140_assigned_attribute_to :painting-pr ;
  crm:P4_has_time-span :1860;
  crm:P14_carried_out_by ulan:500326948. # Thore
```

Listing 3: Competing attributions in CIDOC-CRM (n-ary relations)

A **singleton** (list. 4) is a unique predicate that is used only once to represent a triple, instead of the original predicate. As such, it can be subject of additional triples. The property `:singletonPropertyOf` maps new predicates to the original ones. However, it is a subproperty of `rdf:type`, therefore the new statements must be considered asserted as well.

```
:painting-pr :P14_carried_out_by#1 ulan:500011051 ; # Rembrandt
:P14_carried_out_by#1 rdf:singletonPropertyOf crm:P14_carried_out_by ;
  crm:P4_has_time-span :XVIII_cent.

:painting-pr :P14_carried_out_by#2 ulan:500020229 ; # Hooch
:P14_carried_out_by#2 rdf:singletonPropertyOf crm:P14_carried_out_by ;
  crm:P4_has_time-span :1821 .

:painting-pr :P14_carried_out_by#3 ulan:500032927 ; # Vermeer
:P14_carried_out_by#3 rdf:singletonPropertyOf crm:P14_carried_out_by ;
  crm:P4_has_time-span :1860 ;
  crm:P14_carried_out_by ulan:500326948. # Thore
```

Listing 4: Competing attributions with Singleton Properties

Named graphs (list. 5) present a peculiar situation. It has been argued that graphs do not contribute in determining the truth of a dataset [17, 18, 24], which depends on the interpretation of the default graph. At least eight model-theoretic semantics [17] have been proposed to decide the truth value of graphs. No agreement exists, and several interpretations can be in place in the same dataset. In our case, all attributions may or may not be asserted.

```
GRAPH :aa1 { :painting-pr conj0001:P14_carried_out_by ulan:500011051. # Rembrandt }
:aa1 crm:P4_has_time-span :XVIII_cent .

GRAPH :aa2 {:painting-pr conj0002:P14_carried_out_by ulan:500020229. # Hooch }
:aa2 crm:P4_has_time-span :1821 .

GRAPH :aa3 {:painting-pr conj0003:P14_carried_out_by ulan:500032927 . # Vermeer }
```

[3] See https://lists.w3.org/Archives/Public/public-rdf-wg/2011Apr/0164.html

```
:aa3 crm:P4_has_time-span :1860 ; crm:P14_carried_out_by ulan:500326948 . # Thore
```

Listing 5: Competing attributions with Named Graphs

In **N3**, graphs can be quoted by other formulas, which do not assert the contents of the RDF graph (list. 6). N3 syntax is compact. Since graphs in N3 do not have an identifier, the annotation must be performed in place. Yet, N3 graphs can nest at arbitrary depth levels, while RDF 1.1 graphs cannot contain other graphs. Recent works [18] have proposed the usage of **N3 rules** to bind graphs to one of the possible model-theoretic semantics. However, this would require parties to adopt only one serialization to serve and consume data, since N3 rules are not backward compatible to RDF.

```
{[crm:P4_has_time-span :XVIII_cent] :assignes [crm:P108_has_produced :painting;
crm:P14_carried_out_by ulan:500011051]} a n3:falsehood .

{[crm:P4_has_time-span :1821] :assignes [crm:P108_has_produced :painting;
crm:P14_carried_out_by ulan:500020229]} a n3:falsehood.

[crm:P4_has_time-span :1860; crm:P14_carried_out_by ulan:500326948]
:assignes [crm:P108_has_produced :painting; crm:P14_carried_out_by ulan:500032927]
```

Listing 6: Competing attributions with N3

RDF* is a recent extension of RDF that allows a concise representation of statement-level metadata (list. 7). However, multiple statements, encapsulated in graphs, cannot be quoted. It is backward-compatible to RDF, requiring the specification of 6 to 9 additional triples for every quoted statement. In order to leverage all the potentialities of this proposal, bespoke languages (RDF* and SPARQL*) and technologies (RDF* graph stores) must be used.

```
<< :painting-pr crm:P14_carried_out_by ulan:500011051 >> crm:P4_has_time-span :XVIII_cent .

<< :painting-pr crm:P14_carried_out_by ulan:500020229 >> crm:P4_has_time-span :1821 .

<< :painting-pr crm:P14_carried_out_by ulan:500032927 >> crm:P4_has_time-span :1860;
    crm:P14_carried_out_by ulan:500326948 .
```

Listing 7: Competing attributions with RDF*

In summary, it is currently possible to achieve EWA respectively, with reification, N3 and RDF*. However, it comes with the cost of adding triples (between 4 and 9), the impossibility to annotate graphs (RDF*), and the complexity of tracking the re-assertion of triples (N3). Nonetheless, we believe it is possible to build on previous work to define a strategy that is fully compliant with RDF1.1., without dramatically increasing the number of triples.

4. Conjectures

The motivation driving this work is to have the possibility to make claims that must not be interpreted as facts (i.e., as asserted statements). In addition, even if in our examples we simplified claims to individual triples, real-world scenarios often include claims that cannot be reduced to a binary relation expressible as a single RDF statement. Therefore we aim at a solution that allows us to express content of named graphs without asserting them.

Conjectures are used for this purpose. A conjectural graph is a named graphs where all triples (s, p, o) are represented with two triples, (s, cp, o) and $(cp, conj{:}isAConjecturalFormOf, p)$, where cp is a unique newly minted predicate created specifically for the triple to conjecture.

```
@prefix conj: <https://w3id.org/conjectures/> .

GRAPH :aa1 {
  :painting-pr conj0001:P14_carried_out_by ulan:500011051 . # Rembrandt
  conj0001:P14_carried_out_by conj:isAConjecturalFormOf crm:P14_carried_out_by .
} :aa1 crm:P4_has_time-span :XVIII_cent .

GRAPH :aa2 {
  :painting-pr conj0002:P14_carried_out_by ulan:500020229 . # Hooch
  conj0002:P14_carried_out_by conj:isAConjecturalFormOf crm:P14_carried_out_by .
} :aa2 crm:P4_has_time-span :1821 .

GRAPH :aa3 {
  :painting-pr conj0003:P14_carried_out_by ulan:500032927 . # Vermeer
  conj0003:P14_carried_out_by conj:isAConjecturalFormOf crm:P14_carried_out_by .
} :aa3 crm:P4_has_time-span :1860 ; crm:P14_carried_out_by ulan:500326948 . # Thore
```

Listing 8: Competing attributions in Conjectures weak form

Listing 8 shows the aforementioned example with conjectures. Conjectures adopt newly minted predicates used exactly once[4], that are mapped to their original predicate via the property `conj:isAConjecturalFormOf`. Similarly to `:singletonPropertyOf`, the property allows to easily retrieve original predicates. However, the conjectural property is not a subproperty of `rdf:type`, meaning that the original statements are not asserted. Conjectural graphs can now be annotated with statements to express their provenance, their temporal validity, and any other constraint that may be necessary to specify the conditions under which the conjecture can be considered true.

Indeed, the use of minted predicates has a few advantages. First, the original triples (i.e. those not using conjectural predicates) are *not* stated, thus fulfilling the basic requirement of expressing without asserting. Second, contradictory statements, each adopting a conjectural predicate derived from the same original predicate, are explicitly mapped to the original one through the `conj:isAConjecturalFormOf` predicate, which ensures clear identification and facilitates querying for unsettled disputes. Moreover, conjectural predicates comply with RDF semantics and only require a minimal increase of triples (one new RDF triple is added for every conjectured triple).

In the introduction we identified (at least) three classes of statements that are of interest to scholars, namely *undisputed*, *disputed* and *settled* statements. Accordingly, we employ plain named graphs for undisputed claims (to be interpreted as asserted until a disagreement is recorded), and conjectural graphs for disputed claims (to be interpreted as expressed without positive assertion). Finally, a settled dispute is a statement that has been put in doubt by someone (and therefore disputed), but for which eventually a consensus was reached and the relevant community (and the dataset that expresses its point of view) record both the fact that the claim was disputed, *as well as* its subsequent assertion. To handle settled disputes we define *collapse graphs*.

A collapse graph $c1$ consists of two graphs: the first is the conjecture $c1$ expressed as in list. 8, and the second is a new graph $cc1$ including all the triples in $c1$ but with their original predicates, excluding $conj : isAConjectualFormOf$, and adding the triple $(cc1, conj : collapses, c1)$.

In our running example, the community has now agreed on Vermeer being the author of the painting (graph `:aa3`), which can be represented as a *settled* conjecture in listing 9.

[4]We mint new predicates by creating URIs with a different prefix for every named graph (in these examples, `conj0001`, `conj0002`, etc.) and the same local part as the original predicate (e.g., `crm:P14_carried_out_by`) to map newly created predicates to the original ones

```
GRAPH :aa3 {
  :painting-pr conj0003:P14_carried_out_by ulan:500032927 # Vermeer
  conj0003:P14_carried_out_by conj:isAConjecturalFormOf crm:P14_carried_out_by }

GRAPH :collapseOfaa3 {
  :painting-pr crm:P14_carried_out_by ulan:500032927 # Vermeer
  :collapseOfaa3 conj:collapses :aa3 .
} :aa3 crm:P4_has_time-span :1860 .
```

Listing 9: Settlement of the attribution of the painting to Vermeer

It is worth noting that we can query conjectural data with plain SPARQL. For instance, a SPARQL query to return all disputed attributions of the painting shown is in listing 10.

```
SELECT DISTINCT ?Conj
WHERE {
  GRAPH ?Conj {
    ?workProduction ?conjpredicate ?author .
    ?conjpredicate conj:isAConjecturalFormOf crm:P14_carried_out_by . }}
```

Listing 10: SPARQL query to retrieve disputed attributions

Conjectures can be expressed as a variant of singleton properties (that we call the *weak* form) or as RDF 1.1 named graphs extension, which we call *strong form*. Strong and weak forms aim to provide two (non alternative) solutions to EWA, preventing technological barriers in their adoption. The full semantics and interpretation of Conjectures is separately documented [25], along with a longer dissertation on the structure of conjectures, and an online parser[5].

5. Discussion and conclusion

In this article we examined solutions for EWA. We showcased benefit and limitations of recent works on uncertainty, provenance, and meta-knowledge with RDF technologies [18, 19, 20, 21, 22]. We consider practical matters as the compatibility to RDF 1.1 semantics, dependency to technologies, and expensiveness (in terms of additional triples). Current proposals for EWA either require technological constraints [18] or expensive mappings in terms of additional triples [1, 4]. We built our solution on top of these proposals to overcome the problem of EWA. We used a real-world scenario to prevent us from seeking for an over-engineered solution. We discarded ontology-dependent solutions [24, 11, 26] since these alone cannot achieve EWA, and we expanded on the definition of Singleton properties [13]. With respect to methods discussed in section 3, the effectiveness of Conjectures is the most representative. In particular, conjectures are the only method that satisfies all the following requirements at the same time: (1) to express without asserting (2) to be RDF compliant with lowest number of additional triples, (3) to make explicit the semantics associated to named graphs, whether these represent undisputed, unsettled (conjectural predicates) or settled (collapsed conjectures) claims. We believe that being able to EWA with Conjectures could be beneficial in a number of tasks, such as information retrieval, disambiguation and recommendation. Future work will address known limitations, such as the definition of the scope of conjectural statements, the official publication of a draft proposal on the semantics of conjectures, a complete evaluation on large datasets like Wikidata, and the extension of existing RDF frameworks and interfaces, like RDFlib, to facilitate its reuse with popular technologies.

[5]http://conjectures.altervista.org/

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