Knowledge Graphs in the Age of Language Models and Neuro-Symbolic AI
A. Salatino et al. (Eds.)

doi:10.3233/SSW240030

What Do We Annotate When We Annotate? Towards a Multi-Level Approach to Semantic Annotations

Carlo Teo PEDRETTI [a,1], Maria Francesca BOCCHI [b,2], Francesca TOMASI [b,3] and Fabio VITALI [b,4]
[a] *La Sapienza University of Rome, Italy*
[b] *University of Bologna, Italy*
ORCiD ID: Carlo Teo Pedretti https://orcid.org/0000-0002-4115-0078, Maria Francesca Bocchi https://orcid.org/0009-0003-0559-0409, Francesca Tomasi https://orcid.org/0000-0002-6631-8607, Fabio Vitali https://orcid.org/0000-0002-7562-5203

Abstract. Purpose: Annotating is considered a 'scholarly primitive' among different fields in the humanities. Nevertheless, the debate on digital annotations has mostly focused on the annotation of textual data, whereas existing models for representing annotations of images still lack sufficient semantic richness to anchor the annotation itself to multiple conceptual levels. We address the challenge of defining a data model to overcome the problem of 'semantic deficit' in this application domain. Finally, we implement an annotation client for testing multi-level semantic annotations.
Methodology: To define a data model for representing digital annotations, we analysed applications which support annotation images through IIIF protocol, focusing on digital representations of palimpsests. We then extended the Web Annotation Data Model by introducing domain standards such as LRMer, CIDOC-CRM, and HiCO. We also validated the model through SPARQL queries corresponding to five competency questions to report on satisfiability. Finally, we developed a prototype annotation client as a plugin for Mirador to evaluate its performances in real-world scenarios.
Findings: The results indicate that our model can effectively disambiguate between a target image and multiple conceptual levels of the entity itself, proving to be decisive in the representation of entities that coexist in the same material item (e.g., palimpsests). Additionally, the model allows users to describe annotations as interpretative acts, incorporating scholarly criteria and multiple viewpoints. An interface plugin enables scholars without technical expertise to create structured annotations that comply with the model.
Value: The proposed approach facilitates the detailed management of the relationships between digital resources and their annotations, improving interoperability and information accessibility in the Semantic Web domain. Future developments will concern further extensions of the model, considering information about versioning, provenance, and authoritativeness of the digital annotations on images, as well as support for meta-annotations and iconological levels of interpretation.

[1] Corresponding author: Carlo Teo Pedretti, carloteo.pedretti@uniroma1.it
[2] Corresponding author: Maria Francesca Bocchi, maria.bocchi4@unibo.it
[3] Corresponding author: Francesca Tomasi, francesca.tomasi@unibo.it
[4] Corresponding author: Fabio Vitali, fabio.vitali@unibo.it

Keywords. Semantic Annotations, Digital Images, Cultural Heritage, Knowledge Representation, Digital Hermeneutics.

1. Introduction

In response to technological advances in digital imaging, an unprecedented number of digital reproductions of cultural heritage artefacts have been made available on the Web. This proliferation of digital content underscored the critical need for a universal standard that could overcome the challenges of information silos and improve the interoperability of these digital assets. The International Image Interoperability Framework[5] (IIIF) emerged as a solution to this issue. Designed to facilitate the widespread sharing, interoperability and integration of digital images, IIIF has seen a progressive uptake by a diverse array of global institutions over the past decade, significantly contributing to the democratisation of access to digital cultural heritage [1]. The possibilities given by the interoperability of images go beyond their mere visualisation, allowing users on the web to interact with them in a more structured way thanks to the integration, within the IIIF protocol, of the Web Annotation Data Model[6] (WADM) and Web Annotation Ontology[7] for producing digital annotations. While scholars gain unprecedented access to manipulation and interaction with digital facsimiles, they must also navigate the complexities introduced by the digital surrogate which now mediates their interaction with the original artefact.

So far, the majority of reflections on digital annotation practices have been undertaken in the field of textual data and connected scholarly needs (i.e., scholarly digital editions) [2], while there is still a lack of proper consideration of the theoretical and technical implications of annotating digital images in the humanities domain.

In the present work, starting from the definition of the concept of annotation and briefly referring to discussions on referentiality and realism in relation to digital images and digital materiality [3], [4], we claim that the ontological and functional distinction between the digital facsimile and the object itself plays a crucial role in defining the practice of annotating images in a digital environment. This is especially relevant to the topic at hand. Indeed, what are we annotating when we annotate a digital facsimile? How does our act of interpretation relate to the underlying information structure? In many cases, there may be a dissonance between what the user and the tool think the annotation refers to, and this could lead to ambiguity or even false claims about the annotated entity, which in turn could prove detrimental to the semantic expressiveness of annotations on the Web.

This paper aims to define a proper data model to describe semantic annotations by anchoring them to multiple conceptual levels, extending the Web Annotation Data Model with domain standards (i.e., LRMer, CIDOC-CRM and HiCO). Firstly, a project implementing digital annotations on IIIF images is analysed, focusing on digital representations of ancient palimpsest, in order to identify a set of modelling choices employing existing ontologies. Employing our data model, we then produced a dataset of annotations and five competency questions in SPARQL language for evaluation purposes. Finally, we developed a prototype annotation client as a plugin for Mirador viewer in order to evaluate our extended model in real-world scenarios.

[5] See https://iiif.io/api/index.html (05.07.2024)
[6] See https://www.w3.org/TR/annotation-model/ (05.07.2024)
[7] See https://www.w3.org/TR/annotation-vocab/ (05.07.2024)

2. Related Works

Annotation is a hermeneutical activity rooted in a wide range of scholarly practices, traditionally associated with biblical studies, exegesis and philology, but also used in informal contexts as a means of contextualising, explaining, commenting on or providing additional information about a text or other data.

Unsworth [5] suggests that annotation could be seen as a *scholarly primitive*, a fundamental scholarly activity deeply embedded in the methodological perspectives of many humanistic approaches to their object of study. Moreover, the purposes of these annotations are diverse: for example, they could be informal comments to help scholars organise and direct their thoughts, or formal links to other research materials, suggesting connections between the edited text and other elements, such as another text or a photograph of a related event [6][7][8]. Moreover, Agosti [9] categorises annotations into three types—*metadata*, *content*, and *dialogue acts*—based on their various functions.

Annotations establish a 'dialogic structure' [10] between two entities by explicitly linking a passage of text or an image to its translation, explanation or another artefact, thus situating and providing insights into the use of the annotated object in a specific context. As such, annotations embody a particular perspective on the object, influenced by the circumstances of their creation, a defined conceptual purpose, and the annotator's scholarly or personal point of view. Zirker and Bauer [11] emphasise the significance of explanatory annotations in hermeneutics, highlighting their role in interpretation and understanding.

Furthermore, as outlined by [10], an annotation always consists of three layers, namely: (1) an *annotatum*, something that is being annotated, the annotation target,(2) an *annotans*, something that is predicated on the *annotatum*, the annotation content, and (3) an *annotator*, who applies the *annotans* to the *annotatum*. Finally, the relationship between the *annotatum* and the *annotans* must be meaningful.

Therefore, an annotation could be described as having a set of minimum requirements, such as:

- *aboutness*: The annotation must contain a reference to the primary content (e.g., a text or other data) that is being commented on or explained. This reference may be explicit (e.g., a page number or citation) or it may be implied by the context of the annotation;
- *separateness*: The annotation must be conceptually separated from the main text or object to which it refers. This separation may be *physical* (e.g., a margin note or caption) or *symbolic* (e.g., a hyperlink). This also reflects the question of the nature of the support in which the annotation is stored (the *host*). Moreover, the support may be *material* (e.g. a sticky note or a relational database) or *immaterial* (e.g., the mental content of the author);
- *informativeness*: The annotation must convey some informational content about the thing to which it refers. The content could range from a comprehensive explanatory note to a remediation of the primary source in another format (e.g., a transcription). As such, *informativeness* does not imply the presence of a structured body of annotation, as in the case of sub-textual annotations such as exclamation marks or underlinings to attract the reader's attention or highlight an element of interest;

- *perspectivism*: The annotation should reflect a certain interpretive choice made by the authors, embodied by the perspective of the *annotator* on the *annotatum*. That is, the fact that an annotation claims something about a particular entity rather than others.

The theoretical analysis of annotation components and their minimum requirements applies equally to both analog and digital annotations. Transitioning from theoretical considerations to the practical activity of creating annotations necessitates further reflection on the concept of the *annotatum*, i.e. the target. Specifically, when annotating a resource, the information contained within the target must be distinguished from the medium that serves as a container for this information. In most cases, what we refer to when creating an annotation is a conceptual entity that often diverges from the actual digital or material resource being annotated.

Bradley [12] further differentiates the target, or *annotatum*, from what he calls the *anchor*, i.e. the referent or the intentional object of the annotation, introducing the concept of *semantic deficit* to explain this distinction. He asserts that benefiting from the informational content of annotations does not necessitate specifying the target as the physical context to which the annotation is attached. Instead, referencing the semantically meaningful mental concept, or anchor, is crucial. This distinction between conceptual and actual annotated resources, coupled with understanding the role of the anchor, is essential for interpreting and creating effective annotations that convey intended meanings across analog and digital domains.

Moreover, the problem of the *semantic deficit* becomes more evident in the context of annotations on digital images, as it comes alongside reflections about the nature of the relation between digital reproduction and the real-world object it embodies. Discussions of referentiality and realism in relation to digital images and digital materiality suggest more nuanced perspectives on the visual nature of the image. These discussions address on one side the notion that digital representations of objects are inferior to, or even "less real" than, real objects. Conversely, they respond to the assumption that an image is a simulation or a one-to-one representation by positing an indexical relationship between the image and the thing it represents. These discussions have highlighted how a digital image is, in important respects, "another thing" that should be examined and comprehended in itself as well as in its own context (i.e., the digital environment) [4].

Bradley himself, by analysing the concept of semantic deficit within the field of digital philology, proposes a concrete solution. Reflecting on scholarly annotation as an individual practice undertaken in the research context, he presents Pliny [13], a software for annotating digital and non-digital resources, mainly texts, but also admitting support for other kinds of media. Bradley recognizes the importance and necessity of an underlying model for annotation and its semantics but doesn't provide us with one, avoiding the implementation of the anchor concept in the Pliny tool. However, the possibility of annotating non-digital resources using a digital application reflects the need he outlined when talking about having references to real-world entities independent of their digital reproductions.

Further research in the field has taken into account the topic of scholarly digital editions and the annotation practices useful to work between the editable and the edition domains. Boot's proposal [6] is quite similar to the one presented in this paper, with one crucial difference. By standing within the edition domain, he proposes a modelization useful to facilitate the annotation anchoring. Our work is, on the contrary,

independent from the annotations' application domain: we model the concept of digital annotation per se as a practice pertaining to scholar's activity in general. By extending FRBRoo and CIDOC-CRM ontology, the SWA Ontology (Scholarly Web Annotation Ontology)[8] proposed by Boot allows users to specify which conceptual level their annotation refers to, enriching the semantics of digital editions, starting from the HTML representation of a work. Therefore, since the majority of digital editions are web-based, annotations concerning their content must follow the Web Annotation Data Model standard to be interoperable and reusable. Boot [2] proposes an implementation of the model into a tool: the Scholarly Web Annotation Client[9], an open-source library embeddable into edition websites and based on the W3C standard for Web Annotations. The application assumes that HTML documents have underlying semantics already expressed and modelled using the SWA Ontology so that the annotation tool is used to refer to the proper conceptual level beside the HTML representation.

In conclusion, Boot proposes that the same approach of modelling different conceptual levels beneath digital representations can prove useful for non-textual resources. This consideration prompts a thorough examination of semantic enrichment with regard to, for instance, images. In order to address the lack of anchors in existing annotation models and to clarify the distinctions between interpretative acts on digital and analog entities, it is evident that semantic technologies prove indispensable. In particular, a model that effectively represents this complexity must address various levels and properties, thereby addressing the gap highlighted by Bradley [12].

3. Modelling Multi-Level Semantic Annotations

From a technical perspective, the World Wide Web Consortium (W3C) has attempted to model human-targeted annotations defining the WADM standard in order to link web resources with human-readable annotations using Semantic Web technologies. WADM is designed for annotating web resources and is employed by the IIIF (International Image Interoperability Framework) protocol for creating annotations on digital images. In accordance with the WADM standard, a digital annotation consists of two fundamental elements: a body and a target. These are referred to as the *annotans* and *annotatum*, respectively. The annotation is formally serialised in the JSON-LD format. In the case of IIIF annotations, the target is always a set of coordinates of a particular fragment or region of the Canvas within a Manifest that contains the image. The body, however, can be any type of resource (or none, depending on the cardinality established by the W3C standard). The WADM documentation permits the inclusion of supplementary information in the annotation's JSON-LD file, primarily metadata concerning the annotation's creation time, the author, and the motivation, which serves to elucidate the intent behind the annotation. However, the model lacks certain semantic enrichments, for which we suggest an extension for a specific use case concerning digital representations of ancient palimpsests.

For comparison, the *e-codices* project[10], which began as a large-scale digitization of Swiss mediaeval and early-modern manuscripts in IIIF format, can be referenced.

[8] See https://github.com/CLARIAH/scholarly-web-annotation-client/blob/master/docs/annotation_ontology.md (05.07.2024)
[9] See https://github.com/CLARIAH/scholarly-web-annotation-client (05.07.2024)
[10] See https://www.e-codices.unifr.ch/en/about/history (05.07.2024)

The project introduced an annotation tool allowing authenticated users to comment and enrich item information collaboratively. However, despite enabling annotations on single pages and adding bibliographic references, it does not support direct image annotations.

In conclusion, the approach proposed in this contribution is the first to integrate semantics within digital image annotations, merging methodologies and approaches from other domains [2].

3.1. Use case

As a use case, we considered the *Vatican Palimpsests*[11] project, part of the broader one named *Thematic Pathways on the Web* developed by the Digital Vatican Library (DigiVatLib)[12] and started in 2016. The massive digitization campaign undertaken on the precious manuscripts preserved by the Vatican Library was followed by an annotation campaign on digital images, which fostered the creation of *Thematic Pathways*, educational resources that help the public rediscover the history of palimpsests through digital images and annotations [14]. Each digital reproduction, for a total of 256 manuscripts, was rendered interoperable using the IIIF protocol. Then, scholars and experts were asked to annotate the IIIF images using the Mirador viewer[13] annotation plugin. All annotations follow WADM, compliant with the IIIF specification.

One of these pathways was dedicated to the study of the phenomenon of palimpsests in ancient Greek and Latin manuscripts and their presentation to the public using digital tools. The term *palimpsest* comes from Greek and means "scraped again": palimpsest manuscripts are therefore manuscripts whose original text has been erased and overwritten with another one. Reasons for adopting such a practice are to be found in the loss of interest in the textual content conveyed by parchment, a very valuable and durable material, which made it suitable for recycling. Various techniques were used to remove the text, from scraping to washing. Over the centuries, philologists developed methods to partially recover erased texts, especially those of great interest that had previously been considered lost. Initially, chemical methods were used to remove text, but these were later found to pose a risk to the manuscripts. In the early 20th century, it was discovered that ultraviolet light could greatly assist in revealing hidden texts. Today, the study of palimpsests relies on advances in photography, especially multispectral imaging, and digital restoration of faded texts is a priority for preservation.

In this paper we choose this collection of palimpsest for two main reasons: 1) the existing digital annotations already contain relevant scientific information from different interpretation criteria (e.g., diplomatic transcription, paleography, chemical testing etc.); 2) the object of the annotation, i.e. the digital reproduction of a palimpsest, has a high level of complexity resulting from the composite nature of the analogue object itself.

Today, the Vatican Library holds one of the most important collections of ancient palimpsests, comprising 550 documents in almost 13 different languages.

[11] See https://spotlight.vatlib.it/palimpsests (05.07.2024)
[12] See https://spotlight.vatlib.it/ (05.07.2024)
[13] See https://projectmirador.org/ (05.07.2024)

The annotations in this scenario can be classified into several categories, including those that elucidate graphical phenomena, provide philological notes, transcribe content, and offer statements about the manuscript's history or content. Technically, annotations adhere to the WADM model and are represented in a dedicated JSON-LD model, which is distinct from the IIIF Manifest.

Upon examination of the annotation's structure and informational content, certain features are discernible:

1. annotations can be subdivided by type or motivation: *philological*, *paleographical*, *transcription*, *comment*;
2. within the same annotation there are multiple bodies to convey different kinds of contents;
3. bodies content can be in form of unstructured data such as text or tags;
4. information about textual levels, concerning the nature of the palimpsest, is conveyed by specific tags in an unstructured manner (labelled *scriptio superior*, *scriptio inferior*, *scriptio infima*) used for browsing and filtering within a dedicated search engine;
5. if present, information about the creator of the annotation is provided in the body as an additional tag.

The current practice of using unstructured tags to indicate textual levels, such as *scriptio superior*, *scriptio inferior* and *scriptio infima*, serves an immediate and practical purpose. However, it falls short in terms of semantic richness and interoperability. While these tags are useful for basic filtering and searching within a dedicated search engine, they do not fully leverage the potential of Linked Data principles. This lack of structure[14] limits the ability of systems to understand the relationships between different annotations and to integrate data across diverse systems and effectively. By adopting a structured approach utilising RDF and LRMer, it is possible to replace imprecise tags with explicit links to defined conceptual levels.

3.2. Competency Questions

Alongside the specification of the annotation's features, we developed six Competency Questions (Table 1) to drive us towards the definition of the model[15]. They were used to evaluate the extended model and to verify if the features identified in annotations were respected and enhanced in the final model.

The CQs have been reviewed through a one-hour unstructured interview by three domain experts having different roles and expertise in ancient or modern philology: one Doctoral student in ancient Greek philology, one Postdoctoral researcher in textual studies, and one Full professor in Italian philology. The main concern that arose during the evaluation was the complexity of assigning conceptual levels to annotations since FRBR model is not something they are used to. Despite that, they all agreed with the necessity of semantically enriching the annotations using an *anchor* pointing at conceptual levels. They've also pointed out that employing semi-automatic techniques to assign conceptual levels to an anchor would be preferable.

[14] See https://spotlight.vatlib.it/palimpsests/catalog/55bb418c-be8a-482d-bd8e-3244d8d33976 as an example of unstructured annotations within the *Vatican Palimpsests* pathway (05.07.2024)
[15] Relevant CQs in SPARQL and their query results are available in the Zenodo repository.

Table 1. Competency questions (Section 4.2) formulated in natural language.

ID	Question
CQ1	Which conceptual level (Work, Expression, Manifestation, Item) is associated with a specific annotation?
CQ2	What annotations reference the underlying texts in a palimpsest (*scriptio inferior*) in the digital reproduction?
CQ3	Which annotations on a palimpsest involve specific scholarly interpretations or methodologies (e.g., paleographical analysis, diplomatic interpretation, chemical testing)?
CQ4	How many annotations with a specific conceptual level have been created by a specific author?
CQ5	Which annotations have the same target but different anchors?
CQ6	What are the different motivations for the annotations, and how many annotations correspond to each motivation?

4. Data Model

In this paper, we introduce Multi-Level Annotation Ontology (MLAO)[16], a data model that leverages the Web Annotation Data Model (WADM) and integrates key domain standards to effectively address and mitigate the issue of *semantic deficit* in digital annotations.

A case in point is the manuscript Vat. gr. 984, which is a distinctive example of a double palimpsest. This manuscript has been reused twice, encompassing three separate intellectual creations. At folios 157v-r, the annotations delineate the oldest text, which is labelled *scriptio infima*. Conversely, annotations associated with the intermediate text employ the tag *scriptio inferior*, and those pertaining to the most recent text use *scriptio superior*. These annotations vary in content, ranging from transcriptions to commentaries, and target multiple areas of the image. The annotations for Vat. gr. 984 were facilitated using the Mirador annotation plugin, which supports various colours and shapes to highlight the diverse nature of the informational content. This content primarily consists of unstructured data and tags. The principal characteristics of the existing annotations on folio 157v-r are presented in Table 2:

Table 2. Characteristics of annotations produced for the Vat.gr.984 manuscripts on IIIF.

Colour	Red	Yellow	Light blue
Shape	Point	Point	Rectangle
Informational content (plain text and tags)	Comment about paleographical aspects. Information about the previous location of the folio reused.	Information about the text content. Information about the original function of the manuscript reused.	Transcription

[16] The ontology is published at http://w3id.org/mlao and also available at https://friendlynihilist.github.io/mlao/.

Furthermore, the thickness of the shape is employed to visually refer to the different texts (thin for the *scriptio inferior*, thick for the *scriptio infima*). The tags associated with the plain text are used to summarise and add further information, such as the one used to identify the creator of the annotation. This overview demonstrates the necessity of linking informational content to appropriate conceptual levels in order to assign scholars' statements to the real-world entities behind the digital image.

As previously indicated, the variety of annotations, subdivided by the type of informational content and treatment of the target, and the specific nature of the object annotated make the Vatican pathway an ideal use case. In light of this specific example and the features identified in Section 4.1, we proceeded to model MLAO by reusing existing ontologies. The data model representation can be seen in Figure 1. The primary objective of this work is therefore to extend the WADM through the integration of the Library Reference Model Ontology[17] (LRMer) and the implementation of its integrated FRBRoo model. Moreover, some elements of the Historical Context Ontology[18] (HiCO) are reused in order to represent the context of hermeneutical activities performed by scholars while generating new information (i.e. an interpretation act [9]), enabling features such as criterion and type of cited sources. CIDOC-CRM and PROV-O standards are also considered to specify entity relationships and provenance. The following sections will present new classes and properties described in MLAO, as well as the existing ontologies which have been reused. Each section will be accompanied by a concrete application of the model to a real-world annotation. All relevant files can be found in the Github repository[19].

[17] See https://www.cidoc-crm.org/frbroo/sites/default/files/LRMoo_V0.9.6.pdf. (05.07.2024)
LRMer is developed from FRBRoo version 2.4, harmonising decisions made in IFLA Library Reference Model.
[18] See https://marilenadaquino.github.io/hico/ (05.07.2024)
[19] https://anonymous.4open.science/r/mirador-multi-level-annotations-3079

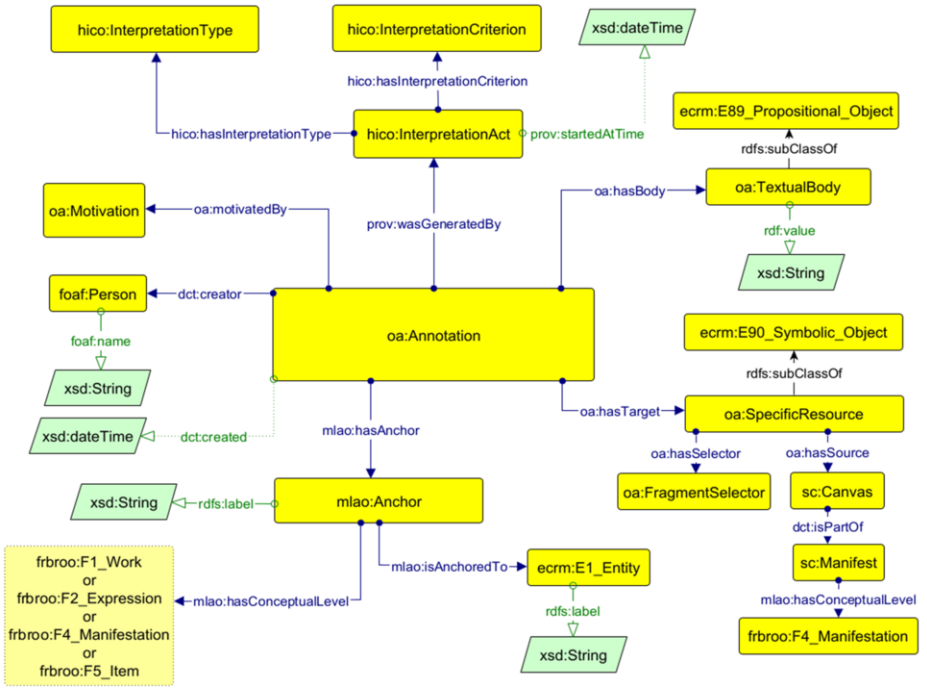

Figure 1. The formal model for the Multi-Level Annotation Ontology (MLAO) represents an extension of the Web Annotation Data Model.

4.1 *Annotation*

Following the Web Annotation Ontology, the annotation itself is an instance of the class `oa:Annotation` with the following properties and object classes:

- The annotation is connected through the `oa:hasTarget` property to a target (i.e. the *annotatum*), represented by an instance of the `oa:SpecificResource` class, which identifies part of another resource (referenced with `oa:hasSource`), e.g. a particular representation of a resource, a resource with styling hints for renders, or any combination of these. In the case of digital images or facsimile using IIIF, the source is the Canvas which conveys the image, while the property `oa:hasSelector` is connected to a `oa:FragmentSelector` instance which describes the set of coordinates of the segment or region of interest within the source resource.
- The annotation is connected through the `oa:hasBody` property to a body represented as an instance of the `oa:TextualBody` class. The body (i.e., the *annotans*) contains the actual content of the annotation, e.g. unstructured textual data such as a comment, a tag, a transcription etc.
- An instance of the `oa:Motivation` class is linked with the annotation through the `oa:hasMotivation` object property, and used to record intents of the annotator for the creation of the Annotation (e.g. commenting, tagging, transcribing etc).

- By employing FOAF and DC Terms, the author of the annotation is represented as an instance of the `foaf:Person` class and connected through `dct:creator` property with the annotation itself.

For instance, the graph in Figure 2 shows an example of annotation modelled by using MLAO data model. The annotation, curated by a person, provides a transcription of the text contained in the *scriptio infima*[20] highlighted by a rectangular shape on the IIIF canvas which contains the digital image. Therefore, the annotation is an instance of the class `oa:Annotation`, the curator responsible for the creation of the annotation is specified by the property `dct:creator` and pertains to the class `foaf:Person`. The transcription is the body of the annotation, connected to it by the property `oa:hasBody`, and is unstructured text whose class is `oa:TextualBody`. The target of the annotation, expressed by the property `oa:hasTarget`, is an instance of the class `oa:SpecificResource` and its source, associated by the property `oa:hasSource`, is the IIIF canvas to which the image is associated; moreover, to specify the portion of image where the *scriptio infima* stands, the property of the target `oa:FragmentSelector` is used to get the coordinates of the region highlighted by the rectangular shape.

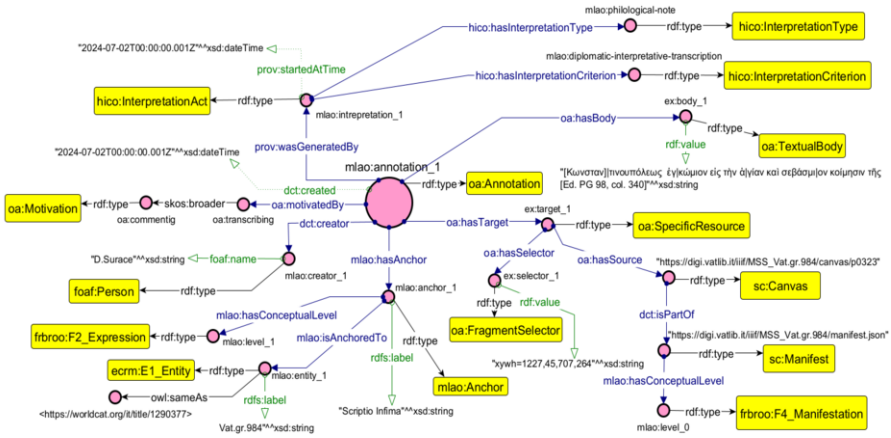

Figure 2. An example of Multi-Level Annotation Ontology (MLAO) use: the modelization of an annotation within the Vat.gr.984 IIIF manifest.

4.2 Conceptual Level

An anchor is then represented as an instance of the `mlao:Anchor` class and connected with an instance of the `oa:Annotation` class by employing the `mlao:hasAnchor` property. The `mlao:Anchor` class describes the intentional object or referent of the annotation, which can be different from the target itself.

The instance of the Anchor is then linked through the `mlao:hasConceptualLevel` object property to an instance of type `frbroo:F1_Work`, `frbroo:F2_Expression`,

[20] The text concerns the title and the beginning of Homily I by Germanus Constantinopolitanus on the Feast of the Dormition of Mary, as transmitted in the edition PG 98.

frbroo:F4_Manifestation or frbroo:F5_Item, describing the FRBR conceptual level. Finally, the Anchor is linked through the mlao:isAnchoredTo object property to an instance of the work it refers to which represents its real-world counterpart. By associating the annotation with a referent in the "real world" (an URI that describes an entity) and with an area in a piece of media that captured it, e.g. the target, we reduce the *semantic deficit* that separates the annotation from the thing being annotated and improve the computer's ability to use the link in a more general manner.

For example, in the annotation modelled in Figure 2 the creator annotates a specific portion of the image to convey content, namely the transcription, which does not refer to the image itself but to another entity. In fact, the transcription does not concern the digital image itself but rather another kind of entity connected to the manuscript Vat. gr. 984 manuscript, which is an Expression according to the FRBR levels. Consequently, the annotation is linked to an anchor by the property mlao:hasAnchor. This allows the annotator to specify the conceptual level to which they are referring. Finally, the instance of mlao:Anchor class has two properties, mlao:hasConceptualLevel and mlao:isAnchoredTo, which are employed to specify the frbroo:F2_Expression and the real-world entity, respectively. The latter is represented by the URI that denotes the manuscript Vat. gr. 984, which is linked to the digital image.

4.3 Interpretation Context

In addition to representing basic annotation information, we employed HiCO and PROV-O to model annotation as the result of an interpretation act. In particular, HiCO addresses features characterising hermeneutical activities performed by scholars while generating new information (i.e. an interpretation act). It allows to represent and reason on reliability of argumentations around attributions, by evaluating features such as motivations, types of cited sources or criteria, dates, relations with other claims (e.g. agreement/disagreement). Specifically, historical context regards events and situations that are part of the life-cycle of cultural heritage objects.

The interpretation act that generates an annotation is represented by employing the class hico:InterpretationAct. In this context, an interpretation act is a situation in which a claim about an event is linked (prov:wasGeneratedBy) to all the pieces of information necessary to validate the claim.

Individuals of hico:InterpretationAct class are also defined through two the hico:hasInterpretationType object property and the hico:hasInterpretationCriterion object property. To state an arbitrary classification of the interpretation, e.g. diplomatic interpretative transcription or an authorship attribution, hico:InterpretationType class is employed and connected to the interpretation act through the use of the hico:hasInterpretationType property.

Finally, a brief explanation of the criteria motivating the statement, e.g. primary sources for a translation or scholar's attribution, is specified through hico:InterpretationCriterion class and connected to the interpretation act by using hico:hasInterpretationCriterion property [15].

Continuing with the example in Figure 2, the annotation concerning a transcription is a philological interpretation of the text in the *scriptio infima* obtained by a diplomatic-interpretative approach. Therefore, the annotation results as a product of a

`hico:InterpretationAct` instance, connected to it by the property `prov:wasGeneratedBy`, which has a `hico:InterpretationType` of philological note and a `hico:InterpretationCriterion` of diplomatic-interpretative type.

4.4 Manifest Information

For our purposes the IIIF Manifest is considered a digital manifestation (`frbroo:F4_Manifestation`) of an analogue object according to [16]. Since this distinction by FRBR levels exists between the entire objects, we can say that the same distinction is reflected in the practice of annotating contents. In other words, the classification by FRBR levels applied to the digital images with respect to the analogue object can be used to establish at which FRBR level an annotation, produced in the digital environment, refers to. Therefore, in our extended model we added a `mlao:hasConceptualLevel` property also to connect the IIIF Manifest to the corresponding instance having FRBR level `frbroo:F4_Manifestation`. While annotations made in IIIF are always anchored to the Manifest, in the context of LRMer they can indeed be made in relation to a particular Item rather than a Work or an Expression of it: e.g., an Item could have specific physical features (like annotations, damages, unique features) useful to be pointed out also on the digital support, or a scholar might want to make an annotation of the intellectual content or refer to a translated text of that particular manuscript, referring in this case to a higher level than the Manifestation one.

In the annotation example, the target is the IIIF Canvas of the IIIF Manifest which is the digital Manifestation, according to FRBR model, of the Vat.gr.984 palimpsest manuscript preserved by the Vatican Library. Therefore, the canvas source of the target is an instance of the class `sc:Canvas` and its relation with the manifest is expressed using `dct:isPartOf`. Then, the manifest representing Vat.gr.984 is an instance of the class `sc:Manifest` and is connected to another instance of class `frbroo:F4_Manifestation` by the property `mlao:hasConceptualLevel`.

4.5 Validation

Based on the expanded model outlined in the previous section and an analysis of the manuscript's annotations, we have serialised in RDF five specific annotations. Among these, the annotation shown in Figure 2 was selected to highlight the key features we aimed to model. Subsequently, four additional annotations, which were already present in the project, were selected to test the model's applicability across different contexts.

The resulting knowledge graph was validated against competency questions to ensure it adheres to domain requirements. All relevant files can be found in the Zenodo[21] repository. The conceptual model is transformed into SHACL constraints to ensure data consistency and structural integrity. SHACL shapes graphs are utilized to validate each entity against the proposed ontology, leveraging tools like the RDFshape web tool for execution. The SHACL constraints and ShapesGraphs can be found in the repository.

[21] https://doi.org/10.5281/zenodo.12680754

5. Multi-Level Annotation Client

To evaluate the relevance of the MLAO model we also developed a prototype annotation client (Figure 3) as a plugin for Mirador viewer, an open-source multi-window image viewing platform which supports IIIF API, which promotes a standardised method of describing and delivering images over the web. This compatibility with IIIF was crucial, as it ensures that our extended annotation functionalities would be interoperable across different institutional repositories that also adopt IIIF standards. Moreover, Mirador's existing infrastructure includes a modular design that allows for significant customization and extension without disrupting its core functionalities. This flexibility made it an ideal candidate for adapting to the specific needs of annotating palimpsests, as it could be tailored to incorporate multi-level semantic annotations.

Figure 3. A screenshot of the Mirador Multi-Level Annotation plugin prototype developed to evaluate the MLAO data model in a real-world scenario. Due to copyright restrictions, this image has been blurred.

The prototype is built as an extension of the existing Mirador Annotation plugin and shares its core features and user interface, while incorporating the possibility to produce annotations according to classes and properties specified in the extended data model. In particular, this extension was designed to support multi-level semantic annotations and integrate domain standards such as LRMer, CIDOC-CRM, and HiCO into the JSON-LD model produced through the Mirador annotator.

We decided to develop the implementation starting from the same use case considered above so that it would be possible to test the process of creating annotations on palimpsests following the new requirements.

The architectural design of the Mirador extension was aimed at integrating a dynamic data model capable of supporting additional semantic layers. These enhancements were conceptualised to allow users to interact with multiple levels of semantic annotations directly through the Mirador interface.

From a User Interface perspective, five autocomplete select dropdowns were integrated, allowing users to select from a taxonomy or create new entries on the fly.

These dropdowns manage various aspects of the annotations such as the selection of the Conceptual Level, Anchor, Referenced Entity, Interpretation Criterion, and Editor.

The custom dropdowns dynamically inject extended metadata into the JSON-LD output produced by Mirador. This approach ensures that the enhanced data model integrates with the existing infrastructure without disrupting the user experience.

The implementation phase involved using React as a framework for the front-end development of the interface and the json-ld[22] processor library to convert JSON-LD into RDF serialisations. The dropdown menus in the user interface were designed to perform CRUD operations on a Blazegraph triplestore via SPARQL and to populate these dropdowns with data retrieved using SPARQL queries. This setup ensures that the annotations are not only stored persistently in a dedicated triple store but are also fully interoperable with other Semantic Web technologies.

Finally, after having manually created five annotations with different requirements, SPARQL queries based on the Competency Questions were employed to validate the adherence of the model to the extended data schema, specifically testing for the accurate serialisation of multi-level semantic annotations during the annotation process.

6. Conclusions

The solution presented here addresses the problem of *semantic deficit* by proposing MLAO: a simple, yet reusable and interoperable ontology and Web Annotation Data Model extension, which includes domain standards such as CIDOC-CRM and LRMer. Moreover, by extending the already existing Mirador annotation plugin, a prototype annotation client has been developed in order to support multi-level annotations and evaluate the MLAO data model in a real-world scenario. The multi-level annotation plugin could also be easily integrated into any instance of Mirador viewer. Finally, annotations are converted into RDF and stored in a dedicated triple store in order to be fully interoperable with other Semantic Web technologies and available for querying, browsing and filtering purposes.

Nevertheless, multi-layered annotations raise problems regarding information visualisation of complex and qualitative data: for this purpose, From Data To Wisdom (FDTW) [17] is an interesting project to keep in mind when working on image visualisation based on annotated content. Also, other extensions concerning provenance and versioning could be integrated in conjunction with the HiCO ontology, specifically to integrate metadata about the *annotator* and describe the diachronic and synchronous relations among interpretation acts (i.e. annotations). Future developments will concern further extensions of the model, considering information about versioning, provenance, and authoritativeness of the digital annotations on images, as well as support for meta-annotations and iconological levels of interpretation. Taking into account the results of the expert reviews upon CQs, future work will focus on simplifying the interaction between annotators and the interface, providing semi-automatic ways to annotate as well as controlled vocabularies for types.

[22] https://github.com/digitalbazaar/jsonld.js

References

[1] Snydman S, Sanderson R, Cramer T. The International Image Interoperability Framework (IIIF): A community & technology approach for web-based images. Arch Conf. 2015 May 1;2015, https://purl.stanford.edu/df650pk4327

[2] Koolen M, Boot P. Facilitating Reusable Third-Party Annotations in Digital Editions. In: Facilitating Reusable Third-Party Annotations in Digital Editions [Internet]. De Gruyter; 2020 [cited 2022 Nov 30]. p. 177–200, doi:10.1515/9783110689112-009

[3] Crane T. Looking up and looking down [Internet]. 2017 [cited 2024 Jan 30]. Available from: https://resources.digirati.com/iiif/an-introduction-to-iiif/looking-up-and-down.html

[4] Lied LI, Marguerat A. Digitization and Manuscripts as Visual Objects: Reflections from a Media Studies Perspective. In: Hamidović D, Clivaz C, Savant SB, editors. Ancient Manuscripts in Digital Culture [Internet]. Brill; 2019 [cited 2024 Feb 5]. p. 15–29. (Visualisation, Data Mining, Communication; vol. 3). Available from: https://www.jstor.org/stable/10.1163/j.ctvrxk44t.6

[5] Unsworth J. Scholarly Primitives: What Methods Do Humanities Researchers Have in Common, and How Might Our Tools Reflect This. 2000.

[6] Boot P, Koolen M. A FRBROO-based annotation ontology for digital editing. In: "Data in Digital Humanities" - the European Association for Digital Humanities 2018 Conference. 2018.

[7] Rehm G. Observations on Annotations. In: Annotations in Scholarly Editions and Research: Functions, Differentiation, Systematization [Internet]. De Gruyter; 2020 [cited 2022 Nov 30]. p. 299–324, doi:10.1515/9783110689112-014

[8] Marshall CC. Annotation: from paper books to the digital library. In: Proceedings of the second ACM international conference on Digital libraries - DL '97 [Internet]. Philadelphia, Pennsylvania, United States: ACM Press; 1997 [cited 2024 Apr 5]. p. 131–40. Available from: http://portal.acm.org/citation.cfm?doid=263690.263806

[9] Agosti M, Ferro N, Frommholz I, Thiel U. Annotations in Digital Libraries and Collaboratories – Facets, Models and Usage. In 2004. p. 244–55, doi:10.1007/978-3-540-30230-8_23

[10] Boot P. Mesotext: Digitised Emblems, Modelled Annotations and Humanities Scholarship. Amsterdam University Press; 2009. 288 p.

[11] Elleström L. An interdisciplinary model: Bridging the gap between image and metaphor through cross-modal iconicity. In: Zirker A, Bauer M, Fischer O, Ljungberg C, editors. Dimensions of Iconicity [Internet]. John Benjamins Publishing Company; 2017 [cited 2024 Feb 2]. p. 167–90. (Iconicity in Language and Literature). Available from: https://benjamins.com/catalog/ill.15.10ell

[12] Bradley J. Towards a Richer Sense of Digital Annotation: Moving Beyond a "Media" Orientation of the Annotation of Digital Objects. Digit Humanit Q. 2012 Oct 12;006(2).

[13] Bradley J. Thinking about interpretation: Pliny and scholarship in the humanities. Lit Linguist Comput. 2008 Sep 5;23, doi:10.1093/llc/fqn021

[14] Manoni P. The Mellon Project at the Vatican Library : WEB thematic pathways of Medieval manuscripts from the Vatican collections using International Image Interoperability Framework. Mellon Proj Vatican Libr WEB Themat Pathw Mediev Manuscr Vatican Collect Using Int Image Interoperability Framew. 2019;265–81.

[15] Daquino M, Tomasi F. Historical Context Ontology (HiCO): A Conceptual Model for Describing Context Information of Cultural Heritage Objects. In: Garoufallou E, Hartley RJ, Gaitanou P, editors. Metadata and Semantics Research. Cham: Springer International Publishing; 2015. p. 424–36, doi:10.1007/978-3-319-24129-6_37

[16] Castelli D, Pagano P. OpenDLib: A Digital Library Service System. In: Agosti M, Thanos C, editors. Research and Advanced Technology for Digital Libraries. Berlin, Heidelberg: Springer; 2002. p. 292–308, doi:10.1007/3-540-45747-X_22

[17] Rodighiero D, Romele A, Rubio JH, Pedro C, Azzi M, Uboldi G. Advanced Interface Design for IIIF. A Digital Tool to Explore Image Collections at Different Scales. Um Digit. 2023 Dec 14;(16):167–92, doi:10.6092/issn.2532-8816/17230