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Integration of Existing Multimedia Metadata Formats and Metadata Standards in the M3O

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Abstract. With the Multimedia Metadata Ontology (M3O), we have developed a sophisticated model for representing among others the annotation, decomposition, and provenance of multimedia metadata. The goal of the M3O is to integrate the existing metadata standards and metadata formats rather than replacing them. To this end, the M3O provides a scaffold needed to represent multimedia metadata. Being an abstract model for multimedia metadata, it is not straightforward how to use and specialize the M3O for concrete application requirements and existing metadata formats and metadata standards.

In this paper, we present a step-by-step alignment method describing how to integrate and leverage existing multimedia metadata standards and metadata formats in the M3O in order to use them in a concrete application. We demonstrate our approach by integrating three existing metadata models: the Core Ontology on Multimedia (COMM), which is a formalization of the multimedia metadata standard MPEG-7, the Ontology for Media Resource of the W3C, and the widely known industry standard EXIF for image metadata.

1 Introduction

A densely populated jungle with a myriad of partially competing species of different colors and size—this might be a good characterization of today's world of multimedia metadata formats and metadata standards. Looking at the existing metadata models like [1–5] and metadata standards such as [6–10], we find it hard to decide which of them to use in a complex multimedia application. They focus on different media types, are very generic or designed for a specific application domain, and overlap in the functionality provided.

However, building a complex multimedia application often requires using several of these standards *together*, e.g., when different tools have to be integrated along the media production process [11]. The integration among tools requires interoperability of different metadata standards, which is a requirement that is not sufficiently satisfied by existing formats and standards. With XMP [7], there exists an important initiative to enable interoperability along the production process of images. Nevertheless, this work is limited with respect to the functionality provided and focuses on the media type image only [12]. Overall, the

XMP initiative is an important step but more is required to facilitate multimedia metadata interoperability along the media production process.

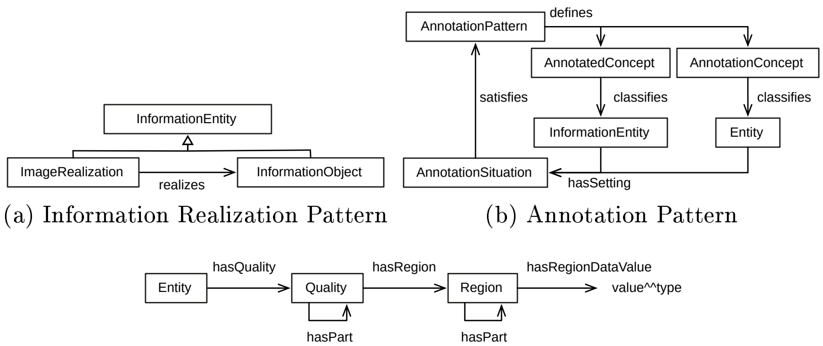
To solve this problem, we have developed the Multimedia Metadata Ontology (M3O) [12]. The M3O is a sophisticated model for representing among others the annotation, decomposition, and provenance of multimedia content and multimedia metadata. The goal of the M3O is to provide a framework for the integration of existing metadata formats and metadata standards rather than replacing them. The M3O bases on a foundational ontology and by this inherits its rich axiomatization. It follows a pattern-based ontology design approach, which allows the M3O to arrange the different functionalities for representing multimedia metadata into smaller, modular, and reusable units.

However, the M3O was designed as an abstract model providing a scaffold for representing arbitrary multimedia metadata. As such, the integration of existing standards is not straightforward, and we are confronted with a gap between the formal model and its application in concrete domains. In this paper, we fill this gap and present a step-by-step alignment method describing how to integrate existing formats and standards for multimedia metadata and the M3O. We describe the tasks that have to be performed for this integration and apply the integrated ontology to a concrete modeling task. We demonstrate this integration at the example of the Core Ontology on Multimedia (COMM) [2], which is a formalization of the multimedia metadata standard MPEG-7 [9], the recently released Ontology for Media Resource [13] of the W3C, and the widely known and adopted industry standard EXIF [6] for image metadata.

2 Introduction to the Multimedia Metadata Ontology

The Multimedia Metadata Ontology (M3O) [12] provides a generic modeling framework to integrate existing multimedia metadata formats and metadata standards. The M3O is modeled as a highly axiomatized core ontology basing on the foundational ontology DOLCE+DnS Ultralight (DUL) [14]. DUL provides a philosophically grounded conceptualization of the most generic concepts such as objects, events, and information. The axiomatization is formulated in Description Logics [15].

The M3O follows a pattern-based approach to ontology design. Each pattern is focused on modeling a specific and clearly identified aspect of the domain. From an analysis of existing multimedia metadata formats and metadata standards [12], we have identified six patterns required to express the metadata for multimedia content. These patterns model the basic structural elements of existing metadata models and are the Decomposition Pattern, Annotation Pattern, Information Realization Pattern, Data Value Pattern for representing complex values, Collection Pattern, and Provenance Pattern. Basing a model like the M3O on ontology design patterns ensures a high degree of modularity and extensibility, while at the same time a high degree of axiomatization and thus semantic precision is retained. In order to realize a specific multimedia metadata format or metadata standard in M3O, these patterns need to be specialized. In the following, we discuss three patterns of the M3O in more detail, namely the *Information Realization Pattern*, *Annotation Pattern*, and *Data Value Pattern*, which we will mainly refer to in the upcoming sections.



(a) Information Realization Pattern (b) Annotation Pattern

(c) Data Value Pattern

Fig. 1: Three Example Patterns of the Multimedia Metadata Ontology (M3O)

Information Realization The information realization pattern in Figure 1a models the distinction between information objects and information realizations [14]. Consider a digital image that is stored on the hard disk in several formats and resolutions. An information object represents the image as an abstract *concept* or *idea*, namely the information object of an image. Different files may *realize* this same abstract idea. As shown in Figure 1a, the pattern consists of the InformationRealization that is connected to the InformationObject by the realizes relation. Both are subconcepts of InformationEntity, which allows treating information in a general sense as we will see in the Annotation Pattern.

Annotation Pattern Annotations are understood in the M3O as the attachment of metadata to an information entity. Metadata comes in various forms such as low-level descriptors obtained by automatic methods, non-visual information covering authorship or technical details, or semantic annotation aiming at a formal and machine-understandable representation of the contents. Our Annotation Pattern models the basic structure that underlies all types of annotation. This allows for assigning arbitrary annotations to information entities while providing the means for modeling provenance and context. In Figure 1b, we see that an annotation is not modeled as a direct relationship between some media item and an annotation. It is defined by a more complex structure, which is inherited by the Descriptions and Situations Pattern of DUL. Basically, a Descriptions and Situations Pattern is two-layered. The *Description* defines the structure, in this case of an annotation, which contains some entity that is annotated and some entity that represents the metadata. The *Situation* contains the concrete entities for which we want to express the annotation. The pattern allows us to add further concepts and entities into the *context* of an annotation, e.g., expressing provenance or confidence information. On the top half, we see that the AnnotationPattern defines an AnnotatedConcept and an AnnotationConcept. The AnnotatedConcept classifies an InformationEntity and thus expresses that the information entity is the subject of the annotation. The AnnotationConcept classifies some Entity, which identifies this entity as the annotation or metadata. The entity can be some complex data value, e.g., representing some low-level features represented using the Data Value Pattern, but also some concept located in a domain ontology such as DBpedia[1]. All the entities have as setting the AnnotationSituation, which satisfies the AnnotationPattern.

Data Value Pattern In ontologies we mainly use abstract concepts and clearly identifiable individuals to represent data. However, we also need the means to represent concrete data values such as strings and numerical values. In DUL, there exists the concept Quality in order to represent attributes of an Entity, i.e., attributes that only exist together with the Entity. Regions are used to represent the values of an Quality and the data space they come from. The Data Value Pattern depicted in Figure 1c assigns a concrete data value to an attribute of that entity. The attribute is represented by the concept Quality and is connected to the Entity by the hasQuality property. The Quality is connected to a Region by the hasRegion relation. The Region models the data space the value comes from. We attach the concrete value to the Region using the relation hasRegionDataValue. The data value is encoded using typed literals, i.e., the datatype can be specified using XML Schema Datatypes [16].

3 Alignment Method

This section introduces our method for aligning multimedia standards and multimedia formats with the M3O. The method has been derived from our experiences applying and specializing the M3O for three existing multimedia formats and standards, namely COMM [2], the Ontology for Media Resource [13], and EXIF [6].

In contrast to automatic, adaptive, or machine learning approaches for ontology alignment [17–19], we conduct a pure manual alignment, as only a manual alignment ensures the high quality of the integration and minimizes ambiguities and imprecise matching. We consider the time and effort for manual alignment manageable, as we assume that each metadata format or standard has to be aligned only once and that updates to the integrated formats or standards will be infrequent and mostly incremental.

For the alignment, we propose an iterative four-step alignment method. In each iteration, we consecutively evolve the alignment of the format or standard

[1] `http://dbpedia.org/`

with the M3O. Following an iterative approach, we are able to identify, analyze, and flexibly react to problems and challenges encountered during previous iterations of the alignment.

Each iteration consists of four steps. The first step targets the understanding of the format or standard to be integrated. The second step reorders concepts into coherent groups. The third step maps concepts and structure with the M3O. The fourth step proves and documents the validity of the alignment, and finalizes the iteration.

To introduce our alignment method, we proceed as follows: For each step, we first outline the goals and provide a brief summarization. Subsequently, we describe the core tasks to be performed within the step, and provide concrete examples that show its relevance and application for concrete ontologies.

3.1 Step 1: Understanding

Summary A precise understanding of the metadata format or standard to be integrated is an import prerequisite for aligning it with the M3O. Consequently, the first step of alignment is an in-depth analysis of the structure and core concepts of the model at hand. While this advise may seem obvious, this is a task easily underestimated and problems neglected at an early stage can cause time-consuming problems along the integration process. Additional documentation, if available, will help to (re-)produce the overall structure not explicitly expressed in the formal specification.

Detailed Description and Examples In general, we have found three distinct modeling approaches to be very common for multimedia metadata formats and metadata standards.

Pattern-based Pattern-based ontologies, e.g., COMM, provide a high degree of axiomatization and structure in a formal and precise way. Through our analysis, we understand the patterns used and the functionality they provide. This allows us to compare the patterns of the ontology to be integrated with those provided by the M3O.

Predicate-centric In a predicate-centric approach, as followed e.g. by the Ontology for Media Resource, the ontology is mainly specified through a set of properties. Such a model offers very little structure in a machine readable format, e.g., in terms of conceptual relations between properties. However, by analyzing the documentation, we infer additional information about intended groupings of properties and the structural composition of the format or standard to be integrated.

Legacy Models Other formats and standards have not yet been semantified at all. By analyzing the concepts and relations expressed in the specification of the format, we decide how the core concepts can be expressed in a formal and precise way using the M3O.

Ambiguities that are found during the initial analysis are discussed at this point. It is not our intention to revise all modeling decisions made for the ontology to be integrated. However, we consider the alignment a good opportunity to correct some of the *bad smells* [20] discovered. Once we have reached a sufficient understanding of the format or standard to be integrated, we proceed with the grouping step.

3.2 Step 2: Grouping

Summary Ontologies should provide structural information on the relation and groupings of concepts it defines. However, although many formats or standards provide this information in their documentation, the information is sometimes lost when the models are transformed to an ontology. By using the original specifications and documentations, we are able to preserve and recreate this information grouping, and provide them through formal specification in the aligned ontology.

Detailed Description and Examples In principle, we distinguish three forms of available grouping information:

Explicit Grouping Pattern-based models provide an explicit grouping of concepts into coherent patterns, often accompanied by a rich axiomatization on how they relate. As an example, the definition of a color histogram annotation in COMM specifies a ColorQuantizationComponentDescriptorParameter that groups the concepts ColorComponent and NumberOfBinsPerComponent.

Implicit Grouping For other metadata models grouping information may not be explicitly represented. This is often the case with predicate-centric approaches, e.g., the Ontology on Media Resource. In these cases, we refer to the textual documentation in order to (re-)construct the implicit groupings of the properties or classes. As an example, the documentation of the Ontology on Media Resource offers a textual description on the grouping of its properties, e.g., in terms of identification or creation. However, this information is not accessible in the RDF representation as proposed by the W3C. By defining the appropriate axioms, we have appended the implicit grouping information in a formal and explicit way, e.g., by stating that an IdentificationAnnotation hasPart some TitleAnnotation, LanguageAnnotation, and LocatorAnnotation.

Recovery of Groupings In other cases grouping information is lost when transferring multimedia formats or standards to RDF. For example the EXIF metadata standard provides textual descriptions about groupings, e.g., in terms of pixel composition and geo location. However, this distinction got lost in the adaption to an RDF schema [21]. For the alignment with the M3O, we have reconstructed the grouping information and appended it to the model in a formal and explicit way.

Once we have provided all relevant grouping relations through a formal specification, we continue with the mapping step.

3.3 Step 3: Mapping

Summary This step achieves the mapping of the ontology's concepts and structure to the scaffold provided by the M3O. The goal of this step is to create a working ontology, which, after validation, can be published or used as basis for further iterations.

Detailed Description and Examples For the alignment we follow a sequence of the following three steps:

1. **Mapping of Concepts** If some superclass of the concept to be aligned is present in both ontologies, direct mapping of concepts is feasible. This is mainly the case for ontologies that share the same foundation, e.g., COMM and the M3O, which both base on the DUL foundational ontology. All axioms of the aligned concepts are preserved as long as they are applicable through the M3O. If a concept is not applicable in the M3O, we align all dependent subclasses and references to the nearest matching M3O concept. As an example, the COMM DigitalData concept, which is a subclass of the DUL InformationObject, was removed during the alignment. The dangling dependencies and references have been resolved by subclassing or referencing the InformationObject instead.
2. **Structural Mapping** For structural mapping, we consider the functionality of the pattern or structure to be mapped. If a pattern or structure offers the same or an equal functionality than a pattern of the M3O, we can replace the pattern. By adapting the M3O pattern, we are often able to express the same functionality using a more generic approach. As an example, COMM proposes the Digital Data Pattern to express data values in a digital domain. A similar functionality is provided by the M3O Data Value Pattern, which expresses data values through the generic concepts of Quality and Region. The COMM Digital Data Pattern can be considered a special case of expressing data values and therefor has been replaced using the M3O Data Value Pattern instead.
   In the same manner, we simplify the structural composition of the existing model by merging multiple concepts and patterns that offer the same or an equal functionality. As an example, COMM defines three annotation patterns. Each deals with a different aspect of multimedia annotation, although they vary only slightly in their structural composition. We have aligned those patterns by adapting the M3O Annotation Pattern. The domain specific concepts that result from the separation into three distinct patterns have been preserved by subclassing the corresponding concepts of the M3O Annotation Pattern. This simplifies the structure of the model, while also preserving the original functionality.
3. **Removing Unnecessary Concepts** We finalize the mapping step by cleaning up unused dependencies from the ontology files. Concepts that either have no further relevance for the target context or are sufficiently covered by the M3O are removed at this point. An example, the COMM

AnnotatedMediaRole offers an equal functionality as the M3O AnnotatedInformationRealizationConcept. We therefore have removed COMM's AnnoatedMediaRole and replaced any formal relation that involves the concept.

3.4 Step 4: Validation and Documentation

In each iteration of the alignment process, we need to check the consistency of the resulting ontology. This can be done by using a reasoner like Fact++[2] or Pellet[3]. Any problem encountered during the alignment can be resolved by reiterating the four steps of the alignment method. After proving the consistency of the resulting ontology, we finalize the process by documenting all major decisions and adjustments made during the alignment.

3.5 Summary

In this section, we have proposed a four-step method for aligning multimedia metadata formats and multimedia metadata standards with the M3O. In the following Sections 4-6, we demonstrate the alignment of three existing formats and standards by applying our method. They are the Core Ontology on Multimedia, the Ontology for Media Resource, and the EXIF metadata standard.

4 Example 1: Core Ontology on Multimedia (COMM)

The Core Ontology on Multimedia (COMM) [2] is a formal specification of the MPEG-7 metadata standard [9]. In contrast to other approaches to modeling MPEG-7 as an ontology COMM is not designed as a one-to-one mapping, but provides a set of patterns that cover the core and repetitive building blocks of MPEG-7. The central challenge of the alignment of COMM and M3O is understanding the patterns of COMM and mapping them to the scaffold provided by the M3O. This section describes the experiences and challenges of aligning COMM and the M3O, using the four-step alignment method proposed above.

4.1 Application of the Alignment Method

Understanding COMM follows a pattern-based approach and builds on the DUL foundational ontology. Some of the core patterns, i.e., the Descriptions and Situations Pattern, are shared between COMM and the M3O. Others, e.g., the Digital Data Pattern, form major structural differences.

COMM defines five structural patterns, namely the Content Annotation Pattern, Media Annotation Pattern, and Semantic Annotation Pattern for media annotation, the Decomposition Pattern for media (de-)composition, and the Digital Data Pattern, which expresses annotations in a digital domain. Domain

[2] `http://owl.man.ac.uk/factplusplus/`

[3] `http://clarkparsia.com/pellet/`

specific knowledge is separated from the core concepts and defined in separate ontologies, e.g., concepts concerning annotation of visual entities are defined in the *visual ontology*.

Some ambiguities that were found in the initial analysis have been resolved at this point. As an example, COMM specifies concepts such as NumberOfBinsPerComponent that are specialization of both Parameter and Region. While this may not be syntactically incorrect, it violates the DnS pattern of DUL. In the DnS pattern, a Parameter parametrizes a Region. Thus, these two concepts should not have common sub-concepts. To solve this problem, we have removed the superclass relations to the Parameter concept and introduced a parametrizes relation. For example, COMM specified a ColorComponent and NumberOfBinsPerComponent, which are subclasses of both the ColorQuantizationComponentDescriptorParameter and the Region concept. We have removed the superclass relation from the ColorComponent and NumberOfBinsPerComponent to the ColorQuantizationComponentDescriptorParameter, which instead now parametrizes these concepts.

Grouping Following a pattern-based design, COMM already provides a rich degree of conceptual groupings and their axiomatization in a machine readable format. However, reusability can be improved by redistributing concepts among the six ontologies of COMM, *core*, *datatype*, *localization*, *media*, *visual*, and *textual* respectively. As an example, the concept RootSegmentRole, located in the COMM *core ontology*, is not used in any pattern definition and has therefore been relocated to the *localization ontology*.

Mapping The main challenge of aligning COMM and the M3O concern the differences of the patterns used and how to relate them. Although some principles are shared between the ontologies, there are also major differences, e.g., the Digital Data Pattern of COMM and the Information Realization Pattern of the M3O.

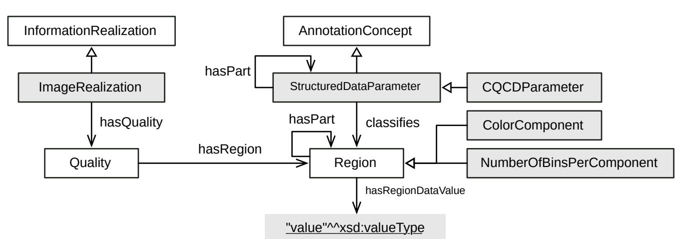


Fig. 2: Excerpt of COMM subsequently to the integration with the M3O. White boxes show the concepts of the M3O or DUL, whereas grey boxes represent concepts of COMM aligned to the M3O.

Often COMM patterns have been replaced using a more generic pattern of the M3O. As an example, Figure 2 displays the adaptation of the COMM Digital Data Pattern through the M3O. For the alignment, we have decided that the functionality of the Digital Data Pattern, i.e., expressing data values, can be maintained by adopting the M3O Data Value Pattern instead. All related concepts have either been removed or mapped to the next matching M3O concept. As an example, the StructuredDataDescription concept has been removed as it held no further relevance in the context of the Data Value Pattern. The StructuredDataParameter concept on the other hand has been preserved as specialization of the M3O Annotation Pattern. To accommodate StructuredDataParameters with the M3O, we consider StructuredDataParameters as subclass of the AnnotationConcept. Through parametrizing the appropriate Region, we can constrain the range applicable for a specific StructuredDataParameter. The value itself is expressed using the hasRegionDataValue relation. In a similar manner, the three annotation patterns of COMM have been replaced through the M3O Annotation Pattern, and all dependent concepts have been mapped to the M3O Annotation Pattern instead.

Validation and Documentation The alignment of COMM and the M3O has been validated using Fact++ and Pellet reasoner. The results have been documented in a publicly accessible wiki page available at: http://semantic-multimedia.org/index.php/COMM_integration.

4.2 Application of the Aligned Ontology

Figure 3 demonstrates the application of StructuredDataParameters using COMM aligned with the M3O. We specify a ColorQuantizationComponentDescriptorParameter (CQCDParameter) as part of the RGBHistogramAnnotationConcept. The CQCDParameter parametrizes the ColorComponents and NumberOfBinsPerComponent, which are considered part of the RGBHistogramRegion. The hasRegionDataValue relation expresses the primitive value for this annotation, e.g., an unsigned int for the NumberOfBinsPerComponent concept. Staying in line with the specification of the M3O Data Value Pattern, we consider the use of StructuredDataParameters optional. Thus, we do not specify that an AnnotationConcept must specify any StructuredDataParameters in a hasPart relation but recommend using them as they add an additional layer of formal expressiveness.

5 Example 2: Ontology for Media Resource

The Ontology for Media Resource [13] developed by the W3C defines a core vocabulary for multimedia annotation. The ontology targets at an unifying mapping of common media formats like EXIF [6] or Dublin Core [10]. The core challenge for this alignment of the Ontology for Media Resource concerns the mapping of properties to either information object or information realization as provided by the Information Realization Pattern of the M3O.

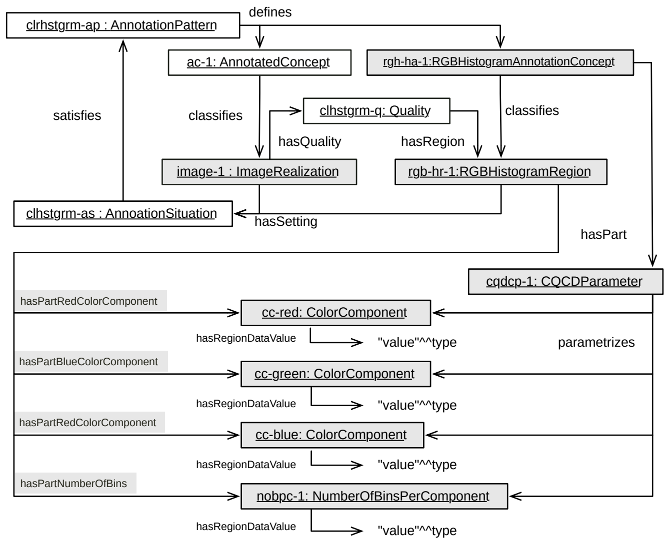


Fig. 3: Application of COMM after its integration with the M3O

5.1 Application of the Alignment Method

Understanding The Ontology for Media Resource presents a property-centric approach to ontology modeling and consists of 28 predicates including properties like *title* and *language*. Some properties are specified in further detail, e.g., through *role* or *type* properties. Only entities such as multimedia items and persons are represented as resources. Any other information such as roles or types are represented using primitive values, e.g., strings. The Ontology for Media Resource defines neither structural patterns nor formal logical constraints beyond the domain and range specification for each property. Unlike the M3O, there is no distinction between information object and information realization.

Grouping The Ontology for Media Resource's documentation on the web provides a number of conceptual groupings for certain aspects of multimedia description, e.g., identification or fragmentation. However, this information is not accessible in a machine readable format. With the alignment of the Ontology for Media Resource and the M3O, we have provided grouping information by defining the appropriate axioms. For example an IdentificationAnnotation concept hasPart some TitleAnnotationConcept, LanguageAnnotationConcept, and LocatorAnnotationConcept.

Mapping For mapping the ontology for Media Resource to the M3O, we define a subconcept of the AnnotationConcept for each predicate of the ontology. For example, we define a LocatorAnnotationConcept to match the *locator* property. Concrete values are expressed using the Data Value Pattern of the M3O. To this end, we define appropriate Region concepts. In the case of the LocatorAnnotationConcept, we define a LocatorRegion with the property hasRegionDataValue and an URI specifying a concrete location on the web.

Of primary concern for this alignment is the mapping with the Information Realization Pattern. By taking into account the difference between information objects and information realizations, we can improve semantic precision of the aligned ontology. To this end, we examine each attribute of the Ontology for Media Resource for its inherent meaning and constrain it to the appropriate concept of the Information Realization Pattern of the M3O. As an example, the *locator* property of the Ontology for Media Resource annotates media files that are locatable on the web. This is a quality only applicable for information realizations and is expressed in the definition of the LocatorAnnotationConcept.

We express the *type* property of the Ontology for Media Resource through specialization, e.g., by specifying an ImageRealization, a subclass of the InformationRealization, as the type for the considered media item. Finally the *fragments* facet of the Ontology for Media Resource has been modeled using the Decomposition Pattern of the M3O. The functionality indicated by the *namedFragments* property can be obtained by decomposing multimedia items using the M3O Decomposition Pattern and by using the M3O Annotation Pattern to annotate the resulting fragment with a FragmentLabelAnnotationConcept.

Consistency Checking and Documentation The resulting ontology has been validated using Fact++ and Pellet.

5.2 Application of the Aligned Ontology

Figure 4 demonstrates the application of the aligned ontology. We explicitly distinguish between an ImageObject and an ImageRealization that realizes the ImageObject. The specific type for each media is expressed through specialization of the corresponding InformationObject and InformationRealization concepts. The ImageObject is annotated with some TitleAnnotationConcept, where the title "Mona Lisa" is expressed using the Data Value Pattern. The ImageRealization is annotated with some LocatorAnnotationConcept that parametrizes a Region for an URI locatable on the web.

6 Example 3: EXIF

EXIF is a common metadata standard for images and supports mainly technical metadata [6]. It is embedded directly into media assets such as JPEG files. The following section presents the alignment of EXIF and the M3O.

6.1 Application of the Alignment Method

Understanding The key-value based metadata specified in EXIF is binary encoded into the header of, e.g., JPEG files. Consequently the mapping of the

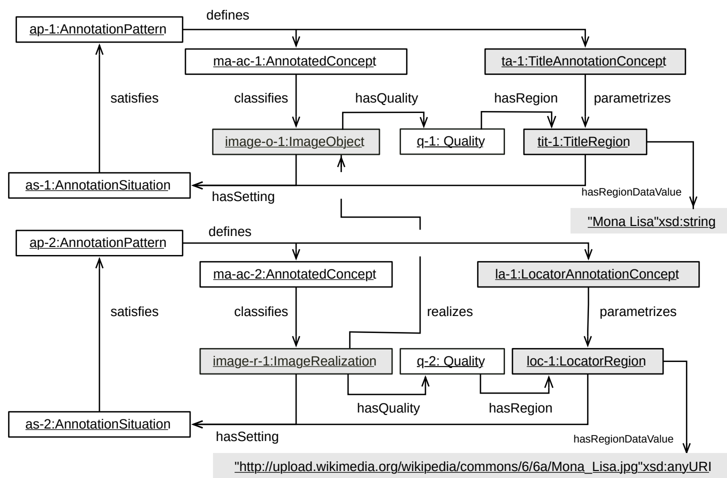


Fig. 4: Application of the Ontology on Media Resource after the alignment

non-semantified concepts onto the scaffold of the M3O posed the major challenge for this particular alignment. Thus, for aligning EXIF and the M3O, we first needed to semantify the key-value pairs of EXIF.

Grouping The EXIF metadata standard has been translated to a RDF Schema [21] by the W3C through an one-to-one mapping. Here, each key of the EXIF specification has been directly mapped to a corresponding property. This approach ignores the groupings of metadata keys that is provided in the original EXIF specification such as pixel composition and geo location. For the alignment, we have reconstructed this grouping information.

Mapping Mapping EXIF to the M3O follows a similar procedure as conducted with the mapping of the Ontology of Media Resource. Special consideration is provided on how to map EXIF properties to information objects and information realizations. For example, locations have been constrained to information objects, as they convey information on where the original picture has been taken. Image resolutions describe a quality of a concrete realization, e.g., a JPEG file, and are therefore associated with the information realization instead. Specific properties can be referred to by using preexisting vocabularies, e.g., the WGS84 vocabulary [22] for GPS information. As EXIF restrains itself to describing qualities of multimedia items all keys have been mapped as specialization of the M3O Annotation Pattern.

Consistency Checking and Documentation We have tested the validity of the resulting ontology using Fact++ and Pellet.

6.2 Application of the Aligned Ontology

The example as shown in Figure 5 defines an EXIFAnnotationPattern concept that allows us to represent EXIF compliant annotations. In this case, the EXIF-AnnotationPattern defines an EXIFGeoParameter that parametrizes a GeoPoint. Within this construct, we accumulate all parameters that can be specified in regards to *GPS Attribute Information* as specified in EXIF. Going conform with the Data Value Pattern, we express the GeoPoint through geo:lat and geo:long, which specify primitive values of type xsd:decimal. In this case, we want to represent the location at which the image was created and thus attach the information to the information object.

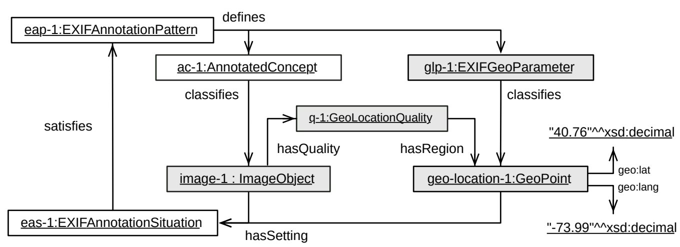


Fig. 5: Application of the EXIF metadata standard using M3O.

7 Related Work

We shortly review the state of aligning different metadata standards. For a detailed analysis of existing metadata formats and metadata standards, we refer to the original M3O paper [12] and specifically to the report of the W3C Multimedia Semantics Incubator Group [23] and the overview of the current W3C Media Annotations Working Group [24].

Numerous metadata models and metadata standards with different goals and backgrounds have been proposed in research and industry. Most focus on a single media type such as image, text, or video, differ in the complexity of the data structures they provide, and provide partly overlapping and partly complementary functionality. With standards like EXIF [6], XMP [7], and IPTC [8] we find metadata models that provide (typed) key-value pairs to represent metadata of the media type image. An example for a more complex standard is MPEG-7 [9]. MPEG-7 provides a rich set of complex descriptors that mainly focus on expressing low-level features of images, audio, and video.

The drawbacks of these standards are the lacking interoperability and the alignment between them. Harmonization efforts like the Metadata Working Group [25] or the Media Annotations Working Group [24] try to tackle these issues and develop a common vocabulary. However, they remain on the same technological level and do not extend their effort beyond the single media type of images and do not provide a generic framework suitable for arbitrary metadata formats and arbitrary metadata standards. XMP aims at an integrated standard for image metadata. However, it tackles the problem from a different point of view. While XMP also aims at providing a framework for multimedia metadata, it focusses on images only and does not consider other media types or structured multimedia content. Another major difference is that XMP stays on the level of standards such as EXIF or IPTC and does not take into account requirements such as provenance of metadata, decomposition, or information realization.

Several approaches have been published providing a formalization of MPEG-7 as an ontology [26], e.g., by Hunter [1] or the Core Ontology on Multimedia [2]. Although these ontologies provide clear semantics for the multimedia annotations, they still focus on MPEG-7 as the underlying metadata standard. More importantly, these ontologies basically provide a formalization of MPEG-7, but do not provide for the integration of different standards.

The alignment method discussed in this paper is fully manual. There are numerous publications about (semi-)automatic alignment and matching methods [17–19]. However, these methods typically do not provide the high accuracy we require in an alignment of different metadata standards and are usually applied to problems such as ontology learning or the alignment of domain models. The M3O is a core ontology, i.e., an ontology providing some underlying structure for specific aspects of an application. The method presented in this paper shows how to align existing metadata formats and metadata standards with such a core ontology. The goal of this work is producing a specialization of the M3O that inherits the same level of formal precision and conciseness. Achieving this goal with an automatic method currently seems not realistic.

8 Conclusions

In this paper, we have shown how the generic scaffold provided by the Multimedia Metadata Ontology (M3O) can be specialized to integrate existing multimedia metadata formats and metadata standards. To this end, we have developed a four-step alignment method that describes the tasks to be performed. We have demonstrated the applicability of our approach at the example of three existing metadata models, the Core Ontology on Multimedia, the Ontology for Media Resource of the W3C, and the industry standard EXIF for image metadata. The experiences made in conducting the alignment with the M3O have been described. The results are also continuously documented on our wiki: http://www.semantic-multimedia.org/index.php/M3O:Main#Mappings

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