Exploiting Cultural Heritage Documentation in Semantic Multimedia Annotations

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Abstract

Descriptive information kept by cultural heritage institutions is of great importance as a means of cultural documentation. However the descriptive information and the domain knowledge organized using standards such as the CIDOC/CRM can be (re)used within Mpeg-7 to describe the semantics of multimedia objects related to culture. In this paper we propose a methodology for integrating the widely accepted standards MPEG-7 and CIDOC/CRM for multimedia and cultural heritage metadata representation respectively. The methodology allows the exploitation of existing cultural heritage information in automatically generating semantic multimedia annotations as well as the generation of cultural application interfaces (for cultural users) for MPEG-7 environments.

1. Introduction

Since 1996 the International Committee for Documentation (CIDOC) of International Council of Museums (ICOM) has developed the CIDOC Conceptual Reference Model (CRM) in order to integrate cultural heritage documentations and to serve as a mediation of semantic data exchange between cultural institutions. CIDOC/CRM has been accepted as an ISO standard (ISO21127) [2] since September 12 2006 and serves as a formal ontology that uses events to provide a connection amongst actors and material/immaterial things through the space and time extents. The ontology provides a rich conceptualization that provides generic concepts (such as Event, Place, Thing, Appellation, Time-Span, etc.) as well as many sub-concepts of them. This rich but still generic conceptualization allows for accurate modeling of cultural heritage documentation that spans many different domains (history, science, arts, etc.) and also helps to achieve uniqueness of properties. CIDOC/CRM provides also an extensibility mechanism by employing the "Type" construct. It is acting as a meta-class which allows further categorization of the default CIDOC/CRM concepts creating hierarchies of typologies.

CIDOC/CRM is currently achieving wide acceptance as more and more cultural heritage institutions and organizations adopt it either as a means of cultural documentation or as a common model to which they map their cultural documentation in order to achieve interoperability with other cultural heritage institutions. Organizations that have adopted the CIDOC/CRM model include the English Heritage, the Finnish National Gallery, the Germanische National Museum, the Research Libraries Group (RLG), etc.

MPEG-7 [1] (formally known as Multimedia Content Description Interface) is an ISO standard developed by the Moving Picture Experts Group (MPEG) to represent information about the content of a multimedia object. It uses Descriptors to describe the low level features and attributes of the content, and Description Schemes for entities and relationships associated with the content. Multimedia Description Scheme (MDS) description tools are defined in order to depict content metadata (Media, Creation & Production, Usage description tools), content description (Structure, Semantics description tools), navigation and access (Summaries, Views, Variations description tools), content organization (Collections, Models) and finally user interaction (User Preferences, User History description tools).

While low-level features of multimedia content can be automatically extracted with the use of content analysis tools and/or services, the semantic annotation of multimedia content is not so easy to achieve and often requires manual user intervention. It is thus frequently seen in multimedia applications that while rich semantic annotation models of the knowledge domain exist or can be developed, only a small part of them is used in practice for multimedia annotation (typically keyword-based domain knowledge), which is often called "the multimedia semantic gap".

In this paper we present a methodology and an infrastructure for exploiting the existing rich semantic documentation of cultural heritage objects in order to support the automatic annotation of multimedia objects (i.e. images, videos, etc.) that refer to them. The developed infrastructure acts as mediation mechanism between CIDOC/CRM and MPEG-7 enabling the semantic integration of the two models and the transformation of rich semantic cultural heritage knowledge into valid MPEG-7 semantic annotations of multimedia objects. In the rest of this paper, we will present the scenarios that have been taken into account, the domain-aware integration approach that we followed, and the mechanisms used to transform the CIDOC/CRM descriptions into valid MPEG-7 multimedia annotations.

2. Scenarios of semantic integration between CIDOC/CRM and MPEG-7

There are at least two different scenarios under which a semantic harmonization of the CIDOC/CRM with the MPEG-7 is valuable.

The first scenario refers to the semantic interoperability between CIDOC/CRM and MPEG-7. This requires a bidirectional integration of the two models enabling knowledge captured by the one model to be represented by the other. In one direction this integration allows cultural semantics and knowledge to be used in semantic multimedia annotations. For example, a picture of Mona Lisa can be annotated (in MPEG-7) with domain knowledge taken from its cultural documentation provided in CIDOC/CRM. In the other direction, this integration allows semantic knowledge captured in MPEG-7 to be accommodated by CIDOC/CRM and provided as cultural documentation. For example, the video with the murder of J.F. Kennedy president can certainly have a cultural interest. This semantic integration will also enable semantic annotations of multimedia objects (using MPEG-7) in a way that is compatible to CIDOC/CRM so that we can develop cultural application interfaces (for cultural users) on top of MPEG-7 servers. In this paper we concentrate mostly in this scenario.

The second scenario refers to the cultural documentation of the multimedia objects themselves. To achieve this, the MPEG-7 description of the multimedia object needs to be mapped to concepts and properties of the CIDOC/CRM ontology. This scenario has been approached by J. Hunter in [4] where she proposed specific extensions to the CIDOC/CRM in order to be able to accommodate the temporal and spatial aspects of information objects.

The focus in our work is on the first scenario with a priority in the direction from CIDOC/CRM to MPEG-7. This scenario requires a mapping of CIDOC/CRM concepts and concept relations into appropriate MPEG-7 Description Schemes and Relations. However, since the CIDOC/CRM model provides a fine-grained conceptualization, a simple mapping of the CIDOC/CRM cultural heritage specific concepts into the generic MPEG-7 ones results in important loss of semantics. In the next section we present the approach that we follow in order to address this particular issue.

3. Domain-aware integration of CIDOC/CRM and MPEG-7

CIDOC/CRM provides an abstract but fine-grained conceptualization for events, objects, agents, things, etc. For example, the class Event has 23 descendent subclasses! This is not the case in MPEG-7 which only provides for semantic annotation the Description Schemes Agent, Object, Event, Place, and Time without any sub-categorization of these generic constructs. A mapping of all the CIDOC/CRM concepts into these generic constructs would result in extensive loss of information from a given cultural heritage documentation. Consider for example the birth of a person to be represented just as an Event in MPEG-7. In this case the semantics of “birth” are completely lost. To overcome this problem some kind of domain aware integration of CIDOC/CRM and MPEG-7 is required. “Domain aware” means to be able to represent CIDOC/CRM specific semantics in MPEG-7. The obvious approach to follow is some kind of domain specific extension of MPEG-7. MPEG-7 provides its own extensibility mechanism through the use of the Description Definition Language (DDL) [5]. DDL is the language which allows the creation of MPEG-7 Description Schemes and Descriptors in a new schema (a DDL file) which specifies the constraints that a valid MPEG-7 description should respect. Thus, a CIDOC/CRM specific extension of MPEG-7 would address the problem mentioned above by providing a specific extension accommodating several sub-categories of the existing semantic Description Schemes provided by the standard. This approach however introduces an important interoperability problem since the new extension will not be a standard one. Thus, the generated MPEG-7 description will not be manageable by standard MPEG-7 repositories and tools.

To overcome this interoperability problem we follow the DSMIRF [3], [6] approach which allows incorporation of domain knowledge into MPEG-7 without any extension of the current standard. The

DSMIRF framework provides an ontological (OWL based) infrastructure where MPEG-7 is represented as a top-level core ontology and the domain-specific conceptualizations are represented as domain specific ontologies with respect to the MPEG-7 core ontology (Figure 1).

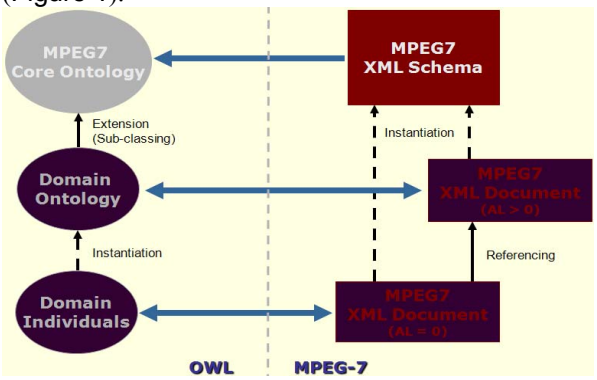

Figure 1: The DS-MIRF approach

Appropriate transformation rules (described in [6]) are applied to transform this ontological representation into valid MPEG-7 descriptions. In MPEG-7 terms both domain specific concepts and instances are represented as MPEG-7 documents. The distinction among them is done by using the abstraction level mechanism provided by the MPEG-7. The MPEG-7 documents that contain the domain specific concepts have abstraction level greater than zero, while the MPEG-7 documents containing the concept instances have abstraction level equal to zero. Concept instances are correlated with their class through referencing.

An example of the application of the DS-MIRF approach in incorporating CIDOC/CRM semantics into MPEG-7 is depicted on Figure 2.

Domain specific concept hierarchies are achieved by using the "specializes/generalizes" relations of MPEG-7. As explained, concept instances are represented as instances of the default MPEG-7 semantic Description Schemes with abstraction level equal to zero.

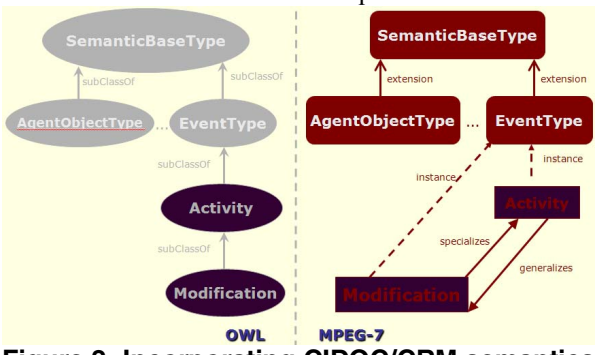

Figure 2: Incorporating CIDOC/CRM semantics into MPEG-7

The correlation of concept instances with their concept is achieved through the MPEG-7 semantic relation "exemplifies/exemplifiedBy".

Figure 3 depicts a specific example of representing a CIDOC/CRM description into MPEG-7 following the DS-MIRF approach.

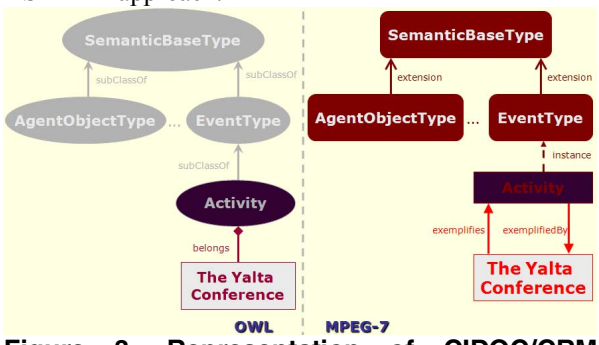

Figure 3: Representation of CIDOC/CRM descriptions into MPEG-7

Domain specific properties are represented through MPEG-7 relations. Since no similar approach can be followed for relations (i.e. sub-classing) in MPEG-7 a mapping of CIDOC/CRM properties into MPEG-7 relations is done. In order to keep the domain specific information in this case, the CIDOC/CRM property name is kept as a comment in particular MPEG-7 relations during the mapping.

4. Transformation of CIDOC/CRM descriptions to MPEG-7 annotations

Following the approach presented above a semantic mapping of CIDOC/CRM has been achieved. The complete list of mappings is described in [8]. Due to space limitations however they cannot be presented in this paper. Whenever CIDOC/CRM entities can be directly mapped to MPEG-7 DSs then a direct mapping is defined. The representation of the mappings is done using Xpath [7], which helps to select individual elements from an XML document. For the numerous sub-concepts that cannot be directly mapped to MPEG-7 DSs appropriate abstract MPEG-7 elements have been defined forming a (CIDOC/CRM-specific) abstract MPEG-7 Document which is referenced when concrete CIDOC/CRM descriptions are transformed to MPEG-7 annotations.

The scenario in which we are working allows for both automatic and manual exploitation of cultural heritage knowledge in creating multimedia annotations. In the first case, existing CIDOC/CRM descriptions (that refer to some multimedia object – e.g. some image) are automatically transformed into valid MPEG-7. In order to achieve the desired functionality, apart from the defined mappings, a

complete transformation process has been defined that allows the detailed manipulation of provided CIDOC/CRM descriptions and their transformation into valid MPEG-7 annotations. The transformation process is divided into two major pars: a) the generation of multimedia object content management and b) the generation of multimedia object semantic content description. Before that, a given CIDOC/CRM description is searched in order to identify the Multimedia Objects (MM Objects) that are described, then for each MM object found in the description (or for those that the user selects) the Content Management (CM) and the Semantic part of its annotation are generated as illustrated in Figure 4.

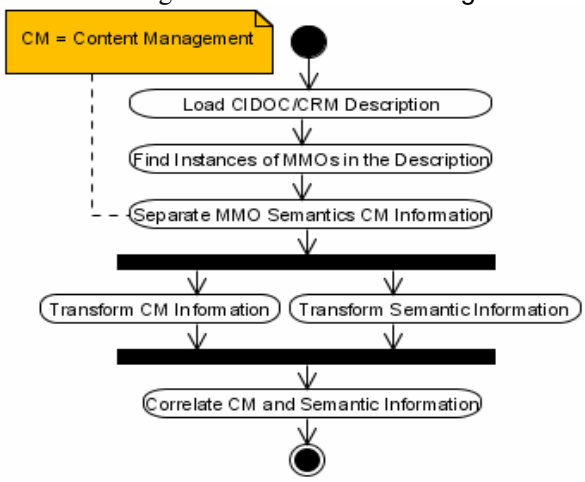

Figure 4: The overall transformation process

The transformation of the Content Management information is further distinguished into a) the transformation of Creation Information, and b) the transformation of the Classification Information as depicted in Figure 5.

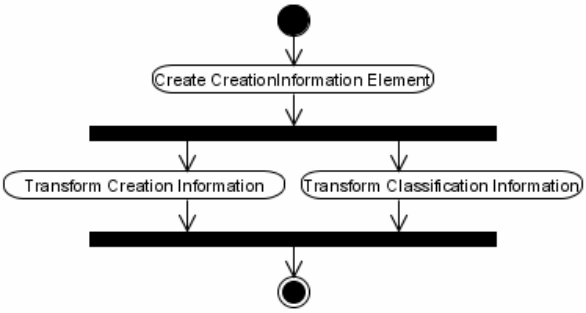

Figure 5: Generation of content management information

The determination of CIDOC/CRM entity instances that describe the creation information for each MM object described in the given CIDOC/CRM description is done as follows: First we identify the creation event instance which is associated with each MM object instance through property 'P94F.has_created'. Having this instance, we can extract the creators by selecting the E39.Actor (or its subclasses') instances that participated in the creation event (and the information regarding these actors, such as contact information etc.). Also, the place and time of the creation are obtained.

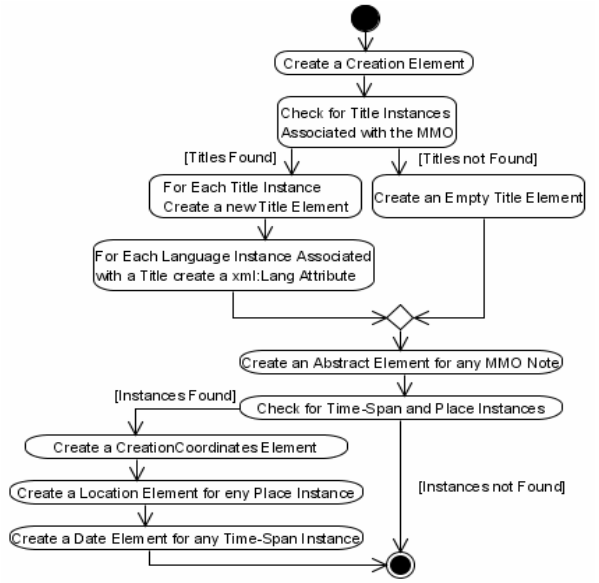

Figure 6: Generation of creation information

Regarding the generation of classification information, the E55.Type instances that are associated with each MM object described in the given CIDOC/CRM description are used. In this particular transformation we only are looking for type instances that are associated with the MM object either through the property 'P2F.has_type' or through the property 'P103F.was_intented_for' as depicted in Figure 7.

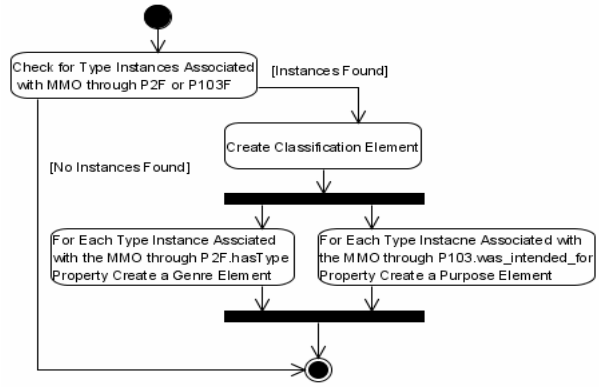

Figure 7: Generation of classification information

All the other entity instances that are found in a given CIDOC/CRM description are used to generate the semantic multimedia content description. The generation of specific types of MPEG-7 DSs is done according to the mappings that have been defined and described in [8]. For CIDOC/CRM entities that are not directly mapped to MPEG-7 DSs appropriate

correlation with abstract MPEG-7 elements (corresponding to CIDOC/CRM entities) is constructed. The overall transformation process for the generation of the semantic annotation is illustrated in Figure 8

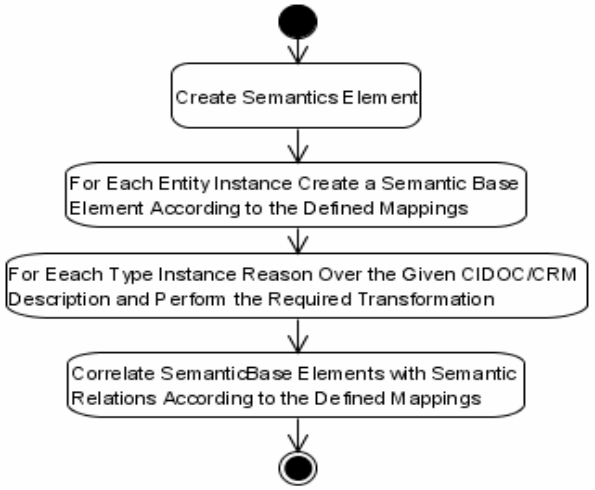

Figure 8: Generation of semantic information

5. Static vs. conditional and real-time transformations

A mapping process between two models is typically a static process. That is, the correspondences of the models are identified at design time and a set of transformation rules are defined as blue-prints of interoperability between systems that have adopted these models. In our work this is not the case. An important aspect of the semantic integration between CIDOC/CRM and MPEG-7 presented in this paper is that not all of the CIDOC/CRM concepts can be mapped into MPEG-7 DSs at design time. That is, in order to perform the transformation of a particular entity instance found in the given CIDOC/CRM description into some MPEG-7 DS some instance-level knowledge is needed (i.e. knowledge that is only known during real-time -i.e. during a particular transformation action).

There are two categories of such transformations: transformations based on conditional mappings, and transformations based on real-time reasoning. A conditional mapping for a given CIDOC/CRM entity defines (for some entity or relation) a set of MPEG-7 DSs to which this entity can be mapped to as well as the condition under which a particular mapping is valid. Although this mapping is defined at design time, the transformation mechanism needs real-time knowledge in order to evaluate the conditions defined for each particular mapping. Conditional mappings have been defined for the following CIDOC/CRM entities:

a) E54.Dimmension. An instance of this entity can be mapped to: i) `duration` element of a `SemanticTimeInterfal` DS if this instance is associated with an E52.Time-Span entity instance, ii) a `SemanticStateType` DS if this instance is associated with an E70.Thing instance.
b) E45.Address. An instance of this entity can be mapped to: i) `AddressLine` element of a `PostalAddress` DS if this instance is used as a place identifier, ii) `Address` element of an `Agent` DSs if it is associated with an E39.Actor instance (or some sub-class of it).
c) E51.ContactPoint. An istance of this entity can be mapped to `telephone`, `e-mail`, or `url` of an `ElectronicAddress` DS subject to appropriate pattern matching.

Apart from the aforementioned conditional mappings, there are situations that a mapping (static or conditional) of some entity cannot be done at design-time. In particular the CIDOC/CRM meta-class "E55.Type" cannot be mapped into particular MPEG-7 concept a-priori since it is a construct provided to define new categorizations of existing CRM concepts. Consider for example the description illustrated in Figure 9.

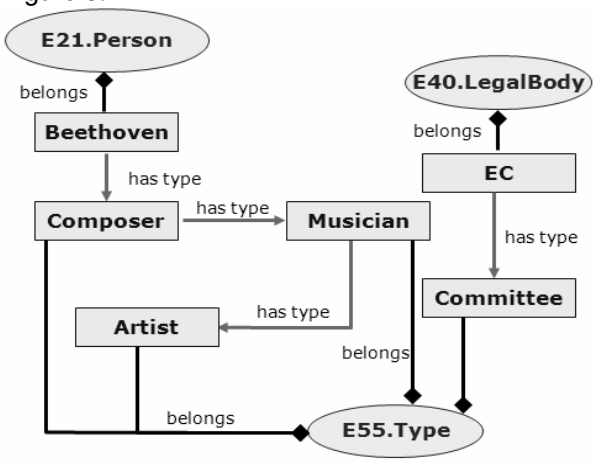

Figure 9: A CIDOC/CRM typology

In this description it is clear that the instances of the entity E55.Type cannot be statically or conditionally mapped to specific MPEG-7 DSs. This is because it is not the E55.Type entity that defines the semantics of its instances but the instances that are typed through these types. For example the instance artist cannot be completely understood until a connection with some concrete entity is found (E21.Person in our case). Thus in order to transform such types into appropriate MPEG-7 DSs we need to find in the given description

(i.e. in instance-level) what is the entity that is further categorized by this particular type.

Thus, some kind of real time reasoning is needed in order to decide to which MPEG-7 DS to map instances of this class. For this purpose a specific algorithm has been defined which is used to reason over the given CIDOC/CRM description at real-time and decide what kind of mapping to perform. The algorithm can be found in [8]. Due to space limitations we briefly describe here the function that determines the mappings for a given Type Instance. Beyond that, there are functions that determine the appropriate semantic relations that should be established between mapped types as well as to identify and correlate instances of the same type instance.

Table 1: Determination of type mappings

```
function determineMapping(instance t)
{
 if not(t instanceof E55.Type) :
   return mappingOf(t);
 else if alreadyMapped[t] not empty :
   return alreadyMapped[t];
 m := new vector;
 for each i in isTypeOf(t) :
    m.add(determineMapping(i));
 if m is empty :
    return null;
 alreadyMapped[t] := m;
 return m; }
```

6. Conclusions and future work

In this paper we have presented a methodology and a mechanism for semantic integration of the CIDOC/CRM and MPEG-7 standards under the idea of supporting semantic annotations of multimedia documents referring to cultural heritage objects. The proposed methodology allows the exploitation of existing CIDOC/CRM descriptions of cultural heritage objects for semantically annotating multimedia documents that refer to them.

In order to enable domain-aware integration of the two standards (i.e. incorporating cultural heritage semantics into MPEG-7) we have followed the DS-MIRF approach that allows domain knowledge incorporation into pure MPEG-7 without any proprietary extension of the current MPEG-7 standard. We have shown how cultural heritage semantics (captured by CIDOC/CRM) can be represented into MPEG-7 and we defined a complete transformation process for appropriate manipulation of CIDOC/CRM descriptions and their transformation into valid MPEG-7 documents.

The transformation process is based on a complete list of mappings between the two models. The mappings are not described in this paper due to space limitations. However they can be found in [8]. There are kinds of mappings: a) static and real-time mappings. Static mappings between model constructs are always treated according to model correspondences that have been identified at design-time. Real time mappings require instance level knowledge and thus they are decided at real-time. Real-time mappings are further distinguished in conditional and reasoning-based. Conditional mappings are defined at designed time. However, the condition that must hold in order for these mappings to be valid, are evaluated at real-time. Reasoning based mappings are used in particular the E55.Type meta-class of the CIDOC/CRM which is used as an extensibility mechanism of the model. In order to decide on the mapping that needs to be done, our mechanism is reasoning over the given CIDOC/CIRM description in order to find ontology paths that specify the concrete instance that is further typed by a given type instance. The implementation of the proposed mechanism is under development based GraphOnto multimedia semantic annotation toolkit [9] that allows transformation of domain knowledge into valid MPEG-7 documents following the DSMIRF approach. The mechanism is going to be used for evaluation/verification purposes of the entire methodology.

7. References

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