Semantic Interoperability Support between Cultural and Multimedia Environments

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Abstract

Cultural heritage institutions are keeping descriptive information for myriads of cultural objects. This knowledge is organized and encoded using standards such as the CIDOC/CRM, Dublin Core, etc. The CIDOC/CRM standard is getting more and more acceptance as many cultural heritage institutions are adopting it by mapping their descriptive information into it as a means of semantic interoperation within the cultural heritage domain. In multimedia environments, lots of multimedia documents (images, documentaries, etc.) refer to cultural objects and are described in MPEG-7. Thus achieving interoperability between cultural heritage and multimedia environments is of great importance since it will allow one environment to semi-automatically exploit knowledge captured in the other. 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.

Categories and Subject Descriptors

D.2.12 [Interoperability]: Data mapping; D.2.13 [Reusable Software]: Domain engineering; H.3.7 Digital Libraries;

General Terms

Management, Verification

1 Introduction

The CIDOC Conceptual Reference Model (CRM) has been developed by the International Committee for Documentation (CIDOC) of International Council of Museums (ICOM) in order to integrate cultural heritage documentations and to serve as a mediation of semantic data interchange between cultural institutions. CIDOC/CRM has been accepted as an ISO standard (ISO21127) [ISO 2006] 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 accommodating 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 *E.55Type* 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 existing 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 [Salembier,P 2001] (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 document. 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 observed 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*".
Many multimedia documents refer to cultural heritage objects. Examples of such documents may be a picture of Napoleon Bonaparte, a video documentary about Parthenon, an audio documentary with the talk of Josef Stalin in the Yalta Conference, etc. Given the intrinsic difficulty in providing semantic annotations for multimedia documents as described above, the ability to exploit existing resources (i.e. descriptions of cultural objects shown in multimedia documents) of documentation in this process is of great importance.
In this paper we present a methodology and an infrastructure for achieving semantic interoperability between cultural heritage and multimedia environments. This interoperability support allows the existing rich semantic documentation of cultural heritage objects to be automatically exploited in providing semantic annotations of multimedia documents that refer to those objects. Another advantage of this interoperability support is that cultural heritage oriented annotation interfaces can be built in multimedia environments allowing cultural heritage experts to provide multimedia annotations following the terminology and semantics they understand. This is achieved by giving them the ability to work on CIDOC/CRM based annotation interfaces and having the system to automatically transform the provided annotations into MPEG-7 ones. 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 interoperability between CIDOC/CRM and MPEG-7

There are at least three 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. The second scenario refers to supporting cultural users to provide semantic annotations of multimedia documents (using MPEG-7) in a way that is compatible to CIDOC/CRM. This can be

achieved by developing cultural application interfaces (for cultural users) on top of MPEG-7 servers since the two models have been harmonized. The third 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 [Hunter 2002] 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 supporting the first and the second scenarios since the third scenario requires extensions of the CIDOC/CRM conceptualization and it has been already approached [Hunter 2002]. To support these scenarios a deep understanding of the two models and a mapping of their concepts and concept relations is required. I first observation on can make is that the CIDOC/CRM model provides a fine-grained conceptualization with respect to MPEG-7. Thus, 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 followed 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 "*E67.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) [ISO 2001]. 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 DS-MIRF [Tsinaraki et al 2003, 2007] approach which allows incorporation of domain knowledge into MPEG-7 without any extension of the current standard. The DS-MIRF 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 3.1). Then, appropriate transformation rules (described in [Tsinaraki et. al 2007]) 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.

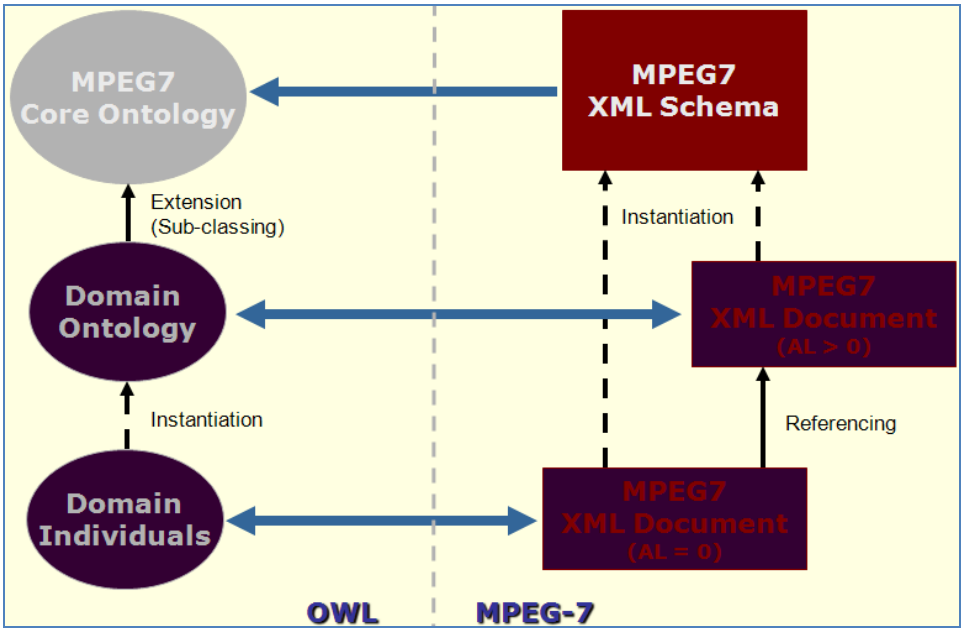


Figure 3.1: The DS-MIRF framework

An example of the application of the DS-MIRF approach in incorporating CIDOC/CRM semantics into MPEG-7 is depicted on Figure 3.2.

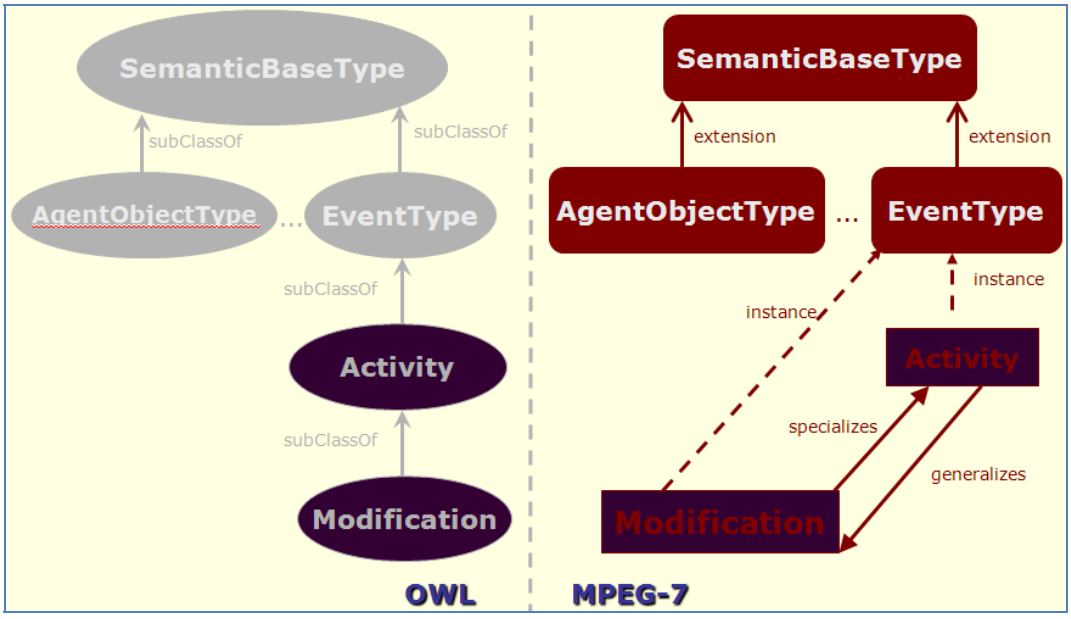


Figure 3.2: Incorporating CIDOC/CRM semantics in MPEG-7

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. The correlation of concept instances with their concept is achieved through the MPEG-7 semantic relation *exemplifies/exemplifiedBy*. Figure 3.3 depicts a specific example of representing a CIDOC/CRM description into MPEG-7 following the DS-MIRF

approach.

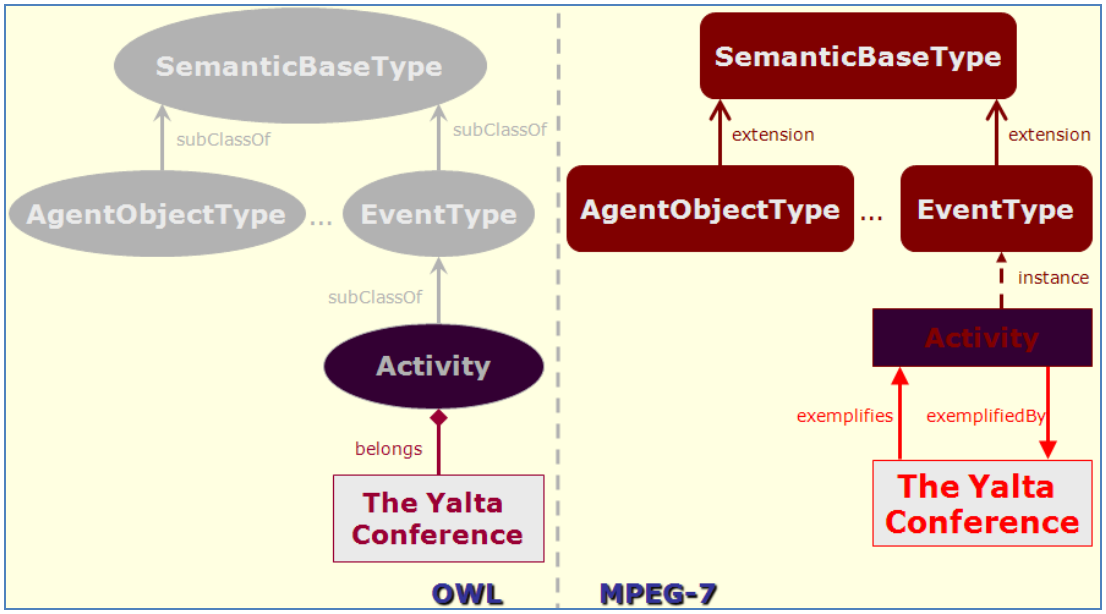


Figure 3.3: Representation of CIDOC/CRM descriptions into MPEG-7

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 Mapping CIDOC/CRM concepts to MPEG-7 constructs

In this section we illustrate our methodology for the semantic mapping of CIDOC/CRM entities and relations into MPEG-7 Description Schemes (DSs) and relations respectively. Whenever CIDOC/CRM entities can be directly mapped to MPEG-7 DSs then a direct mapping is defined. When appropriate, the representation of the mappings is done using Xpath [W3C 1999], which helps to select individual elements from an XML document. For the numerous sub-entities that cannot be directly mapped to MPEG-7 DSs appropriate abstract (i.e. Abstraction Level greater than zero) 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. Conditional mappings are informally described in order to better explain the context under which they are valid. Due to the large number of concepts and concept relations (the total number is ~85 entities and ~245 properties) of the CIDOC/CRM, we cannot present in this paper the entire list of mappings. Thus, we only provide some examples of these mappings. The complete list of the mappings can be found in [Delos 2007]. Table 4.1 shows some of the mappings defined for the CIDOC/CRM entities and MPEG-7 DSs, while Table 4.2 shows some of the mappings defined for the CIDOC/CRM Properties and MPEG-7 Semantic Relations. It should be noted that when mapping CIDOC/CRM properties into MPEG-7 Semantic Relations the name of the CIDOC/CRM property is kept as a *Property* sub-element of the MPEG-7 *semantic relation*. This is done in order to distinguish between the various CIDOC/CRM properties that can be mapped to the same MPEG-7 *semantic relation*.

CIDOC/CRM Entities	**MPEG-7 Elements**

E1 CRM Entity	DSType
E2 - Temporal Entity	UnionOf (SemanticStateType, SemanticTimeType, EventType)
E3 - - Condition State	SemanticBase[@type="SemanticStateType" @id="ConditionState"]
E4 - - Period	SemanticBase[@type="SemanticTimeType" @id="Period"]
E5 - - - Event	SemanticBase[@type="EventType"]
E63 - - - Beginning of Existence	SemanticBase[@type="EventType" id="BeginningOfExistence"]
E12 - - - - Production	SemanticBase[@type="EventType" id="Production"]
E65 - - - - Creation	If content description semanctics : SemanticBase[@type="EventType" id="Creation"] Else if content metadata semantics : Creation
E83 - - - - - Type Creation	SemanticBase[@type="EventType" id="TypeCreation"]
E66 - - - - Formation	SemanticBase[@type="EventType" id="Formation"]
E67 - - - - Birth	SemanticBase[@type="EventType" id="Birth"]
E81 - - - - Transformation	SemanticBase[@type="EventType" id="Transformation"]
…	…

Table 4.1: Examples of CIDOC/CRM Entity mappings

CIDOC/CRM Properties	MPEG-7 Relations
P1F.is_identified_by [E1.CRM_Entity-->E41.Appellation]	identifier
P1B.identifies [E41.Appellation-->E1.CRM_Entity]	identifier
P2F.has_type [E1.CRM_Entity-->E55.Type]	specializes
P2B.is_type_of [E55.Type-->E1.CRM_Entity]	generalizes
P4F.has_time-span [E2.Temporal_Entity-->E52.Time-Span]	Time
P4B.is_time-span_of [E52.Time-Span-->E2.Temporal_Entity]	timeOf
P5F.consists_of [E3.Condition_State-->E3.Condition_State]	part
P5B.forms_part_of [E3.Condition_State-->E3.Condition_State]	partOf
…	…

Table 4.2: Examples of CIDOC Property mappings

5 Conditional and real-time mappings

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. This peculiarity is raised due to the following two reasons:

CIDOC/CRM provides concepts whose mapping into proper MPEG-7 elements presents some ambiguity and requires some kind of instance-level knowledge. That is, for some of the CIDOC/CRM entities there have been defined conditional mappings to MPEG-7. A conditional mapping (for some CIDOC/CRM entity) defines a set of MPEG-7 description schemes 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:

i. **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.

ii. **E45.Address.** An instance of this entity is used either as a place identifier or as a contact point for an actor. For both cases it is mapped to an MPEG-7 *SemanticPlace* element but depending on the case a different MPEG-7 *semantic relation* is employed to associate it with the identified element. In particular:

1. If it is a place identifier of an *E53.Place* instance (in the CIDOC/CRM description), then the MPEG-7 semantic relation *Identifier* is employed to associate it with the *SemanticPlace* element (which corresponds to the *E53.Place* instance)
2. If it is a contact point of an actor (in the CIDOC/CRM description), then it associated with the MPEG-7 *Agent* element (which corresponds to the *E39.Actor* instance) as a contained *AddressRef* element.

iii. **E51.ContactPoint.** An instance of this entity can be mapped to *Telephone*, *Email*, or *Url* elements of an *ElectronicAddress* DS subject to appropriate pattern matching. If none of the above can be applied, then a new *Property* element is created with value *Contact Information* and id as the one of the instance.

2. The fact that CIDOC/CRM provides a mechanism for further refinement of its entities through instantiation of *E55.Type* entity. This entity comprises arbitrary concepts, as well as properties to organize them into a hierarchy. Instances of *E55.Type* could be considered as *Classification Schemes* defined according to each user group's needs. These *Classification Schemes* are created through sub-typing of those entities which do not require further analysis of their formal properties, but which, nonetheless, represent typological distinctions, important to some users. With respect to its mapping into some MPEG-7 element the problem is that it is not known at design time what kind of mapping should be performed for a given instance of the *E55.Type*.

In order to come up with the conditional mappings, we have further developed the transformation process so that it can take into account instance-level knowledge in order to perform the appropriate mappings when transforming CIDOC/CRM descriptions into MPEG-7 multimedia annotations. To overcome the conditional mappings problem the transformation process when reaches at some point where some ambiguity exists it examines the given CIDOC/CRM description to evaluate the condition and then it decides which mapping to consider as valid. The mapping of *E55.Type* instances is not straightforward since the nature of each instance of *E55.Type* depends on the nature of the classified instance. For this reason, we handle them in Mpeg-7 as nested terms (according to the defined hierarchy) of a *Classification Scheme*. A *Classification Scheme* in Mpeg-7 is used to define and organize sets of standard *Term* elements, which describe some domain. Each *Term* represents a well-defined concept in a specific domain and is comprised by a unique identifier (*termID*), a name and a definition of the term. The reference of instances to the terms which were created is implemented via *StructuredAnnotation* elements, and the use of the proper sub-element of *StructuredAnnotation*, depending on the nature of each instance. Specifically:

- *WhatObject* element is used for material and immaterial objects
- *Who* element is used for people, groups and organizations
- *WhatAction* element is used for events
- *Where* element is used for places, and
- *When* element is used for time-spans

Along with the appropriate element, the value of *href* attribute must be also set to point to the *termId* of the *Term* element.

6 Transforming CIDOC/CRM descriptions to MPEG-7 annotations

Based on the DS-MIRF framework and the mappings between CIDOC/CRM and MPEG-7 that have been

defined the transformation of CIDOC/CRM descriptions into MPEG-7 annotations is feasible. The scenario in which we are working with 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 the second case, MPEG-7 exploitation of cultural heritage knowledge can be done by allowing MPEG-7 annotation tools to import CIDOC/CRM descriptions and to manually select which concepts to instantiate. For the first case and in order to achieve the desired functionality, apart from the defined mappings, a complete transformation process needs to be defined in order to allow a controlled manipulation of the CIDOC/CRM description that will that allow its proper transformation into valid MPEG-7 annotation. To this end, we have defined a complete transformation process which is divided into two major pars: a) the generation of multimedia object content management MPEG-7 description and b) the generation of multimedia object semantic content description. The content management information refers to the information about the creation of the multimedia object (e.g. creation events, creators, etc.), while the semantic content description refers to information about the content of the multimedia object. However, the entire process starts by searching the input CIDOC/CRM description in order to identify the multimedia objects (i.e. instances of the *E31.Document* and *E38.Image* CIDOC/CRM entities) that are defined in it. Then, for each multimedia object identified 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 6.4: The Content Management part under the general MPEG-7 element *CreationInformation* for the specified multimedia object, and the semantic part under the MPEG-7 element *Semantics*.

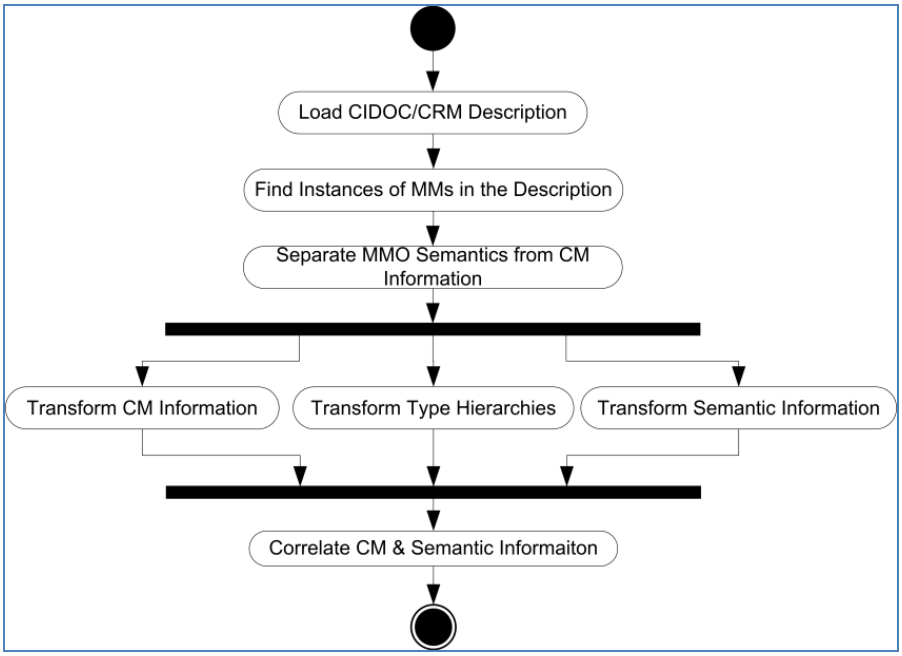


Figure 6.4: The overall transformation process

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 6.5.

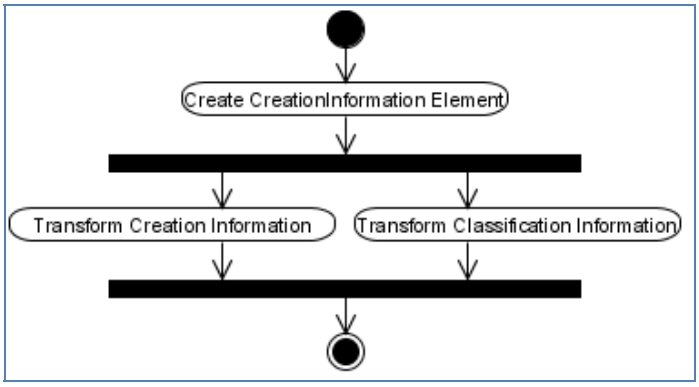


Figure 6.5: Generation of content management information

The determination of CIDOC/CRM entity instances that describe the *Creation* information for each multimedia object described in the given CIDOC/CRM description is done as follows: First we identify the *E65.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.

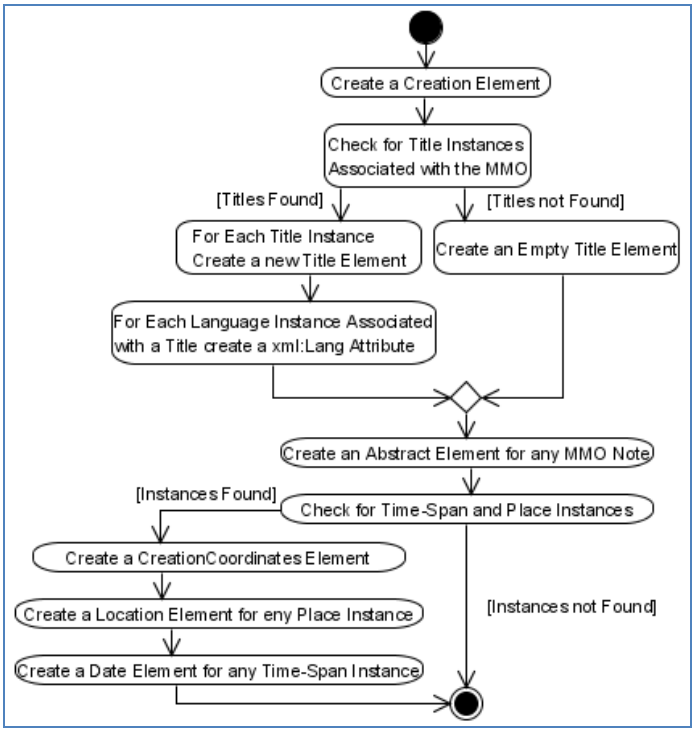


Figure 6.6: Generation of creation information

For the generation of *ClassificationInformation* 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 6.7.

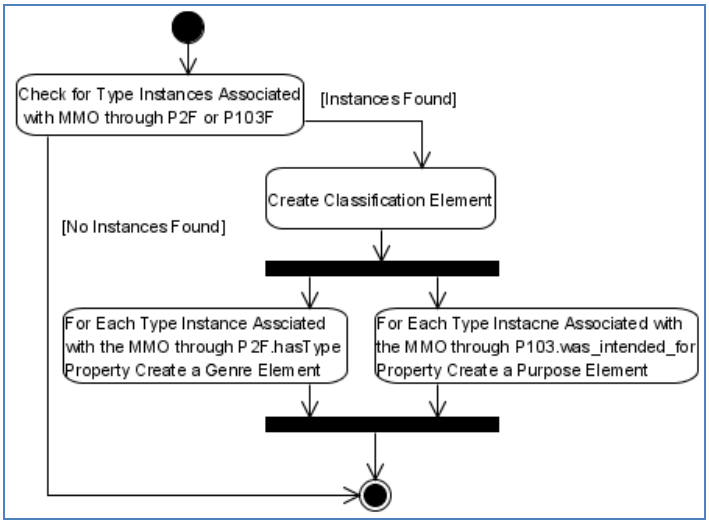


Figure 6.7: Generation of classification information

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 [Delos 2007]. 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 6.8.

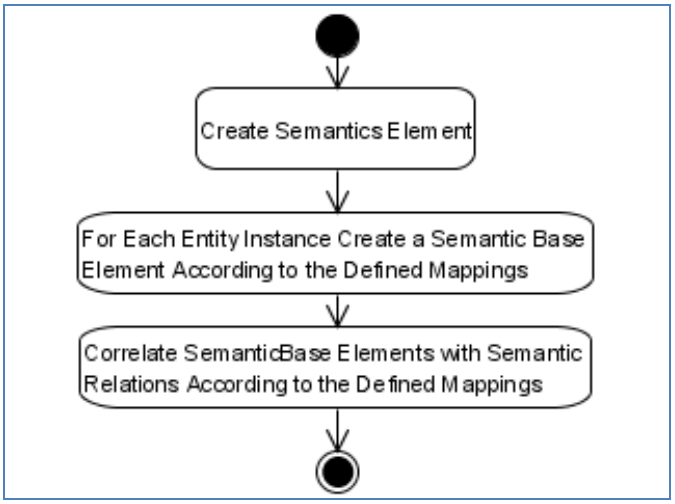


Figure 6.8: Generation of Semantic Information

The generation of MPEG-7 classification scheme that addresses the transformation of *E55.Type* hierarchies is achieved as follows: for each Mpeg-7 document that is created, if there are any *E55.Type* instances in the given CIDOC/CRM description, a *ClassificationScheme* description will be generated. For each type found, a *Term* element will be created inside this *ClassificationScheme*. This process is described in Figure 6.9.

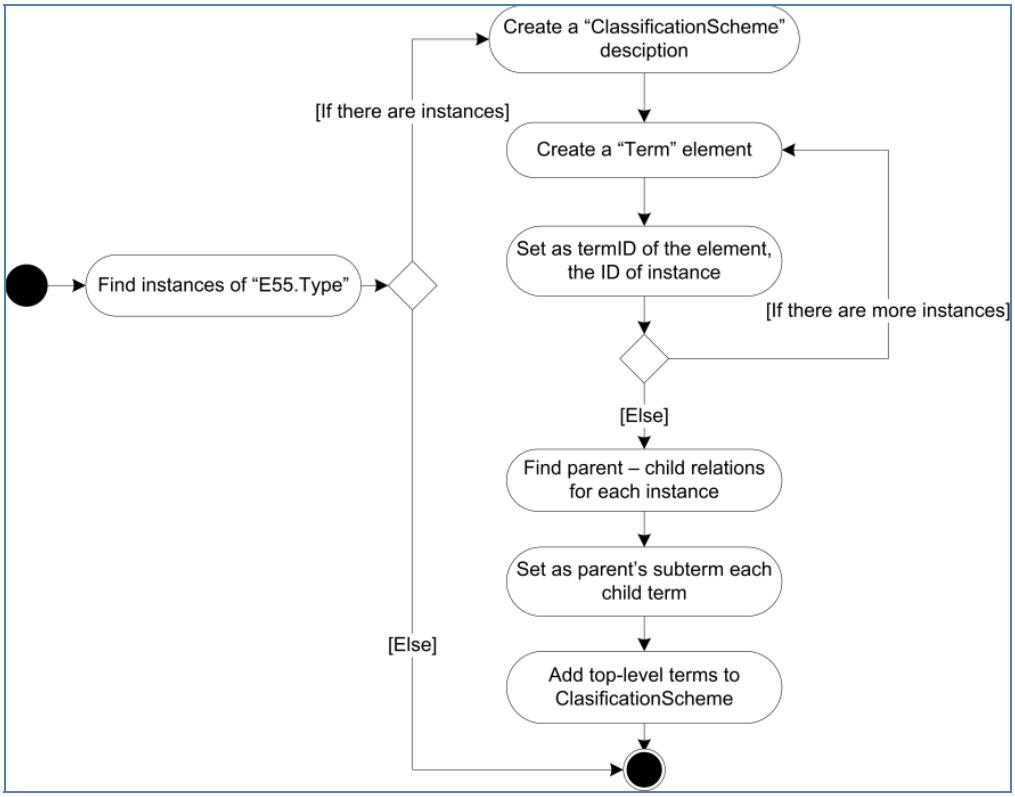


Figure 6.9: Classification Scheme Creation

7 Implementation and Evaluation

The approach presented in this paper for achieving interoperability support between cultural heritage and multimedia environments has been implemented in a transformation toolkit which allows CIDOC/CRM descriptions (encoded in RDF) to be transformed into proper MPEG-7 annotations of multimedia objects. The toolkit materializes the transformation process described in the previous section, and implements the DS-MIRF transformation rules described in [Tsinaraki et al 2007] exploiting the mappings between the two models (described in [Delos 2007]). It should be noted however, that the transformation process described in the previous section is automated for a given multimedia object found in a CIDOC/CRM description. However, in order to identify a specific multimedia object of interest within a CIDOC/CRM description some user intervention is needed (i.e. the user has to specify what kind of multimedia object is described in it). This is due to the fact that most multimedia documents are described in CIDOC/CRM as instances of the entity *E31.Document*. Thus, it is not clear during a specific transformation what kind of multimedia object is described by the given CIDOC/CRM description. The only exception in this rule is the utilization of the entity *E38.Image*. For this reason the transformation toolkit developed to support the proposed methodology allows the user to specify what kind of multimedia object is described in a given CIDOC/CRM description and then it generates automatically its corresponding MPEG-7 annotation. For this reason the transformation toolkit provides a Graphical User Interface through which the user is not only able to specify the type of the multimedia object described in the given CIDOC/CRM description, but also to see a graphical representation of both the loaded RDF and the generated MPEG-7 documents in order to better identify the mappings that were performed. A screenshot of the toolkit's environment is presented in Figure 7.10.

This toolkit was implemented using the Java programming language, which makes it platform-

independent, the Jena framework [HP Labs 2007] for parsing the RDF documents that contain the CIDOC/CRM descriptions, and the XMLBeans framework [Apache Foundation 2003] for schema-aware manipulation of MPEG-7 XML documents.
This toolkit's environment is divided in two panels: the function panel on the left, and the mappings panel on the right. The function panel contains all the necessary buttons to perform every available action in the application, such as opening new CIDOC/CRM descriptions, saving the generated Mpeg-7 annotations, executing the conversion, generating the graph layout of the selected CIDOC/CRM description (in order to see the connections of a node in this graph layout, you have to select the desired node), and representing the selected Mpeg-7 document as a tree construct.

The use of the toolkit in creating new MPEG-7 documents from existing CIDOC/CRM descriptions is fairly easy. The user first loads all the descriptions he may want to convert. After that, the conversion can start by pressing the *Execute* button. The program will automatically identify all the instances of the loaded descriptions, that are likely to contain content management information (that is instances of *E31.Document* and *E38.Image* classes) and will urge the user to specify which instances are of interest and of what type they are. Then, the MPEG-7 annotation for the specified multimedia object is automatically generated.

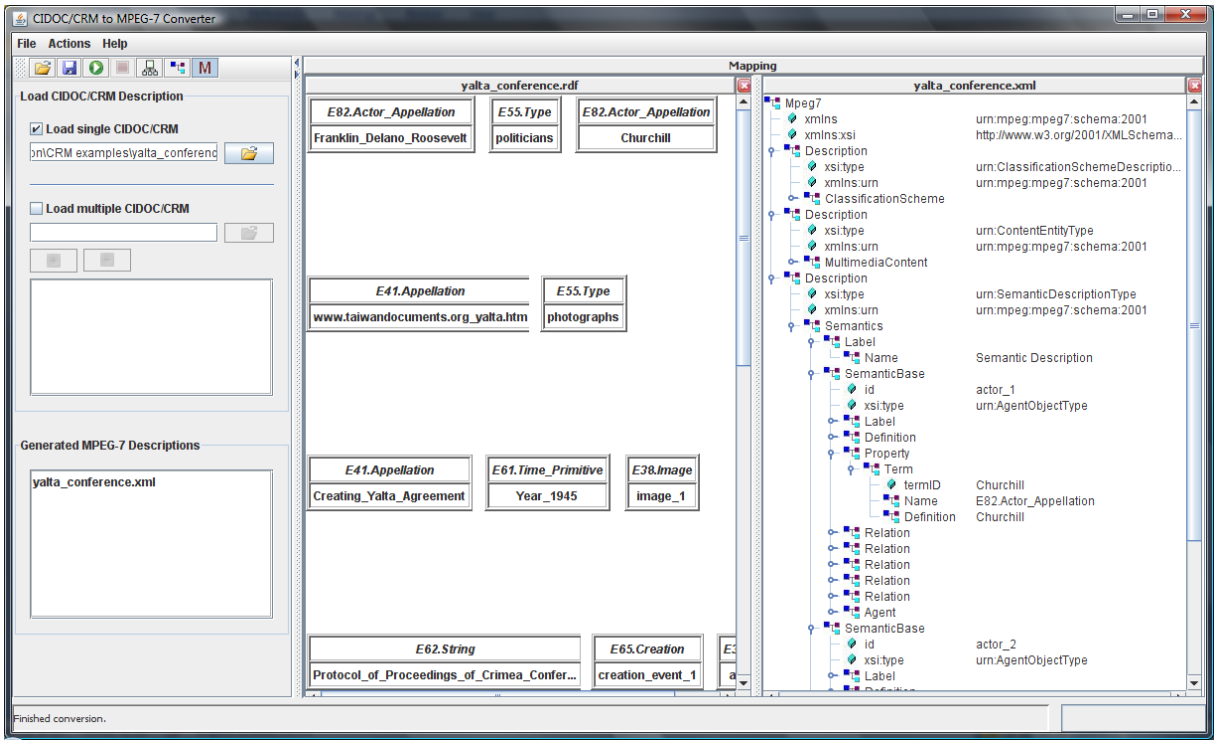
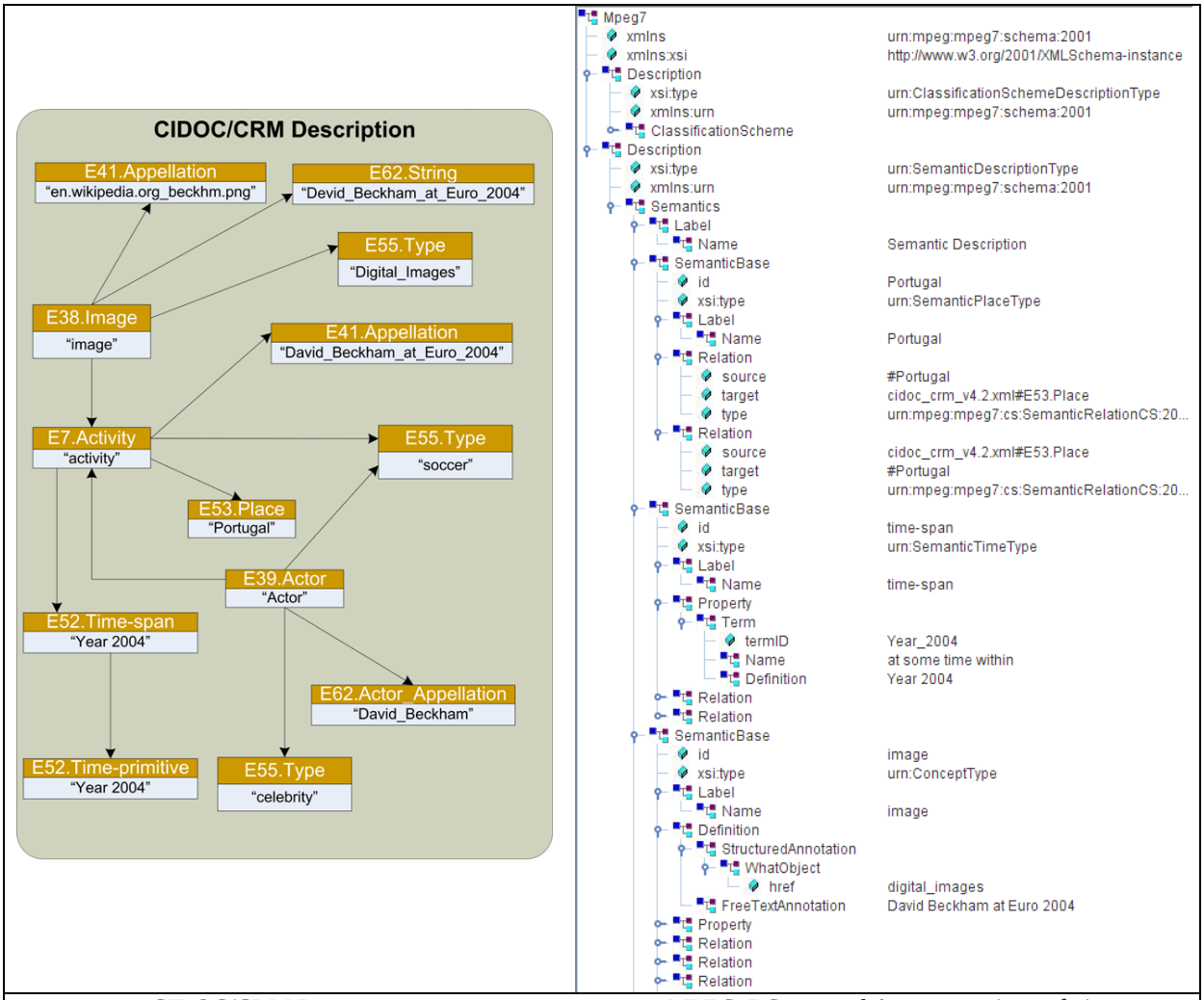


Figure 7.10: The CIDOC/CMR to MPEG-7 transformation toolkit

In order to evaluate the entire methodology and the corresponding toolkit, we have been working on several CIDOC/CRM examples trying to automatically generate MPEG-7 annotations for existing multimedia objects described in them. The complete list of examples can be found in [Ntousias 2007]. We only provide in this section a short example in order to illustrate the validity of the proposed methodology. The following figure shows a given CIDOC/CRM description in RDF and the generated MPEG-7 annotation.



CIDOC/CRM Description | MPEG-7 Generated Annotation (part of it)

Figure 7.11: CIDOC/CRM to MPEG-7 Transformation Example

8 Summary and future work

In this paper we have presented a methodology and a toolkit for supporting semantic interoperability between Cultural Heritage and Multimedia environments. The interoperability support is based on the semantic integration of the CIDOC/CRM and MPEG-7 standards (the dominant metadata standards in these application areas) under the idea of supporting automatic generation of semantic annotations of multimedia documents that refer 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. It also allows the generation of application interfaces for manual annotation (in MPEG-7) of multimedia objects by cultural users who are familiar with CIDOC/CRM conceptualization and terminology.

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 complete list of mappings is not described in this paper due to its size (~85 classes and ~245 properties). They can be found in [Delos 2007].The transformation is possible to face some ambiguities. Ambiguities are generated due to conditional mappings that have been defined for some CIDOC/CRM entities as well as due to user defined type hierarchies that may be included in a given CIDOC/CRM description. Conditional mappings are evaluated by the transformation process at real-time by exploiting instance-level knowledge from the given CIDOC/CRM description. Type hierarchies are treated as specific MPEG-7 Classifications Schemes that further classify MPEG-7 concepts and they are generated automatically.
The proposed methodology for semantic interoperability between cultural and multimedia environments is supported by a transformation toolkit (the CIDOC/CRM2MPEG-7 Converter) which allows end users to automatically transform CIDOC/CRM descriptions that include semantic descriptions of multimedia objects into MPEG-7 annotations for those objects. The only user intervention needed for such a transformation is to select which (and its type) of the numerous multimedia objects that may be found in a given CIDOC/CRM description wants to be annotated in MPEG-7.
The planned next step in our work is to support the reverse process. That is, to allow knowledge captured in MPEG-7 environments to be mapped into CIDOC/CRM. For that, we will look on the required concept mappings from MPEG-7 to CIDOC/CRM and on the required process that will be needed to properly manipulate MPEG-7 documents in order to transform them into valid CIDOC/CRM descriptions.

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