# Rich Metadata and Context Capturing through CIDOC/CRM and MPEG-7 Interoperability

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## ABSTRACT

It is now accepted that powerful retrieval of multimedia data can be achieved with the integration of semantic and contextual metadata that relate to multimedia objects. In the case of objects related to culture and history there is a wealth of related information stored in Digital Libraries. CIDOC/CRM is a new, rapidly adopted standard in the field of cultural heritage that provides a very powerful model for encoding cultural heritage knowledge. In this paper we propose that knowledge is extracted and encoded in MPEG-7 multimedia object descriptions in an automatic manner so that the multimedia objects are augmented with very rich metadata descriptions coming from Digital Libraries. We analyze the mapping problem between CIDOC/CRM and MPEG-7 and we present the algorithms and a software system that supports this mapping.

## 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

## Keywords

Context Capture, Metadata, Mapping Algorithm, MPEG-7, CIDOC/CRM

## 1. INTRODUCTION

Extensive work has been done in the past in the area of multimedia indexing. Content based approaches start from the low level image descriptions and try to infer semantic meaning that describes the picture contents. It has been found difficult however to bridge the semantic gap between the low level features and the rich semantic content of multimedia, such as video. Recent approaches in this area try to bridge the semantic gap by focusing in particular application domains [1], [2], [3]. Ontology based approaches start from the semantic knowledge about a domain as described by some domain ontology, and they use the ontology concepts and instances to provide annotations for multimedia objects. Most of those approaches rely on manual metadata provision, although in some cases where textual or voice information exists the process can be at least partially automated [4], [5], [7], [8] and [17]. Manual metadata provision is difficult to expect despite the need for powerful retrieval mechanisms.

It has been emphasized that contextual information can greatly enhance multimedia retrieval [1]. For example consider a picture of a painting in a museum that shows the battle of Thermopylai. Typical metadata descriptions of the painting will include the painter, the name of the paint, the year of painting, its history of ownership in museums, etc. With such metadata however, queries asking about the paintings of the battles between the Greeks and the Persians before the 300 BC will not be able to find the picture of the painting. The contextual historical metadata are important in this case. However, rich contextual metadata, as well as rich semantic metadata are very expensive to be manually inserted.

Digital libraries all over the world contain immense amounts of cultural and historical information that can potentially provide cultural and historical metadata descriptions for the content and context of cultural and historical objects and events. Since 1996, the International Committee for Documentation (CIDOC) of International Council of Museums (ICOM) has developed the Conceptual Reference Model (CRM) [14], which is a standard for cultural heritage that was recently adopted by the International Standardization Organization (ISO) and provides very rich structuring mechanisms for metadata descriptions. CIDOC/CRM has capabilities to model events that happen at specific time periods in specific places and affect (i.e. change, result in, etc.) specific material or conceptual things. It also provides capabilities to refer from a concept to other concepts, and capabilities for extensibility (like ISA type hierarchies that further classify its original concepts). The standard has already been adopted by very large cultural heritage organizations, including the English Heritage, the Finnish National Gallery, the Germanische National Museum, the Research Libraries Group (RLG), etc. and mappings have already been established from numerous other standards [6] that are used in cultural heritage documentation, to CIDOC/CRM.

CIDOC/CRM can for example be used to describe the metadata of the paintings of the Thermopylai battle including the time of the painting, the painter, the history of the paint (what time intervals was owned by what museum), the artistic aspects of the paint, etc.. CIDOC/CRM is also suited to maintain historical ontologies for structuring the historical knowledge in (the same or other) libraries in order to support effective retrieval of their contents. Such knowledge descriptions may include the knowledge about the Thermopylae battle, such as time interval, location, participant cities and armies, etc. It may also have references to digital information concerning the battle, such as library documents, Wikipedia descriptions, etc. All this metadata about the painting itself , as well as about the context of the Thermopylai battle can be extracted and used to form the semantic metadata descriptions of the picture of the painting. This way, very powerful semantic queries can be supported in the multimedia or picture database. We propose in this paper to use the metadata descriptions of CIDOC/CRM to (almost) automatically provide rich MPEG-7 content and context metadata descriptions for multimedia objects related to culture and history.

It is important to note here the role of the standards in the process. To automatically exploit the cultural data of digital libraries we have to rely on a standard language interface with digital libraries (CIDOC/CRM). To be able to have a software that will use the extracted metadata to a user's application environment we need to have the user metadata structured according to a standard (MPEG-7). If the user was using his/her own structures or database schema for metadata, different software would be needed by each user. The architecture and software that we propose in this paper will be automating the content and context metadata descriptions for MPEG-7 multimedia applications. The main emphasis of this paper is in the provision of mapping algorithms between CIDOC/CRM and MPEG-7.

## 2. MAPPING CIDOC/CRM TO MPEG-7

The first observation we can make in trying to define mappings from CIDOC/CRM to MPEG-7 is that the first model provides a fine-grained conceptualization with respect to the second. 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 into MPEG-7 is required. "Domain aware" means the ability 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) [12]. 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 [16], [17] 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 1). Then, appropriate transformation rules (described in [17]) 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.

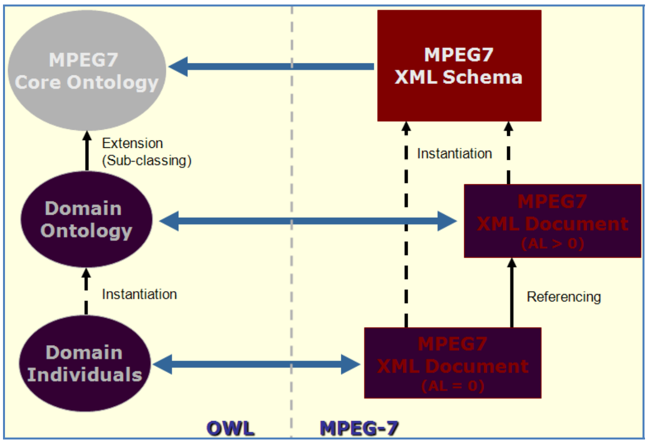


**Figure 1. The DS-MIRF framework**

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

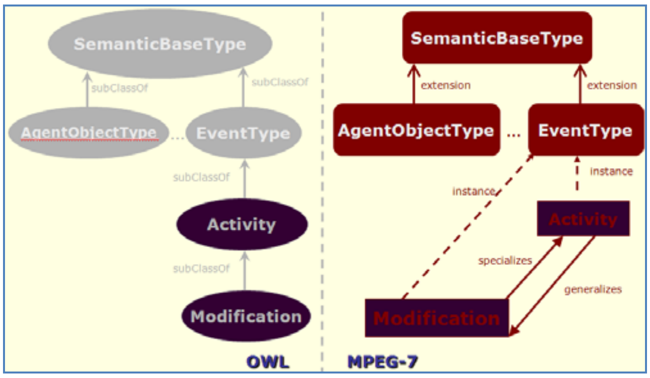


**Figure 2. Incorporating CIDOC/CRM semantics in MPEG-7**

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

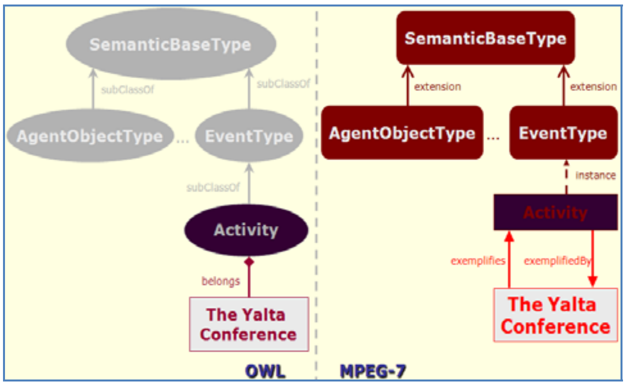


**Figure 3. Representation of CIDOC/CRM descriptions into MPEG-7**

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.

## 3. MAPPINGS OF 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. The basic principles that we followed in this process are:

- a) 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 [18], 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.
- Concept relation mappings are defined according to the semantic relatedness of theCIDOC/CRM properties and MPEG-7 Semantic Relations.

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 [10]. Table 1 shows some of the mappings defined for the CIDOC/CRM entities and MPEG-7 DSs, while Table 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.

**Table 1. Examples of CIDOC/CRM entity mappings**

| 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 2. Examples of CIDOC/CRM Property 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 |
| … | … |

# 4. 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:

2. 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:

    - **E54.Dimension.** 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

    - **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:

        a. 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)

        b. 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.

    - **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.

3. 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 algorithm 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 algorithm 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.

# 5. THE TRANSFORMATION ALGORITHM

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 algorithm 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 algorithm 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 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.

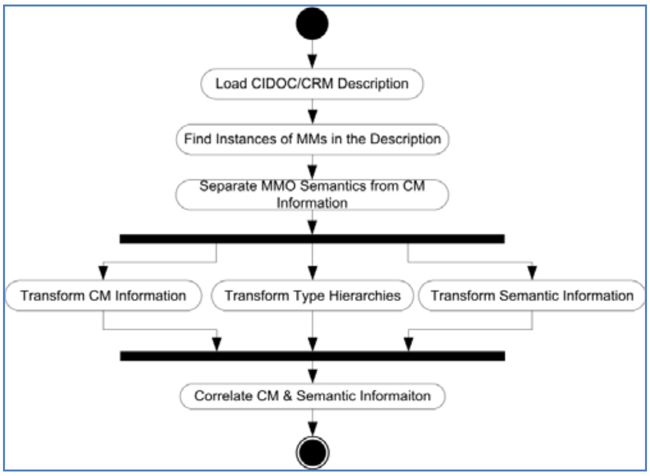


**Figure 4. The overall transformation algorithm**

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.

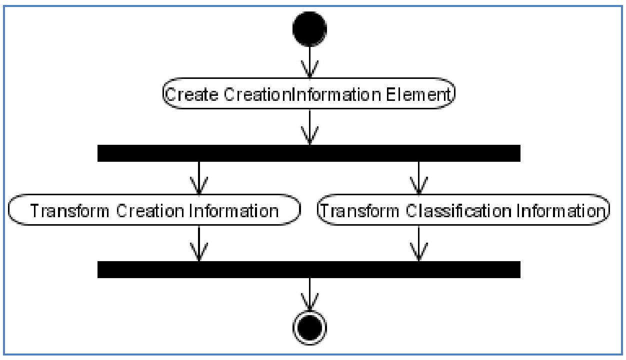


**Figure 5. Generation of content management information**

The determination of CIDOC/CRM entity instances that describe the Creation information for each 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. The process of transformation of these instances to MPEG-7 elements is depicted in Figure 6.

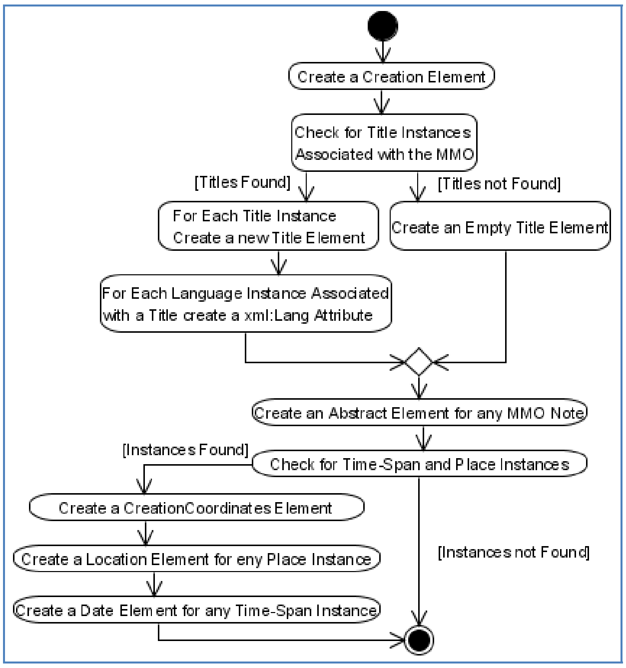


**Figure 6. Generation of creation information**

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 7.

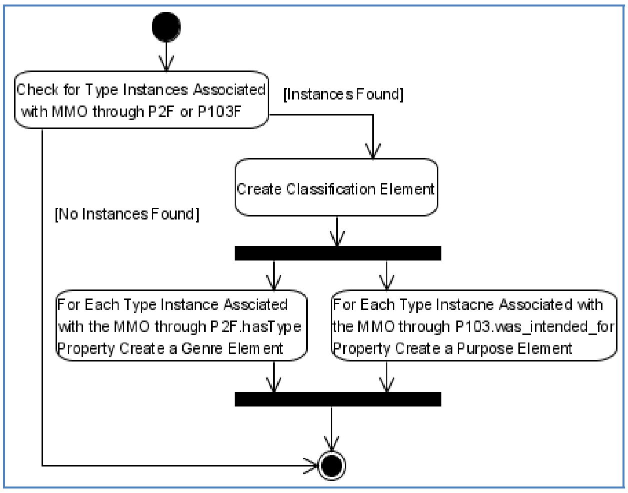


**Figure 7. Generation of classification information**

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 [10]. 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. This correlation is achieved through the utilization of the Relation element and the use of exemplifies/exemplifiedBy semantic relations, as described in section 2. The overall transformation process for the generation of the semantic annotation is illustrated in Figure 8.

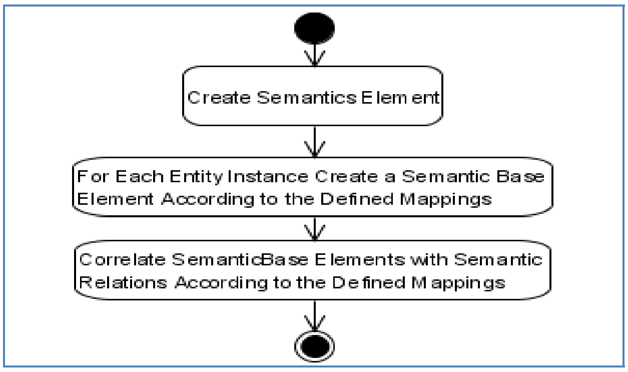


**Figure 8. Generation of semantic information**

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 9.

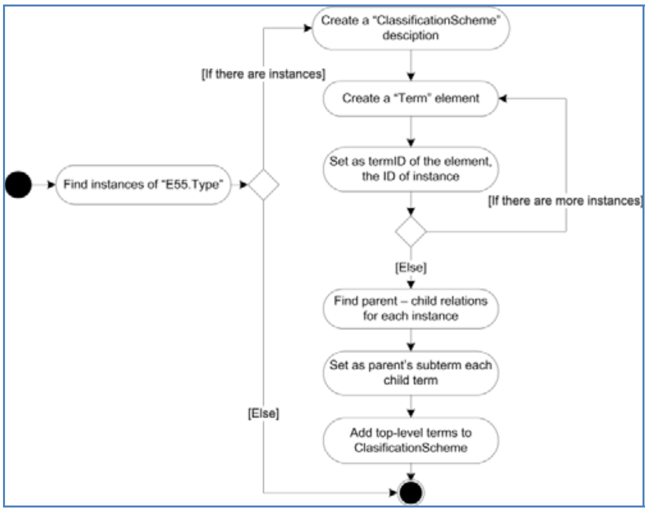


**Figure 9. ClassificationScheme creation**

## 6. IMPLEMENTATION

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 implements the transformation algorithm described in the previous section exploiting the mappings between the two models (described in [10]) and the DS-MIRF transformation rules described in [17]. In the case where a multimedia object is found in a CIDOC/CRM description, some user intervention is required in order to identify it (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 10.

This toolkit was implemented using the Java programming language, which makes it platform-independent, the Jena framework [11] for parsing the RDF documents that contain the CIDOC/CRM descriptions, and the XMLBeans framework [1] 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.

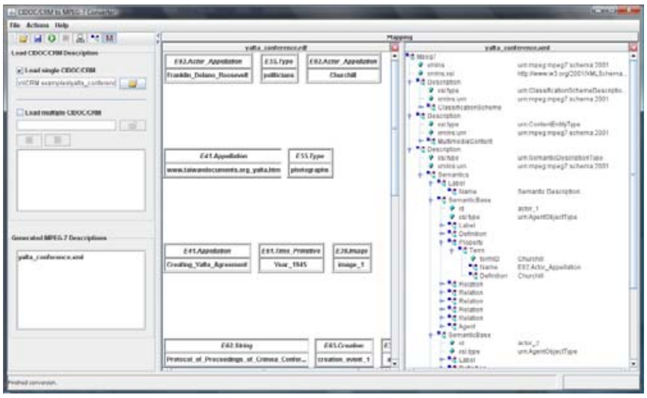

**Figure 10. The CIDOC/CRM to MPEG-7 transformation toolkit**

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.

## 7. TRANSFORMATION EXAMPLE

In order to evaluate the entire methodology and the corresponding toolkit, we have been working on several CIDOC/CRM examples trying to generate MPEG-7 annotations automatically for existing multimedia objects described in them.

In this section we will show the steps of the transformation on a short example, in order to understand how the theoretical background, that was presented earlier, is applied to a real description. Assume the following scenario: A multimedia collection owner wants to annotate (in MPEG-7) the picture of the painting of the battle in Thermopylae. Instead of manually annotating the picture, it would be desirable to exploit the painting's description that the museum owns. So, what the multimedia collection owner needs is an appropriate knowledge discovery interface to museum repositories. The scenario can be even more advanced if we think that the museum bases the painting annotation on a Greek History Digital Library (GHDL). In that case, the museum can bet the painting's context (i.e. the historical information about the event Thermopylae battle) from the history digital library. The museum annotator needs (again) only a knowledge discovery interface to the GHDL. The cultural descriptions are illustrated Figure 11 and Figure 12.

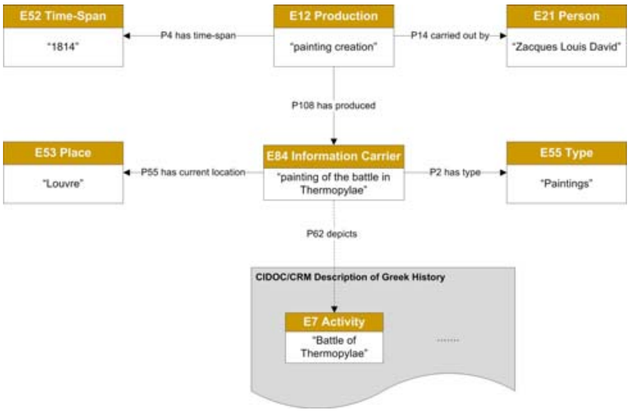


**Figure 11. Part of CIDOC/CRM description of the painting of Zacques Louis David depicting the battle in Thermopylae**

As shown, the museum CIDOC/CRM description contains information only about the creation of the painting, the creator, its current location etc. As for the depiction (i.e. the multimedia object context as considered in this paper), it uses a reference to an activity describing the battle in Thermopylae, that can be located in a CIDOC/CRM description of the GHDL repositories. This historical description captures knowledge regarding the Greek history, and a part of it is illustrated in Figure 12.

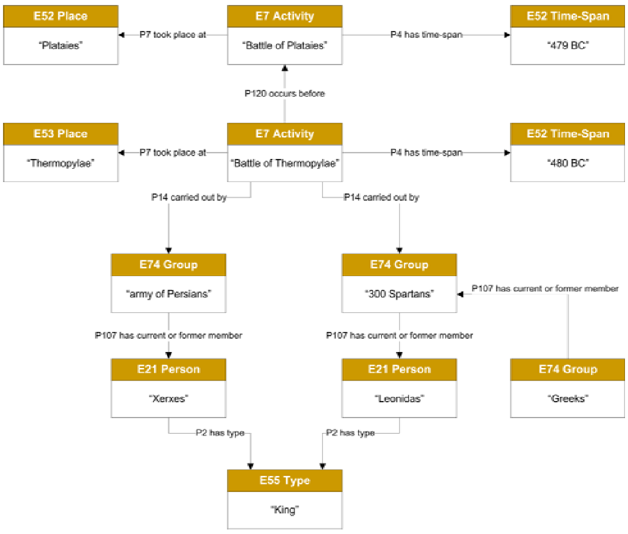


**Figure 12. Part of CIDOC/CRM description of the Greek history**

Back to the starting of our scenario, the once the multimedia collection owner finds the CIDOC/CRM description of the painting (s)he has also the contextual description of the painting. Then, s(he) can use the transformation process and the mappings presented earlier to create the semantic description needed for his/her multimedia object (the image of the painting in the particular example). Due to the lack of content management (CM) information, the process is completely automatic and the instances participating can be classified in the following categories:

- **Type Hierarchies** (all instances of E55 Type class): “King” (E55 Type), “Paintings” (E55 Type)
- **Semantic Information** (the rest of the instances): “painting of the battle in Thermopylae” (E84 Information Carrier), “battle of Thermopylae” (E7 Activity), “army of Persians” (E74 Group), “300 Spartans” (E74 Group), etc.

According to the activity diagram in Figure 4, we will follow a different set of steps for the instances of each of the above categories. For the transformation of the types of a CIDOC/CRM description, the algorithm described in Figure 9 will be used. Due to the existence of instances “King” and “Paintings” in our example, two Terms will be created as nested elements inside a ClassificationScheme. These Terms will be referenced later, by the instances “Xerxes”, “Leonidas” and “painting of the battle in Thermopylae” that use them as their types.

```
<DESCRIPTION
XSI:TYPE=”CLASSIFICATIONSCHEMEDESCRIPTIONTYPE
”>
  <CLASSIFICATIONSCHEME
  URI=”CRM2MPEG7:TYPES”>
    <TERM TERMID=”KING”>
      <NAME>KING</NAME>
    </TERM>
    <TERM TERMID=”PAINTINGS”>
      <NAME>PAINTINGS</NAME>
    </TERM>
  </CLASSIFICATIONSCHEME>
</DESCRIPTION>
```

**Figure 13. Part of MPEG-7 annotation, representing the type hierarchies**

Finally, for each of the instances representing semantic information in our description, the appropriate MPEG-7 element will be employed, according to the entity mappings of section 3. Since the instances of our example are not mapped directly to MPEG-7 DSs, a reference to the abstract elements representing the respective entity of CIDOC/CRM must be established. These abstract elements have already been created according to the methodology of DS-MIRF framework to provide the appropriate domain-awareness into MPEG-7, in order to represent properly the metadata of CIDOC/CRM without any loss of information. The reference to them is achieved through the use of Relation elements and “exemplifies/exemplifiedBy” semantic relations.

For every instance that is correlated with a type through property “P2 has type”, a StructuredAnnotation element is created along with the proper sub-element. The sub-element that will be employed depends on the nature of the instances, as described in section 4. Thus, for instances “Xerxes” and “Leonidas”, the Who element will be utilized, while for the “painting of the battle in Thermopylae” the element WhatObject.

For the properties of each instance, semantic relations will be used, according to the property mappings defined in section 3. Due to the numerous properties that are mapped to each semantic relation, the Comment element of Relation must be employed in order to keep track which of the properties of CIDOC/CRM represents each relation in the annotation.

Due to space limitations we will show only few of the transformed instances representing semantic information. A complete list of all the examples used to evaluate our methodology can be found in [10].

```
<DESCRIPTION
XSI:TYPE=”SEMANTICDESCRIPTIONTYPE”>
  <SEMANTICS>
    ……
    <SEMANTICBASE XSI:TYPE=”AGENTOBJECTTYPE”
    ID=”LEONIDAS”>
      <LABEL>
        <NAME>LEONIDAS</NAME>
      </LABEL>
      <DEFINITION>
        <STRUCTUREDANNOTATION>
          <WHO HREF=”KING” />
        </STRUCTUREDANNOTATION>
      </DEFINITION>
      <RELATION SOURCE=”#LEONIDAS”
        TARGET=”CIDOC_CRM_V4.2.XML#E21.PERSON”
        TYPE=”URN:MPEG:MPEG7:CS:SEMANTICRELATIO
      NCS:2001:
        EXEMPLIFIES” />
      <RELATION SOURCE=”
      CIDOC_CRM_V4.2.XML#E21.PERSON”
        TARGET=”#LEONIDAS”
        TYPE=”URN:MPEG:MPEG7:CS:SEMANTICRELATIO
      NCS:2001:
        EXEMPLIFIEDBY” />
    </SEMANTICBASE>
    <SEMANTICBASE XSI:TYPE=”EVENTTYPE”
      ID=”BATTLE_IN_THERMOPYLAE”>
      ……
      <RELATION TARGET=”#THERMOPYLAE”
        TYPE=”URN:MPEG:MPEG7:CS:SEMANTICRELATIO
      NCS:2001:
        LOCATION”>
        <HEADER
        XSI:TYPE=”DESCRIPTIONMETADATATYPE”>
          <COMMENT>
```

<FREETEXTANNOTATION>
CIDOC/CRM PROPERTY: P7F.TOOK_PLACE_AT
</FREETEXTANNOTATION>
</COMMENT>
</HEADER>
</RELATION>
</SEMANTICS>
</DESCRIPTION>

**Figure 14. Part of MPEG-7 annotation, representing semantic information**

The generated semantic multimedia description of the image can now be handled by any standard MPEG-7 repository that provides indexing of given multimedia objects. Thus, what we have achieved in the previous example is that we provided automatically semantic and contextual indexing of a multimedia object by exploiting already existing (in a cultural heritage museum and the Greek History Digital Library) information.

This rich contextual indexing of multimedia objects can be further exploited in multimedia environments by allowing end users to search and locate multimedia objects based on rich semantic criteria. One issue here is how the end users can express such complex semantic queries. For that, an MPEG-7-oriented language that will be able to express domain specific semantics is needed. In our work, MP7QL [4] is such a language that can be used by end users to allow the expression of semantically enhanced MPEG-7 queries. MP7-QL allows the expression of queries that may pose both high-level semantic and content based criteria for multimedia objects. MP7-QL is also able to accommodate knowledge that is captured by domain specific ontologies following the DS-MIRF framework. Thus, in our example users can use MP7-QL to express queries like:

- “Give me Images that show the Battle of Thermopylae”,
- “Show me the battles between Greeks and Persians Before Christ.
- “Show me paintings of the 300 Spartans”
- ….

It should be noticed that the expression of such semantic queries could be driven by the same ontology that was used in annotating the multimedia object. That is, the ontology of the GHDL.

## 8. CONCLUSIONS

Rich semantic and contextual metadata about the objects in pictures and video are essential for the support of powerful retrieval mechanisms for multimedia, but they typically rely on manual annotation techniques. Since it is unrealistic to expect that the users will have all the semantic knowledge to complete all these metadata descriptions, and also since users do not want to invest the time for such rich manual annotations, it is important that we provide as much automation as possible to the annotation process. In the case of pictures or video of cultural resources much automation in the semantic metadata annotation is possible since libraries and museums all over the world maintain such knowledge and they are also moving rapidly towards the knowledge based structuring and digitization of their resources.

We described in this paper a methodology, algorithms, and software to convert rich CIDOC/CRM descriptions about cultural objects as well as about cultural and historical context to MPEG-7 metadata descriptions. This methodology essentially allows the export of the immense cultural and historical knowledge that exists in cultural institutions all over the world to MPEG-7 descriptions, thus automating the rich semantic annotation of the cultural multimedia objects. The expected metadata descriptions can be managed by any multimedia management software that is based on standards

In order to enable domain-aware mappings of CIDOC/CRM to MPEG-7 (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 algorithm for appropriate manipulation of CIDOC/CRM descriptions and their transformation into valid MPEG-7 documents.

The transformation algorithm is based on a complete list of mappings between the two models which can be found in [10]. The transformation is possible to face some ambiguities which 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 algorithm 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 planned next step in our work is to walk the reverse path. 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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