Mapping MPEG-7 to CIDOC/CRM

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Abstract. The MPEG-7 is the dominant standard for multimedia content description; thus, the audiovisual Digital Library contents should be described in terms of MPEG-7. Since there exists a huge amount of audiovisual content in the cultural heritage domain, it is expected that several cultural heritage objects, as well as entities related with them (i.e. people, places, events etc.), have been described using MPEG-7. On the other hand, the dominant standard in the cultural heritage domain is the CIDOC/CRM; consequently, the MPEG-7 descriptions cannot be directly integrated in the cultural heritage digital libraries.

We present in this paper a mapping model and a system that allow the transformation of the MPEG-7 descriptions to CIDOC/CRM descriptions, thus allowing the exploitation of multimedia content annotations in the cultural heritage digital libraries. In addition, the proposed mapping model allows linking MPEG-7 descriptions to CIDOC/CRM descriptions in a Linked Data scenario.

Keywords: MPEG-7, CIDOC/CRM, Mapping, Multimedia, Cultural Heritage.

1 Introduction

The MPEG-7 is the dominant standard for multimedia content description [1] and allows describing all the aspects of the multimedia content, including the semantics, the low-level image, audio and motion features, the structural information, the media-related information etc. The MPEG-7 descriptions can be captured automatically (using, for example, camera sensors) or semi-automatically. The amount of multimedia data captured daily is increasing extremely fast due to the proliferation of inexpensive cameras and associated sensors (see for example [17]). Very frequently the digital audiovisual content captured contains cultural heritage objects.

On the other hand, the dominant standard in the cultural heritage domain for the description of cultural heritage objects (i.e museum exhibits, archival material, books etc.) is the CIDOC/CRM [2]. Several other standards used in the cultural heritage domain have been mapped to the CIDOC/CRM (like [3] [4]). However, the MPEG-7 descriptions of the audiovisual content cannot be directly integrated in the cultural heritage digital libraries since the MPEG-7 has not been mapped to the CIDOC/CRM.

The need for transforming MPEG-7 descriptions to CIDOC/CRM ones as well as the capability of linking them in CIDOC/CRM descriptions in a Linked Data scenario has been recognized by important consortiums in the Digital Library domain like, for example, the Europeana consortium [5]. Europeana aims to develop a European

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digital library containing digitized material about the European scientific and cultural heritage. In particular, the *Europeana Data Model (EDM)* [7] has adopted the CIDOC/CRM core, while the consortium emphasizes the need for linking existing descriptions of the digitized material in the EDM descriptions [6], according to the linked data approach [8].

The previous research in interoperability support between MPEG-7 and CIDOC/CRM focuses on the representation of CIDOC/CRM descriptions in MPEG-7 syntax. In particular, [9] proposes specific extensions to the CIDOC/CRM in order to be able to accommodate the temporal and spatial aspects of information objects, while [10] has developed a methodology that allows automatically generating semantic MPEG-7 multimedia annotations from CIDOC/CRM descriptions. However, in both cases, the inverse functionality, which should allow the transformation and/or linking of MPEG-7 multimedia annotations in CIDOC/CRM descriptions, is missing.

We present in this paper *MPEG72CIDOC*, a *mapping model* that maps the MPEG-7 constructs to CIDOC/CRM constructs and a software component that, based on MPEG72CIDOC, allows the transformation of MPEG-7 descriptions to CIDOC/CRM descriptions as well as linking them to CIDOC/CRM descriptions. These mechanisms allow the multimedia content descriptions to be exploited in the cultural heritage digital libraries. This work complements our previous research for the transformation of CIDOC/CRM descriptions in MPEG-7 syntax [10]. The MPEG72CIDOC mapping model differs from that of [10] in the following: *(a)* It has adopted the MPEG-7 viewpoint for mapping the MPEG-7 constructs to CIDOC/CRM constructs. As a consequence, there do not exist corresponding CIDOC/CRM constructs for some MPEG-7 constructs (like, for example, the spatial relations above, south, left etc.) and some of the mappings specified in [10] for the inverse process are not appropriate from this viewpoint, since the two standards describe several aspects in different levels of granularity; and *(b)* It takes into account all the MPEG-7 MDS and not only the semantic part, as was done in [10]. Moreover, the implementation of the MPEG72CIDOC mapping model in order to allow the automatic transformation of MPEG-7 descriptions to CIDOC/CRM ones has been integrated in the toolkit developed in [10] for the automatic transformation of CIDOC/CRM descriptions in MPEG-7 syntax.

The MPEG72CIDOC mappings may also be applied between CIDOC/CRM and any ontology like [12] that captures the MPEG-7 semantics, since the mappings have not been based on the XML Schema syntax of MPEG-7. They also allow the exploitation of user preferences that have been expressed for multimedia content described using MPEG-7 [14] in the cultural heritage domain.

In addition, the transformation of the MPEG-7 descriptions to CIDOC/CRM ones allows using the Semantic Web technologies over the transformed descriptions in the cultural heritage domain, without having to use any MPEG-7 based ontology and thus not having to face the interoperability issues arising from the existence of several MPEG-7 based ontologies [13].

The rest of this paper is structured as follows: The MPEG72CIDOC mapping model is presented in Section 2, the MPEG-7 to CIDOC/CRM transformation process is described in Section 3, the implementation is discussed in Section 4, a transformation example is presented in Section 5 and the paper concludes in Section 6, which also outlines our future research directions.

2 The MPEG72CIDOC Mapping Model

In this section we present the MPEG72CIDOC mapping model that we have developed in order to allow the exploitation of MPEG-7 descriptions in CIDOC/CRM working environments.

The MPEG-7 focuses on multimedia content description, while the CIDOC/CRM focuses on cultural heritage concepts. Thus, the MPEG-7 provides a more extended set of description tools for multimedia content description, while the CIDOC/CRM provides a fine-grained conceptualization within the cultural heritage domain. As a consequence, we faced the problem of the accurate representation of the multimedia-specific MPEG-7 concepts in CIDOC/CRM. This problem was solved through the representation of these concepts using the CIDOC/CRM entity "E55.Type", which is an extensibility mechanism of the CIDOC/CRM model and its instances can be considered as classes that are organized in class hierarchies using the properties "P127 has broader term/has narrower term". The association of an "E55.Type" entity instance to its type is implemented through the property "P2 has type".

In the MPEG72CIDOC mapping model, the MPEG-7 *types*, which represent the MPEG-7 concepts, are mapped to semantically correspondent CIDOC/CRM *entities*. Moreover, the MPEG-7 *relations*, which associate instances of the MPEG-7 types, are mapped to CIDOC/CRM *properties* that associate CIDOC/CRM entities.

There are two types of mappings in the MPEG72CIDOC mapping model: a) *static* mappings, which essentially are *correspondences* [15] between the MPEG-7 and the CIDOC/CRM constructs and are specified at design-time; and b) *conditional* mappings that are evaluated in real-time according to the given context since they are based on *mapping rules* [16] that have been specified at design-time.

MPEG-7 Type Mappings. The MPEG72CIDOC mapping model is based on the following principles for mapping the MPEG-7 types to CIDOC/CRM entities:

- For every MPEG-7 type *mt* that can be directly mapped to a CIDOC/CRM entity *ce*, an exact static mapping between *mt* and *ce* is defined. For example, the MPEG-7 type "PersonType" that represents persons is mapped to the semantically correspondent CIDOC/CRM entity "E21 Person".
- Every MPEG-7 type *mmt* that represents a multimedia-specific concept for which does not exist a corresponding CIDOC/CRM entity is mapped to an instance *ramd* of the CIDOC/CRM entity "E55 Type". For example, the MPEG-7 type "VideoType" is mapped to the "VideoType" instance of the CIDOC/CRM entity "E55 Type".
- The MPEG-7 provides *abstraction* support, which allows the representation of both instance-level semantic abstract descriptions and class-level semantic descriptions. In particular, the representation of the abstract MPEG-7 description *amd* is based on the value of its *dimension* attribute that indicates its abstraction level:
  - If *dimension* has a value greater than or equal to 1, *amd* is a class-level abstract semantic description that represents a class and is mapped to an instance *tme* of the CIDOC/CRM entity "E55 Type". For example, an abstract MPEG-7 description that represents a class of buildings is mapped to an instance of the CIDOC/CRM entity "E55 Type".

  - If *dimension* has a value of 0, *amd* is an instance-level semantic description independent from the multimedia content and it describes a reusable instance (e.g. Parthenon). In this case *amd* is a concrete semantic description and is represented by an instance *tme* of the CIDOC/CRM entity "E77 Persistent Item". For example, an abstract MPEG-7 description that represents Parthenon is mapped to an instance of the CIDOC/CRM entity "E77 Persistent Item".
- The representation *rte* of any element *te* of the MPEG-7 type *mt* is associated with the representation *rmt* of *mt* using one of the following CIDOC/CRM properties:
  - **P141 assigned** if *te* is an object.
  - **P140 assigned attribute to** if *te* is a relation.
- The MPEG-7 attributes "id", "href", "xml:lang" and "xsi:type" are transformed to the appropriate CIDOC/CRM properties using specialized algorithms that are described in Section 3.

Due to the large number of the MPEG-7 types, the presentation of the MPEG72CIDOC mappings here is non-exhaustive (an exhaustive presentation is available in [11]). An excerpt of the MPEG72CIDOC mappings between MPEG-7 types and CIDOC/CRM entities is shown in Table 1.

Table 1. Excerpt of the MPEG72CIDOC MPEG-7 Type Mappings

MPEG-7 Type	CIDOC/CRM Entity
VideoType	E55 Type ("VideoType")
AgentType	E39 Actor
MultimediaContentType	E31 Document
PersonType	E21 Person
…	…

MPEG-7 Relation Mappings. The MPEG72CIDOC mapping of an MPEG-7 relation *mr* to a CIDOC/CRM property *cp* falls in one of the following categories:

- **Exact mapping.** In this case, the MPEG-7 relation *mr* is mapped to the CIDOC/CRM property *cp* that has exactly the same meaning. For example, the MPEG-7 relation "inside" is mapped to the semantically correspondent CIDOC/CRM property "P89 falls within".
- **Mapping to the closest meaning.** In this case *mr* is mapped to the CIDOC/CRM property *cp* with the closest semantic meaning. For example, the MPEG-7 relation "key" is mapped to the CIDOC/CRM property "P1 is identified by".
- **No Mapping.** In this case *mr* cannot be mapped to a CIDOC/CRM property, since there does not exist a CIDOC/CRM property with the same (or at least similar) semantics. For example, the MPEG-7 relation "above" is not mapped to any CIDOC/CRM property.
- **Conditional Mapping.** In this case, *mr* is mapped to different CIDOC/CRM properties based on the type of its source *mrs* and its target *mrt*. This happens if *mr* is of type *location*, *location of* or *overlaps*:

- If *mr* is of *location* type, then: *(a)* If *mrs* is an event, *mr* is mapped to the CIDOC/CRM property "P7 took place at"; and *(b)* If *mrs* is an object, *mr* is mapped to the CIDOC/CRM property "P53 has former or current location".
- If *mr* is of *location of* type, then: *(a)* If *mrt* is an event, *mr* is mapped to the CIDOC/CRM property "P7 witnessed"; and *(b)* If *mrt* is an object, *mr* is mapped to the CIDOC/CRM property "P53 is former or current location of".
- If *mr* is of *overlaps* type, then: *(a)* If *mrs* is a place, *mr* is mapped to the CIDOC/CRM property "P121 overlaps with"; and *(b)* If *mrs* is a time period, *mr* is mapped to the CIDOC/CRM property "P132 overlaps with".

An excerpt of the MPEG72CIDOC MPEG-7 relation mappings is shown in Table 2 (an exhaustive presentation of the mappings is available in [11]).

Table 2. Excerpt of the MPEG72CIDOC MPEG-7 Relation Mappings

MPEG-7 Relation	CIDOC/CRM property
Exact mapping	
inside	P89 falls within
precedes	P120 occurs before
agent	P14 carried out by
depictedBy	P62 is depicted by
…	…
Mapping to the closest meaning	
refines	P70 documents
user	P125 used object of type
key	P1 is identified by
goal	P21 had general purpose
…	…
No Mapping	
south	-
left	-
above	-
…	…

3 MPEG-7 to CIDOC/CRM Transformation

In this section we present the MPEG-7 to CIDOC/CRM transformation process that implements the MPEG72CIDOC mapping model.

The MPEG-7 to CIDOC/CRM transformation process is outlined in Fig. 1. The transformation of an MPEG-7 description *md* starts by locating all the elements of *md*. Then the MPEG-7 relation elements are separated, the transformation of the *md* elements and relations takes place and the produced CIDOC/CRM description is finalized after the association of the transformations of the individual MPEG-7 constructs (i.e. elements and relationships).

The transformation of the MPEG-7 elements is outlined in Fig. 2 (due to space limitations, details on the MPEG-7 element transformation are available in [11]): For every MPEG-7 element *e* the element name and value are located first. Then the

mapping of the type of *e* to the appropriate CIDOC/CRM entity *ce* is used for the transformation of *e* in an instance *re* of *ce*. At this stage it is also checked if *e* has attributes. If this is the case, they are transformed in CIDOC/CRM properties. Finally, the representation *re* of *e* is associated with the CIDOC/CRM properties that represent its attributes and is added in the CIDOC/CRM description.

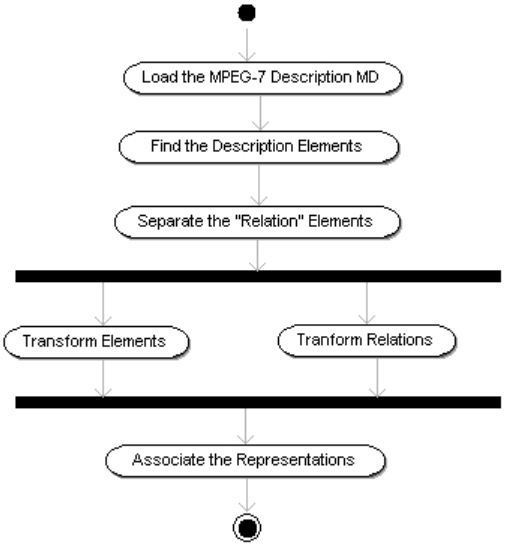

Fig. 1. The overall MPEG-7 to CIDOC/CRM transformation process

During the transformation of a "Relation" element *mre* the source, the type and the target of *mre* are located. The source and the target of *mre* are transformed, respectively, in the CIDOC/CRM entities *crs* and *crt* and the type of *mre* is transformed in a CIDOC/CRM property *cp* that has *crs* as range and *crt* as domain.

The transformation of the MPEG-7 element attributes depends on the attribute type. In particular, the following hold for the transformation of an attribute *a* of the element *e*, where *e* has been transformed to an instance *re* of the CIDOC/CRM entity *ce* (details on the MPEG-7 attribute transformation are available in [11]):

- If *a* is the "xsi:type" attribute, a CIDOC/CRM individual *at* of type "E55 Type" is created and *a* is transformed in the CIDOC/CRM property "P2 has type" that associates *at* with *re*.
- If *a* is the "id" attribute, a CIDOC/CRM individual *ai* of type "E42 Identifier" is created and *a* is transformed in the CIDOC/CRM property "P1 is identified by" that associates *ai* with *re*.
- If *a* is the "xml:lang" attribute, a CIDOC/CRM individual *al* of type "E56 Language" is created and *a* is transformed in the CIDOC/CRM property "P72 has language" that associates *al* with *re*.

– If *a* is the "href" attribute, a CIDOC/CRM individual *aio* of type "E73 information Object" is created and *a* is transformed in the CIDOC/CRM property "P67 refers to" that associates *aio* with *re*.

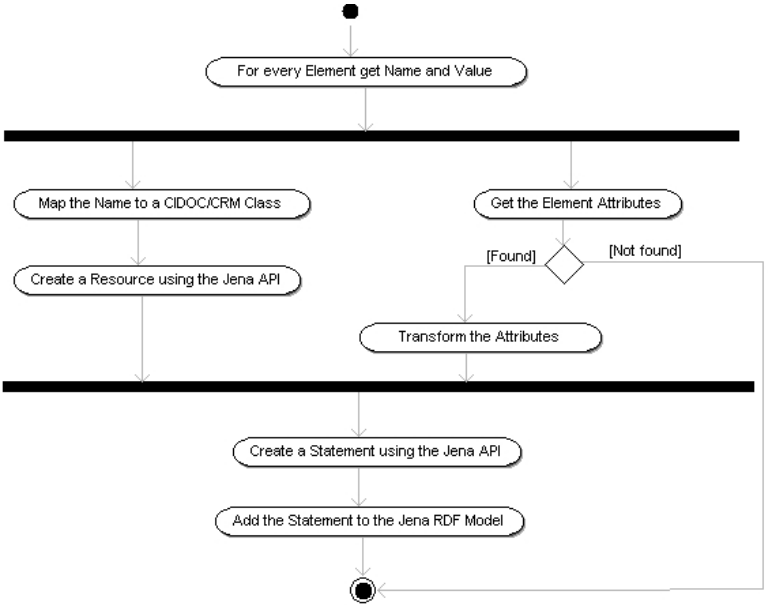

Fig. 2. MPEG-7 Element Transformation

4 Implementation

In this section we present the software that implements the MPEG-7 to CIDOC/CRM transformation process described in section 3. This software extends with the MPEG-7 to CIDOC/CRM transformation functionality the transformation toolkit developed in [10], which allows the automatic transformation of CIDOC/CRM descriptions to valid MPEG-7 multimedia object descriptions.

The toolkit provides a Graphical User Interface that allows the user to see a graphical representation of loaded and generated descriptions (MPEG-7 and CIDOC/CRM descriptions). A screenshot of the toolkit is presented in Fig. 3.

The toolkit GUI is divided in two panels: the *function panel* on the left, and the *mapping panel* on the right. The function panel contains all the necessary buttons for the user actions, such as loading descriptions, saving the generated documents, performing conversions between CIDOC/CRM and MPEG-7 descriptions, and presenting the graphs of the loaded and generated descriptions. The mapping panel shows an MPEG-7 description on the left side and the equivalent CIDOC/CRM description on the right side.

The toolkit has been implemented using the Java programming language, the XML Beans framework [6] for the manipulation of the MPEG-7 XML documents and the Jena framework [5] for parsing the CIDOC/CRM descriptions (in RDF syntax).

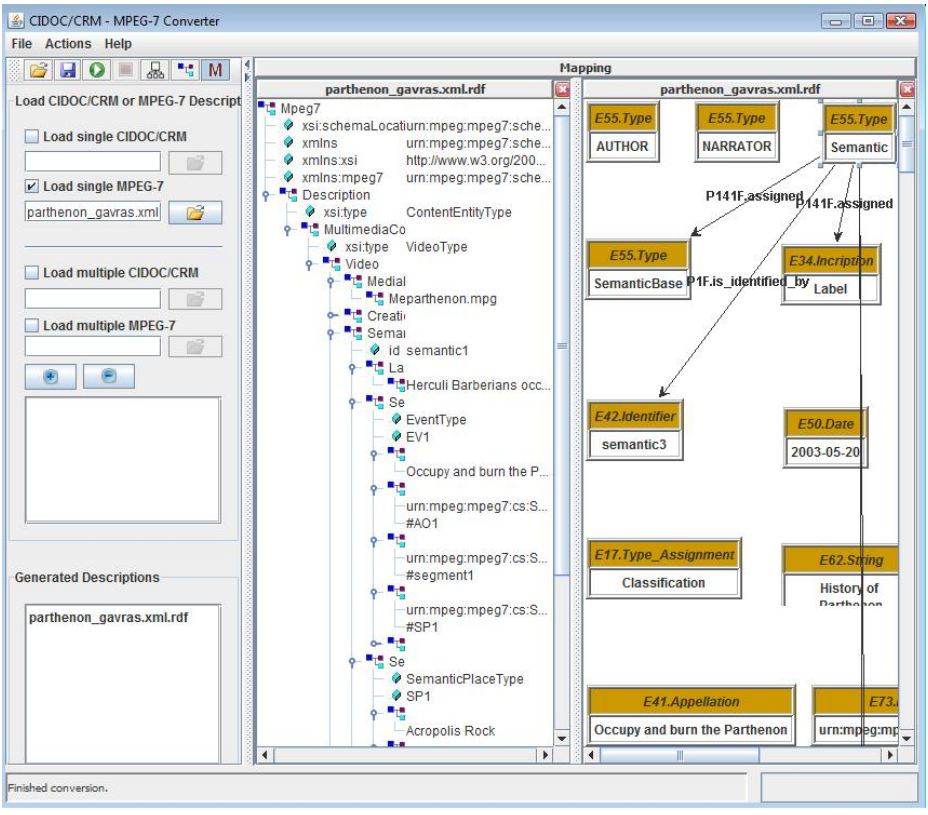

Fig. 3. Screenshot of the toolkit

5 Transformation Example

We provide in this section a short example of the MPEG-7 to CIDOC/CRM transformation, in order to demonstrate the entire transformation methodology and understand how the MPEG-7 to CIDOC/CRM transformation is applied on a real-world description. In particular, we used a part of the MPEG-7 description "Parthenon by Costas Gavras" (Fig. 4), which describes the event "Occupy and burn the Parthenon" in a video on the history of Parthenon.

```
<Description xsi:type="ContentEntityType">
 <MultimediaContent xsi:type="VideoType">
  <Video id="parthenon">
   <MediaLocator>
    <MediaUri>parthenon.mpg</MediaUri>
   </MediaLocator>
   <CreationInformation>
    <Creation>
     <Title xml:lang="en">Parthenon</Title>
    <Creator>
      <Role href="urn:mpeg:mpeg7:cs:RoleCS:2001:AUTHOR"/>
```

Fig. 4. An excerpt of the MPEG-7 description of the video «Parthenon by Costas Gavras»

```
    <Agent xsi:type="PersonType">
     <Name>
      <GivenName>Costas</GivenName>
      <FamilyName>Gavras</FamilyName>
     </Name>
    </Agent>
   </Creator>
   <CopyrightString>Hellenic Culture Organisation S.A.</CopyrightString>
  </Creation>
 </CreationInformation>
 <Semantic id="semantic1">
  <Label>
   <Name>Herculi Barberians occupy and burn the Parthenon </Name>
  </Label>
  <SemanticBase xsi:type="EventType" id="EV1">
   <Label>
    <Name> Occupy and burn the Parthenon </Name>
   </Label>
   <Relation target="#AO1" type="agent"/>
   <Relation target="#segment1" type="depictedBy"/>
   <Relation target="#SP1" type="location"/>
   <Relation target="#ST1" type=" time"/>
  </SemanticBase>
  <SemanticBase xsi:type="SemanticPlaceType" id="SP1">
   <Label>
    <Name> Acropolis Rock </Name>
   </Label>
   <Place>
    <Name xml:lang="en">Acropolis Rock in the City of Athens</Name>
    <Region> gr </Region>
   </Place>
  </SemanticBase>
  <SemanticBase xsi:type="SemanticTimeType" id="ST1">
   <Label><Name> 267 A.D.</Name></Label>
   <Relation source="#ST1" target="#ST2" type="precedes"/>
  </SemanticBase>
  <SemanticBase xsi:type="AgentObjectType" id="AO1">
   <Label><Name>Herculi Barberians</Name></Label>
   <Agent xsi:type="OrganizationType">
    <Name>Herculi Barberians</Name>
   </Agent>
  </SemanticBase>
 </Semantic>
 <MediaTime>
  <MediaTimePoint>T00:00:00</MediaTimePoint>
  <MediaDuration>PT07M33S</MediaDuration>
 </MediaTime>
 <TemporalDecomposition gap="false" overlap="false">
  <VideoSegment id="segment1">
   <TextAnnotation>
    <FreeTextAnnotation>
     267 A.D. Herculi Barberians occupy and burn the Parthenon
    </FreeTextAnnotation>
   </TextAnnotation>
   <Relation target="key1.gif" type="key"/>
   <Relation target="segment1.rm" type="representedBy"/>
   <MediaTime>
    <MediaTimePoint>T00:01:22</MediaTimePoint>
    <MediaDuration>PT00M09S</MediaDuration>
   </MediaTime>
```

Fig. 4. (*continued*)

```
    </VideoSegment>
   </TemporalDecomposition>
  </Video>
 </MultimediaContent>
</Description>
```

Fig. 4. (*continued*)

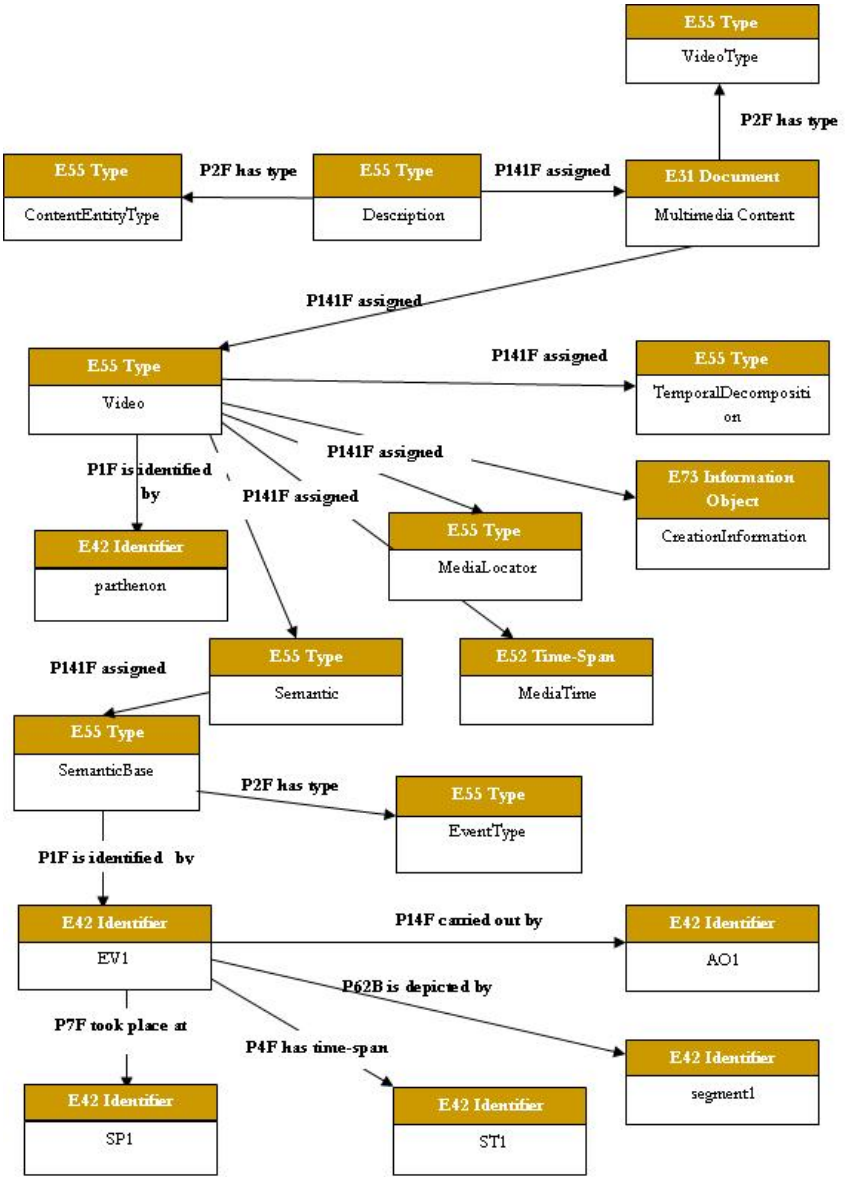

Fig. 5. An excerpt of the CIDOC/CRM description generated for the (the bold regions of the) MPEG-7 description of Fig. 1

When the transformation process starts, the MPEG-7 constructs are located and classified in the following categories:

- **Elements:** "Description", "MultimediaContent", "Video", "MediaLocator", "MediaUri", "CreationInformation", "Creation", "Title", "Abstract", "Creator", "FreeTextAnnotation", "Role", "Agent", "Name", "FamilyName", "GivenName", "CopyrightString", "Region", "Semantic", "Label", "SemanticBase", "Place", "MediaTime", "MediaTimePoint", "MediaDuration", "TemporalDecomposition", "VideoSegment", "TextAnnotation".
- **Relations:** "agent", "depictedBy", "location", "time", "key", "representedBy", "precedes".

According to the activity diagram of Fig. 1, a different set of steps is followed for the constructs that belong to each category. An excerpt of the CIDOC/CRM description generated for the MPEG-7 description of Fig. 4 is shown in Fig. 5.

Notice that the MPEG-7 elements have been transformed to instances of the CIDOC/CRM entities that have been mapped to their element types. For example, recall that the MPEG-7 type "MultimediaContentType" has been mapped to the CIDOC/CRM entity "E31 Document", and notice that the MPEG-7 element "MultimediaContent", of type "MultimediaContentType", has been transformed to an instance of "E31 Document".

Notice also that the MPEG-7 relations have been transformed to the mapped CIDOC/CRM properties. For example, recall that the MPEG-7 relation "depictedBy" has been mapped to the CIDOC/CRM property "P62 is depicted by" and notice that the MPEG-7 relation "depictedBy" has been transformed to the CIDOC/CRM property "P62 is depicted by".

6 Conclusions – Future Work

In this paper we have presented the MPEG72CIDOC mapping model, which allows the transformation of MPEG-7 descriptions to CIDOC/CRM descriptions as well as linking them to CIDOC/CRM descriptions, and a software that implements it. Using our methodology and software the multimedia content annotations can be exploited in the cultural heritage digital libraries. This work complements our previous research for the transformation of CIDOC/CRM descriptions in MPEG-7 syntax [10].

Since the EDM has adopted the CIDOC/CRM core, the work presented here is a first step towards supporting the transformation and/or linking of MPEG-7 descriptions to EDM descriptions in a Linked Data scenario.

Our future research includes: *(a)* The definition of a two-way mapping between the MPEG-7 and the EDM, which will allow full interoperability support among these standards. Such functionality is very important for the Digital Library community; and *(b)* The extensive evaluation of the MPEG72CIDOC mapping model over real-world datasets.

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