Mapping MPEG-7 to CIDOC/CRM *(Extended)*

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Abstract. The MPEG-7 is the dominant standard for multimedia content description; thus, the audiovisual Digital Library contents are described in terms of MPEG-7. Since the cultural heritage is one of the domains for which exists a huge amount of audiovisual content, 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 here a mapping model and a system that allow the transformation of the MPEG-7 descriptions into CIDOC/CRM ones, thus allowing the exploitation of multimedia content annotations in the cultural heritage digital libraries. In addition, the proposed mapping model allows linking (parts of) the MPEG-7 descriptions to CIDOC/CRM descriptions in a Linked Data scenario.

Keywords: MPEG-7, CIDOC/CRM, Mapping, Interoperability, 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 low-level image, audio and motion features, the multimedia content semantics, the structural information, the media-related information etc. MPEG-7 includes content and semantic metadata descriptions. These descriptions can be captured automatically (for example by camera sensors, etc.) or semi-automatically. Today the increase of the amount of multimedia data captured daily is extremely fast due to the proliferation of inexpensive cameras and associated sensors (see for example [12]). Very frequently the digital audiovisual content captured contains (partially or totally) cultural heritage objects.

On the other hand the dominant standard in the cultural heritage domain is the CIDOC/CRM [2]; however, the MPEG-7 descriptions of the audiovisual content cannot be directly integrated in the cultural heritage digital libraries.

The need for transforming MPEG-7 descriptions into CIDOC/CRM ones as well as the capability of linking, in a Linked Data scenario, (parts of) them in CIDOC/CRM

descriptions has been recognized by important consortiums in the Digital Library domain like, for example, the Europeana consortium [3]. Europeana aims to develop a European digital library containing digitized material about the European scientific and cultural heritage. In particular, the *Europeana Data Model (EDM)* [5] has adopted the CIDOC/CRM core, while the consortium emphasizes the need for linking existing descriptions of the digitized material in the EDM descriptions [4], according to the linked data approach [6].

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, [7] proposes specific extensions to the CIDOC/CRM in order to be able to accommodate the temporal and spatial aspects of information objects, while [8] 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 a *mapping model* that maps the MPEG-7 constructs to CIDOC/CRM constructs and a system that, based on the mapping model, allows the transformation of the MPEG-7 descriptions into CIDOC/CRM descriptions as well as linking (parts of) 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 [8]. The mapping model presented here differs from that of [8] 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 [8] 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 [8]. Moreover, the implementation of the MPEG-7 to CIDOC/CRM transformation has been integrated in the system developed in [8] for transforming CIDOC/CRM descriptions in MPEG-7 syntax.

The mappings specified within the proposed mapping model may also be applied between CIDOC/CRM and any ontology like [9] that captures the MPEG-7 semantics, since the mappings have not been based on the XML Schema syntax of MPEG-7.

In addition, transforming the MPEG-7 descriptions into 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 rising from the existence of several MPEG-7 based ontologies [10].

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

2 Mapping Model

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

The MPEG-7 focuses on multimedia content descriptions, 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.

There are two types of mappings in the mapping model: a) *static* mappings, which essentially are *correspondences* [11] between the MPEG-7 and the CIDOC/CRM constructs and are defined at design-time; and b) *conditional* mappings that are essentially conditional *mapping expressions* [11] that are decided at design-time and are evaluated in real-time according to the given context.

In our mapping model, the MPEG-7 *types* are mapped to CIDOC/CRM *entities* and the MPEG-7 *relations*, which associate instances of the MPEG-7 types, are mapped to CIDOC/CRM *properties*. For the representation of the MPEG-7 multimedia-specific types we use the "E55.Type" CIDOC/CRM entity which is used as an extensibility mechanism of the CIDOC/CRM model. This entity is the interface of the CIDOC/CRM to domain specific ontologies and thesauri. The "E55 Type" 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 entity instance to its type is implemented through the property "P2 has type".

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

- 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" is mapped to the 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. Thus, an abstract MPEG-7 description *amd* is conditionally mapped to an instance *rmmt* of one of the CIDOC/CRM entities "E55 Type", if it is a class-level abstract description, and "E77 Persistent Item", if it is an instance-level abstract description. For example, an abstract MPEG-7 description that represents buildings is mapped to an instance of the CIDOC/CRM entity "E55 Type".
- 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 *mt* is an object associated with the object *te*.
  - **P140 assigned attribute to** if *mt* is an object associated with the relation *te*.

– 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.

The mappings between MPEG-7 elements and CIDOC/CRM entities are shown in **Error! Reference source not found.**.

Table 1. Mappings between MPEG-7 types and CIDOC/CRM entities

MPEG-7 Type	CIDOC/CRM Entity
DSType	E1 CRM Entity
RelationType	E90 Symbolic Object
MultimediaContentType	E31 Document
UniqueIDType	E42 Identifier
TimeType	E52 Time-Span
MediaTimeType	E52 Time-Span
AgentType	E39 Actor
PersonType	E21 Person
PersonGroupType	E74 Group
OrganizationType	E40 Legal Body
PersonNameType	E82 Actor Appelation
NameComponentType	E82 Actor Appelation
ElectronicAddressType	E51 Contact Point
PlaceType	E53 Place
GeographicPointType	E47 Spatial Coordinates
RightsType	E30 Right
CostType	E55 Type
IncomeType	E55 Type
CreationType	E65 Creation
TitleMediaType	E35 Title
CreatorType	E39 Actor
MediaAgentType	E39 Actor
MaterialType	E55 Type
SemanticBagType	E78 Collection
GraphType	E90 Symbolic Object
ConceptType	E28 Conceptual Object
SemanticStateType	E3 Condition State
ActionType	E55 Type
DType	E55 Type(“DType”)
CompleteDescriptionType	E55 Type ("CompleteDescriptionType")
ContentDescriptionType	E55 Type ("ContentDescriptionType")
ContentEntityType	E55 Type ("ContentEntityType")
ContentAbstractionType	E55 Type ("ContentAbstractionType")
SemanticDescriptionType	E55 Type ("SemanticDescriptionType")
ModelDescriptionType	E55 Type ("ModelDescriptionType")

SummaryDescriptionType	E55 Type ("SummaryDescriptionType ")
ViewDescriptionType	E55 Type ("ViewDescriptionType")
VariationDescriptionType	E55 Type ("VariationDescriptionType")
VariationType	E55 Type(“ VariationType ”)
ContentManagementType	E55 Type ("ContentManagementType")
UserDescriptionType	E55 Type ("UserDescriptionType")
MediaDescriptionType	E55 Type ("MediaDescriptionType ")
CreationDescriptionType	E55 Type ("CreationDescriptionType")
UsageDescriptionType	E55 Type ("UsageDescriptionType")
ClassificationSchemeDescriptionType	E55 Type ("ClassificationSchemeDescriptionType")
DescriptionMetadataType	E55 Type ("DescriptionMetadataType")
MediaLocatorType	E55 Type("MediaLocatorType")
TemporalSegmentLocatorType	E55 Type ("TemporalSegmentLocatorType")
ImageLocatorType	E55 Type ("ImageLocatorType")
TextualBaseType	E55 Type("TextualBaseType")
TextualType	E55 Type("TextualType")
TextAnnotationType	E55 Type("TextAnnotationType")
StructuredAnnotationType	E55 Type ("StructuredAnnotationType")
KeywordAnnotationType	E55 Type ("KeywordAnnotationType")
DependencyStructureType	E55 Type ("DependencyStructureType")
DependencyStructurePhraseType	E55 Type ("DependencyStructurePhraseType")
NonDependencyStructurePhraseType	E55 Type ("NonDependencyStructurePhraseType")
ClassificationSchemeBaseType	E55 Type ("ClassificationSchemeBaseType")
ClassificationSchemeType	E55 Type ("ClassificationSchemeType")
TermDefinitionBaseType	E55 Type ("TermDefinitionBaseType")
TermDefinitionType	E55 Type("TermDefinitionType")
InlineTermDefinitionType	E55 Type ("InlineTermDefinitionType ")
TermUseType	E55 Type("TermUseType")
ControlledTermUseType	E55 Type ("ControlledTermUseType")
ClassificationSchemeAliasType	E55 Type ("ControlledTermUseType")
GraphicalClassificationSchemeType	E55 Type ("GraphicalClassificationSchemeType")
GraphicalTermDefinitionType	E55 Type ("GraphicalTermDefinitionType")
GraphicalRuleDefinitionType	E55 Type ("GraphicalRuleDefinitionType ")
PullbackDefinitionType	E55 Type ("PullbackDefinitionType ")
DoublePullbackDefinitionType	E55 Type

	("DoublePullbackDefinitionType")
PushoutDefinitionType	E55 Type ("PushoutDefinitionType")
DoublePushoutDefinitionType	E55 Type ("DoublePushoutDefinitionType")
GraphType	E55 Type(“GraphType”)
OrderingKeyType	E55 Type(“OrderingKeyType”)
AffectiveType	E55 Type(“AffectiveType”)
PhoneticTranscriptionLexiconType	E55 Type (“PhoneticTranscriptionLexiconType”)
MediaInformationType	E55 Type (“MediaInformationType”)
MediaIdentificationType	E55 Type (“MediaIdentificationType”)
MediaProfileType	E55 Type (“MediaProfileType”)
ComponentMediaProfile	E55 Type (“ComponentMediaProfile”)
MediaFormatType	E55 Type (“MediaFormatType”)
ColorSamplingType	E55 Type (“ColorSamplingType”)
MediaTranscodingHintsType	E55 Type (“MediaTranscodingHintsType”)
MediaQualityType	E55 Type (“MediaQualityType”)
RatingType	E55 Type (“RatingType”)
MediaInstanceType	E55 Type (“MediaInstanceType”)
UsageInformationType	E55 Type ("UsageInformationType")
FinancialType	E55 Type ("FinancialType")
AvailabilityType	E55 Type ("AvailabilityType")
DisseminationType	E55 Type ("DisseminationType")
UsageRecordType	E55 Type ("UsageRecordType")
CreationInformationType	E55 Type ("CreationInformationType")
CreationToolType	E55 Type ("CreationToolType")
ClassificationType	E55 Type("ClassificationType")
ParentalGuidanceType	E55 Type (“ParentalGuidanceType”)
MediaReviewType	E55 Type (“MediaReviewType”)
InkMediaInformationType	E55 Type (“InkMediaInformationType”)
HandWritingRecogInformationType	E55 Type (“HandWritingRecogInformationType”)
HandWritingRecogResultType	E55 Type (“HandWritingRecogResultType”)
MaskType	E55 Type(“MaskType”)
SpatialMaskType	E55 Type(“SpatialMaskType”)
TemporalMaskType	E55 Type (“TemporalMaskType”)
SpatioTemporalMaskType	E55 Type (“SpatioTemporalMaskType”)
MediaSpaceMaskType	E55 Type (“MediaSpaceMaskType”)
SceneGraphMaskType	E55 Type (“SceneGraphMaskType”)
OrderedGroupDataSetMaskType	E55 Type (“OrderedGroupDataSetMaskType”)
MatchingHintType	E55 Type (“MatchingHintType”)

PointOfViewType	E55 Type (“PointOfViewType”)
SemanticBaseType	E55 Type (“SemanticBaseType”)
SemanticType	E55 Type (“SemanticType”)
ObjectType	E55 Type “ObjectType”
AgentObject Type	E55 Type (“AgentObjectType”)
EventType	E55 Type (“EventType”)
SemanticPlaceType	E55 Type (“SemanticPlaceType”)
SemanticTimeType	E55 Type (“SemanticTimeType”)
ExtentType	E55 Type(“ExtentType”)
PositionType	E55 Type(“PositionType”)
SummarizationType	E55 Type (“SummarizationType”)
SummaryType	E55 Type(“SummaryType”)
HierarchicalSummaryType	E55 Type(“HierarchicalSummaryType”)
SummaryThemeList	E55 Type(“SummaryThemeList”)
SummarySegmentGroup	E55 Type(“SummarySegmentGroup”)
SummaryThemeListType	E55 Type(“SummaryThemeListType”)
SummarySegmentGroupType	E55 Type (“SummarySegmentGroupType”)
SummarySegmentType	E55 Type (“SummarySegmentType”)
SequentialSummaryType	E55 Type (“SequentialSummaryType”)
VisualSummaryComponentType	E55 Type (“VisualSummaryComponentType”)
VideoSourceLocator	E55 Type (“VideoSourceLocator”)
AudioSummaryComponentType	E55 Type (“AudioSummaryComponentType”)
TextualSummaryComponent Type	E55 Type (“TextualSummaryComponentType”)
PartitionType	E55 Type(“PartitionType”)
SignalPlaneType	E55 Type(“SignalPlaneType”)
SignalPlaneFractionType	E55 Type (“SignalPlaneFractionType”)
SignalPlaneSampleType	E55 Type (“SignalPlaneSampleType”)
SignalPlaneOriginType	E55 Type (“SignalPlaneOriginType”)
FilterType	E55 Type (“FilterType”)
Filter1DType	E55 Type(“Filter1DType”)
Filter2DType	E55 Type(“Filter2DType”)
FilteringType	E55 Type(“FilteringType”)
ViewType	E55 Type(“ViewType”)
SpaceViewType	E55 Type(“SpaceViewType”)
FrequencyViewType	E55 Type(“FrequencyViewType”)
SpaceFrequencyViewType	E55 Type (“SpaceFrequencyViewType”)
ResolutionViewType	E55 Type(“ResolutionViewType”)
SpaceResolutionViewType	E55 Type (“SpaceResolutionViewType”)
ViewDecompositionType	E55 Type (“ViewDecompositionType”)

ViewSetType	E55 Type(“ViewSetType”)
SpaceTreeType	E55 Type(“SpaceTreeType”)
FrequencyTreeType	E55 Type(“FrequencyTreeType”)
SpaceFrequencyGraphType	E55 Type (“SpaceFrequencyGraphType”)
VideoViewGraphType	E55 Type (“VideoViewGraphType”)
MultiResolutionPyramidType	E55 Type (“MultiResolutionPyramidType”)
PreferenceConditionType	E55 Type (“PreferenceConditionType”)
UserPreferencesType	E55 Type (“UserPreferencesType”)
UserIdentifierType	E55 Type(“UserIdentifierType”)
FilteringAndSearchPreferencesType	E55 Type (“FilteringAndSearchPreferencesType”)
CreationPreferencesType	E55 Type (“CreationPreferencesType”)
ClassificationPreferencesType	E55 Type (“ClassificationPreferencesType”)
SourcePreferencesType	E55 Type (“SourcePreferencesType”)
BrowsingPreferencesType	E55 Type (“BrowsingPreferencesType”)
SummaryPreferencesType	E55 Type (“SummaryPreferencesType”)
UsageHistoryType	E55 Type(“UsageHistoryType”)
UserActionHistoryType	E55 Type(“UsageHistoryType”)
UserActionListType	E55 Type(“UserActionListType”)
UserActionType	E55 Type(“UserActionType”)
ImageType	E55 Type ("ImageType")
VideoType	E55 Type ("VideoType")
AudioType	E55 Type ("AudioType ")
AudioVisualType	E55 Type ("AudioVisualType ")
MultimediaType	E55 Type ("MultimediaType ")
AudioDSType	E55 Type("AudioDSType")
VisualDSType	E55 Type ("VisualDSType")
AudioDType	E55 Type (“AudioDType ”)
VisualDType	E55 Type (“VisualDType ”)
SegmentType	E55 Type ("SegmentType")
SegmentDecompositionType	E55 Type (“SegmentDecompositionType”)
SpatialSegmentDecompositionType	E55 Type ("SpatialSegmentDecompositionType")
TemporalSegmentDecompositionType	E55 Type ("TemporalSegmentDecompositionType")
SpatioTemporalSegmentDecompositionType	E55 Type ("SpatioTemporalSegment DecompositionType ")
MediaSourceSegmentDecomposition Type	E55 Type ("MediaSourceSegment DecompositionType ")
StillRegionType	E55 Type (“StillRegionType”)
StillRegion3DType	E55 Type (“StillRegion3DType”)
VideoSegmentType	E55 Type (“VideoSegmentType”)

MovingRegionType	E55 Type (“MovingRegionType”)
AudioSegmentType	E55 Type (“AudioSegmentType”)
AudioVisualSegmentType	E55 Type (“AudioVisualSegmentType”)
AudioVisualRegionType	E55 Type (“AudioVisualRegionType”)
MultimediaSegmentType	E55 Type (“MultimediaSegmentType”)
InkSegmentType	E55 Type (“InkSegmentType”)
ImageTextType	E55 Type (“ImageTextType”)
MosaicType	E55 Type (“MosaicType”)
VideoTextType	E55 Type (“VideoTextType”)
EditedMovingRegionType	E55 Type (“EditedMovingRegionType”)
AnalyticEditedVideoSegmentType	E55 Type (“AnalyticEditedVideoSegmentType”)
EditedVideoType	E55 Type (“EditedVideoType”)
AnalyticClipType	E55 Type (“AnalyticClipType”)
AnalyticTransitionType	E55 Type (“AnalyticTransitionType”)
CompositionShotType	E55 Type (“CompositionShotType”)
ShotType	E55 Type (“ShotType”)
IntraCompositionShotType	E55 Type (“IntraCompositionShotType”)
GlobalTransitionType	E55 Type (“GlobalTransitionType”)
CompositionTransitionType	E55 Type (“CompositionTransitionType”)
InternalTransitionType	E55 Type (“InternalTransitionType”)
StillRegionSpatialDecompositionType	E55 Type (“StillRegionSpatialDecompositionType”)
StillRegion3DSpatialDecomposition Type	E55 Type (“StillRegion3DSpatial DecompositionType”)
VideoSegmentSpatialDecomposition Type	E55 Type (“VideoSegmentSpatial DecompositionType”)
MovingRegionSpatialDecomposition Type	E55 Type (“MovingRegionSpatial DecompositionType”)
AudioVisualSegmentSpatial DecompositionType	E55 Type (“AudioVisualSegmentSpatial DecompositionType”)
AudioVisualRegionSpatial DecompositionType	E55 Type (“AudioVisualRegionSpatial DecompositionType”)
InkSegmentSpatialDecomposition Type	E55 Type (“InkSegmentSpatialDecompositionType”)
VideoSegmentTemporal DecompositionType	E55 Type (“VideoSegmentTemporal DecompositionType”)
MovingRegionTemporal DecompositionType	E55 Type (“MovingRegionTemporal DecompositionType”)
AudioSegmentTemporal DecompositionType	E55 Type (“AudioSegmentTemporal DecompositionType”)
AudioVisualSegmentTemporal DecompositionType	E55 Type (“AudioVisualSegmentTemporal DecompositionType”)
AudioVisualRegionTemporal	E55 Type (“AudioVisualRegionTemporal

DecompositionType	DecompositionType")
InkSegmentTemporalDecomposition Type	E55 Type ("InkSegmentTemporal DecompositionType")
EditedVideoEditingTemporalDecom positionType	E55 Type ("EditedVideoEditingTemporal DecompositionType")
ShotEditingTemporalDecomposition Type	E55 Type ("ShotEditingTemporal DecompositionType")
CompositionShotEditingTemporalDe compositionType	E55 Type ("CompositionShotEditing TemporalDecompositionType")
IntraCompositionShotEditingTempor alDecompositionType	E55 Type ("IntraCompositionShotEditing TemporalDecompositionType")
VideoSegmentSpatioTemporalDeco mpositionType	E55 Type ("VideoSegmentSpatioTemporal DecompositionType")
MovingRegionSpatioTemporalDeco mpositionType	E55 Type ("MovingRegionSpatioTemporal DecompositionType")
AudioVisualSegmentSpatioTemporal DecompositionType	E55 Type ("AudioVisualSegment SpatioTemporalDecompositionType")
AudioVisualRegionSpatioTemporal DecompositionType	E55 Type ("AudioVisualRegionSpatio TemporalDecompositionType")
AnalyticEditedVideoSegmentSpatio TemporalDecompositionType	E55 Type ("AnalyticEditedVideoSegment SpatioTemporalDecompositionType")
VideoSegmentMediaSource DecompositionType	E55 Type ("VideoSegmentMediaSource DecompositionType")
AudioSegmentMediaSource DecompositionType	E55 Type ("AudioSegmentMediaSource DecompositionType")
MovingRegionMediaSource DecompositionType	E55 Type ("MovingRegionMedia SourceDecompositionType")
AudioVisualSegmentMediaSource DecompositionType	E55 Type ("AudioVisualSegmentMedia SourceDecompositionType")
AudioVisualRegionMediaSource DecompositionType	E55 Type ("AudioVisualRegionMedia SourceDecompositionType")
MultimediaSegmentMediaSource DecompositionType	E55 Type ("MultimediaSegmentMedia SourceDecompositionType")
CollectionType	E78 Collection
ContentCollectionType	E55 Type ("ContentCollectionType")
SegmentCollectionType	E55 Type ("SegmentCollectionType")
DescriptorCollectionType	E55 Type ("DescriptorCollectionType")
ConceptCollectionType	E55 Type ("ConceptCollectionType")
MixedCollectionType	E55 Type ("MixedCollectionType")
StructuredCollectionType	E55 Type ("StructuredCollectionType")
ModelType	E55 Type("ModelType")
ProbabilityModelType	E55 Type("ProbabilityModelType")
ProbabilityDistributionType	E55 Type ("ProbabilityDistributionType")
DiscreteDistributionType	E55 Type("DiscreteDistributionType")

HistogramProbabilityType	E55 Type (“HistogramProbabilityType”)
ContinuousDistributionType	E55 Type (“ContinuousDistributionType”)
FiniteStateModelType	E55 Type(“FiniteStateModelType”)
StateTransitionModelType	E55 Type (“StateTransitionModelType”)
AnalyticModelType	E55 Type(“AnalyticModelType”)
CollectionModelType	E55 Type(“CollectionModelType”)
DescriptorModelType	E55 Type(“DescriptorModelType”)
ProbabilityModelClassType	E55 Type(“ProbabilityModelClassType”)
ClusterModelType	E55 Type(“ClusterModelType”)
ClassificationModelType	E55 Type (“ClassificationModelType”)

MPEG-7 Relation Mappings. The 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* has exactly the same meaning with the CIDOC/CRM property *cp* that it is mapped to. For example, the MPEG-7 relation “inside” is mapped to the 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 the *mr* source and/or target.

The MPEG-7 relation mappings that fall in the first three categories are shown in **Table 2**, while the conditional mappings, which are applied in case of *abstraction* and of *conditionally mapped relations*, are discussed in the following paragraphs.

Table 2. The MPEG-7 relationship mappings

MPEG-7 Relation	CIDOC/CRM property
Direct mapping	
inside	P89 falls within
contains	P89 contains
touches	P122 borders with
separated	P133 is separated from
member	P107 has current or former member
memberOf	P107 is current or former member of
equals	P139 has alternative form
identity	P1 identifies
similar	P130 shows features of
instance	P2 is type of
equivalent	P139 has alternative form

precedes	P120 occurs before
follows	P134 continued
meets	P119 meets in time with
metBy	P119 met-by in time
overlaps	P118 overlaps in time with
overlappedBy	P118 overlapped-by in time
contains	P86 contains
during	P86 falls within
strictContains	P117 includes
strictDuring	P117 occurs during
starts	P116 starts
startedBy	P116 is started by
finishes	P115 finishes
finishedBy	P115 is finished by
coOccurs	P114 is equal in time to
coBegin	P116 starts
coEnd	P115 finishes
parallel	P82 at some time within
overlapping	P118 overlaps in time with
shows	P65 shows visual item
appearsIn	P65 is shown by
references	P67 refers to
referencedBy	P67 is referred to by
source	P27 moved from
sourceOf	P27 was origin of
destination	P26 moved to
destinationOf	P26 was destination of
time	P4 has time-span
timeOf	P4 is time-span of
depicts	P62 depicts
depictedBy	P62 is depicted by
represents	P138 represents
representedBy	P138 has representation
interprets	P73 is translation of
interpretedBy	P73 has translation
patient	P15 was influenced by
patientOf	P15 influenced
stimulus	P17 was motivated by
stimulusOf	P17 motivated
theme	P129 is about
themeOf	P129 is subject of
result	P123 resulted in
resultOf	P123 resulted from

specializes	P127 has broader term
generalizes	P127 has narrower term
exemplifies	P137 exemplifies
exemplifiedBy	P137 is exemplified by
interchangeable	P139 has alternative form
identifier	P1 is identified by
part	P46 is composed of
partOf	P46 forms part of
component	P46 is composed of
componentOf	P46 forms part of
property	P56 bears feature
propertyOf	P56 is found on
state	P44 has condition
stateOf	P44 condition of
influences	P15 was influenced by
substance	P45 consists of
substanceOf	P45 is incorporated in
similar	P130 shows features of
instrument	P126 employed
instrumentOf	P16 was used for
agent	P14 carried out by
agentOf	P14 performed
entails	P16 used specific object
entailedBy	P16 was used for
annotates	P3 has note
quality	P56 bears feature
qualityOf	P56 is found on
causer	P123 resulted in
causerOf	P123 resulted from
dependsOn	P136 was based on
symbolizes	P138 represents
symbolizedBy	P138 has representation
combination	P46 is composed of
Mapping to the closest meaning	
covers	P89 contains
coveredBy	P89 falls within
refines	P70 documents
refinedBy	P70 is documented in
union	P5 consists of
intersection	Synthesis of overlaps
disjoint	P133 is separated from
sequential	P134 continued (was continued by)
contiguous	P134 continued (was continued by)

accompanier	P119 meets in time with
accompanierOf	P119 is met in time by
path	P76 has contact point
pathOf	P76 provides access to
context	P69 is associated with
contextFor	P69 is associated with
experiencer	P15 was influenced by
experiencerOf	P15 influenced
annotatedBy	P3 has note
user	P125 used object of type
userOf	P125 was type of object used in
membershipFunction	P107 has current or former member
contrasts	P133 is separated from
key	P1 is identified by
keyFor	P1 identifies
goal	P21 had general purpose
goalOf	P21 was purpose of
manner	P32 used general technique
mannerOf	P32 was technique of
beneficiary	P51 has former or current owner
beneficiaryOf	P51 is former or current owner of
No Mapping	
south	-
north	-
west	-
east	-
northwest	-
northeast	-
southwest	-
southeast	-
left	-
right	-
below	-
above	-
over	-
under	-
opposite	-

In case of abstraction, the representation of the abstract MPEG-7 description *ad* is decided according to the value of its *dimension* attribute that indicates its abstraction level:

In case of abstraction, the representation of the abstract MPEG-7 description *ad* 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, *ad* is a class-level abstract semantic description that represents a class (e.g. buildings) and is mapped to an instance *tme* of the CIDOC/CRM entity "E55 Type".
- If *dimension* has a value of 0, *ad* is an instance-level semantic description independent from the multimedia content and it describes a reusable instance (e.g. Parthenon). In this case *ad* is a concrete semantic description and is represented by an instance *tme* of the CIDOC/CRM entity "E77 Persistent Item".

In case of a conditionally mapped relation, an MPEG-7 relation *cmr* exists that should be mapped to different CIDOC/CRM properties, according to the *cmr* source and target values. This happens if *cmr* is of type *location*, *location of* or *overlaps*:

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

3 MPEG-7 to CIDOC/CRM Transformation

In this section we present the MPEG-7 to CIDOC/CRM transformation process that we have determined based on the mapping model described in section 2.

The information that is expressed in the MPEG-7 descriptions can be distinguished into: *a)* Information that refers to the *CIDOC/CRM entities*, which consists of the MPEG-7 description elements; and *b)* Information that refers to the *CIDOC/CRM properties*, which consists of the MPEG-7 Classification Schemes.

The MPEG-7 to CIDOC/CRM transformation is shown in **Fig. 1**. According to **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 individual MPEG-7 construct (i.e. element and relationship) transformations.

The transformation of the MPEG-7 elements is shown in **Fig. 2**: For every MPEG-7 element *e* the element name and value are firstly located. Then the mapping of the type of *e* to the appropriate CIDOC/CRM entity *ce* is used for the transformation of *e*. It is also checked if the *e* has attributes; if this is the case, they are transformed in CIDOC/CRM properties as is described below. Finally, *e* is associated with the CIDOC/CRM properties that represent its attributes and is added in the CIDOC/CRM description.

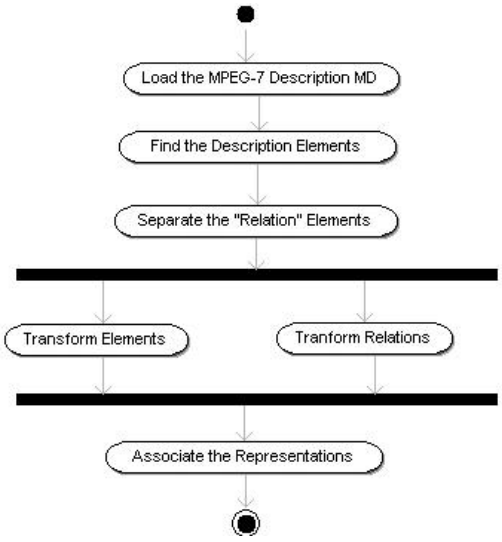

Fig. 1. The overall MPEG-7 to CIDOC/CRM transformation process

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 the CIDOC/CRM entity *ce*:

- 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 *ce*. The transformation of the "xsi:type" attribute is shown in **Fig. 3**.
- 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 *ce*. The transformation of the "id" attribute is shown in **Fig. 4**.
- 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 *ce*. The transformation of the "xml:lang" attribute is shown in **Fig. 5**.
- If *a* is the "href" attribute, a CIDOC/CRM individual *aio* of type "E73 information Object" is defined and *a* is transformed in the CIDOC/CRM property "P67 refers to" that associates *aio* with *ce*. The transformation of the "href" attribute is shown in **Fig. 6**.

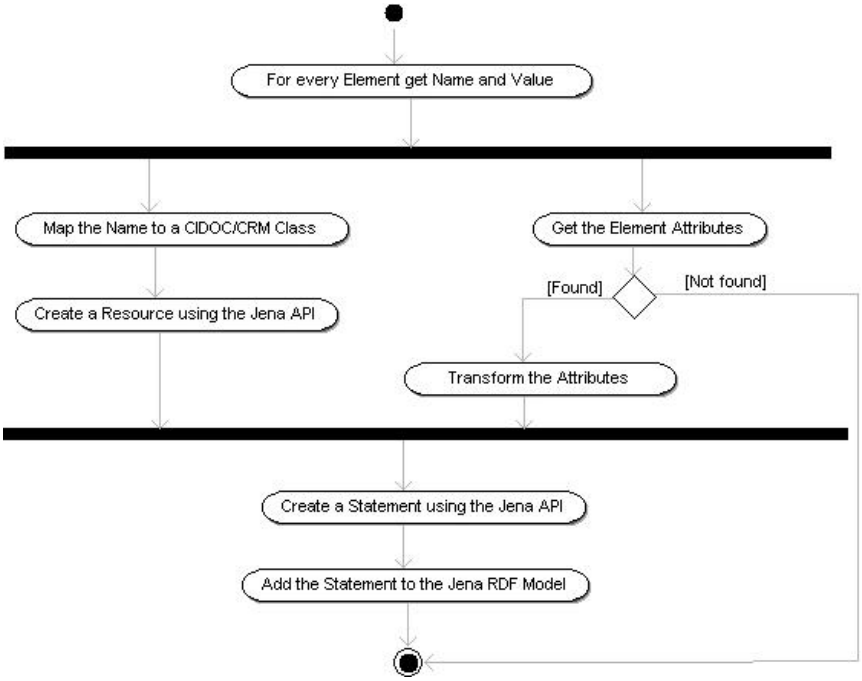

Fig. 2. MPEG-7 Element Transformation

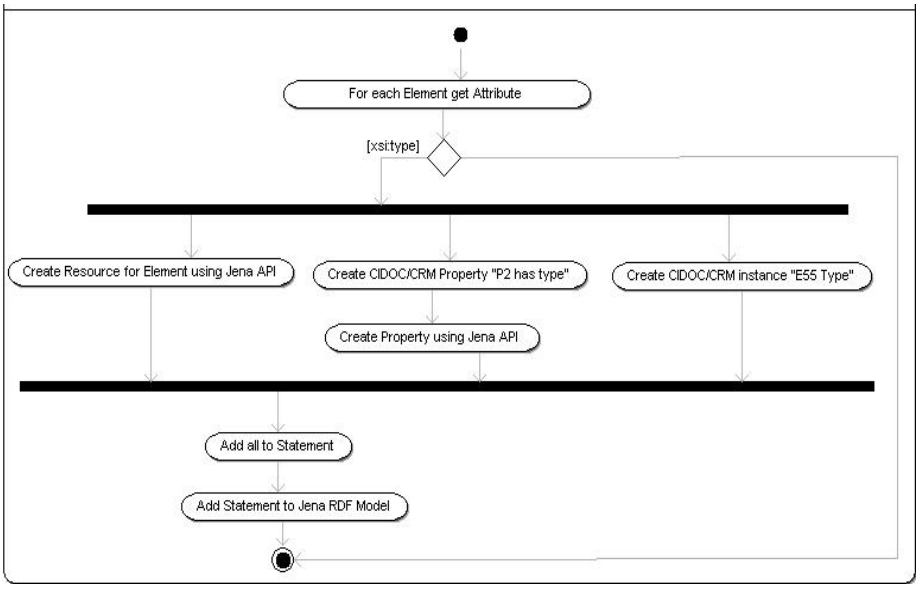

Fig. 3. Transformation of the “xsi:type” attribute

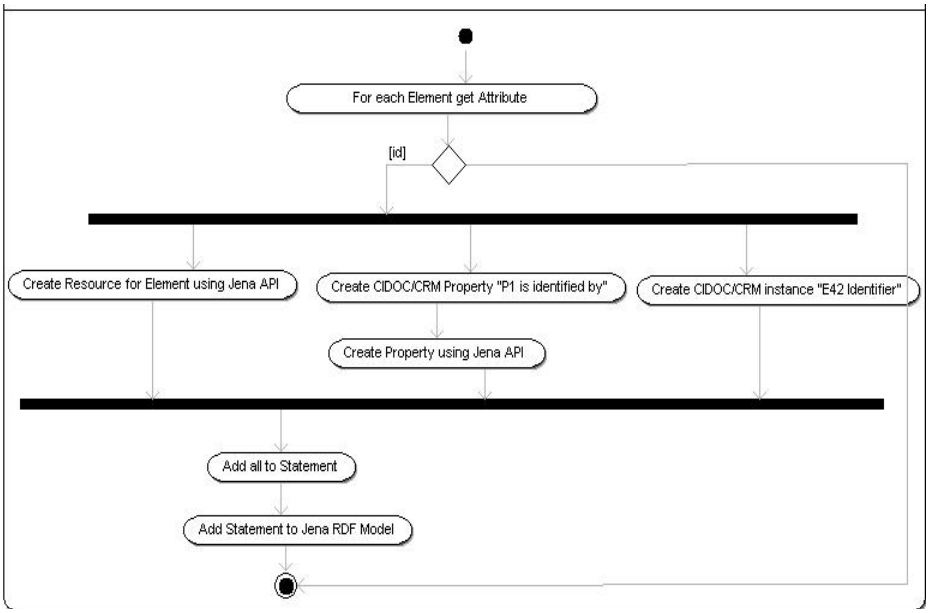

Fig. 4. Transformation of the “id” attribute

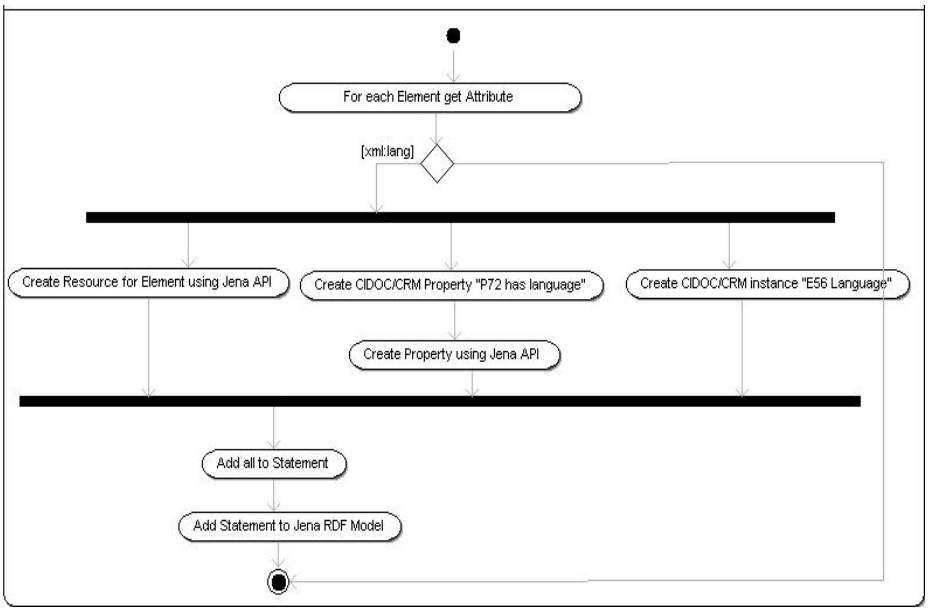

Fig. 5. Transformation of the “xml:lang” attribute

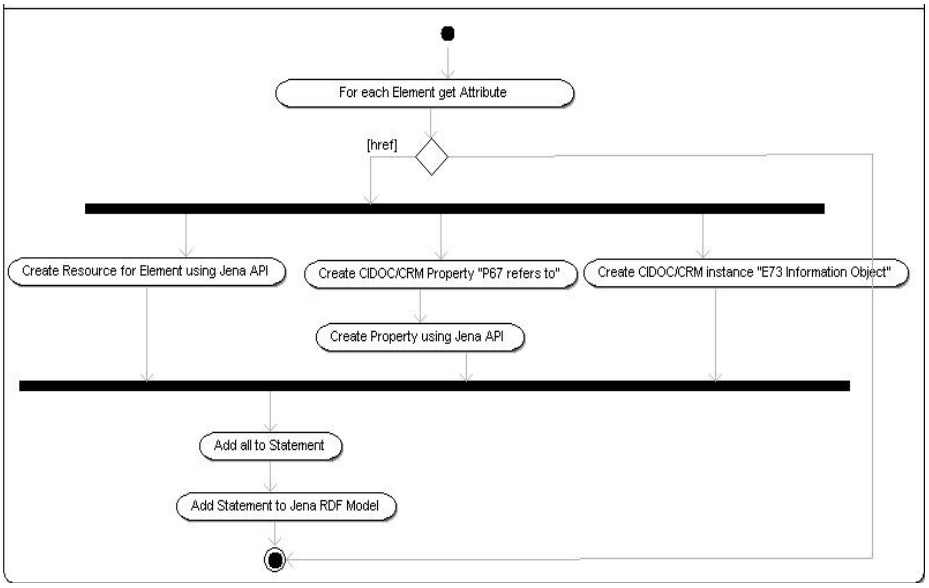

Fig. 6. Transformation of the “href” attribute

During the transformation of a “Relation” element *re* the source, the type and the target of *re* are located. The source and the target of *re* are transformed, respectively, in the CIDOC/CRM entities *crs* and *crt* and the type of *re* is transformed in a CIDOC/CRM property *cp* that has *crs* as range and *crt* as domain. The transformation of the MPEG-7 “Relation” elements is shown in Fig. 7.

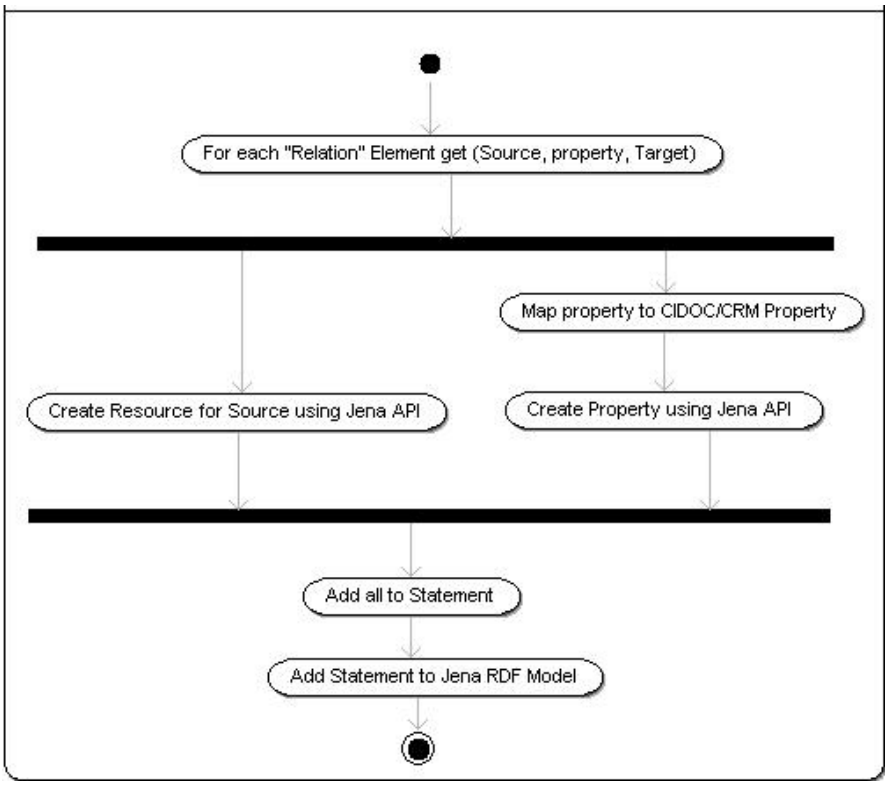

Fig. 7. Transformation of the "relation" element

The transformation of the nested MPEG-7 elements is also detailed in [**Error! Reference source not found.**]. For every MPEG-7 element *e* that has been transformed to the CIDOC/CRM entity *ce*, the set *CEL* of its child nodes is computed. Every element *cel* ∈ *CEL* is transformed in a CIDOC/CRM entity *ccel* that is associated with *ce* through the appropriate CIDOC/CRM property *p*, as it was described in section 2.

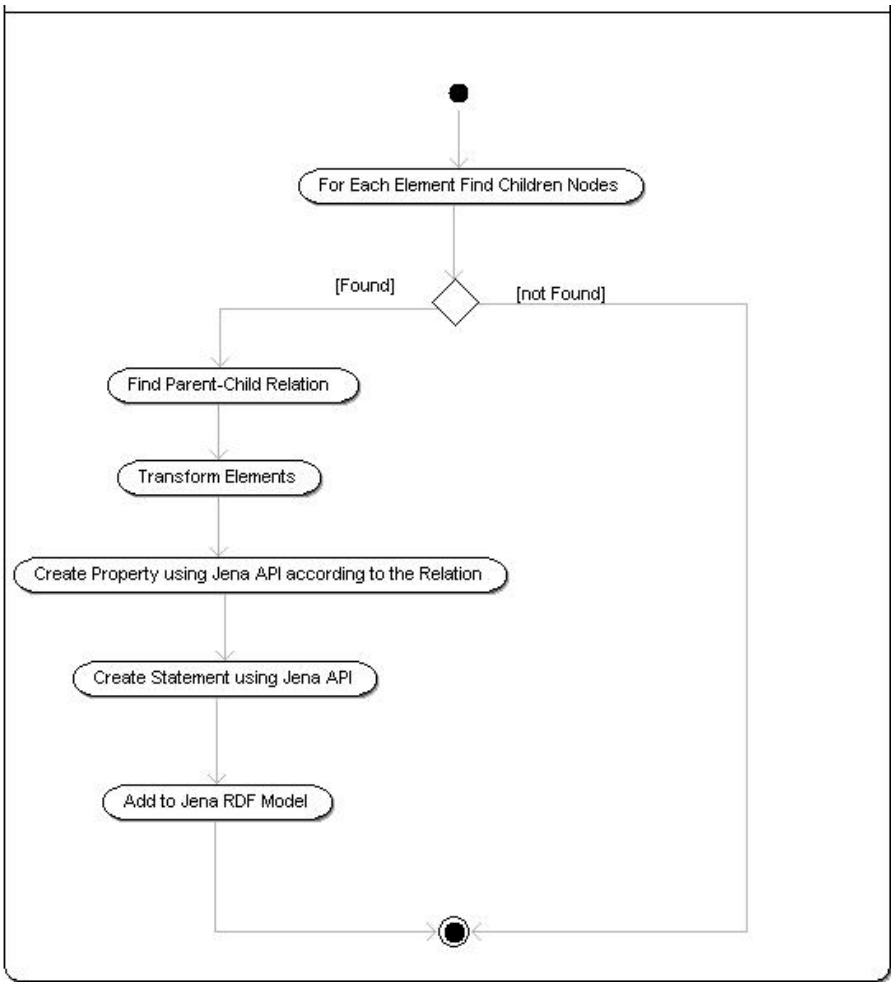

Fig. 8. Nested Element Transformation

4 Implementation

In this section we present the software system that implements the transformation process described in section 0. This system is an extension of the transformation toolkit developed in [8] that allows CIDOC/CRM descriptions (encoded in RDF syntax) to be transformed into valid MPEG-7 annotations of multimedia objects. We extended this toolkit in order to support the transformation of MPEG-7 descriptions into valid CIDOC/CRM 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. 9.

This toolkit was implemented using the Java programming language, the XMLBeans 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). 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, and presenting the graphs of the loaded and generated descriptions. The mapping panel shows the MPEG-7 description on its left side and the equivalent CIDOC/CRM description on its right side.

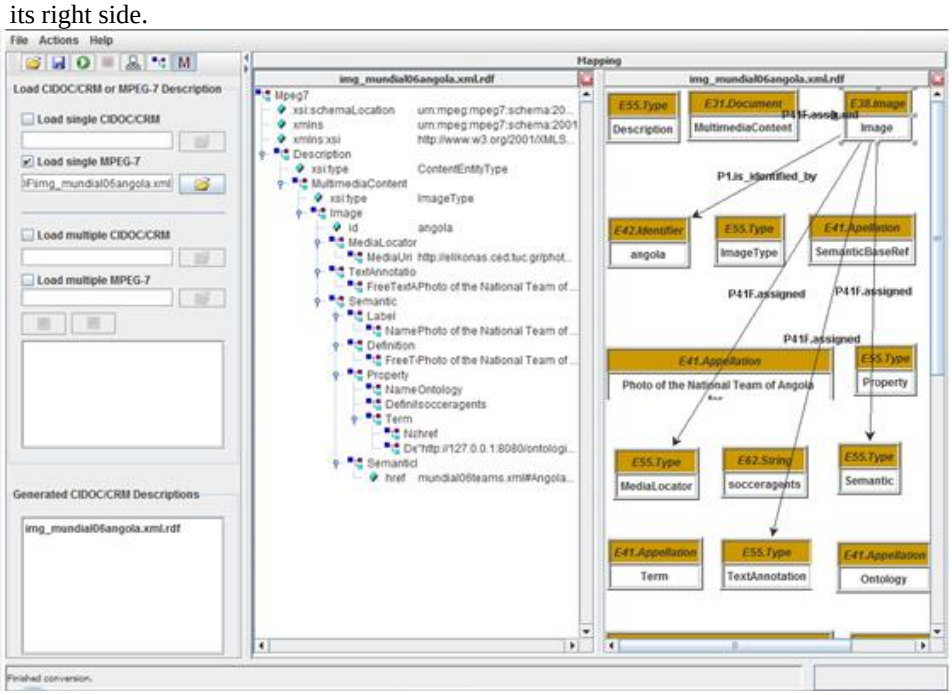

Fig. 9. Screenshot of the toolkit

The steps that should be followed for a description transformation are the following:

- First, the user loads the MPEG-7 or CIDOC/CRM descriptions (s)he wants to convert. If the user wants to convert a CIDOC/CRM description the system will identify all the instances that contain content management information and will prompt the user to specify what type the instances are.
- The conversion starts by pressing the Execute button.
- The CIDOC/CRM or MPEG-7 description is automatically generated.

5 Transformation Example

We provide in this section a short example of the MPEG-7 to CIDOC/CRM transformation, in order to evaluate the entire transformation methodology and understand how the theoretical background, that was presented earlier, is applied on a real description. In particular, we used a part of the MPEG-7 description "Parthenon by Costas Gavras" (see Fig. 10), which describes a video on the history of Parthenon and specifically the event "Occupy and burn the 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>
     <Abstract>
      <FreeTextAnnotation>Description of the history of Parthenon, created
by Costas Gavras.</FreeTextAnnotation>
     </Abstract>
     <Creator>
      <Role href="urn:mpeg:mpeg7:cs:RoleCS:2001:AUTHOR"/>
      <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>
    </VideoSegment>
   </TemporalDecomposition>
  </Video>
 </MultimediaContent>
</Description>
```

Fig. 10. An excerpt of the MPEG-7 description of the video «Parthenon by Costas Gavras»

When the transformation process starts, the MPEG-7 instances are located and are 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 instances of each of the above categories. An excerpt of the CIDOC/CRM description generated for the MPEG-7 description of the video «Parthenon by Costas Gavras» is shown in **Fig. 11**. Notice that the MPEG-7 elements have been transformed to instances of the CIDOC/CRM entities that have been mapped to the

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”.

In addition, 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”.

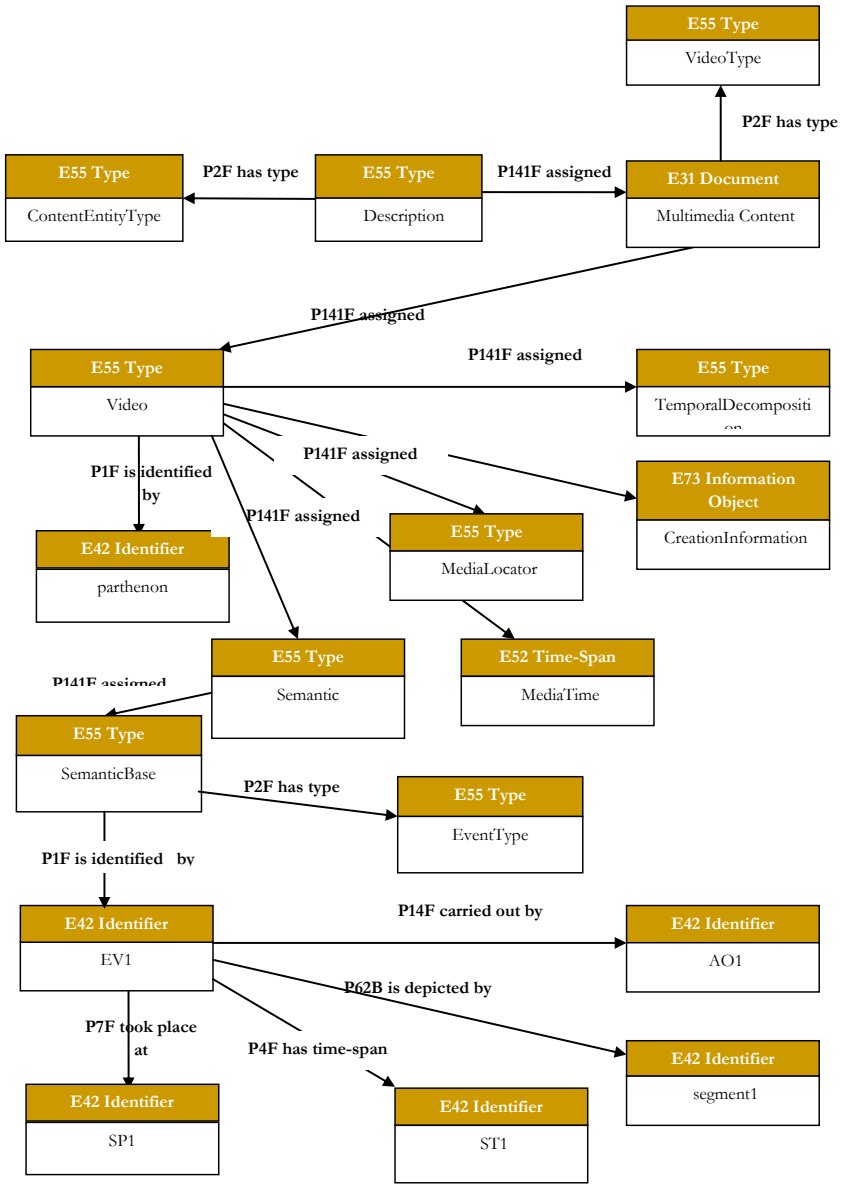

Fig. 11. An excerpt of the CIDOC/CRM description generated for the MPEG-7 description of the video «Parthenon by Costas Gavras»

6 Conclusions – Future Work

We have presented here a mapping model and a system that allow the expression of the MPEG-7 descriptions in CIDOC/CRM syntax as well as mapping (parts of) them

to specific parts of CIDOC/CRM descriptions. This way, 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 [8]. Moreover, the implementation of the MPEG-7 to CIDOC/CRM transformation has been integrated in the system developed in [8] for transforming CIDOC/CRM descriptions in MPEG-7 syntax.

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

7 References

1. Salembier P (2001). MPEG-7 Multimedia Description Schemes. IEEE TA on Circuits and Systems for Video Technology, 11, 6, 2001, 748-759
2. ISO 21127:2006 Information and documentation – A reference ontology for the interchange of cultural heritage information (CIDOC/CRM)
3. The Europeana consortium, http://www.europeana.eu/
4. Zeinstra M., Keller P. (2010). Open Linked Data and Europeana. In Europeana business documents, available at: http://version1.europeana.eu/c/document_library/get_file?uuid=374c381f-a48b-4cf0-bbde-172cf03672a2&groupId=10602
5. Isaac A (ed.). Europeana Data Model Primer. In Europeana technical documents, available at: http://version1.europeana.eu/c/document_library/get_file?uuid=718a3828-6468-4e94-a9e7-7945c55eec65&groupId=10605
6. WWW Consortium (W3C). Open Linked Data. Available at: http://www.w3.org/standards/semanticweb/data
7. Hunter J. (2002) Combining the CIDOC CRM and MPEG-7 to Describe Multimedia in Museums, In the Proc. of the Museums and the Web international conference, Boston, April 2002
8. Ntousias A., Gioldasis N., Tsinaraki C., Christodoulakis S.: "Rich Metadata and Context Capturing through CIDOC/CRM and MPEG-7 Interoperability". In the proceedings of the ACM Conference on Image and Video Retrieval (ACM CIVR) 2008, pp. 151-160.
9. Tsinaraki C., Polydoros P., Christodoulakis S.: "Interoperability support between MPEG-7/21 and OWL in DS-MIRF". In IEEE Transactions on Knowledge and Data Engineering (IEEE TKDE), Special Issue on the Semantic Web Era, 2007, 19(2): 219-232.
10. Troncy R., Celma O., Little S., Garcia R., Tsinaraki C.: "MPEG-7 based Multimedia Ontologies: Interoperability Support or Interoperability Issue?". In the proceedings of the MaReSO workshop, December 5, 2007.
11. Jérôme Euzenat and Pavel Shvaiko. Ontology matching. Springer, Heidelberg (DE), 2007.
12. S. Christodoulakis, M. Foukarakis, L. Ragia, H. Uchiyama, T. Imai: Picture Context Capturing for Mobile Databases. IEEE MultiMedia 17(2): 34-41 (2010)