Coupling OWL with MPEG-7 and TV-Anytime for Domain-specific Multimedia Information Integration and Retrieval

Chrisa Tsinaraki, Panagiotis Polydoros, Nektarios Moumoutzis, Stavros Christodoulakis
MUSIC-TUC
Technical University of Crete Campus,
73100 Kounoupidiana, Crete, Greece
{chrisa, panpolyd, nektar, stavros}@ced.tuc.gr

Abstract

The success of the Web is due to a large extent in the development of standards that allow interoperability in open environments. Future work in the field will have greater impact if it is based and built on existing standards. Well-accepted international standards for multimedia content descriptions are MPEG-7 and TV-Anytime. However, these standards do not propose a concrete methodology and language for the integration of domain-specific knowledge for the multimedia content. Moreover, domain-specific knowledge for a specific domain related to the content of a video may be described in a well-accepted ontology description language such as OWL, which is independent of MPEG-7 and TV-Anytime.

We describe a methodology that allows the coupling of OWL with MPEG-7 and TV-Anytime, so that first, domain-specific knowledge is transparently integrated into MPEG-7 and TV-Anytime thus enhancing multimedia retrieval performance and second, multimedia content and domain-specific information described in OWL is mapped into MPEG-7 and TV-Anytime and vice versa. The methodology greatly facilitates information integration, retrieval and interoperability in Web application environments. We also describe an MPEG-7 compatible Retrieval API that has been developed for expressing powerful retrieval queries on multimedia content utilizing domain-specific knowledge and application specific metadata knowledge.

1 Introduction

The success of the Web is due to a large extent in the development of standards that allow interoperability in open environments. Future work in the field will have greater impact if it is based and built on existing standards. Well-accepted international standards for multimedia content descriptions are *MPEG-7* (MPEG Group 2003) and *TV-Anytime* (TV-Anytime Forum). MPEG-7 provides in the Semantic Part of the MPEG-7 MDS (MPEG Group 2001) the complex data types needed for the complete semantic description of audiovisual content as a set of *Description Schemes (DSs)*, while TV-Anytime provides only keyword-based semantic description capabilities. However, these standards do not propose a concrete methodology and language for the integration of domain-specific knowledge for the multimedia content as they provide only general-purpose structures for metadata representation. Moreover, domain-specific knowledge for a specific domain related to the content of a video may be described in a well-accepted ontology description language like *OWL* (Mc Guiness & van Harmelen 2004), which is independent of MPEG-7 and TV-Anytime.

A methodology for MPEG-7 to be used as an ontology specification language, for ontologies that are relevant to and can be expressed in MPEG-7, has been recently proposed in the context of the *DS-MIRF (Domain-Specific Multimedia Indexing, Retrieval and Filtering)* framework (Tsinaraki, Fatourou & Christodoulakis 2003; Tsinaraki, Polydoros, Kazasis & Christodoulakis 2004). This way domain-specific ontologies can be used together with MPEG-7. However, a major issue of interoperability with other ontology specification languages remains and becomes more apparent since OWL has become the dominant standard in this area. This implies that in the future several ontologies in specific knowledge domains will be expressed in OWL and OWL ontologies will be utilized for the support of interoperability across applications. Thus, it is important to be able to integrate OWL ontologies that extend the semantics of the MPEG-7 MDS and map them to MPEG-7 as well as vice versa, to transform MPEG-7 ontologies into OWL ontologies.

In this paper, we describe a systematic methodology that allows the coupling of OWL with MPEG-7 and TV-Anytime, so that first, domain-specific knowledge is transparently integrated into MPEG-7 and TV-Anytime thus enhancing multimedia retrieval performance and second, multimedia content and domain-specific information described in OWL is mapped into MPEG-7 and TV-Anytime and vice versa. The methodology greatly facilitates information integration, retrieval and interoperability in Web application environments. We also describe an MPEG-7 compatible Retrieval API that has been developed for expressing powerful retrieval queries on multimedia content utilizing domain-specific knowledge and application specific metadata knowledge.

An essential part of the methodology for coupling MPEG-7 and TV-Anytime with OWL is the development of an OWL ontology that fully captures the metadata model defined in the Semantic Part of the MPEG-7 MDS. The need for an ontology that fully captures the MPEG-7 metadata model has been mentioned by several research groups (Troncy R. 2003; Hunter 2003). Some important work in this direction has been carried out in (Hunter 2001), but it has some limitations: Classes corresponding to the MPEG-7 complex types have been defined, but not all of the attributes of the classes are represented. In addition, typed relationships among the metadata items are not represented. Furthermore, this work has been based on the Resource Description Framework (RDF) (Klyne & Caroll 2004), which suffers form several limitations for representing ontologies, while the dominant standard for ontology representation is now OWL.

The rest of the paper is organized as follows: A brief overview of the DS-MIRF framework is provided in section 2. The methodology of OWL ontology integration in the framework is discussed in section 3. The retrieval API developed for the support of semantic queries is presented in section 4. Conclusions and future work are discussed in section 5.

2 Overview of the DS-MIRF Framework

In this section we provide an overview of the DS-MIRF (Domain-Specific Multimedia Indexing, Retrieval and Filtering) framework, in the context of which the coupling of OWL with MPEG-7 and TV-Anytime for domain-specific multimedia information integration and retrieval takes place.

The DS-MIRF framework supports both MPEG-7 and TV-Anytime through the provision of appropriate search APIs and compatible semantic indexing for both standards. In addition, end-user search interfaces based on both MPEG-7 and TV-Anytime are provided, in order to permit the usage of search and profiling software developed by third-parties that is compatible to MPEG-7 and TV-Anytime to access the audiovisual content. OWL ontologies are used in order to integrate domain-specific knowledge in the metadata models provided by MPEG-7 and TV-Anytime. The utilization of ontologies assists semantic indexing and enhances the retrieval effectiveness but does not affect the software that uses MPEG-7 and TV-Anytime constructs only. The DS-MIRF framework architecture is comprised of the following major components:

- The *Segmentation & Semantic Indexing Tool*, which is used during audiovisual content segmentation, including semantic indexing. The *Semantic Indexing Component* of the tool is used for semantic indexing and is responsible for the import of *domain-specific OWL ontologies* and existing content-description metadata, the definition of metadata for the description of audiovisual content, and their storage in the system database. MPEG-7 compliant semantic metadata as well as TV-Anytime metadata (keywords) are then produced (through the transformation of the RDF metadata defined according to the ontologies to metadata compliant to MPEG-7 and TV-Anytime) and used for the indexing of programs and segments.

- A relational database, where audiovisual programs and segments and the metadata produced for their description are stored. The relational database contains an *MPEG-7 compliant Semantic Base*, where the semantic metadata are stored and a *TV-Anytime compliant Database* where TV-Anytime metadata for audiovisual programs and segments are stored. References from the

Semantic Base and the TV-Anytime database to the corresponding programs and/or segments are maintained.

- Appropriate interfaces that permit the end users to pose both simple TV-anytime compliant keyword-based queries and more powerful, MPEG-7-based semantic queries. The interfaces are based on the existence of appropriate *query APIs (Application Programming Interfaces)*.

3 OWL Ontology Integration Methodology

In this section we describe the methodology we developed for the coupling of OWL with MPEG-7 and TV-Anytime, which is a cornerstone of the DS-MIRF framework.

The metadata model for multimedia metadata descriptions adopted in the DS-MIRF framework is two-layered (Tsinaraki, Papadomanolakis & Christodoulakis 2001a; Tsinaraki, Papadomanolakis & Christodoulakis 2001b). The first layer is the metadata model defined in the Semantic Part of the MPEG-7 MDS, and the second layer is a set of domain-specific extensions of the first layer. The first layer of the model is implemented as a core OWL ontology, while the second layer is comprised of domain-specific OWL ontologies that describe the concepts of specific application domains. Three mechanisms have been developed for the integration of OWL ontologies in the DS-MIRF framework:

(a) A core OWL ontology, which captures the semantics of the Semantic Part of the MPEG-7 MDS. We have decided to capture in the core ontology the MPEG-7 semantic metadata model, as it is more complete than the respective TV-Anytime model. The core ontology definition methodology is described in subsection 3.1.

(b) A methodology for the definition of domain-specific ontologies that comprise the second layer of the multimedia metadata model and extend the concepts present in the core ontology with domain-specific knowledge. The methodology for domain-specific ontology definition is discussed in subsection 3.2

(c) Two sets of rules, used for the transformation of semantic metadata, formed according to the core ontology and its domain-specific extensions, to MPEG-7 and TV-Anytime compliant XML documents respectively. The transformation rules for the production of both MPEG-7 and TV-Anytime compliant metadata are described in subsection 3.3.

3.1 Core Ontology Definition Methodology

The core ontology, an OWL ontology that captures the semantics of the first layer of the two-layered model for semantic metadata used in the DS-MIRF framework is described in this subsection. As already referred, the first layer of the two-layered model is essentially the model for the semantic description of audiovisual content provided in the Semantic part of the MPEG-7 MDS. It is comprised of complex data types defined in a set of Description Schemes (DSs) rooted in the SemanticBase DS, which have been defined using the syntax of XML Schema language (Fallside 2001). The more important among the description schemes are listed below:

- *SemanticBase DS:* The abstract type *SemanticBaseType* defined here is the base type extended by other description schemes.

- *SemanticBag DS* and *Semantic DS:* Description schemes used for the description of collections of semantic entities. *SemanticBagType* is an abstract type, defined in the SemanticBag DS, which extends SemanticBaseType, while *SemanticType* is a concrete type defined in the Semantic DS.

- *Object DS:* The *ObjectType* defined here extends SemanticBaseType and is used for the description of objects and object abstractions (e.g. a car).

- *AgentObject DS:* The actors that appear in an audiovisual segment are related with the instances of the *AgentObjectType* type that extends the ObjectType. Actors are represented using the *AgentType*, an abstract type extending SemanticBaseType defined in the *Agent DS*. *PersonType*, *OrganizationType* and *PersonGroupType* extend AgentType, are defined respectively in the *Person DS*, the *Organization DS* and the *PersonGroup DS* and are used for the representation of persons (e.g. Formula 1 drivers), organizations and groups of persons.

- *Event DS:* The *EventType* defined here extends SemanticBaseType and is used for the description of events (e.g. a Formula 1 race).

- *SemanticState DS: The SemanticStateType* defined here extends SemanticBaseType and is used for the description of a state of the world described in an audiovisual segment.

- *SemanticPlace DS:* The *SemanticPlaceType* defined here extends SemanticBaseType and is used for the description of a place (e.g. Paris).

- *SemanticTime DS:* The *SemanticTimeType* defined here extends *SemanticBaseType* and is used for the description of semantic time (e.g. Easter).

- *SemanticRelation DS:* The *SemanticRelationType* defined here extends SemanticBaseType and is used for the description of typed relationships among semantic entities.

For the definition of the core ontology that represents the Semantic part of MPEG-7 in OWL we developed the following methodology:

1 *MPEG-7 Complex Type Representation:* For every complex type a respective OWL class[1] has been defined.

  1.1 All the simple attributes of the complex type have been represented as OWL datatype properties[2] of the appropriate type.

  1.2 For the representation of the complex attributes of the complex type the following actions have been performed:

    1.2.1. An OWL class for the representation of the complex attribute instances has been defined (if it was not already available).

    1.2.2. An OWL object property[3] that relates the complex attribute instances with the appropriate complex type instances has been defined.

  Constraints regarding cardinality, type, domain etc. for simple and complex attributes are expressed using the restriction mechanisms provided by OWL.

  As an example, we show in Figure 1 the OWL definitions of the "PersonType" class, the "Name" object property and the "citizenship" datatype property, corresponding to the "citizenship" simple attribute and the "Name" complex attribute respectively. As shown in Figure 1, the "Name" property of "PersonType" is restricted to occur at least once in each "PersonType" individual.

2 *MPEG-7 Relationship Representation:* Relationships among semantic entities are represented by the instances of the "SemanticRelationType" class and the instances of its subclasses. A

[1] An OWL class defines a group of individuals that belong together because they share some properties.
[2] An OWL datatype property relates an instance of a class to an instance of a datatype (e.g. integer, string etc.).
[3] An OWL object property relates an instance of a class to an instance of another class.

relationship is "attached" to a semantic entity through the "Relation" object property (corresponding to the "Relation" complex attribute of "SemanticBaseType"). Restrictions on the relationship properties are defined using the restriction mechanisms provided by OWL.

```
<owl:Class rdf:ID="PersonType">
  <rdfs:subClassOf rdf:resource="#AgentType"/>
  <rdfs:label>Person</rdfs:label>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#Name"/>
      <owl:minCardinality rdf:datatype="&xsd;nonNegativeInteger">1</owl:minCardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>
<owl:ObjectProperty rdf:ID="Name">
  <rdfs:domain rdf:resource="#PersonType"/>
  <rdfs:range rdf:resource="#PersonNameType"/>
</owl:ObjectProperty>
<owl:DatatypeProperty rdf:ID="Citizenship">
  <rdfs:domain rdf:resource="#PersonType"/>
  <rdfs:range rdf:resource="&datatypes;countryCode"/>
</owl:DatatypeProperty>
```

Figure 1: OWL Definition of the "PersonType" class

The complete core ontology has been designed using the above rules but is not shown here due to space limitations.

3.2 Methodology for the Definition of Domain-Specific Ontologies

We present in this subsection the methodology for the definition of domain-specific ontologies, which comprise the second layer of the semantic metadata model used in the DS-MIRF framework, with the first layer of the model encapsulated in the core ontology. Thus, the classes representing the domain-specific entities should be defined in a way that extends the core ontology. Having these in mind, the domain-specific ontologies are defined according to the following methodological steps:

1 Domain-specific entity types are represented by OWL classes defined to be subclasses of the appropriate core ontology classes. For example, in a football tournament application, the "Player" subclass of the "PersonType" core ontology class is used for the representation of football players as is shown in Figure 2.

1.1 Attributes (simple or complex) that cannot be covered by the existing properties of the superclass are represented as appropriate object or datatype properties.

1.2 On the attributes inherited from the parent class, some constraints may be applied using the restriction mechanism provided by OWL in order to and guide the indexers for the production of valid metadata.

```
<owl:Class rdf:ID="Player">
  <rdfs:label>Player</rdfs:label>
  <rdfs:subClassOf rdf:resource="#PersonType"/>
</owl:Class>
```

Figure 2: OWL Definition the "Player"class

2 Relationships with additional restrictions compared with the ones of the general relationships defined in the core ontology are usually needed (e.g. a "Penalty" event may have only players as causers). In these cases, the following actions are performed:

2.1 A subclass of the "SemanticRelationType" or of its appropriate subclass is defined and all the restrictions needed are defined for the newly defined class.

2.2 An appropriate subproperty[4] of the "Relation" property (inherited from "SemanticBaseType") is defined in the domain of the classes capable of being sources of the relationship.

3.3 Transformation Rules

We describe in this subsection the transformation rules for the production of MPEG-7 and TV-Anytime compliant metadata from the RDF metadata structured according to the core ontology and the domain-specific ontologies and vice versa.

Transformation to/from MPEG-7: We describe here the rules for transforming into MPEG-7 compliant metadata the RDF metadata structured according to the OWL core ontology and the domain-specific ontologies developed according to the methodology discussed above.

Since MPEG-7 does not provide direct support for domain-specific ontologies, we automatically translate the entities of the supported domain-specific ontologies into abstract MPEG-7 descriptions using the "AbstractionLevel" optional attribute of "SemanticBaseType" in order to form abstraction hierarchies. "AbstractionLevel" is of type "AbstractionLevelType", which has only one attribute, "Dimension", of non-negative integer type. When a semantic description refers to specific audiovisual material "AbstractionLevel" is not present, while it is present when abstraction exists in the description. When the "Dimension" of "AbstractionLevel" is 0, there exists a description of a semantic entity (e.g. the Formula 1 driver Montoya) that is related to every audiovisual segment where the entity appears. When "AbstractionLevel" has a non-zero "Dimension", it can specify classes for the description of abstract semantic entities. We preferred to use this methodology (instead for example from subtyping) as it permits remaining completely compatible to MPEG-7 so that all tools and applications that use MPEG-7 still work transparently with the produced MPEG-7 metadata.

The rules for the transformation of OWL domain-specific ontologies into MPEG-7 compliant documents containing abstract semantic descriptions are the following:

1 Every OWL class is transformed into an instance of the MPEG-7 class corresponding to its nearest ancestor in the core ontology.

1.1 The id of the instance is the OWL class name.

1.2 The type of the instance is the type of the MPEG-7 class corresponding to its nearest ancestor in the core ontology.

2 For the representation of subclass/superclass relationships, the following relationships are generated for every instance representing an OWL class:

2.1 A "specializationOf" relationship that relates the instance with the class or instance representing its direct superclass.

2.2 A set of "generalizationOf" relationships relating the instance with the instances representing its subclasses.

3 For each of the OWL class properties restricted to have a specific value in the abstract instance, the following take place:

3.1 If the property exists in its nearest ancestor in the core ontology, an instance of the corresponding MPEG-7 class attribute having the desired value is generated.

[4] OWL subproperties permit the implementation of property hierarchies: If an individual A is related to another individual B by property C, which is a subproperty of property D, then A is also related to B by D.

3.2 If the property is a subproperty of a property of the class nearest ancestor in the core ontology, an instance of the attribute of the MPEG-7 class corresponding to the ancestor, having the desired value, is generated.

3.3 If none of the above holds, an MPEG-7 “TermUseType” instance holding the information needed for the representation of the value and the type of the property is generated.

According to the above rules, the MPEG-7 abstract instance generated for the “Player” class defined in Figure 2 is shown in Figure 3.

```
<Organization id="Player" xsi:type="PersonType">
  <AbstractionLevel dimension="1"/>
  <Relation type="specializationOf" target="PersonType" source="Player"/>
</Organization>
```

Figure 3: MPEG-7 abstract description for the “Player” class

We must mention here that OWL restrictions are not taken into account during the transformation process, as MPEG-7 does not support such restrictions for semantic entity instances (MPEG-7 supports restrictions at the schema level, in DS definition). The restrictions are used during the semantic indexing process in order to enforce the indexers to define valid semantic metadata. This way, the produced MPEG-7 metadata are also valid.

Specific metadata descriptions are defined as specializations of the abstract entities, with AbstractionLevel.Dimension=0. Individuals belonging to OWL classes defined in the core ontology are transformed into instances of the corresponding MPEG-7 classes. Individuals belonging to an OWL class defined in a domain-specific ontology are transformed into instances of the nearest ancestor of the class they belong in the core ontology and are related to the instance representing the OWL class they belong with an “exampleOf” relation.

The inverse process, for the transformation of MPEG-7 compliant metadata containing abstract object descriptions to OWL ontologies and the transformation of non-abstract MPEG-7 compliant metadata to RDF metadata structured according to the OWL ontologies is possible and of great importance, because working with MPEG-7 is common in the multimedia community. The limitation in this case is that a part of the domain knowledge (e.g. restrictions) cannot be expressed in MPEG-7, so the produced OWL ontologies and the corresponding RDF metadata will be less expressive.

Transformation to/from TV-Anytime: We discuss here the rules for transforming the RDF metadata structured according to the OWL core ontology and the domain-specific ontologies into TV-Anytime compliant metadata.

As already mentioned, the only mechanism for the semantic description of audiovisual content provided by TV-Anytime is annotation based on keywords and keyword phrases. Thus, when translating RDF metadata defined using the OWL ontologies, each metadata item is transformed into a set of keywords according to the following rules:

1 The name of the class to which an individual belongs, together with the rdf:ID of the individual, form a keyword phrase.

2 The name of each of the object properties of the individual is represented as a keyword.

2.1 The individuals related to the described individual through the object property are used for the production of keywords and keyword phrases.

3 A keyword phrase composed of the name and the value of every datatype property and a keyword containing the value of the datatype property are produced.

The TV-Anytime compliant annotation can be exploited in a less flexible and efficient way than the equivalent MPEG-7 compliant one, since keyword-based descriptions have less expressive power than structured metadata descriptions. This also implies that even if OWL ontology and RDF metadata production from the TV-Anytime compliant metadata is possible, it will give as a result ontologies where much of the domain knowledge is not precisely captured and incomplete RDF metadata descriptions.

4 Multimedia, Ontology-based Retrieval API

We present in this section the MPEG-7 compatible retrieval API developed in the context of the DS-MIRF framework for the support of advanced semantic queries that make use of the semantic metadata for audiovisual content description.

The API has been implemented in Java, using JDBC on top of a relational database. It is comprised of two functions that are capable of supporting queries that contain one or more criteria combined with the logical operators AND and OR. More specifically, the API functions are:

1. *GetSegment((AND|OR)? (informationID informationType semanticID)+),* where:

   - The first argument denotes the operator (AND/OR) used for the combination of the different criteria expressed in the rest of the query. The argument can appear at most once and may be omitted if there is only one criterion.

   - The second argument is a set of triplets that describe the query terms, that is the metadata items that must be related to the query results: *informationID* is the id of the item, *informationType* is the type of the item and *semanticID* is the role of the item. There must appear at least one triplet in a query. The "null" value should be used when we do not want to set a criterion for any part of the triplet.

   The GetSegment function permits queries that retrieve audiovisual segments related to specific metadata items, treated as equivalent query terms. No relationships among the metadata items can be defined, while the query terms may be combined using the AND and OR logical operators.

   In Table 1 we present examples of queries expressed using GetSegment, where we assume that the informationID of the person named "Ronaldo" is 1, the informationID of the person named "Zidane" is 2 and the informationID of the soccer stadium named "Old Trafford" is 1.

Query	Description in Free Text
`GetSegment(1 Person null)`	"Give me the segments where Ronaldo appears" (not only as a player!)
`GetSegment(OR, (1 Person Player) (2 Person Player))`	"Give me the segments where the players Ronaldo or Zidane appear"
`GetSegment(AND, (1 Person Player) (1 SemanticPlace SoccerStadium))`	"Give me the segments where the player Ronaldo appears in the soccer stadium Old Trafford"

Table 1: Examples of queries expressed using GetSegment

2. *GetSegmentMQT(informationID informationType semanticID (AND|OR) (informationID informationType semanticID relationType)*)*, where:

   - The first argument is a triplet that describes the main query term that is a metadata item related to the other ones: *informationID* is the id of the item, *informationType* is the type of the item and *semanticID* is the role of the item.

- The second argument denotes the operator (AND/OR) used for the combination of the query terms expressed in the rest of the query. The argument can appear at most once and may be omitted if no query terms follow.

- The third argument is a set of quadruplets that describe the query terms that are related to the main query term: *informationID* is the id of the item, *informationType* is the type of the item, *semanticID* is the role of the item and *relationType* is the type of the relationship of the current item with the main query term. There can appear any number of quadruplets in a query. The "null" value should be used when we don't want to set a criterion for any part of the quadruplet. The relationType, if not null, must be one of the relationship types supported by MPEG-7.

The GetSegmentMQT function permits queries that retrieve audiovisual segments that relate to a specific metadata item that is the main query term. The main query term may be related, through specific relationships, to the other metadata items. This way, the rich set of relationships (spatial, temporal, partof etc.) provided by MPEG-7 is exploited, in order to form expressive queries where events, persons, places, times and objects may be combined in order to form the search criteria.

In Table 2 we present examples of queries expressed using GetSegmentMQT, where we assume that the informationID of the person named "Ronaldo" is 1, the informationID of the person named "Zidane" is 2 and the informationID of the person named "Kahn" is 3. We also assume that the informationID of the soccer stadium named "Old Trafford" is 1, the informationID of the Europe is 2, the informationID of the date 1/1/2003 is 1 and the informationID of the date 1/12/2003 is 2.

Query	Description in Free Text
`GetSegmentMQT(null Event Goal AND 1 Person Player hasCauserOf)`	"Give me the segments where the player Ronaldo scores"
`GetSegmentMQT(null Event Goal AND (1 Person Player hasCauserOf) (3 Person Player hasPatientOf))`	"Give me the segments where the player Ronaldo scores against the goalkeeper Kahn"
`GetSegmentMQT(null Event Goal AND 1 SemanticTime GameTime hasTimeOf)`	"Give me the segments where a goal takes place in 1/1/2003"
`GetSegmentMQT(null SemanticPlace null AND 1 SemanticPlace SoccerStadium north)`	"Give me the segments where places north of the Old Trafford stadium appear"
`GetSegmentMQT(null Event Goal AND (1 Person Player hasCauserOf) (1 SemanticPlace SoccerStadium hasPlaceOf))`	"Give me the segments where the player Ronaldo scores in the soccer stadium Old Trafford"

Table 2: Examples of queries expressed using GetSegmentMQT

The combination of the API functions (through the union and intersection operators supported by the retrieval API) can facilitate the description of more complex queries. The API functions support the *MOREL (Multimedia, Ontology-based REtrieval Language)* language, which is under development in the context of the DS-MIRF framework.

5 Conclusions – Future Work

In this paper we have presented the coupling of OWL with MPEG-7 and TV-Anytime for domain-specific multimedia information integration and retrieval in the DS-MIRF framework. In the DS-MIRF framework, semantic indexing produces consistent MPEG-7 and TV-Anytime compliant semantic descriptions for the audiovisual content. The indexing process is guided by appropriate domain-specific ontologies, which are based on the Semantic Part of the MPEG-7 MDS and are defined using the syntax of the OWL language. We have also presented an interoperability methodology for transforming audiovisual content descriptions in MPEG-7 and TV-Anytime together with the domain-specific extensions in OWL and vice-versa. In addition, a search API has been presented for the support of advanced semantic queries that make use of the domain-specific semantic metadata for audiovisual content description.

The above-described work is being implemented. More details on the methodology and the tools implemented in this context can be found in (Tsinaraki, Polydoros & Christodoulakis 2004). Our future work in the domain of semantic description of audiovisual information includes:

- The complete development of the *MOREL (Multimedia, Ontology-based REtrieval Language)* language in the context of the DS-MIRF framework.
- The extension of the core ontology, using the methodology discussed in section 3.1, in order to capture the other parts of the MPEG-7 metadata model (segmentation, user profiles, views etc.).

6 Acknowledgments

The work presented in this paper was partially funded in the scope of the DELOS Network of Excellence in Digital Libraries (IST – Project Record Number 16872).

7 References

Fallside D. (2001). XML Schema Part 0: Primer. *W3C Recommendation*, http://www.w3.org/TR/xmlschema-0/
Mc Guiness D. & van Harmelen F. (2004). OWL Web Ontology Language Overview, *W3C Recommendation* http://www.w3.org/TR/owl-features/
Hunter J. (2001). Adding Multimedia to the Semantic Web - Building an MPEG-7 Ontology. In *Proceedings of International Semantic Web Working Symposium (SWWS*), Stanford, July 30 - August 1, 2001
Hunter J. (2003). Enhancing the Semantic Interoperability of Multimedia through a Core Ontology. In *IEEE Transactions on Circuits and Systems for Video Technology*, Special Issue on Conceptual and Dynamical Aspects of Multimedia Content Description, Feb 2003
Klyne G.& Caroll J. (2004). Resource Description Framework (RDF): Concepts and Abstract Syntax. *W3C Recommendation*. http://www.w3.org/TR/rdf-concepts/
MPEG Group (2001). ISO/IEC JTC 1/SC 29/WG 11/N3966, Text of 15938-5 FCD Information Technology – Multimedia Content Description Interface – Part 5 Multimedia Description Schemes. *MPEG Group*, Singapore 2001
MPEG Group (2003). ISO/IEC JTC1/SC29/WG11N5525 MPEG-7 Overview (version 9). Pattaya 2003. http://www.chiariglione.org/mpeg/standards/mpeg-7/mpeg-7.htm
Troncy R. (2003). Integrating Structure and Semantics into Audio-visual Documents. In *Proceedings of 2nd International Semantic Web Conference (ISWC)*. 20-23 October 2003, Florida, USA
Tsinaraki C., Fatourou E. & Christodoulakis S. (2003). An Ontology-Driven Framework for the Management of Semantic Metadata describing Audiovisual Information. In *Proceedings of CAiSE, Velden, Austria, 2003.* pp 340-356
Tsinaraki C., Papadomanolakis S. & Christodoulakis S. (2001a). A Video Metadata Model supporting Personalization & Recommendation in Video-based Services. In *Proceedings of MDDE Workshop (in conjunction with RETIS) Lyon, France, 2001*. pp. 104-109
Tsinaraki C., Papadomanolakis S. & Christodoulakis S. (2001b). Towards a two - layered Video Metadata Model. In *Proceedings of DEXA Workshop - DLib, Munich, Germany, 2001*. pp 937-941
Tsinaraki C., Polydoros P. & Christodoulakis S. (2004). Integration of OWL ontologies in MPEG-7 and TV-Anytime compliant Semantic Indexing. *Submitted for publication*, 2004
Tsinaraki C., Polydoros P., Kazasis F. & Christodoulakis S. (2004). Ontology-based Semantic Indexing for MPEG-7 and TV-Anytime Audiovisual Content. *In Special issue of Multimedia Tools and Applications Journal on Video Segmentation for Semantic Annotation and Transcoding*, 2004
TV-Anytime Forum, http://www.tv-anytime.org/