A Multimedia User Preference Model that Supports Semantics and its Application to MPEG 7/21

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Abstract[1]

Semantic interoperability is usually provided in open environments through standards and domain ontologies. The dominant standards for multimedia content and service descriptions are MPEG-7 and MPEG-21. The MPEG-7 Semantic DS has powerful semantic description capabilities and supports using semantic entities specified in domain ontologies in multimedia content descriptions. However, the MPEG-7/21 Usage Environment allows neither the specification of semantic user preferences nor the exploitation of domain knowledge and MPEG-7 semantic metadata descriptions. In addition, the users cannot explicitly specify, in the hierarchical MPEG-7/21 filtering and search preferences, the boolean operators that should be used during content filtering to combine the hierarchy components. We think these as serious limitations and we propose a hierarchical semantic user preference model that allows for the explicit specification of boolean operators. Then, we present the application of the model in MPEG-7/21 and the model implementation within the DS-MIRF framework.

1. Introduction

The high penetration of the traditional TV and the advances in the digital media industry led to the development of digital multimedia content services. This paper focuses on the provision of services satisfying high-level user demands, including semantic retrieval and retrieval personalization, which are becoming increasingly important.

Semantic interoperability is usually provided through standards and domain knowledge encoded in domain ontologies that are adopted by wide user communities. Domain ontologies are very important for interoperability support in open environments, as the language expressions utilizing domain ontology terms have semantic, not just syntactic, meaning for the user community. In particular, they can be used in many retrieval aspects (like interface support, indexing, query disambiguation, etc.), thus being very useful for the semantic retrieval of multimedia data. Domain ontologies are usually specified using ontology description languages like OWL [12].

Standards are necessary in open environments for interoperability support among the multimedia content services offered by different providers. The dominant metadata standards for multimedia content and service description are *MPEG-7* [1] and *MPEG-21* [2].

MPEG-7 provides, in the *Semantic DS* [2] of the *MPEG-7 Multimedia Description Schemes (MDS)* [4], powerful primitives for the description of complex real-world concepts and relationships among concepts. This way, the inadequacies of keyword-only descriptions (like reduced expressiveness, too many false drops etc.) are prevented. The rich structures of the MPEG-7 Semantic DS may also be used for both domain ontology description and multimedia content description based on domain ontologies. Such a uniform representation of ontologies and semantics within MPEG-7 allows powerful retrieval support. However, the utilization of existing OWL domain ontologies makes interoperability support within user communities easier. A methodology for the integration of OWL domain ontologies in MPEG-7 has been developed in the *DS-MIRF (Domain-Specific Multimedia Indexing, Retrieval and Filtering) framework* [5][6] [7][8]. A powerful retrieval API that utilizes semantic multimedia content descriptions has also been implemented.

Although MPEG-7 allows semantic multimedia content descriptions, MPEG-7/21 allow only for limited semantic user preference descriptions and they cannot currently exploit the rich semantic multimedia content descriptions formed according to the MPEG-7 Semantic DS. The user context model specified in the *MPEG-21 Digital Item Adaptation (DIA)* Architecture [3] and the MPEG-7 MDS for content and service personalization and adaptation captures the device capabilities and the user-related, natural environment and network characteristics, but has two major limitations:

- It cannot make use of the MPEG-7 semantic multimedia content descriptions, as it follows a keyword-based approach that may work reasonably for movies, but has serious limitations in other application domains like news, sports etc. As a consequence,

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[2] An MPEG-7 *DS (Description Scheme)* essentially is an MPEG-7 complex type defined using XML Schema syntax.

the MPEG-7 based systems either utilize keyword-only metadata thus ignoring the structured MPEG-7 semantic metadata [15][16][17] or ignore the MPEG-7/21 user context model and follow proprietary filtering approaches on top of the structured MPEG-7 semantic metadata [14].

- In the hierarchical MPEG-7/21 *filtering and search preferences (FASP)*, the user cannot explicitly specify how the criteria stated in the FASP hierarchy should be combined using the boolean operators (AND/OR); it is rather left to the retrieval system to decide how to interpret them.

The need for extending the MPEG-7/21 framework to provide new more powerful constructs for the accommodation of real-world applications is emphasized also in [10], [11]. However, no concrete model as the one described in this paper is presented.

In this paper we present a hierarchical semantic user preference model that allows for the explicit specification of boolean operators. The proposed user preference model is described using regular expression syntax. Then, we present the application of the model in MPEG-7/21 and the model implementation within the DS-MIRF framework. Our model preserves the hierarchical structure of the current MPEG-7/21 user preference descriptions and has them as a special case. In addition, it allows the knowledgeable users to explicitly specify how the boolean operators should be used during content filtering to combine the FASP hierarchy components. The model allows the utilization of the knowledge structured according to the MPEG-7 Semantic DS, which encodes semantic multimedia content descriptions (for example to say that a user is interested in all the segments where Ronaldo scores outside the territory of the opponent team).

The rest of the paper is structured as follows: In section 2 we give an overview of the MPEG-7/21 Usage Environment. The limitations of the MPEG-7/21 Usage Environment and our contributions are discussed in section 3. Our semantic user preference model is presented in section 4. The application of the proposed model in MPEG-7/21 is discussed in section 5 and its implementation within the DS-MIRF framework is described in section 6. The paper conclusions and future research directions are presented in section 7.

2. The MPEG-7/21 Usage Environment

We present in this section the MPEG-7/21 Usage Environment, which essentially forms the context model proposed in the MPEG-7/21 framework. The *Usage Environment Description* is a part of the MPEG-21 DIA architecture, and consists of the following description elements:

- The *Terminal Capabilities*, which capture the capabilities of the user devices.
- The *Natural Environment Characteristics*, where the features of the user natural environment are captured.
- The *Network Characteristics*, where the network parameters are represented.
- The *User Characteristics*, where the user features are captured, including:
  - The *User Info*, which contains information about the user.
  - The *User Preferences*, where the user browsing, filtering and search preferences are described.
  - The *Usage History*, which represents the user's history of interaction with multimedia items.
  - The *Presentation Preferences*, where multimedia information should be presentation and rendering are specified.
  - The *Accessibility Characteristics*, which allow content adaptation according to possible user auditory or visual impairments.

The user preferences are placed, in MPEG-7/21, inside the user characteristics. A user preference description comprises of:

- A set of *FilteringAndSearchPreferences (FASP)* elements, which describe the user preferences regarding multimedia content filtering and searching. A FASP element is decomposed:
  - A set of FASP elements, which describe the sub-preferences of the current element, thus allowing the definition of FASP preference hierarchies.
  - A set of *ClassificationPreferences* elements, which describe the user preferences regarding the multimedia content classification attributes.
  - A set of *SourcePreferences* elements, which describe the user preferences regarding the multimedia content source.
  - A set of *PreferenceCondition* elements, which describe, in terms of time and place, the usage conditions for the current FASP description.
  - A set of *CreationPreferences* elements, which describe the user preferences regarding multimedia content creation.
- A set of *BrowsingPreferences* elements, which describe the user preferences regarding multimedia content navigation and browsing. A BrowsingPreferences element is decomposed into:
  - A set of *SummaryPreferences* elements, which describe the user preferences regarding the multimedia content summaries.
  - A set of *PreferenceCondition* elements, which describe in terms of genre, location and time the usage conditions for the current description.

3. Limitations of the MPEG-7/21 Usage Environment and contributions

We discuss in this section the limitations of the MPEG-7/21 Usage Environment and we present the contributions of our user preference model. It has been

shown that MPEG-7 has structural primitives that can be used for encoding rich domain knowledge semantics of the multimedia content [5], [7]. The major shortcoming of the MPEG-7/21 environment is that domain knowledge cannot be integrated in a systematic way in the MPEG-7/21 Usage Environment, and therefore the end users cannot express accurately their preferences about the semantics of the content. As a result, structured semantic descriptions of the multimedia content cannot be utilized in the MPEG-7/21 Usage Environment:

- In the *filtering and search preferences (FASP)*, the users may specify their preferences regarding the semantics of the content only through the textual *Subject* element of the *classification preferences* or the textual *Keyword* element of the *creation preferences*. This is limiting, as the user may specify, for example, that the goals in a soccer game should be recorded for him, but cannot state that only the home team goals should be recorded (if the user relies in the keyword "goal" and the home team name it may be the case that a goal is scored against the home team).
- In the *browsing preferences*, the users may specify only textual *Theme* elements in their *summary preferences* describing the content of the summaries created for them. This way, a user may specify that he would like to have a summary containing all the goals in a soccer game, but cannot ask for a summary containing the home team goals.

The more expressive user preference descriptions are useful for demanding users particularly interested in a domain such as a sport event as well as people working in the domain: A soccer team coach would like to see, every Monday, a prepared summary containing all the attack actions made in the games played so far by the next opponent of his team.

Another limitation of the MPEG-7/21 Usage Environment is that in its hierarchical filtering and search preferences (FASP) the user cannot explicitly specify how the criteria stated in the FASP hierarchy should be combined using the boolean operators (AND/OR); it is rather left to the retrieval system to decide how to interpret them. Thus, a user may state that he is interested in corners with weight 0.4, in goals with weight 0.8 and in AEK with weight 0.9, but cannot state that he is interested in (goals AND AEK) with weight 1.0 OR in (corners AND AEK) with weight 0.5.

To overcome the serious limitations of the MPEG-7/21 Usage Environment that prohibit the users from having user preference specifications describing their interests in specific domains, we have developed and present in this paper a semantic user preference model. Our user preference model is compatible with the MPEG-7 Semantic DS, and can exploit its structures and the human knowledge encoded with them for audiovisual content description. In addition, it allows the users to explicitly specify how the boolean operators should be used in the FASP hierarchies during content filtering.

We have described in the recent past how to utilize domain ontologies for describing the human knowledge in audiovisual content using structures of the MPEG-7 Semantic DS in a way that is completely transparent to the applications [5], [7] and a framework that allows to utilize domain ontologies described in OWL (the dominant ontology description language) [12] for this purpose [6], [8]. We now present how to extend this framework with a user preference model that allows exploiting the knowledge encoded in the MPEG-7 Semantic DS to respond to domain-specific user preferences. We design this user preference model to be as compatible as possible with the MPEG-7/21 Usage Environment and to have it as a special case. We show how to achieve interoperability between our user preference model and the current MPEG-7/21 Usage Environment.

4. Semantic User Preference Model

We present in this section a model for the specification of semantic user preferences (which include browsing, filtering and search preferences) that are compatible with the MPEG-7 Semantic DS. The model allows expressing user content preferences using domain knowledge encoded according to the MPEG-7 Semantic DS as well as how the boolean operators should be used in the FASP hierarchies during content filtering.

In the rest of this section, we provide formal descriptions (in regular expression syntax) of the constructs of our proposed user preference model. This formal syntax allows the application of our semantic user preference model in different frameworks. A straightforward application is the extension of the MPEG-7/21 Usage Environment with the constructs of our semantic user preference model, as described in section 5. Other applications may utilize a different language (for example, an ontology definition language like OWL) for the syntactic description of our model (see the details of the OWL implementation of our semantic user preference model in the DS-MIRF framework in section 6).

In our semantic user preference model, a *user preference description (UP)* is comprised of an optional *user identifier (UI)*, *filtering and search preferences (FASP)* and *browsing preferences (BP)*. The user preference descriptions may be allowed to be automatically updated, according to the *allow automatic updates (aau)* boolean attribute. The weight of a user preference element is specified by the *preference value (pv)* attribute, an integer value set by the user, in the range [-100, 100] (the negative preference values denote negation). The formal syntax for the representation of user preference descriptions (UP) is shown in Expression 1.

UP = aau[UI](FASP pv)*(BP pv)*

Expression 1: Formal syntax of user preference descriptions (UP). UI is a user identifier, FASP is a set of filtering and search preferences and BP is a set of browsing preferences. pv is a preference value. The value of aau states if the user preferences are automatically updatable.

A set of browsing preferences is comprised of *summary preferences (SuP)*, which describe the user preferences regarding the multimedia content summaries and *preference conditions (PC)*, which describe the usage conditions for each browsing preference description. The formal syntax of browsing preferences is shown in Expression 2.

BP = (SuP pv)*PC*

Expression 2: Formal syntax of browsing preferences (BP). SuP is a set of summary preferences and PC is a preference condition.

A set of summary preferences allows the user to express the *preferred, minimum* and *maximum summary duration* (*SD, MaxSD* and *MinSD* respectively), the *preferred, minimum* and *maximum number of keyframes* (*KF, MaxKF* and *MinKF* respectively), the *preferred, minimum* and *maximum number of characters for textual summaries* (*C, MaxC* and *MinC* respectively), the *preferred summary type (SType)*, the *preferred summary theme (STheme)* and a set of *semantic summary descriptions (SS)* regarding the preferred audiovisual content. Summary preferences follow the regular expression syntax shown in Expression 3.

SP = (SType pv)*(STheme pv)*(SS pv)*[SD][MaxSD] [MinSD][NoKF][MaxNoKF][MinNoKF][NoC] [MaxNoC][MinNoC]

Expression 3: Formal syntax of summary preferences (SP). SS is a semantic summary description. SType and STheme are the summary type and theme. NoC, MaxNoC and MinNoC are the preferred, minimum and maximum number of characters for textual summaries. NoKF, MaxNoKF and MinNoKF are the preferred, minimum and maximum number of keyframes. SD, MaxSD and MinSD are the preferred, minimum and maximum duration.

A semantic summary description is a set of semantic entities (T) that describe the desired audiovisual content. A semantic summary description may contain:

- The *id* of the semantic entity *(Tid)*, which plays the role of a variable name.
- The semantic entity *type (TType)*.
- The *name (AName)* and the desired *value (AValue)* respectively of an attribute of the semantic entity.
- Descriptions of semantic entity relationships. The necessary relationship description information consists of the relationship *type (RType)* and the *target* of the relationship *(RTarget)*, while the optional information includes the *source (RSource)* and the *strength (RStrength)* of the relationship.

  The relationship types that a semantic entity may use includes the rich set of (more than 100) relationship types that are specified in the standard *classification schemes (CSs)* of the MPEG-7 MDS. The relationship types are classified into: (a) Basic relationship types (equals, inside, refines etc.), which are specified in the *BaseRelation CS*; (b) Types of relationships existing among graph nodes (identity, equivalent etc.), which are specified in the *GraphRelation CS*; (c) Spatial relationship types (over, below, north etc.), which are specified in the *SpatialRelation CS*; (d) Temporal relationship types (precedes, overlaps, contains etc.), which are specified in the *TemporalRelation CS*; (e) Semantic relationship types (shows, agent, causer etc.), which are specified in the *SemanticRelation CS*.
- *Semantic entities nested in T.*

When some criteria are specified for the same semantic entity inside a semantic summary preference description, are implicitly assumed to be logically ANDed. The formal syntax of a semantic entity is shown in Expression 4.

T = (Tid TType) | (Tid TType) AND ((T)|(RType RTarget [RSource] [RStrength])|(AName AValue)) (AND((T)| (RType RTarget [RSource] [RStrength])|(AName AValue)))*

Expression 4: Formal syntax of a semantic entity (T). Tid and TType are the id and the type of T. RType, RTarget, RSource and RStrength are the type, target, source and strength of a relationship of T. AName and AValue are the name and the desired value of an attribute of T.

The formal syntax of a semantic summary description, which essentially is a weighed semantic entity collection, is shown in Expression 5:

SS = (T* pv)*

Expression 5: Formal syntax of semantic summary descriptions.

In the filtering and search preferences (FASP) we allow the naïve users not to explicitly specify the boolean operators to be used by the filtering process that will match their preferences with the available content. On the other hand, the knowledgeable users are allowed to express which boolean operators should be used and in which place within their preferences.

A FASP is comprised of the *preference conditions (PC)* that should hold so that the user preferences in the current FASP apply, the user's *classification preferences (CP)*, *semantic creation preferences (BSCrP)* and *source preferences (SP)*. The boolean operators are explicitly specified. The formal syntax of a FASP is shown in Expression 6.

FASP = (CP|PC|SP|BSCrP)pv ((AND (CP|PC|SP|BSCrP)pv)*| (OR(CP|PC|SP|BSCrP)pv)*) ((OR FASP pv)*|(AND FASP pv)*)

Expression 6: Formal syntax of a FASP. PC is a preference condition. SP, BSCrP and CP, are the source, semantic creation and classification preferences.

The semantic creation preferences (BSCrP) explicitly specify the boolean operators as well as preferred *title (TT)*, *keywords (K)*, *creator (Cr)*, *location (L)*, *creation tool (CT)* and the desired *semantic content preferences (BSCP)*. The formal syntax of semantic creation preferences are expressed in regular expression syntax as shown in Expression 7.

BSCrP = ((TT|K|Cr|L|D|CT|BSCP) pv) [(AND|OR) ((TT|K|Cr|L|D|CT|BSCP) pv)*]

Expression 7: Formal syntax of semantic creation preferences (BSCrP). TT is the preferred title, K a keyword, Cr the creator, L the location, CT the creation tool and BSCP the semantic content preferences.

The semantic content preferences are weighed semantic entity collections with boolean operators. The formal syntax of semantic content preferences is shown in Expression 8.

BSCP = ((T(OR T)*) pv) | (((T(AND T)*) pv)

Expression 8: Formal syntax of content preferences (BSCP).

A special case of the generalized FASP syntax is the syntax of FASPs with implicit boolean operators. The formal syntax of a FASP with implicit boolean operators is shown in Expression 9.

FASP = ((CP|PC|SP|SCrP|FASP)pv)*

Expression 9: Formal syntax of a FASP with implicit boolean operators. PC is a preference condition. CP, SCrP and SP are the classification, semantic creation and source preferences in the FASP.

The semantic creation preferences for FASPs with implicit boolean operators do not contain boolean operators and are a special case of the semantic creation preferences of Expression 7. They have the MPEG-7 creation preferences, which do not have semantic content preferences, as a special case. The formal syntax of semantic creation preferences for FASPs with implicit boolean operators is shown in Expression 10.

SCrP = ((TT|K|Cr|L|D|CT|SCP) pv)*

Expression 10: Formal syntax of semantic creation preferences for FASPs with implicit boolean operators (SCrP). TT is the preferred title, K the keywords, Cr the creator, L the location, CT the creation tool and SCP the semantic content preferences.

The formal syntax of the semantic content preferences with implicit boolean operators, which essentially are weighed semantic entity collections, is shown in Expression 11.

SCP = (T* pv)*

Expression 11: Formal syntax of semantic content preferences with implicit boolean operators (ScrP).

As an example of user preferences with implicit boolean operators, consider the preferences of a user who is interested in the goals scored by AEK. They are expressed in regular expression syntax as shown in Expression 12. We assume in this example that AEK's goals are bound to the "AGoal" variable and that an abstract semantic entity exists, having as id "Goal", which represents the class of all the goals. We also assume the existence of a semantic entity having as id "AEK", which represents the soccer team AEK. The "exemplifies" relation states that "AGoal" is an example of the abstract "Goal" event, the "agent" relation states that the "AGoal" has been scored by "AEK".

UP1 = ((AGoal, EventType) AND ((exemplifies, Goal) AND (agent, AEK)) 100)

Expression 12: Formal syntax of the preferences of a user who is interested in the goals scored by AEK.

An example of user preferences with explicit boolean operators are the preferences of a user who is interested in goals (pv=80), in AEK's goals (pv=100) and in AEK's corners (pv=50). They are expressed in regular expression syntax as shown in Expression 13. We additionally assume here that goals in general are bound to the "XGoal" variable and AEK's corners are bound to the "ACorner" variable. We also assume that an abstract semantic entity exists, having as id "Corner", which represents the class of all the corners.

UP2 = ((((XGoal, EventType) AND ((exemplifies, Goal)) 80) OR ((AGoal, EventType) AND ((exemplifies, Goal) AND (agent, AEK)) 100) OR ((ACorner, EventType) AND ((exemplifies, Corner) AND (agent, AEK)) 50))

Expression 13: Formal syntax of the preferences of a user who is interested in goals (pv=80), in AEK's goals (pv=100) and in AEK's corners (pv=50).

5. Application of the Semantic User Preference Model in MPEG-7/21

We discuss in this section the application of our semantic user preference model in MPEG-7/21. This has been implemented as an extension of the MPEG-7/21 Usage Environment defined following the methodological steps described below:

- We defined the *SSummaryPreferencesType* type for the representation of semantic summary preferences. SSummaryPreferencesType is a subtype of the MPEG-7 MDS *SummaryPreferencesType*. SSummaryPreferencesType has a set of semantic summary preference description elements (namely *SummarySemantics*), which are essentially weighed

semantic entity collections. The definition of the SSummaryPreferencesType is shown in Figure 1.

```
<complexType name="SSummaryPreferencesType">
  <complexContent>
    <extension
base="mpeg7:SummaryPreferencesType">
      <sequence>
        <element name="SummarySemantics"
type="mpeg7:WeighedSemanticBagType"
minOccurs="0" maxOccurs="unbounded"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
```

Figure 1: Definition of SSummaryPreferencesType.

- We defined the *SCreationPreferencesType* type, for the representation of semantic creation preferences with implicit boolean operators. SCreationPreferencesType is a subtype of the MPEG-7 MDS *CreationPreferencesType* that represents the creation preferences of the users. The semantic content preferences are set in its *SContentPreferences* element, which is a weighed semantic entity collection. For the representation of weighed semantic entity collections we defined *WeighedSemanticBagType*, a subtype of the MPEG-7 type *SemanticBagType* (which is used for the representation of semantic entity collections). WeighedSemanticBagType has the *preferenceValue* attribute for the specification of the value of a content preference description (preferenceValue is used in MPEG-7 whenever the weight of an element should be specified). The definitions of SCreation-PreferencesType and WeighedSemanticBagType are shown in Figure 2.

```
<complexType name="SCreationPreferencesType">
  <complexContent>
    <extension
base="mpeg7:CreationPreferencesType">
      <sequence>
        <element name="SContentPreferences"
type="mpeg7:WeighedSemanticBagType"
minOccurs="0" maxOccurs="unbounded"/>
      </sequence>
    </extension>
  </complexContent>
</complexType>
<complexType name="WeighedSemanticBagType">
  <complexContent>
    <extension base="mpeg7:SemanticBagType">
      <attribute name="preferenceValue"
type="mpeg7:preferenceValueType" use="optional"
default="10"/>
    </extension>
  </complexContent>
</complexType>
```

Figure 2: SCreationPreferencesType and WeighedSemanticBagType definitions.

- We defined the *BooleanFASPType* type for the representation of FASPs with explicit boolean operators. BooleanFASPType is a subtype of the MPEG-7 type *FilteringAndSearchPreferencesType*. As shown in Figure 3, BooleanFASPType has two attributes, both of *operatorType* (that takes one of the values "AND" and "OR"): (a) the *operatorFASP*, which represents the operator applied to the current FASP by its parent FASP element to combine it with its sibling FASPs; and (b) the *operator*, which represents the operator applied by the current FASP to combine its non-FASP components.

```
<complexType name="BooleanFASPType">
  <complexContent>
    <extension
base="mpeg7:FilteringAndSearchPreferencesType">
      <attribute name="operatorFASP"
type="mpeg7:booleanOperatorType"
use="required"/>
      <attribute name="operator" use="required"
type="mpeg7:booleanOperatorType"/>
    </extension>
  </complexContent>
</complexType>
<simpleType name="booleanOperatorType">
  <restriction base="NMTOKEN">
    <enumeration value="OR"/>
    <enumeration value="AND"/>
  </restriction>
</simpleType>
```

Figure 3: BooleanFASPType and booleanOperatorType definitions.

- We defined the *BooleanSCreationPreferencesType* type for the representation of semantic creation preferences with explicit boolean operators. BooleanSCreationPreferencesType is a subtype of CreationPreferencesType and extends them with *SContentPreferences* elements, that essentially are weighed collections of semantic entities combined with a boolean operator. The SContentPreferences elements of a BooleanSCreationPreferencesType description are combined with the boolean operator specified in the *operator* attribute. Then, we defined, for the representation of collections of semantic entities on which a boolean operator is applied, the *BooleanWeighedSemanticBagType*, a subtype of WeighedSemanticBagType. The operator to be applied in the semantic entity collection contents is specified through the *operator* attribute. The definitions of BooleanWeighedSemanticBagType and BooleanSCreationPreferencesType are shown in Figure 4.

```
<complexType
name="BooleanSCreationPreferencesType">
  <complexContent>
    <extension
base="mpeg7:CreationPreferencesType">
      <sequence>
        <element name="SContentPreferences"
type="mpeg7:BooleanWeighedSemanticBagType"
minOccurs="0" maxOccurs="unbounded"/>
      </sequence>
      <attribute name="operator" use="required"
type="mpeg7:booleanOperatorType"/>
    </extension>
  </complexContent>
</complexType>
<complexType
name="BooleanWeighedSemanticBagType">
  <complexContent>
    <extension
base="mpeg7:WeighedSemanticBagType">
      <attribute name="operator" use="required"
type="mpeg7:booleanOperatorType"/>
    </extension>
  </complexContent>
</complexType>
```

Figure 4: Definitions of BooleanWeighedSemanticBagType and BooleanSCreationPreferencesType.

An example of a semantic user preference description with implicit boolean operators is shown in Figure 5, which corresponds to the formal syntax of Expression 12.

```
<UserPreferences id="UP1">
  <FilteringAndSearchPreferences>
    <CreationPreferences
xsi:type="SCreationPreferencesType">
      <SContentPreferences>
        <SemanticBag preferenceValue=100
xsi:type="WeighedSemanticBagType">
          <SemanticBase xsi:type="EventType"
id="AGoal">
            <Relation type="agent" target="#AEK"/>
            <Relation type="exemplifies"
target="#Goal"/>
          </SemanticBase>
        </SemanticBag>
      </SContentPreferences>
    </CreationPreferences>
  </FilteringAndSearchPreferences>
</UserPreferences>
```

Figure 5: Semantic user preference description that corresponds to the regular expression of Expression 12.

An example of a semantic user preference description with explicit boolean operators is shown in Figure 6, which corresponds to the formal syntax of Expression 13.

```
<UserPreferences id="UP2">
  <FilteringAndSearchPreferences operator="OR"
operatorFASP="OR" xsi:type="BooleanFASPType">
    <CreationPreferences operator="OR"
xsi:type="SCreationPreferencesType">
      <SContentPreferences>
        <SemanticBag preferenceValue=80
xsi:type="BooleanWeighedSemanticBagType">
          <SemanticBase xsi:type="EventType"
id="XGoal">
            <Relation type="exemplifies"
target="#Goal"/>
          </SemanticBase>
        </SemanticBag>
        <SemanticBag preferenceValue=100
xsi:type="BooleanWeighedSemanticBagType">
          <SemanticBase xsi:type="EventType"
id="AGoal">
            <Relation type="agent" target="#AEK"/>
            <Relation type="exemplifies"
target="#Goal"/>
          </SemanticBase>
        </SemanticBag>
        <SemanticBag preferenceValue=50
xsi:type="BooleanWeighedSemanticBagType">
          <SemanticBase xsi:type="EventType"
id="ACorner">
            <Relation type="agent" target="#AEK"/>
            <Relation type="exemplifies"
target="#Corner"/>
          </SemanticBase>
        </SemanticBag>
      </SContentPreferences>
    </CreationPreferences>
  </FilteringAndSearchPreferences>
</UserPreferences>
```

Figure 6: Semantic user preference description that corresponds to the regular expression of Expression 13.

Our semantic user preference model is available in XML Schema as an MPEG-7 MDS extension at: http://elikonas.ced.tuc.gr/ontologies/MPEG7ext/semUP.xsd.

6. Implementation of the Semantic User Preference Model in DS-MIRF

We present in this section how the model described in section 5 for the MPEG-7/21 Usage Environment is implemented in the DS-MIRF framework. The objective of this section is to present the extensions made in the DS-MIRF framework to support user preference descriptions containing boolean operators, semantic descriptions of multimedia content and domain knowledge (ontologies) utilizing OWL as knowledge representation language.

The DS-MIRF framework is based on OWL and allows the integration of domain knowledge in semantic MPEG-7 metadata. In order to achieve this, four mechanisms are utilized:

- An OWL *Upper Ontology* [8], which fully covers the MPEG-7 MDS. The Upper Ontology has been defined systematically, according to a methodology that was developed for the representation of the MPEG-7 simple and complex types and relationships in OWL.
- A set of OWL *Application Ontologies* that provide additional functionality in OWL that either makes easier the use of the MPEG-7 MDS from the users or allows the provision of advanced multimedia content services.
- A *methodology for the definition of domain ontologies* that extend the Upper Ontology, in order to fully describe the semantic entities present in specific application domains [6].
- A *set of rules*, used for the transformation of semantic metadata (formed according to the ontologies) to MPEG-7 compliant XML documents [6]. This way, interoperability with standard MPEG-7 software is allowed.

We have expressed our semantic user preference model in OWL as an application ontology integrated in the DS-MIRF framework. Having the semantic user preference model integrated in the DS-MIRF framework allows in the user preference descriptions to take advantage of the domain specific extensions that become available through the integration of domain knowledge expressed in OWL domain ontologies. The application ontology that expresses our semantic user preference model in OWL syntax is available at http://elikonas.ced.tuc.gr/ontologies/AppOntos/SUPAO/SUserPreferences.

We provide support for semantic user preferences in the DS-MIRF framework and, at the same time, allow interoperability with MPEG-7/21 software that is based on the current MPEG-7/21 specification. In the later case the semantics of the user preferences will not be completely preserved, of course. This is achieved

through the support of the usage scenario of Figure 7: The user specifies in OWL/RDF his preferences using a user interface based on the Upper ontology, the domain ontologies and the user preference application ontology. The user preferences are then transformed and stored in both the extended format we have proposed in section 5 and in standard MPEG-7/21 format. The output of the user preference specification is in OWL/RDF format. When stored it is transformed into both a semantic user preference description and a standard user preference description, using the appropriate transformation rules. The standard descriptions allow MPEG-7/21 software to interoperate with them, but it offers limited functionality.

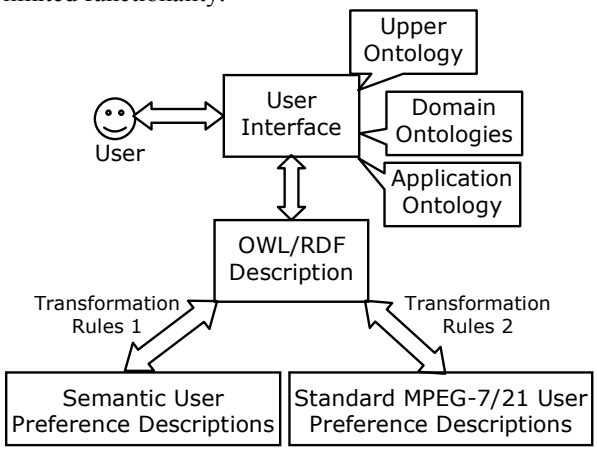

Figure 7: Usage scenario that supports both interoperability with standard MPEG-7/21 software and semantic user preferences

7. Conclusions – Future Work

We have pointed out in this paper that while MPEG-7 allows rich semantic multimedia content descriptions, the MPEG-7/21 user preferences do not provide mechanisms to exploit those semantic descriptions. We have then presented a model for semantic MPEG-7/21 user preferences that allows semantic specifications of the desired multimedia content. Our approach utilizes completely the functionality offered by the MPEG-7 Semantic DS for multimedia content description and it respects all the MPEG-7/21 conventions. The proposed approach allows the explicit specification of boolean operators, while it preserves the hierarchical structure of the current MPEG-7/21 user preference descriptions, which are a special case of the proposed ones.

The proposed user preference model has been implemented in the DS-MIRF framework. In order to achieve interoperability with standard MPEG-7/21 software, we also provided a methodology to produce systematically standard MPEG-7/21 descriptions from the extended ones, even if only the former are supporting all the enhanced functionality provided.

Our future research in the area includes the implementation of a graphical tool, based on our GraphOnto component [9], for specifying the extended user preferences, and the integration of a Natural Language interface based on the OntoNL framework [13].

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