Semantic User Preference Descriptions in MPEG-7/21

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ABSTRACT
Standards and domain ontologies are very important for providing semantic interoperability and information access in open environments. The MPEG-7 and MPEG-21 are the dominant efforts for the description of multimedia content and multimedia content services. The MPEG-7 Semantic DS has been shown to have powerful semantic description capabilities, which can utilize complex concepts, relationships and individuals specified in domain ontologies in multimedia content descriptions. However, the MPEG-7/21 Usage Environment does not provide concrete methodologies for expressing semantic user preferences and exploiting the domain knowledge and the MPEG-7 semantic metadata descriptions that may exist. We believe that this is a serious limitation and we propose a concrete methodology as well as model and language capabilities for integrating semantic user preference descriptions within the MPEG-7/21 standard. The proposed approach preserves the hierarchical structure of the current MPEG-7/21 user preference descriptions, which are a special case of the proposed ones. We also present the implementation of the model within the DS-MIRF framework, which allows descriptions of domain ontologies, semantic content descriptions and user preference descriptions in an OWL/RDF environment and automatic conversion to MPEG-7/21 descriptors.

Categories and Subject Descriptors
[H.5.1 Multimedia Information Systems] Video, **[H.3.3 Information Search and Retrieval]** Information Filtering

General Terms
Algorithms, Standardization, Languages.

Keywords
User Preferences, Search and Filtering, Browsing, Summaries, MPEG-7/21, Interoperability, Ontologies, OWL.

1. INTRODUCTION
The popularity of the traditional TV and the convergence of the computer, home electronics, software, broadcasting and multimedia information provision industries have led to the development of digital multimedia content services. In the near future the demand for higher quality digital multimedia services will be increasingly important. Higher level user demands, including semantic retrieval and retrieval personalization, are very important for the future environments. This paper focuses on the provision of such services.

The need for interoperability among the services provided by different digital multimedia content providers in open environments has made the need for standards apparent. Thus, standards have been proposed for both the multimedia content coding and the metadata used for the description of the multimedia content and the associated services. The dominant metadata standards for the description of multimedia content and services are *MPEG-7* [1] and *MPEG-21* [2].

Powerful content descriptions can not be based only on keywords. Video often contains complex real-life content with semantics included in conversations or real-life events with several participants interacting in complex ways (like in sports events). Content description in such cases with keywords only is simply inadequate, since it leads to too many false drops at retrieval time. To prevent this, the MPEG-7 semantic descriptors (defined in the *Semantic* DS[1] of the *MPEG-7 Multimedia Description Schemes (MDS)* [4]) have provided powerful primitives that can be used to describe complex real-world concepts and relationships among concepts.

Domain knowledge is today often encoded in domain ontologies, which are adopted by wide user communities. A domain ontology describes in a precise and formal way the meaning of concepts, roles (relationships) and individuals that are relevant and are used in a domain of knowledge. Thus, language expressions utilizing terms from the domain ontology have semantic, not just syntactic, meaning for the user community. Domain ontologies are now considered very important for open (Internet) environments in order to provide semantic descriptions of the information content and services. Domain ontologies are also very useful for many retrieval aspects, like indexing, query disambiguation, browsing, interface support, and natural language processing. Thus, they are very useful for the semantic retrieval of multimedia data (together with multimedia content description standards like MPEG-7/21).

Domain ontologies are typically described with ontology description languages like OWL [12]. However, the MPEG-7 Semantic DS has also rich structures that could be used for encoding domain ontologies and semantic metadata descriptions for multimedia content based on domain ontologies. It is clear that a uniform representation of ontologies and semantics within MPEG-7 presents significant advantages for powerful retrieval within the MPEG-7 framework.

A methodology for domain knowledge integration in MPEG-7 has been developed in the *DS-MIRF (Domain-Specific Multimedia Indexing, Retrieval and Filtering) framework* [5], [6], [7], [8]. The methodology allows the description of domain ontologies within MPEG-7 and the encoding of semantic multimedia metadata descriptions that utilize the domain ontologies in the

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

Semantic DS of the MPEG-7 MDS. A powerful retrieval API that utilizes these descriptions has also been implemented. For example, in a soccer game repository the user can ask for segments that show the goals scored by the visiting team.

Although semantic multimedia content descriptions utilizing domain ontologies can be done within MPEG-7, the capabilities of MPEG-7/21 for semantic user preference descriptions are very limited and they cannot currently exploit the rich semantic content descriptions that may be encoded with the MPEG-7 Semantic DS. The user context model for MPEG-7/21 is specified in the *MPEG-21 Digital Item Adaptation (DIA)* Architecture [3] and the MPEG-7 MDS for content and service personalization and content adaptation. The model takes into account the user characteristics, the device capabilities, the network characteristics and the natural environment characteristics. The major limitation of this context model is that it cannot make use of the structured Semantic Information used in MPEG-7 for the semantic description of the multimedia content. The MPEG-7/21 context model follows a keyword-based approach that may work reasonably for movies, but has serious limitations in other knowledge domains like news, sports etc. As a consequence, 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].

The need for extension in the MPEG-7/21 framework to provide new more powerful constructs for accommodating real-world applications is emphasized also in [10], [11]. However, no concrete methodology and model as the ones described in this paper are presented.

Our aim is to provide a model for MPEG-7 user preferences that will be compatible with the MPEG-7/21 user context model, but also capable of exploiting the powerful primitives of the MPEG-7 MDS as well as domain knowledge to describe complex real-world concepts and relationships among concepts.

In this paper we present a model and a methodology for semantic user preference descriptions and their integration in the MPEG-7/21 Usage Environment. The model and the methodology are able to utilize 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 that Alonso overtakes Raikonen, or the goals Ronaldo scores outside the territory of the opponent team). The concepts, roles and individuals of the domain ontologies defined utilizing the constructs of the MPEG-7 Semantic DS can be used to formulate user preference profiles. Our model preserves the hierarchical structure of the current MPEG-7/21 user preference descriptions and has it as a special case. Generic user preference profiles are formulated with regular expression language constructs from the user preference profiles. These constructs are integrated within the appropriate constructs provided by MPEG-7/21 for browsing preferences and filtering and search preferences, thus creating MPEG-7/21 semantic user preference profiles. We present an implementation of this model and methodology in the DS-MIRF framework.

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 proposed model for semantic user preferences is presented in section 4, and the implementation of semantic user preferences in the DS-MIRF framework is discussed in section 5. The paper conclusions and future research directions are presented in section 6.

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 *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 history of interaction with multimedia items.
  - The *Presentation Preferences*, where the user preferences about the means by which multimedia information should be presented or rendered are specified.
  - The *Accessibility Characteristics*, which allow content adaptation according to possible user auditory or visual impairments.
- 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, including audiovisual attributes, location and time of usage.
- The *Network Characteristics*, where the network parameters are represented.

According to the above, the user preferences in MPEG-7/21 are captured in the User Characteristics and in particular in the User Preferences. These are structured according to the *UserPreferences* DS, which is defined in the MPEG-7 MDS and is comprised of:

- A set of FilteringAndSearchPreferences elements, structured according to the *FilteringAndSearchPreferences* DS, which describe the user preferences regarding multimedia content searching and filtering. Each FilteringAndSearchPreferences element is decomposed into the following elements:
  - A set of FilteringAndSearchPreferences elements, which describe the "child" preferences of the current element, thus allowing the definition of FilteringAndSearchPreferences preference hierarchies.
  - A set of ClassificationPreferences elements which describe the user preferences regarding the multimedia content classification attributes (i.e. country of origin, time of the first content release, spoken language, auxiliary language formats available, caption language, production format, genre, subject, available reviews and ratings, reviewers and parental guidance classification).

  - A set of CreationPreferences elements, which describe the user preferences regarding multimedia content creation (i.e. title, creator(s), descriptive keyword(s), creation tool, location and/or date of content creation).
  - 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 FilteringAndSearchPreferences description.
- A set of BrowsingPreferences elements, which describe the user preferences regarding multimedia content navigation and browsing. Each BrowsingPreferences element is decomposed into the following elements:
  - A set of SummaryPreferences elements, which describe the user preferences regarding the multimedia content summaries (i.e. summary type, preferred summary theme, preferred/minimum/maximum summary duration, preferred/ minimum/maximum number of key frames in the summary, preferred/minimum/maximum number of characters in textual summaries and allowed summary component types).
  - A set of PreferenceCondition elements, which describe, the usage conditions for the current BrowsingPreferences description.
  - The *Genre*, which is a term specifying that the current BrowsingPreferences description applies only to multimedia content of a specific genre.

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 work. 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], [6], [7], [8]. 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 FilteringAndSearchPreferences, the users may specify their preferences regarding the semantics of the content only through the textual *Keyword* element of the CreationPreferences or the textual *Subject* element of the ClassificationPreferences. This is limiting, as the user may specify, for example, that the goals in a soccer game should be recorded for him/her, but cannot state that only the visiting team goals should be recorded (if the user relies in the keyword "goal" and the visiting team name it may be the case that a goal is scored against the visiting team).
- In the BrowsingPreferences, the users may specify only textual *Theme* elements describing the content of the summaries created for them for a specific genre of multimedia content. This way, a user may specify that (s)he would like to have a summary containing all the goals in a soccer game, but cannot ask for a summary containing the visiting team goals.

The more "complex" preference descriptions are useful for demanding users particularly interested in a domain such as a sport event as well as people working in the application domain: A soccer team coach would like to see all the mistakes made by his/her players in the last game, while a formula 1 team engineer would be highly interested in the overtakes of the opponent teams' drivers.

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 human knowledge domains we have developed and present in this paper a methodology that allows the description of such user preferences. The user preference descriptions that we developed is compatible with the MPEG-7 Semantic DS, and it can exploit its structures and the human knowledge that can be encoded with them for describing the contents of a video.

We have described in the recent past how to utilize domain ontologies for describing the human knowledge in a video utilizing 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 user preference descriptions that can exploit the knowledge encoded in the MPEG-7 Semantic DS to respond to domain-related user preferences. We design these user preference specifications 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 of the extended Usage Environment and the current MPEG-7/21 Usage Environment.

4. A MODEL FOR SEMANTIC USER PREFERENCES IN MPEG-7/21

We present in this section a model and a methodology for the creation of semantic user preferences that are compatible with the MPEG-7 Semantic DS. The model and the methodology allow to express user content preferences using domain knowledge. The system will match these descriptions with the content descriptions, which are structured according to the MPEG-7 Semantic DS, and contain related knowledge. Our objective is to describe a concrete model for extensions of the MPEG-7/21 User Preferences so that they exploit domain knowledge encoded according to the MPEG-7 Semantic DS. In doing this we want to remain as much as possible compatible with the existing MPEG-7/21 Usage Environment, so that the current specification becomes a special case of the proposed Usage Environment.

In particular, we describe here models that correspond to the MPEG-7/21 descriptors for:

- The FilteringAndSearchPreferences/CreationPreferences, where the end users specify their content preferences about the multimedia content delivered to them. The model for semantic CreationPreferences is discussed in detail in subsection 4.1.
- The BrowsingPreferences/SummaryPreferences, where the end users specify their preferences about the summaries that will be defined for them. The model for semantic SummaryPreferences is described in subsection 4.2.

4.1 Semantic Creation Preference Model

We describe in this subsection a model that allows the systematic integration and utilization of structured semantic metadata and domain knowledge in the MPEG-7/21 FilteringAndSearchPreferences and in particular in their CreationPreferences element, where the users specify their content preferences.

The major shortcoming in the existing descriptors is that the end-users cannot utilize in a systematic way neither domain knowledge in the form of ontologies nor structured semantic metadata (based on these ontologies) when expressing their preferences regarding the content of the multimedia material delivered to them. However, the MPEG-7 Semantic DS has rich structures that can be used to encode domain knowledge. Given that a methodology [5], [6], [7], [8] exists that allows to integrate domain knowledge in the semantic MPEG-7 metadata describing the multimedia content, the problem becomes only the integration of the CreationPreferences with the structured MPEG-7 semantic metadata.

Semantic Creation Preference Model. To allow semantic creation preferences[2] in MPEG-7/21 we define a subtype of the MPEG-7 MDS CreationPreferencesType, the *SCreationPreferencesType*, for the representation of semantic creation preferences. Then, we introduce in the SCreationPreferencesType a set of content preference description elements, which are essentially semantic entity collections. The type of the content preference descriptions is an extension of the MPEG-7 *SemanticBagType*, the type that represents collections of instances of the MPEG-7 *SemanticBaseType*, which is the base of the types used for the description of the semantic entities present in the multimedia content.

The semantic entities in MPEG-7 SemanticBaseType may be places, times, objects, agent objects (representing persons, person groups or organizations), events, states and concepts. The semantic entity descriptions inside the CreationPreferences express the criteria the user wishes to set for the semantic entities that (s)he wishes to exist in the content delivered to him/her. Thus, the user can specify the desired values of the attributes and the elements of the semantic entities. Of major importance are the *Relation* elements of the MPEG-7 SemanticBaseType, which represent the relationships of a semantic entity to other semantic entities. The relationships have relationship types that can also be seen as a model for the content description functionality that can be specified for a particular MPEG-7 semantic type. In our model for the semantic creation preferences we will be using the relationship types also for specifying user preferences. For example, for the semantic places the functionality that can be specified in the semantic creation preferences can use the MPEG-7 Semantic DS relationship types over, under, above, west etc.

More than 100 types of relationships among semantic entities are specified in the standard classification schemes (CSs) of the MPEG-7 MDS. The relationship types are classified as follows:

- Basic relationship types (equals, inside, refines etc.), which are specified in the *BaseRelation CS*.
- Types of relationships existing among graph nodes (identity, equivalent etc.), which are specified in the *GraphRelation CS*.
- Spatial relationship types (over, under, above, below, north, west etc.), which are specified in the *SpatialRelation CS*.
- Temporal relationship types (precedes, follows, overlaps, contains etc.), which are specified in the *TemporalRelation CS*.
- Semantic relationship types (shows, references, agent, patient, causer etc.), which are specified in the *SemanticRelation CS*.

The content preference descriptions are instances of the subtypes of the *WeighedSemanticBagType*, which is a subtype of the MPEG-7 type SemanticBagType. WeighedSemanticBagType is enriched with the *preferenceValue* attribute, which allows the specification of the relevant importance of a content preference description. The relevant importance of a content preference description may be an integer value (by default equal to 10) in the range [-100, 100]. Negative preferenceValue values denote fuzzy negation[3]. The definitions of the *WeighedSemanticBagType* type and its subtypes *BooleanWeighedSemanticBagType* and *UWeighedSemanticBagType* are shown in Figure 1.

```
<complexType name="WeighedSemanticBagType">
  <complexContent>
    <extension base="mpeg7:SemanticBagType">
      <attribute name="preferenceValue"
type="mpeg7:preferenceValueType" use="optional"
default="10"/>
    </extension>
  </complexContent>
</complexType>
<complexType name="UWeighedSemanticBagType">
  <complexContent>
    <extension base="mpeg7:WeighedSemanticBagType">
    </extension>
  </complexContent>
</complexType>
<complexType name="BooleanWeighedSemanticBagType">
  <complexContent>
    <extension base="mpeg7:WeighedSemanticBagType">
      <attribute name="operator"
type="mpeg7:booleanOperatorType" use="required"/>
    </extension>
  </complexContent>
</complexType>
<simpleType name="booleanOperatorType">
  <restriction base="NMTOKEN">
    <enumeration value="OR"/>
    <enumeration value="AND"/>
  </restriction>
</simpleType>
```

Figure 1: Definitions of the *WeighedSemanticBagType* type and its subtypes *BooleanWeighedSemanticBagType* and *UWeighedSemanticBagType*

The content preference descriptions may belong to one of the following classes:

- Content preference descriptions that do not explicitly specify the logical operator that should be applied in the criteria expressed in the individual semantic entities inside them. Such content preference descriptions are represented by

[2] The Semantic User Preference specifications are available at: http://elikonas.ced.tuc.gr/ontologies/MPEG7++/semanticUP.xsd

[3] The preferenceValue attribute, having as domain the integer values in the range [-100, 100], is used in the MPEG-7 User Preferences for all the elements for which the relevant importance should be specified.

ContentPreferences elements, of type *UWeighedSemanticBagType*. UWeighedSemanticBagType represents semantic entity collections for which no operator has been specified to be applied in their contents.

- Content preference descriptions that explicitly specify the logical operator (OR/AND) that should be applied in the criteria expressed in the individual semantic entities inside them. Such content preference descriptions are represented by *BooleanContentPreferences* elements of type *BooleanWeighedSemanticBagType*. The *BooleanWeighedSemanticBagType* represents semantic entity collections where the AND or the OR operator is specified, in the *operator* attribute, to be applied in their contents.

An SCreationPreferencesType description should contain either only ContentPreferences elements or only BooleanContentPreferences elements. The definition of the SCreationPreferencesType, where our model extensions to the MPEG-7 CreationPreferences are specified, is shown in Figure 2.

```
<complexType name="SCreationPreferencesType">
  <complexContent>
    <extension base="mpeg7:CreationPreferencesType">
      <sequence>
        <choice>
          <element name="ContentPreferences"
type="mpeg7:UWeighedSemanticBagType" minOccurs="0"
maxOccurs="unbounded"/>
          <element name="BooleanContentPreferences"
type="mpeg7:BooleanWeighedSemanticBagType"
minOccurs="0" maxOccurs="unbounded"/>
        </choice>
      </sequence>
    </extension>
  </complexContent>
</complexType>
```

Figure 2: Definition of the *SCreationPreferencesType*, which represents semantic creation preferences

Formal Description of the Semantic Creation Preferences. We describe next the formal syntax of the semantic creation preferences allowed by our model.

When some criteria are specified for the same semantic entity inside a content preference description, the user has in mind that they should be logically ANDed. Thus, if we consider the semantic entity descriptions as complex terms (T), every semantic entity description is described by the regular expression of Expression 1, where:

$$T = (T^{id}, T^{type}) \mid (T^{id}, T^{type}) \text{ AND } ((T')|(R^{type}, R^{target}\,[R^{source}], [R^{strength}])|(A^{name}, A^{value}))(\text{AND}((T')|(R^{type}, R^{target}\,[R^{source}], [R^{strength}])|(A^{name}, A^{value})))^*$$

Expression 1: Regular expression that can be used for describing semantic entities as complex terms (T)

- T^{id} is the id of the semantic entity, which plays the role of a variable name.
- T^{type} is the type of the semantic entity.
- T' represents a semantic entity nested in T.
- R^{type} and R^{target} are the necessary information for the description of a relationship, representing the type and the target of the relationship respectively.
- $[R^{source}]$ and $[R^{strength}]$ are the optional information for the description of a relationship, representing the source and the strength of the relationship respectively.
- A^{name} and A^{value} are the name and the desired value respectively of an attribute of the semantic entity.

Then, the collections of semantic entities where no operator has been specified to be applied may be described as parenthesized lists of complex terms (T). Each of these collections is characterized by its relevant importance (I). This way, a SCreationPreferences element comprised of ContentPeferences elements (USCP) is described by the regular expression of Expression 2.

$$USCP = ((T^*)I)^*$$

Expression 2: Regular expression that describes an SCreationPreferences Element comprised of ContentPeferences Elements

The collections of semantic entities where the AND and OR operators have been specified to be applied may be described as parenthesized lists of complex terms (T) separated by the operators. Each of these collections is also characterized by its relevant importance (I). This way, a SCreationPreferences element comprised of BooleanContentPeferences elements (SCP) is described by the regular expression of Expression 3.

$$SCP = (((T(OR\ T)^*)I)^*((T(AND\ T)^*)I)^*)$$

Expression 3: Regular expression that describes an SCreationPreferences Element comprised of BooleanContentPeferences Elements

Examples. We present next some examples to clarify the capabilities of the semantic creation preferences. As an example, consider the extended *UserPreferences* description of Figure 3. We assume in this example that an abstract *EventType* instance exists, having as id "Goal", which represents the class of all the goals. We also assume that *AgentObjectType* instances exist, having as ids "Charisteas" and "Ricardo", which represent the soccer players Charisteas and Ricardo respectively.

```
<UserPreferences id="UP1">
  <FilteringAndSearchPreferences>
    <CreationPreferences
xsi:type="SCreationPreferencesType">
      <ContentPreferences>
        <SemanticBag preferenceValue=90
xsi:type="UWeighedSemanticBagType">
          <SemanticBase xsi:type="EventType"
id="ChGoal">
            <Relation type="agent"
target="#Charisteas"/>
            <Relation type="exemplifies"
target="#Goal"/>
            <Relation type="patient"
target="#Ricardo"/>
          </SemanticBase>
        </SemanticBag>
      </ContentPreferences>
    </CreationPreferences>
  </FilteringAndSearchPreferences>
</UserPreferences>
```

Figure 3: Extended *UserPreferences* description, stating that the user is interested in multimedia content that contains the goals scored by Charisteas against Ricardo

As shown in Figure 3, the user states in his/her preferences that (s)he is interested in multimedia content containing the goals scored by Charisteas against Ricardo. This is achieved by including in his/her CreationPreferences a ContentPreferences element, which is a SemanticBag that contains a SemanticBase element of type EventType, having as id "ChGoal", which represents the goals scored by Charisteas against Ricardo. This is stated through the three Relation elements contained in "ChGoal": The "exemplifies" relation states that "ChGoal" is an example of the abstract "Goal" event, the "agent" relation states that the "ChGoal" has been scored by "Charisteas" and the "patient" relation states that the "ChGoal" has been scored against "Ricardo".

The Creation Preferences of the user preferences description of Figure 3 correspond to the regular expression of Expression 4.

USCP1 = ((ChGoal, EventType) AND ((exemplifies, Goal) AND (agent, Charisteas) AND (patient, Ricardo)) 90)

Expression 4: Regular expression that describes the creation preferences of the user preferences description of Figure 3

4.2 Semantic Summary Preference Model

We describe in this subsection a model that allows the systematic integration and utilization of structured semantic metadata and domain knowledge in the MPEG-7/21 BrowsingPreferences and in particular in their SummaryPreferences element.

To allow semantic summary preferences, we define a subtype of the MPEG-7 MDS SummaryPreferencesType, the *SSummaryPreferencesType*, for the representation of semantic summary preferences. Then, we introduce in the SSummaryPreferencesType a set of semantic summary preference description elements, which are essentially semantic entity collections. The semantic summary preference descriptions may belong to one of the following classes:

- Semantic summary preference descriptions that do not explicitly specify the logical operator that should be applied in the criteria expressed in the individual semantic entities inside them. Such semantic summary preference descriptions are represented by *SummarySemantics* elements, of type *UWeighedSemanticBagType*.
- Semantic summary preference descriptions that explicitly specify the logical operator (OR/AND) that should be applied in the criteria expressed in the individual semantic entities inside them. Such semantic summary preference descriptions are represented by *BooleanSummarySemantics* of type *BooleanWeighedSemanticBagType*.

An SSummaryPreferencesType description should contain either only *SummarySemantics* elements or *BooleanSummarySemantics* elements. The definition of the SSummaryPreferencesType, where our model extensions to the MPEG-7 SummaryPreferences are specified, is shown in Figure 4.

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

Figure 4: Definition of the *SSummaryPreferencesType*, which represents semantic summary preferences

Thus, the semantic summary preference descriptions utilize the types defined in the MPEG-7 Semantic DS to describe the semantic content of video, and therefore are completely compatible with the MPEG-7 Semantic DS. Our model for semantic summary preferences allows the description of summary preferences using regular expressions similar to the ones used for describing semantic creation preferences.

Figure 5 presents an example of user preference description using our semantic summary preference description model. The same assumptions as in the example of Figure 3 are made.

```
<UserPreferences "UP2">
  <BrowsingPreferences>
    <SummaryPreferences
xsi:type="SSummaryPreferencesType">
      <SummarySemantics>
        <SemanticBag preferenceValue=90
xsi:type="UWeighedSemanticBagType">
          <SemanticBase xsi:type="EventType"
id="ChGoal">
            <Relation type="agent"
target="#Charisteas"/>
            <Relation type="exemplifies"
target="#Goal"/>
            <Relation type="patient"
target="#Ricardo"/>
          </SemanticBase>
        </SemanticBag>
      </SummarySemantics>
      <Genre
href="urn:mpeg:mpeg7:cs:GenreCS:2001:1.3.1">
        <Name>Soccer</Name>
      </Genre>
    </SummaryPreferences>
  </BrowsingPreferences>
</UserPreferences>
```

Figure 5: Extended *UserPreferences* description, stating that the user wishes to have a soccer game summary that contains the goals scored by Charisteas against Ricardo

In the example of Figure 5, the user states in his/her preferences that (s)he wishes, when the genre of the material is "soccer" as specified in the *Genre* element, to have a summary containing the goals scored by Charisteas against Ricardo.

5. THE IMPLEMENTATION OF SEMANTIC USER PREFERENCES IN THE DS-MIRF FRAMEWORK

We present in this section how the model described in section 4 for the MPEG-7/21 Usage Environment is implemented in the DS-MIRF framework. We aim both to provide support for semantic user preferences in the DS-MIRF framework and, at the same time, to provide interoperability with MPEG-7/21 software that is based on the current MPEG-7/21 version. In the later case the semantics of the user preferences will not be completely preserved, of course.

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, three 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 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.

The objective of this section is to present the extensions made in the DS-MIRF framework to support not only semantic descriptions of multimedia content and domain knowledge (ontologies) utilizing OWL as knowledge representation language, but also to be able to represent interactions with the semantic multimedia content descriptions. The semantic interaction primitives in DS-MIRF are defined in OWL/RDF using the new concept of *Application Ontology*. They can then be used to describe user preferences as the ones that we described in the previous sections, but using OWL/RDF syntax. The result is automatically converted in the Semantic MPEG-7/21 user preference descriptions of the previous sections.

We provide both semantic user preference descriptions and interoperability with MPEG-7/21 software that does not support our semantic model by supporting the usage scenario shown in Figure 6: The user specifies in OWL/RDF his/her preferences using a user interface based on the Upper ontology, the domain ontologies and the application ontology. The user preferences are then transformed and stored in both the extended format we have proposed in section 4 and in standard MPEG-7/21 format.

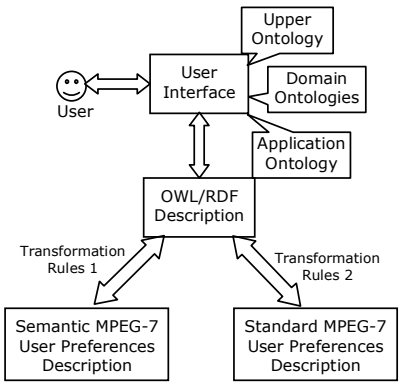

Figure 6: A usage scenario that allows to provide both semantic user preference descriptions and interoperability with standard MPEG-7/21 software

As shown in Figure 6, 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.

The application ontology, available at http://elikonas.ced.tuc.gr/ontologies/AppOntology/SUserPreferences, is a set of primitives used to define interactions with the semantic multimedia descriptions.

The transformation of the OWL/RDF metadata, which are essentially OWL individuals, into (standard or extended) MPEG-7/21 descriptions is carried out according to the following transformation rules:

1. Every individual is transformed into an appropriate instance of the MPEG-7 class which corresponds to the OWL class it belongs.
2. For every object property of the individual, an element, which has the desired value, is generated.
3. For every datatype property of the individual an attribute or a simple type element, which has the desired value, is generated.
4. The id of the instance is the rdf:ID of the individual.

The only individuals for which a different policy is followed, are the MPEG-7/21 Usage Environment extensions proposed in section 4. For them, a different set of rules is applied, depending on the type of the UserPreferences description:

- In the extended descriptions, the individuals representing semantic entities are transformed according to the transformation rules defined in [6].
- In the standard descriptions, in order not to lose the information captured in the semantic descriptions, the semantic information is systematically transformed into textual descriptions. In particular:
  - The FilteringAndSearchPreferences/CreationPreferences/ContentPreferences are transformed into a set of textual values, that become the values of FilteringAndSearchPreferences/CreationPreferences/Keyword and FilteringAndSearchPreferences/ClassificationPreferences/Subject.
  - The BrowsingPreferences/SummaryPreferences/SummarySemantics are transformed into a set of textual values, that become the values of BrowsingPreferences/SummaryPreferences/SummaryTheme.

The transformation rules used for the transformation of the structured semantic metadata contained in the FilteringAndSearchPreferences/CreationPreferences/ContentPreferences and in the BrowsingPreferences/SummaryPreferences/SummarySemantics into textual values are listed below:

1. The preferenceValue of all the textual values produced from the elements of the same semantic entity collection as value the preferenceValue of the semantic entity collection.
2. The name of the OWL class to which an individual representing a semantic metadata item belongs, together with the rdf:ID of the individual, form a textual value.
3. The name of each of the object properties of the individual forms a textual value.
   3.1 The individuals related to the described individual through the object property are used for the production of textual

values after the textual value containing the name of the object property.

4. A textual value, composed of the name and the value of every datatype property, is produced.

   4.1 A textual value containing the value of the datatype property is produced.

As an example, consider the extended part of a FilteringAndSearchPreferences/CreationPreferences description stating that the user is interested in multimedia content containing the goals scored by Charisteas against Ricardo, which is captured in the extended UserPreferences description of Figure 3. According to the usage scenario of Figure 6, after the user preferences are specified by the user, they are expressed in OWL/RDF and form the user preferences available at http:// elikonas.ced.tuc.gr/ontologies/AppOntology/examples. According to the transformation rules, the OWL/RDF description is transformed into the standard FilteringAndSearchPreferences description available at http://elikonas.ced.tuc.gr/MPEG7++/keywords.xml.

6. 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 preserves the hierarchical structure of the current MPEG-7/21 user preference descriptions, which are a special case of the proposed ones.

The proposed extension 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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