Automatic Conversion of MPEG-7 Specification and Data into RDF(S) For Semantic Interoperability in Information Retrieval

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Abstract

Interoperability between different metadata schemas and data is an important issue for various semantic web-related applications. The definitions and MPEG-7 data for multimedia content instances can't be used with other metadata standards in a semantically interoperable way. As part of an attempt to build a retrieval system that uses various metadata standards such as MPEG-7 and Dublin Core in a semantic web environment, we first developed a method for automatically converting the MPEG-7 specification into a RDF schema (RDFS) and MPEG-7 data into RDF data. Our approach is to develop a set of conversion rules for XML Schema definitions into RDF Schema definitions, rather than interpreting the semantics of individual components of the MPEG-7 specification.

1. Introduction

Metadata and metadata schemas are usually described in XML and XML Schema [1], respectively. The XML Schema language has been chosen to describe syntactic, structural, cardinality, and typing constraints to be enforced for metadata descriptions.

With XML and XML Schema, metadata and metadata schemas in different domains can be exchanged at syntactic level for different applications like information retrieval, but not at semantic level. This implies that retrieval systems developed for different metadata, for example, must be integrated in an ad hoc manner for semantic interoperability or operated independently with no semantic level interoperability.

For a semantic web environment, however, ontology languages like Resource Description Framework (RDF) plus RDF Schema (RDFS) [2], DAML+OIL [3], and OWL [4] have been proposed to allow for a semantic description of resources so that semantic level interoperability of metadata and information systems can become possible.

RDF provides facilities like URI (Universal Resource Identifier) and namespaces for a universal access to resources and their semantic relationships. Given metadata schemas for different domains and corresponding metadata describing resources in those domains, RDF(S) can serve as a glue to describe them in a single framework, facilitating semantic interoperability among the metadata.

In our research, we attempt to build a universal retrieval system that uses various metadata standards such as MPEG-7[5] and Dublin Core in a semantic web environment. Instead of developing retrieval systems specially geared toward a particular metadata standard and building a wrapper style integrated retrieval system, we envision a retrieval system that handles multiple metadata standards all described in RDF and utilizes ontology in RDFS or some other common language, which is essential for inference. In order for this system to work, we need core ontology like ABC ontology [6, 7] and a method for converting metadata descriptions in XML into those in RDF. The core ontology is essential for relating the terms defined in different domains, but not included in the scope of the current work.

As the first step toward the goal, we need to develop a method for automatically converting every metadata schema and corresponding metadata into RDFS and RDF, respectively. In particular, we developed a set of rules for automatically converting

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the MPEG-7 specification into RDF Schema and MPEG-7 data into RDF data.

In Section 2, we show the architecture of our envisioned retrieval system to provide a motivation for the work described in this paper. Section 3 is devoted for related research. Section 4 is devoted to the conversion rules for the MPEG-7 specification and Section 5 to the rules for MPEG-7 data. Finally we discuss about limitations of the conversion process and why they have little impact on the original purpose of building a semantically interoperable metadata for a retrieval system in Section 6 before the conclusion.

2. Retrieval System Architecture

Metadata schemas defined in XML Schema facilitate creation of metadata and their use in applications. From information retrieval perspectives, emergence of a variety of metadata standards either mandate development of special-purpose retrieval systems that take advantage of the semantics of each metadata standard, or calls for a universal retrieval system that understands not only the syntax but also the semantics of the individual metadata standards and their relationships.

A universal retrieval system based on RDF(S), on the other hand, allows for much richer processing of the available metadata using their schemas. The system would be specialized for processing RDF(S) only and handling metadata developed in different domains but converted into the common format together with their schemas in RDFS.

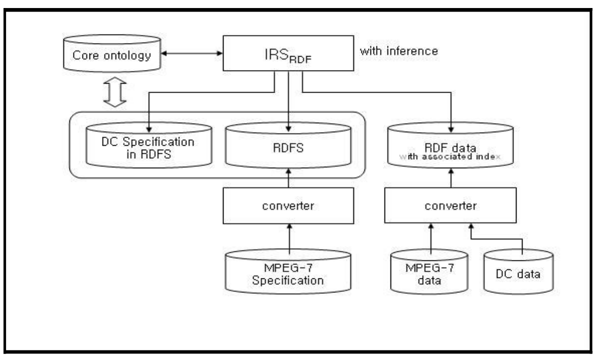

Figure 1. Universal retrieval system

As shown in Figure. 1, a single retrieval system handles an integrated metadata and metadata schema for which we need to have a conversion process.

It should be noted that one can envision a distributed environment where each site has the identical retrieval system with its own RDF(S)-based metadata and schema. In this case, the integrator can make more intelligent decisions compared to the case with the conventional heterogeneous retrieval system architecture, but the integration would not be as smooth as the system shown in Figure. 1.

For increased semantic interoperability and powerful inference, we need to have a core ontology as in Figure. 1 that relates the terms defined in different metadata standards (see [6, 7] for example). Terms from different metadata standards should be interrelated so that references and inference can be made across the underlying metadata descriptions.

We believe that systems and system environments should be more standardized to take advantage of the availability of metadata standards.

3. Related Research

With the increase of metadata and diversified metadata standards in various application areas (e.g. education, cultural heritage), there have been research activities for standardization and integration of metadata. Semantic web research has served as a catalyst and accelerated these activities. Most notable are efforts on RDF(S), DAML+OIL, and OWL, the main goal of which is to provide a language or framework for construction of ontologies that are essential to knowledge exchange.

On the other hand, as the demand on multimedia data and associated services increases, there have been serious attempts to describe multimedia content and properties with metadata. Hunter and Armstrong [8] compared existing metadata standards for description of videos. Subsequently, Hunter and her group proposed a method for interoperability and integration of MPEG-7 and Dublin Core standards [9]. A method was proposed to increase interoperability among metadata standards by analyzing the characteristics of RDF Schema and XML Schema and devising ways to use the both standards together [10]. In a subsequent work [11], Hunter proposed a way of constructing ontology for the MPEG-7 standard using both RDFS and DAML+OIL and integrating different metadata vocabularies with a concept network called Meta-Net. He further proposed a method of combining the MPEG-7 and Dublin Core standards for video descriptions [12], where the integration was done by make a reference from the XML-based MPEG-7 data to Dublin Core elements with namespaces. In [13,14,15,16], they described a methodology that they have developed for the interoperability of OWL with the complete MPEG-7 MDS[17] so that domain ontologies described in OWL can be transparently integrated with the MPEG-7 MDS metadata.

Unlike the previous research where the focus was to standardize various metadata themselves and integrate them with core ontology, we propose in this article that schema information in a metadata framework as well as the metadata themselves into an intermediate language/data model like RDFS and RDF so that a common representation of various metadata and their schemas is used. Another unique aspect lies in our attempt to focus on semantic aspects of metadata standards for interoperability in information retrieval.

4. Conversion of MPEG-7 Specification

The descriptors and description schemes comprising the MPEG-7 specification are defined in DDL [18], which is based on the XML Schema-defined types and the extended types specified in MPEG-7. In this paper, therefore, our approach to converting the MPEG-7 specifications based on XML Schema is to devise rules for converting the essential XML Schema components used in defining the descriptors and description schemes into RDFS. More specifically, we only deal with type definitions, element and attribute declarations, and group definitions because the other components are used to describe the syntactic constraints occasionally

4.1 Type Definitions

Complex, simple, and anonymous type definitions in MPEG-7 are converted into classes in RDFS. In the case of complex and simple types, expressed with Complex-Type and SimpleType, the name of the type is used as the name of the class defined in RDFS. Given <ComplexType name = “Mpeg7Type” abstract = “true”>, for example, a class named “Mpeg7Type” is created in RDFS.

A derived type defined with “extension” or “restriction” in MPEG-7 establishes an inheritance relationship with an existing type. This relationship is converted into a semantic relation “subClassOf” between the derived type (i.e. a class) and the base type (i.e. the class defined already). The name of the type is used as the name of the class being defined in RDFS.

4.2 Elements

An element can be defined or declared. When an element is defined like the MPEG-7 root element, it is converted into a RDFS class. On the other hand, an element being declared within a type or element definition is converted into a RDFS property. For a declared element, a type can be assigned explicitly with the name of pre-defined type or can be defined anew anonymously. The type definition within which the element is declared serves as the domain and the type of the element being declared as the range.

4.3 Attributes

An attribute created with an attribute declaration is converted into a property in RDFS. An attribute can be expressed in two different ways: one with an explicit name and type and the other with a reference to an attribute defined already. In the former case, the name is used as the name of the RDFS property, and the type of the attribute is used as the range. The type being defined with the attribute serves as the domain. In the latter case, the name of the pre-defined attribute being referenced becomes the name of the property. The domain of the property is the type being declared with attribute and the range the type of the referenced attribute.

4.4 Attribute Groups

Multiple attributes can be declared together to form an attribute group. Using our conversion rule, an attribute group is converted into a class in RDFS. Since the attributes declared in an attribute group are assigned explicit names and types, the names become RDFS properties with ranges being the types and the common domain being the class generated from the attribute group.

When an attribute group is declared within a type definition, a pre-defined definition is referenced with its name. In this case, the attribute group name is converted into a RDFS property name. The type being defined becomes the domain of the property and the class with the attribute group name becomes the range.

5. Conversion of MPEG-7 Data

Since MPEG-7 data or documents are constructed with the guidance of MPEG-7 definitions (i.e. Ds and DSs), they are basically XML documents that can be converted into RDF in principle. In retrieval system for metadata based on XML, it is not allowed to search the metadata fields by using interoperability between the related metadata fields. The reason is that we can not find the relationship between the metadata field selected in a user’s query and the other metadata field. We only find the retrieval scope of the user’s query by using the metadata filed structure in XML.

The metadata based on XML has the much information in element or attribute. But, we can not distinguish the information in element from in element's attribute usually. We only use the metadata by using the user interface system that understands the metadata structure. We can not guarantee that the system fully understands the metadata structure. In order to solve the problems, we have to convert the metadata in XML into RDF based in information retrieval system. As a result, MPEG-7 data can be converted into RDF based on a set of rules. We explain those rules below.

5.1 Basic rules

Since a RDF document consists a set of triples in the form of (Subject, Predicate, Object), the main role of the conversion rules is to produce a set of RDF triples from MPEG-7 data. Rules for different constructs are explained below.

Creation of a resource for the root element While MPEG-7 data must begin with a root element called "Mpeg7," RDF specifies the type of a resource by beginning with either a combination of "rdf:Description" and its type definition or a class name. Since MPEG-7 data always begins with the root element, the type of the resource must be the "Mpeg7" class in the corresponding RDFS representation.

ID assignment to the root element The root element may or may not have an "id" attribute. If the attribute exists, the attribute value can be used as the ID for the resource being described in RDF. If not, an ID must be generated automatically and assigned to the resource.

Conversion of other elements Since MPEG-7 documents are written in XML format, they may contain nested elements. When an element is defined with a value without a sub-element (i.e. no nesting) as in <Coeff> 1 2 3 … </Coeff>, it can be converted into a triple where the subject, predicate, and object are the element at the next higher level, the element name, and the value of the element, respectively. When an element has a sub-element, on the other hand, the object component of the triple cannot be a literal value. As a result, an anonymous resource must be created to serve as the object component of the triple. In this case, the element becomes the subject and the sub-element the predicate of the triple. For the newly defined resource with the sub-element, the same rule can be applied recursively.

Conversion of attributes An attribute in MPEG-7 data is converted into a predicate of a resource. In this case, the element associated with the attribute serves as the resource or the subject and the attribute value as the object of the triple. While this is a natural conversion of an attribute to a triple in RDF, this conversion rule is a result of the RDF convention that an element cannot have an attribute within its description as in XML.

5.2 Additional Considerations

A general rule for sub-elements described above states that an anonymous resource is created for the sub-element to conform to the triple format. Even when a URI is used as the value of triple whose purpose is to describe the fact that a resource has a URI, the triple is created and cascaded with others corresponding to the elements at a higher level. For example, the following MPEG-7 data

```
…
<MediaLocator>
<MediaUri> Image.jpg </MediaUri>
</MediaLocator>
…
```

is converted into a triple

```
…
<rdf: Description>
<rdf:type  rdf:resource
        http://www.cs.cnu.ac.kr/mpeg7#MediaLocator
>
<mpeg7: has_MediaURI> image.jpg
</mpeg7:has_MediaURI>
</rdf: Description>
...
```

where the type information has been pre-defined and adopted accordingly. In this case, it may be useful to specify the ID directly for the actual multimedia resource defined at an outer level so that it can be referenced with the ID. While it is conceivable to parse the RDF descriptions and attach the ID in the ID-revealing resource with the correct multimedia resource, it may be unclear which resource must be chosen especially when multiple resources are described in a nested form.

For the above example, we can express the additional information as follows:

…

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```
<mpeg7:has_MultimediaContent>
<rdf:Description
rdf:about=http://www.cs.cnu.ac.kr/Image#image.jpg>
<rdf :type ...
...
<rdf: Description>
<rdf:type  rdf:resource
 =http://www.cs.cnu.ac.kr/mpeg7#MediaLocator>
<mpeg7:has_MediaURI>image.jpg
</mpeg7:has_MediaURI>
</rdf: Description>
```

where the URI for the multimedia content is assumed to be reconstructed.

Another case not covered by the general rules arises when a type is defined to be abstract using "abstract" attribute. In this case, a sub-type must be chosen from the hierarchy of types when the MPEG-7 data are generated. When the type definition has the form "xsi:type = …" in MPEG-7 data, we need to use the type specified as such, not the one specified as the domain class in RDFS, in conversion.

5.3 Updates of Existing MPEG-7 Data

When the converted metadata, now in RDF, are to be updated, we must take a caution. It is conceivable that a data administrator can make necessary changes to the metadata described in RDF by looking at the corresponding RDFS description. Since some syntactic and structural constrains were not converted in RDF, however, the updates made in the RDF version would be different from the updates that should be made if they were made to the original MPEG-7 data. That is, if the updates made to the RDF version were to be transferred back to the MPEG-7 version, the result would be different from the updates made directly to the original MPEG-7 version, causing a possible data integrity problem.

In order not to lose any information and maintain data integrity, we propose all updates be made to the original MPEG-7 data and apply the conversion rules again to obtain the corresponding RDF version. If changes were to be made only to MPEG-7 data without affecting the related XML Schema (i.e. Ds and DSs), no changes to the RDF version would be necessary. The same RDFS can be used as ontology for inference.

6. Discussion

There are some parts of descriptors and descriptions schemas defined in the MPEG-7 specification that are not carried to the resulting RDFS. We discuss below what they are and why they do not affect semantic interoperability and hence the application.

6.1 Element Declarations

Element declarations make it possible to include an element of a particular type with a particular name. In other words, an element declared in the MPEG-7 specification appears in MPEG-7 data with a particular name and type. Elements can be declared in two different ways: one is to declare it with an explicit type definition and the other is to make a reference to an element that has been defined. While the two different ways are not distinguished when they are converted into properties in the resulting RDFS representation, we don't see any problem in application systems. It should be noted that if necessary, the "label" feature provided by RDFS can be utilized to enrich the property information.

Attributes like "minOccurs" and "maxOccurs" are used to specify the frequency of an element in XMLS (hence in the MPEG-7 specification). Although this kind of cardinality information cannot be expressed in RDFS, this inability is not detrimental to the application. When some RDF data are in need of an update or re-creation, they do not have to be modified directly. Instead their original MPEG-7 can be modified and converted under the guidance of MPEG-7 specification (i.e. XML Schema definitions).

Other aspect ignored in the conversion process is the "default" attribute used in declaring an element. The information provided by this attribute is the default value for an element. However, since the value of an element has been determined by the time the MPEG-7 data need to be converted into RDF, this information does not have to be converted into RDFS.

6.2 Attribute Declarations

When an attribute is declared, other attributes can be used to provide necessary information. For example, the "use" attribute carries information about whether the attribute being declared is "required", "optional", or "prohibited". Like attribute information for an element, however this information is useful only when an XML document (hence MPEG-7 data) is created. As a result, this information does not have to be included in RDFS; the conversion process is applied only to the MPEG-7 data that have been created already.

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6.3 Type Definitions

In the MPEG-7 specification, a new simple type can be defined with the existing simple types defined in XML Schema. For this purpose, facets like "enumeration", "min-Inclusive" or "maxInclusive" are used, which are necessary when XML documents (hence MPEG-7 data) are created. Again these facets are not included in RDFS because the data have been created already and not necessary for conversion.

For complex types, XML schema provides various methods for constraining the content model. For example, attributes like "empty" and "mixed", default content type like "compexContent", and compositors like "sequence", "choice", and "all". These are not preserved in the resulting RDFS because they have no role in converting MPEG-7 data to RDF data.

7. Conclusions

We showed how the MPEG-7 specification in terms of descriptors and description schemes can be converted into RDFS and subsequently MPEG-7 data into RDF data, so that a retrieval system can work on the RDF representation of metadata of various kinds. The underlying principle is that since the MPEG-7 specification is expressed in XML Schema, the conversion rules were devised to handle semantically relevant components of MPEG-7 the specification, excluding other components that are only structural and syntactic in their nature.

The work reported in this paper should be extended in several ways. First, the conversion rules must be applied for automatic conversion of the entire MPEG-7 specification and actual MPEG-7 data and tested for its accuracy and completeness. Second, we are in the process of developing a retrieval system that makes use of the RDF(S) in conjunction with text. For interoperability testing among different metadata standards, we plan to use Dublin Core in addition to the MPEG-7 data. A core ontology that integrates Dublin Core and MPEG-7 terms must be either obtained or constructed for this purpose.

The compositors like "sequence" and "choice" cannot be converted because RDF does not have their counterparts. This is natural since RDF expresses semantics, not syntax. However, inability to convert them to a RDF version of the MEPG-7 specification would not hurt any inference capability in the application system. This is true for the cardinality constrains like "minOccurs" and "maxOccurs," for which RDF does not have corresponding parts.

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