MPEG-SCORM: an Ontological Approach of Interoperable Metadata for Digital Television and e-Learning

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***Abstract*— The convergence of digital media offers an integration of ICT focused on telecommunications and multimedia domain (under responsibility of the Moving Picture Experts Group, ISO/IEC JTC1 SC29) and the ICTE (the ICT for Education), managed by the ISO/IEC JTC1 SC36, highlighting the MPEG standards, employees as content and metadata to the multimedia Digital TV and the technologies applied to e-Learning. Regarding this, there is the problem of developing an interoperable matching for normative bases, achieving an innovative proposal in the convergence between digital telecommunications and applications for e-Learning, also essentially multimedia. To reach this purpose it is proposed to create a standard ontology of interoperable metadata for web, digital TV and extensions for mobile devices based on the integration between MPEG-21 and SCORM metadata standards. The methodology used consists on building ontology between MPEG-21 SCORM which can be achieved on making a correspondence through the XPath language, managed by the W3C. The employ of the XPath language is desirable for matching and mapping both metadata schema patterns – integrating MPEG-21 (mostly Digital Item Declaration Language) and SCORM metadata schema. The practical purpose is the creation and storage of objects for use in digital telecommunications as Digital Television, in an interoperable way with the e-Learning industry, here as description metadata for all sorts of media and hypermedia to create learning objects.**

***Keywords*— Digital Television, e-Learning, Metadata, MPEG, SCORM**

I. INTRODUCTION

THE technological innovation issue comprehends a research in a hybrid field that comprises a breakthrough on the media convergence process, on purposing an interface between the norms and standard implemented in the field of interactive multimedia, highlighting the Digital Television (standardized by the ISO SC29 subcommittee), and the field of the technologies for e-Learning (standardized by the ISO SC36 subcommittee).

The whole bunch of ICT is subject to convergence and interdependence of media. These techniques rely heavily on standards that are negotiated and designed in standard-setting bodies. An important role of ISO / IEC JCT1 is to converge instances that define both components and services attached to these topics.

It is proposed to analyze the constraints of possible convergences between the MPEG family norms (conceived by the JCT1 SC29, the standards body that carries MPEG) and those of the ICTE (the ICT for Education, work under responsibility of the JCT1 SC36), in particular the SCORM metadata standard, as well the future "SCORM 2.0" standard.

As a second decisive state, it is therefore mapped the prospective normative framework matched between MPEG-21 multimedia document and the normative world of ICTE - SCORM. The purpose of the project is to provide the specification of a hybrid Ontology mapping the MPEG-21 and SCORM metadata standards.

From this context, the research in conclusion propose the study based on the convergence of digital media working on the hypothesis of the integration of both ICT and ICTE focused on the telecommunications and the multimedia domain.

This convergence covers two breaking questions up to be solved in our digital era: the interoperability of data and formats; and the integration of cited ISO working groups

Technically, Digital Television lies within the field of MPEG multimedia, since it employs as its exhibition format the digital video standard MPEG-4 AVC H264, the worldwide industry standard today.

However, the standardization of the multimedia MPEG is not restricted to MPEG-4, since other MPEG technologies are in process of specification by the SC29 subcommittee and actually are more powerful in terms of metadata description and so on, as MPEG-7 and MPEG-21.

These distinct MPEG norms and its main defining characteristics are highlighted in the Fig. 1, translated from the source reference in French [1]:

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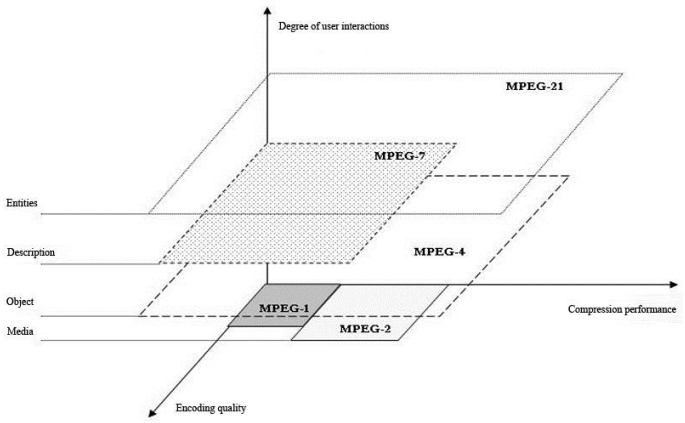


Fig. 1 Different MPEG norms and its main characteristics in terms of encoding quality, compression performance and user interaction [1].

According the *Moving Picture Experts Group* (MPEG), MPEG-1 is a "suite of standards for audio-video and systems particularly designed for digital storage media". MPEG-2 is a "suite for standards for digital television". On the other hand, MPEG-4 is a "suite of standards for multimedia for the fixed and mobile web"; and MPEG-7 is a "suite of standards for description and search of audio, visual and multimedia content".

MPEG-21, however, is a "suite of standards that defines a normative open framework for end-to-end multimedia creation, delivery and consumption that provides content creators, producers, distributors and service providers with equal opportunities in the MPEG-21 enabled open market, and also be to the benefit of the content consumers providing them access to a large variety of content in an interoperable manner".

It can be noticed from these definitions and from the interpretation of the graphic demonstrated in Fig. 1 that the main characteristic for MPEG-4 is the possibility of object creation and manipulation.

For MPEG-7, the main gain achieved by its adoption would be the metadata description of all media content only.

MPEG-21, as its major characteristic, allows the modelling of entities, entities which could comprehend content and an object oriented domain of descriptors as well.

Still from the perspective of this analysis, in this research we could conclude that MPEG-21 become the most suitable option for metadata description as a breakthrough in this field since its framework allows not only content description, but all kinds of elements presented within the consumption channel, from the content and object creation, through broadcasting and reaching the end user (who otherwise can perform the role of a producer as well).

Regarding this, the main objective on this work is contributing on the development of an interoperable matching between the normative bases in question, achieving an innovative proposal in the convergence between digital telecommunications and applications for e-Learning, also essentially multimedia, integrating MPEG-21 (mostly its *Digital Item Declaration Language*) and SCORM metadata schema. To reach this purpose the proposition is developing a standard ontology of interoperable metadata for web, digital TV and extensions for mobile devices based on the integration between MPEG-21 and SCORM metadata standards.

This hybrid ontology, possibly claimed as a new hybrid metadata standard, would allow the creation and storage of objects for use in digital telecommunications, operating on media like Digital Television, in an interoperable way with the e-Learning industry, which in its turn employs all sorts of media and hypermedia technologies to create learning objects.

Regarding the challenges for the standardization of the ICT applied to e-Education, it comprises a telecommunications engineering problem still in developing the issue concerning how the MPEG Video family, specially the MPEG-21 [2] standard, could offer a normative basis for the implementation of multimedia metadata related to e-Learning.

This development demands the adoption and employ of some tools to match all these learning and media objects, further to the content itself (video, still images, sound, text, hypertext etc), and must lie within a normative frame to guarantee interoperability, reusability and referring to the major platforms or digital environments in both fields, multimedia and e-learning.

For this purpose it was adopted in this research the XPath language, managed by the W3C.

The software engineering to support this normalization comprehends XML, MPEG-7, MPEG-21, themes approached by the SC36. Otherwise, experts from ADL, entity which developed the SCORM standard, are engaged in SC36 subcommittee too, and already proposed to in a certain way explore the capabilities of MPEG-21 to make this idea viable.

ADL strategy lies on capitalize the other subcommittees norms, and encourage the adoption of the Part 5 of MPEG-21 [3] (REL, or Rights Expression Language), to solve copyright issues, besides it delegates to the LOM standard its metadata description (or parts to other standards like IMS or DCMI – Dublin Core). This reveals a very converging approach and acceptation concerning the metadata and MPEG-21 issue on the industry and market.

II. Learning Objects and Metadata Standards

A Learning Object can be defined, in a perspective of Engineering, according to IEEE 1484.12.1 standard (Standard for Learning Object Metadata) [4], "For this standard, a learning object is defined as any entity, digital or non-digital, that may be used for learning, education, or training".

According to the IEEE LTSC [4], the LOM standard focus on the minimum attributes needed to allow a learning object to be found and evaluated. Metadata allow the cataloging and coding of the objects to turn them comprehensible within most e-learning platforms.

For instance, SCORM doesn't define itself a metadata model – it recognizes the LOM standard as the standard in fact [5]. Yet, SCORM defines XML as the syntax for metadata representation (process called *XML binding*). That is the

reason why the LOM standard is used for represented metadata on SCORM mapped elements on this research.

Actually, the standard SCORM 2014, or SCORM 1.4, presents 3 Parts (or sub-specifications) [5]:

- Content Packaging (CAM) section: specifies how content should be packaged and described. It is based primarily on XML.
- Run-Time section: specifies how content should be launched and how it communicates with the LMS. It is based primarily on ECMAScript (JavaScript).
- Sequencing section: specifies how the learner can navigate between parts of the course (SCOs). It is defined by a set of rules and attributes written in XML.

Within its CAM model published by ADL [5], SCORM defined in its part related to Metadata nine categories to describe learning objects attributes. The definition must be applied to assets, SCO (groups of assets), activities, content organizations and content aggregations, for their identification, categorization, consult and findability, to facilitate sharing and reusability.

For instance, it is presented an example of SCORM metadata XML coding in Fig. 2:

```
<resource identifier="RES-D2D28CCE" type="webcontent" adlcp:scormType="sco"
href="dd_sepsis.html">
  <metadata>
   <lom:lom>
    <lom:general>
     <lom:title>
      <lom:string language="en">Sepsis</lom:string>
     </lom:title>
     <lom:language>en</lom:language>
     <lom:description>
      <lom:string language="en">An introduction to Sepsis...</lom:string>
     </lom:description>
     <lom:keyword>
      <lom:string language="en">intro, sepsis</lom:string>
     </lom:keyword>
     <lom:structure>
      <lom:source>LOMv1.0</lom:source>
      <lom:value>hierarchical</lom:value>
     </lom:structure>
    </lom:general>
   </lom:lom>
  </metadata>
  <file href="dd_sepsis.html"></file>
  <file href="dd_sepsis.mov"></file>
  <file href="AC_QuickTime.js"></file>
  <file href="SCOHelper.js"></file>
 </resource>
```

Fig. 2 SCORM metadata file highlighting the description of a hypermedia document resource for the web.

To match specifications of theses metadata standards the proceeding is mapping their categories using, in this research, the XPath language, as it was primary done mapping and matching DCMI–Dublin Core and SCORM metadata standards, as shown in Table I. Mapping is expressed in *XPath syntax*.

As we can observe in Table I, these identifiers cover from the most generic ones to the most specifics, related to the Rights, for example, which is a focus of ADL standardization concerning MPEG-21 and SCORM.

TABLE I
MAPPING OF SCORM AND DCMI METADATA (XPATH SYNTAX)

Matching SCORM (LOM) / DCMI	
SCORM	**DCMI**
/lom/general/identifier/entry	/dc/identifier
/lom/general/title	/dc/title
/lom/general/language	/dc/language
/lom/general/description	/dc/description
/lom/general/keyword or /lom/classification/keyword com classification/purpose equals to “Discipline” or “Idea”	/dc/subject
/lom/general/coverage	/dc/coverage
/lom/educational/learningresourcetype	/dc/type
/lom/lifecycle/contribute/date com lifecycle/contribute/role equals to “Publisher”	/dc/date
/lom/lifecycle/contribute/entity com lifecycle/contribute/role equals to “Author”	/dc/creator
/lom/lifecycle/contribute/entity with the contributing type specified in lifecycle/contribute/role	/dc/othercontributor
/lom/lifecycle/contribute/entity com lifecycle/contribute/role equals to “Publisher”	/dc/publisher
/lom/technical/format	/dc/format
/lom/rights/description	/dc/rights
/lom/relation/resource/description	/dc/relation
/lom/relation/resource com relation/kind equals to “IsBasedOn”	/dc/source

From the Table I, concerning the matching between SCORM and Dublin Core metadata standards, it is possible to analyze a projection for the expected results achieved through the work on the further mapped hybrid ontology proposed, implying in its turn SCORM and MPEG-21 metadata standards.

It can be noticed the syntax of the XPath language used for the mapping and matching system, in a neutral way, between both metadata structures of representation.

It were found out the matches among the 15 (fifteen) elements presented in the Dublin Core standard and in the other hand 15 equal elements found within the SCORM metadata structure, actually LOM structure, as already explained in this article.

III. DIGITAL TELEVISION AND E-LEARNING METADATA

The metadata systems integration is already a longtime issue of investigation for the telecommunications community, mostly linked to Digital Television. In [1], [6], [7] and [8], we have samples of the discussion involving MPEG-7, MPEG-21 and TV-Anytime. Even the issue of Digital TV and SCORM was initially discussed [11].

MPEG-21 became the modular development and standardization platform (a *framework*) [12] towards global integration of all multimedia documents. The multimedia are not the product of an specific area of knowledge, but is a direct consequence of standardization of digital practices such as telecommunications, audiovisual, informatics.

Although the fact that MPEG-21 came up from a community that focuses on audio and video, the so called *MPEG-21 Framework* [12] can host all kinds of complex digital objects, such as electronic text, digital magazines, scientific data etc.

As can be seen from the scientific literature [13], [7] and [1] and from the norm itself [3], the MPEG-21 standard have a non-rigid structure of metadata, and Part 2 standard, DID, exposes the digital Item as the most generic approach for this purpose structural description of use of metadata in digital objects of all kinds.

The MPEG-21 standard holds today 21 parts [3]. MPEG-21 is an XML-based metadata specification that brings two fundamental pillars:

- The definition of a unit or essential object of distribution and transaction, which is called *Digital Item*;
- And the notion of "reader" – the concept of users interacting with it.

The MPEG-21 metadata standard, however, is currently partitioned in 22 parts, as follows [3]:

1. Vision, Technologies and Strategy (Digital Item definition)
2. Digital Item Declaration
3. Digital Item Identification
4. IPMP (Intellectual Property Management and Protection)
5. Rights Expression Language
6. Rights Data Dictionary
7. Digital Item Adaptation
8. Reference software
9. MPEG-21 file format
10. Digital Item Processing
11. Evaluation methods for persistent association Technologies
12. Test bed for MPEG-21 resources delivery
13. *Scalable Video Encoding – Transferred to MPEG-4 AVC standard*
14. Conformance testing
15. Event reporting
16. Binary format
17. Fragment identification of MPEG-21 resources
18. Digital Item Streaming
19. Media Value Chain Ontology
20. Contract Expression Language
21. Media Contract Ontology
22. User Description

The central concept within the MPEG-21 metadata standard can be understood as the DI - Digital Item, as defined in Part 2 of the standard [12].

The DID, or Digital Idem Declaration, relates a digital product, which can be simple or composite. A typical example is a webpage, containing different multimedia resources.

The use of MPEG-21 DIDL (Digital Idem Declaration Language) as a generic standard for the representation, cataloging and storage of digital learning objects in the library has been proposed by [14]. It demonstrated the applicability of the DIDL for representing complex objects of any type of media or content to create a digital collection in the library.

The second key concept in MPEG-21 format is the description of the production and interaction with the media, for all stakeholders in the process, from content producer to the end user. Therefore, it can be said that the main objective of MPEG-21 is to define the technologies needed to support the exchange, access, consumption, trade or handling of Digital Items in an efficient and transparent way [12].

A workflow exemplifying the metadata representation of a media like a digital music album, in the MPEG-21 standard, can be represented as designed on Fig. 3:

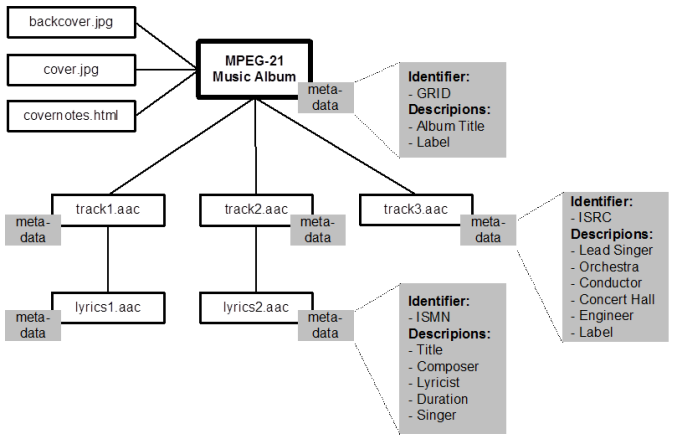


Fig. 3 MPEG-21 metadata representation of a descripted media – a digital music album [3].

As we can infer from the Fig., there are key elements like an identifier and a descriptor whose coding is mandatory for representing data aspects of each subpart of the hereby exemplified digital media.

IV. Methodology: A Convergent Ontology for the Integration Between MPEG-21 SCORM

The intended Ontology between SCORM and MPEG-21 can be carried out by matching their syntax correspondences, through the W3C XPath language.

The use of XPath language is directed to carry out the comparative study of mapping between the standards of SCORM metadata and MPEG-21, applying this methodology. XPath is a language maintained by the W3C with the primary objective of addressing parts of an XML document, and it is also used to test whether a code matches a pattern, or another code.

There are some key features regarding XPath language which were strongly considered on the decision for this proposed methodology:

- XPath is a syntax for defining parts of an XML document
- XPath uses path expressions to navigate XML documents
- XPath contains a library of standard functions
- XPath is a major element in XSLT*
- XPath is a W3C recommendation

*XSL stands for *EXtensible Stylesheet Language* (and it is applied on XML files).

The MPEG-21, as already stated, provides the DIDL (*Digital Item Declaration Language*), but also other schemes and their languages, within other of the many parts of the standard, for the cataloging of objects and the flow of information, the case also DII (*Digital Item Identification*), and DIA (*Digital Item Adaptation*); but also for dealing with copyright data (MPEG-21 Part 5 REL - *Rights Expression Language*), CEL (*Contract Expression Language*), IPMP (*Intellectual Property Management and Protection*); and even use cases (UD - *User Description*).

The orientation of the work of JTC1 SC36, as can be accompanied by papers published by IEEE [13] and [17] is based essentially on the portability, interoperability and adaptability of technologies for education, teaching and learning. The SC36 does not, therefore, calling to extend the work carried out by other technical committees, such as the SC29 itself, the media committee, which deals with sound encoding, image, multimedia and hypermedia information.

However, the SC36 was a pioneer in pointing to the need for synergy with the SCORM MPEG-21 standard, proposition however limited to addressing issues of copyright and eventually the e-commerce of ICTE (Part 5 of the standard).

The MPEG-21 normalization lies in perfect continuity with the ones previously carried out within the *MPEG-7 framework*. And many MPEG-7 standard descriptors are part of the MPEG-21 metadata schema [12] scope.

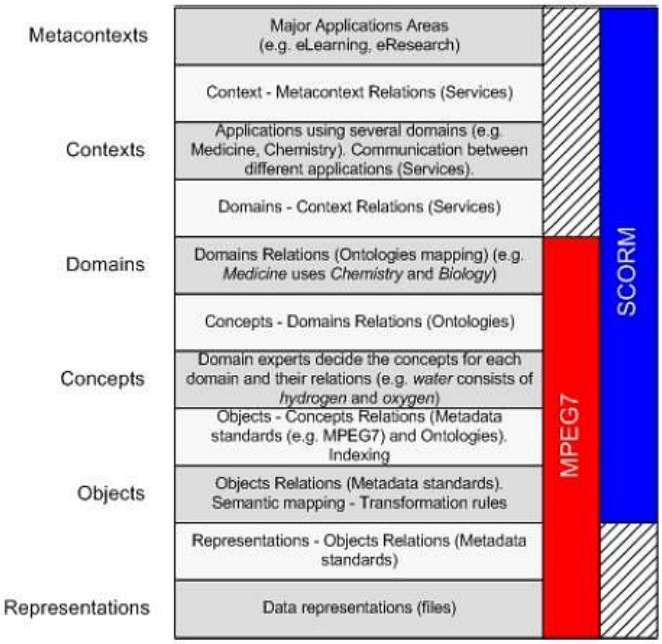
The descriptors and corresponding description schemes are developed under the responsibility of MDS group, whose data description is founded on the semantics of XML markup language.

The interrelationships between MPEG and e-Learning metadata standards are outlined in Table II [15] and in Table III [16]:

TABLE II
MAPPING AMONG THE MPEG AND E-LEARNING MAIN METADATA STANDARDS [15]

	Métacontextes des applications	Relation métacontextes - contextes	Contexte des applications	Relation contextes - domaines	Domaines	Relation domaines-concepts	Concepts	Relation concepts-objets	Objets	Relation Objets-représentations	Représentations	Relation représentations-échanges	Echanges
DUBLIN CORE													
SCORM													
LOM													
MPEG-7													
MPEG-21													

TABLE III
MAPPING BETWEEN MPEG-7 AND SCORM [16]



DIDL documents are actually XML 1.0 documents. The DIDL syntax is based on an abstract structure defined in the *Digital Item Declaration Model*.

This model defines the DIDL elements, namely: *Container; Item, Component, Anchor, Descriptor, Choice, Selection, Condition, Annotation, Assertion, Resource, and Statement*. Thus structurally represented as Fig.s 4 and 5:

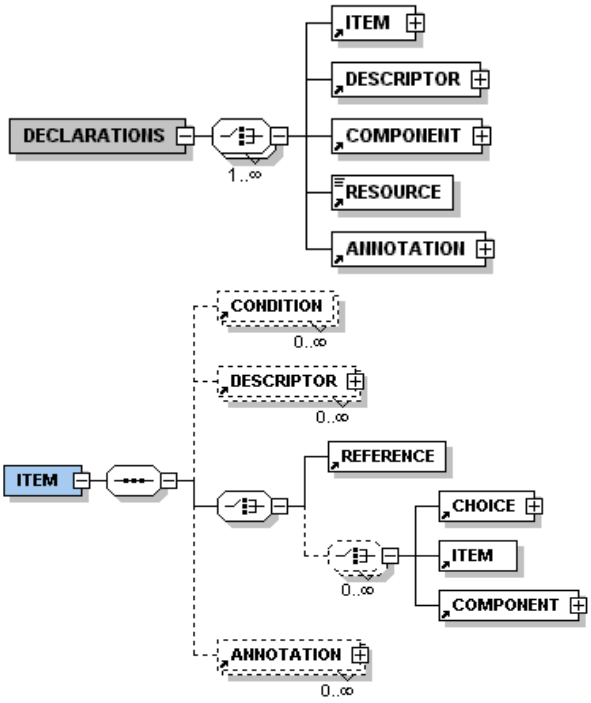


Fig. 4 Partial graphical representation of DIDL schema [12]. Highlighting the Declarations and Item elements.

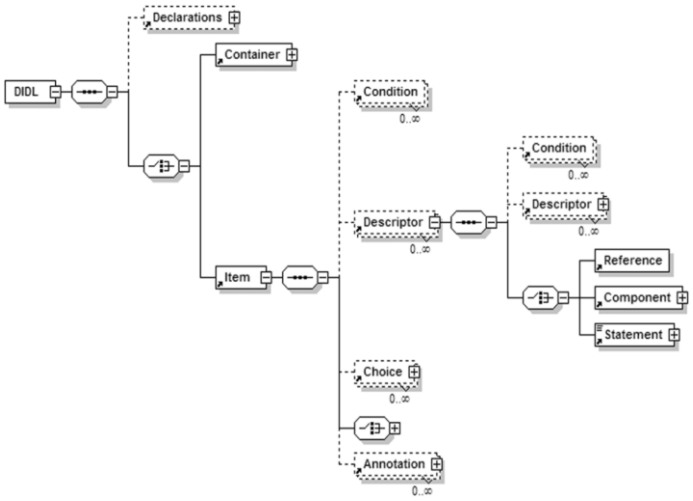


Fig. 5 Partial graphical representation of the DIDL schema generalized from the ISO/IEC norm 21000-2:2003 [12].

The DIDL XML code for *Declarations* element (a special element that defines a selection of elements without instantiate them) would be displayed in the following generic form [12]:

```
<xsd:element name="DECLARATIONS">
    <xsd:complexType>
        <xsd:choice maxOccurs="unbounded">
            <xsd:element ref="ITEM"/>
            <xsd:element ref="DESCRIPTOR"/>
            <xsd:element ref="COMPONENT"/>
            <xsd:element ref="RESOURCE"/>
            <xsd:element ref="ANNOTATION"/>
        </xsd:choice>
    </xsd:complexType>
</xsd:element>
```

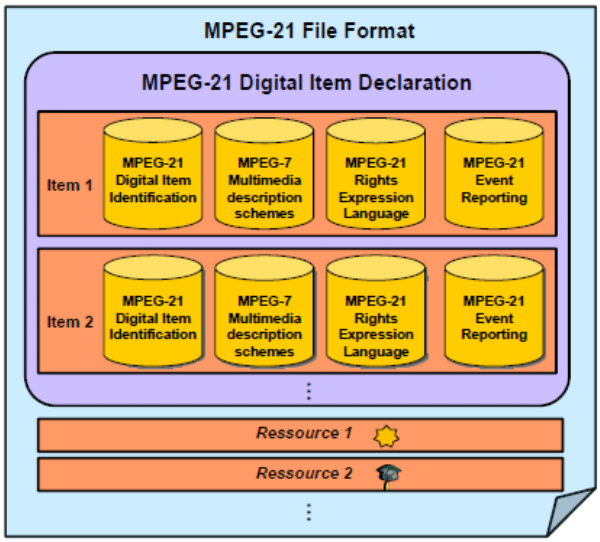


Fig. 6 Hierarquical metadata structure within an expected MPEG-21 general purpose file in its complete structure [18].

To perform the integration of standard patterns, the solution being implemented is to make the correspondence between the categories of SCORM metadata and those defined by MPEG-21 metadata schema.

Using the XPath language as the default to format the taxonomies and create a new ontology, there were first mapped the following standard SCORM metadata (LOM), which would correspond to the multimedia standard MPEG-21, aligned to the concept of platforms convergence. As follows in Table IV:

TABLE IV
SCORM AND MPEG-21 METADATA STANDARDS MAPPED

SCORM Multimedia Metadata	MPEG-21 Metadata (under development)
/lom/general/identifier/entry	<mpeg21>
/lom/general/title	<mpeg21>
/lom/general/language	<mpeg21>
/lom/general/description	<mpeg21>
/lom/general/keyword	<mpeg21>
/item[@identifier]	<mpeg7>
/lom/general/coverage	<mpeg21>
/lom/educational/learning/resource/type	<mpeg21>
/lom/lifecycle/contribute/role	<mpeg7>
/lom/lifecycle/contribute/date	<mpeg7>
/lom/technical/format	<mpeg7>
/lom/technical/size	<mpeg7>
/lom/technical/location	<mpeg7>
/lom/technical/duration	<mpeg7>
/lom/rights/description	<mpeg21>
/lom/relation/kind	<mpeg7>
/lom/relation/resource/description	<mpeg21>
/lom/relation/resource/catalogentry	<mpeg21>

Table IV stands for the mapping and matching between both metadata standards: SCORM and MPEG-21.

The mapped elements of both standards are up to be matched, on the purpose of achieving the hybrid ontology witch establishes the convergence between e-learning SCORM metadata standard with multimedia MPEG-21 metadata standard, interoperable and applicable for the wide range of digital media, including the web, mobile media or even digital television.

This proposed interoperable SCORM MPEG-21 ontology, employing the W3C XPath language, focus on the main items whose approaching is mandatory for achieving a significant representation of the metadata elements necessary to both a multimedia digital item description and a learning object description as well, developing a common hybrid new ontology based on the body and syntax of the existing ones.

V. CONCLUSIONS

Until the present moment it was possible to obtain successful results concerning the stages already overcame on this research, which progresses at an advanced pace regarding to the implementation of the specific goal of correspondence between metadata standards of the knowledge domains issued.

The development work has consisted in creating an Ontology focused on these mapped taxonomies in order to propose, from this ontology, an integration between the fields of Multimedia (comprehending Digital Television) and MPEG ICTE for distance education / e -Learning.

In other words, the convergence between MPEG-21 and SCORM as a standard for describing objects used for cataloging and for use in e-learning, in a broader sense, and e-learning via Digital Television in a specific perspective of the field of research.

A SCORM MPEG-21 Ontology, employing the W3C XPath language, is already in an advanced stage in order to make its contribution to the body of knowledge and the process of standardization in the metadata study domain, as well to further the research there have been in development the run-time and sequencing sections within this ontology.

It also contributes to a latent need for integration between the universes of Multimedia and ICTE, represented by working groups of SC29 and SC36 standards subcommittees, ISO / IEC JTC1, in this context of convergence.

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