Analyzing and Ranking Multimedia Ontologies for their Reuse

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Abstract

Reusing knowledge resources (ontologies, non-ontological resources, and ontology design patterns) has become a popular technique within the ontology engineering field. Such a reuse allows speeding up the ontology development process, saving time and money, and promoting the application of good practices. Recently, the NeOn Methodology has emerged to support this new approach in the development of ontologies based on reusing knowledge resources. In this Master Thesis the main goal is to identify the most appropriate multimedia ontologies to be reused in the development of a new ontology in such a domain (an ontology called M3 that should cover the following three perspectives: multimedia, multidomain, and multilingual). To achieve this goal we have applied the NeOn Methodology, particularly the methodological guidelines for reusing domain ontologies. These guidelines imply the process of searching, analyzing and selecting ontologies.

First we have searched multimedia ontologies that could satisfy the needs of the ontology to be developed, that is the M3 ontology focused on the multimedia perspective. Second we have performed a deeper study of the candidate MM ontologies to analyze their scope, purpose, functional and non-functional requirements with respect to the requirements established for the ontology to be built (that is, the M3 ontology). And finally, we have carried out an analysis of the candidate MM ontologies with respect to a set of criteria in order to obtain a ranked list of such ontologies. During the application of the methodological guidelines for reusing domain ontologies, we have realized that at some point those guidelines were not prescriptive enough. For this reason, we have improved and extended such guidelines in different aspects and activities (as it is shown in this document).

Finally, it is important to mention that the existence of detailed examples of real use cases on how to follow a methodology favours the adoption and application of such a methodology. Thus, in this regard, another objective of this Master Thesis is to show a pedagogic application of the NeOn Methodology, particularly the guidelines for reusing domain ontologies, in the multimedia domain.

Key words:
Ontology Reuse, Neon Methodology, Multimedia Ontologies, Semantic Web.

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Chapter 1

Introduction

The correct handling of multimedia information is based on a correct semantic annotation and representation of multimedia content. Nowadays, the standards of representation and classification of multimedia content such as MPEG-4[1] or MPEG-7[2] provide important functionalities for manipulation and modeling of structures and semantic annotation. Descriptors based on the automatic analysis of audiovisual content are far from what users require. Consequently, recent research has begun to focus on the reduction of semantic and conceptual gap between user and machine, based on the content of high-level descriptions. The expression *"Semantic gap"* is used to refer to the mismatch between the information that can be extracted from audio-visual data and the interpretation that each user makes in a given situation for the same data [SW00]. Searching in digital libraries has been a topic widely studied for years, especially those that focus on textual information retrieval using text-based methods. These consultations may be supplemented and enhanced with advanced recovery methods using content descriptors based on descriptors extracted from the audiovisual information by applying signal processing and machine learning techniques. Despite this, it is necessary to knowledge management and representation of Multimedia (MM) content. From the viewpoint of content providers, multimedia metadata represent an added value to audiovisual content. However, manual annotation remains a labor intensive task and is prone to introduce errors. Thus, the essence of media content management involves the structure of their associated metadata, using description schemes, taxonomies and ontologies to better organize the knowledge representation of data.

[1] http://mpeg.chiariglione.org/standards/mpeg-4/mpeg-4.htm
[2] http://metadata.net/mpeg7/

During the last decade, there have been many initiatives to build multimedia ontologies. The first initiatives were focused on transforming existing standards to ontology-alike formats (e.g, MPEG7 transformation in [GC05]). However, as there were many subdomains to cover in MM domain (audio, video, news, image, etc.) with different proprietary standards, the need of converging efforts to build MM ontologies taking into account existing standards and resources was an imperative. COMM Ontology [AT07] was one of the first reference in that direction. However, it is still missing in many of the existing approaches, a complete design, implementation and documentation based on a precise methodology. Without underestimating all the efforts and results obtained in previous works, we consider that building ontologies is an engineering process and should be guided by an underlined methodology to guarantee a good result.

Having a look at the literature, it is worth mentioning the great apportation of the Ontology Engineering Group (OEG)[3] of the Universidad Politécnica de Madrid (UPM) by many of its contributions in this field, begining from the proposal of METHONTOLOGY [FGJ97, GPGPFLB98] methodology. This methodology guides the process of building ontologies from scratch, including a life cycle based on evolving prototypes.

However, today the ontology development process is evolving into a distributed architecture, where ontologies, due to their complexity can be created and maintained by multiple groups of users in collaborative environments. In addition, ontology engineers and developers in Semantic Web, in order to accelerate the process of ontology development are beginning to reuse as much as possible ontologies and ontology design patterns as well as existing non-ontological resources such as thesauri, lexicons, databases, UML diagrams and classification schemes that have already been developed and possess a degree of consensus.

With this in mind, it is not wrong to say that a new paradigm of ontology development is emerging, which focuses on (a) the possible reuse and reengineering of existing knowledge sources, as opposed to the construction of new ontologies from scratch, (b) the development of ontologies in a collaborative and argumentative way, and (c) the building of ontology networks[4]. In this context arises the NeOn Methodology [SF10] for building ontology networks as part of the objectives of the European project NeOn - Lifecycle Support for Networked Ontologies (FP6-027595). The NeOn Methodology is based on scenarios for ontology building and offers pre-

[3]http://www.oeg-upm.net

[4]A network of ontology is defined as a collection of ontologies related to each other through different relationships and correspondence (mapping), modularization, versioning and dependency [PWH06]

scriptive methodological guidelines that guide developers of ontology networks in their collaborative construction through various development opportunities, such as reusing ontological resources, reusing ontology design patterns, etc.

1.1 Objectives

In this Thesis, our main objective is to *search, find, analyze, rank and select suitable multimedia (MM) ontologies to be reused in the development of a multimedia ontology called M3.* To achieve this objective, we have performed a systematic review and study of existing ontologies related to the MM domain, we have catalogued them and we have carried out a formal study to compare each of them and have obtained with the most appropriate ontologies to be reused.
All this process refers to the ontology reuse process that is covered by the NeOn Methodology by means of providing methodological guidelines [SF10]. Such methodological guidelines provide prescriptive help to the ontology developer in the following activities: domain ontology search, domain ontology assessment, domain ontology selection, and domain ontology integration. The objective of the **domain ontology search** is to look for candidate domain ontologies that could satisfy the needs of the ontology network to be developed. This search should be performed in libraries, repositories and registries taking as input those terms appearing in the pre-glossary of the Ontology Requirements Specification Document (ORSD) and introducing such terms in a Semantic Web Search Engine. In this regard it is important to choose the most suitable engine for the ontology domain search. The objective of the **domain ontology assessment** is to find out if the set of candidate domain ontologies are useful for the development of the ontology network. Thus, this activity consists of a deeper study of the candidate ontologies to analyze their scope, purpose, functional and non-functional requirements with respect to the requirements established for the ontology to be built. This activity can be seen as an ontology audit, where the ontology and its associated documentation are inspected and analyzed. The objective of the **domain ontology selection** is to find out which domain ontologies are the most suitable for the development of the ontology network. To distinguish between those candidate domain ontologies which are the most suitable, a set of criteria are used. Finally, the objective of the **domain ontology integration** is to integrate the domain ontologies selected in the ontology network to be developed.

As already mentioned the NeOn Methodology [SF10] proposed methodological guidelines for the ontology reuse process, and thus, for performing the four aforementioned activities. However, in some cases such guidelines are not prescriptive enough, and thus, in this Master Thesis we have had to adapt and/or extend such guidelines as explained in the document.

1.2 Structure of the document

This Master Thesis is structured as follows:

Chapter 2: Motivation and Approach. In this chapter we present our main motivation on why we are dealing with multimedia ontology reuse. We also present the objectives of our approach in the contribution of bridging the *semantic gap* in multimedia domain. Finally, we briefly show how we achieve the objectives.

Chapter 3: Multimedia Ontologies. In this chapter we offer a survey of media ontologies, classified by their scope which are Multimedia, Shape & Image, Visual Resource, Audio & Music and Application.

Chapter 4: Searching Multimedia Ontologies. In this chapter, we briefly summarize five popular Semantic Search Engines (Swoogle, Watson, Sindice, FalconS and SWSE) commonly used. We perform a comparative study of these engines to decide the most appropriate engine that is used in the search of multimedia ontologies. This chapter also includes the results of the multimedia ontologies search performed with the engine selected.

Chapter 5: Assessing Multimedia Ontologies. In this chapter we present the analysis of the candidate domain ontologies in order to find out the set of useful ontologies for the development of the ontology M3. This analysis is based on whether the domain ontology covers (totally or partially) the requirements identified in the ORSD of the ontology network to be developed. To perform this analysis we propose in this Master Thesis a detail methodological procedure.

Chapter 6: Selecting Multimedia Ontologies. In this chapter we describe how we have applied the methodological guidelines and the criteria proposed by the NeOn Methodology to rank the multimedia ontologies and to select the most appropriate ones for the development of the M3 ontology. In addition, in this chapter we propose prescriptive guidelines for analyzing the ontologies with respect to a subset of the criteria.

Chapter 7: Conclusions. In this chapter, we explain the main results of this Thesis with a brief summary of how we have achieved our objectives. Also, we present lessons learned during the overall process of searching-selecting-evaluating Ontologies in MM domain. We finally derive some future works which could open new research issues related to some aspects discussed in this Thesis.

Appendix A: Requirements of the M3 Ontology. This appendix contains the Requirements and the Competency Questions (CQs) for the development of the M3 ontology. These requirements and CQs have been defined in the context of the Buscamedia Project[5].

[5]http://www.cenitbuscamedia.es

Chapter 2

Motivation and Approach

In this chapter, we present a general vision of our motivation and the approach used to achieve the objectives proposed in this Master Thesis. The chapter is therefore divided in three main sections. In Section 2.1 it is presented the overall motivation. The objectives we pursue are then presented in Section 2.2. We finally describe in Section 2.3 the detail process used to achieve our objectives with an emphasis on the NeOn methodological guidelines related to the reuse of domain ontologies.

2.1 Motivation

Nowadays, we are continuously consuming multimedia contents of different formats and from differents sources using Google[1], Flickr [2], Picassa[3], Youtube[4], and so on. Many of these contents are available online and need to be semantically described and interpreted both by human agents (users) and machines agents (computers). Hence, there is a strong need of annotating MM contents to enhance the agents interpretation and reasoning for an efficient search in the Web of Data. Also, the necessity of interoperability among different standards and metadata describing MM documents can be of great help for Web API programmers to easily access and use contents of any type, and thus increasing their performance in terms of fiability and efficiency. Finally, the challenge of unifying both low level elements (colour, textures, fragments, etc.) and high level descriptions of MM contents in a unique ontology is a way to contribute to bridge the "*semantic gap*" still existing in the domain of multimedia.

[1]http://www.google.es/
[2]http://www.flickr.com/
[3]http://picasaweb.google.com
[4]http://www.youtube.com/

In this regard, there are differents MM ontologies (e.g., VDO, SAPO, Music ontology) oriented to cover only some parts of MM aspects. However, none of those ontology integrate both low level descriptions (e.g., color, textures, fragments, etc.) and high level descriptions (voice, videoclip, slides presentation, domain content, etc.) of MM resources in all its aspects (audio, video, image, text, Web content, etc.). In addition, none of them take into account multilingualism. For this reason, in the context of Buscamedia([5](Hacia una adaptacion semantica de medios digitales multirredmultiterminal) project, the challenge is to develop an ontology named M3 which covers three perspectives: Multimedia, Multilingual and Multidomain. In this Master Thesis we are focused on the MM perspective with the objective to build a multimedia ontology that covers both low and high level descriptions of a MM resource. To achieve that, we follow the NeOn Methodology, and specially in this document we explain how we have applied the prescriptive guidelines for reusing ontologies. It is worth mentioning that at some points we have had to extend and improve such methodological guidelines.

In this Master Thesis we have searched, studied, and evaluated related MM ontologies for reusing purpose. It is straightforward that the benefit of the ontology developed reusing appropriate existing ontologies will improve multimedia content web services such as the archival, retrieval, and management. Taking these factors into account, it has been decided to model multimedia resources as a network of ontologies using the NeOn Methodology [SF10]. More specifically, we have focused on the main activities to be performed as part of the reuse process that are the following ones: (1) search for ontological resources in repositories and registries; (2) assess the ontological resources in order to find out if such resources satisfy the developers needs; (3) compare and select the ontological resources on the basis of a set of criteria and requirements; and (4) integrate the ontological resources selected in the ontology network being built.

2.2 Objectives

The two main objectives to be achieved within this Master Thesis are the following:

- **Goal 1: To obtain a rank of MM ontologies to select the most appropriate ones that will be reused in the development of the M3 ontology**. This goal can be achieved by means of applying the methodological guidelines for reusing domain ontologies described in the NeOn Methodology [SF10].
- **Goal 2: To describe in detail and in a pedagogic way an example of how to apply the methodological guidelines for reusing ontologies in**

[5] http://www.cenitbuscamedia.es/

the multimedia domain. This goal can be achieved by presenting in detail the application of the NeOn Methodology and by extending and improving the guidelines when it is necessary.

2.3 General Process

First of all, it is important to mention that the NeOn methodology [SF10] recommends developing ontologies reusing knowledge resources as opposed to develop ontologies from scratch. Therefore, the development of the M3 ontology has been focused on the reuse of ontologies. To carry out the overall process, we apply the NeOn methodology particularly Scenario 3 named "*Building ontology networks by reusing ontological resources*", using Swoogle for keywords querying; NeOn Toolkit[6] for analyzing and building ontologies and Excel spreadsheet for calculating score and ranking. We have followed the methodological guidelines for reusing domain ontologies described in [SF10] which are constitued of four activities:

- **Activity 1: Domain Ontology Search.** The objective of this activity is to search in bookstores, record repositories and registries for domain ontologies candidates that meet the needs of the network of the ontology being developed.
- **Activity 2: Domain Ontology Assessment.** The objective of this activity is to find out if the set of candidate domain ontologies are useful for the development of the ontology network.
- **Activity 3: Domain Ontology Select.** The purpose of this activity is to find the most appropriate domain ontologies for the development of the ontology network.
- **Activity 4: Domain Ontology Integration.** The objective of this activity is to integrate the domain ontologies selected in Activity 3 in the ontology network being developed.

Second, it is worth mentioning that to meet the objectives proposed in this Master Thesis, we have conducted the following activities with respect to the objectives presented in Section 2.2:

- Activities related to **objective 1**:
  - Study of the Methodological Guidelines [SF10] for Reusing Domain Ontologies as a Whole.

[6] http://neon-toolkit.org/wiki/Main_Page

- Study in the literature some related works on Multimedia metadata initiatives (e.g. World Wide Web Consortium (WSC) Media initiative) and Multimedia ontologies.
- Extraction of relevant terms from the ORSD document and querying activity using Swoogle[7]. This activity takes as input a set of keywords in English extracted from the Competency Questions (CQs). In addition, we make a pre-selection , filtering of results and generation of a table with ontologies gathered from the search engine and the literature. We select appropriate set of candidate ontologies based on a first round study of results gathered from the SSE.
- Compilation of relevant features to compare ontologies in the multimedia domain. It consists of a deeper study of the candidates ontologies to analyze their scope, purpose, functional and non-functional requirements with respect to the requirements identified in the Buscamedia Project. It can be seen as an ontology audit or evaluation based on some specific criteria, where the code ontology is inspected and analyzed very carefully .
- Application of the formulae to obtain the score of each candidate ontology [SF10]. It consists of a deeper analysis of the candidates ontologies based on a set of criteria to objectively ranked them and be able therefore to determine which are the best candidates to be reused in the newly created ontology in the MM domain. The output of this activity is a set of ranked ontologies ready to decide which are the most adequate to be reused in the ontology being built.

• Activities related to **objective 2**:

  - Comparative study and guides to choose between two Search Web Engines to improve the query process.
  - Methodological procedure to determine whether the candidates ontologies are able to answer the CQs included in the ORSD.
  - Methodological procedure to determine what are the ontologies with best ranking scores to integrate in the ontology being developed.

[7]http://swoogle.umbc.edu/

Chapter 3

Multimedia Ontologies

3.1 Introduction

Media objects are generally associated to text, image, sound, video and animation. In [CC09] a distinction between media objects that are time-based and those which they called static media is provided. It is straightforward to say that images or texts are static media and that sounds, videos or animations do not exist without time feature. Additionally, in the abovementioned paper, the notion of multimedia is refered to the resulting combination of media. Thus, we consider a Multimedia object as a composite media object (text, image, sound, video, animation) that is composed of a combination of different media objects. A growing amount of multimedia data is produced, processed and stored digitally. Therefore, the current main challenge is to index this data in order to make it searchable and reusable. This requires the multimedia content to be annotated in order to create metadata which contains a concise and compact description of the features of the content. In the Semantic Web community, especially in the state-of-the-art of semantic annotation and analysis of multimedia, there has been a huge effort to bridge the so called semantic gap. Semantic gap is in our sense the lack of expressivity or semantic associated to many standards in multimedia area that mostly describe visual aspects at a very low level, e.g., dominant colour of a still image. MPEG-7 is an international standard that includes descriptors of a media, but it is not fully suitable for describing multimedia content because of two main reasons: (1) it is not open to standards that represent knowledge and make use of existing controlled vocabularies for describing the subject matter, and (2) its XML Schema based nature has led to design decisions that leave the annotations conceptually ambiguous and therefore prevent direct machine processing of semantic content descriptions.

Many multimedia metadata formats, such as ID3[1], Exif[2] or MPEG-7[3] are available to describe what a multimedia asset is about, who has produced it, how it can be decomposed, etc. [Hau07]. For professional content found in archives and digital libraries, a range of in-house or standardised M3 formats is used. Similar issues arise with the dissemination of user generated content found at social media sites such as Flickr[4], YouTube[5], or Facebook[6]. To enable the deployment of existing multimedia metadata formats on the Semantic Web, we agree with proposals that advocate the use of the RDF data model. A large number of existing Multimedia (MM) formats have been used for years in diverse applications. One of the proposal made by Hausenblas was not to discard the existing multimedia metadata standards, but propose a solution that allows hooking existing multimedia metadata formats into the Semantic Web by using RDFa-deployed Multimedia Metadata (ramm.x) [HW07]. In 2001, with the initial work of Jane Hunter [Hun01], many efforts to build ontologies that can bridge the semantic gap have been done (and even still undergoing) involving sometimes many national projects or international ones for diverse applications (annotation areas, multimedia retrieval, etc.). Application fields of multimedia objects range from TV news, TV broadcast news, film (textual closed captions; subtitles of the audio) to video (detection of shot boundaries, attempt to identify key frames from within identified shots), visual resources, cultural heritage community, refer to [Gar04] for a more description. Hence for each field or domain application there exists in the literature many standards. Only for video domain, the following standards are available: *Escort 2.4* [7] (the EBU System of Classification Of Radio and Television programs defines 115 terms), *SMPTE* [8] (Society of Motion Picture and Television Engineers), *IPTC Core Metadata* (NewsML, SportsML, and Program-GuideML from International Press Telecommunications Council), *P/Meta Metadata Scheme*[9] (EBU, European Broadcasting Union, an audio-visual metadata schema), *SLA News Division*[10](provides 108 terms from the Special Libraries Association's News Division Web site), etc.

We are concern in this chapter by revising all the well-known ontologies designed and implemented for describing multimedia objects, from 2001 up to now, with special attention to the ones that are available in RDF/RDFS or OWL format.

[1]http://www.id3.org
[2]http://www.exif.org/specifications.html
[3]http://www.chiariglione.org/mpeg
[4]http://www.flickr.com
[5]http://www.youtube.com
[6]http://www.facebook.com
[7]http://www.ebu.ch/trev_284-hopper.pdf
[8]http://www.smpte.org/home/
[9]http://www.ebu.ch
[10]http://www.ibiblio.org/slanews/

Therefore we do not treat controlled vocabularies or standards, nor thesaurus, generally called Non Ontological Resources (NOR). However, we describe the MPEG-7 standard (a) for its importance in the multimedia domain to describe media contents in low level descriptors and (b) for having being transformed to owl-alike formats in various ontologies presented in the literature. In these following sections we describe ontologies that we found of special interest for multimedia. After describing the MPEG-7 standard in Section 3.2, we follow in Section 3.3 by the presentation of the ontologies dedicated to describe Multimedia objects. Section 3.4 presents ontologies describing Shapes and Images; while Section 3.5 presents ontologies for describing Visual Resource Objects (painting works, cultural heritage). In addition, Audio and Music ontologies are presented in Section 3.6; followed in Section 3.5 by specific ontologies in the field of media campaign. The last part in Section 3.7 is dedicated to ontologies applied for more specific uses: atheletic events and virtual representation of humans. We use therefore a top-down analysis, that means we present the ontologies from the most generic ones to the most specific ontologies.

3.2 MPEG-7

MPEG-7 is an ISO/IEC standard developed by MPEG (Moving Picture Experts Group), formally named "Multimedia Content Description Interface". It is a standard for describing the multimedia content data that supports some degree of interpretation of the information meaning, which can be passed onto, or accessed by, a device or a computer code. The MPEG-7 standard, formally named "Multimedia Content Description" aims to be a set of descriptors for describing any multimedia content. MPEG-7 standardizes the so-called "description tools" for multimedia content: *Descriptors (Ds), Description Schemes (DSs)* and the *relationships* between them. Descriptors are used to represent specific features of the content, generally low-level features such as visual (e.g. texture, camera motion) or audio (e.g., melody), while description schemes refer to more abstract description entities (usually a set of related descriptors). These description tools as well as their relationships are represented using the Description Definition Language (DDL), a core part of the language. MPEG-7 descriptions can be serialized as XML or in a binary format defined in the standard. MPEG-7 Multimedia Description Schemes (DSs) are metadata structures for describing and annotating audio-visual (AV) content. The standard describes some the following descriptors:

- **Visual Features**: Color, Texture, Shape, Motion, Localization, and Face recognition. There are five Visual related Basic structures: the Grid layout, and the Time series, Multiple view, the Spatial 2D coordinates, and Temporal interpolation.

- **Color Fescriptors**: There are seven Color Descriptors: Color space, Color Quantization, Dominant Colors, Scalable Color, Color Layout, Color-Structure, and GoF/GoP Color.
- **Texture Descriptors**: There are three texture Descriptors: Homogeneous Texture, Edge Histogram, and Texture Browsing.
- **Shape Descriptors**: There are three shape Descriptors: Region Shape, Contour Shape, and Shape 3D.
- **Motion Descriptors**: There are four motion Descriptors: Camera Motion, Motion Trajectory, Parametric Motion, and Motion Activity.
- **Localization Descriptors**: There are two descriptors for localization: Region locator and spatio-temporal locator
- **Audio Framework**: Basic (AudioWaveform, AudioPower), Basic Spectral, Timbral Temporal and Timbral Spectral.

3.3 Ontologies for describing Multimedia Objects

In this section, we first present three ontologies (COMM, M3O, Media Resource Ontology) which can be considered to be "generic" for Multimedia domain. The way some of these ontologies (COMM, M3O) have been developed is a nice example of what it is nowadays used and recommended by Web Semantic Community Experts: the so-called Ontology Design Patterns (ODP) qualified as "Best Practices" of designing and implementing ontologies. In the second part of this section, we present three initiatives (MPEG-7 Upper MDS, MPEG-7 Tsinaraki, MPEG-7 Rhizomik) focused on "translating" MPEG-7 standard to RDF/OWL and finally we present an ontology for mobile access (SWIntO).

3.3.1 COMM: Core Ontology for MultiMedia

One of the ontology that can be considered like "generic" for Multimedia is certainly the Core Ontology for Multimedia (COMM), because it takes into account DOLCE as the top-ontology and two design patterns to combine with MPEG-7 standard. The arrival of COMM changed the way of designing ontology for MM, after previous efforts focused on how to "translate" MPEG-7 standard to RDF/OWL. Arndt et al. [AT07] proposed COMM in 2007 as a response to the need of having a formal description of a high quality multimedia ontology satisfying a set of requirements such as MPEG-7 standard compliance, semantic interoperability, syntactic interoperabiliy, separation of concerns, modularity and extensibility. COMM is designed using DOLCE and two ontology design patterns: one pattern for contextualization called *Descriptions & Situations* (DnS) and the second pattern for information objects called *Ontology for Information Object* (OIO). The ontology is implemented in OWL DL. The aim of COMM is to enable and facilitate multimedia annotation. That is the reason why it specifies the signification of a multimedia data (an abstract concept in the sense of MPEG-7 multimedia content that has to be further specialized for concrete multimedia content types) and provides patterns for semantic annotation issue that formalize the decomposition of multimedia content into segments and/or allow their annotation. Hence it derived four patterns to be used with COMM that are: the Decomposition Pattern, the Content Annotation Pattern (features of the multimedia document), the Media Annotation Pattern and the Semantic Annotation Pattern. When Descriptions & Situations is used with DOLCE, the entities from the DOLCE domain of quantification are called ground entities, while the newly introduced entities from the domain of quantification of Descriptions & Situations are called descriptive entities. Table 3.1 shows an excerpt of some classes and relations in COMM.

Class Name	**Object Property**	**Other Class Name**
MultimediaData	*subClassOf*	DigitalData
DigitalData	*express*	LocalilizationDescriptor
DigitalData	*express*	StructuredDataDescription
MultimediaData	*isRealizedby*	Media
Media	*subClassOf*	InformationRealization
SegmentDecomposition	*settingFor*	MultimediaData, DigitalData

Table 3.1: Excerpt of some classes and relations in COMM

3.3.2 M3O: Multimedia Metadata Ontology

M3O[11] is based on requirements extracted from existing standards, models and ontologies and provides patterns that satisfy five requirements, which are: identification of resource, separation of information objects and realizations, annotation of information objects and realizations, decomposition of information objects and realizations and representation of provenance information.

M3O is targeted for rich presentations in the web using Synchronized Multimedia Integration Language (SMIL)[12], Scalable Vector Graphics (SVG)[13] and Flash. The problem comes from the fact that many metadata models and metadata standards

[11] http://www.uni-koblenz-landau.de/koblenz/fb4/AGStaab/Research/ontologies/m3o
[12] http://www.w3.org/AudioVideo/
[13] http://www.w3.org/Graphics/SVG/

(XMP, JEITA, IPTC Core, MPEG-7) do not distinguish for e.g., different roles of location of an image [SS10]. The ontology M3O aims providing a pattern that allows accomplishing exactly the assignment of arbitrary metadata to arbitrary media. To fullfil the five requirements abovementionned, M30 represents data structures in form of ODPs based on the formal upper-level ontology DOLCE & DnS Ultralight (DUL). Thus, there is a clear alignment with DOLCE & DnS Ultralight[14] as formal basis. The following three patterns specialized from Dolce + DUL are reused in the M3O:

- Description and Situation Pattern (DnS),
- Information and Realization Pattern,
- Data Value Pattern.

The main application of M3O, also classified as a core ontology, is *Semantic Annotation*, but specially focused on an aspect orthogonal to many domains, namely *media annotation*.

Besides, M3O provides four patterns (annotation, decomposition, collection, provenance) that are respectively called annotation pattern[15], decomposition pattern[16], collection pattern[17] and provenance pattern[18]. M3O annotations are in RDF and be embedded into SMIL multimedia presentation. The ontology is used and currently implemented in the SemanticMM4U Team. M3O resources are available at the following URIs:

3.3.3 Media Resource Ontology

Media ontology[19] aims at integrating data resources related to media, especially those used on the Web. It is rather a vocabulary to describe a mapping among the different formats of video metadata. It recognized 23 formats (MPEG7, IPTC, Dublin Core, Exif, VRA, DIG35, etc.) where a proposal for unification of properties is being done. The basic properties include elements to describe: the identification, creation, content description, relational, copyright, distribution, fragments and technical properties[20]. The core set of properties and mappings provides the basic information needed by targeted applications for supporting interoperability among the various kinds of metadata formats related to media resources that are

[14]http://www.loa-cnr.it/ontologies/DUL.owl
[15]http://m3o.semantic-multimedia.org/ontology/2010/02/28/annotation.owl
[16]http://m3o.semantic-multimedia.org/ontology/2010/02/28/decomposition.owl
[17]http://m3o.semantic-multimedia.org/ontology/2010/02/28/collection.owl
[18]http://m3o.semantic-multimedia.org/ontology/2010/02/28/provenance.owl
[19]http://dev.w3.org/2008/video/mediaann/mediaont-1.0/ma-ont-rev24.owl (version 2.4)
[20]See the document specification at: http://www.w3.org/TR/2010/WD-mediaont-10-20100309/

available on the Web. The properties defined in the ontology are used to describe media resources that are available on the web. Media resources here can denote both the abstract concept of a media resource (e.g., the movie "Notting Hill") as well as a specific instance (e.g., a certain file with an MPEG-4 encoding of the English version of "Notting Hill" with French subtitles). For the sake of simplicity, the Media Resource Ontology do not make distinctions between these different levels of abstraction that exist in some formats. In addition, the ontology is accompanied by an API that provides uniform access to all its elements. Regarding some important classes, it is worth mentioning that a MediaResource can be one or more images and/or one or more Audio Visual MediaFragment. By definition, in the model, an AV MediaResource is made of at least one MediaFragment. A MediaFragment is the equivalent of a segment or in some standards like NewsML-g2 or EBUCore, a part. At the same time, a MediaFragment is composed of one or more media components organized in tracks (separate tracks for captioning/subtitling or signing if provided in a separate file): audio, video, captioning/subtitling, signing. There could be other types of tracks like a 'data' track, etc.

3.3.4 MPEG-7 Upper MDS

This MPEG-7 ontology[21] was firstly developed in RDFS, then converted into DAML + OIL, and is now available in OWL-Full. The ontology covers the Upper part of the Multimedia Description Scheme (MDS) of the MPEG-7 standard. The ontology comprises 69 classes and 38 object properties. In conjunction with Laura Hollink [HLH05], some extensions to MPEG-7 were added to MPEG-7 Upper MDS. The so-called MPEG-7x ontology[22] incorporates more specific image analysis terms from the MATLAB Image Processing Toolbox.

3.3.5 MPEG-7 Tsinaraki

This MPEG-7 ontology[23] covers the full Multimedia Description Scheme (MDS) part of the MPEG-7 standard. The ontology is available in OWL DL. The authors explain how they fully capture the concepts of the MEPG-7 MDS. MPEG-7 complex types correspond to OWL classes, which represent groups of individuals interconnected because they share some properties. The simple attributes of the complex type of the MPEG-7 MDS are represented as OWL datatype properties. Complex attributes are represented as OWL object properties, which relate class instances.Relationships between the OWL classes correspond to the complex MDS

[21] http://metadata.net/mpeg7/mpeg7.owl
[22] http://metadata.net/mpeg7/mpeg7x.owl
[23] http://elikonas.ced.tuc.gr/ontologies/av_semantics.zip

types and are represented by the instances of the "*RelationBaseType*" [TPC04]. The ontology contains 420 classes and 175 properties.

3.3.6 MPEG-7 Rhizomik

This MPEG-7 ontology has been produced fully automatically from the MPEG-7 standard in order to give it a formal semantics, based on a generic XML Schema to OWL mapping. The ontology aims to cover the whole standard and it is thus the most complete one (with respect to the aforementioned ones). For such a purpose, a generic mapping XSD2OWL has been implemented. The definitions of the XML Schema types and elements of the ISO standard have been converted into OWL definitions according to the set of rules given in [GC05]. The ontology contains about 525 classes, 814 object properties and 2552 axioms. The ontology can easily be used as an upper-level multimedia ontology for other domain ontologies (e.g., music ontology). For instance, it is applied in the MusicBrainz[24] initiative.

3.3.7 SWintO

The Smart Integrated Ontology (SWIntO) was developed for mobile access within the SmarWeb[25] Project. The ontology is based on a multi-layer partitioning into partial ontologies. The core ontology (based on DOLCE) and domain-independent ontology (based on SUMO[26]) establish the basic layers. Domain specific knowledge (e.g., sport events, navigation, web services) is defined in dedicated ontologies modelled as sub-ontologies. SWintO integrates a media ontology to represent multimodal information constructs. The ontology is available in RDFS.

3.4 Ontologies for describing Shapes and Images

3.4.1 DIG35

Digital Imaging Group (DIG)[27] provides DIG35, which is a standard set of metadata for digital images. The standard promotes interoperability and extensibility, as well as a "uniform underlying construct to support interoperability of metadata between various digital imaging devices" [DIG00]. The metadata properties are encoded within an XML Schema and cover the following aspects:

- *Basic Image Parameter* (a general-purpose metadata standard);

[24] http://musicbrainz.org/
[25] http://www.smartweb-project.org
[26] http://suo.ieee.org/SUO/SUMO/index.html
[27] http://www.i3a.org/

- *Image Creation* (e.g. the camera and lens information);
- *Content Description* (who, what, when and where aspects of an image);
- *History* (partial information about how the image got to the present state);
- *Intellectual Property Rights* (metadata to either protect the rights of the owner of the image or provide further information to request permission to use it)
- *Fundamental Metadata Types and Fields* to define the format of the field described in all the metadata block.

The DIG35 ontology[28] , developed by the IBBT Multimedia Lab [29] (University of Ghent) in the context of the W3C Multimedia Semantics Incubator Group, provides an OWL Schema covering the entire DIG35 specification. The DIG35 ontology is an OWL Full ontology with 179 classes and 203 properties.

3.4.2 MSO

ACEMedia[30] extended and enriched ontologies to include low level audiovisual features, descriptors and behavioral models in order to support automatic annotation. They developed the Multimedia Structure Ontology (MSO) based on MPEG-7 MDS, along with the following ontologies: Visual Descriptors Ontology, Spatio-Temporal Ontology, and Midlevel Ontology. The main aims of their core ontology is the support of audiovisual content analysis and object/event recognition, the creation of knowledge beyond object and scene recognition through reasoning processes and at enabling user-friendly and intelligent search and retrieval. It combines high-level domain concepts and low-level multimedia descriptions, enabling for new media content analysis.

3.4.3 SAPO

The Shape Acquisition and Processing Ontology (SAPO)[31] was intended to provide a starting point for the formalization of the knowledge of the creation and processing of digital shapes. The ontology was developed within the AIM@SHAPE Project[32]. The ontology domain covered the development, usage and sharing of hardware tools, software tools and shape data in the field of acquisition and reconstruction of shapes.

[28] http://multimedialab.elis.ugent.be/users/chpoppe/Ontologies/DIG35.owl
[29] http://www.mmlab.be
[30] http://www.acemedia.org/aceMedia
[31] http://www.aimatshape.net/resources/aas-ontologies/shapecommonontology.owl/download
[32] http://www.aimatshape.net/

The core ontology describes classes such as *Acquisition Condition, Acquisition Device, Shape Type, Shape Data,* and *Acquisition Type.* SAPO is an OWL Full ontology with 51 classes and 41 objects properties.

3.4.4 CSO

The purpose of the Common Shape Ontology (CSO)[33] is to integrate some shared concepts and properties from the domain ontologies and the metadata information from the Shape Repository that can be associated with any shape model. This metadata information is considered common to any kind of shape regardless of the domain. The mission of AIM@SHAPE was to advance research in the direction of semantic-based shape representations and semantic-oriented tools to acquire, build, transmit, and process shapes with their associated knowledge. The multimedia world can be classified into one-dimensional media like text and sound, and multi-dimensional media. Among the latter, those that are characterized by a visual appearance in a space of 2, 3, or more dimensions are called shapes within AIM@SHAPE project. Examples of shapes are pictures, sketches, images, 3D models of solid objects, videos (disregarding the sound track), 4D (=3D+Time) animations. CSO is an OWL Full ontology with 38 classes and 14 object properties.

3.4.5 MIRO

The Mindswap Image Region Ontology (MIRO)[34] is an OWL Full ontology which models concepts and relations covering various aspects of the digital media domain (Image, Segment, Video, Video Frame, etc). The main purpose of the ontology is to provide the expressiveness to assert what is depicted within various types of digital media, including image and videos [HWS05]. The ontology defines concepts including image, video, video frame, region, as well as relations such as depicts, segmentOf, hasRegion, etc. MIRO consists of 14 classes and 12 object properties.

3.5 Ontologies for describing Visual Resource Objects

In this section, we present two ontologies, VRA Core 3 and VDO; describing respectively collection of cultural works and visual descriptors. The former was implemented in OWL by two different authors and the latter was developed within an European project called aceMedia.

[33] http://www.aimatshape.net/resources/aas-ontologies/shapecommonontology.owl/
[34] http://www.mindswap.org/2005/owl/digital-media

3.5.1 VRA Core 3

The Visual Resource Association (VRA)[35] is an organization consisting of many American Universities, galleries and art institutes. These often maintain large collections of (annotated) slides, images and other representations of works of art. The VRA has defined the VRA Core Categories [VRA02] to describe such collections. The last release version is VRA Core 4.0[36] and consist of 19 descriptors for 3 types of objects: work (vra:Work), collection of works and/or images (vra:Collection) and finally an Image (vra:Image). The VRA Core 3.0 elements were designed to facilitate the sharing of information among visual resources collections about works and images. A work is a physical entity that exists, has existed at some time in the past, or that could exist in the future (e.g., painting, composition, an object of material culture). An image is a visual representation of a work (it can exist in photomechanical, photographic and digital formats). A visual resources collection may own several images of a given work. Two versions of VRA 3.0 were developed in RDFS[37] and OWL[38], which we refer in this document to VRA Core 3_SIMILE and VRA Core 3_ Assem, respectively.

3.5.2 VDO

VDO[39] is the Visual Descriptor Ontology that deals with semantic multimedia content, analysis and reasoning. It contains representations of MPEG-7 visual descriptors and models concepts and properties that describe visual characteristics of objects (e.g., BasicDescriptors, ColorDescriptor, MotionDescriptor). VDO was developed within the aceMedia Project in RDFS and contains 61 classes for 237 properties.

3.6 Ontologies for describing Audio and Music

In this section, ontologies that are targeted to music and audio are described to better understand the way they are designed and implemented. The ontologies concerned are the following: Music ontology, Kanzaki Music vocabulary, and Music Recommendation ontology.

[35] http://www.vraweb.org/

[36] http://www.vraweb.org/projects/vracore4/index.html

[37] http://simile.mit.edu/2003/10/ontologies/vraCore3

[38] http://www.w3.org/2001/sw/BestPractices/MM/vracore3.owl

[39] http://www.acemedia.org/aceMedia/files/software/m-ontomat/acemedia-visual-descriptor-ontology-v09.rdfs

3.6.1 Music Ontology

The Music Ontology[40] is an attempt to provide a vocabulary for linking a wide range music-related information, and to provide a democratic mechanism for doing so. The parts of the Music Ontology related to the production process of a particular piece of music (composition, performance, arrangement,etc.) as well as the parts dealing with time-related information are based on three external ontologies: Time, TimeLine (a timeline being a coherent backbone for temporal things) and Event (to express knowledge about the production process of a piece of music) ontologies [RJ10]. Likewise, in order to describe music-related events, they consider describing the workflow beginning with the creation of a musical work to its release on a particular record. The Music Ontology is mainly influenced by (apart from the three ontologies cited before): the FRBF Final report[41], the ABC ontology from the Harmony Project[42] and the FOAF project[43]. The Music Ontology has a total of 138 classes and 267 object properties.

3.6.2 Kanzaki's Music Vocabulary

Kanzaki[44] is an OWL DL music/audio ontology to describe classical music and performances. Classes for musical works, events, instruments and performers, as well as related properties are defined. In Kazanki, it is important to distinguish musical works (e.g. Ballet) from performance events (Ballet_Event), or works (Choral_Music) from performer (Chorus) whose natural language terms are used interchangeably. Kanzaki contains 112 classes and 14 properties.

3.6.3 Music Recommendation Ontology

The Music Recommendation Ontology[45] is a music ontology, implemented in OWL DL that describes basic properties of the artists and the music titles, as well as some descriptors extracted from the audio (e.g. tonality -key and mode-, rhythm-tempo and measure-, intensity, etc.). The ontology is part of a music recommender system (foafing the music) [Cel06] which aims to recommend music to users depending on personalized profiles (FOAF profile, listening habits). The authors proposed [GC05] a way to map their ontology and the MusicBrainz ontology, within the MPEG-7 standard.

[40] http://motools.sourceforge.net/doc/musicontology.rdfs
[41] http://www.ifla.org/en/publications/functional-requirements-for-bibliographic-records
[42] http://metadata.net/harmony/
[43] http://www.foaf-project.org/
[44] http://www.kanzaki.com/ns/music
[45] http://foafing-the-music.iua.upf.edu/music-ontology

3.7 Application Ontologies

In this section, we present three ontologies (MEPCO, AEO, VHO) which were implemented to take into account the multimedia aspect in three specificic areas. MEPCO was targeted to media campaigns over the television, while AEO was implemented to take into account multimedia content in athletics events. Finally, VHO aims was to provide a better interaction of virtual humans with virtual objects.

3.7.1 MEPCO

The main goal of the Media Presence and Campaign Ontology (MEPCO)[46] is the cross-relation of media campaigns over the media TV, press and Internet and furthermore the ambitious goal to cross link media campaigns also over different countries. What makes a media campaign unique from others is not completely straight forward; however, there are heuristic rules encoded to describe media campaigns in a generic way. The MediaCampaign[47] Ontology (MEPCO) is based on the upper-level ontology PROTON[48] (all the four modules together: System module, Top module, Upper module and Knowledge Management module developed within the SEKT[49] project) and was aligned to media-related standards. It provides consistent formal definitions of about 328 general concepts and 136 properties in RDF format. MEPCO was intended to be aligned with existing standards for media-related metadata, such as NewsML and News Codes from the International Press Telecommunications Council (IPTC)[50].

3.7.2 AEO

The Athletics Event Ontology (AEO)[51] is a formal conceptualization of the domain of interest of the BOEMIE[52] use case scenario which is public athletics events, i.e. jumping, running and throwing events held in European cities. The basic goal is to allow the user of the BOEMIE system to navigate through multimedia documents with content relevant to the domain of athletics. BOEMIE tries to combine multimedia extraction and ontology evolution in a bootstrapping process involving extraction of semantic information from multimedia content in order to populate and enrich the ontologies. The project uses MPEG-7 for the description of

[46]http://www.media-campaign.eu/resources/publicdeliverables/MEPCO-ontology-V2.xml
[47]http://www.media-campaign.eu/
[48]http://proton.semanticweb.org/
[49]http://www.sekt-project.com/
[50]http://www.iptc.org/
[51]http://www.boemie.org/ontologies
[52]http:// www.boemie.org

multimedia content and its properties, domain specific ontologies and a geographic information ontology. AEO is an OWL DL ontology and contains 760 classes and 14 object properties.

3.7.3 VHO

The Virtual Humans ontology (VHO) aims at organizing the knowledge and data of three main research topics and applications involving the virtual representations of humans: (i) Human body modeling and analysis: morphological analysis, measuring similarity, model editing and reconstruction; (ii) Animation of virtual humans: autonomous or pre-set animation of virtual humans; (iii) Interaction of virtual humans with virtual objects: virtual -smart- objects that contain the semantic information indicating how interactions between virtual humans and objects are to be carried out. VHO is implemented in OWL Full with 73 classes and 48 objects; and it uses CSO (described in Section 3.4.4) as an imported module.

3.8 Conclusion

In this chapter we have described relevant works, particularly MM ontologies, done for bridging the semantic gap in multimedia field. We have presented important issues addressed by each multimedia ontology. We have first noticed the existence of many standards in multimedia and that the mostly used for implementing ontologies is MPEG-7. In addition, we have classified the MM ontologies according to their level of ganularity, their scope and their target application. It is worth stating that COMM proposal marked "a new vision" of designing multimedia ontologies, by the use of an upper ontology (in that case DOLCE) in order to have an extensible ontology with respect to multimedia vocabulary. Hence, COMM marks an inflection point in MM ontology development. Tables 3.2, 3.3 and 3.4 give a general overview of the state-of-art in Multimedia ontologies.

It is important to realize that many works that came after COMM were focused on audio or music aspects; quite different from those focused on image, audio o video before COMM. Moreover, recent efforts to have a generic MM ontology reusing all the existing standards, combining "Best practices" in ontology engineering and patterns reusing are reflected in the M30 and Media Ontology proposals.

Finally, we notice that there still some works to be done, since there is not any ontology (from the best of our knowledge) that is able to describe multimedia resources of different domains and in different natural languages. Thus, our object in this work is to reuse the most appropriate MM ontologies with the aim of developing an ontology called M3 that covers this gap related to the description of high level features of resources in different domains and in different languages.

Ontology	Description	Authors	Owners/Project	Year	Language
Multimedia Ontologies					
COMM	It is composed of multimedia patterns specializing the DOLCE design patterns for Descriptions & Situations and Information Objects.	Arndt et., al		2007	OWL DL
MPEG-7x	Some extensions to the MPEG-7 ontology incorporating more specific image analysis terms from the MATLAB Image Processing Toolbox.	Jane Hunter, Suzanne Little, Laura Hollink		2006	OWL Full
MPEG-7_Hunter	The ontology covers the upper part of the Multimedia Description Scheme (MDS) part of the MPEG-7 standard.	Jane Hunter, Suzanne Little		2001-2004	OWL Full
MPEG-7_Tsinakari	MPEG-7 ontology covers the full Multimedia Description Scheme (MDS) part of the MPEG-7 standard.	Tsinaraki, et al.		2004	OWL DL
MPEG-7_Rhizomik	Produced fully automatically from the MPEG-7 standard in order to give it a formal semantics.	Garcia et al.,	Rhizomik	2005	OWL Full
SWIntO	Ontology for mobile access.	SmartWeb		2007	RDFS
M30	It is targeted for rich presentations in the web like SMIL, SVG and Flash.	C. Saathoff, A. Scherp	SemanticMM4U	2010	OWL Full
Media Ontology	It aims at integrating data resources related to media, especially those used on the Web.	W. Lee, T. Brger, F. Sasaki, V. Malais, F. Stegmaier, J. Sderberg	W3C	2010	OWL

Table 3.2: General comparison of ontologies related to multimedia aspects.

Ontology	Description	Authors	Owners/Project	Year	Language
Shape and Image Ontologies					
SAPO	Creation and processing digital shapes.	Marios Pitikakis	AM@SHAPE	2007	OWL Full
DIG 35	Ontology for describing metadata for digital images.	Raphael Troncy + Ughent University		2007	OWL Full
MIRO	The ontology models concepts and relations covering various aspects of the digital media domain. It defines concepts including image, video, video frame, region, as well as relations such as depicts, regionOf, etc.	Halaschek-Wiener et. al.		2005	OWL Full
MSO	It combines high-level domain concepts and low-level multimedia descriptions, enabling for new media content analysis.	Kosmas Petridis., et al.	aceMedia	2005	-
VRA Core 3_SIMILE	Visual Resource Association (Version SIMILE)	Andy Seaborne	SIMILE Project	2003	RDFS
VRA Core 3_Assem	Visual Resource Association (Version Assem)	Mark van Assem	MultimediaN project (Cultural Heritage Community)	2005	
Audio and Music Ontologies					
Music Ontology	The Music Ontology Specification provides main concepts and properties for describing music (i.e. artists, albums and tracks) on the Semantic Web.	Frederick Giasson Yves Raimond		2010	RDF
Kanzaki Music	A vocabulary to describe classical music and performances.	Kanzaki		2003-2007	OWL DL
Music Recommendation	Recommending music to a user, depending on the user's musical tastes and listening habits.	Oscar Celma	Universitat Pompeu Fabra /SALERO	2006	OWL DL

Table 3.3: General comparison of ontologies related to Shape, Image, Audio and Video aspects.

Ontology	Description	Authors	Owners/Project	Year	Language
Application Ontologies					
AEO	Domain Ontology for Athletic Events.	Boemie project		2008	OWL DL
MEPCO	Automate to a large degree the detection and tracking of media campaigns on television, Internet and in the press.	MediaCampaign		2006	RDF
VHO	Organizes the knowledge and data of three main research topics and applications involving the virtual representations of humans.	Marios Pitikakis	AM@SHAPE	2007	OWL Full

Table 3.4: General comparison of ontologies related to application aspects.

Chapter 4

Searching Multimedia Ontologies

In this chapter, we firstly present an overview of the most popular Semantic Web Engines (SWEs) used to find semantic documents. After, we proceed to perform a comparative study to choose the most appropriate SWE for searching MM ontologies based on a set of terms obtained from the Functional Requirements identified in the context of the Buscamedia Project. The results of the searching activity is presented in various tables showing the MM candidate ontologies classified by the aforementioned terms related to the Multimedia domain.

4.1 Semantic Web Engines

Semantic Web (SW) search engines are applications for finding semantic documents: queries are usually written using natural language keywords and results are ranked. Some additional information (e.g., metadata, ranking, file type and size) is often provided[1]. The features of a search engine in SW are: a tool that automatically collects, analyses and indexes ontologies and semantic data available online to provide efficient access. SWEs could also be used as a semantic discovery of knowledge at run-time.
In this section, we describe the five most used SWEs to find semantic documents, that are the following: Swoogle, Watson, Sindice, Falcons and the Semantic Web Search Engine. Apart from the abovementioned SWEs, some other existing semantic web engines also aim at providing efficient access to ontologies and semantic data online. It is worth mentioning OntoKhoj [Chi03] (an ontology portal which crawls, classifies, ranks and searches ontologies); Oyster [PHGP06] (focused on ontology sharing in a peer-to-peer network of local registries); OntoSelect [SM06] (an ontology library to access ontologies by means of natural language) and MultiCrawler

[1] http://esw.w3.org/Ontology_Dowsing

[HDU06] (focused on discovering, exploring and indexing structured data in the Web). However, they have not being studied in this document.

4.1.1 Swoogle

Swoogle is a SWE based on "Web view" and relies on the classical web search engine [Din05] because it is inspired by classical Web search engines. Thus, one of the mayor limitation is that it ignores the semantic particularities of the data indexed. The three principal elements underlying Swoogle are the following:

1. **Considering only the explicit relations**: Swoogle considers simple and declared relations, such as imports, it does not take into account implicit relations among pieces of knowledge, such as equivalence, inclusions and versions. For that same reason, there is no syntactic or semantic ontology duplicate checking. Consequently, it is usual to find the same ontology several times with different ranking measures.

2. **Weak notion of semantic quality**. Swoogle uses a PageRang-like algorithm to order its results, opting for measuring the popularity of an ontology. However, for ontolgy developers reusing o exploiting ontologies; the quality of the ontologies can be as important as their popularity.

3. **Weak access to semantic content**. Querying facilities are limited to keyword based search (plus a pre-canned queries offered via Web services).

Swoogle's architecture, as shown in Figure 4.1, is composed of four major components: SWD discovery, metadata creation, data analysis, and interface.

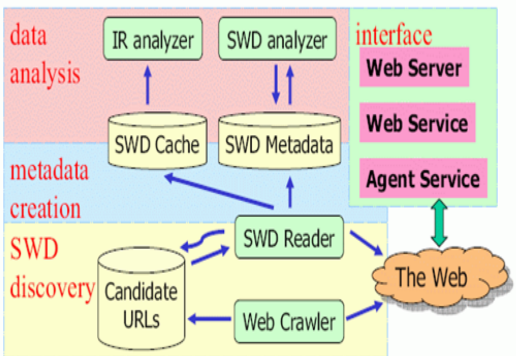

Figure 4.1: Swoogle Architecture [Din05]

4.1.2 Watson

Watson design aims at providing a system based on assumptions valid for the Semantic Web [SDB07]. Its design is focused on three mayor principles:

1. **Making implicit relations** between ontologies explicit to apply a wide range of analysis tasks (e.g., detect duplications) to process, compare and relate semantic documents.

2. **Semantic quality**: To provide information about ontology quality is crucial for a relevant access by users and applications. It implies a validation process useful for understanding the content of the Semantic Web based data, e.g., the expressivity of the employed ontology language, the level of axiomatization, etc.

3. **Provide rich, semantic access to data**: The search engine supports a variety of different applications that can require an access, depending on the level of formalization of data required. This feature takes into account a wide range of access mechanisms that combine various specifications, ranking measures and interfaces, integrating also results from the fields of ontology selection, ontology evaluation and ontology modularization.

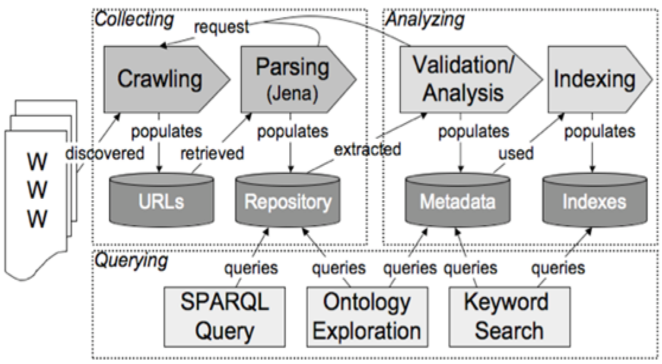

Figure 4.2: A functional overview of the main components of the WATSON architecture [SDB07]

Watson[2] gateway plays three main roles, as depicted in Figure 4.2:

- (i)- It collects the available semantic content on the Web: ontology crawling and discovery, in particular by exploring ontology based links.

[2]http://kmi-web05.open.ac.uk/WatsonWUI/

- (ii)- It analyzes the semantic content to extract useful metadata and indexes: this is performed by the validation and analysis layer that ensures that data about the quality of the collected semantic information is computed, stored and indexed,

- (iii)- It implements efficient query facilities to access the data, which is supported by the query and navigation layer that grants access to the indexed data through a variety of mechanisms that allow exploring its various semantic features.

The crawling layer of WATSON relies on Heritrix[3], the Internet Archive's Crawler. It has a way of comparing ontologies semantically, abstracting them from their serialization, the employed language and syntax. WATSON supports keyword-bases query, similar to Swoogle, and a limited subset of SPARQL expressivity. Sabou et al. [SDB07] point out that their experiments indicate that the *sparseness of knowledge on the Web often makes it impossible to find a single, all-covering ontology but that several ontologies can jointly cover the query terms.*
In Watson approach, topic domains and the sets of terms that define them are established by using the 17 top level categories of the Open Directory Project Web catalogue[4]. The approach also considers that an ontology belongs to a topic domain if the local names of its classes are the same of the defining terms for that domain, and a mapping between ontologies and topic domains is done afterwords.

4.1.3 Sindice

Sindice[5] allows property-value pair look-up to find documents knowing a property of an object, and also allows keyword-based RDF document and MICROFORMAT search. In fact, what Sindice does is to collect RDF documents from the Semantic Web and to index them using URIs, Inverse Functional Properties (IFPs), and keywords [DO08]. It was designed not as a end-user application, but as a service to be used by decentralised Semantic Web client application to locate relevant data sources. The results of the search is ranked in order of relevance. The approach in Sindice to index RDF documents is through information retrieval techniques, where all identifiers and literal words are indexed in the graph to allow lookups over them, and return pointers to sources that mentioned these terms. The overall architecture of Sindice is shown in Figure 4.3

[3]http://crawler.archive.org
[4]http://www.dmoz.org
[5]http://sindice.com/

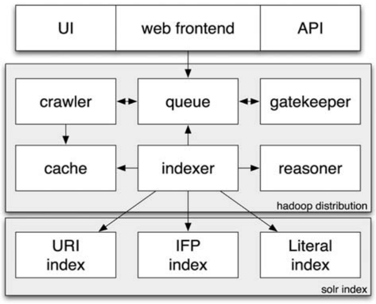

Figure 4.3: Sindice architecture [DO08]

4.1.4 Falcons

Falcons[6], which stands for **F**inding, **A**ligning and **L**earning ontologies, ultimately for **C**apturing knowledge via **ON**tology-driven approaches, is a keyword-based search engine for the Semantic Web. Falcons provides keyword-based search for URIs identifying objects, concepts (classes and properties), and documents on the Semantic Web. In Falcons object search, keywords objects search and boolean queries are supported. In the results page, for each object or class/property, it is provided its title (label or local name), URI, types, and a snippet consisting of its RDF descriptions hit by the keyword query. Concept search allows entering keywords about a class or a property. Besides, document search is another feature that retrieve RDF triples in the document hit by the keyword query [QC09] . Falcons parses RDF/XML documents using Jena, stores data in MySQL, and indexes data using Apache Lucene. Figure 4.4 gives an overview of the Falcons architecture.

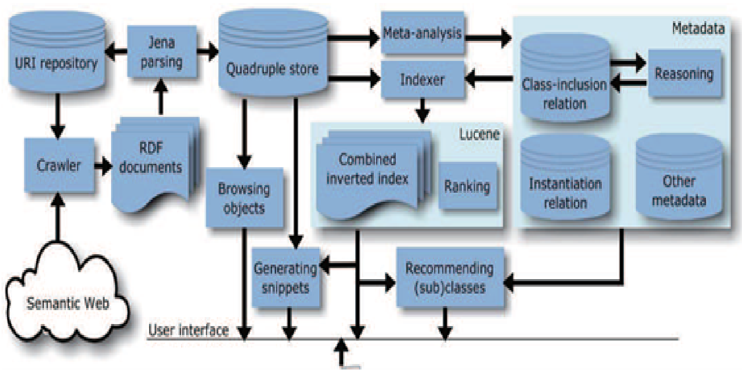

Figure 4.4: Falcons system architecture [QC09]

[6]http://ws.nju.edu.cn/falcons/

4.1.5 SWSE: Semantic Web Search Engine

SWSE [HH07] is a keyword-based Semantic Web search engine that adpats the PageRank algorithm to Semantic Web data by combining ranks from the RDF graph with ranks from the data source graph. SWSE focus on Web-sale object search. Indeed, the realisation of SWSE has implied two major research challenges: the system must scale to large amounts of data, and must be tolerant to heterogeneous, noisy, and possibly conflicting data collected from a large number of sources. The authors claim that the Semantic Web standards and methodologies are not naturally applicable in such an environment; and show by their approach that standard SemanticWeb approaches can be tailored to meet these two callenging requirements, often taking cues from traditional information retrieval techniques. SWSE contains components for crawling, ranking and indexing data; as it contains also some other components specically designed for handling RDF data. SWSE performs semantic integration of structured data: not only from the Web but also from monolithic data sources such as XML database dumps, large static datasets and even live sources [HHRU07]. Figure 4.5 presents the architecture of the Semantic Web Search Engine.

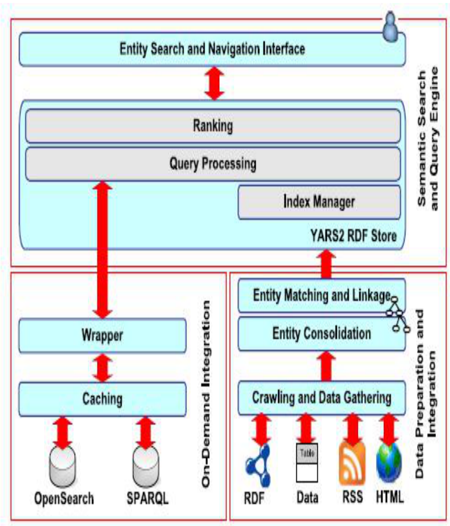

Figure 4.5: Semantic Web Search Engine architecture [HHRU07]

4.2 Selection of the SWE for MM Searching

One of the difficult task for an Ontology Engineer in the reuse ontology process is to decide which Semantic Search engine to use for obtaining an efficient result in the search of ontologies. As we present in Section 4.1, there are five well-known and tipically used SWSEs in the literature. The main question here is how to know what are the criteria to choose one Semantic search engine given the problem of searching ontologies in a particular domain. In the literature, there are no guidelines helping ontology developers to decide between SWSEs. Guidelines proposed here could potentially help ontology designers in taking such a decision. Consedering the previous analysis, we can divide SW search engines in 3 groups:

- **Ontology-oriented Web engines:** Swoogle, Watson.
- **Triple-oriented Web engines or RDF-oriented:** SWSE, Sindice.
- **Hybrid-oriented Web engine:** Falcons

.

Also, a rapid observation while experimenting the use of the abovementioned engines is that there is not a clear separation between ontologies and RDF data coming from blogs and DBPedia[7]. Hence the task of finding ontologies among other semantic resources is time consuming, as it is performed manually.

As far as our work is concerned, we had to choose between Swoogle and Watson. They both permit RDF and ontology document search and we classify them as ontologies oriented Web engines. We have carried out a comparative study of these engines. We have then performed a practical experiment of searching ontology using five terms (image, multimedia, audio, music style and format) extracted from the CQs. The criteria used for the selection are the following:

- *The total number of documents retrieved (T)* for a specific keyword search;
- *The number of OWL documents per each 10 documents (OWL)*[8]; that we extrapolate to compute an average ratio;
- *A valoration* of the retrieval results using the symbols (+) and (-) of the result. We set to (+) if there are more than 2 OWL files per page, and (-) otherwise.

The terms used for the experiments are: Image, Multimedia, Audio, Music Style and Format; taken from the ORSD document. We present the results in table 4.1.

Based on the results, Swoogle has both good valoration and better average percentage of OWL documents per results pages. Thus, we choose Swoogle for the searching activity. Of course, we can not generalise the present results to all other domains. However, we recommend such a study for decision making concerning Semantic Search engines in the selection activity in the ontology reuse process. For this reason we are now working in a more general comparative study of Semantic Search engines (as we mention in Chapter 7).

[7]http://dbpedia.org/
[8]Minimal Number of documents retrieved per page[9] by SWE

SWE	Watson			Swoogle		
Terms/Criteria	T	OWL	Valoration	T	OWL	Valoration
Image	7051	1(10%)	-	3022	2(20%)	+
Multimedia	651	2(20%)	+	978	4(40%)	+
Audio	1774	0	-	707	3(30%)	+
Music Style	1063	3(30%)	+	60	3(30%)	+
Format	1906	1(10%)	-	4307	4(40%)	+

Table 4.1: Watson vs Swoogle selection

4.3 Searching ontologies based on requirements

Our activity of searching MM ontologies is applied for implementing a multimedia ontology network, called M3, within the Spanish project Buscamedia[10] (Hacia una adaptacion semantica de medios digitales multirredmultiterminal). This project aims at providing a real multimedia semantic search engine, which is based on a new ontology defined within the project (the M3 ontology: multilingual, multidomain, and multimedia). This searching activity is based on a set of Functional and Non-Functional Requirements to fulfill, which are presented in the appendix section of this document (Appendix A). From the ORSD document, we have 17 accepted CQs (which are presented in Appendix A), from those CQs we extract the pre-glossary of terms presented in Table 4.2 where each term is associated with frequency of appearence in the ORSD. Besides, some objects are also identified: *Estilo de música, modelo YUV, fotografía, dibujo, and imágenes prediseñadas*[11].

CQ terms	**Frequency**
Musica	1
Formato	5
Audio	1
Video	2
Texto	1
Imagen	5
Voz	3
Modelo 3D	1
Multimedia	2

Answers terms	**Frequency**
Formatos audio	30
Formatos video	14
Formatos imagen	13
Formatos texto	11
Formatos 3D	12
Cromatica	2
Formato europeo, americano	1

Table 4.2: Preglossary of Multimedia Terms

[10] http://www.cenitbuscamedia.es

[11] Obviously, all the documents generated for the project are in Spanish, reason why these words also are not in English.

For this activity, Swoogle is used as SW search engine, and the keywords are manually translated to English as shown in Table 4.3, to make it possible the retrieval of relevant results.

CQs Terms- In Spanish	**Keywords for searching- In English**
Música	Music, Sound, Reggae Music, Music Rights, Hip Hop
Audio	Audio
Película	Movie, Video Clip, Audio Visual
Gráfica	Graphic, Shape
Formato texto	Text Format
Estilo de música	Music Style

Table 4.3: Preprocess translation of CQs to English

After performing the query using terms and some of their combinations, Swoogle gives us results for each of the terms queried. In the results pages, documents can be RDF, RDFS, DAML or OWL. And sometimes, URI are duplicated and URL broken. Therefore, it is necessary to perform a **filtering activity** consisting of the following tasks:

- Go through each results pages;
- Find out OWL file and check if the URI/URL is not broken. That is to check if the ontology is available to download;
- Retain the ontology if and only if it is not a General or Common ontology[12].

Hence, from the abovementioned tasks, we found a total of 30 candidates multimedia ontologies shown in Table 4.4, and Table 4.5; grouped by the terms (or combination of the terms) used to make the queries.

The classification of the candidate ontologies in the two tables [Table 4.4 and Table 4.5] depends on the scope of each ontology. So, the categories (e.g., Music, Movie, Shape, camara motion) are the result of the identification of the scope of the ontologies attached to them. This analysis suppose a previous download and opening of the ontologies to be classified. Concerning the disponibility of the ontologies, all of them where easily accessible online and for free. However, problems sometimes have occured when trying to open them in an ontology editor for the classification analysis. We had identified three ontologies that gave us "error" while opening them with two differents ontology editors[13]: UNSPC Code, Andrei ontology and CERIF ontology.

[12]General ontologies or Common ontologies are normally based on philosophical theories used to formalize knowledge, such as the mereology theory, the topology theory and the time theory [SF10]

[13]The editors used to open were Protg and the Neon Toolkit

Name	**Link**
Music	
UNSPSC Code	http://www.ksl.stanford.edu/projects/DAML/UNSPSC.daml
Kanzaki Music	http://www.kanzaki.com/ns/music
Sound	http://dublincore.org/2008/01/14/dctype.rdf#Sound
Movie DB	http://139.91.183.30:9090/RDF/VRP/Examples/moviedatabase.rdf
MySpace artist	http://grasstunes.net/ontology/myspace.owl (2 Classes-Not relevant)
Music Onto.	http://pingthesemanticweb.com/ontology/mo/musicontology.rdfs
Music Onto.	http://moustaki.org/resources/musicontology.rdfs
Music Rights	http://aperture.sourceforge.net/ontology/nid3.rdfs
Open Drama	http://rhizomik.net/ontologies/2004/11/OpenDrama.owl
SSUN	http://www.csd.abdn.ac.uk/ ggrimnes/tmp/ssun.rdfs
Movie, Shape	
Shape Rep.Onto	http://vrlab.epfl.ch/~alegarcia/OWL/shapeOntology_v2.3.1.owl
Onto. Audiovisuel	http://homepages.cwi.nl/~troncy/DOE/ontologies/Audiovisuel-v0.4.daml (in French)
Camera motion	
Device Onto.	http://164.125.36.51/ontology/Fileformat.owl
MPEG7 Onto.	http://www.image.ece.ntua.gr/~gstoil/VDO/MPEG7Ontology.owl
Camera Onto.	http://www.co-ode.org/ontologies/photography/photography.owl
Image Creation	http://multimedialab.elis.ugent.be/users/gmartens/Ontologies/
Mp3	
Andrei Onto.	http://derpi.tuwien.ac.at/~andrei/ontology/MultimediaS.rdfs

Table 4.4: I-Candidate multimedia ontologies

Figure 4.6 gives an overview of the tasks done in this activity of domain searching. The details of this searching tasks are the following:

- In the first step, CQs terms are translated to English. And from each term translated, generate a suitable combination of terms "similar" to the term. The ouput of this step is a set of all possible terms to be queried.

- The next step is to query each of the terms obtained in the previous step using Swoogle. For each results page, search for OWL documents that can be download for assessment and that are not general ontologies. Each "relevant" ontologies is reported in a table and dynamically updated from the any new coming ontology.

- The final step is to build the candidate ontologies table. The generated table is formed by the set of candidate ontologies grouped by the terms used for the

Name	**Link**
	Multimedia
Mindswap	http://www.mindswap.org/˜glapizco/technical.owl
Dolce and Dns	http://multimedia.semanticweb.org/COMM/dolce-very-lite.owl (Generic ontology)
CERIF Onto.	http://derpi.tuwien.ac.at/˜andrei/cerif.rdfs (failed to open in Protege and Neon)
ATC Onto.	http://www.weblab.isti.cnr.it/projects/ATC/ontologies/PICO1.owl (in Italian)
MPEG7 MDS	http://polysema.di.uoa.gr/ont/mds.owl (ontology for the MPEG-7 MDS)
Histemm Onto.	http://www.historiographus.org/owl/histemm.owl
M3O.	http://m3o.semantic-multimedia.org
Media Onto.	http://dev.w3.org/2008/video/mediaann/mediaont-1.0/
	Image, Jpeg
Exif DDV	http://www.w3.org/2003/12/exif/ns (Exif data description vocabulary)
VraCore 3 Simile	http://simile.mit.edu/2003/10/ontologies/vraCore3
Exif Kanzaki	http://www.kanzaki.com/ns/exif (Exif data vocabulary from Kanzaki)
Nokia DP-1.26	http://sw.nokia.com/schemas/nokia/DP-1.26.owl (Nokia Device Profile Ontology)
Nokia DP-1.27	http://sw.nokia.com/schemas/nokia/DP-1.27.owl
Nokia DP-1.28	http://sw.nokia.com/schemas/nokia/DP-1.28.owl
Exif Kanzaki	http://aperture.sourceforge.net/ontology/nexif.rdfs (From Kanzaki)
Exif DFKI	http://www.dfki.uni-kl.de/˜sauermann/2007/08/nie/output/exif.rdfs

Table 4.5: II-Candidate multimedia ontologies

queries.

4.4 Problems and Lessons learned

The task of searching using the Semantic Web engine has some drawbacks that is worth mentioning in this section. Some of the drawbacks and lessons learned while performing the searching activity are the following:

- The uncertainty to know when to use the right combination of terms to retrieve relevants ontologies.

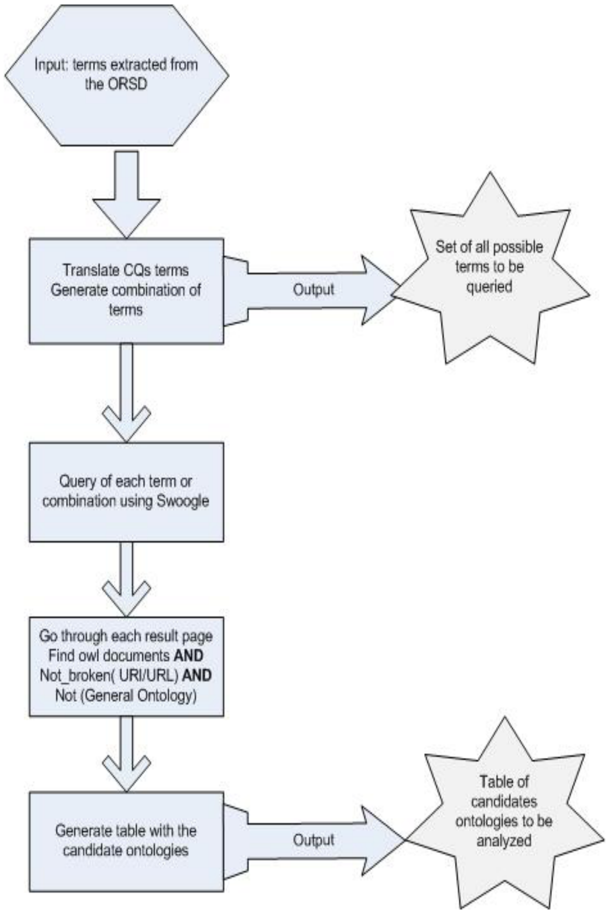

Figure 4.6: Tasks for searching multimedia ontologies.

- The difficulty of parsing all the results manually and inspect each URI/URL to know whether it is broken or no. Hence, it is a time consuming task.
- Some of the ontologies retrieved were differents versions of the the same ontology (e.g, Nokia Device Profile). Therefore, the versioning problem of how to consider which ontology is the most appropriate to be analyzed and/or reused.
- The developer should be very patient during the activity to guaranty its success. One of the frustrating aspect here is when many queries use some combination of terms do not give successfull results or even no result at all. The developer should be aware of that and continue trying with other possible combinations.
- The query task should be carry out in different period of times. This can be useful to check if a particular URI/URL is temporaly down.

In this process of selecting ontologies for multimedia using Swoogle, it was not possible to retrieve some of the "importants/relevants" ontologies in the domain, which were described in Section 3. Comparing the two lists of ontologies (the one obtained from Swoogle and the other obtained from the state-of-the-art), the results were the following:

- *Number of ontologies retrieved:* From Swoogle, we retrieve 23 ontologies, while in the state-of-the-art, we had 20 ontologies. Thus, there were more ontologies retrieved using Swoogle.
- *Ontologies present in both sides:* there were only three ontologies (CSO, Vra Core 3 and Kanzai Music) presented both in the literature and using Swoogle.
- *Unfication process:* It was necessary to unify the two lists result for the ontologies assessment. Theorically, it was expected a list of 40 ontologies, but 32 (80%) were the final list of ontologies, obtained after eliminating duplicated URIs.

Hence it is important the "unification" process of the results of this searching activity , taking into consideration the revision of the state-of-art in the multimedia domain. Therefore, it is of higher importance (a) to gather information from any publication in the domain of multimedia, (b) to browse webpages of projects related to multimedia, (c) to find out if there are initiatives at the level of the World Wide Web Consortium(W3C)[14], and (d) to contact authors -if necessary- to obtain the ontologies they built when they are not accessible. We have presented in Table 4.4 and Table 4.5 the tables obtained after the unification of both studies.

4.5 Conclusion

We have presented in this chapter an overview of the Semantic Web Search Engines, principally the most popular (Swoogle, Watson, Sindice, Falcons and SWSE). After the overview, we explain the process we have followed to choose Swoogle to search ontologies using keywords from the ORSD document. The choice of Swoogle was based on the mayor number of MM ontologies retrieved, the relevance based on some precise criteria dicussed in Section 4.2 and the convenience presentation of the results, in comparison with others Semantic Web Search engines. The approach used for the comparative study of the Semantic Web engines was targed to the multimedia domain. We believe that such a study should be extended to any domain with much more general criteria for the selection of Semantic Web engines. The results of the searching process were listed in differents tables, grouped by their scope such as

[14]http://www.w3.org

Multimedia, Image/Shape, Audio, Video, Music, etc. The output of this searching part is used as input for the Chapter 5 which is all about the analysis activity. Finally for a future work, we plan to (semi) automatize the process of filtering the ontologies retrieved from the page results of the Semantic Web engines to speed up the time spend in selecting "relevants" candidates ontologies for their reuse. We have also observed in this chapter that some relevants ontologies in MM domain are were not retrieved by the SWSEs. To address this issue, we need to merge the ontologies obtained from the state-of-art with the results obtained by the SWSEs. For future works, we plan also to solve this problem by providing way of gathering all the potential candidate ontologies for a domain.

Chapter 5

Assessing Multimedia Ontologies

This chapter deals with the assessing activity of the candidate ontologies found in the search. We show here an application of the Neon Methodology in the reuse process. This activity is a deeper analysis and code checking to evaluate the quality of the ontologies. To perform this analysis we propose first a comparative framework based on the criteria similar scope, similar purpose, Non-Functional Requirements covered and Functional Requirements covered. This framework will help ontology developer to better understand the candidate ontologies as well as to be informed of the knowledge resources that have been reused in the candidate ontologies. In addition, this framework could be as basis for carrying out the analysis of the candidate ontologies with respect to the requirements.

5.1 Comparative Framework for MM Ontologies

We propose a comparative framework which can guide the ontology designer in the activity of analysis. This framework is based on: (1) which particular multimedia features (multimedia content, audio/music, video, image, visual and audiovisual) are covered by an ontology, and (2) whether the ontology was developed by reusing any knowledge resource (ontologies, ODPs and Non Ontological Resources NORs). In Table 5.1 and Table 5.2 we present the results of manually analyzing the candidate MM ontologies with respect to the comparative framework. These results help the ontology developer to understand the fields covered by each ontology, as well as how the ontology development was performed.

In addition, it is straightforward to derive the following observations:

1. There are a few number of ontologies that cover audiovisual and broadcasting news. Probably because there are not many standards for that specific area or just because there is not yet any interest.

2. Visual part in multimedia almost refers to Visual Description Schema of MPEG-7 standard. Hopefully, Visual Resource Elements are used by the Cultural Heritage Community to help save painters works.

3. Audiovisual ontologies do not necessary cover both audio and video. It happens only when the ontology used MPEG-7 as non ontological resource to implement the ontology (e.g., MPEG-7_Hunter). Besides, MEPCO is the only ontology which does not make use of MPEG-7, but rather standards dedicated to broadcasting (e.g., NewsML).

4. Audio and Music ontologies are classified in the same category, although they could have different and separate target usage.

5.2 Analysis based on Requirements

This analysis is manual and consists of checking whether the ontology fulfill the following: scope, purpose, non-functional requirements and functional requirements. That is , having the ORSD document of the project (presented in Appendix A), we "scan" one by one each candidate ontology to see how near or far it is from what we want to model in the M3 ontology. Hence, come out with the most useful and appropriate to be reused. To perform this analysis, we have followed the following actions proposed in the NeOn Methodology [SF10]:

- **Action 1.** To check whether the scope and purpose established in the ORSD are similar to those of the candidate domain ontology.

- **Action 2.** To check whether non-functional ontology requirements established in the ORSD are covered by the candidate domain ontology.

- **Action 3.** To check whether functional requirements in the form of CQs included in the ORSD are covered (totally or partially) by the candidate domain ontology. This checking has been performed with the following approach: "analyzing if the essential terms for the new ontology development appear in the candidate domain ontology to be reused".

To improve the methodological guidelines provided by the NeOn Methodology [SF10], we propose in this Master Thesis a clear procedure to perform Action 3 (that is, to check whether functional requirements in the form of CQs included in the ORSD are covered (totally or partially) by the candidate domain ontology).

The ORSD file comes with a set of Functional Requirements to be fulfiled by the ontology. The document has three columns: CQ identificator, the CQ itself and the answer for that CQ. To check if an ontology fits the requirements, we use the following procedure in a manual way:

```
0  Function CQfitOntoHeuristic (input: CQs, Onto): [setOfCQID]
1  begin
2  setOfCQID ={}
3  Open Onto with NeonToolkit
4  Open CQS
5  loop
6  for each CQi
7  RelevCat=detectrelevantCategories();
8  MatchCategories(Onto, RelevCat, CQi);
9  If true set setOfCQID = setOfCQID Union {CQi}
10 end loop
11 Return setOfCQID
12 End
```

Procedure Explanation

- *Line 0:* We need as input two objects: the competency questions (CQs) and one ontology selected from the searching activity. The result is a set of CQs identifiers that cover the given ontology.

- *Lines 1-2*: Initialize the set of CQs identifiers to empty.

- *Line 3:* Open the ontology to analyze in the Neon Toolkit editor[1].

- *Line 4:* Open also the document with the list of Competency Questions. You could also consider the possibility to print it and have it at hand for a practical convenience.

- *Lines 5-7:* For each CQs, detect the relevant categories[2] and create a list of "Relevant Categories" (RelevCat). Those categories are subset of the terms in the "Questions" and "Answers" columns of the CQs document. Indeed to identify these categories we should obtain all the noun both in the questions and the answers. For example, let us consider the following question: "What are Audio Format", with the answer: "AVI, MP3"; Relevant Categories is formed by RelevCat=Format, Audio, AVI, MP3.

- *Lines 8-11:* The matching task consists of finding for each term of the relevant categories, if it is present in the ontology as a class or an individual. If there is

[1]http://neon-toolkit.org/wiki/Main_Page

[2]A category refers to a noun or term present in a CQ line.

any, the function returns "*True*" and the corresponding CQ identifier is added in the set of CQs, hence it is an update operation. The process continue until the end of the CQs list. Finally, the list of identifiers builded in Line 9 is returned as the function result.

Figure 5.1 gives a visual representation of the procedure used to analyze which competency questions are covered by the candidate ontologies. After analysing the set of candidate ontologies according to the abovementioned criteria, we have obtained the assessment table (Tables 5.3, 5.5 and 5.5), where SS stands for /Similar Scope/, SP means /Similar Purpose /, NFRC for /Non-Functional Requirements Covered /and finally FRC is /Functional Requirements Covered/.

To decide whether a candidate ontology is not useful, the following heuristic has been taken into account:
For a particular candidate domain ontology, if the ontology developer has answered /No/ to the criteria Similar Scope and/or Similar Purpose and/or Functional Requirements covered, then the candidate ontology should be considered not useful, and thus, it should be eliminated from the set of candidate ontologies. Therefore, the "useful" ontologies obtained are the following:

- *"Useful" ontologies from SWEs:* We have obtained 14 ontologies which are: Kanzaki Music, Music Ontology, Music Rights, MPEG7 MDS, Exif DDV, VraCore3 Simile, Nokia DP-1.26, Nokia DP-1.27, Nokia DP-1.28, Shape Representation Ontology, Device Ontology, MPEG7 VDO and Camara Ontology.
- *"Useful" ontologies from the literature:* We have obtained 12 ontologies which are: COMM, MPEG7_Hunter, MPEG-7x, SAPO, DIG35, CSO, AceMedia VDO, VRA Core3_Assem, Boemie VDO, Music Ontology, M3O and Media Ontology.

Some observations and comments should be made with respect to the requirements we are dealing with. From 32 ontologies analyzed; *four* ontologies give us errors while opening them using either NeOn or Protégé[3]; *one* ontology was tagged to be non-relevant because of the number of classes (only 2). Besides, in *ten* of them it was not possible to identify exactly if they were of the same purpose[4], whereas the same situation occurs with three of them with respect to the Functional Requirements Covered (FRC). However, one positive point in this latter feature is that five ontologies (Nokia, Device Ontology, M3O and MPEG7 MDS) have a highest number of FRC. It is obvious that we were not expectig a full covered of FRC by a given ontology. We give a small summary of this situation in form of percentage in Table 5.6.

[3]http://protege.stanford.edu/

[4]The principal function of the abovementioned 10 ontologies is to describe semantically resources and multimedia contents.

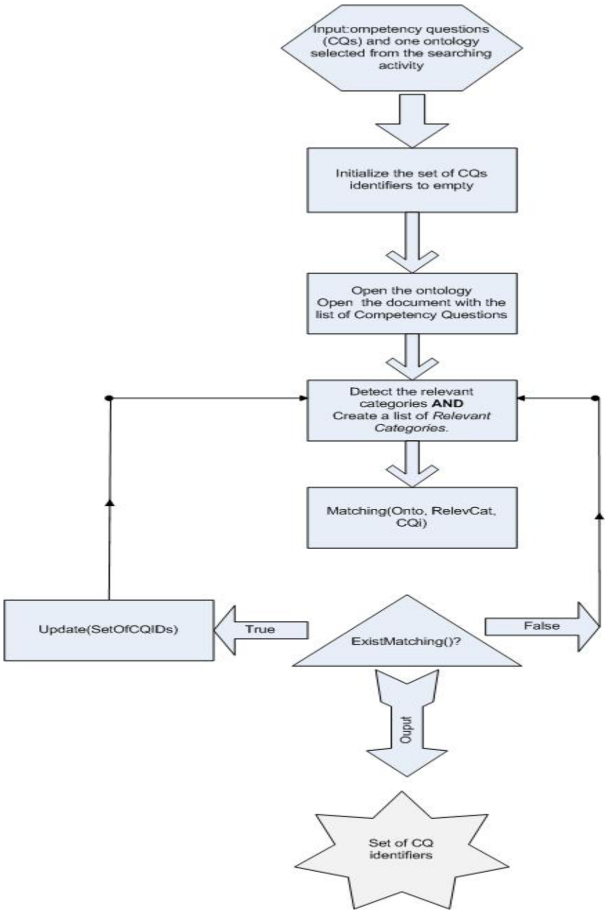

Figure 5.1: Procedure for analyzing CQs with candidate Ontologies

5.3 Conclusion

In this chapter, we have presented how practically we have analysed each of the ontologies for a deeper comprehension and evaluation for their possible reuse in the upcoming activity. We have also proposed a framework that could be useful to the engineer ontology developer, as a complementary of the NeOn Methodology guideline related to the analyzing activity. From this ontology assessment, we have obtained 23 "useful" ontologies that are the input for the selecting the most appropriate ones for the M3 ontology. In Chapter 6, we will rank the ontologies based on a set of criteria and the best scored ontologies will be integrate for reuse in M3 ontology. Finally, for future works, we pretend to automate the process of checking whether an ontology fits the Competency Questions.

	Fields Covered						Resource Reused	
Ontology Name	Multimedia	Audio	Video	Image	Visual	Audiovisual	Onto.Reuse	NOnto.Reuse
Multimedia								
COMM	Yes	Yes	No	Yes	No	No	DOLCE, DnS, IO	MPEG-7
MPEG-7x	Yes	Yes	Yes	Yes	No	Yes	Mpeg-7_Hunter	MPEG-7
MPEG-7_Hunter	Yes	Yes	Yes	Yes	No	Yes	N/A	MPEG-7
MPEG-7_Tsinakari	Yes	Yes	No	Yes	Yes	No	N/A	MPEG-7
MPEG-7_Rhizomik	Yes	Yes	No	Yes	Yes	No	N/A	MPEG-7
SWIntO	Yes	(*)	Yes	Yes	No	No	DOLCE, SUMO	MPEG-7
Media Onto.	Yes	Yes	Yes	(*)	No	(*)	DULCE	N/A
M3O	Yes	Yes	Yes	Yes	No	(*)	N/A	SKOS
Shape and Image Ontologies								
SAPO	No	No	No	Yes	Yes	No	N/A	N/A
DIG 35	No	(*)	No	Yes	No	No	N/A	IIA
MIRO	No	No	Yes	Yes	No	No	N/A	N/A
MSO	Yes	No	Yes	No	(*)	No	DOLCE	MPEG-7(MDS)
CSO	No	No	(*)	Yes	Yes	No	N/A	N/A

Table 5.1: I-Specific comparison of ontologies related to multimedia aspects. Legend: (*) stands for "*cover more or less the domain*"

Ontology Name	Fields Covered						Resource Reused	
	Multimedia	Audio	Video	Image	Visual	Audiovisual	Onto.Reuse	NOnto.Reuse
Visual Resource Ontologies								
AceMedia VDO	No	No	Yes	Yes	(*)	No	DOLCE Extension	MPEG-7
VRA Core 3	No	No	No	Yes	Yes	No	N/A	VRA Element Set
Audio and Music Ontologies								
Audio Ontology	No	Yes	No	No	No	No	Time, TimeLine, Event, FOAF	ABC Data Model
Kanzaki Music	No	Yes	No	No	No	No	N/A	N/A
Music Recommendation	No	Yes	No	No	No	No	FOAF	RDF Site Summary (RSS)
Application Ontologies								
AEO	Yes	(*)	(*)	(*)	Yes	(*)	GIO	TeleAtlas DB, IAAF, MPEG-7
MEPCO	No	No	No	No	No	Yes	PROTON	NewsML, News Codes
VHO	No	No	(*)	Yes	Yes	No	CSO	N/A

Table 5.2: II-Specific comparison of ontologies related to multimedia aspects. Legend: (*) stands for "*cover more or less the domain*"

	Criteria			
Ontologies	**SS**	**SP**	**NFRC**	**FRC**
UNSPSC Code	Error while opening the file			
Kanzaki Music	Unknown	Yes	Partially [NFR5,9]	Partially [PC14]
Sound	Yes	Unknown	Partially [NFR5,9]	No
Movie DB	Unknown	Yes- (movie)	Partially [NFR5,9]	No
Music Onto.	Unknown	Yes	Partially [NFR5,9]	Partially [PC14]
MySpace artist	Not relevant. Only 2 classes: *SpatialThing* and *Point*.			
Music Rights	Unknown	Yes	Partially [NFR5,9]	Partially [PC2]
Open Drama	Yes	Yes	Partially [NFR5,9]	Partially [PC2,14]
SSUN	Error while opening the file			
Mindswap	Yes (Actuality)	Yes	Partially [NFR5,9]	–
Dolce & Dns	No	Unknown	Partially [NFR1,9]	Unknown
CERIF Onto.	Error while opening the file			
ATC Onto.	Unknown	Unknown	Partially [NFR5,9]	No
MPEG7 MDS	Yes	Yes	Partially [NFR4, 9]	Partially [PC2,3, 4]
Histemm Onto.	No	No	Partially [NFR5, 9]	No
Exif DDV	Yes	Yes	Partially [NRF9]	Partially

Table 5.3: Candidate MM ontologies analysis I

	Criteria			
Ontologies	**SS**	**SP**	**NFRC**	**FRC**
VraCore3 Simile	Unknown	Yes	Partially [NFR5,9]	Partially [PC18, 21]
Exif Kanzaki	Yes	Yes	Partially [NFR3,9]	No
Nokia DP-1.26	Yes	Unknown	Partially [NFR3,4,9]	Partially [PC2,3, 4,6]
Nokia DP-1.27	Yes	Unknown	Partially [NFR3,4,9]	Partially [PC2,3,4,6]
Nokia DP-1.28	Yes	Unknown	Partially [NFR3,4,9]	Partially [PC2,3,4,6]
Exif Kanzaki	No	Unknown	Partially [NFR5, 9]	Unknown
Exif DFKI	No	Unknown	Partially [NRF9]	Unknown
Andrei Onto.	Error while opening the file			
Shape Rep.Onto	Yes (Shape)	Yes	Partially [NRF5,9]	Partially [PC18]
Onto. Audiovisuel	Yes (Audio-visual)	Yes	Partially [NRF2,4,5,9]	No
Device Onto.	Yes	Unknown	Partially [NFR3,4,9]	Partially [PC2,3,4,7]
MPEG7 VDO	Yes	Yes	Partially [NFR5, 9]	Partially [PC19,20]
Camera Onto.	Yes	Yes (Photography)	Partially [NFR3,9]	Partially [PC18,19]
Image Creation	No	Unknown	Partially [NFR5, 9]	No
M3O	Yes	Yes	Partially [NFR1,2,3,4,5,9]	Partially [PC2,3,4,6,7, 8]
Media Onto.	Yes	Yes	Partially [NFR1,3,5,9]	Partially [PC2,3,4,21]

Table 5.4: Candidate MM ontologies analysis II

	Criteria			
Ontologies	**SS**	**SP**	**NFRC**	**FRC**
COMM	Yes	Yes	Partially [NFR1,2,3,9]	Partially [PC2,3,4,6,8]
MPEG7_Hunter	Yes	Yes	Partially [NFR3,5,9]	Partially [PC2,3,7,20]
MPEG7-7x	Yes	Yes	Partially [NFR3,5,9]	Partially [PC2,3,7,20]
MPEG7_Tsinakari	Yes	Yes	Partially [NFR3,4,5,9]	No
SWintO	Yes	Yes	Partially [NFR3, 5, 9]	No
SAPO	Unknown	Unknown	Partially [NFR3,5,9]	Partially [PC1,2,4,6]
DIG35	Yes	Yes	Partially [NRF3,4,9]	Partially [PC4]
MIRO	Yes	Yes	Partially [NRF9]	No
MSO	Yes	Yes	Partially [NRF2,9]	No
CSO	Yes	Unknown	Partially [NRF3,4,5,9]	Partially [PC7]
AceMedia VDO	Yes	Yes	Partially [NFR2, 4, 9]	Partially [PC20]
VRA CORE3_Assem	Unknown	Yes	Partially [NFR5,9]	Partially [PC18, 21]
MEPCO	Unknown	Yes	Partially [NFR2,4,5,9]	No
Boemie VDO	Yes	Yes	Partially [NFR2, 9]	Partially [PC11,12,19, 20]
Music Onto.	Unknown	Yes	Partially [NFR2,3,4,5,9]	Partially [PC14,21]

Table 5.5: Candidate MM ontologies analysis III

TotalOnto	%Error	%NotRelevant	%UnknownSP	%UnknownFRC
32	12.5%	3.125%	31.25%	9.375%

Table 5.6: Percentage of some wrong situations

Chapter 6

Selecting Multimedia Ontologies

Here we are at the stage of selecting the most relevant MM ontologies to be reused in the development of the M3 ontology. The purpose of this chapter is to describe how we have applied the methodological guidelines and the criteria proposed by the NeOn Methodology to rank the multimedia ontologies and to select the most appropriate ones for the development of the M3 ontology. In addition, in this chapter we propose prescriptive guidelines for analyzing the ontologies with respect to a subset of the criteria and performing an objective selection of MM ontologies.

6.1 Criteria for selecting Multimedia ontologies

We "slightly" adapt the set of criteria described in [SF10] to fit our purpose in the MM domain. The number of criteria for domain ontology selection defined in [SF10] by Mari-Carmen is 16 organized in four dimensions (reuse cost, understandability effort, integration effort, and reliability). However, in our case, after a first round study and with some difficulties to give objective values, we decided to exclude the following three criteria (knowledge clash, adaptation to the reasoner and necessity of bridge terms) and to add one new criterion. The reasons for the exclusion where the following:

- *Knowledge clash:* It consists of comparing modelling decisions and knowledge representation decision of two ontologies. We were not able to determine "contradictory bits of knowledge" since at the time of performing this activity there was no version of the M3 ontology that could be used in the comparison with the candidate ontologies.

- *Adaptation to the reasoner:* Measuring this criterion supposes comparing the reasoners of both ontologies. In our case, many of the candidate ontologies where either OWL DL or OWL Full; and the MM ontology is going to be implemented in OWL DL. So, *a priori* there were nothing to do because the value will be constant to all the ontologies. That is, this criterion does not affect the final result score.

- *Necessity of bridge terms:* This refers to how necessary is to add new axioms or relations to the ontology to be build in order to reuse the candidate ontologies. Again here, in the absence of some explicit constraints about the ontology to be built (the M3), we have decided not taking into account this criterion.

As already mentioned, we introduce a new criteria called *Number of Functional Requirements covered (NFRC)* to be a very important criteria to be considered as it is more realistic when scoring MM ontologies. Thus, we have performed the analysis of the candidate MM ontologies based on the following 14 criteria: Reuse economic cost, Reuse time required, Quality of the documentation, Availability of external knowledge, Code clarity, Number of functional requirements covered, Adequacy of knowledge extraction, Adequacy of naming conventions, Adequacy of the implementation language, Availability of tests, Former evaluation, Development team reputation, Purpose reliability and Practical support.
In addition, to improve the methodological guidelines provided in [SF10], in this Master Thesis we have established some rules to objectively analyze the ontologies. Here we present such rules for each criterion:

- **Reuse Cost.** It refers to the estimate of the cost (economic and temporal) needed for the reuse of the candidate ontology. In this case, the following criteria are analysed:
  - **Reuse economic cost (REC):** Many of the ontologies were free and accessible online, and also have the case of one ontology received directly from the author. So for this criterion, it was in general set to low cost.
  - **Reuse time required (RTR):** It refers to the time for accessing the candidate ontology. Hopefully, we have a good internet conection, working with a "normal PC". Thus, the value here was somehow easy to be analyse.
- **Understandability Effort**. It refers to the estimate of the effort needed for understanding the candidate ontology. In this case, the following criteria are analysed:
  - **Quality of the documentation (QD):** It refers to wheter there is any comunicable material explaining some aspects of the candidate ontology. Here, we assume a high level quality if there is a wiki, an article or even a web page explaining and/or describing the candidate ontology.

- **Availability of external knowledge (AEK):** It refers to if there is any external resource that could be used to better understand the ontology. We observe that this criterion is very closed to the previous criterion, and we add some elements like: (i) if the ontology is build within a project, (ii) the information quality to be analyzed in the project, and (iii) the references of the authors.
- **Code clarity (CC):** It refers to whether the code is easy to understand and modify; we inspect the following aspects in the code: (i) if the concepts names are clear, (ii) if the definitions are coherent and (iii) if the ontology provides comments and metadata. In general, we consider "Low" for this criterion when the concepts/classes are not clear and "High" when the ontology in general is intuitively understandable.

- **Integration Effort:** It refers to the estimate of the effort needed for integrating the candidate ontology into the ontology being developed. In this case, the following criteria are analysed:
  - **Number of functional requirement covered (NFRC)**: This refers to the number of CQs covered, which is obtained as a result of the assessing activity (Chapter 5). We use the following formulae ValueT = (Value[1] x MaximumNumericalValueinLinguisticTransformation) / TotalNumberOfCQs, where MaximumNumericalValueinLinguisticTransformation is set to 3.
  - **Adequacy of knowledge extraction (AKE):** It refers to check if the ontology is modularized or can be modularized in an easier way. This criterion was generally set to "Medium" or "High".
  - **Adequacy of naming conventions (ANC):** It is set to *"Medium"* if the names are clearly understandable; *"High"* if they come from a given standard (e.g: W3C, MPEG7,etc.), and finally *"Low"* if they are not intuitive.
  - **Adequacy of the implementation language (AIL):** If it is an OWL ontology, then the value is *"High"* (H). But if it is an RDF(S) rendering, the criteria has the value set to *"Medium"*(M).

- **Reliability:** It refers to analyzing whether we can trust in the candidate ontology to be reused. In this case, the following criteria are analysed:
  - **Availability of tests (AT):** It refers to whether tests are available. Unfortunately, it was difficult to get access to this information, and when

[1] Value is the number of CQs covered

possible, it was not precise. Thus, the value "High" was not possible to set to any of the ontologies analyzed in this Master Thesis.

– **Former evaluation (FE):** The same problem occurs here like in the AT criterion. FE refers to find in the documentation existing unit tests and the result of such tests. Many of the ontologies studied do not have this data or sometimes it is not explicitly present. Therefore the range of the values in our study were bounded in "Unknown" and "Low".
– **Development team reputation (DTR):** It refers to find relevant informations about the development team of the candidate ontology. For this task, we review the scientific impact of the team visiting their team projects, home page profiles, publications and research interests. Generally this criterion is very high for an ontology cited in a W3C Media Annotation Group[2].
– **Purpose reliability (PR):** It refers to the purpose for which the ontology was developed. We set to "Low" when it is an ontology created for academic use; to "Medium" when it is an ontology transformed from a standard metadata by a reputation team; and "High" when it is developed in a project.
– **Practical support (PS):** It refers to check whether well-known projects or ontologies have reused the candidate ontology. Here again, ontologies built within a project and those built using *"Ontology Design Patterns"* (ODP) have the highest scores.

In Table 6.1 are listed the criteria used, along with the weights for each criterion[3] and the range of values[4]. Both the weights and the possible values were established in [SF10]. The only exception is for the criteria "Number of functional requirements covered (NFRC)" whose weight and possible values has been established in this Master Thesis.

6.2 Determining the most appropriate MM Ontologies

To determine the most appropriate MM ontologies, we have analysed the candidate MM ontologies with respect to the criteria presented in Section 6.1, taking into account the different ways to measure each criterion and the possible values that can

[2]http://www.w3.org/TR/mediaont-10/

[3]The symbols (+) and (-) in the weights are established to note whether the criterion counts in a positive or a negative way, respectively

[4]Unknown (U), Low (L), Medium (M), High (H)

Criteria	Range of values		Values
Reuse Cost			
Reuse economic cost	(-)	9	[U,L,M,H]
Reuse time required	(-)	7	[U,L,M,H]
Undestandability effort			
Quality of the documentation	(+)	8	[U,L,M,H]
Availability of external knowledge	(+)	7	[U,L,M,H]
Code clarity	(+)	8	[L,M,H]
Integration effort			
Number of functional requirements covered	(+)	10	[0-1]
Adequacy of knowledge extraction	(+)	9	[U,L,M,H]
Adequacy of naming conventions	(+)	5	[U,L,M,H]
Adequacy of the implementation language	(+)	7	[U,L,M,H]
Reliability			
Availability of tests	(+)	8	[U,L,M,H]
Former evaluation	(+)	8	[U,L,M,H]
Development team reputation	(+)	8	[U,L,M,H]
Purpose reliability	(+)	3	[U,L,M,H]
Practical Support	(+)	7	[U,L,M,H]

Table 6.1: Criteria used for selecting ontologies

be assigned. In the following we summarize the main considerations used to analyze the candidate MM ontologies taking into account the criteria explained in Section 6.1. For this activity, we assume for practical reasons that all the ontologies available locally -except for Audio ontology-, because of the previous analysis. Furthermore, this assumption affects the reuse cost to its minimal value. It is true that we get it from a remote server, but again it was without efforts, both financially and time cost. Besides, we also agree that there will not be many changes if we were obliged to use remote URI location for their study. Summary of the considerations:

1. All the ontologies were easily accessible from their respective URL and free, thus they have very low reuse cost.

2. Most of the ontologies were developed within a project or institutional initiatives like AM@SHAPE, AceMedia, Boemie, have the higest scores in the Quality of the documentation, the availability of external knowledge, and code clarity. The rest are made by academic researchers to prove some concepts in MM semantic world.

3. Some ontologies were developed or transformed by one author: e.g: MPEG7_Hunter (by Jane Hunter), VRA_CORE3_ASSEM (by ASSEM). So their reputation

and purpose reliability are lower than others ontologies built by a team of at least two authors, and in the scope of a project.

4. When an ontology has been developed within a project, we assume also that it has practical support, at least within the same project.

5. In the *"practical support"* criterion, we consider very relevant others publications referencing the ontology or the use of the same ontology in a large project, like the case of COMM, SAPO, DI35, CSO, AceMedia VDO, Boemie VDO.

6. The language used for the ontologies are either OWL Full, OWL DL or RDFS. Thus they have good adequacy for the DL implementation of the ontology M3 to be implemented also in OWL DL. VRA CORE_3_ASSEM is the unique exception in this case (level medium) because of the use of object properties of type *xxx.xx*, like *location.creationSite*.

7. There were no possibility to know if the ontologies were tested and/or evaluated after their implementation.

After analyzing the candidate ontologies taking into account the criteria and the aforementioned considerations, we obtained Tables 6.2, 6.4, 6.6 which shows the different values for each criterion and for each MM candidate ontologies. These tables shown linguistic values assigned to criteria, in order to obtain a numerical score for the ontologies, we have applied the transformation process defined in [SF10]. This transformation process is based on the following:
To calculate the score of ontologies weighted (+), we use the following formulae [SF10]: $Score_{i(+)} = \sum_{j(+)} Value_{T_{i,j}} X \frac{Weight_j}{\sum_j Weight_j}$; whereas for ontologies weighted (-), we use $Score_{i(-)} = \sum_{j(-)} Value_{T_{i,j}} X \frac{Weight_j}{\sum_j Weight_j}$. The final score is obtained for each ontology doing $Score_i = Score_{i(+)} - Score_{i(-)}$.

Applying the transformation process we obtained the results shown in Tables 6.3, 6.5, and 6.7. As it can be observed:

- In the first group of ontologies, we find out that the top-five with final best scores are in this order: COMM; MPEG_7 Hunter; MPEG7_X; SAPO and DIG35.

- In the second group of ontologies, we find out that the top-two with final best scores are in this order: VRACore3_SIMILE and Music Ontology.

- In the last group of ontologies, we observe that they have smallest scores and the best among them are MSO and Photo Ontology.

In our Thesis, we have made a list of all the scores obtained by all the ontologies. This list is shown is Table 6.8. Then we have selected the first five ones to be used for the first version of our M3 Ontology:

- *Boemie VDO:* This ontology covers video and image aspects of multimedia. It also covers 4 CQs.
- *Media Onto:* Media ontology covers multimedia objects, audio/music, video and image. It also covers 4 CQs.
- *COMM:* This ontology covers multimedia, audio/video and image. It also covers 5 CQs.
- *DIG35:* This ontology only covers image aspect. It also covers 1 CQ.
- *SAPO:* This ontology covers image and visual aspects. It also covers 4 CQs.

We have taken this decision because those five ontologies cover almost 11 of 16 CQs (70 %), which is a good news for the ontology developer. It talks us that he will only have to cover the 30% left of the CQs, and thus reduce drastically the implementation process. However, some other considerations about the number of Competency Questions covered could altered this choice. For example, consider DIG35 ontology which has a good score but has only one Competency Questions Covered.
After the selection of the 5 ontologies best scored (Boemie VDO, Media Ontology, COMM, DIG35, and SAPO), we have practically analyze their reuse in the first version of the M3 ontology (focused at this point in the multimedia perspective). As already mentioned, we have decided not to use DIG35 because it only covers one CQ. In addition, (1) we have decided to select the next ontology in the score table, that is, the Music Ontology and (2) due to current restrictions in this first version of the M3 ontology we have decided not to use SAPO. Thus, the list of ontologies selected to be reused in the development of M3 is: Boemie VDO, Media Ontology, COMM, and Music Ontology. After this selection, the last activity to be performed is the domain ontology integration. At this stage of the development, we have integrated the 4 ontologies selected as it can be observed in Figures 6.2 (that show the general vision of the MM ontologies reused) and **??** (that show an overview of the main ontology elements in M3 after the integration of the MM ontologies selected).

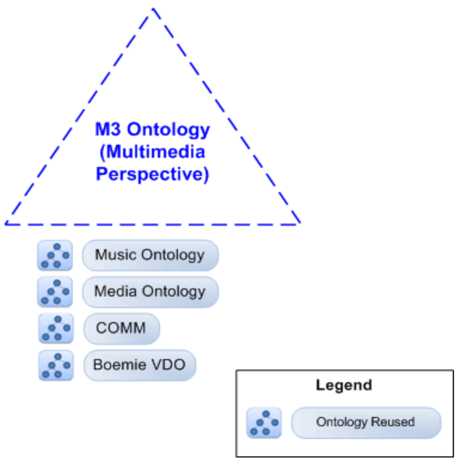

Figure 6.1: General vision of the MM ontologies reused.

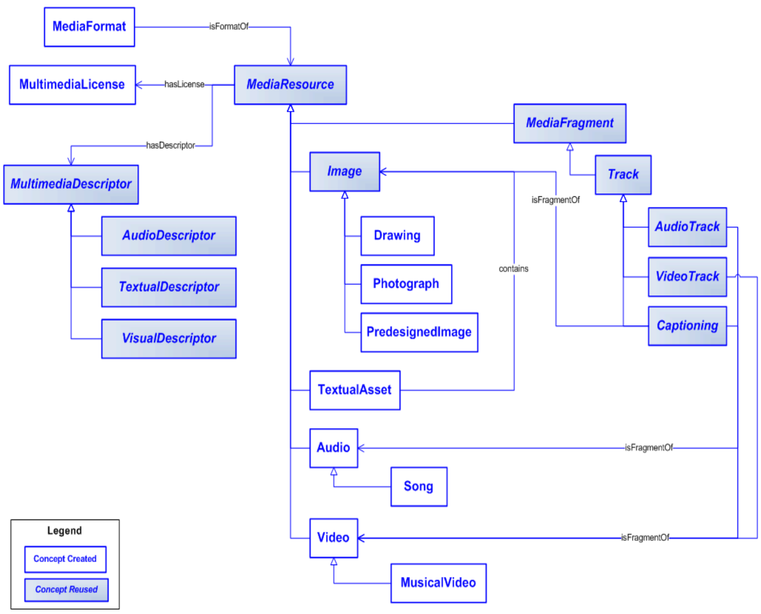

Figure 6.2: Overview of the main ontology elements in M3 after the integration of the MM ontologies selected.

Criteria		**Values**										
		Id1	Id2	Id3	Id4	Id5	Id6	Id7	Id8	Id9	Id10	Id11
		5CQC	4CQC	4CQC	4CQC	1CQC	1CQC	1CQC	2CQC	4CQC	2CQC	4CQC
Reuse Cost												
REC	(-)	L	L	L	L	L	L	L	L	L	L	L
RTR	(-)	L	L	L	L	L	L	L	L	L	L	L
Understandability effort												
QD	(+)	H	M	M	M	H	M	H	H	H	H	H
AEK	(+)	H	M	M	H	H	H	H	H	H	H	H
CC	(+)	H	H	H	H	H	H	M	M	H	H	H
Integration Effort												
NFRC	(+)	0.93	0.75	0.75	0.75	0.18	0.18	0.18	0.37	0.75	0.37	0.75
AKE	(+)	H	H	H	H	H	H	H	H	H	H	H
ANC	(+)	M	H	H	H	H	H	H	M	H	H	H
AIL	(+)	H	H	H	H	H	H	M	H	H	M	H
Reliability												
AT	(+)	U	U	U	U	U	U	U	U	U	U	U
FE	(+)	U	U	U	U	U	U	U	U	U	U	U
DTR	(+)	H	M	H	H	H	H	H	M	H	H	H
PR	(+)	H	M	H	H	H	H	H	M	H	H	H
PS	(+)	H	U	U	H	H	H	H	U	H	H	H

Table 6.2: Anaysis for a first group of ontologies. From left to right: COMM, MPEG7 Hunter, MPEG-7x; SAPO; DIG35; CSO; AceMedia VDO; VRACORE3 ASSEM; Boemie VDO; Music Ontology and Media Ontology.

	Positive Score	Negative Score	Final Score
COMM	1,830	0,154	1,676
MPEG_Hunter	1,409	0,154	1,255
MPEG7_X	1,514	0,154	1,361
SAPO	1,784	0,154	1,630
DIG35	1,806	0,154	1,652
CSO	1,729	0,154	1,575
AceMedia VDO	1,662	0,154	1,508
VRA CORE3_ASSEM	1,391	0,154	1,238
Boemie VDO	1,861	0,154	1,707
Audio Onto.	1,757	0,154	1,603
Media Onto.	1,861	0,154	1,707

Table 6.3: Score results for ontologies in Table 6.2

		Values					
Criteria		Id1	Id2	Id3	Id4	Id5	Id6
		1CQC	1CQC	1CQC	2CQC	3CQC	2CQC
Reuse Cost							
REC	(-)	L	L	L	L	L	L
RTR	(-)	L	L	L	L	L	L
Understandability effort							
QD	(+)	M	H	M	L	L	H
AEK	(+)	L	M/H	L	L	H	H
CC	(+)	H	M	H	M	L	H
Integration Effort							
NFRC	(+)	0.18	0.18	0.18	0.37	0.56	0.37
AKE	(+)	M/H	M	H	M	L	M/H
ANC	(+)	M	M	M	L	M	H
AIL	(+)	H	H	M	H	H	M
Reliability							
AT	(+)	L	M	L	U	U	L
FE	(+)	L	L	L	U	U	L
DTR	(+)	L	H	H	M	H	M
PR	(+)	L	H	H	M	H	H
PS	(+)	L	M	U	L	M	H

Table 6.4: Analysis for a second group of ontologies. From left to right: Kanzaki Music; Music Ontology; Music Rights; Open Drama; MPEG7 MDS and VraCore3 Simile.

	Positive Score	Negative Score	Final Score
Kanzaki	1,267	0,154	1,113
Music Ontology	1,690	0,154	1,537
Music Rights	1,431	0,154	1,277
Open Drama	1,036	0,154	1,882
MPEG7 MDS	1,246	0,154	1,092
VraCore3 Simile	1,747	0,154	1,593

Table 6.5: Score results for ontologies in Table 6.4

		Values					
Criteria		Id1	Id2	Id3	Id4	Id5	Id6
		4CQC	1CQC	4CQC	2CQC	2CQC	6CQC
Reuse Cost							
REC	(-)	M	H	M	U	U	U
RTR	(-)	H	H	U	U	U	U
Understandability effort							
QD	(+)	L	H	U	U	U	U
AEK	(+)	U	M	U	L	L	M
CC	(+)	H	M	H	M	M	H
Integration Effort							
NFRC	(+)	0.75	0.18	0.75	0.37	0.37	1.12
AKE	(+)	M	M	M	M	M	M
ANC	(+)	M	H	L	M	M	M
AIL	(+)	H	H	H	H	H	H
Reliability							
AT	(+)	U	U	U	L	L	L
FE	(+)	U	U	U	L	L	L
DTR	(+)	M	H	U	M	H	H
PR	(+)	U	H	U	L	L	L
PS	(+)	U	H	U	L	L	L

Table 6.6: Analysis for a third group of ontologies. From left to right: Nokia Ontology; SRO; Device Ontology; MPEG7 Ontology; Photography Ontology and M3O.

	Positive Score	Negative Score	Final Score
Nokia Ontology	0,851	0,375	0,476
SRO	1,575	0,462	1,113
Device Ontology	0,726	0,000	0,726
MPEG7 Ontology	1,209	0,067	1,141
Photography Onto.	1,286	0,202	1,084
M3O	1,502	0,202	1,300

Table 6.7: Score results for ontologies in Table 6.6

Ranking	Ontology	Score
1	Boemie VDO	1,707
2	Media Onto	1,707
3	COMM	1,676
4	DIG35	1,652
5	SAPO	1,630
6	Music Ontology	1,603
7	VraCore 3 Simile	1,593
8	CSO	1,575
9	Music ontology (from SWE)	1,537
10	AceMedia VDO	1,508
11	MPEG7_X	1,361
12	M3O	1,300
13	Music Rights	1,277
14	MPEG_Hunter	1,255
15	VRA CORE3_ASSEM	1,238
16	MPEG7 Onto	1,141
17	Kanzaki Music	1,113
18	SRO	1,113
19	MPEG7 MDS Polysema	1,092
20	Photography Onto	1,084
21	Open Drama	0,882
22	Device Onto	0,726
23	Nokia- DP-1.28	0,476

Table 6.8: Final Results score

Chapter 7

Conclusions

This Master Thesis was focused on the reusing process as basis for the development of an ontology called M3, applied on the field of multimedia contents, in a real use case within a research Spanish project named Buscamedia. The aim of the process of reusing domain ontologies is to find and select one or more domain ontologies related to the ontology to be developed for ensuring interoperability and reducing time consuming in the ontology building. On the other hand, we are continuously consuming multimedia contents from differents sources such as Google, Flickr, Picassa, Youtube, and so on. The continued progress in digital libraries and the many multimedia resources available online today, make it necessary to employ more effective and innovative tools such as the use of ontologies for the recovery of those resources; one of the main motivation behind the M3 ontology being developed.

In this Master Thesis we have searched, studied, and evaluated related MM ontologies for a reusing purpose. It is straightforward that the benefit of the ontology developed reusing appropriate existing ontologies will improve multimedia content web services such as the archival, retrieval, and management. Taking these objectives into account, we have used the NeOn Methodology [SF10] to perform a systematic analysis of all the candidates ontologies. More specifically, we have been focused on the main activities that are part of the reuse process: (1) searching for ontological resources in repositories and registries ; (2) assessing the ontological resources in order to find out if such resources satisfy the developers needs; (3) comparing the ontological resources on the basis of a set of criteria and selecting the set of ontological resources that are the most appropriate for their ontology network requirements; and (4) integrating the ontological resources selected in the ontology network being built.

The main objectives we have achieved in this Master Thesis are the following:

- **Multimedia Ontology Search:** we have found *40* candidate MM ontologies that could satisfy the needs of the ontology network to be developed, that is the M3 ontology focused on the multimedia perspective. To perform this search we have used those terms appearing in the pre-glossary of the ORSD and introducing such terms in a Semantic Web Search Engine. In addition, we have performed in this Master Thesis a comparative study to choose the most suitable engine for this search in the MM domain. This study allowed us to select Swoogle as search engine that has been used in the search of MM ontologies.

- **Multimedia Ontology Assessment:** we have performed a deep study of the candidate MM ontologies to analyze their scope, purpose, functional and non-functional requirements with respect to the requirements established for the ontology to be built (that is, the M3 ontology). After this study we have obtained a set of 23 candidate MM ontologies useful for the development of the M3 ontology. To perform this study we have proposed in this Master Thesis (1) a comparative framework of MM ontologies and (2) a procedure to check which functional requirements are covered by a particular ontology.

- **Multimedia Ontology Selection:** we have carried out an analysis of the candidate MM ontologies with respect to a set of criteria. These criteria were proposed in the NeOn Methodology [SF10], but in this Master Thesis we have improved and extended them with specific rules to analyze the ontologies. We have created these extensions with the aim of being more prescriptive in the guidelines and help in this way to the ontology developer. The analysis performed allowed us to distinguish between those candidate MM ontologies which are the most suitable, by means of obtaining a ranked list of ontologies. In addition, we have taken some practical decisions about how many ontologies to select and we have developed the first version of the M3 ontology (focused on the multimedia perspective) by means of reusing the MM ontologies selected.

As already mentioned along this document, in those cases in which has been necessary, we have adapted, improved, and extended the methodological guidelines for reusing domain ontologies provided in the NeOn Methodology [SF10]. The improvements proposed in this Master Thesis aims to help the ontology developer in the reuse of domain ontologies by means of providing more prescriptive methodological guidelines.

Besides, this Master Thesis work aims to reduce the "semantic gap" in multimedia contents. The result of the whole process described here is an objective selection of the MM ontologies used for the implementation of the first version of the M3 Ontology, available online[1]. The first version of M3 Ontology (the M3 Ontology focused on the multimedia perspective) reuses the following candidates ontologies:

[1]http://wiener.dia.fi.upm.es/MM3Onto/

COMM multimedia ontology; Media Ontology, VDO Boemie and Music Ontology.

In addition, we present in this chapter (a) some lessons learned during the processes carried out during this Thesis (Section 7.1 and (b) some future works related to the topic of this Thesis (Section 7.2.

7.1 Lessons learned

After carrying out the activities and processes discussed in this Master Thesis based on the NeOn Methodology guidelines, some lessons have been learned:

- Many of the processes described in the reuse ontologies activities are described in natural language and need to be formalized and if possible to be automatized for an efficient evaluation.

- Searching activity is not exclusive to the used Semantic Search Engines, and must be extended to articles, project web pages, and W3C groups related to the domain. It is also important to make a state-of-art of the domain (in our case multimedia) to collect information about fields covered; authors; projects owners and language implementation for an easy analysis of selecting the criteria.

- Semantic Web Engines do not clearly distinguish in the results from keywords queries, RDF data coming from blogs and DBPedia resources to ontologies documents implemented in OWL.

- Some criteria proposed in [SF10] concerning ranking ontologies need to be adapted to the domain of the ontology being developed.

- There is lack of multilingual ontologies in multimedia domain. Thus, promoving the implementation of multilingual ontologies, it may permits cross-language semantic interpretation of a domain.

7.2 Future works

In the current state of work, some future lines of research could be interesting to investigate in the following three directions:

- *CQs Enhancing Ontology Search Tasks*: Competency Questions contain categories and objects that are used for the searching activity. They are after used to query a given Semantic Web Engine. How to choose the right SWE that gives better results? What could be the criteria that guide deciding which SWE to use in function of the domain? Such an analysis can help the developer to easily decide which Semantic Search Engine to use and what combination of terms to use to query to retrieve appropriate ontologies for the searching activity, thus improving the quality of the analysis of the candidate ontologies. In this regard, we are working in a general analysis of the most used Semantic Web Search Engines with the aim of creating a framework that allows ontology developers to decide the most appropriate engines based on their needs. In addition, we are also working on a technique that allows the combination of terms in a logical way to be used in an automatic way in the ontology search.

- *How to select the right ontology from the results retrieved by search engines*: Many SWE presents their results mixing documents from blogs with ontologies ones. This situation confused a lot the developer and force him to go through many pages to discover ontologies. It is a time consuming task and to reduce it in domain reuse step, an API can help the developer to extract efficiently disseminated ontologies in the whole documents retrieved by a SWE. Therefore, it will reduce the ontology selection process and also improve the quality of the results.

- *Semi-automatic ontology population* using existing data. In the answers column of a CQ, some categories or terms are implemented as individuals in the ontology to be built. With the continuously growing of the DBPedia resources, some further works can be conducted to analyse how to populate the ontology with those resources and their reliability with respect to the one to be built.

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Appendix A

Requirements of the M3 ontology

Buscamedia project describes in the ORSD[1] the purpose, scope, the intended uses, functional and non-functional requirements of the ontology. In this section, we briefly present some relevant aspects considered in our study.

Purpose-Scope-Intended Uses

1. **Purpose:** The main function of the M3 ontology, from a media perspective, is to semantically described resources or multimedia products.

2. **Scope:** The ontology should describe any audiovisual content (text, video, audio or image). The multimedia content is characterized to be particularly complex because it contains many elements distributed in spatial-time domain. The ontology should be able to describe events that happen in an instant of time (at the 0:23 second of the song, there is a chord change, or at the 0:43 second of video clip, a singer starts singing, and also the background image changes from blue to red, etc.).

3. **Implementation Language:** The formal language of implementation of the M3 ontology will be OWL DL.

4. **Intended End-Users:** Intended end users for the M3 ontology are: (i) Annotators of multimedia content (professional and private); (ii) Finders of media content (corporate and public); and (iii) Professional users producing audiovisual resources.

Intended Uses

General applications planned for the M3 ontology are:

[1]Ontology Requirements Specification Document

- Semantic description of audiovisual content, including both high-level attributes as low-level descriptions.
- Semantic searches in different languages, in order to retrieve multimedia content:annotation text (natural language processing); audio annotation; video annotation; image annotation and hybrid annotation.
- Automatic Reasoning from audiovisual content descriptions.
- Identification of the ontology concepts from different text strings associated with each concept. Text strings can be represented in different languages.
- Particular applications, related to professional users of the M3 ontology are:
  - Professional production (film maker or editor) that seeks to create new visual resources from existing audio-visual resources.
  - Documentary that indexes new audiovisual resources incorporating relevant information from the perspective of news, sports or learning skills.

Non-Functional and Functional Requirements

There are nine Non-Functional Requirements related to what the ontology should fulfil. There are the following:

- **NFR1:** M3 ontology has to be modifiable, scalable and able to incorporate both new domains and new languages.
- **NFR2:** M3 ontology must be based on at least one high-level ontology.
- **NFR3:** M3 network must reuse ontologies (as far as possible) existing knowledge resources (available ontologies, controlled vocabularies, taxonomies, thesauri, standards, etc..).
- **NFR4:** M3 ontology in its multimedia approach should include different levels of granularity.
- **NFR5:** M3 ontology should be able to develop their own ideas, not only to adapt, to build or extend other existing proposals that use or convert to OWL complex multimedia standards (like MPEG-7).
- **NFR6:** M3 ontology must include a multilingual model has to be separated from the knowledge model of ontology.
- **NFR7:** Multilingualism in the model should be conferred on the ontology during design time.

- **NFR8:** M3 ontology should consider the various hierarchical structures depending on the language.
- **NFR9:** M3 ontology should follow the UTF-8 for all tags of the elements of the ontology, in order to ensure its multilingual character.

Competency Questions

The Competency Questions (CQs) of the Buscamedia Project are all written in Spanish. At the time of doing this study, it was already accepted 17 CQs that we implemented in the first version of the M3 Ontology.

Id	**Preguntas de Competencia**	**Respuesta**
MM_PC2	Qué tipos de formatos de audio existen?	WAV,AIFF,MPEG FLAC,MIDI,AU WMA,Codec, 669,OGG,MP3, AIF,ACC Real Audio,MP2,AC3,ATRAC,iLBC, Monkey'a Audio,Musepack SHN,Speex,Vorbis HE-AAC,MOV,Formatos ITU-T,AIFC,AMF,ASF AudioCD
		MPEG-1, MPEG-2, MPEG-4 VC-1,AVS,Dirac
MM_PC3	Qué tipos de formatos de video existen?	MPEG-4/AVC, Formatos ITU-T,Theora,VP7
		Indeo, MJPEG,RealVideo,WMV
		JPEG-1,JPEG-2000, PNG, JPEG-LS,JBIG ,JBIG2

Table A.1: Competency Questions MM_PC2..MM_PC3

Id	Preguntas de Competencia	Respuesta	
MM_PC4	Qué tipos de formatos de imagenes existen?	BMP, GIF, ILBM,PCX TGA, TIFF, WMP	
MM_PC6	Qué tipos de formatos de texto existen?	TXT, DOC, XLS, PPT	MDB,RTF ,PDF
		XLT ,CSV	PPS, POT
MM_PC7	Qué tipos de formatos de modelos 3D existen?	3D2, 3DM ,3DS, POV	MTV ,NURBS
		DXF, FLT,MGF	VRML ,OBJ, MD2
		3GP,ASF, AVI	FLV,Matroska, MP4

Table A.2: Competency Questions MM_PC4..MM_PC7

Id	Preguntas de Competencia	Respuesta	
MM_PC8	Qué tipos de formatos multimedia existen?	QuickTime ,RealMedia	OGG , OGG Media
		WMP ,SWF	NUT,MXF
MM_PC10	Qué generos de voz existen?	Mujer, Hombre	Nio/a.
MM_PC11	Qué tesituras puede presentar una voz femenina?	Soprano, Contralato	Alto
		Heavy Metal Samba	Dance ,Rock,Clásica
		Flamenco, Jota, Tango	Merengue,Bachata,Cumbia

Table A.3: Competency Questions MM_PC8..MM_PC11

Id	Preguntas de Competencia	Respuesta	
MM_PC14	En qué recursos multimedia puede haber música?	Punk,Salsa , Reggaeton	Country,Folk,Electrónica
		Blues ,Celta,Disco ,Jazz	House, Infantil,Rap
		Soul,Techno	Reggae,Pop
MM_PC18	Qué tipos de imágenes existen?	Fotografías:Realidad, Pinturas,Facsímiles	Dibujos: A mano, Por ordenador
		Prediseadas: Gráficos, Composiciones	
MM_PC19	Qué características cromáticas tiene la imagen?	Cromática, Monocromática	

Table A.4: Competency Questions MM_PC14..MM_PC19

Id	**Preguntas de Competencia**	**Respuesta**
MM_PC20	Qué color predomina en las imégenes cromticas?	Indicar color segn Modelo YUV
MM_PC19	Qué caractersticas cromáticas tiene una imagen?	Cromáticas, Monocromáticas

Table A.5: Competency Questions MM_PC19..MM_PC20

Id	Preguntas de Competencia	Respuesta	
		*Todos los derechos reservados:	El titular de los derechos de autor no quiere
			renunciar a ninguno de los derechos exclusivos
			que la legislación sobre derecho de autor le concede.
		* Atribución sin derivadas:	no se puede utilizar para crear
			un trabajo derivado del original.
MM_PC21		*Atribución no comercial:	Atribución sin fin comercial.
	Qué tipo de licencia pueden tener los recursos multimedia?	* Atribución no comercial- licenciarIgual:	El material original se puede
			copiar, distribuir, comunicar y ejecutar públicamente
			la obra y hacer obras derivadas.
		*Atribución licenciarIgual:	El material se puede copiar,
			distribuir, comunicar y ejecutar públicamente la obra,
			hacer obras derivadas reconociendo y citando la obra
			de la forma especificada por el autor o el licenciante.
		* Atribución:	El material puede ser distribuido,
			copiado y exhibido por terceras personas
			si se muestra en los crditos.
MM_PC25	Qué resolucin tienen los archivos de vídeo?	Formato americano: 720x480	Formato europeo: 720x576

Table A.6: Competency Questions MM_PC21..MM_PC25

Identificador	**Requisito-Característica General (CA)**
MM_CA1	Una película tiene secuencias de video, audio e imágenes y en ocasiones 3D
MM_CA2	Una canción tiene elementos de audio
MM_CA3	Un videoclip tiene elementos de audio y video musicales
MM_CA4	Una banda sonora es la música de una pelicula
MM_CA5	Una película muda no tiene secuencias de audio
MM_CA6	Un vídeo con resolución 480x480 es un SVCD (Super Video CD)
MM_CA7	Una canción se descompone en secciones
MM_CA8	En una canción aparecen instrumentos musicales que crean sonidos
MM_CA9	En una cancióen puede haber partes donde predomina la voz cantada, y partes mas instrumentales
MM_CA10	En un video puede haber subtítulos.

Table A.7: Requirement-General Characteristic (GC)