Semantic Middleware to Enhance Multimedia Retrieval in a Broadcaster

Gorka Marcos[1], Petra Krämer[1], Arantza Illarramendi[2], Igor García[1], and Julián Flórez[1]

[1] VICOMTech, Mikeletegi Pasealekua 57, Parque Tecnológico, 20009 Donostia-San Sebastián, Spain
gmarcos@vicomtech.org
[2] LSI Department, University of the Basque Country, Apdo. 649, 20080 Donostia-San Sebastián, Spain

Abstract. The digitalization of video and recent progress in semantic multimedia indexing and retrieval transform the workflow and tools involved in the information retrieval process of the broadcasters. To this end, we present in this paper a theoretical framework which addresses the semantic needs of this workflow from a semantic-centric view. Accordingly, we propose a pluggable middleware designed to provide the services covering the semantic needs spread all over the workflow in the system, including, the needs of independent software modules, of archivists, and of journalists. It is then shown how this can be employed in a real system to index and retrieve rushes material in a broadcaster.

1 Introduction

During the last decade the metadata lifecycle in the massive audiovisual content creation environments has undergone a significant development. The migration from tape archives to digital libraries accessible on the Intranet has changed the way how the metadata is generated and how the agents involved in the metadata workflow [1]. This, of course, opens new opportunities to exploit the content.

To date, most of Serb's premonitions [2] have come true. For instance, nowadays the annotations of the broadcasters' archives are not generated and managed only by the archivist. Consequently, the metadata related with the production and the content are not treated in a uniform way. Besides, despite the existence of different standards for the management of the metadata, most of the solutions in the broadcast industry are proprietary or customized solutions [3].

In such a context, let us consider the case of a broadcaster that acquires the Panasonic PS2 professional camera that embeds DMS-1[4] compliant annotations in a MXF (Multimedia eXchange Format) [5] container. This allows the cameramen to add metadata from the very beginning of the generation of the content such as coordinates, information about the device, date and location. However, once the memory cards arrive at the ingest department, what happens with this metadata? How is this metadata manipulated and enriched as the

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workflow of the content continues? When, how and who modifies this piece of information? What happens if the content and its metadata are exchanged with another organization? How do the current architectures semantically support the digital workflow?

Since is not an unique answer to these questions [6, 7], this paper aims at describing a platform independent semantic middleware that centralizes all the issues related with the knowledge and semantics of the organization. Furthermore, the middleware is easily plugable to any Multimedia Asset Management system. Therefore, all the processes that require exploiting the semantics can be adapted to the nature of the organization as they rely on the proposed middleware.

Focusing on the lifecycle of the content in a multimedia information retrieval system, a lot of work has been done for using the semantics of the content and its context in order to improve a concrete process of that workflow. Exhaustive literature has been presented dealing with the use of semantic techniques to improve the query processing and natural language processing [8, 9], query expansion [10, 11, 12, 13], query adaptation and federation [14, 15, 17, 18], information integration [15, 19, 20], results ranking [21, 22, 23] and information visualization [24, 25]. However, there are few reported initiatives that aim to tackle the semantic needs that arise during the workflow, from a centralized perspective.

Candela et al. [26] highlight the lack of standards in order to implement the mechanisms to access these semantic services. To solve this situation, they propose the Information Mediator Layer, whose main target is to make that information accessible in a unified way for the higher level services. The Intelligent Media Framework [27] integrates several components of a retrieval system relying on the existence of the Knowledge Content Objects to provide access to services for the storage of media, knowledge models and metadata relevant for the live staging process and providing services for the creation and management and delivery of intelligent media assets. Wei and Ngo [28] propose an architecture module which is designed to solve in a generic way the semantic needs of two main processes of a multimedia digital workflow: the analysis of the content and the mapping of the queries into the internal vocabulary. In [15], Kerschberg and Weishar address several issues related to the use of conceptual modeling to support services oriented, advanced information systems. They propose an "infomediation" layer in order to present (different views), to handle (intelligent thesaurus creation and management) and to gather (wrappers to internet, image and text analysis, . . .) the information. In our previous work, the Meta Level [29], we describe a semantic middleware implementation deployed in the WIDE project [18]. It gathers the semantic information and functionalities of an information retrieval system in combination with multiple information sources. Meta Level is in charge of the semantic needs to carry out the query creation, analysis, mapping and federation, the results ranker and evaluation and the concept-based visualization of the domain and results. The work of Catells [21] is mainly focused on the semantic search in the Semantic Web. However, it employs an ontology based schema that integrates the semi-automatic annotation, search and retrieval of documents.

The above cited articles have something in common: they propose a layer or an architecture involved in the provision of at least more than one service that rely on some kind of semantic resources. However, those approaches either assume some requirements for the content that avoid its integration in current broadcasters workflows [21, 27], or they strengthen the accessing of the semantic information excluding the provision of the services from their approach [15, 26], or they do not tackle the provision of the services from a generic perspective [28].

Therefore, we present in this paper a semantic middleware which, using the information of the semantic resources of the system, centralizes the provision of all the semantic services needed for the retrieval process. The design of the middleware that we propose has been deeply influenced by the current information retrieval systems and workflow in a broadcaster. The objective of this design has been to enrich that workflow with new services that exploit the semantics of the domain. In addition, this design covers the semantic needs of that workflow. Furthermore, our middleware design has been tested through its deployment in a system where it provides full support for critical tasks like the automatic indexing of multimedia, including fuzziness techniques and the conduction of knowledge during the analysis process. Finally, our middlware is a transparent module for the remaining components. It is responsible for mapping between the different external information encapsulation formats and the internal format and terminology. According to this, our implementation embeds several intermediation parsers (DMS1 of MXF [4], the format for information exchange between modules...) to improve the scalability of the system.

The structure of this paper is the following. Section 2 presents our reference model for multimedia information retrieval. In Section 3, the architecture and target of the proposed middleware is described. Section 4 presents a deployment of the middleware in a search system.Therein, we describe the different services provided by the middleware. Finally, Section 5 concludes our work and outlines future work.

2 Reference Model for Multimedia Information Retrieval

Here, we present our model for multimedia retrieval which is based on a extension made by Larson on the Soergel reference model [30]. Figure 1 depicts our specialization of this model for the broadcast domain. The specialization consists in the following points:

- First of all, the model has been extended with the browsing line, in order to include in the information retrieval, the user experience during the browsing, navigation of the results and possible refinement of the query. We propose to include this line in the model to consider the semantic services provided by the middleware in those steps of the information retrieval process.
- Taking into account that our information retrieval analysis is carried out from the perspective of the workflow of a broadcaster, the components have been adapted to the terminology and idiosyncrasy of that domain.

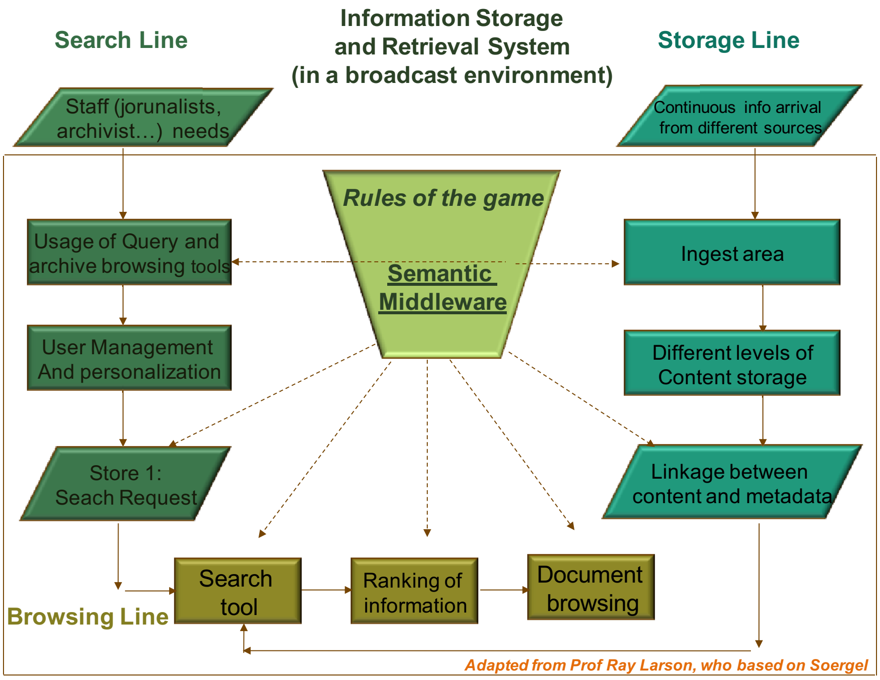

Fig. 1. Reference model for MIR in a broadcaster

- The content involved in the retrieval process is predominantly composed by audiovisual items. Therefore, the retrieval can be based either on the audiovisual features of the content (i.e. query by example techniques) or using the textual metadata gathered in the different steps of the workflow. The indexing of the material is more critical than in the case of text documents repositories. Each piece of the annotations composing the metadata of the asset will contribute significantly to the chances of the asset to be retrieved.
- Nowadays there are different metadata standards available defined both by the industry and the academia [6, 7]. However, it can be assumed that there is not a unique standard adopted by the broadcasters and that in many cases, different extended versions of various standards are used in different moments of the workflow.
- Considering that the limited amount of metadata available for those items and the diversity of the information, in a vision fully aligned with Styltsvig [31], our work supports the change from keyword-based to concept-based information retrieval utilizing ontologies as reference for concept definitions.

3 Generic Architecture of the Semantic Middleware

The Semantic Middleware (SMD) that we propose centralizes the semantic needs in a potential real deployment in an information retrieval system. Thus, in this section we briefly describe a generic architecture used for the deployment of such a middleware.

The SMD has to provide different semantic services to different components of the architecture where it will be deployed. Hence, the main objective behind the SMD architecture is to allow the implementation of this service in a scalable way. The outer layers of the architecture rely and trust on the implementation of the inner ones, whereas the inner layers are not aware of the behavior of the outer ones.

To achieve this, the architecture defined for SMD is composed by three layers:

- *Semantic Middleware Knowledge Base (SMD KB)*: The inner layer is devoted to the representation of the knowledge needed in the workflow and it is composed by several semantic resources.
- *Semantic Middleware Inference Engine (SMD IE)*: The medium layer is in charge of the inference and reasoning operations over the inner layer.
- *Semantic Middlware Gateway (SMD GW)*: The outer layer is responsible for the communications with the rest of the components of the system and provides the different services.

These components will be described more precisely in the following sections.

3.1 Semantic Middleware Knowledge Base

The SMD KB layer represents the "passive" knowledge modeled by the knowledge engineers and domain experts involved in the design of the information retrieval workflow and paradigm. From the information perspective, it is the key element of the middleware. Any piece of knowledge that must be used in order to solve the different needs of the system must be modeled here.

In order to implement the SMD KB the following criteria are crucial:

- There are different tools to gather the needed "knowledge": semantic repositories, populated ontologies, knowledge bases, syntactic grammars relational databases. According to the needs, expertise and idiosyncrasy of the environment where the SMD KB is going to be deployed, the optimum tool can be different. However, in any case, the tools have to guarantee the usability, maintenance and scalability of the information.
- The existence of an appropriate authoring tool for the experts involved in the creation and management of the information is decisive. Also the versioning control of the information is highly advisable.
- Together with the SMD KB, in a similar way to [15], a methodology and procedure for the correct generation and updating of the knowledge base has to be established. The different services that will be provided using this information, may impose different criteria for the definition of the relationships between the involved concepts. This has to be clear for the people involved in that task.
- Whenever possible, the usage of standards is very recommendable. In many sectors, the main concepts to be handled by the information retrieval are

agreed between the entities of the sector. These initiatives are mapped into standards that define common terminologies, exchange formats and common data models. The selected tool should be compliant with the inclusion of such initiatives.

3.2 Semantic Middleware Inference Engine

The SMD ID groups all the software items that we call *Processing Elements (PEs)*. PEs are related with the automatic extraction of knowledge out of the information stored in the SMD KB. Accordingly, this layer can include PEs that perform sequential query operations over a database in order to link several concepts or parse a sentence according to a syntactic grammar, to build a semantic graph out of a list of concepts, or to provide some feedback to a list of concepts according to some rules. The nature of these PEs is constrained by the following issues:

- They are highly dependent on the elements involved in the SMD KB.
- PEs perform an atomic semantic operation that could rely on other modules of the same layer.
- PEs are not context-aware. Therefore, the PEs do not need to know the objective of the action they are performing, in which part of the workflow they are invoked or even who is invoking them.
- There can be some intermediate PEs whose task is a merely mapping between some external available tools that handle the different elements of the SMD KB and some modules developed from scratch according to the needs of the concrete workflow.

3.3 Semantic Middleware Gateway

Finally, the SMD GW intermediates between the capacity of the inner layers of the SMD and the rest of the components of the retrieval system. Hence, the SMD GW is composed by different service providers or support processors that provide concrete semantic services hiding the knowledge represented in the SMD KB and the complexity of the PEs.

All the support processors in the SMD GW must be aware of the context of the service that they provide to the exterior and must use that information in order to invoke the different PEs of the SMD IE. The appropriate combination of the different invocations will lead the provision of the right service.

4 Semantic Middleware in a Multimedia Retrieval System

This section describes the real ongoing implementation of a SMD in a system developed in the context of the European project RUSHES[1] [32]. The objective of the project is to implement and validate a system for indexing, accessing and

[1] European project (FP6-045189), `http://www.rushes-project.eu/`

retrieving raw, unedited audio-visual footage known in broadcasting industry as "rushes". In order to accomplish this, many different technologies are required, including multimedia analysis, multimedia search, user interfaces as well as models for taxonomies and metadata. The project aims at testing and validating a proof of concept of the incoming semantic driven multimedia retrieval.

4.1 Metadata Model

The *Metadata Model (MDM)* is the SMD in the RUSHES system. Its architecture is based on a service-oriented architecture with loosely coupled services. Therein, the interfaces are usable without knowledge of the underlying implementation of the component exposing the service. The architecture defines a number of service domains, each of them represent some vital functionality of the RUSHES system. Functionalities exposed through services include storage, content processing, training of classification models, searching, and manual data annotation. The actual components implementing the service interfaces are hidden, and can be replaced by other components implementing the same service interface.

According to the architecture, as illustrated in Figure 2, the MDM constitutes a service domain. The MDM provides services to the following modules of the architecture: content capture and refinement module (CCR), the offline analysis component, the different user interfaces (through the query results and refinement module) and the search engine components. The different services provided to the different modules are described in section 4.2.

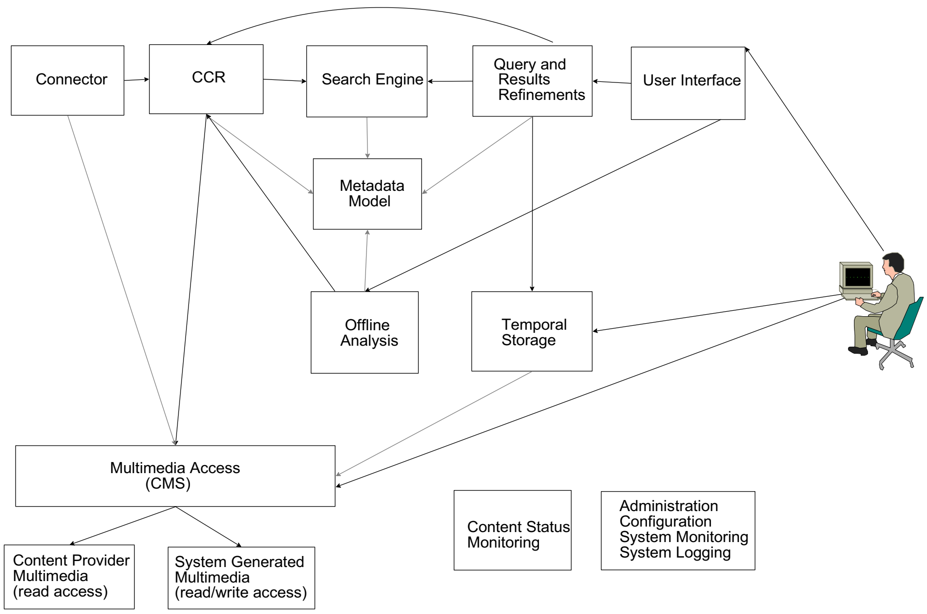

Fig. 2. General architecture of the RUSHES system

4.2 Semantic Services Provided by the Metadata Model

As previously mentioned, the MDM provides semantic services for the rest of the components during the different subprocesses that compose the RUSHES multimedia information retrieval workflow. Some of them are performed offline, before the user logs into the system, and others are invoked online. In the following the most important services are described and linked to the example of the Panasonic PS2 camera introduced in the first section of this paper.

Information Mediation. Before the user arrives, the video ingesting and analysis is performed. As a result, there are diverse annotations that belong to different semantic levels that are indexed by the search engine. During this process, the MDM carries out different parsing processes that should be taken between the external data schemas and the internal one defined in the system.

According to this the MDM is in charge of parsing the metadata provided by the PS2 camera (DMS-1 annotations) of the organization into the internal model. Beside this, once the analysis of the videos has been performed, which is explained in the next paragraph, the MDM is in charge of ensuring that these annotations arrive to the professional engine(s) that must handle them. In this case, this component is the FAST ESP engine, which is the key search-component in the media asset management of the broadcaster. In this case, the MDM parses the searchable annotations into a MEX (Multimedia Exhange Format) file. This MEX file, which is an XML document, is compliant with the schema defined in the search engine to index the annotations. This transforms the video into a retrievable document in the system. Beside this, the users are also able to use the manual annotation tool of the broadcaster to enrich those annotations.

Knowledge Conduction during the Multimedia Analysis Process. The CCR component provides an integrated environment for processing multimedia content such as image, audio and video. It provides an intuitive and efficient way for designing data flows from any content source to any content target. In the CCR component, a data flow is represented by an execution graph which consists of operators which are components performing some operation on data.

The set of operators invoked by the CCR is composed by expert modules (low level analysis operators, concept detectors and bayesian network classifiers) that work at different steps of the video analysis process. The information generated by some modules is needed by the remaining.

Some of them need additionally pieces of the semantic model in order to perform their analysis. During this process, the MDM is responsible for the persistency and availability of the intermediate information generated (i.e. low level features extracted, representative key-frames) and the semantic metadata obtained (i.e. list of faces recognized for each key-frame).

Furthermore, the MDM stores every piece of information generated for each video, preserving the semantic meaning of it by establishing its relation with the semantic entities gathered in its knowledge base.

Following the example, the video generated by the Panasonic cameras would be processed by the analysis algorithms of the broadcaster. Assuming that the analysis operators consist of a OCR text detector, a module which splits the video into shots and detects their key-frames, and a module to provide the probability of average number of faces in a shot, the MDM stores and relates the information provided by them. Additionally, the MDM ensures that the input needed by the face detector module is semantically equivalent to the information provided by the shot boundary detector.

Fuzzy Reasoning. Once the analysis of the video is finished, the MDM semantic repository is populated with all the information generated by the different operators. This information is related with the structure of the asset (number of tracks that compose the asset, main shots of the video and their representative keyframes) and with the content (number of faces present in each frame, type of audio, vegetation presence in a shot). These annotations, often linked to a confidence value, are inferred by the MDM in order to extract new knowledge.

In our example, the archivist, who is aware of the annotations provided by the stack of analysis modules, may employ the fuzzy inference engine in order to add the following rule: "A shot must be tagged with the word "DEMONSTRATION" and with a confidence value of 0,8 if the OCR detects the words "PEACE" or "NOT WAR" and if the shot contains more than 20 faces with a confidence value higher than 0,6".

Components of the User Interfaces. Within the RUSHES deployment, several interfaces are in charge of the interaction with the user in order to query the system, to retrieve and browse the results, and to annotate the assets. These interfaces implement interaction paradigms that employ tailored semantic services provided by the MDM. For instance, some of those services are: concept-based browsing, query recommendations based on the concepts typed by the user in the search, query parsing and enrichment, and support during the manual annotation.

Continuing with the example, when journalist searches a shot longer than 10 seconds with an average number of people bigger than 5, the semantics gathered by the MDM ("anything that contains a face contains a person") allows the the semantic mapping between the query related with the persons and the information about faces generated by the face detector.

4.3 Implementation of the Metadata Model

Here, we describe the implementation of the MDM that fulfills the requirements of the project and that follows the approach of the SMD presented in Section 3. The requirements are mainly derived from the specifications of the final users and from the general architecture defined in the project. The first group of requirements is mainly related with the functionality of the middleware (i.e. provided services, modeled domain, employed tools ...) whereas the second group of requirements has influenced the decisions related with the integration (i.e. language, fuzziness aspects, ...).

Metadata Model Knowledge Base. The MDM KB is composed of a set of interrelated OWL ontologies. The objective is to collect the work done in different initiatives according to the needs of the system. MDM KB is composed of the three ontologies:

- SMPTE 380: DMS-1 Ontology [4]: DMS-1 is the metadata schema of the MXF standards family. We migrated this schema into an OWL ontology to represent the structural information of the video where the semantic annotations must be attached to.
- MPEG-7 Detailed Audiovisual Profile (DAVP) [33]: In order to handle the information provided by the different analysis operators the MDM includes an OWL ontology of the DAVP profile.
- Domain Ontology for News Domain: The MDM includes an extended version of the LSCOM Lite ontology [34], which gathers the main concepts of the news videos domain according to the scope of the system.

For the edition of the model, the chosen language is OWL-DL. The edition is made offline by the experts with Protégé. The output is an OWL file (T-Box and A-Box) with all the information related to the domain.

In order to handle the uncertainty present in the multimedia analysis, OWL annotations are used. For instance, in Figure 3 an explanatory OWL fragment with such annotations is shown. This example expresses that "The key frame instance named as "10392" contains an instance of Face named as "Tony Blair" with a probability of 0,78". For the reasoning over this information, which is described later, a parsing between the T-Box and the fuzzy inference engine is done.

Metadata Model Inference Engine. The last version of the Jena API together with the FIRE fuzzy reasoner [35, 36] provided by NTUA have been used for the inference of the project. Regarding the FIRE reasoner, the input of the fuzziness inference is the A-Box and T-Box generated after the analysis. The MDM is responsible for the provision of the information needed by the Fuzzy reasoner: concepts, axioms and the instances and their probabilities.

Regarding the Jena API, it has been extended since, the methods implemented by this engine are mainly related with search and navigation of the concepts and instances of the model. The extension performed is due to the need to reduce the amount of time required by the API to browse and search the concepts of the model (T-Box), when the search criteria complexity is increased. For instance, inference methods have been implemented to enhance the Jena API in order to retrieve all the "intermediate" concepts and their subclasses that link the concepts A and B. This kind of knowledge extraction is needed, for example, for the generation of graphs that facilitate the generation of the query by the user.

Metadata Model Gateway. The MDM GW is composed by a set of web-services that expose the services mentioned in Section 4.2. The MDM GW is implemented as a standalone windows server and is able to attend parallel invocations from the different modules of the system. The server is stateless for all the services but the ones related with the analysis of the ingested videos. During that process, the server must keep the information of the different analysis

```
<?xml version="1.0"?>
<rdf:RDF
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
    xmlns:owl="http://www.w3.org/2002/07/owl#"
    xmlns="http://www.owl-ontologies.com/Ontology1196180634.owl#"
  xml:base="http://www.owl-ontologies.com/Ontology1196180634.owl">
  <owl:Ontology rdf:about=""/>
  <owl:Class rdf:ID="Face"/>
  <owl:Class rdf:ID="Video_Keyframe"/>
  <owl:ObjectProperty rdf:ID="contains">
    <rdfs:range rdf:resource="#Face"/>
    <rdfs:domain rdf:resource="#Video_Keyframe"/>
  </owl:ObjectProperty>
    <owl:DatatypeProperty rdf:ID="name">
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
    <rdfs:domain>
      <owl:Class>
        <owl:unionOf rdf:parseType="Collection">
          <owl:Class rdf:about="#Video_Keyframe"/>
          <owl:Class rdf:about="#Face"/>
        </owl:unionOf>
      </owl:Class>
    </rdfs:domain>
  </owl:DatatypeProperty>
    <owl:DatatypeProperty rdf:ID="withAProbability">
    <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#float"/>
    <rdf:type rdf:resource="http://www.w3.org/2002/07/owl#AnnotationProperty"/>
  </owl:DatatypeProperty>
  <Video_Keyframe rdf:ID="keyframe_10392">
    <withAProbability rdf:datatype="http://www.w3.org/2001/XMLSchema#float"
    >0.78</withAProbability>
    <name xml:lang="en">10392</name>
    <contains>
      <Face rdf:ID="face_tonyBlair">
        <name xml:lang="es">Tony Blair</name>
      </Face>
    </contains>
  </Video_Keyframe>
</rdf:RDF>
```

Fig. 3. Annotation fragment with fuzziness information

operations performed on each video. In order to do that, a instance of part of the MDM GW is created to attend the requests related to each video.

In Figure 4, a partial view of this set of interfaces is shown. For example, the mdm2ccr represents the services provided by the middleware to the CCR module, in order to ensure the knowledge conduction during the video analysis process. In that view the functionalities are grouped according to the unit of information they are related with: the whole asset, a video segment, a cluster, a keyframe and so on. The methods available through these classes are used by

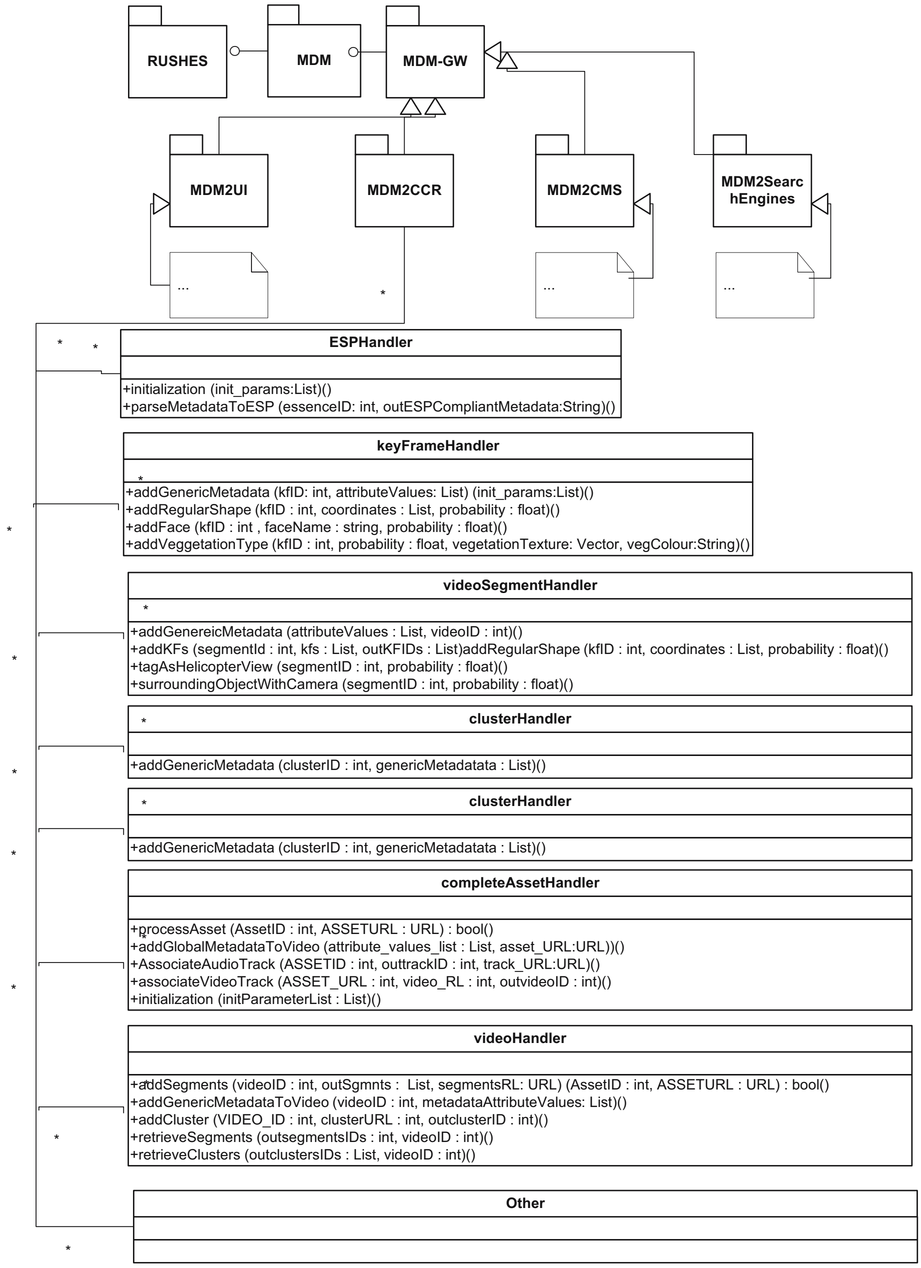

Fig. 4. Partial view of the MDM GW interfaces

the CCR module to store the information generated by the multimedia analysis algorithms in the MDM KB.

5 Conclusions and Future Work

First of all, we presented a generic architecture to implement customizable semantic middlewares that can be plugged into a multimedia information retrieval system to provide the different semantic services needed in the complex workflow, as the one present in a broadcaster. The main target of this middleware is to facilitate the adaptation of their systems to the new semantic needs generated by the employment of multimedia analysis techniques and the increase of the number of agents (journalists, camera manufacturers, industrial forums, ...) involved in the lifecycle of the metadata.

Secondly, we presented a real deployment where our middleware integrates the semantics distributed over the whole workflow in a unique model. The current services implemented are the ones described in Section 4.2. Initial metadata is obtained from the camera, semantic support is provided for the search and manual annotation processes, annotations are generated by the different analysis algorithms and linked with the annotations made by journalists and archivists using an annotation tool. During the analysis of the video, the middleware plays a central role for the semantic analysis of the video material by centralizing the management of the low level features together with the medium level and high level annotations. In this process, the middleware also becomes the main support for the fuzziness inference carried out over the annotations generated by the different analysis operators. Additionally, the middleware is able to handle DMS-1 annotations, thanks to the inclusion of the first DMS-1 OWL ontology in the bibliography.

Regarding the main activities planned for the next period, the first one is related with the evaluation. The MDM has been integrated with the CCR and the ESP components. This can be understood as a proof of concept of the architecture. However, the user interface components and the most of the analysis algorithms have not been finished and integrated. During the next months a first implementation of the whole RUSHES system will be available, which will allow the usage of real data and exhaustive testing and evaluation with final users. During this trials, the feasibility of the integration of a middleware as the presented one and the advantages of its usage will be performed.

Beside this, the increasing of the number of services provided by the middleware and the integration of the middleware knowledge base with external semantic resources accessible through Internet will be also targeted.

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