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Multimedia Semantics and the Semantic Web[1]

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1. Introduction

The need of multimedia metadata was recognized a long time ago. One reason for that is the absence of self-descriptive ability and formal semantics of the audiovisual materials. Metadata provides additional information to the users of the described objects or to the multimedia software. It is also used to speed up and to facilitate the searching of resources. The simplest way of multimedia annotation is fee-text annotation. Such metadata is very expressive and the most natural for the human but provides least formal semantics and hence is very hard for computer processing. The next step toward adding semantic to multimedia is denoted by the term tagging. Tagging is the process of assigning keywords or terms to a piece of information. Tags are chosen informally and personally by the item's creator or by its viewer, depending on the system. Tags have no formal semantics but could be useful for multimedia annotation if a fixed vocabulary is used. Annotations alone do not establish the semantics of what is being described. The disadvantage of simple annotations is that their representation as strings is not interpretable by software programs. The meaning of the metadata elements or their semantics must be encoded into a formal, machine interpretable form. A possible solution is to unify the worlds of media metadata and their representation and to provide for a specific domain a shared and common vocabulary. This vocabulary may serve as a base for ontologies. Ontologies are widely used in different areas like Knowledge Engineering or Computer Science in applications that are related to information

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integration, information retrieval, knowledge management or in the Semantic Web. The Semantic Web is not a separate Web but an extension of the current one, in which information is given well-defined meaning, better enabling computers and people to work in cooperation. Ontologies provide a common understanding of a domain and capturing this domain knowledge by modeling its basic objects and relations between them and by providing rules stating restrictions on the usage of terms and relations as defined in [1]. They are the third basic component of the Semantic Web. The other two are XML and RDF.

An essential requirement for information exchange between different systems is a common representation of data. In the area of description of audiovisual material a range of metadata standards has been developed. Some of them are developed prior the Semantic Web and most of them are based on XML. The problem of such XML based standards is the lack of formal semantics. To manually annotate via these standards is time consuming and expensive process, because of the complexity of such standards and the lack of appropriate tools. Current work in the area of multimedia annotation is targeted toward cooperation of existing practices in multimedia industry with the current technologies and practices of the Semantic Web.

Such kind of integration [2] would give metadata providers immediate payoff because they could directly benefit from the Semantic Web software that is available. Second, it would enable the deployment of more intelligent applications to reason over multimedia metadata in a way that is currently not possible because current multimedia metadata standards are usually (XML) syntax-oriented, and thus lack a formal semantics. Third, the "open world" approach of the Semantic Web would simplify the integration of multiple vocabularies from different communities. Finally, it could provide small, simple but extensible vocabularies. These vocabularies should be suitable for private use (e.g., simple annotation of online photo albums like Flickr) but at the same time be sufficiently flexible to be extended for more complex and professional annotation tasks.

2. Semantic multimedia annotation state of the art

A powerful way of semantic annotation is the creation of multimedia ontologies. The most well-known ontology languages are the OWL family [3] (OWL Lite, OWL DL, and OWL Full) and RDF-S [4], which are basic components of the Semantic Web. The Semantic Web provides a common framework that allows data to be shared and reused across application, enterprise, and community boundaries [5]. For the integration of the current Semantic Web technologies and the multimedia annotation standards a W3C Multimedia Semantics Incubator Group has been created. The goals of this Incubator Group are [6]:

- use SW technologies to make existing multimedia metadata standards interoperable – leverage and combine existing formats;
- show the added value of the SW formal semantics – practical applications and services that provide extra functionality by using, for example, subsumption reasoning or rule-based approaches; multi-platform applications, adapted to any device that accesses the web;

- provide best practices for annotating and using multimedia content on the Web – practical use cases that identify the users, the type of content and the type of metadata that they want to provide.

W3C Multimedia Semantics Incubator Group is working on the creation of documents describing problems related to the image annotation on the Semantic Web. Two reports are finalized. How interoperability among metadata, vocabularies/ontologies and services is enhanced using Semantic Web technologies is presented in the report "Image Annotation on the Semantic Web" [7]. The goals of this document are to explain the advantages of using Semantic Web languages and technologies for the creation, storage, manipulation, interchange and processing of image metadata. In addition, it provides guidelines for Semantic Web-based image annotation, illustrated by use cases. Relevant RDF and OWL vocabularies are discussed, along with a short overview of publicly available tools. Several problems related to professional image annotation are discussed:

- *Production versus post-production annotation* – obviously most of the information needed for annotation is available during production. Therefore the creation of image annotation during production is a better approach.
- *Generic versus task-specific annotation* – task-specific annotations usually provide solutions for a single application and are characterized with poor reusability. Generic annotations are created without a specific context which can lead to inapplicability for a specific task. An ideal scenario for the development of particular image annotation is to be sufficiently specific for the application but with minimum application-specific assumptions.
- *Manual versus automatic annotation and the "Semantic Gap"* – the difference between the low level future descriptions provided via automatic annotation and high level content descriptions created by manual annotation is denoted by the term *Semantic Gap*.
- *Different types of metadata* – annotations describe different aspects of the multimedia objects (properties of the image itself or properties of the objects depicted by the image, etc.). There different vocabularies describing the different aspects of images that differ in size, granularity, formality, etc. In some cases one vocabulary is not enough for the development of the annotations for a specific task. One vocabulary is targeted toward the specification of properties of multimedia objects while another may define the values for those properties.
- *Lack of Syntactic and Semantic Interoperability* – a lot of metadata formats are available for use. The syntactic interoperability problem arises when it turns out to be impossible to use the metadata created by help of a software tool with some other multimedia tool. Semantic interoperability is the problem of an image metadata interpreted differently by different multimedia tools. The proposed solution to the problem is to use the Semantic Web technology. The Semantic Web provides technologies to explicitly specify the syntax and the semantics of the metadata and allows the annotator to specify the relation between terminologies of different tools.

The second finalized report "Multimedia Vocabularies on the Semantic Web" [8] gives an overview on the state-of-the-art of multimedia metadata formats. This document focuses on the integration of the multimedia vocabularies into the Semantic Web and provides both overview of practical relevant vocabularies for developers of Semantic Web application and discussions on the formal representations of the vocabularies.

A separate document concerning the interoperability among multimedia metadata “Multimedia Annotation Interoperability Framework” [9] is started by the W3C Multimedia Semantics Incubator Group. This document presents how interoperability among metadata, vocabularies/ontologies and services is enhanced using Semantic Web technologies. In addition, it provides guidelines for semantic interoperability, illustrated by use cases. Finally, it presents an overview of the most commonly used metadata standards and tools, and provides the general research direction for semantic interoperability using Semantic Web technologies. Some of the multimedia metadata standards are presented in the section “Multimedia Vocabularies” of the current document. The second document in working stage “MPEG-7 and the Semantic Web” describes the four current OWL/RDF proposals of MPEG-7, as well as a comparison of the different modeling approaches in the context of practical applications. In addition a wiki page containing an overview of Relevant Tools and Resources is created. Some of the tools are considered in the section “Multimedia Annotation Tools” of this document.

The abstraction levels of multimedia annotations and the application of semantic web languages for the definition of multimedia ontologies are presented in [2]. The multimedia metadata is considered as an abstract structure composed of three layers: the subsymbolic, the symbolic and the logical. At the bottom the subsymbolic layer contains the raw data (well known formats for video, image, audio, text, metadata, etc). The middle layer contains metadata describing the raw data and finally the metadata on the top (the logical layer) allows logical reasoning using the symbolic layer. The middle layer provides structural description of the multimedia object and represents the syntactic level of abstraction. The upper layer denotes the semantic and logical level. It provides semantic description of the multimedia. The stack of RDF-based languages and technology provided by the W3C community are suitable for the top layer. As stated in [2] a combination of the standards of the top layer (RDF, OWL, etc) and the standards from the middle layer (XML, MPEG-7, etc) seems to be the most promising way for multimedia document description in the near future. Finally some of the open issues related to the integration of multimedia annotations and the Semantic Web mentioned in [2] are:

- *Interoperability and tool support* – relates to the compatibility of semantic web tools and standards with the current multimedia standards and tools.
- *Linking media data with metadata* – relates to the problem of a flexible attachment of metadata to media resources, it should be possible to link metadata to the appropriate part of the target media item and also a standard way to link a piece of metadata and its target media item should be developed. Another open problem is the distinction between metadata about a physical object and the metadata about a digital representation of that object.
- *Vocabularies for multimedia annotations* – example multimedia vocabularies using semantic web languages should be collected and published; their practical use in the area of multimedia annotation should be demonstrated with the current multimedia metadata tools.

According to [10] the problems related to multimedia annotation fall into three categories. First, the association between the real world objects and the digital artifact representing it and between the metadata expressing the concepts in the domain and metadata about the media asset must be made explicit. Second, a distinction between content level-annotations and technical descriptions of the media items is required by the multimedia applications. Third, often a variety of multimedia vocabularies describing different aspects of multimedia are used. The complexity of multimedia vocabularies is discussed and as result the benefits of using the technical infrastructure of the Semantic Web as an opportunity to make multimedia annotation accessible for non-professional end-users are revealed. Semantic Web languages are pointed out as a solution for the interoperability problem and the URIs may be used for the definition of explicit links between artifacts, media assets and their annotations.

The next step in multimedia annotation according to [2, 7, 10] requires the joint effort of semantic web, multimedia and digital library communities.

3. Multimedia vocabularies

There are different vocabularies describing the different aspects of images that differ in size, granularity, formality, etc. Usually one vocabulary is not enough for the annotation of a digital library. This section gives an overview on some of the existing multimedia metadata formats. A more comprehensive look at the list of currently existing multimedia metadata formats is made in [11]. A common characteristic of the listed vocabularies is their formal representation which is discussed in the next section “Multimedia ontologies”.

Visual Resource Association (VRA) – VRA Core [12] is a data standard for the cultural heritage community. The element set provides a categorical organization for the description of works of visual culture as well as the images that document them. A XML Schema for the VRA Core 4.0 is developed by the VRA Data Standards Committee.

Exchangeable image file format (Exif) – the Exchangeable image file format [13] specifies the formats to be used for images, sound and tags in digital still cameras and in other systems handling the image and sound files recorded by digital still cameras. The Exif header carries the metadata for the captured image or sound. This includes metadata related to the image data structure (e.g., height, width, orientation), capturing information (e.g., rotation, exposure time, flash), recording offset (e.g., image data location, bytes per compressed strip), image data characteristics (e.g., transfer function, color space transformation), as well as general tags (e.g., image title, copyright holder, manufacturer). In these days new camera also write GPS information into the header.

Multimedia Content Description Interface 7 (MPEG-7) – MPEG-7 [14] is an ISO/IEC standard developed by MPEG (Moving Picture Experts Group). The MPEG-7 standard, formally named “Multimedia Content Description Interface”, provides a rich set of standardized tools to describe multimedia content. Both human users and automatic systems that process audiovisual information are within the scope of MPEG-7. MPEG-7 offers a comprehensive set of audiovisual Description Tools (the metadata elements and their structure and relationships that are defined by the standard in the form of Descriptors and Description Schemes) for the creation of modular descriptions on different levels of abstraction. The problems that arise as result of the flexibility of the standard are complexity and limited interoperability. The complexity is a result of the use of generic concepts, which allow deep hierarchical structures, the high number of different descriptors and description schemes, and their flexible inner structure. Its XML-based syntax enables smooth interchange across applications and over the web, but the lack of precise semantics hinders metadata interoperability.

Material Exchange Format (MXF) – the Material eXchange Format [15] is an open file format, targeted at the interchange of audio-visual material with associated data and metadata. It has been designed and implemented with the aim of improving file based interoperability between servers, workstations and other content-creation devices. These improvements should result in improved workflows and in more efficient working practices than is possible with today's mixed and proprietary file formats.

Synchronized Multimedia Integration Language (SMIL) – SMIL [16] is a W3C recommended XML markup language for describing multimedia presentations. It defines markup for timing, layout, animations, visual transitions, and media embedding, among other things. SMIL allows the presentation of media items such as text, images, video, and audio, as well as links to other SMIL presentations, and files from multiple web servers. SMIL markup is written in XML, and has similarities to HTML.

Scalable Vector Graphics (SVG) **–** SVG [17] is a language for describing two-dimensional graphics. SVG allows for three types of graphic objects: vector graphic shapes (e.g., paths consisting of straight lines and curves), images and text. Graphical objects can be grouped, styled, transformed and composited into previously rendered objects. The feature set includes nested transformations, clipping paths, alpha masks, filter effects and template objects. SVG drawings can be interactive and dynamic. Animations can be defined and triggered either declaratively (i.e., by embedding SVG animation elements in SVG content) or via scripting.

3.1. Multimedia ontologies

This section gives an overview of the formal representations of some of the existing multimedia metadata formats. For these formal representations the term "Multimedia ontology" is used. Several types of multimedia ontologies are considered: core and upper ontologies, content ontologies. Specific domain ontologies are not presented in the current document.

3.2. Core and upper level ontologies

Core ontologies are very basic and minimal ontologies consisting only of the minimal concepts required to understand the other concepts. There purpose is to serve as basis for the development of new ontologies and to bridge existing ontologies. Upper ontologies describe very general concepts that are the same across all domains. The aim is very broad semantic interoperability between large numbers of ontologies accessible "under" this upper ontology.

WordNet **–** the standard [18] is a large lexical database of English, developed under the direction of George A. Miller. Nouns, verbs, adjectives and adverbs are grouped into sets of cognitive synonyms, each expressing a distinct concept.

Synonyms are interlinked by means of conceptual-semantic and lexical relations. The resulting network of meaningfully related words and concepts can be navigated with the browser. WordNet's structure makes it a useful tool for computational linguistics and natural language processing. More recently, it has also been adopted in Semantic Web research community [19]. It is used mainly for annotation and retrieval in different domains such as cultural heritage, product catalogs and photo metadata. Currently there exist several conversions of WordNet to RDF(S) or OWL.

DOLCE **–** the Descriptive Ontology for Linguistic and Cognitive Engineering [20] is an upper level ontology which has a clear *cognitive bias*, in the sense that it aims at capturing the ontological categories underlying natural language and human common sense.

CIDOC-CRM **–** the CIDOC Conceptual Reference Model (CRM) [21] provides definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation. The CIDOC CRM is intended to promote a shared understanding of cultural heritage information by providing a common and extensible semantic framework that any cultural heritage information can be mapped to.

COMM – the Core Ontology for Multimedia [22] is based on both the MPEG-7 standard and the DOLCE foundational ontology. COMM is OWL DL ontology. It is composed of multimedia patterns specializing the DOLCE design patterns for Descriptions & Situations and Information Objects. The ontology covers a very large part of the MPEG-7 standard. The explicit representation of algorithms in the multimedia patterns allows also describing the multimedia analysis steps, something that is not possible in MPEG-7.

MPEG-7 MDS Upper Ontology **–** the MPEG-7 MDS Upper Ontology [23] is an OWL DL ontology that fully captures the MPEG-7 MDS (including all the classification schemes) and partially the MPEG-7 Visual and Audio Parts. The ontology is currently used for annotation, retrieval and personalized filtering.

3.3. Content ontologies

Content ontologies describe content and structure of multimedia.

MPEG-7 Upper MDS Ontology by Hunter – this MPEG-7 ontology [24] 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), part of the MPEG-7 standard. It comprises about 60 classes and 40 properties.

MPEG-7 MDS Ontology by Tsinaraki **–** the MPEG-7 MDS Ontology by Tsinaraki [25] covers the metadata model provided by the MPEG-7 MDS. It contains 420 classes and 175 properties. This is an OWL DL ontology.

MPEG-7 Ontology by Rhizomik – this MPEG-7 ontology [26] has been produced fully automatically from the MPEG-7 standard in order to give it a formal semantics. For such a purpose, a generic mapping XSD2OWL has been implemented. This ontology aims to cover the whole standard and it thus the most complete one. It contains finally 2372 classes and 975 properties.

aceMedia Visual Descriptor Ontology – the Visual Descriptor Ontology [27] developed within the aceMedia project for semantic multimedia content analysis and reasoning, contains representations of MPEG-7 visual descriptors and models concepts and properties that describe visual characteristics of objects. Although the construction of the VDO is tightly coupled with the specification of the MPEG-7 Visual Part, several modifications were carried out in order to adapt to the XML Schema provided by MPEG-7 to ontology and the data type representations available in RDF Schema.

Mindswap Image Region Ontology – the Mindswap digital-media [28] is an OWL ontology which models concepts and relations covering various aspects of the digital media domain. 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. The ontology defines concepts including image, video, video frame, region, as well as relations such as depicts, regionOf, etc. Using these concepts and their associated properties, it is therefore possible to assert that an image/imageRegion depicts some instance, etc.

3.4. Multimedia annotation tools

Various multimedia annotation tools are created. Some of them are intended for description of still images while others are used to describe video, audio content or other multimedia types. A wiki page with existing annotation tools is maintained at [29]. Multimedia annotation tools can be classified according to various criteria and technical features. In this paper a division between ontology-based image annotation systems, tagging systems and systems based on free-text annotations is made. Few ontology based photo annotation systems have been developed, some of them provide their own ontology or require the user to load the ontologies used. Follows a generalized overview of some of the key features of ontology based annotation tools:

- Cross-media annotation
- Ontology visualization
- Metadata generation based on ontologies, storage, retrieval and reuse
- Metadata search
- Assistance in the annotation process
- Region-based annotation of image content
- Extraction of existing metadata embedded in image files and serialization of the information in the generated metadata
- Automatic generation of metadata
- Reusing existing knowledge and reasoning on existing knowledge
- Mechanism for content sharing

Current multimedia annotation tools support a subset of the listed features. In RDFpic [30] three domain specific RDF schemas are used to annotate digital images. The user is proposed a graphical user interface that is dynamically generated according to the underlying schemas. Resulting RDF/XML is then embedded in the header of the JPEG files, which means that it supports only JPEG file format. PhotoStuff [31] provides the ability to annotate image regions with custom defined ontologies. The ontologies are visualized both in a class tree and a list. It is possible to load multiple ontologies at once and to mark-up images with concepts from any of the loaded ontology. The terms listed in both the tree and list can be dragged into any region, or into the image itself, creating a new instance of the selected class. An instance creation form is dynamically generated from the properties of the selected class (range restrictions are imposed). Especially valuable, existing instances can be loaded from any URI on the Web. Using these preloaded instances, depictions can reference existing instances and thus reuse existing metadata definitions. PhotoStuff only loads digital images. The tool currently takes advantage of existing embedded image metadata by extracting and encoding this information into RDF/XML, thus allowing embedded metadata to be directly incorporated into the metadata. PhotoStuff maintains a loose coupling with a Semantic Web portal. There are three ways in which PhotoStuff interacts with the portal, namely retrieving all instances that have been submitted to the portal, submitting generated RDF/XML, and uploading local images so they can be referenced by a URI. Semantics based image browsing and searching is provided after the metadata of annotated images is submitted to the Semantic Web portal. AKTiveMedia [32] supports most of the functionality provided by PhotoStuff. It supports all types of image formats and import of multiple ontologies. Additional functionality provided by the tool includes integration with web services, to find relevant images, knowledge suggestion during annotation, EXIF Metadata extraction, batch annotation, where users can annotate an entire collection of images at the same time, auto RDF import and export facility, export the annotated data to RDF for later access or to publish this information to the semantic web. M-OntoMat-Annotizer Visual Editor and Media Viewer [33] provides ontology based image and video frame annotation at both the image and image-region level. Additionally, the tool supports automatic, low-level MPEG-7-based feature extraction from annotated regions, thus providing visual descriptors of the annotated regions.

Among the numerous tools used for image description the semantic multimedia annotation with the proper annotation tool is still a challenging task. Tutorials and best practices for multimedia annotation should guide the user when working with a particular tool. Another open issue is the development of toolkits that will facilitate the implementation of intelligent multimedia services. Some future directions of ontology based image annotation systems are:

- *automating portions of the annotations process* – automatic metadata extraction and presentation as formalized knowledge via ontologies;
- *assistance in the annotation process of images* – for example knowledge suggestion during annotation;
- *batch annotation* – users can annotate an entire collection of images at the same time;
- *basic ontology editing functionalities* – allowing the user to customize the used ontologies;
- *ontology based search in the created metadata stores*;
- *interoperability support* – the issue of heterogeneity is addressed, functionality that provides mappings between different ontologies is missing in current multimedia annotation tools.

4. Conclusion

The analyzed problems of multimedia annotation in this paper are still open issues that will be further discussed by both Semantic Web and multimedia communities. Even when the media gets associated with metadata a lot of problems will remain. Usually multimedia metadata comes from different places: from the multimedia creator, publisher, editor, and users. Automatically generated or manually produced multimedia metadata describe different levels of multimedia information. Another important issue is also the quality of the supplied metadata. The integration of the Semantic Web technologies and the current multimedia annotation methodologies comes along with other open problems. Such integration must be achieved in a way that decreases the complexity of the multimedia annotation and multimedia services development. First, most semantic web based applications are distributed and heterogeneous. Some work has to be done to achieve interoperability between different ontologies. Ontology alignment techniques must be developed and applied. Second, multimedia annotation tools must be available and accessible to non-professional users in order to support users in the creation of quality annotations. From a technical point of view the annotation tools should hide the implementation details of the underlying standards and the way and location the annotations are stored and provide distributed access to the created metadata. Third, tutorials, best practices and supporting tools for the creation of multimedia services as well as application programming interfaces to manage the intelligent storage of metadata are needed. Such association of metadata to multimedia will provide a new area for intelligent multimedia services development and will force further scientific research.

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(Р е з ю м е)

Мультимедийная аннотация является трудным, продолжительным и дорогим процессом. Развитие стандартов, средств и технологий, которые уменьшают сложность мультимедийной аннотации, представляет большое предизвыкательство не только перед общности мультимедийной аннотации, но и перед людми, работающими в области интеграции семантического уэба. Следующий шаг к мультимедийной аннотации требует объединеных усилий общностей семантического уэба, мультимедий и цифровых библиотек. В статье показаны проблемы и результаты экипов, работающих в области интеграции технологий семантического уэба и мультимедийной аннотации.