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An Annotea-Based Approach for Multimedia Data Integration and Semantic Annotation Services in the SINUS Platform

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Abstract: *The paper discusses an Annotea-based approach for the development of annotation services for digital multimedia objects used as fundamental building blocks of compound learning objects created in the SINUS platform. Annotea provides an annotation protocol to support collaborative Semantic Web-based annotation of digital resources accessible through the Web. It provides a model whereby a user may attach supplementary information to a resource or part of a resource in the form of a simple textual comment, a hyperlink to another web page, a local file or a semantic tag extracted from a formal ontology or controlled vocabulary. Such annotations can be used for the implementation of enhanced search capabilities in the SINUS platform. SINUS annotation services will enable communities of experts to collaboratively select and annotate digital resources with annotations that are based on domain-specific terms from either controlled vocabularies and/or ontologies.*

Keywords: *Annotea-based approach, annotation services, ontologies.*

1. Introduction and background

The ability to create semantic annotations of heterogeneous digital resources in a standardized format has the potential to add significant value to distributed collections of digital resources and especially multimedia digital resources. Multimedia annotation can be performed on different levels, i.e., on the metadata level (e.g., administrative or technical descriptions such as title, identifier, or format), the content level (e.g., depicted persons, locations, events), and the multimedia level (e.g., low-level descriptors such as colour histograms). In the following chapters we analyze approaches, in which multimedia resources are annotated on the content level with human involvement. A number of initiatives have been proposed for modeling annotations and tags [12, 22, 25], etc. Among them the W3C's Annotea RDF model [20] is emerging as a defacto standard having been adopted by a large array of both clients and servers. Annotea annotations are metadata associated with a web document or web resource without requiring write access to the annotated artifact which means that the annotated object is unchanged but metadata from distributed annotation servers can be associated with it. This metadata uses vocabularies grounded in semantically rich ontologies that are published in the Internet. In addition, the association between the metadata and the Web resource is itself described through extensible semantics [19].

This paper targets the issue of semantic multimedia objects representation, storage and use for teaching purposes within the discipline of e-Learning. It tries to investigate the potential of finding an efficient approach to make heterogeneous sources like relational databases, Web 2.0 content (e.g. tags and other social networks information) and semantic annotations accessible through common search services enhanced by reasoning capabilities and automatic annotations extension. A special attention will be paid on the Annotea since it uses W3C Semantic Web technologies, specifically RDF [18] and RDFS [4], and can be easily extended to support many kinds of annotations and annotation-like collaborative applications.

The remainder of this paper is structured as follows. Section 2 presents the basic Annotea model and different extensions to the Annotea schema. The SINUS [9] project's objectives are outlined on Section 3. Section 4 provides a brief description of an e-Learning scenario that should be made possible in the SINUS platform. A description of the semantic annotations model and corresponding functionality is provided in Section 5. The underlying technologies that would be used for the implementation of the presented model are discussed in Section 6. Section 7 concludes with some additional thoughts and recommendations concerning the implementation of the presented approach.

2. Annotea basic model and extensions

The Annotea model specifies the following attributes associated with an [14]:

Body – the actual textual description or tag value(s);

Type – the top-level class is *annotation*, but possible sub-classes include: *comment, query, review, rating, assessment*;

Creator – the author of the annotation or tag;

Date_created – the date the tag/annotation was attached and published.

Developers are encouraged to create new types of annotations by sub-classing from the *Annotation* class and creating sub-properties of the related property. RDF/S allows easy addition of metadata properties from other schemas, such as the Dublin Core (title, date, creator) and FOAF (Friend-of-A-Friend) namespaces, which are used to describe the provenance of an annotation.

A user can attach an annotation to a given Web resource and a collaborator will see the annotation when he or she uses an Annotea capable client that subscribes to the common annotation server and retrieves annotations associated with the same Web resource (Fig. 1). Annotations are written to the server using the

HTTP POST and PUT requests and queried using the HTTP GET request for all queries [27]. After the annotations are retrieved from the server they can be presented to the user in several ways (e.g., as icons on the annotated resource or as embedded data in the annotated document) depending on the Annotea client. Each Annotea server is a generic RDF store. The HTTP protocol is used to store and retrieve the RDF/XML metadata describing the annotations from the server. XPointer [7] syntax is used to refer to the part of the document being annotated. The metadata infrastructure of the Annotea project makes it easy to support a wide variety of annotation related scenarios.

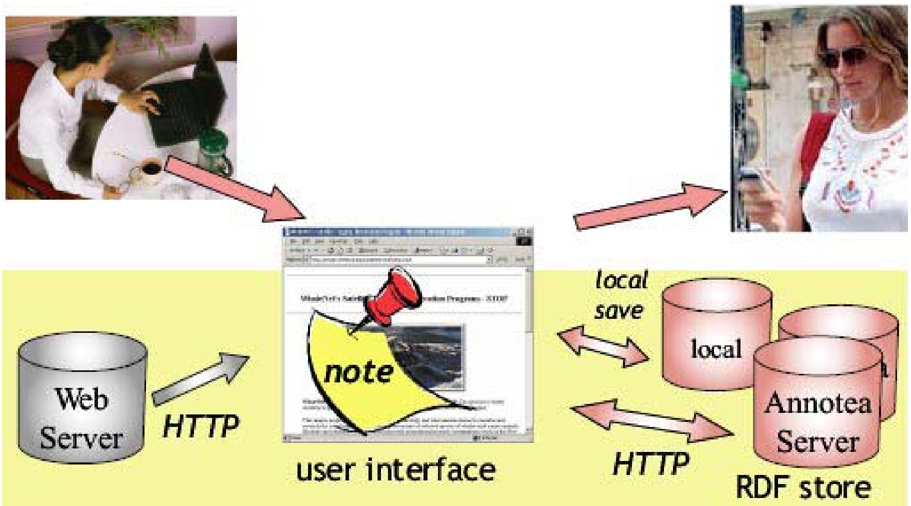

Fig. 1. The basic Annotea architecture [20]

A key strength of the Annotea protocol is that it uses open W3C standards such as RDF, XPointer, XLink [7] and HTTP. The use of machine-processable RDF descriptions enables easy search, retrieval and linking of the annotations to related resources and services using semantic web technologies (e.g., OWL [6], SPARQL [24]).

Annotea has recently been conceptually extended to support collaborative tag- or ontology based annotations. For example, the basic Annotea model, HarvANA, being explored [14] aims at developing an efficient streamlined system that can leverage the explosion of community annotation/tagging systems and exploit the resulting metadata to improve discovery and reasoning across open repositories. Such community annotations are stored on (one or more) Annotea-compliant annotation servers that are separate from the collections that they are annotating.

The Aus-e-Lit [11] annotation services enable communities of experts to collaboratively select, tag and annotate digital resources (with keywords, notes, comments, interpretations, queries, links to related resources, etc.) and to share these annotations with the research community to enrich the collection and enhance discovery services.

In Co-Annotea [13] the Annotea model has been further extended to capture associations between resources (e.g., videos and images) and their parts.

Vannotea [12] is a collaborative tool that enables fine-grained annotation of objects of any media type, where the annotations themselves can be free-text, files or URLs or from a controlled vocabulary (e.g., WordNet) or ontology. The Vannotea project implemented its own specific extensions. For example, Vannotea allows the creation of annotations in the form of drawings on top of media types such as images or videos through the use of Scalable Vector Graphics (SVG) [1]. Furthermore, Vannotea team presented various Annotea extensions [26].

Koivunen introduced new Bookmark and Topic objects to Annotea [19]. These social bookmarks and topics can be used for semantic authoring by letting ordinary users tag interesting web documents with their *own personal* concepts or folksonomies. Currently, the Boomark class is a separate, new class within Annotea. According to [26] bookmarks are just a special type of annotations. Rather than attaching a free-text comment to a specific resource, the user can build their own folksonomy using the topic hierarchies and attach those topics to the resource. In addition, [26] illustrates how Annotea can be extended to allow users to take advantage of these formal concepts in order to create subjective semantic annotations.

One extension to Annotea using controlled vocabularies is to allow users to attach pre-defined controlled terms to a specific web resource. The controlled vocabulary or ontology modelled in RDFS or OWL is publicly available over the web, so an Annotea client can access and present it to the user when he/she wants to attach a controlled term to the resource. For example, the user searches for the term "animal" and then browses through WordNet Ontology to navigate to a controlled vocabulary of a specific animal, which can be further attached to the resource (or part of the resource) that the user is currently viewing in his browser or Vannotea client. This is very similar to creating bookmarks except that the topic is being replaced by a predefined controlled vocabulary. The benefit of using the controlled vocabularies is that we can perform searches using these terms, taking advantage of the ontology to infer that a "fish", for example, is a subclass of an "animal", and therefore returning all resources about a "fish" when querying for resources about "animals".

Using the same interface users can also attach formal triple statements based on ontologies to a resource, i.e., relate a formal statement to the annotated resource and context. A statement is a more complex instance of an ontology compared to the controlled terms. Fig. 2 illustrates the schema of the *FormalStatement*. A *states* property which is a sub-property of *related* and has a range of *rdf:Statement* is introduced. The statement itself consists of a subject, a predicate and an object from an *Ontology*.The example in Fig. 2 shows a statement that says "*lion eats gazelle*" from a simple Wildlife Ontology which defines a lion as being a subclass of a carnivore and a gazelle – as a subclass of a herbivore. As above, we can now perform ontology based searches to retrieve all video segments or images where "*a carnivore eats a herbivore*", which would include scenes that were formally labelled as "*a lion eating a gazelle*".

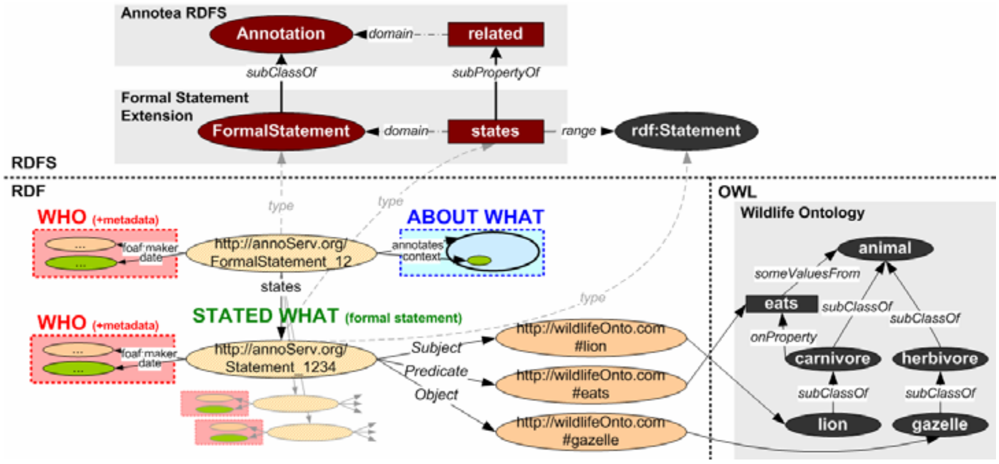

Fig. 2. Formal statement

3. SINUS Project

The primary objective of the current national research project SINUS – Semantic Technologies for Web Services and Technology Enhanced Learning (**sinus.iinf.bas.bg**) is to provide intuitive methods for users for collaboratively authoring learning content [9]. More specifically it aims at developing easy-to-use, light-weight tools for creating machine-processable and human-understandable semantic annotations in a standardized format for digital multimedia objects and compound learning objects. The functionality of the SINUS platform will be tested on several use cases illustrating some aspects of Technology Enhance Learning process in the arts including the creation, exchange and reuse of semantic multimedia objects as building blocks of compound learning resources for the purposes of teaching and learning-by doing. The concrete domain of the use cases is the discipline of Bulgarian iconography presented by means of a legacy database with structured information about the digital multimedia objects implemented as the Virtual Web-based encyclopaedia of the Bulgarian icons [23]. The use cases put an additional requirement for the SINUS platform concerning the data integration issue since the Virtual encyclopaedia of the Bulgarian icons provides a rich set of services for the user that could be used during the process of learning content creation. The objectives concerning the semantic digital multimedia annotations are:

- to identify a common model for modelling semantic annotations across Web-based collaborative systems;
- to develop a standardized approach for retrieving, aggregating, using and presenting metadata attached by a number of users of the system;
- to develop and evaluate an architecture that involves integration of heterogeneous data sources, e.g. multimedia content, relational databases, semantic annotations and/or eventually tags and other social media content;

- to develop an effective approach to making both the relational data and the semantic annotations accessible to the search engine to enhance search services and to allow the creator of semantic annotation to author semantic descriptions based on the available relational data; a declarative query language to be used in SINUS to access the data should provide easy access to the repositories and enable the programmers to implement quickly and efficiently advanced querying and browsing services;
- to experiment with different approaches for automatic annotations extraction based on machine learning algorithms and the available semantic descriptions.

4. e-Learning scenario

The aim of the SINUS e-Learning scenario is to outline possibilities to enhance the learners' knowledge and skills by specific learning-by-doing activities, which may be called learning-by authoring. According pre-assigned tasks the learners have to develop scholarly essays (*projects*), analysing some characteristics of objects of arts (Bulgarian icons in this scenario), available from digital repositories. For this they have to pre-select appropriate (limited, manageable) *collections* of representative and sufficiently diverse digital objects, adequate to the assigned tasks.

The e-Learning scenario *Analysis of iconographic representation of Christ in Bulgarian icons* comprises a list of tasks (use cases) to be fulfilled by students from different humanitarian disciplines, e.g.:

- analysis of the theological meaning of the iconographical representation of Christ in the Bulgarian icons;
- analysis of the representation of Christ in icons created by different iconographic schools in Bulgaria;
- analysis of the basic iconographic techniques used in the representation of Christ in the Bulgarian icons.

Main data source for the scenario is the Virtual encyclopaedia of Bulgarian icons which provides a collection of digital representations of icons together with associated structured data [23]. This general-purpose digital library offers an enhanced set of services, oriented towards any kind of users. The SINUS platform is supposed to organise specialised information services on top of this (and similar) digital repositories in order to support learning needs of learners in humanities while accomplishing learning-by-authoring actions as marked above. Considering the specific characteristics of learners (possible gaps, non-exactness, insecurity, etc., in the knowledge about the subject domain, about how to analyse, how to benefit enough from available digital services) the platform has to be oriented towards a set of learning goals like:

- enhancement, systematization, précising and consolidation of the subject domain knowledge;

- mastering the creation of analytical essays (structure, balance of parts, adequate argumentation, sufficient illustrative material, etc.);
- improving skills for better use of digital repositories.

The analysis of the learning scenario allows to shape the functionalities of the SINUS information support for the learning-by-authoring activities, based on the platform internal knowledge:

- information help in constructing collections of digital objects according the assigned tasks and teachers' guidelines, if available (e.g., possible stepwise refinement of the search in the digital library; proactive consultation about the possible search attributes, their exact meaning and interrelations; desirable volume of search results, etc.);
- flexible multiple presentations of the search results to the learners (diverse layouts of pictures and explanatory metadata-based text with selectable levels of details; sorting the search results according the task and learner profile);
- editing support in development of an analytical essay as multimedia document (*project*) on top of a *collection,* using teachers' guidelines;
- forming of the (approved by the teacher) developed *collections* and *projects* as reusable learning resources in the SINUS platform (annotated with IEEE LOM metadata and possibly also with folksonomic annotations to mark possible educational context of use).

The successful realization of the scenario depends on the available data and learning resources provided by the digital library and complemented with additional knowledge about the subject domain, specific learning-by doing process and learners profiles. The internal knowledge is embedded in the system essentially by meta-data and supporting information structures (including ontologies and semantic descriptions), provided by the developers of the digital library, the developers of SINUS platform and by the authors of learning materials (teachers and learners). Special attention should be paid on "online" annotation by the authors of learning materials: facilities for teachers, to provide concrete tasks, guidelines and additional semantic descriptors to fit them; facilities for teachers and learners to describe the created learning objects (collections, projects) for future reuse.

The learning scenario requires data of two types: relational data containing structured information about digital objects and machine-processable and human-understandable semantic descriptions. The integration of both types of data will facilitate the search for multimedia objects used as building blocks of compound learning objects. Some important points being indirectly mentioned in the scenarios are:

- combinations of heterogeneous data (e.g, relational data, ontologies used for the definition of semantic metadata, personal information ontology);
- machine-understandable semantics of meta-data;
- human-understandable semantics of meta-data;
- interoperability between tools, the underlying formalism should allow different tools to use the same underlying data;
- distributed annotation of resources;

- personalization of tools, queries and interfaces, affecting the provided functionalities and data access.

5. A common model for semantic annotations

A common extensible model for representing semantic descriptions (e.g., annotations and/or other collaboratively created content) is essential to ensure compatibility and interoperability, sharing and reuse of semantic annotations. In developing SINUS, we aim to apply semantic web technologies as attempt to find corresponding solutions to the objectives presented in Section 3 and to analyze the benefits of using standards and tools based on semantic web technologies over conventional software technologies. A model which partially matches the requirements set by the SINUS platform is the model for semantic annotations creation proposed by Vannotea [25]. This model supports the annotation of different media types, structural annotations of parts and whole resources, collaboration, and the storage of provenance information. It facilitates the development and reuse of standardized tools for storing, retrieving, using and presenting metadata attached to multimedia objects. Furthermore, the model used for the creation of semantic descriptions allows the creation of two types of semantic descriptions containing:

- controlled terms from a predefined vocabulary;
- formal statements compliant with a predefined ontology.

The ontology-based annotations model is chosen because it describes a resource with respect to a formal conceptual model, allowing a whole new range of retrieval techniques, which can be based on the knowledge schema expressed in the ontology. It benefits from reasoning and co-occurrence of annotation or entities in the same resource or context, as well as combines this with visual data extracted from images such as Content-Based Image Retrieval (CBIR) techniques. The ontology and the corresponding instance bases capture background knowledge about a domain. Furthermore, the relational data describing the multimedia resources and providing rich knowledge about the domain can be incorporated in the background knowledge and used as a basis for the definition of new ontological knowledge. An example from the SINUS scenario is the concept *festive scene with Christ*. The concept does not exist in the background knowledge, but the teacher could define it based on other existing concepts and annotate the corresponding iconographical objects with this new term, or just use the combination of the concepts that comprise the definition of *festive scene with Christ* and create a complex description to be used later in the scenario for implementing an enhanced search based on the concrete task of the students.

One of the strengths of the Annotea model is that it does not change the annotated artefact. That is why in the SINUS platform it would allow to annotate multimedia resources directly using the Virtual encyclopaedia of Bulgarian icons by help of an appropriate Annotea client providing interface to link descriptions to Web resources and back to controlled vocabularies. The Aus-e-Lit [11] annotation services are an example of such Annotea based editor and server. They provide functionality for annotation of each particular Web resource accessible through the Internet. Moreover, the implementation of an Annotea compliant server in the SINUS platform would allow using arbitrary Annotea clients and the creating the basic types of annotations presented in the Annotea documentation.

6. Underlying technologies

Since the Annotea server is a generic RDF store, the underlying data store in the SINUS platform should be implemented using a semantic repository (e.g., OWLIM [17], Sesame [5], Jena [2]). As the SINUS platform will have to deal with a big amount of triples and the requirements concerning usability are high, SINUS requires the storage system to make use of a relational database. Relational databases offer a convenient way to store a great variety of data. In the special case of storing semi-structured data, the graph model could be mapped to the relational model and stored in a Relational DataBase (RDB). Thus, ontology repositories can use the functionality of RDBs that provides reliable and efficient data management. In this sense some of the RDF-based databases strengths can be summarized as follows:

- *Semantic web integration* – integrated access to the data on the Web that is represented via semantic web languages. In its original conception, Tim Berners-Lee viewed the Semantic Web as allowing Web-based systems to take advantage of ”intelligent” reasoning capabilities [3]. RDF is at the core of W3C’s Semantic Web architectural layers. It is the standard specifically designed to provide a way to produce and consume data on the Web. It sits on top of standards such as XML, URIs, and Unicode and is used as a basis for schemas and ontologies. The W3Cs proposed standard, SPARQL [24], is set to provide a declarative language to query and manipulate Semantic Web data. SPARQL consists of operations that are reasonably similar to those found in existing and mature technologies such SQL.
- *Decoupling of schema and data* – traditional databases require an agreement on a schema, which must be made before data can be stored and queried. One of the great strengths of the RDF model is that it allows data to be stored and queried without first requiring a schema. This decoupling of schema and data also allows the schema to change independently of the data without requiring any existing data to be thrown away or padded with NULLs. It also allows a schema to be automatically generated by looking at relationships between imported instance data. RDF also allows database design and management to be much more agile, similar to agile software development, where a schema can be designed incrementally, after the data has been collected. It allows data that is structured slightly differently to be stored together in the lowest common denominator of an RDF statement (subject, predicate, and object). It eliminates the decision to weigh good design against performance in order to store data that might be slightly different in structure.
- *Easy integration of diverse data* – as a consequence of the decoupling of schema and data semantic repositories provide the possibility for easier integration of diverse data over traditional DataBase Management Systems (DBMS).

- *Automatic reasoning* – the underlying model of the semantic repositories are ontologies as semantic schemata and this allows them to automatically reason about the data. Semantic repositories are engines similar to the DBMS – they allow the storage, querying, and management of structured data.

In addition, some shortcomings of RDF-based databases which can be defined as a consequence of their semantic nature or inherited from the relational databases, can be identified as follows:

- *Complex design process when manually constructing ontologies* – the process of manually constructing ontologies would be enhanced in the SINUS platform in two ways. First, the existing relational databases will be partially exposed as an RDF view based on the declaration of mappings between ontological concepts and relational data. Furthermore the automatic reasoning capabilities of the underlying RDF database (e.g. semantic repository) will be used to infer additional knowledge. Future implementations could include the use of tagging capabilities as an alternative to the semantic annotations. Second, approaches for automatic knowledge extraction and extension of the existing models based on machine learning algorithms will be investigated.
- *Complex programmer environment and lack of a standard API for RDF database management* – there is no standard API for RDF database access, thus the resulted RDF application source code is tightly coupled with the underlying repository. However, the actual implementation of the RDF database access could be enhanced by the SINUS software architecture and isolated by help of different software techniques based on the usage of interfaces (e.g., IoC pattern [10]).
- *Longer running applications* – many relational database users argue that the RDF-based data access is inefficient in respect to relational databases. However experiments show different results as shown in [17].
- *Initial training required for the users* – the semantic annotations model should be as intuitive as possible in order to facilitate construction of semantic descriptions and the wider adoption of the system.

7. Conclusion

The present paper has investigated the requirements for semantic descriptions of digital multimedia objects, considering both the requirements for annotation models and a set of further functional and non-functional requirements for storage, scalability and performance of an annotation platform supporting the presented model and implementation of semantic descriptions editors. These requirements may provide the foundation for further work on the SINUS platform. The presented investigations have revealed that the annotation model to be developed has to be easily integrated in an existing Web application (e.g. the Virtual encyclopaedia of Bulgarian icons) and benefit from its presentation tier (GUI), the underlying data and possibly from the existing services provided by the application.

Further investigations will target the implementation of enhanced search capabilities based on the provided semantic information and the visual analysis of the multimedia content. The search functions will facilitate the construction of complex compound learning resources which is a general functionality in the SINUS platform.

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