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Toward Semantic Digital Libraries: Exploiting Web2.0 and Semantic Services in Cultural Heritage*

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Abstract

Developing and maintaining a digital library requires substantial investments that are not simply a matter of technological decisions, but include also organizational issues (user roles, workflows, types of contents, etc.). These issues are often handled by approaches based on a physical perspective that treats the stored information either in terms of data formats or physical space needed to archive them. All these perspectives completely ignore the semantic aspects of the digital contents. In this paper, we address such a semantic perspective. More specifically, we propose a service-oriented architecture that explicitly includes a semantic layer which provides primitive services to the applications built on top of the digital library. As part of this layer, a specific component is described: the PIRATES framework. This module assists end users to complete several tasks concerning the retrieval of the most relevant content with respect to a description of their information needs (a search query, a user profile, etc.). Techniques of user modeling, adaptive personalization, and knowledge representation are exploited to build the PIRATES services in order to fill the gap existing between traditional and semantic digital libraries.

I. Introduction

Improvements in digitization have led, in the last decades, to a huge evolution in the way cultural digital libraries and archives are conceived, designed, and used. Both the transition of library materials from traditional to digital formats and the large (and continuously growing) availability of digital content pose new challenges. More sophisticated software tools are needed to meet the expectations of users, which are often high due to the classical information overload problem.*Searching* everything everywhere is becoming a habit also in digital libraries, but *finding* exactly what it is needed remains a very hard job [Celino et al., 2006]. Data interoperability and sharing is another issue that must be faced when developing tools concerning digitized cultural heritage: often, contents and archives should be shared across different platforms and applications, usually by means of a Web-based infrastructure. Moreover, according to the growth of the Web 2.0 philosophy, new ways to access such contents should be provided to users: they could add their own contributions to the collections, share such contributions with other users and improve the effectiveness of information access.

These trends in design and development of digital libraries have not been fulfilled as a whole; *preservation* of multimedia contents and data is still addressed mainly by means of technological factors, e.g., reliable storage mechanisms able to guarantee long-term accessibility of digital support [Barkstrom et al., 2002]. *Evolution*, at the same time, is typically considered a matter of scalability of the *physical* system, concerning stored information either in terms of data formats or physical space needed to archive them. These perspectives, as claimed by Ross in [Ross, 2006], completely ignore the *semantic aspects* of the preserved objects.

In this paper we embrace the "semantic perspective" of digital libraries, introducing a general approach to digitized cultural heritage exploitation (preservation, evolution, classification, and access) that is not restricted only to the physical preservation of the contents available in a digital library. Our approach is focused on delivering a platform specialized in management of cultural heritage collections that:

1. promotes the (logical) independence of data from their physical representations
2. promotes data interoperability at both archive and platform level
3. integrates a set of primitives aimed at providing support to evolution at different levels of abstraction (archived contents, user requirements, technological infrastructures, user roles and workflows)
4. integrates a set of tools aimed at supporting users during information access, classification, and retrieval
5. integrates a set of services aimed at supporting the semantic digital library vision [Kruk and McDaniel, 2008].

Our semantic perspective is complementary to the use of traditional Semantic Web features such as RDF schemas and resource descriptions, triple stores, or ontology languages. Indeed, we aim at developing a platform that provides its users an environment capable of dealing with information retrieval tasks where the intended meaning is important but not the presence of the "*exact word*". Our proposal includes the vision of a system capable of providing accurate search results by exploiting several tools coming from automatic categorization algorithms, content-based information filtering and retrieval, adaptive personalization, and Web 2.0 features. More specifically, we are designing and developing a digital platform capable of maintaining the *semantic* meaning of each digital object and its content, of maintaining its origin and authenticity, and of retaining its interrelatedness, as suggested by [Ross, 2007]. In this way, our approach aims to provide a "content-based semantic layer" on top of the digital archives, giving a semantic connotation to digital libraries, regardless of the specific knowledge representation mechanism exploited (be it RDF, OWL or any other KR language).

This work is based on a three-year experimentation with the EU-India E-Dvara project [1] : a digital platform devoted to Indian and Italian cultural heritage, as described in Section III. E-Dvara represents our current development and experimentation in the area of digital libraries. In previous work, we presented the overall project goals [Challapalli et al., 2006], a conceptual model to handle evolution issues in digital libraries [Baruzzo et al., 2009a], and the technical details concerning the E-Dvara software architecture [Baruzzo and Casoto, 2008, Baruzzo et al., 2008]. The main and new contributions of this work exploit both automatic and manual tagging as a way of implementing the exploitation process and of improving the effectiveness of information access. Such features are provided by integrating the PIRATES framework [Baruzzo et al., 2009b] in E-Dvara, an automatic tagging environment. Other approaches to information access and visualization (like a Virtual 3D Museum) could be plugged into the proposed architecture without affecting the way contents are stored.

This paper is organized as follows: Section II describes the state of the art in the field of semantic digital libraries, Section III introduces the E-Dvara project and Section IV summarizes the E-Dvara service-oriented architecture. Then, in Section V, we illustrate our approach to semantic digital libraries and next, in Section VI, we discuss our strategy of exploiting "semantic services" (e.g., ontologies and tagging) to annotate, classify, retrieve, and recommend contents in cultural heritage digital libraries. Finally, Section VII outlines both conclusions and future work.

II. Related Work

In the last few years several research projects have been proposed for effective cultural heritage content organization, preservation, and integration [Bekaert et al., 2005, Lutzenkirchen, 2002, Candela L. and Pagano, 2007]. Storage of XML-based documents has been proposed in Greenstone [Bainbridge et al., 2001, Witten et al., 2000], a digital library designed to provide librarians with the ability to create and publish heterogeneous collections of digital contents on the Web like text, images, videos and e-books. Each content item in Greenstone can be described using *metadata* compliant with the Dublin Core[2] standard.

D-Space [Tansley et al., 2003] is a digital library aimed at providing long-term preservation of heterogeneous contents, by improving some of the limitations affecting Greenstone. Authors usually submit their documents to the system and define metadata for them; for such reasons D-Space is also referred to as an *author oriented* digital library. D-Space also introduces a multi-roles approach to content publishing, identifying the following actors: *authors* and *organizations* who provide the contents, *librarians* who perform content validation and *users* who are interested in content retrieval. Content-based workflows can be customized in order to cope with the needs of specific organizations and to delegate different tasks to different stakeholders.

In order to provide a flexible and reusable solution to data preservation and organization, the Fedora project [Lagoze et al., 2005] explored a service-oriented approach to data interoperability in digital libraries by designing and developing a distributed architecture for contents publishing, aggregation, and retrieval. Composite information is obtained by aggregating physical contents, viewed as bit-streams, located worldwide into the Fedora repositories. Fedora allows content editors and archivists to define semantic connections between archived contents, treated as a set of physical contents.

Other work related to content preservation in digital libraries is described in [Bekaert et al., 2005, Lutzenkirchen, 2002]; in particular, the aDORe project adopts the MPEG-21 DID content representation model in order to provide preservation and retrieval of heterogeneous multimedia contents.

The above mentioned systems are centred on contents, defined as *binary resources* enriched by metadata devoted to preservation, storage and retrieval purposes but not intended for data structuring. Preservation and evolution of a data model in those approaches is implemented as a low-level mechanism, where data is processed as bit-streams instead of as instances of well-defined structures (i.e., XML Schema).

Several research projects, on the other hand, have been focused on improving the effectiveness of digital libraries in cultural heritage by moving towards a deeper semantic representation of the stored data, integrating ontologies and tools devoted to content annotation [Woroniecki et al., 2007].

CultureSampo[3] is a platform aimed at combining and accessing heterogeneous archives of cultural heritage related contents. Each metadata schema used to represent data has been mapped onto a shared ontology, the ONKI ontology, in order to provide semantic interoperability between contents. This semantic enrichment leads to new approaches to information access: CultureSampo introduces a perspective-based access to contents, where each perspective is represented by a subset of semantic features of the stored contents, such as temporal or geographical information.

CultureSampo provides a set of functionalities required for content publication, annotation and retrieval; content retrieval is exploited by means of both relation-based and semantic features-based approaches. Collaborative content generation, according to the Web 2.0 philosophy, has been introduced into the CultureSampo infrastructure, in order to improve the amount of semantic information added to the contents; such tasks have also been partly automated by introducing domain independent annotation agents based on common thesauri and ontologies.

Interoperability of cultural heritage datasets and schemas between different platforms available on the Web has also been exploited by the *AMA: Archive Mapper for Archeology* project [Eide et al., 2008] as a part of *EPOCH*[4]. The tools developed during the *AMA*project are aimed at providing semi-automated mapping of cultural heritage custom data to the CIDOC-CRM, a formal ontology devoted to facilitate the integration, mediation and interchange of heterogeneous cultural heritage information.

CCHO: Cantabria's Cultural Heritage Ontology [Hernandez et al., 2008] is also aimed at effectively integrating cultural heritage data in the region of Cantabria. Contents have been properly annotated by using the CCHO and, as in CultureSampo, can be browsed by a semantic-based search engine according to several perspectives like geographical maps, historic event timelines and semantic relations between items.

In contrast to the previously described projects, which are based on a wide and formally defined ontology such as the CIDOC-CRM, the *OCHRE: Online Cultural Heritage Research Environment* project [5] adopts an approach based on a lightweight, extendable and general ontology called the *Core Ontology*. This ontology covers the domain of cultural heritage by means of a small set of highly general concepts and relationships, in order to grant an higher level of abstraction. The OCHRE's ontology can be extended and refined for each different project according to the amount of specialized semantic information required to characterize a given collection.

Digital libraries specialized in cultural heritage management have been further improved by integrating social practices, like social and collaborative tagging, arising from the Web 2.0 experience. Using tags and annotations, provided either manually by the users or in a semi-automatic way, contents can be semantically enriched in order to improve the effectiveness of both navigation and retrieval tasks.

In [van der Sluijs and Houben, 2008] an example of the effectiveness of integration between the Web 2.0 approaches and a cultural heritage devoted DL is exploited: the *CHI* system, designed and developed by the *RHCe* (Regional Historic Centre Eindhoven). CHI is devoted to storage and access of photo and video archives; a specific set of metadata has been assigned to each of these archives. Users can search, browse and visualize the collections hosted by the RHCe by accessing them according to different dimensions, each one identified by a specific set of metadata, as in CultureSampo. However metadata could refer either to a specific domain ontology (e.g., OWL time ontology [6] used to represent the temporal dimension) or to a user defined set of keywords (tags) assigned to a specific resource by the users in a collaborative way.

Annotations regarding a specific content item could also be harvested and collected from the network, looking at metadata used by different platforms and users to describe the same contents (e.g., the metadata assigned to the same painting into two different collections, hosted by different digital libraries devoted to cultural heritage).

The *HarvANA: Harvesting and Aggregating Networked Annotations* [Hunter et al., 2008] system uses a RDF model to represent tags/annotations and OAI-PMH [7] to harvest the tags/annotations of a specific content item (e.g., a book characterized by a specific ISBN code) from a network of heterogeneous digital libraries.

Finally, another relevant related project that is facing similar challenges on a larger scale is the Europeana [8] initiative, a search platform integrating a collection of European digital libraries with digitized paintings, books, films and archives.

III. The E-DVARA Project

E-Dvara is a project focused on the development of a new platform for storage of digital contents [Challapalli et al., 2006].

Since its inception, it has been explicitly designed to overcome some limitations that characterize the process of building a digital library. In particular, E-Dvara was initially meant to:

1. reduce the effort required by the archivist to define the data structure used to represent data into the archives
2. provide to archivists with no expertise in data management a set of wizards devoted to data schemata creation in a completely automatic and transparent way (with respect to the physical database)
3. allow content providers to easily share their archives on the Web by means of a build-in Web interface or with several other applications, allowing archivists and system administrators to define the way data should be rendered to final users
4. allow archivists to provide for each archive of digital contents a specific visualization template and a set of search forms.

More recently, we started introducing in the E-Dvara platform a set of semantic services aimed at assisting final users to select from the archives the most appropriate content with respect to their current information needs [Baruzzo et al., 2009a].

In order to cope with all of these requirements, the E-Dvara platform has been designed to adopt a layered modular architecture, as illustrated in Figure 1.

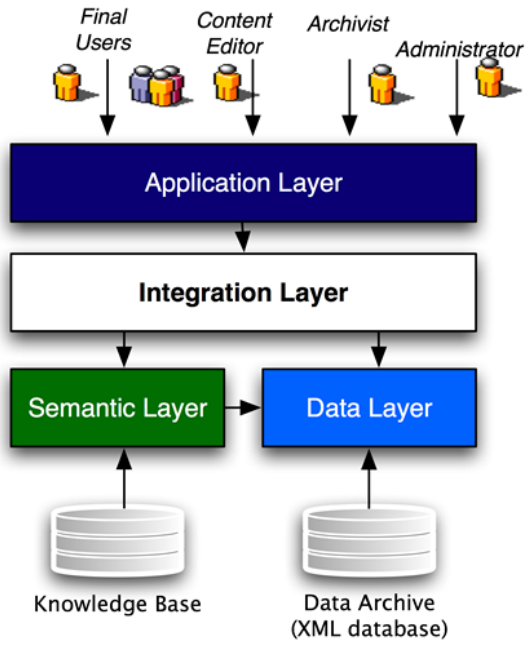

Figure 1: The high-level E-Dvara software architecture.

At the bottom of the architecture, digital archives are stored in XML databases by a core layer devoted to data storage and persistence (*Data Layer*). The access to these archives can be provided directly by the Data Layer services, or by a *Semantic Layer* which exploits a Knowledge Base in order to find (suggest) the most relevant content fulfilling the user needs (e.g., a user query submitted from a search engine). The *Integration Layer* forms the "architectural glue" that brings the digital library beyond the scope of a single application, unifying the interfaces of different subsystems into the same interoperable environment. The standard set of Web service technologies (XML, SOAP, WSDL) provides the means to describe, locate, and invoke a Web Service, simplifying the integration of new applications in the E-Dvara platform. The Integration layer uses a component called Enterprise Service Bus (see Figure 3), which implements the orchestration of different application-specific services in order to integrate these applications in the digital library. Finally, at the top of the architecture, the *Application Layer* hosts the programs used by the digital library users (archivists, content editors, final users, etc.) in order to edit, publish and access the contents stored in the archives.

Figure 2: The homepage of the first prototype of E-Dvara platform.

Figure 2 illustrates the homepage of the E-Dvara project, developed in 2005. During the last three years the first prototype has been largely tested by expert users involved into professional content publishing for cultural heritage. From this experimentation, we have gathered several evolution issues, weaknesses and mistakes, which led us to rethink the entire project. Currently, a second prototype is under development which introduces several heterogeneous services more oriented toward realizing the semantic digital library vision introduced in the introduction.

IV. A Service-Oriented Architecture for Intelligent Information Access in Digital Libraries

The second prototype of E-Dvara is based on a service-oriented architecture presented in [Baruzzo and Casoto, 2008, Baruzzo et al., 2008]. Here we concentrate on describing the Semantic layer which is the new contribution of this paper. As illustrated in Figure 3, this layer exposes its services to the user applications through the Enterprise Service Bus located in the Integration layer. Two main components characterize the Semantic layer:

- *PIRATES Framework*, which communicates with a Knowledge Base in order to retrieve or suggest potentially relevant information from the archives. This framework provides primitive services to automatically classify, annotate and recommend specific content using techniques based on natural language processing. PIRATES is composed of three components, a *Cognitive Filtering Tools* module, an *Automatic Tagger*, and a *Knowledge Base Builder*, which are described in Section V-B.
- *Meta Search Engine*, which exploits the document annotations provided by PIRATES in order to recommend similar contents with respect to those retrieved by a traditional search engine fulfilling user queries. This module can also be used for refining a user query which has not provided enough results (query reformulation).

The presence of the Semantic Layer is aimed at improving the information access mechanism of the E-Dvara digital library, empowering its environment by semantic services.

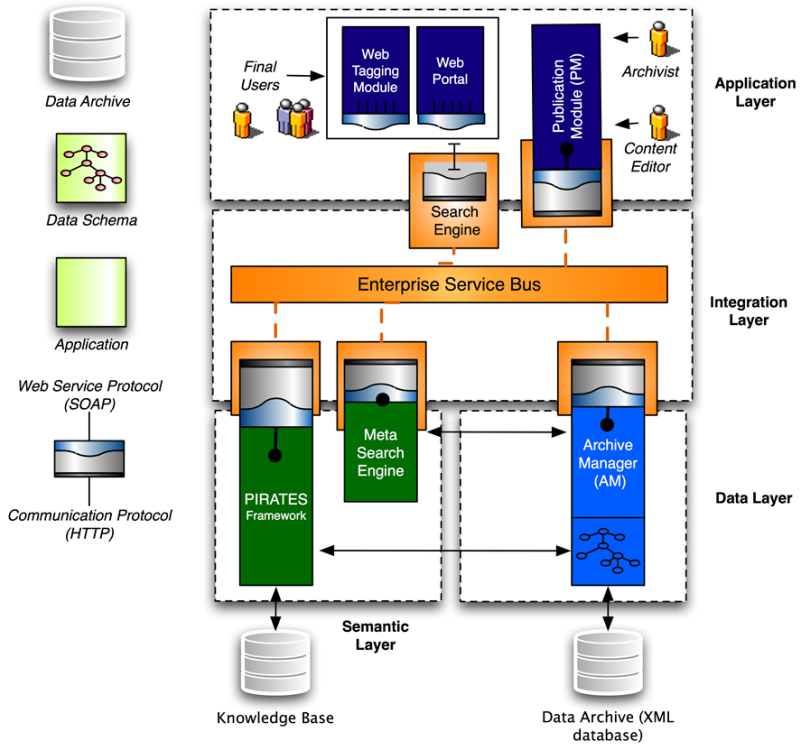

Figure 3: E-Dvara 2 Service Oriented Architecture.

V. Accessing Digital Library Archives by means of "Semantic Services"

Semantically enabled technologies are expected to bring a number of benefits to the users of digital libraries such as helping people to find relevant information more efficiently, giving better access to that information, and aiding the sharing of knowledge within the user community. Starting from these motivations, in this section we outline an approach for adding semantics to archives using tags suggested by an automatic system (the PIRATES framework) that is based on information extraction techniques. Before introducing PIRATES, we describe the ways an archivist can exploit tagging services to annotate a digital content item. We discuss also some notable limitations inherent to the use of manual tags that lead us to propose an automatic approach to tagging. Finally, in Section VI we present an example illustrating different usage scenarios of PIRATES in the E-Dvara digital library.

A. Adding Semantics to Digital Archives: the Tagging Approach

Tagging is a textual annotation technique based on *meta-data information* (i.e., tags). A *tag* is a keyword users use to annotate a content, in order to organize knowledge, describe it, correlate it with other contents, or simply to retrieve it easily in future searches. The tagging activity may be *manual* if it is provided by a human user, or *automatic* if is it generated by a dedicated software. Archivists can employ tags differently because they can be guided by different tasks. Typically, tagging is used with the explicit intent of:

1. *classifying content* by means of a corpus of concepts that are familiar to the archivist (e.g., taxonomies, thesauri, or any bag of keywords representing meaningful categories for him/her)
2. *summarizing resource content* by means of a short list of keywords representing the user-generated content description
3. *expressing a polarity judgment* about a content by means of proper adjectives provided as tags (e.g., *"sad"*, *"wonderful"*)
4. *correlating tagged resources with people and their skills* such as the level of expertise, the reputation, or the importance of a person mentioned in the resource content (e.g., *"guru"*, *"geek"*, *"vip"*, *"bill-gates"*, etc.)

5. *creating dichotomous classification criteria* in order to describe resources as belonging or not belonging to a particular category (e.g., *"clinical"/"not-clinical"*, *"statistical"/"not-statistical'*, *"accepted"/"rejected"*, and so on)
6. *providing temporal information* to a resource, for example annotating the date of an event related to that resource.

To some extent, all these forms of tagging express a classification intent targeted to establish effective schemata for organizing the knowledge and facilitating content retrieval.

Tagging allows users to determine suitable labels for their resources freely without relying on any predetermined vocabulary or hierarchy [Mathes, 2004]. Moreover, tags can be very effective for serendipitous browsing of a digital archive of documents (or bookmarks) in order to find relevant information. Hence people tag the content with their own vocabulary and ultimately their mental models in order to facilitate the process of recall. Besides with these potential benefits, manual tags suffer with some of notable limitations [Dattolo et al., 2009]:

- *Ambiguity*: with an uncontrolled vocabulary, many tags can be ambiguous. Indeed in tags we can find the same ambiguity that we find in natural language (e.g., homonymy, polysemy, synonymy, spelling mistakes, disambiguation, words which have more than one common spelling or morphology etc.).
- *Undistinguished concerns*: social tagging systems do not enforce, or even propose, a schema for distinguishing the purpose of a meta-data value. Tags might be variously, subject descriptors, genres, self-reminders, tangential remarks (such as colors or years, especially for non-textual information such as pictures) or proper names.
- *Independence of terms*: social tagging does not provide relationships to connect and relate different terms: each tag is independent of the others and no inference is possible. In other words, the structure of a tag system is "flat".
- *Effort*: systematically (and consistently) tagging Web resources is tedious, error prone and rather wearying.

In order to alleviate these limitations, we propose an automated approach that assists the user when (s)he tags a Web resource. A software system analyzes the textual document and provides suggestions/recommendations for new tags by exploiting information extraction tools [Cunningham, 2002] and ontologies. Using this approach, we try to achieve two different goals:

- *use a controlled, ontology-based vocabulary*, not necessarily present in the original Web resource, in order to classify it as result of the automatic tagging process; our vocabulary is a structured form of knowledge representation (the ontology) and provides entities (classes), instances and relations (is-a links between entities).
- *reduce the manual effort* required to tag a Web resource

B. The PIRATES Framework: Merging Cognitive Filtering, Web 2.0 and Semantic Services

This section presents the PIRATES framework: a Personalized Intelligent Recommender and Annotator TEStbed for text-based content retrieval and classification. Using an integrated set of tools, this framework lets the users experiment, customize, and personalize the way they retrieve, filter and organize the large amount of information available on the Web. Furthermore, the PIRATES framework undertakes a novel approach that automates typical manual tasks, such as content annotation and tagging, by means of personalized tags recommendations and other forms of textual annotations (e.g., key-phrases).

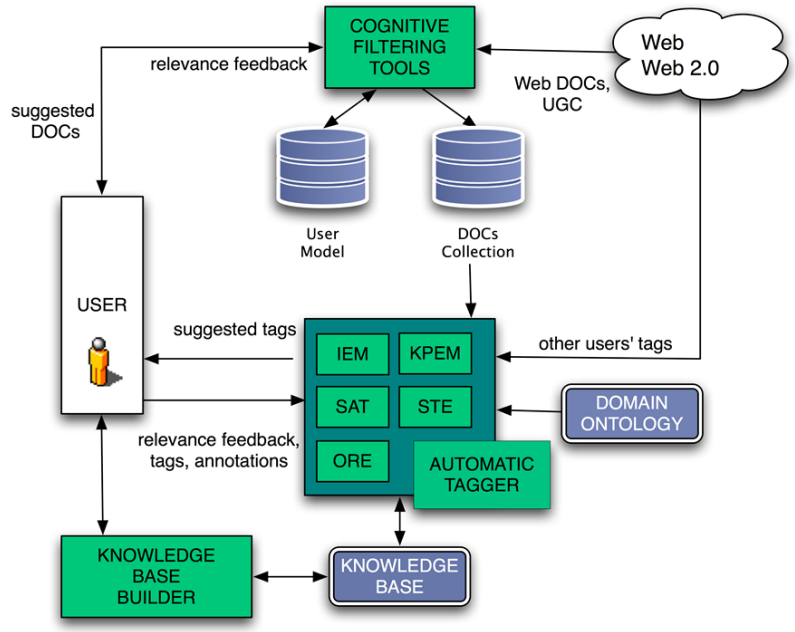

Figure 4: PIRATES main modules.

The PIRATES architecture, shown in Figure 4, is formed by three major components:

- The *Cognitive Filtering Tools* module implements the IFT (Information Filtering Tool) module. The IFT algorithm [Tasso and Asnicar, 1997] is used to build representations of user interests (*IFT user models*), to provide mechanisms of relevance feedback and to classify the textual content of a document belonging to an incoming stream of documents. The classification process produces evaluations of the relevance (in the sense of topicality) of a document according to a specific model of user interests represented by semantic networks. Semantic networks are built in a supervised way, by integrating a priori knowledge provided by domain experts, expressed as a training set constituted by keywords, short excerpt of textual description, and links to relevant documents. This knowledge is then encoded by the IFT algorithm into a vector of weighted terms and connections, linking terms which co-occur in the training set.
- The *Automatic Tagger* module implements several modules devoted to automatically annotating an incoming stream of text (the content of a document) by means of tag recommendations: the submodule IEM (Information Extraction Module) suggests entity, names, and dates, KPEM (Key-Phrases Extraction Module) key-phrases, SAT (Sentiment Analysis Tool) polarity judgments, STE (Social Tagger Engine) tags used by a community of Web 2.0 users, while ORE (Ontology Reasoner Engine) extracts tags from an ontology. The user can choose the combination of annotator modules to exploit in order to obtain suggestions for tags.

- The *Knowledge Base Builder* module organizes documents in a Knowledge Base repository and produces annotated documents.

The PIRATES framework operates on a set of input documents stored in the Information Base (IB) repository and suggests personalized tags and other forms of textual annotations (e.g., key-phrases) in order to classify them. The original documents are then annotated with these tags forming the Knowledge Base (KB) repository.

Our main goal in integrating PIRATES in the E-Dvara platform is to empower information access, allowing users to find new relevant contents easily and automatically support them when categorizing documents by means of keywords (tags) in a personalized and adaptive way. We have designed PIRATES keeping in mind several applications where it can provide innovative adaptive tools enhancing user capabilities: in e-learning portals for supporting the tutor and teacher activities in monitoring student performance, behavior, and participation; in knowledge management contexts (including scholarly publication repositories and digital libraries [Omero et al., 2007]) for supporting document filtering and classification and for alerting users in a personalized way about new posts or document uploads relevant to their individual interests.

Although the PIRATES framework is still a theoretical model, a prototype version has been already developed, integrating the IFT subsystem and, at the same time, implementing two different KPEM algorithms (respectively domain dependent and domain independent), and a preliminary version of both the IEM module and the ORE module. In particular, the ORE module does inference over a local ontology written in OWL format, using a reasoning mechanism based on is-a relationship between the ontology concepts.

VI. Improving Information Access in Cultural Heritage Archives using Semantic Services

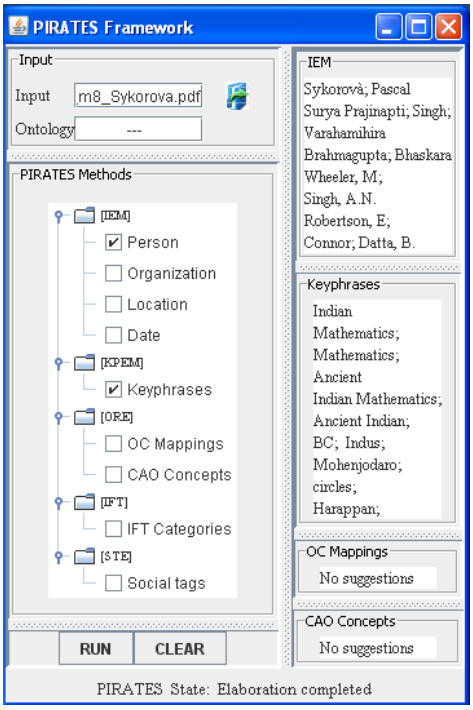

Figure 5: Tags suggested by PIRATES for a document.

In order to show a usage scenario of PIRATES, consider an archivist who is going to update an E-Dvara archive concerning ancient Indian science, adding a scientific paper by Sykorova entitled "Ancient Indian Mathematics." [9] Before storing the document, the archivist prepares a card summarizing the paper contents. As part of this card, he can provide one or more keywords which will be exploited by the E-Dvara applications (typically, search engines) to retrieve the document efficiently. The PIRATES framework assists the archivist in this task, performing both statistical and semantic analysis of the document content and suggesting a set of tags, as illustrated in Figure 5. The archivist can select each annotator tool individually; in this case, he was interested in extracting names and key-phrases. Eventually, he will select from the list those tags that best represent the document and in this way annotate the item.

Automatic tag recommendation may lead to several improvements in content access, one of these being *annotation-based content recommendation*. For example, if a user is accessing a document similar to the Sykorova one already available in the platform and not yet tagged by PIRATES, the set of the most similar contents may be retrieved and presented to the user. Similarity is defined as the set of common tags shared by a source content item and the other content items available in the platform. In this scenario, each user can provide a query to the platform search engine, browse the results and, in real-time, receive a list of suggested contents that do not necessarily contain the same keywords used in the query (tags identified by PIRATES may represent concepts which are not directly referred to in the resource, but obtained as result of ontology base inference).

Another scenario concerns the task of *query reformulation*. Semantic representation of available contents, provided manually or in an automatic way, may also be exploited to improve the effectiveness of traditional keyword-based retrieval. More specifically, semantic knowledge can be used to augment the effectiveness of traditional keyword search, moving further toward the concept of semantic search. In order to achieve such goals, a query reformulation engine will be included in the Semantic Layer of the E-Dvara platform. Using both the contents metadata and the ontologies constituting the Knowledge Base of the platform, the query reformulation engine will intercept the requests submitted by users and suggest, in addition to the retrieved contents, a list of potentially related queries.

According to the workflow and the nature of the set of modules constituting the PIRATES framework, the query reformulation task will be based on two different kinds of knowledge: ontology-based reformulation and annotations-based reformulation. *Ontology-based reformulation* will be used to identify concepts similar to the terms used in the query by browsing the domain-dependent ontology used by the ORE module to annotate resources. Such concepts may be included into the query or can be used to substitute existing terms. *Annotations-based reformulation*, on the other hand, is based on the tags assigned to the

contents retrieved using the original query; by ranking tags and looking at the most relevant ones (relevance will be defined as a tag frequency function), reformulation engines can generate a new query. Annotations-based reformulation exploits all the different kinds of annotations provided by the PIRATES framework; such an approach may be seen as complementary to the one used by the ontology-based reformulation, where only knowledge occurring in the domain ontology is considered.

In the next few months we will formally define both the concepts of ontology-based and annotation-based similarity and, according to this model, we will integrate the query reformulation service into the E-Dvara Semantic Layer.

VII. Conclusions

In this paper we have proposed a service-oriented architecture for the E-Dvara digital library that explicitly integrates a semantic layer. The integration of semantic services is aimed at better addressing changes in final users' information needs and improving the effectiveness of information access. To support this new semantic layer, we have designed a framework based on adaptive and personalized services, distinguishing the digital library from an old-fashioned DBMS/structured archive system. Giving access to the semantics of contents helps to realize the vision of a semantic digital library, which is possibly one of the most innovative evolutions in current digital libraries.

The ideas discussed in this article come from the lessons learned during the experimentation with the first prototype of the E-Dvara platform over the last three years. We are now working to complete a second version of E-Dvara which will embody the improvements discussed in this paper. Our future plans include a validation of the overall prototype in different areas, concerning the exploitation of both information and services by means of mobile applications, virtual museums and Web 2.0 environments.

Notes

[1] http://edvara.uniud.it/india

[2] See for more details: http://dublincore.org/

[3] http://www.kulttuurisampo.fi/

[4] EPOCH is a network of about a hundred European institutions collaboratively producing applications involving digital versions of Cultural Heritage.

[5] http://ochre.lib.uchicago.edu/index.htm

[6] http://www.w3.org/TR/owl-time/

[7] OAI-PMH: The Open Archives Initiative Protocol for Metadata Harvesting provides an application-independent interoperability framework based on metadata harvesting.

[8] http://europeana.eu

[9] http://www.mff.cuni.cz/veda/konference/wds/contents/pdf06/WDS06_101_m8_Sykorova.pdf

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