The Indiana MAS Project: Goals and Preliminary Results

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***Abstract*—The Indiana MAS project, funded by the Italian Ministry of Education, University and Research "Futuro in Ricerca 2010" program, aims at providing a framework for the digital protection and conservation of rock art natural and cultural heritage sites, by storing, organizing and presenting information about them in such a way to encourage scientific research and to raise the interest and sensibility towards them from the common people.**

The project involves two research units, namely Genova (Dipartimento di Informatica, Bioingegneria, Robotica e Ingegneria dei Sistemi) and Salerno (Dipartimento di Matematica e Informatica), for a period of 36 months, starting from march 8th, 2012.

The technologies adopted in the project range from agents to ontologies, as requested by the complex nature of the platform, where each module is devoted to a specific task: sketch and symbol recognition, semantic interpretation of complex visual scenes, multi-language text understanding, storing, classification and indexing of multimedia and heterogeneous digital objects. All of them should cooperate and coordinate in order to enable higher level components to reason on them and to detect relationships among different digital objects, hence providing new hypothesis based on such relationships.

I. Introduction

According to the UNESCO World Heritage Convention Concerning the Protection of the World Cultural and Natural Heritage, signed in 1972 (http://whc.unesco.org/?cid=175), "cultural heritage" includes: works of man or the combined works of nature and man, and areas including archaeological sites which are of outstanding universal value from the historical, aesthetic, ethnological or anthropological point of view; natural sites or precisely delineated natural areas of outstanding universal value from the point of view of science, conservation or natural beauty that are defined as "natural heritage".

To cite the UNESCO World Heritage Convention

> *To ensure that effective and active measures are taken for the protection, conservation and presentation of the cultural and natural heritage situated on its territory, each State Party to this Convention shall endeavour, in so far as possible, and as appropriate for each country:*
>
> ...
>
> 1) *to develop scientific and technical studies and research and to work out such operating methods as will make the State capable of counteracting the dangers threaten its cultural or natural heritage;*
>
> ...

By adhering to some of the most significant objectives of the UNESCO World Heritage Convention, the European Community has recently founded several projects aiming at fostering the quality and effectiveness of ICT in the cultural heritage field: the *Epoch* network of excellence (http://www.epoch-net.org/); the STREP project *MultiMatch* (http://www.multimatch.eu/) focusing on facilitating the interaction between users and multi-modal and multilingual online cultural contents; the CIDOC CRM (http://www.cidoc-crm.org/) and Europeana Data Model (http://pro.europeana.eu/) standard efforts, for knowledge representation in cultural heritage; the FP6-IST *BRICKS* project (http://www.brickscommunity.org/) and the *DELOS* network of excellence (http://www.delos.info/), both aiming at designing, organizing, integrating and preserving digital objects in cultural heritage digital libraries; the FP6-IST *AGAMEMNON* project (http://services.txt.it/agamemnon/), where Prof. Massimo Ancona was actively involved, with the goal of offering to the visitor of an archaeological site a personalised and enriched experience through the use of mobile phones; and many other projects.

Although all such projects represent a source of inspiration for Indiana MAS and share many objectives with it, the peculiarity of the artifacts handled by Indiana MAS makes it necessary the adoption of specific tools and technologies that are not applicable in the above projects, due to their more general scopes.

The aim of Indiana MAS, funded by the Italian Ministry of Education, University and Research "Futuro in Ricerca 2010" program, is the development of a framework for the digital preservation of *rock art*, able to complement the techniques adopted for the cultural heritage field with the adoption of context specific techniques.

Rock carving art is an example of cultural and natural heritage, since it is often located in wonderful natural sites and represents an invaluable resource for understanding our history. It is not a case that the well known rock carving sites of Tanum in Sweden, Altamira is Spain, Alta in Norway, Lascaux in France, Valcamonica in Italy are all listed in the UNESCO World Heritage Sites.

Many other rock carving sites are spread all over Europe and from Northern to Southern Italy (Ciappo delle conche, Ciappo dei ceci, Ciappo del sale, Pietra delle coppelle, Monte Beigua in Ligury; Val Camonica and Valtellina in Lombardy; val Chisone, val di Susa, Val Sangone, Val Maira in Piedmont; Monte Sagro in Tuscany; Lillianes in Aosta Valley; Grotta del Genovese and Grotte dell'Addaura in Sicily).

The Indiana MAS project aims at the digital protection and conservation of rock art natural and cultural heritage sites, by storing, organizing and presenting information about them in such a way to encourage scientific research and to raise the interest and sensibility towards them from the common people. The platform that will be designed and implemented during the project should support domain experts in the creation of the repository, which may become a reference at Italian and, maybe, European level as a thorough database of rock carvings, and in the interpretation of rock carvings. It should also promote the awareness and the preservation of the cultural treasure by making cultural information accessible to all on the Internet and preserve it for future generations.

In this paper we illustrate the objectives and the application domain of the project (Section II) as well as the expected results (Section III), and describe the preliminary results obtained in the first months of the project activities (Section IV). Section V concludes the paper with some reflections and future work.

II. Objectives and Application Domain

Indiana MAS has five main objectives:

- O1. integrating heterogeneous unstructured data (multi-lingual textual documents, pictures, and drawings) related to rock carvings into a single repository;
- O2. normalizing data by recognizing those referring to the same object, correctly associating them with its digital representation, and removing duplicate data;
- O3. classifying normalized data according to the "Indiana ontology" that will be extracted in a semi-automatic way from the unstructured data, and that will evolve as data will;
- O4. organizing classified data into a Digital Library and making the library accessible thanks to a web-based, multilingual, user-friendly interface;
- O5. interpreting data stored in the Digital Library, finding relations among them, and enriching them with the semantic information extracted thanks to this interpretation and relation retrieval stage.

To this end, such a platform should enable the preservation of all kinds of available data about rock carvings, such as images, geographical objects, textual descriptions of the represented subjects, and the organization and structuring of such data into an existing collaborative tool set, and it should supply domain experts with collaborative facilities for processing the data and making assumptions about the way of life of the ancient people based on these data. The digital preservation, classification, and interpretation of rock carvings raises many research challenges, such as the integration of data coming from multiple sources of information and the interpretation of drawings whose meaning may vary based on several information such as the objects depicted in the whole carving.

The solution we propose to suitably face these challenges is based on the integrated use of intelligent software agents, ontologies, natural language processing and sketch recognition techniques. Multi-agent systems (MASs) represent an optimal solution to manage and organize data from multiple sources and to orchestrate the interaction among the components devoted to the interpretation of the carvings.

Ontologies allow to define a common vocabulary that can be profitably exploited to organize data associated with rock carvings, included their semantic annotations, and create semantic relationships between them. Natural Language Processing techniques can be used to extract relevant concepts from text and for mining semantic relationships among them, hence supporting the definition and evolution of ontologies devoted to describe the domain.

Sketch recognition techniques can be applied to classify the elementary shapes of the carving drawings and associate their possible interpretations with them, and can also be used to obtain an automatic interpretation of a symbol that users draw on their tablet device. In the end, bidimensional image recognition techniques can be successfully used to compare different rock carvings reliefs, or reliefs of the same carving done by different archaeologists, in order to detect similarities between geographically distant carvings and to assess differences and analogies between techniques used by different archaeologists in different ages.

The multi-agent framework ("Indiana Multi-Agent System" or simply "Indiana MAS") will be general enough to be used in any cultural heritage domain where rock carving is a central feature. However, in order to demonstrate the feasibility of our proposal and to measure its results in a quantifiable way, we will apply it to the preservation of the rock art of Mount Bego.

The choice of Mount Bego testbed was made because, thanks to a consolidated collaboration between the University of Genova and the Laboratoire Départemental de Préhistoire du Lazaret, Nice, France, the University of Genova has partial access to the ADEVREPAM database containing information about all the rock carving reliefs of that site (45.000 records). Also, the University of Genova owns an inedited and invaluable collection of up to 16.000 drawings and reliefs made by Clarence Bicknell between 1898 and 1910, in his campaigns on Mount Bego. Bicknell's legacy also includes nine notebooks, filled with notes in Victorian English, mostly unpublished. The integration of Bicknell's legacy with the ADEVREPAM database represents the best possible way for safeguarding Bicknell's precious work. This is another important objective of the project.

Besides these "organizational" reasons, there are also scientific ones motivating the choice of Mount Bego as a testbed for making the project's objectives and results more concrete. Archaeologists and historians look at the area around Mount Bego as an incredibly valuable source of knowledge, due to the up to 40,000 figurative petroglyphs and 60,000 non-figurative petroglyphs scattered over a large area at an altitude of 2,000 to 2,700 meters. The historical relevance of the Mount Bego petroglyphs is unquestionable, as they date back to the early Bronze Age, when humans left no written evidences and the only witnesses of their existence are their tools and, indeed, their "drawings". Mount Bego rocks are not protected in a safe place such as a museum and thus they are constantly exposed to rough weather as well as vandalism of careless or malicious visitors. If the latter may not be the main source of damage (the Mount Bego area is hardly accessible in wintertime), the first is definitely a constant threat; 8 months a year many of the petroglyphs are drown into a thick curtain of snow and rains are also frequent in summertime. It comes with no surprise that many petroglyphs have been (and are still being) eroded and some have been totally destroyed.

Finally, there are historical and geological reasons making Mount Bego rock art understanding relevant for Italian rock art understanding too. In fact, until 1947 Mount Bego belonged to Italy, and it shows close relationships with carvings that we can find in Italian sites. A section of the engraved area of Mount Bego still lies on the Italian side and is included in the Argentera Park. Also, Mount Bego, Monte Beigua, and Monte Sagro share the same role of relevant sanctuaries for the ancient Ligures. Finally, strong relationships exist between Mount Bego and Val Camonica rock art sites too: Val Camonica rock is named "permian sandstone". It is a siliceous fine granulated sandstone, heavily polished by the glacier during the last glacial era: it looks like and it acts as a real natural blackboard. Only one other valley in the Alps shows similar condition, although the rock there is called "pelite": it is, not by chance, the Mount Bego.

III. Expected Results

According to the objectives introduced in the previous Section, the results expected from the Indiana MAS project are the following:

- Integration of Bicknell legacy, written documents (in English, Italian and French) and pictures with the Adevrepam database. As a measurable indicator, we assert that we will add to the Adevrepam database data (already storing about 55,000 documents relevant for Mount Bego rock art) 10,000 new data by the end of the project.
- Bicknell legacy contains drawings and annotations of petroglyphs which are already stored in the Adevrepam database. The Indiana MAS needs to recognize duplicates in order to avoid the creation of multiple separate entries for the same object. We expect that the Indiana MAS will be able to automatically recognize duplicate or very similar documents (text and images) in 35% cases on average.
- We already developed an ontology [1], based on the taxonomy by de Lumley and Echassoux [2], for tagging drawings with concepts taken from that ontology (namely, for classifying drawings according to the ontology); that ontology will be extended in a semi-automatic way in order to correctly classify multilingual documents and pictures, and not only drawings, and will be used to classify newly inserted documents according to it. As far as textual documents are concerned, we expect that at least 80% documents (in English, Italian and French) will be correctly classified according to the ontology. As far as drawings are concerned, the correct classification will be at least 25%.
- A Digital Library will be developed according to the current standard formats and accessibility protocols in order to make a part of the knowledge on Mount Bego rock art available to everyone. The Digital Library, named "Indiana GioNS" - Genoa, Nice, Salerno - will be hosted by Genova and will be available, via a web and agent-based interface, starting from the beginning of the project's second year.
- The Knowledge represented in this project will be also analysable and visualisable from a spatio-temporal perspective, and tools and services will be provided in order to deal with these aspects. Reference works that will inspire us in this direction are [3], [4], [5].
- The Indiana MAS will integrate agents able to analyze and interpret drawings, agents able to reason on pictures, and agents able to understand natural language (in at least Italian, English, French). From the interaction among agents of these three different kinds, more sophisticated interpretations of documents and correlations among them will emerge. These results will be integrated into Indiana GioNS as well, thus implementing a dynamically growing repository of knowledge. This outcome is much more difficult to measure in a quantifiable way than the previous ones; independent domain experts will be required to assess the quality of the interpretations and relationships resulting from this activity.

IV. Preliminary Results Obtained

In the next sections we are going to illustrate the results obtained in the very first months of the project activities, in particular since the proponents received the notification of funding (September 2011), by following the work package structure reported in the Gantt shown in Figure 1. The work package relative to the integration of the components in the initial and final Indiana MAS prototypes did not start yet.

A. Project Management

The communication among all the parties takes place easily and efficiently via the indianaMAS@unige.it mailing list and via Skype.

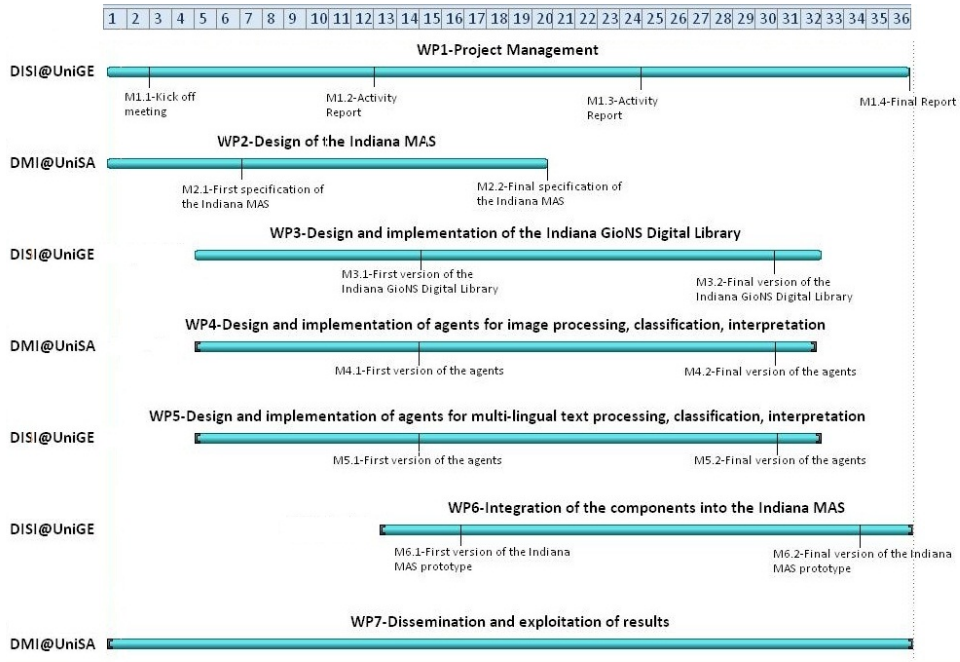

Fig. 1. Work Packages: Gantt chart.

The work plan is fully respected (many tasks have already started even if their official start date is month 5), as shown by the results achieved in the following sections.

As a software application for the project management we are currently using both DropBox and Google Drive, since we are not yet developing software in a joint way and a shared repository is enough. We will install SVN or other software management applications if needed.

The Kick-off meeting has successfully taken place on May 25th, 2012, in Capri, associated with the "Advanced Visual Interfaces" conference where the first Indiana MAS paper [1] was presented.

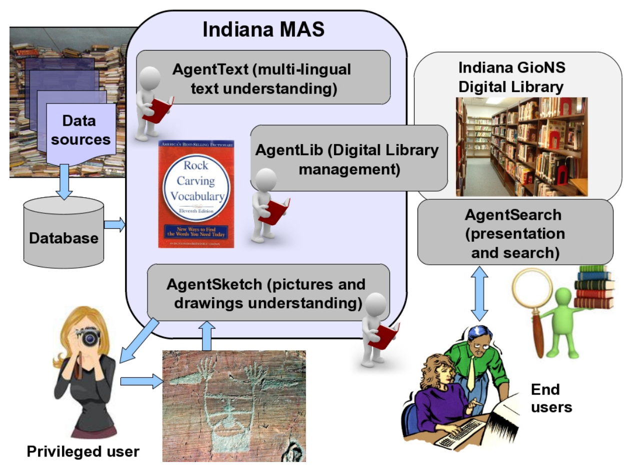

Fig. 2. High level architecture of the system.

B. Indiana MAS Design

Figure 2 depicts the Indiana MAS architecture as it has been conceived in the project proposal, together with its main components (all the agents interact with each other; communication arrows have been omitted for sake of clarity).

To refine this architecture and to clarify the functionalities that will be offered by our system, we have conducted a requirements analysis starting from what kind of information we will store and manage, how these are related and how they will be available to the end users. Instead of listing all the functionalities using a text representation or a Use Case form, we developed a prototype of the Web Interface for the system. Such interface is available online (http://www.disi.unige.it/person/MascardiV/Download/IndianaMAS/ReqAnalysis/) and its mere goal is to present the requirements, that is, to define the main Indiana MAS functionalities that we plan to offer to the users.

The system will represent different types of users: at this stage of requirements analysis we consider having "registered users" and "simple users". The former will insert new data into the Indiana GioNS library, while the latter will only query it. The system interface will handle different languages, namely Italian, English and French. In Figure 3 the homepage is shown.

The "new digital object insertion functionality" will be provided to the "registered users" only. Every digital object inserted into the library will be characterised by a set of common metadata, for example *Title, Object, Description*, and a list of optional common metadata, for example *Author, Age, GPS coordinate*; the "insertion functionality" will be different for each specific digital object, either text or image.

Fig. 3. Interface Prototype devoted to the Requirements Analysis.

For example, text related metadata are relative to the *Type of text* (Article, book, Master thesis etc.), the *Language*, the *Abstract*, and so on. These metadata will be a superset of a standard language for the description of digital objects such as Dublin Core[1].

The image related metadata are relative to the *Type of image* (for example, whether it is a colored image or a black and white image, whether it depicts something real or it is a manual drawing, a panorama, and so on), the *Symbol(s)* appearing in the image, their *Interpretation*.

All the values allowed for the metadata will be chosen from the Indiana ontology. Furthermore, the system will allow the users to specify related digital objects already inserted into the repository. The *AgentSketch* [6] functionality will be provided to manually draw a picture (that will be then treated as an image): this can be useful to insert a new relief or to trace a relief using a real picture as background.

The system will accept from the user as many metadata as s/he knows, then an automatic procedure will be called to fill and check all such metadata, with the aim to deduce more information from the digital object than the user knows, helping him to link this new object to those already existing in the library, hence to infer new information about the object itself. For example, Indiana MAS will analyse the image and will recognise the atomic symbols it contains, and will suggest a possible interpretation of them, while reporting the list of similar digital objects.

After this process terminates, the user can either accept the metadata automatically extracted by Indiana MAS or modify them, before confirming the insertion of the new digital object.

The query phase follows the above mentioned data structure: the user is able to specify many kinds of queries, based on all the metadata described before. Queries will be performed:

- by entering common metadata,
- by entering image specific metadata,
- by entering text specific metadata,
- by inserting an image to be compared with the already exiting ones,
- by inserting a text to be compared with the already existing ones,
- by using *AgentSketch* to draw a sketch to be compared with the other images.

In addition, all these queries can be combined. Queries can be executed only over the Indiana GioNS library or over a set of related libraries, selected by the user from the ones exposed by the metadata harvester (see the next Section for details).

The “simple users” will be able to follow a procedure called “analysis”, that is the same procedure of the insertion, but without inserting a new object into the digital library. This procedure will help the user to evaluate an image or a text against what already exists in the system, by taking advantage of the Indiana MAS support in extracting features, without any desire/permission to insert this object into the library.

C. Design and Development of the Indiana GioNS Digital Library

During the last months we were actively involved in a project for the design and development of a Digital Library Management System called MANENT [7]. The system is evolving towards an innovative architecture that is based on big data management systems that run upon distributed frameworks such as Hadoop[2] and HBase[3]. These technologies are exploited by social networks such as Facebook, Twitter, and LinkedIn and everywhere a support for the effective analysis and computation of TeraBytes of information is needed. Following Google BigTable database[4], the open source community developed the Hadoop high-scalable distributed filesystem that is de facto a clone of BigTable, and is based on the MapReduce algorithm for the creation of parallel tasks that work in each datanode of a cluster, without the need for a developer to implement the mechanism of task distribution, delivery, and execution. The master node, that is the namenode, checks and handles automatically the different processes that run on each datanode of the system.

MANENT is the core of a digital library that should contain a metadata harvester for collecting information on the digital repositories that all over the world expose their data and metadata in a standard format, such as those provided through the OAI-PMH protocol[5], as well as proper information coming from its local digital library. By following the Digital Library Reference Model provided by the DELOS project[6], the system

[1] http://dublincore.org/.

[2] http://hadoop.apache.org/.
[3] http://hbase.apache.org
[4] http://en.wikipedia.org/wiki/BigTable.
[5] http://www.openarchives.org/OAI/openarchivesprotocol.html.
[6] http://www.delos.info/index.php?option=com_content&task=view&id=345.

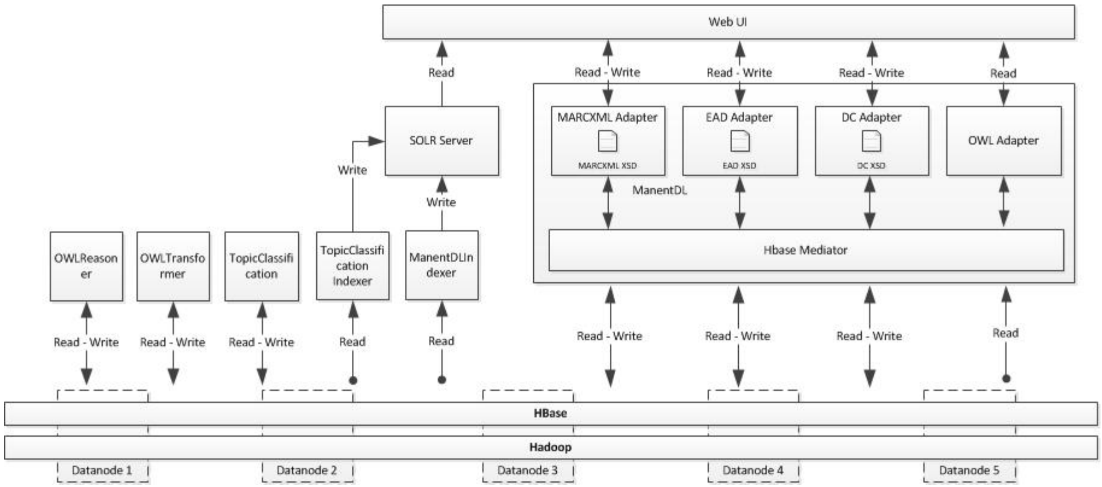

Fig. 4. the MANENT Architecture.

should provide functionalities for the collection, organisation, search, and browsing of digital resources, such as documents, images, people, and external sources of knowledge.

The Indiana GioNS Digital Library should be hence equipped with semantic services for the multi-language text analysis, automatic classification, similarity matching, semantic annotation, and indexing of all the sources of information collected inside the library and all over the world.

Figure 4 depicts the high-level architecture of the MANENT system that should be the core of the digital library management system developed inside Indiana MAS. The core component for the local digital library is organised according to different standard languages for the description of repositories and digital objects (such as Dublin Core, EAD[7] and Marc[8]). In addition, it provides functionalities to the user for the insertion of new objects and the search and browsing of them according to such descriptions. Different adapters are finally conceived to interface the system with the below cluster infrastructure and the above web interface.

D. Design and Development of Image Analysis, Classification and Interpretation Agents

In order to analyse and properly classify the relief drawings several similarity measures have been evaluated so far. In particular, we analysed three descriptors which have been widely used for shape recognition: Shape Context [8], Inner-Distance Shape Context [9], and Radon transform [10]. To allow a fast and effective drawing classification, the use of such descriptors has been combined with Self-Organizing Map (SOM) [11], a clustering and data visualization technique based on neural networks. In general, the process used for relief classification can be organized in three steps:

1) Extracting the features from the drawing dataset based on the considered descriptor;
2) Training the SOM by using the extracted features;
3) Classifying the query drawing Q by looking for the map cluster in the SOM most similar to the features extracted from Q.

In order to verify the effectiveness of such descriptors, we evaluated the constructed SOM on three datasets: MPEG7, Relief75 and Relief1400. MPEG7 shape database is one of the most popular dataset used for comparing the performances of image similarity algorithms [12], and it contains about 1400 images divided into 70 classes. Relief75 and Relief1400 are two datasets built by ourselves to understand the effectiveness of our approach on the project test-bed, namely the Mont Bego reliefs. The former contains 75 images divided into 10 classes while the latter contains 1400 images derived by the previous 75 by means of a distortion algorithm.

The results we collected at the end of the experiments are shown in Figures 5, 6, and 7:

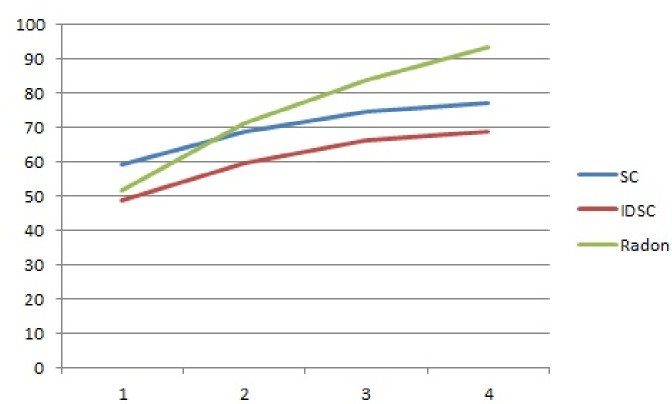

Fig. 5. Percentage of MPEG7 correct classifications considering: the top scored class, the top-2 scored classes, and so on.

It is worth to note that no algorithm generally provides optimal classification in the first hit, but a good classification

[7]http://www.loc.gov/ead/.
[8]http://www.loc.gov/marc/.

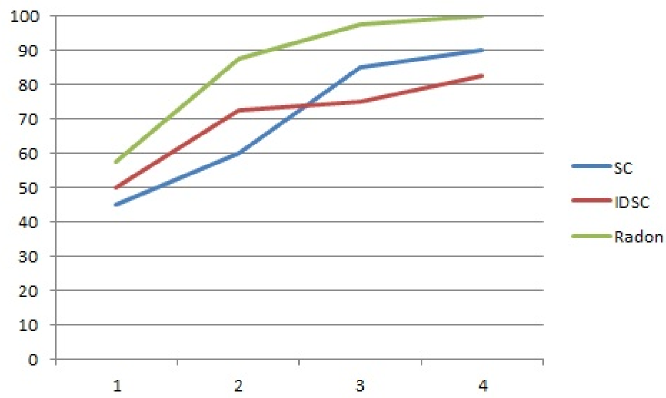

Fig. 6. Percentage of relief75 correct classifications considering: the top scored class, the top-2 scored classes, and so on.

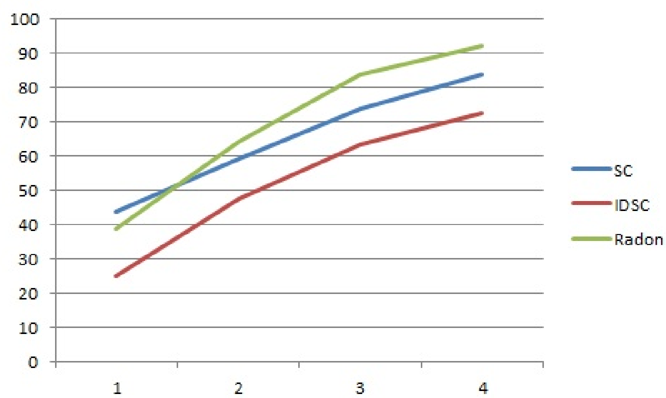

Fig. 7. Percentage of relief1400 correct classifications considering: the top scored class, the top-2 scored classes, and so on.

can be obtained in a semi-automatic way considering the top-scored results of the search. More precisely, by considering the three descriptors and the three datasets, the Radon provides the correct class into the first 4 hits in almost the 100% of cases while, a less precise solution can be achieved by considering only 3 hits. In this case, the correct class appears into the first three hits in the 80% of cases.

E. Design and Development of the Agents devoted to the Analysis, Classification and Interpretation of Multilingual Documents

Some work in the direction of multilingual services was accomplished during the design and development of the MUSE project [13] that addresses the problem of the provision of multilingual services in the domain of Public Administrations, supporting business and interpersonal communication and enabling people to make sense of content and services already available in this domain. MUSE exploits state of the art machine translators, a formalized domain description ontology, a flexible and distributed architecture based on intelligent agents, a set of stepwise procedures codified in form of plans in an existing declarative agent oriented programming language. Also, it can be run as a service in the cloud. MUSE, whose design is completed and whose implementation is under way, will be soon experimented in the Registry Office of Genoa Municipality. A sketch of the different components of the system is reported in Figure 8

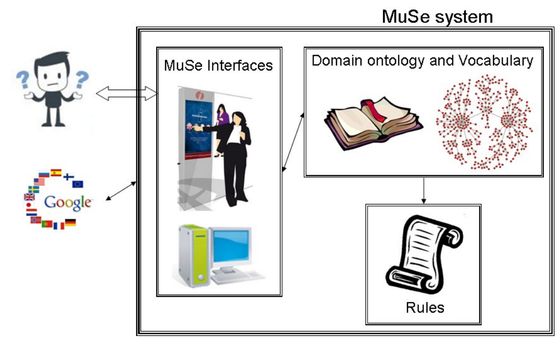

Fig. 8. The MUSE system.

Some modules of the MUSE system have been integrated as black box items (e.g. Google Translate). Once a translation is made from the user query formulated in his native language to the Italian language, a query expansion procedure is run to help disambiguate the request and find a match with one of the "well-known problems" encoded in the MUSE ontology. The aim of the ontology is that of driving the system to retrieve the correct procedural rule against the user query, once the query has been properly expanded and interpreted. To this aim, the ontology contains all the different paths elicited by the domain experts. If users do mistakes when formulating their queries MUSE records such mistakes and the relative correction, and ranks the pairs obtained as they are repeated during real-time interactions. In this way the system increases the strength of its hypothesis on the occurrence of such patterns more often than chance, and may provide an automatic correction when the same situation happens again, as well as top ranking the more probable translations associated with the more probable requests.

F. Dissemination of Results

The dissemination activity has been conducted by creating the project web site http://indianamas.disi.unige.it, and by publishing the papers cited in the above paragraphs.

The Indiana MAS project has been mentioned in the seminar with title "Le incisioni rupestri al Monte Bego nei rilievi di Clarence Bicknell 1906-1917" held on April 26th, 2012 in Genova by Antonella Traverso ("Soprintendenza per i Beni Archeologici della Liguria") and Cristina Bonci (Università degli Studi di Genova) at the "Accademia Ligure di Scienze e Lettere".

A PhD course on "Computational Archaeology" is foreseen in 2013, based on the expertise acquired during the project.

V. Conclusions and Future Work

The project has just started (the official date is march 8th, 2012), but the results already obtained are meaningful and encouraging.

The project goals are very ambitious, due to the combination of multi-modality, multi-linguality, and heterogeneity of the data, and the necessity to give a semantic interpretation of them based on sophisticated reasoning. It was hence decided to face some work before the official starting date, in order to have time to widely experiment all the single elements of the system, and to design and develop all the rules necessary to infer new knowledge starting from the objects stored and analysed inside the system. Such rules are so complex that a strict and long-term collaboration with domain expert is unavoidable.

Future works are those envisioned for each work package during the proposal step. At the moment no deviation from the work plan seems necessary. The only limitation has emerged during the experiments conducted by Alessandro Ricciarelli in his Bachelor's Thesis, and described in [6]. Such experiments were further conducted by the Salerno Unit, and are focusing on the possibility of recognising and classifying pictures of engravings. The rock veins, the presence of stains and moss, and the light effect on the irregular surface of the rocks make quite impossible to distinguish the engraving trace from noise. This challenge has been also highlighted in [14] where the authors state that the extraction of petroglyph contours within pictures is a very challenge task, even in the case of images with a high and clear contrast. As a consequence, automatic recognition and classification of petroglyph pictures where contours are difficult to delineate even by people is almost impossible to perform. For this reason we will concentrate on black and white relief images and will postpone the treatment of pictures to a future activity.

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