AGENTS AND ONTOLOGIES FOR UNDERSTANDING AND PRESERVING THE ROCK ART OF MOUNT BEGO

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Keywords: MAS for rock-art preservation, ontology extraction, sketch interpretation, visual database for rock-art.

Abstract: This paper describes the joint effort of computer scientists, archaeologists, and historians for designing a multi-agent system that exploits ontologies for the semantic description of the Mount Bego petroglyphs, thus moving a step forward their preservation. Most components of the MAS have already been developed and tested, and their integration is under way.

1 INTRODUCTION

For decades the area around Mount Bego has been deemed as a sort of a bewitched place, rocks being carved with "thousand devils", to use the words of Pierre de Montfort, a XV century French voyager. This is also confirmed by the gloomy toponymy of the area, characterized by the *Lacs de l'Enfer* (Lakes of the Hell), dominated by the *Cime du Diable* (Peak of the Devil) and surrounded by the *Vallée de la Sorcière* (Valley of the Witch). It is common belief that the Church had come up with such names to keep people away from the region due to the presence of symbols reeked of paganism; other prefer to ascribe the origin of these names to the inclement weather that plagues the area. However that may be, archaeologists and historians (which in this paper we will refer to as *domain experts*) look at this place 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. As a matter of fact, they prefer to refer to the area as the Valley of Marvels, which is all but a reference to a hellish or bewitched world. The historical relevance of the Mount Bego petroglyphs is unquestionable, as they date back to an era (early Bronze Age) when humans left no written evidences of what they were and the only witnesses of their existence are their tools and, indeed, their "drawings". It is evident to both domain experts and common people that rock art of Mount Bego is the key of our understanding of those who populated that area; the petroglyphs are actually ideograms from which the whole conception of the world of their authors comes out and is transmitted from generation to generation by using a graphic code (de Lumley and Echassoux, 2009). A religious meaning is usually attached to the petroglyphs, which are deemed to be part of a ritual to propitiate the favours of the gods in daily activities (Burikitt, 1929). While learning from written sources is relatively easy, even if this may actually depend on the source, images generally lend themselves to a number of different and often conflicting interpretations, which is the case of the Mount Bego carved rocks. It turns out that "reading" the petroglyphs to understand how people who created them lived and what they believed in is not an unfeasible task, as the petroglyphs are all related and show common patterns that domain experts can leverage to come up with possible interpretations. However, assessing theories and interpretations is never straightforward; a certain interpretation may explain one or a group of petroglyphs while being questioned by other petroglyphs or by knowledge acquired from other sources. We should not forget, in fact, that what we know about Mount Bego is not only due to the carved rocks, but also to finds belonging to different areas and yet dating back to the same era. Therefore, the coherence of any new interpretation must be checked against multiple sources.

Another major issue is that the Mount Bego carved rocks are not protected in a safe place such as a museum and thus they are 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), thr 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; as a result, the only knowledge we have about missing petroglyphs is due to the unflagging work of passionate researchers such as Clarence Bicknell, who, at the turn of XX century, created an important catalogue of most of the petroglyphs in Mount Bego (Bicknell, 1913). For the sake of preservation, the most important rock in the area, referred to as the *Chef de Tribu* (Chief of the Tribe), was even moved to a museum and replaced with an accurate cast (Fabre, 1989). It is self-evident that it would not be possible to get all petroglyphs to museums as some rocks cannot be moved at all!

The cultural relevance of the Mount Bego area calls for immediate action for preservation. For this reason the domain experts that co-author this paper welcomed the computer scientists' proposal to complement the techniques they usually adopt to preserve the area with digital preservation and restoration techniques. In this paper we describe our research in this direction, which aims at creating tools that help domain experts to integrate, analyze and interpret all available data on Mount Bego. We propose a framework that on one hand supports the creation of a structured and semantically annotated Web repository from multiple sources and on the other provides the necessary functionalities to interpret the data and assess theories and conjectures on them. The proposed framework formalizes the knowledge related to the available multimedia content (especially images and texts) through ontologies and uses a multi-agent system that helps the creation of the repository in a semi-automatic way by using a sketch interpretation algorithm. Although most components of the framework have been already implemented, their integration is yet to be completed and, consequently, no experimental results are available yet; however, throughout the paper we will give motivated and solid grounds to prove the feasibility of the whole framework. Our ultimate goal is to design our repository to be a reference at European level as a thorough database of Bronze Age petroglyphs, which would be a definite contribution for domain experts, as rock art sites are spread all over Europe (Chippindale and Nash, 2002). To this purpose we move along two directions: first, we integrate the wonderful collection of Bicknell into an existing database of data relative to Mount Bego currently hosted by the Laboratoire Départemental de Préhistoire du Lazaret (Adevrepam), based in Nice, France; then we implement methods and interfaces in order to add other data that might become available in the future which is recognized and semi-automatically categorized, according to specific ontology-driven criteria.

The reminder of this paper is organized as follows. After a short introduction to the Mount Bego heritage and a description of Bicknell's collection (Section 2), we outline our approach in Section 3, discussing goals and solutions. Details on the implementation of a multi-agent system supporting sketch interpretation algorithms are given in Section 4; this multi-agent system uses knowledge formalized through ontologies that are extracted in a semi-automatic way from texts (Section 5). In section 6 we describe how our framework is used to integrate, analyze and interpret data on Mount Bego. An overview of related work and concluding remarks are finally presented in section 7.

2 Mount Bego and the Bicknell's legacy

Mount Bego is located in the heart of the Argentera-Mercantour massif in Southeastern France and attracts lot of tourists every year. After the words by Pierre de Montfort, the petroglyphs were mentioned for the first time in a book in 1650, when Piero Gioffredo wrote: "These lakes are called *Lakes of Marvels* because rocks of various colors were found near them, with a thousand engraved figures". However, no scientific study was carried out on them until the end of XIX century. Clarence Bicknell first came in this area in June 1881, but the snow prevented him from beginning his studies (Chippindale, 1984). This happened in 1897, when he came back to the area with his friend Luigi Pollini and sketched 450 drawings on small sheets of paper. Between 1898 and 1910 Bicknell realized up to 13,000 drawings and reliefs, part of which were then published in (Bicknell, 1913). Because of his botany background, he identified seven types of figures taking a natural history approach: horned figures (mainly oxens), ploughs, weapons and tools, men, huts and properties, skins and geometrical forms (Chippindale, 1984). Since 1967 several équipes led by Henry de Lumley have been surveying and mapping this important archaeological area. More than 100,000 graphic signs, of which 40,000 are figurative, were carved on around 4,000 rocks in the Mount Bego region.

The high concentration of petroglyphs in this area, which has no comparisons in any other place in Europe, pushed scientists to think that Mount Bego was sacred and a religious meaning was attached with the petroglyphs. Another factor that may explain the impressive number of petroglyphs may be rocks themselves. In this archaeological complex, in fact, rocks are made of sandstone and thus are not exfoliated and are perfectly polished by the glaciers. This makes them perfectly suitable to be engraved.

2.1 The Bicknell Legacy

Most of the drawings realized by Clarence Bicknell have been published and made available to everybody (Bicknell, 1913). The collection is completed by inedited drawings which are currently owned by the University of Genoa. These amount to 16,000 drawings and reliefs on different materials, including paper sheets for botanists of standard size (44-45 cm x 56-58 cm), large rolls of tissue paper applied on a canvas and tissue paper stored in rolls 70cm high and 50cm-2m long. The collection also includes 72 sheets of blotting paper used to obtain bas-relief casts. At the foot of almost all sheets Bicknell wrote personal notes on the depicted subject, the location of the petroglyph, a name assigned to the rock with the petroglyph and the date of the relief. The legacy also includes nine notebooks, filled with notes in Victorian English, which can be subdivided into five excavation diaries and four note books. which cover a timespan of 10 years (1902-1912). The four note books date back to 1911-1912, and he probably used them to write his book, published in 1913 (Bicknell, 1913). The Bicknell legacy is a precious source of knowledge for the Mount Bego area. First, Bicknell proposes an highly accurate classification of the petroglyphs, which is commonly accepted by the archaeologists; actually, our framework also benefits from this classification. Second, every drawing is annotated with relevant and useful semi-structured metadata; Second, every drawing is annotated with relevant and useful semi-structured metadata; the techniques we describe in Section 5 for semi-automatically extracting knowledge from free text, can be adapted to semi-structured notes too. Finally, some of the drawings in Bicknell's collection refer to petroglyphs that have been eroded and are not visible anymore; this enables their digital reconstruction which is an important step towards the digital preservation of the area.

3 Overview of our Approach

As outlined in the introduction, our long-term objective is the creation of a repository which may eventually become a reference at European level as a repository for Bronze Age petroglyphs. To this aim the repository needs to come with tools that ease the integration of new data and allow analysis, comparison and search on them. Although here we only focus on Mount Bego, our approach is general enough to handle scenarios other than Mount Bego. Just to make an example, many studies[1] demonstrate that there are strong similarities between Mount Bego and Valcamonica's petroglyphs. Hence, our approach should easily apply to preserve and maintain in digital form Valcamonica's petroglyphs, in the same way as it applies to Mount Bego's ones, coherently with our long-term objective.

In the current setting we have access to a database managed by Adevrepam. This PostgreSQL database, equipped with the PostGIS module to manage geographical objects and accessed through the PyGreSQL module, includes up to 45,000 among images, texts and cards obtained from reliefs in Mount Bego area. Each carved rock has a unique identifier number and precise GPS coordinates along with semi-structured annotations about the petroglyphs. As illustrated in Figure 1, our goal is to integrate into the Adevrepam database data from multiple sources, notably the Bicknell legacy as well as unstructured or semi-structured data on Mount Bego or related sites. Here the multi-agent system operates on unstructured data and multimedia content from which the relevant semantic and visual features are extracted and tagged with concepts from the domain ontologies, in order to obtain a semantically enriched repository of the Mount Bego petroglyphs.

As from Figure 1, three aspects form the basis of our work:

1. Integration and Semantic annotation. Our main short-term goal is the integration of the Bicknell legacy, which is the most valuable source of knowledge on the petroglyphs that have been destroyed, into the Adevrepam database. As already observed (Section 2), Bicknell did not limit himself to faithfully depicting the petroglyphs, which would have been a remarkable contribution itself, but he also wrote semi-structured annotations, including location, rough description of the represented subjects and personal thoughts and interpretations. We remark that even if the Bicknell legacy is relatively small, a manual integration would be time-consuming and error-prone,

[1] `http://www.rupestre.net/pdf_rtf/valca_bego_fr.pdf`

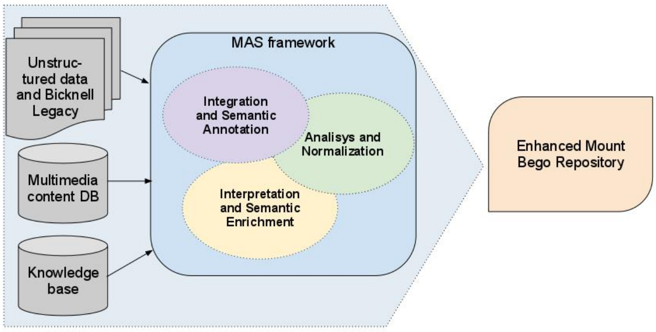

Figure 1: A schema providing the general idea of our approach.

besides being not scalable to our long-term goals. Therefore, we need to design a tool which helps domain experts integrate the data in a semi-automatic way. In this scenario duplicates are the major issue; the Bicknell legacy, in fact, contains drawings and annotations of petroglyphs which are already in the Adevrepam database. If this is the case, the integration tool needs to recognize duplicates in order to avoid the creation of two separate entries on the same subject. Recognizing duplicates is not straightforward, especially in the field of rock art, where different petroglyphs may share more or less the same patterns while being different. As far as semantic annotation is concerned, we aim at creating semantic relations among similar petroglyphs (that is those sharing the same patterns) thus allowing successive full and partial retrieval according to ontology-driven metadata and visual content.

2. Analysis and Normalization. The new integrated data must be checked against the existing ones for coherence. We recall that Bicknell was not an archaeologist and, even if the scientific community agrees on the importance of his work, some inaccuracies are still possible in his drawings. Moreover, to the best of our knowledge, an in-depth analysis and assessment of his work has not been done before. To this extent, both techniques based on image similarity and ontology-driven metadata matching are exploited.

3. Interpretation and Semantic Enrichment. Since giving an interpretation to petroglyphs is not straightforward and two or more different interpretations may coexist and complement each other, we plan on developing a tool that helps domain experts to assess their interpretations and theories. Petroglyphs are elementary drawings, with shapes that can be found in many of them and so they are repeated. Given a shape, different interpretations can be assigned to it. For example, a zigzag line is likely to represent water (de Lumley and Echassoux, 2009), a figure with two intersecting lines may represent a man and so on. Therefore, our tool is able to analyze all petroglyphs and, using ad-hoc sketch interpretation techniques, takes out all the “meaningful shapes” that occur frequently and propose them to the domain expert. The domain expert assigns an interpretation to each shape and adds ontology-driven metadata to that shape. Afterward, she can also access the petroglyphs to check whether its interpretation fits in the depicted scene, and the system provides suggestions of interpretations, thus being a real support for the experts. Moreover, the tool is also able to check for frequent co-occurrences of two shapes in the same petroglyph which may denote a possible joint interpretation of the two shapes (that is the two shapes have different interpretations if they occur in the same petroglyph).

In the following sections we will describe the technology we use to implement these three steps.

4 Multi-agent System Architecture

As it is well-known MASs are an optimal solution when it comes to manage and organize data from multiple sources, which is the case in most Cultural Heritage applications such as ours. That is why we turned to a MAS as a basis of our framework.

The architecture of our MAS extends the one discussed in (Casella et al., 2008) by adding specific classes of agents to it and enriching the system with ontology-driven knowledge, thus extending the communication interfaces with Semantic Web facilities. More specifically, the framework presented in (Casella et al., 2008) serves as a basis for a multi-domain sketch interpretation system, called *AgentSketch*, that recognizes and interprets symbols and simple shapes. *AgentSketch* uses either on-line or off-line interpretation of symbols; in the first case, the system starts the interpretation process while the symbol is being drawn, whereas in the latter the interpretation is carried out on a complete image. Sketch interpretation is the linchpin to implement our framework, as

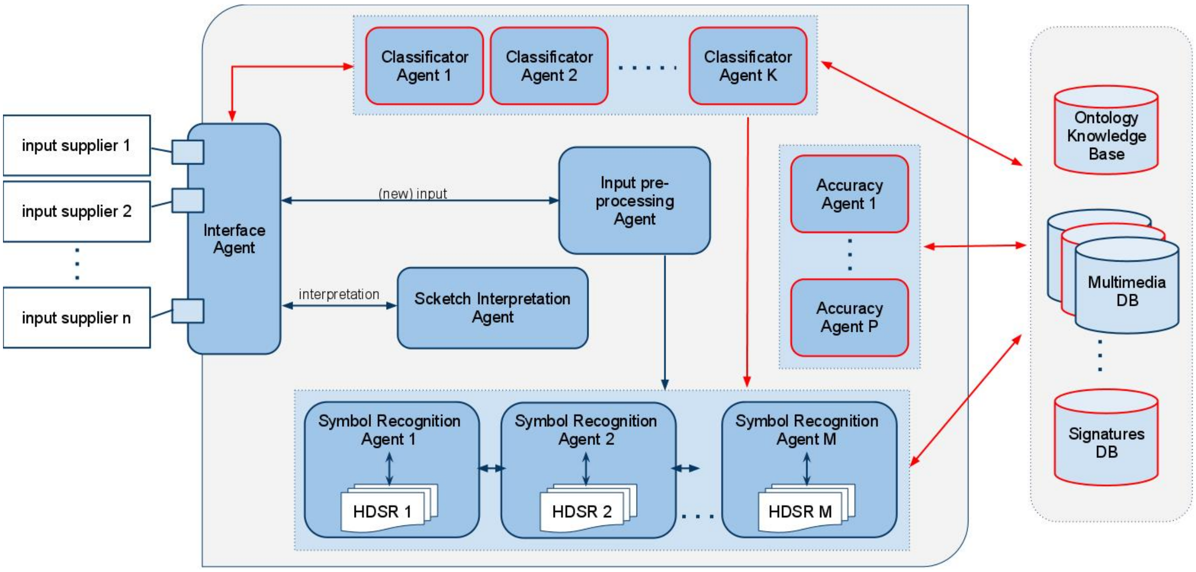

Figure 2: The schema of the overall architecture. The red components in the Figure represent the extension of the initial MAS architecture. Red lines identifies new communication interfaces developed in order to let the agents interact.

stated in Section 3 and *AgentSketch* works reasonably well on such tasks; therefore, we use it while adapting it to our specific case. In the following we summarize the main features of our framework (Section 4.1) and we show how we extend (Section 4.2). How we use it is the subject of Section 6.

4.1 The Agent Framework

The main novelty of the agent framework in (Casella et al., 2008) over existing approaches is its flexibility, as it can be used in different contexts. Current solutions (Cohen et al., 1997; Achten and Jessurun, 2002; Mackenzie and Alechina, 2003; Kaiser et al., 2004; Juchmes et al., 2005; Azar et al., 2006) either borrow techniques from stroke recognition, therefore limiting the set of symbols that can be recognized, or restrict themselves to particular domains, or they impose apriori an usage mode (either on-line or off-line).

The agent framework (Fig. 2) is composed of four kinds of agents:

- *Interface Agent* (IA), that represents an interface between the agent-based framework and any input device used to draw a sketch. In the case of an online interpretation, this may be a pen-based device.
- *Input Pre-Processing Agent* (IPPA), that processes the input received from the Interface Agent and sends the obtained results to the Symbol Recognition Agents described below, using a format compliant with the interpretation approach they apply.
- *Symbol Recognition Agents* (SRAs), each one devoted to recognize a particular symbol of the domain by controlling one hand-drawn symbol recognizer (HDSR). HDSR are not considered agents since they are just passive providers of services within the MAS. They must be programmed by the system developer in order to recognize the symbols of the graphical language under consideration. SRAs may collaborate with other SRAs in order to apply context knowledge to the symbols they are recognizing, and with the Sketch Interpretation Agent described below that deals with the sketch interpretation activity. Of course, we must assume that a professional with skills on the computer science side specifies the patterns of symbols of interest, by defining one hand-drawn symbol recognizer for each of them. This activity is time consuming and expensive, but the archaeologists involved in the activities described in this paper, namely the end users of the designed MAS, believe that it should be worth devoting time and resources to this activity, given the benefits that they could gain from it.
- *Sketch Interpretation Agent* (SIA) that provides the correct interpretation either of the sketch drawn so far (in case of an on-line drawing process) or of the entire sketch (in case of an off-line interpretation process) to the IA.

AgentSketch instantiates the general agent framework architecture and has been exploited for recog-

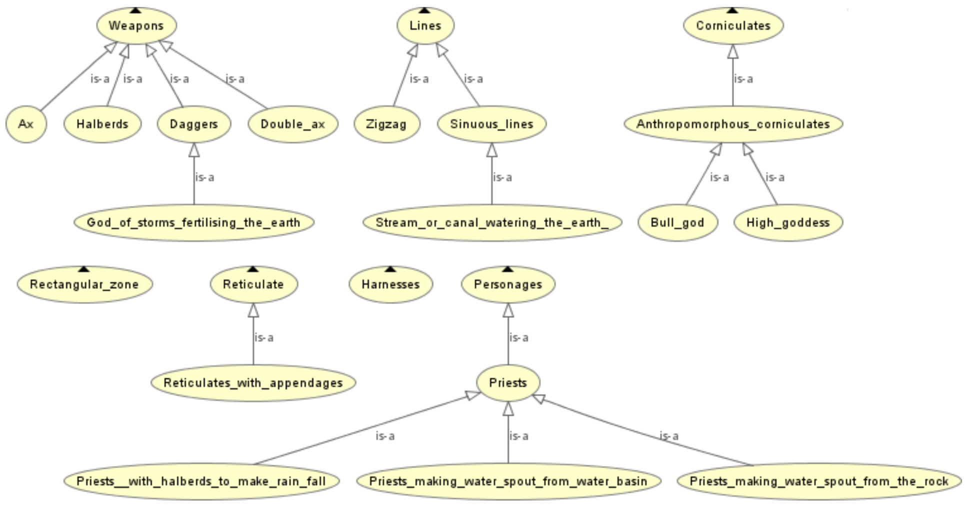

Figure 3: A classification of the Mount Bego petroglyphs implemented in OWL.

nizing UML Use Case Diagrams in both on-line and off-line modes. It is implemented on top of Jade (Bellifemine et al., 2007).

4.2 Our extensions

We extend Casella et al.s architecture by adding the new agents with new functionalities and by defining ad-hoc communications interfaces among the agents and the data layer (namely the knowledge base, the multimedia dbs and the signaturs db in Figure 2). The added agents are:

- *Classificator Agents* (CA), that use both the interpretation of the sketch or image processed by the SIA and additional information that may be attached to the image itself (see Section 6.1) to classify the image (or sketch) according to the ontologies defining the MAS domain vocabulary.
- *Accuracy Agents* (AA), that exploit CBIR (Veltkamp and Tanase, 2002; Datta et al., 2008; Shishir K. Shandilya, 2010) techniques by extracting a characterization (signature) of the images content (given ad-hoc heuristics, possibly formalized in the ontology), used for indexing and searching according to visual content similarity. This activity is performed also for measuring the accuracy of Bicknell's drawings with respect to the more recent reliefs made by De Lumley's equipe.

Note that the domain vocabulary of agents populating our MAS is provided by a set of ontologies (stored in the Ontology Knowledge Base) that may be both developed by hand, or extracted in a semi-automatic way from existing information sources (see Section 5).

5 Semi-automatic Ontology Extraction

The MAS described in Section 4 heavily relies on the exploitation of ontologies for multimedia content classification and retrieval. We developed an ontology describing the petroglyphs found in Mount Bego. Figure 3 shows a section of the ontology focusing on the main concepts taxonomy. Our ontology was manually built and is based on the results of the archaeological reliefs of De Lumley and his equipe (de Lumley and Echassoux, 2009).

We remark that our aim is to integrate in our repository new data as they are available and this may require updating the ontology or creating new ones: it is self-evident that manual updates take time and are error-prone. Therefore we designed and implemented a *Role Ontology Extractor* tool that generates semi-automatically concepts and relations from texts, thus easing the process of creating new ontologies from scratch and/or updating existing ones. The *Role Ontology Extractor* tool extracts from a textual document the most relevant concepts that may be used in the MAS as well as relationships among them and their generalized super-concepts (Bozzano et al., 2010). The selection of meaningful relationships among the ones output by the extractor must be supervised by the domain expert: it is well known that Word Sense Disambiguation (Agirre and Edmonds, 2006) that the extractor applies in order to give each word its correct meaning within the context provided by the text, is an AI-complete problem, and a software tool can only support, but not substitute, the human user. Once the selection of meaningful relationships has been completed, the Role Ontology can be created from them: concepts are mapped into OWL *classes*, relationships among concepts are modeled as OWL *properties*, and the taxonomic relationships between concepts and their generalization is translated into the OWL *subClassOf relation*. The Role Ontology generated in this way can be used inside the MAS as a reference vocabulary among agents.

To show how the Role Ontology Extractor works, we run it on the following sentence from (de Lumley and Echassoux, 2009).

> *These petroglyphs, [...] ,translate not just the daily preoccupations of these populations who needed rain, sources and lakes in order to fertilize their fields, but also their cosmological myths. At the center of these myths are the bull god, brandishing lightning, master of the storm and provider of fertilizing rain, and the high goddess, mother goddess or goddess earth, who needs to be fertilized herself by rain from the sky in order to bring abundance to humans.*

Meaningful relationships are listed below.

Quality → concept relationships
bull → god ; pastoral → population; agricultural → population; southern → alps; ancient → bronze age; daily → preoccupation; cosmological → myth; high → goddess; mother → goddess; goddess → earth.

Concept → action → concept
bull → brandish → lightning; god → brandish → lightning; population → need → rain; population → need → source; population → need → lake; source → fertilize → field; lake → fertilize →field; rain → bring → abundance.

The selection of *meaningful* generalizations and relationships from all those produced by the Role Ontology Extractor has been made by hand. Once this hand-made filtering stage has been completed, the OWL ontology can be generated in an automatic way. We are currently working at making the ontology compliant to CIDOC-CRM, a high-level ontology that enables information integration for Cultural Heritage data (Doerr, 2003) which is also known as standard ISO 21127:2006. The code of the Role Ontology Extractor, developed by Michele Bozzano as part of his Bachelor Thesis at the CS Department of Genoa University, is available under GPLv2 license (`http://www.disi.unige.it/person/MascardiV/Software/roleExtractor.html`). It was implemented using SWI Prolog extended with the ProNTo_Morph library for natural language processing (`http://www.ai.uga.edu/mc/pronto/Schlachter.pdf`).

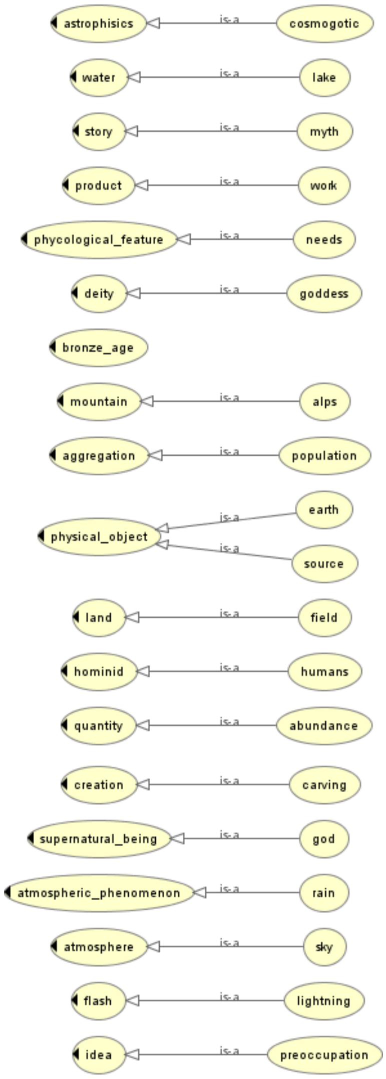

Figure 4: Concepts and "is_a" relationship in the Role Ontology extracted from De Lumley and Echassoux' abstract.

6 Sketch Interpretation and Ontologies for Integration and Retrieval

In this section we show how our framework is used to integrate new data into the Adevrepam database and to retrieve content based on sketch interpretation, as described before.

6.1 Data integration

Classificator Agents (CAs) are responsible for integrating new data into the existing Adevrepam repository while updating the knowledge base and keeping the repository consistent. CAs work at the *semantic* *level* of images (photographs of Bicknell's drawings like those shown in the right hand side of Figures 6 and 7, new photographs or sketches of Mount Bego petroglyphs, as well as of petroglyphs dating back to the same period, but discovered in other places) and may take annotations from existing sources or specific metadata attached to images into account. A CA is activated when a new image is ready to be integrated. The CA sends the image to the Interface Agent (IA) responsible for the interpretation process. When the Sketch Interpretation Agent (SIA) completes the interpretation task, the IA sends the result back to the CA that triggered the interaction. This result is a set of concepts taken from the domain ontologies, stating the interpreted meaning of the set of recognized symbols, and used to tag the image. If metadata or annotations were attached to the image, the CA exploits them to provide an even more refined tagging of the image, by identifying those concepts in the ontologies closest to the expected meaning of metadata. To carry out this task we developed and experimented with success an ontology matching algorithm that heavily exploits natural language processing (Mascardi et al., 2009).

If the set of concepts that tag the image is identical to the set that tags another image already stored in the database, the CA suggests to the user that the image might refer to content already present in the database and hence should not be considered as a new entry but as an update of existing information. On the other hand, if no similar tags are associated with any entry, the CA suggests that the image should be added as a new entry. Indeed, the CA must always interact with the domain expert in order to correctly add new content in the database. However, the CA provides suggestions to the human user that lighten the burden upon her.

After a decision has been made, the CA classifies the image according to the ontology concepts that tag it and stores it in the multimedia database with all the necessary metadata. Figure 5 illustrates the set of tasks and the communication among the agents in the MAS and the user.

After the integration step, the framework must ensure that the new data are correct and coherent with the existing data. In our specific case this means that we assess the accuracy of the drawings of Clarence Bicknell and to do so we need to compare his drawings with the data already in the repository. To this aim, techniques based on image similarity measures have been exploited. An Accuracy Agent (AA) is activated by the user in order to establish if the selected image is part of one or more already existing classes of signatures (stored in the signatures DB) or if a new similarity class must be determined. If necessary, the new signature class is created and the signatures DB updated accordingly. Thus, inclusion, exclusion and intersection predicates are implemented to ensure partial similarity measures and ranking list of result answers. Once stored, the user can ask to an Accuracy Agent the similarity measure between two images. For example, it should make sense to measure the similarity between the images shown in Figure 6 and 7. Accuracy Agents operate at the *image level* by running algorithms that compute the similarity between images, without knowing nothing of their meaning.

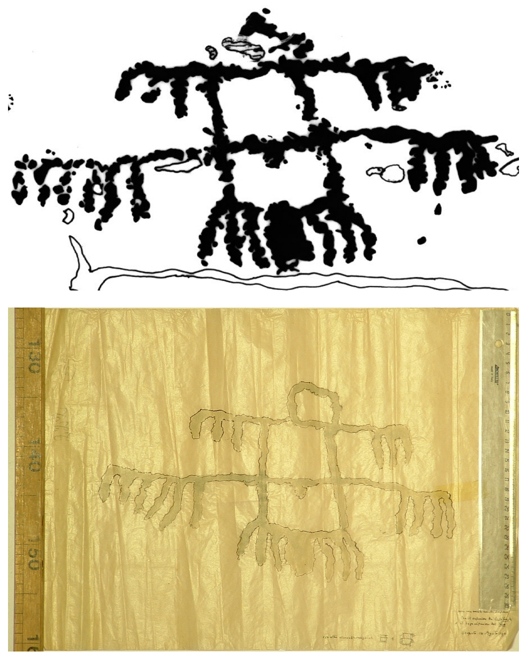

Figure 6: Petroglyph identified by id. ZIIGIR3: De Lumley equipe's relief (left) and Bicknell's relief (right)

The assessment of Bicknell's drawings has never been done and is very important for the preservation of Mount Bego. Suppose that after this assessment we find out that Bicknell's drawings are accurate for every figure but the horned one; this would imply that we could digitally recreate all missing petroglyphs with high accuracy, except for those representing the horned figures.

6.2 Content-based Image Retrieval

Since Bicknell, the way archaeologists work today has dramatically changed. Instead of botanical paper sheets and pencil, they bring portable devices in their excavation campaigns, often equipped with sketch-based interfaces, as well as cameras and technical in-

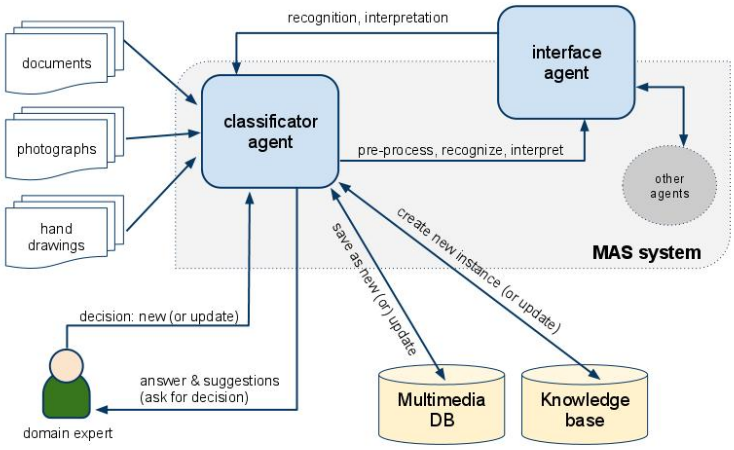

Figure 5: A schema describing the communication between a Classificator Agent and the Interface Agent in our MAS. The integration task is performed under the supervision of the domain expert who, on the basis of the information provided by the Classificator Agent on tags, decides whenever the content must be added as "new item" in the multimedia DB or as an "update" of an existing entry.

struments for documenting with high precision their discoveries. Consider the scenario where an archaeologist making excavations either in the Mount Bego region or in any region where similar petroglyphs have been found (for example, the Valcamonica Valley[2]) discovers a new petroglyph. She may wonder if similar petroglyphs have been already recorded in the "Bronze Age petroglyphs" repository. To this aim, she may either take a picture of the petroglyph (Figure 9a) or draw a sketch by means of her PDA's sketch based interface (Figure 9b).

In both cases, the agents devoted to sketch interpretation may start their interpretation task (in on-line mode if the archaeologist sketched the petroglyph, in off-line mode otherwise) and discover that the pattern of the sketch (or of the picture given in input) respects the pattern of a known symbol, namely that of corniculates, based on the results of previous campaigns (Figure 8). The new sketches (or images) can be uploaded in the repository and structured according to the semantic data provided (ontology-driven and visual) thus enriching the repository with new multimedia content and new knowledge.

A Sketch Interpretation Agent can be activated also in the case in which a user wants simply to search for content in the repository "similar" to an input data. In this case, after the interpretation has taken place, a Classification Agent must compare the tags resulting from the interpretation process with those tagging content in the database, in the same way described in Section 6.1.

The Classification Agent will return a ranked list of multimedia content according to tag similarity criteria that can be different depending on users's needs (which can be defined using specific ontology-driven parameters). Also, users can decide to browse the repository according to the structure of the knowledge base, using specific ontology-driven path and constraints, similarly to the approach presented in (Vrochidis et al., 2008).

7 Related Work and Concluding Remarks

As it is well known in the research community, there exist a lot of research, projects and tools which operate in the wide context of Cultural Heritage. The most notable example is the "Epoch" Network of Excellence (EPOCH EU NoE, 2002), recently concluded, which aimed at providing a clear organisational and disciplinary framework for increasing the effectiveness of work on the interface between technology and the cultural heritage of human experience. The Epoch NoE collected several tools for managing and organizing CH multimedia content, as for example AMA (Archive Mapper for Archaeology)[3], a web tool for mapping archaeological datasets to a CIDOC-CRM compliant format, or MAD (Managing Archaeological Data)[4] an application designed to store, manage and browse structured and unstructured archaeological datasets encoded in a semantic format. Recently, in (Vrochidis et al., 2008) a hybrid multimedia

[2]http://www.rupestre.net/alps/valcamonica.html

[3]http://ama.ilbello.com/

[4]http://www.epoch-net.org/index.php?option=com_content&task=view&id=216&Itemid=332

Figure 8: Petroglyphs of corniculates of the Mont Bego region. From de Lumley, H. and Echassoux, A. (2009), courtesy of the authors.

retrieval model is presented which provides a search engine that is capable to perform similar tasks to those we presented in this paper, without explicit use of a MAS. The model allows cultural heritage multimedia data retrieval based on the combination of semantic information and visual content.

Within this wide scenario, our key application is related to the preservation of Bronze age petroglyphs, by also taking advantage of the incredible valuable Bicknell's collection; we aim, as our ultimate goal, at designing a semantically annotated multimedia repository as a reference at European level as a thorough database of Bronze Age petroglyphs, which would be a definite contribution for domain experts, as rock art sites are spread all over Europe. To this purpose, here we proposed a framework able to formalize the knowledge related to the available multimedia content through ontologies and we proposed to use a multi-agent system that helps the creation of the repository in a semi-automatic way by using ad-hoc sketch interpretation algorithms. As future activities we plan, on the one hand to interact with the actors of Epoch in order to understand if our goal can be part of the more wide research community and on the other hand, to compare our approach with the one in (Vrochidis et al., 2008) in order to evaluate possible improvements. Finally, we point out that our framework focuses on the management, structuring and organization of multimedia content related to the Bronze Age but a lot of work could be done also in the "presentation" of this content to non-expert final users. We have already obtained preliminary results (Ancona et al., 2010) on interactions among 3D virtual worlds, living autonomous agents and semantic enriched multimedia content. The integration of those achievements on the presentation side within this framework will allow us to provide the domain experts, but also the potential virtual tourists and curious, with immersive experiences engaging on both the educational and ludic sides.

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Figure 7: Petroglyph identified by id. ZVIIGIIR7: De Lumley equipe's relief (left) and Bicknell's relief (right)

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Figure 9: Picture (from `http://www.cg06.fr/cms/annexes/merveilles/w_musee_merveilles/`) and sketch of an petroglyph.

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