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Scalable semantic personalized search of spoken and written contents on the Semantic Web

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Abstract

The continuous growth of contents in text and other media on the Web and intranets demands a parallel progress of information access technologies. This projects aims at a) the development of a novel semantic search model, with ontology-based content ranking algorithms, improving and complementing the achievements in this direction in the Semantic Web field, and enhancing the effectiveness of content retrieval with respect to current keyword-based techniques; b) the combination of personalization techniques with the semantic-based representation models, to achieve improvements in the relative precision and relevance of search results with respect to the particular interests of individual users; c) the integration of text and voice contents in a single access platform for large-scale repositories; and d) an experience in the realization the of Semantic Web proposals, to contribute to its advancement, including the definition of ontologies, the semi-automatic construction of knowledge bases, and a semi-automatic content annotation system, incorporating speech recognition and human language technologies.

Keywords: semantic search, personalization, information retrieval, ontology, knowledge bases, human language technologies

1 Project goals

The project starts with the following research goals:

G1. Semantic search: development of novel models and algorithms for the enhancement of mainstream Information Retrieval (IR) technologies with further semantic awareness, by taking advantage of fine-grained domain ontologies and knowledge bases (KBs). This goal is further subdivided into the following subgoals:

a. Ontology-based knowledge modeling.
b. Semi-automatic semantic annotation.
c. Semantic indexing and ranking algorithms.
d. Query user interface for semantic search.

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G2. Personalized content retrieval: development of techniques and algorithms for personalizing search and retrieval, exploiting the advantages of enhanced semantics to improve the performance of the automatic adaptation to user preferences. This comprises the following subgoals:
   a. User modeling: representation of user interests with respect to contents and meanings.
   b. Automatic user preference learning and update.
   c. Personalization effects: personalized search result ranking, and query disambiguation based on user preferences.

G3. Speech recognition and indexing: audio annotation and indexing, oriented to the identification of domain ontology entities in spoken discourse. This is broken down into the following topics:
   a. Acoustic, speaker-independent recognition of spontaneous speech, using robust grammars and vocabularies for Spanish, based on Hidden Markov Models (HMM).
   b. Design and implementation of stochastic grammars (N-grams) for spontaneous speech in Spanish.
   c. Effects of spontaneous speech in audio recordings from radio and TV: study and characterization of different noise sources (music, background noise, voice overlapping, etc.).
   d. Improvement of voice signal in real conditions: inclusion of new acoustic units in the recognizer and the grammar, to cope with the aforementioned effects.

G4. Experimental work for the validation and evaluation of the developed technology.
   a. Construction, reuse and extension of domain ontologies and knowledge bases.
   b. General setup of test beds, benchmarks, content corpora and datasets.
   c. Testing, evaluation and iterative refinement of techniques.

The tasks and timetable initially planned at the onset of the project for the achievement of the above goals are shown in Table 1.

Activities/tasks	Year 1	Year 2	Year 3
A1. Requirements analysis & specification	X|X|X|X| | | | | | |	| | | | | | | | | | | |	| | | | | | | | | | | |
A2. Domain ontology definition	| | | |X|X|X|X|X|X| |	| | | | | | | | | | | |	| | | | | | | | | | | |
A3. Semi-automatic KB construction	| | | | | | | |X|X|X|X	X|X|X|X|X| | | | | | |	| | | | | | | | | | | |
A4. Semi-automatic text & speech annotation	| | | | | | | | | | | |	| | |X|X|X|X|X|X|X|X|X	X|X| | | | | | | | | |
A5. Content retrieval & ranking	| | | | | | | | | | | |	| | | | | | | |X|X|X|X	X|X|X|X|X|X| | | | | |
A6. Personalization	| | | | | | | | | | | |	| | | | | | | |X|X|X|X	X|X|X|X|X|X| | | | | |
A7. Integration, evaluation & refinement	| | | | | | | | | | | |	| | | | | | | | | | | |	X|X|X|X|X|X|X|X|X|X|X|X
A8. Dissemination	| | | | | |X|X|X|X|X|X	X|X|X|X|X|X|X|X|X|X|X|X	X|X|X|X|X|X|X|X|X|X|X|X

Table 1. High-level task breakdown and time plan

2 Level of achievement reached in the project

The description of work provided next is structured following the task breakdown proposed in the submitted application to the approved grant, which is shown in Table 1, except for the activity A8 on dissemination, the results of which are reported later, in Sections 3.1 and 3.6. Overall the progress of the project is on plan, except for activities A5 and A6, which are ahead of schedule.

A1. Requirements analysis & specification

A collection of examples, scenarios and use cases has been created, illustrating the functionalities, addressed problems and envisioned solutions in the project. A thorough state of the art revision has been undertaken in the relevant areas, to identify the available starting points, and get a finer

identification of the open problems and opportunities for innovation in the envisioned research. The detailed needs for the work in the different areas of the project have been defined, such as the materials, test data, training and evaluation corpora, tools, formats, etc. Languages, standards, libraries and other tools have been evaluated with a view to their selection for the planned developments. OWL and RDFS have been selected for the definition of ontologies; Protégé for the manual edition of the latter; the Jena library for accessing KBs from Java programs; the SPARQL and RDQL standards for the representation and execution of semantic queries; and the Lucene library as a search engine for keyword-based retrieval. A first detailed architecture has been designed, identifying the modules and submodules needed to provide the functionalities for the different areas addressed in the project, as well as the required communication between the modules.

A2. Domain ontology definition

Three small-scale test ontologies have been defined (in the order of a hundred classes per ontology, and about as many properties), in the domains of Politics, Sports, and Geography, for testing and validation of the initial versions of the modules to be developed. The public-domain, medium-sized KIM ontology has been also adapted for conducting experiments on a larger scale [1]. Complementarily, collaborative methods for the selection and reuse of ontologies have been explored [13], [14], [15].

A3. Semi-automatic KB construction

Two automatic ontology population experiences have been undertaken, using semi-structured Web data sources. In particular, two test domain ontologies have been manually created (the ones mentioned earlier in A2) based on the Web sites of Sportec on the one hand (for the Sports domain), and several Spanish institutions on the other (for the Politics domain), such as the Parliament, Royal House, Government, Constitutional Court, and the *CGPJ*. The ontologies have been semi-automatically populated by scrapping instances from the Web sites and storing them into a KB. The procedure has been tested in experiments of restricted reach, up to the order of a hundred instances per ontology. On the other hand, NLP approaches have been explored for the automatic enrichment of ontologies with new relationships extracted from different text-based sources, such as on-line encyclopedic information [3], [8], [17].

A4. Semi-automatic text & speech annotation

Keyword spotting techniques have been researched for the automatic tagging of uttered words in speech recordings. A first version of the keyword spotting tool has been implemented [18], [24], [23], based on HMM with Gaussian mixtures (GMM) for the acoustic modeling of allophones, and the Viterbi algorithm for decoding. The spotted keywords are stored in an index along with the time interval where they are uttered, and a confidence measure. This index is the input for the semantic indexing layer, which adds conceptual annotations from domain ontologies, based on keyword-concept mappings. The conceptual annotation module of this layer can be applied to both tagged speech and untagged free text [1] (i.e. it includes automatic text tagging capabilities).

A5. Content retrieval & ranking

A novel ontology-based IR model has been developed. This comprises conceptual content indexing, the integration of an external ontology query engine based on SPARQL, and the definition of a result ranking algorithm [1]. The indexing procedure applies a weighting algorithm for the annotations produced by the annotation module described in the previous subsection. The weighting and ranking approach are based on an adaptation of the classic vector-space IR model, where ontology

concepts are used in place of keywords. The proposed model articulates two search spaces: an ontology KB, and an unstructured content corpus, in contrast with prior models in both the Semantic Web and IR fields, which only consider one of either spaces respectively. The inherent coverage limitations of domain ontologies are addressed by combining the output of the ontology-based content retrieval with that of a standard keyword-based engine (namely, Lucene), using a dynamic score normalization technique [7].

A6. Personalization

A model for content search personalization has been defined, based on an adaptation of the vector-space IR model, in which user preferences are defined as weighted concept vectors, where the weights represent the degree of interest of the user for a concept [4], [19]. This research has been extended with dynamic context modeling capabilities, by virtue of which general user preferences are filtered or activated differently depending of the semantic context of the ongoing retrieval user activity and her thematic focus of attention, reducing the intrusion of irrelevant preferences when the system applies long-standing user interests to personalize the search results [20], [21].

Complementarily, the definition of personalized content recommendation strategies has been explored [5], [9], [10], [11], [12], based on the comparison of semantic user profiles, following collaborative filtering principles, by which users are recommended items which have interested (or might interest) other users with semantically similar tastes. The novelty in the undertaken research lies in the enhancement of the semantic description layer by means of the introduction of rich, detailed domain ontologies and KBs, and the extra precision they enable.

Finally, advanced user interfaces are being researched to facilitate the interaction of the user with the system when querying and inspecting audiovisual content. Techniques for the definition of queries by demonstration have been devised [2], [22]. Two specialized tools have been built for navigation, one to inspect content and metadata, and one to browse the knowledge structures used in the semantic content annotations [16], [18].

A7. Integration, evaluation & refinement

An API has been defined for communication between the speech recognition module and the semantic indexing based on ontologies, and a first syntactic integration of the two components has been completed. Further work is needed on the joint system operation and the quality of results. A key aspect here is the proper alignment of the domain ontologies which support the semantic search, and the lexicon that the voice processing module is able to successfully recognize.

A first voice corpus on geographic information has been set up, obtained from the Albayzin database for Spanish. A small set of 80 words has been selected for the first tests. The corpus has been annotated with a manually defined geographic ontology, mentioned in Section A2. On the other hand, the Diari SEGRE (EPO[1] of this project) has supplied several sets of voice recordings from its radio station archives. The current corpus contains over 20 hours of clean voice recordings from news bulletins in Catalan by several speakers, along with their manual text transcription. This corpus is currently under preparation for the needs of the voice recognition modules, including both the training and test phases. An additional file with Catalan phonemes will be supplied for training, along with recordings of their utterance by the radio station speakers.

Parallel to this, larger-scale experiments have been conducted on semantic search for text content, for which purpose a test corpus has been set up with over 150.000 news from the CNN available on the Web (published between 1998 and 2004), along with the KIM ontology and KB, which

[1] In Spanish, "*Ente Promotor Observador*", industrial advisory partner.

include 281 classes, 138 types of property and semantic relations, 35.689 instances, and 465.848 sentences, plus a concept-keyword mapping. Current experiments show positive results, compared to a keyword-based search engine [1]. Further experiments have been undertaken on personalized search and semantic contextualization, based on the same corpus and two different evaluation methodologies. The first is based on a set of scenarios simulating interactive retrieval sessions [4]. In the second, 18 users where given three retrieval tasks which they could freely undertake in the system. In both approaches, the performance of the search system without personalization, with semantic personalization, and with contextual personalization, are compared. Initial results are positive, and will be used to refine the algorithms and drive the continuation of the research.

3 Result indicators

3.1 Scientific and technological production

The results of the undertaken research in this period have been submitted and accepted for publication in well-established international journals and events. The publications in this period include:

- 4 papers in international journals listed in the JCR index.
- 2 papers in the Springer Verlag LNCS series (international conference proceedings).
- 1 book chapter (by Springer Verlag).
- 14 papers in international workshops.
- 3 papers in national conferences.

The full list of publications is given in the references section at the end of this report.

3.2 Human resource training

Two Master's Theses (Spanish equivalent: "*Trabajos de Iniciación a la Investigación conducentes a la obtención de la Suficiencia Investigadora*") were successfully completed by members of the project team, under the supervision of the project PI:

- D. Vallet. *Personalized Information Retrieval in Context Using Ontological Knowledge.* Universidad Autónoma de Madrid, 15 June 2007. Supervisor: P. Castells.
- M. Fernández. *An Ontology-Based Approach to Semantic Awareness in Information Retrieval.* Universidad Autónoma de Madrid, 22 June 2007. Supervisor: P. Castells.

As the title of the theses suggest, they are strongly related to the core research of this project.

Besides these achievements, several junior members of the team have pursued international internships in foreign research groups, as reported in the next subsection.

3.3 Collaboration with international research groups

Related to the topics of this project, members of the team are also collaborating with international academic and industrial groups through the participation in the two following FP6 IP projects:

- MESH: Multimedia semantic syndication for enhanced news services (FP6-027685), http://www.mesh-ip.eu, led by Telefónica I+D, March 2006 to February 2009.
- aceMedia: Integrating knowledge, semantics and content for user-centred intelligent media services (FP6-001765), http://www.acemedia.org, led by Motorola UK, January 2004 to Dec. 2007.

Aside the general collaboration among all partners in the respective consortia, we may highlight our collaborations on context modeling and semantic personalization [21], [20] with the Image, Video and Multimedia Systems Lab (http://www.image.ntua.gr) of the National Technical University of Athens, and the Motorola Personalization and Knowledge Lab (co-located in Paris, and Basingstoke, UK), as well as the collaboration on semantic technologies for information retrieval with the Human Media Interaction group (http://hmi.ewi.utwente.nl) of the University of Twente, more recently established.

A collaboration was also started with M. Okumura, from the Precision and Intelligence Laboratory (http://www.lr.pi.titech.ac.jp/en) at the Tokyo Institute of Technology, on the automatic extraction of semantic relations from text based on NLP techniques [8].

In addition to these activities, the following research internships were pursued by members of the project team:

- D. Vallet, eBiquity group, University of Maryland Baltimore County (USA), http://research.ebiquity.org, 1st August to 30 November 2006.
- D. Vallet, Information Retrieval Group, University of Glasgow (UK), http://ir.dcs.gla.ac.uk, 1st August to 31 October 2007.
- M. Fernández, Knowledge Media Institute, Open University (UK), http://kmi.open.ac.uk, 1st July to 30 September 2006, and 1st July to 30 September 2007.
- I. Cantador, Knowledge Media Institute, Open University (UK), 1st July to 30 September 2007.
- J. Tejedor, Centre for Speech Technology Research, University of Edinburgh (UK), http://www.cstr.ed.ac.uk, 1st April to 30 September 2007.

3.4 National collaborations and activities

Several contacts and collaborations related to the research topics of this project have also been started at the national level.

- In November 2006 a new national thematic network on the semantic Web (TSI2006-26928-E, http://www.redwebsemantica.es) has been started, led by the Ontological Engineering Group (http://parla.dia.fi.upm.es/oeg) of the Universidad Politécnica de Madrid, and involving a total of 200 researchers from 27 groups, plus a number of Spanish researchers in foreign centres. Members of our team are actively participating in this network, as well as all the EPOs of the project.
- A semantic Web doctoral symposium (http://nets.ii.uam.es/redwebsemantica/simposio-caepia-07), chaired by F. Díez and organized in collaboration with members of the aforementioned research network, will be held in conjunction with the CAEPIA 2007 conference.
- Hugo Zaragoza from Yahoo! Research Barcelona held a working meeting with our team at UAM (15 January 2007), for the exchange of information on the respective ongoing research work, and the discussion of possible collaborations. The activities included a research seminar by Dr. Zaragoza for the whole Department. Our group is currently envisioning research internships by students from our team at Yahoo's Barcelona lab in the very near future.
- P. Castells was invited to give a lecture on semantic technologies for Information Retrieval and personalization on July 11 2007, at a summer school on "*Tecnologías lingüísticas: Acceso y visibilidad de la información multilingüe en la red –el rol de la semántica*", chaired by Prof. Felisa Verdejo from the Universidad Nacional de Educación a Distancia.

3.5 Usefulness of results and relations with the socio-economic environment

The results and acquired expertise of our group in the areas of semantic technologies IR, and personalization, has given rise to new collaborations in two national industrial projects:

- i3media: *tecnologías para la creación y gestión automatizada de contenidos audiovisuales inteligentes* (CENIT-2007-1012), http://www.i3media.org, January 2007 to December 2010.
  The project is led by Mediapro and includes 12 industrial partners and 10 academic partners.
- *Tecnologías de Indexación y Recuperación de información en la Web profunda* (FIT-350400-2006-5), http://nets.ii.uam.es/~dwir, June to December 2006.
  The project was led by Ándago Ingeniería, S.L.

Regarding the use of specific technology assets developed in the project, several software modules are being currently adapted for their use in the MESH project mentioned in Section 3.3. Specific components of the semantic search and personalized filtering modules are being adapted and integrated in the MESH system, prototypes and demonstrators.

Among the continued contacts, information flow, and collaborations with the EPOs of the project, we may highlight the strong involvement of the Diari SEGRE in project tasks, supplying voice contents from their radio station (as reported in Section A7), and collaborating in the requirements analysis and specification work. On their side, BET and TIF provide (and are interested in results from) the vertical perspective to the retrieval and semantics representation problems in their business domain (respectively, Healthcare and Finance). iSOCO specializes in semantic-based technologies, and in particular their application to knowledge management and retrieval, which are key research topics of this project.

3.6 Project development and management

The project currently involves a total of eight PhD researchers (four from UAM and three from UdL), and eight PhD students. One of the latter was hired on the project budget for the first 18 months. Two of the students from UAM and a PhD from UdL joined the project after it had started.

Internal coordination and external dissemination instruments have been put in place, including:

- A public project portal: http://nets.ii.uam.es/s5t.
- An internal wiki to facilitate the exchange and sharing of documents, drafts and materials, the coordination of management activities, as well as planning and monitoring the technical work.
- A mailing list for the communication among project team members.

Three plenary meetings have been held so far: in February 2006, November 2006, and September 2007 respectively. Many other meetings and telephone conferences take place on a regular basis. A detailed initial work plan was defined at the beginning of the project, along with a more general plan of objectives for the two following years. At the end of each year, the plan for the following year is updated and defined in more detail.

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