Activity Report 2011

Project-Team EXMO

Computer-mediated communication of structured knowledge

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Project-Team EXMO

Keywords: Semantic Web, Artificial Intelligence, Knowledge Representation, Ontology Matching

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2. Overall Objectives

2.1. Overall Objectives

We assume that expressing formalised knowledge on a computer is useful, not especially for the need of the computer, but for communication. In future information systems, formalised knowledge will be massively exchanged. *Exmo*'s goal is the development of theoretical and software tools for enabling interoperability in formalised knowledge exchange. *Exmo* contributes to an emerging field called the semantic web which blends the communication capabilities of the web with knowledge representation.

There is no reason why knowledge should be expressed in a single format or by reference to a single vocabulary (or ontology). In order to interoperate, these representations will have to be matched and transformed. Moreover, in the communication process computers can add value to their memory and medium role by formatting, filtering, classifying, consistency checking or generalising knowledge.

We currently build on our experience of alignments as representing the relationships between two ontologies on the semantic web. Ontology alignments express correspondences between entities in two ontologies. They allow maximising sharing on the semantic web: various algorithms can produce alignments and various uses can be made of these alignments. Such alignments can be used for generating knowledge transformations (or any other kind of mediators) that will be used for interoperating. In order to guarantee properties of these transformations, we consider the properties of alignments and generate transformations preserving them.

Our current roadmap focusses on the design of an alignment infrastructure and on the investigation of alignment properties (and especially semantic properties) when they are used for reconciling ontologies.

On a longer term, we want to explore "semiotic" properties, i.e., properties which concern the interpretation of the communicated representation by a human user. This goal should require an analysis of the extra-semantic rules that govern the choice of subsets of models.

Anticipated applications are in transformation system engineering (in which the information system is seen as a transformation flow) and semantic web infrastructure.

3. Scientific Foundations

3.1. Knowledge representation semantics

We usually work with semantically defined knowledge representation languages (like description logics [], conceptual graphs and object-based languages). Their semantics is usually defined within model theory initially developed for logics. The languages dedicated to the semantic web (RDF and OWL) follow that approach. RDF is a knowledge representation language dedicated to the annotation of resources within the framework of the semantic web. OWL is designed for expressing ontologies: it describes concepts and relations that can be used within RDF.

We consider a language L as a set of syntactically defined expressions (often inductively defined by applying constructors over other expressions). A representation ($o \subseteq L$) is a set of such expressions. It is also called an ontology. An interpretation function (I) is inductively defined over the structure of the language to a structure called interpretation domain (D). This expresses the construction of the "meaning" of an expression in function of its components. A formula is satisfied by an interpretation if it fulfills a condition (in general being interpreted over a particular subset of the domain). A model of a set of expressions is an interpretation satisfying all these expressions. An expression (δ) is then a consequence of a set of expressions (o) if it is satisfied by all of their models (noted $o \models \delta$).

A computer must determine if a particular expression (taken as a query, for instance) is the consequence of a set of axioms (a knowledge base). For that purpose, it uses programs, called provers, that can be based on the processing of a set of inference rules, on the construction of models or on procedural programming. These programs are able to deduce theorems (noted $o \vdash \delta$). They are said to be sound if they only find theorems which are indeed consequences and to be complete if they find all the consequences as theorems. However, depending on the language and its semantics, the decidability, i.e., the ability to create sound and complete provers, is not warranted. Even for decidable languages, the algorithmic complexity of provers may prohibit their exploitation.

To solve this problem a trade-off between the expressivity of the language and the complexity of its provers has to be found. These considerations have led to the definition of languages with limited complexity - like conceptual graphs and object-based representations - or of modular families of languages with associated modular prover algorithms - like description logics.

Exmo mainly considers languages with well-defined semantics (such as RDF and OWL that we contributed to define), and defines the semantics of some languages such as multimedia specification languages, in order to establish the properties of computer manipulations of the representations.

3.2. Ontology alignments

When different representations are used, it is necessary to identify their correspondences. This task is called ontology matching and its result is an alignment. It can be described as follows: given two ontologies, each describing a set of discrete entities (which can be classes, properties, rules, predicates, etc.), find the relationships, e.g., equivalence or subsumption, if any, that hold between these entities.

An alignment between two ontologies o and o' is a set of correspondences $\langle e, e', r \rangle$ in which

- e and e' are the entities between which a relation is asserted by the correspondence, e.g., formulas, terms, classes, individuals;
- r is the relation asserted to hold between e and e'. This relation can be any relation applying to these entities, e.g., equivalence, subsumption.

In addition, a correspondence may support various types of metadata, in particular measures of the confidence in a correspodence.

Given the semantics of the two ontologies provided by their consequence relation, we define an interpretation of two aligned ontologies as a pair interpretations $\langle m, m' \rangle$, one for each ontology. Such a pair of interpretations is a model of the aligned ontologies o and o' if and only if each respective interpretation is a model of the ontology and they satisfy all correspondences of the alignment.

This definition is extended to networks of ontologies: a set of ontologies and associated alignments. A model of such an ontology network is a tuple of local models such that each alignment is valid for the models involved in the tuple. In such a system, alignments play the role of model filters which will select the local models which are compatible with all alignments.

So, given an ontology network, it is possible to interpret it. However, given a set of ontologies, it is necessary to find the alignments between them and the semantics does not tell which ones they are. Ontology matching aims at finding these alignments. A variety of methods is used for this task. They perform pairwise comparisons of entities from each of the ontologies and select the most similar pairs. Most matching algorithms provide correspondences between named entities, more rarely between compound terms. The relationships are generally equivalence between these entities. Some systems are able to provide subsumption relations as well as other relations in the support language (like incompatibility or instanciation). Confidence measures are usually given a value between 0 and 1 and are used for expressing preferences between two correspondences.

4. Application Domains

The main application context motivating our work is the "semantic web" infrastructure (§4.1), but it can be applied in any context where semantic technologies are used: semantic social networks, ambient intelligence, linked data, etc. [4]

4.1. Semantic web technologies

Internet technologies support organisations in accessing and sharing knowledge, often difficult to access in a documentary form. However, these technologies quickly reach their limits: web site organisation is expensive and full-text search inefficient. Content-based information search is becoming a necessity. Content representation will enable computers to manipulate knowledge on a more formal ground and to carry out similarity or generality search. Knowledge representation formalisms are good candidates for expressing content.

The vision of a "semantic web" [] supplies the web, as we know it (informal) with annotations expressed in a machine-processible form and linked together. In the context where web documents are formally annotated, it becomes necessary to import and manipulate annotations according to their semantics and their use. Taking advantage of this semantic web will require the manipulation of various knowledge representation formats. *Exmo* concerns are thus central to the semantic web implementation. Our work aims at enhancing content understanding, including the intelligibility of communicated knowledge and formal knowledge transformations.

In addition, *Exmo* also considers a more specific use of semantic web technologies in semantic peer-to-peer systems, social semantic networks and ambient intelligence (see §6.2). In short, we would like to bring the semantic web to everyone's pocket. Semantic peer-to-peer systems are made of a distributed network of independent peers which share local resources annotated semantically and locally. This means that each peer can use its own ontology for annotating resources and these ontologies have to be confronted before peers can communicate. In social semantic networks, relationships between people are infered from relationships between knowledge they use. In ambient intelligence, applications have to reconcile device and sensor descriptions provided by independent sources.

5. Software

Exmo's work can be implemented in software: in particular, we have developed an API for expressing ontology alignment (§5.1) and a library of ontology distances and similarities *OntoSim* (§5.2).

5.1. Alignment API: manipulating ontology alignments

Participants: Jérôme Euzenat [Contact], Jérôme David, Cássia Trojahn dos Santos.

We have designed a format for expressing alignments in a uniform way []. The goal of this format is to be able to share available alignments on the web. It should help systems using alignments, e.g., mergers, translators, to take advantage of any alignment algorithm and it will help alignment algorithms to be used in many different tasks. This format is expressed in RDF, so it is freely extensible, and has been defined by a DTD (for RDF/XML), an OWL ontology and an RDF Schema.

The API itself [3] is a *Java* description of tools for accessing the common format. It defines five main interfaces (OntologyNetwork, Alignment, Cell, Relation and Evaluator) and proposes the following services:

- Storing, finding, and sharing alignments;
- Piping matching algorithms (improving an existing alignment);
- Manipulating alignments (thresholding and hardening);
- Generating processing output (transformations, axioms, rules);
- Comparing alignments.

We provide an implementation for this API which can be used for producing transformations, rules or bridge axioms independently from the algorithm which produced the alignment. The proposed implementation features:

- a base implementation of the interfaces with all useful facilities;
- a library of sample matchers;
- a library of renderers (XSLT, SWRL, OWL, C-OWL, SEKT mapping language);
- a library of evaluators (various generalisation of precision/recall, precision/recall graphs);
- a library of wrapper for several ontology API;
- a parser for the format.

To instanciate the API, it is sufficient to refine the base implementation by implementing the `align()` method. Doing so, the new implementation will benefit from all the services already implemented in the base implementation.

We have developed on top of the *Alignment API* an Alignment server that can be used by remote clients for matching ontologies and for storing and sharing alignments. It is developed as an extensible platform which allows to plug-in new interfaces. The Alignment server can be accessed through HTML, web service (SOAP and REST) and agent communication interfaces.

This year, within the SEALS project (see §8.2.1), we have developed a flexible test generation framework within the *Alignment API* which allows for generating new evaluation datasets [12].

The *Alignment API* is used in the Ontology Alignment Evaluation Initiative data and result processing. It is also used by more than 30 other teams worldwide.

The *Alignment API* is freely available since december 2003 under the LGPL licence at http://alignapi.gforge.inria.fr

5.2. The OntoSim library

Participants: Jérôme David [Contact], Jérôme Euzenat.

OntoSim is a library offering similarity and distance measures between ontology entities as well as between ontology themselves. It materialises our work towards better ontology proximity measures.

There are many reasons for measuring a distance between ontologies. For example, in semantic social networks, when a peer looks for a particular information, it could be more appropriate to send queries to peers having closer ontologies because it will be easier to translate them and it is more likely that such a peer have the information of interest. *OntoSim* provides a framework for designing various kinds of similarities. In particular, we differentiate similarities in the ontology space from those in the alignment space. The latter ones make use of available alignments in an ontology network while the former only rely on ontology data. *OntoSim* is provided with 4 entity measures which can be combined using various aggregation schemes (average linkage, Hausdorff, maximum weight coupling, etc.), 2 kinds of vector space measures (boolean and TF.IDF), and 4 alignment space measures. In addition, the framework embeds external similarity libraries which can be combined to our owns.

This year, we have implemented the measures of agreement and disagreement between ontologies recently proposed by Mathieu d'Aquin (Open university).

OntoSim is based on an ontology interface allowing for using ontology parsed with different APIs.

OntoSim is written in Java and is available under the LGPL license at http://ontosim.gforge.inria.fr.

6. New Results

In the continuation of our previous work, in 2011 we developed our work on evaluation of ontology matching and especially in running new experiments and generating new tests (§6.1.1). We also continued our work on trust in semantic peer-to-peer systems (§6.2.2), the use of the μ-calculus for evaluating RDF path queries (§6.2.1) and ontology matching for linking data (§6.1.2).

6.1. Ontology matching and alignment

We pursue our work on ontology matching and alignment support with contributions to evaluation, data interlinking and multilingual matching.

6.1.1. *Evaluation*

Participants: Cássia Trojahn dos Santos [Contact], Jérôme Euzenat, Jérôme David.

Evaluation of ontology matching algorithms requires to confront them with test ontologies and to compare the results. Since 2004, we run the Ontology Alignment Evaluation Initiative (OAEI) which organises evaluation campaigns for assessing the degree of achievement of actual ontology matching algorithms [4]. This year, the evaluation campaign had 16 different teams entered the evaluation which consisted of 5 different sets of tests. The participating systems and evaluation results were presented in the 6th Ontology Matching workshop, that was held in Bonn, DE [17][9].

The main activities carried out in 2011 were related to the automation and execution of the OAEI 2011 campaign, in the framework of the SEALS project (see §8.2.1). This involved the following main tasks:

- describe evaluation processes within the early version of the SEALS platform [11];
- develop a client allowing participants to validate their wrapped tools and evaluate (offline and locally) their tools;
- develop a test generator for automatic generation of systematic benchmarks [12];
- providing participants with a better way to bundle their tools so that they can be evaluated within the SEALS platform; and
- analysis and report of the evaluation campaign results [9].

This work has been used in the OAEI 2011 evaluation campaign. More information on OAEI can be found at http://oaei.ontologymatching.org/.

6.1.2. *Ontology matching for linked data*

Participants: Zhengjie Fan, Jérôme Euzenat [Contact], Jérôme David.

The web of data consists of using semantic web technologies to publish data on the web in such a way that they can be interpreted and connected together. It is thus critical to be able to establish links between these data, both for the web of data and for the semantic web that it contributes to feed.

In the context of the *Datalift* project (see §8.1.1), we are developing a data interlinking module. Based on our analysis of the relationships between ontology matching and data interlinking [13], our goal is to generate data interlinking scripts on from ontology alignments. For that purpose, we have integrated existing technologies within the *Datalift* platform: the *Alignment API*, for taking advantage of the EDOAL language and *Silk*, developed by Frei Universtität Berlin, for processing linking scripts. So far we have demonstrated the ability to process simple scripts.

This work is part of the PhD of Zhengjie Fan, co-supervised with François Scharffe (LIRMM), within the *Datalift* project.

6.1.3. *Multilingual ontology matching*

Participants: Cássia Trojahn dos Santos [Contact], Jérôme David, Jérôme Euzenat, Giuseppe Pirrò.

We have participated in the creation of a benchmark for multilingual ontology matching, the MultiFarm dataset. This dataset is composed of a set of ontologies translated in different languages and the corresponding alignments between these ontologies. It is based on the OntoFarm dataset, which has been used successfully for several years in the Ontology Alignment Evaluation Initiative. By translating the ontologies of the OntoFarm set into eight different languages – Chinese, Czech, Dutch, French, German, Portuguese, Russian, and Spanish – we created a comprehensive set of realistic test cases. We plan to include this new dataset in the OAEI 2012 campaign.

Finally, in the context of the *Cameleon* project (see §8.3.1) we have been working on the creation of a multilingual comparable corpora using as seed a set of multilingual aligned ontologies. These resources will be exploited in the process of populating and enriching ontologies as well as in the process of cross-lingual ontology alignment.

6.2. Ontology networks

Dealing with the semantic web, we are interested in ontology networks, i.e., sets of distributed ontologies that have to work together. One way for these systems to interact consists of exchanging queries and answers. For that reason, we pay particular attention to query systems.

6.2.1. *Path queries and μ-calculus*

Participants: Melisachew Wudage Chekol [Contact], Jérôme Euzenat, Pierre Genevès, Nabil Layaïda.

Querying the semantic web is mainly done through SPARQL [15]. One of its extensions, PSPARQL (Path SPARQL) provides queries with paths of arbitrary length. We study the static analysis of queries written in this language with techniques based on μ-calculus interpretation that have been used for XPATH. We have more specifically considered PSPARQL query containment: determining whether, for any graph, the answers to a query are contained in those of another query [18][14]. To that extent, we proposed an encoding of RDF graphs as transition systems and PSPARQL queries as μ-calculus formulas. We then reduce the containment problem to testing satisfiability in the logic.

This work is part of the PhD of Melisachew Wudage Chekol, co-supervised with Nabil Layaïda (WAM).

6.2.2. *Trust in peer-to-peer semantic systems*

Participants: Manuel Atencia [Contact], Jérôme Euzenat, Marie-Christine Rousset.

In a semantic peer-to-peer network, peers use separate ontologies and rely on alignments between their ontologies for translating queries. Nonetheless, alignments may be incorrect –unsound or incomplete– and generate flawed translations, thus leading to unsatisfactory answers. We have put forward a trust mechanism that can assist peers to select those peers in the network that are better suited to answer their queries [8]. The trust that a peer has towards another peer depends on a specific query and represents the probability that the latter peer will provide a satisfactory answer. In order to compute trust, we exploit both alignments and peers' direct experience, and perform Bayesian inference. We have implemented our technique and conducted an evaluation. Experimental results showed that trust values converge as more queries are sent and answers received. Furthermore, the use of trust is shown to improve both precision and recall of query answers.

This work has been developed in collaboration with Marie-Christine Rousset (LIG) in tge context of the *DataRing* project (see §8.1.2).

7. Contracts and grants with industry

7.1. Contracts with industry

7.1.1. *Thesaurus alignment environment*
Participants: Jérôme Euzenat [Contact], Jérôme David, Cássia Trojahn dos Santos.

Exmo has been subcontractor of the *Mondeca* company in a project for the OPOCE (the office for the official publications of the european union) which developed a matching environment for thesauri. *Exmo*'s role has been to integrates the *Alignment API* technology within *Mondeca*'s thesaurus edition environment and the development and evaluation of new matchers adapted to thesauri matching. We have developed a special version of our matcher *AROMA* for this task, which uses a a consensus-based matcher.

Concerned thesauri are large multilingual vocabularies expressed in SKOS, such as Eurovoc, GEMET and ETT.

8. Other Grants and Activities

8.1. National grants and collaborations

8.1.1. *Datalift ANR contint platform*
Participants: Zhengjie Fan, Jérôme David, Jérôme Euzenat [Contact].

Exmo coordinates with LIRMM the *Datalift* project whose goal is to produce a platform for publishing governmental data as linked data. *Exmo* is particularly involved in the generation of links between datasets [22] [19].

More information on *Datalift* can be found at http://www.datalift.org.

8.1.2. *DataRing ANR Verso Project*
Participants: Manuel Atencia [Contact], Jérôme Euzenat.

Exmo participates, as part of the LIG partner, in the *DataRing* project about peer-to-peer data sharing for online communities. We work more directly with Marie-Christine Rousset on trust in semantic peer-to-peer networks.

More information on *DataRing* can be found at http://www.lina.univ-nantes.fr/projets/DataRing/.

8.2. European initiatives

8.2.1. *SEALS infrastructure project: Evaluating semantic technologies*
Participants: Cássia Trojahn dos Santos [Contact], Jérôme Euzenat.

Exmo is a partner of the SEALS European commission infrastructure project whose goal is to provide the infrastructure for evaluating semantic technologies. Jérôme Euzenat is vice-coordinator in charge of the research area.

More particularly, *Exmo* is in charge of providing an infrastructure for evaluating ontology matching systems and algorithms, to be aggregated in the SEALS platform. This task involves:

- designing evaluation campaigns, including identifying criteria, metrics, datasets, and tools to be used in each campaign,

- designing and implementing services for automatic evaluation of systems and algorithms,

- analysing the results of evaluation campaigns and using them to produce a detailed report on both the effectiveness of the testing methodologies, and the systems that have been tested.

This year we have prepared the second SEALS evaluation campaign and designed a fully automated evaluation process [20][23][24]. We have also organised the OAEI 2011 campaign (§6.1.1) [9].

More information on SEALS can be found at http://www.seals-project.eu/.

8.3. International Initiatives

8.3.1. *Collaborative and Automatic Methods for the Multilingualisation of Lexica and Ontologies (Cameleon)*

Participants: Cássia Trojahn dos Santos [Contact], Jérôme Euzenat.

The *Cameleon* project is a 4 years joint CAPES-COFECUB project. It aims at creating, reinforcing and continuing academic exchanges between French and Brazilian researchers in the domain of multilingual lexica and ontologies. *Exmo*'s main tasks is to contribute to multilingual matching and interfacing ontologies and lexica.

More information on *Cameleon* can be found at http://cameleon.imag.fr/.

9. Dissemination

9.1. Leadership within scientific community

- Jérôme Euzenat is founding member of the "Semantic Web Science Association" (steering committee for the ISWC conference series) and member of the steering committee of the LMO conference series.

9.2. Editorial boards, conference and workshop committees

- Editorial board of the journal "Journal of Web Semantics", "Journal on Data Semantics" and "Semantic web journal" (Jérôme Euzenat).

- Manuel Atencia has been programme committee member of the International work conference on artificial neural networks (IWANN), and the International Semantic Web Conference (ISWC).

- Jérôme David has been programme committee member for the 2011 issues of the the Ontology matching workshop (OM), and the International Conference on Mobile Web Information Systems (MobiWIS).

- Jérôme Euzenat has been programme committee member for the 2011 issues of the conferences International Joint Conference on Artificial Intelligence (IJCAI), International Semantic Web Conference (ISWC), Worldwide Web Conference (WWW), ACM conference on Knowledge capture (KCap), International and Interdisciplinary Conference on Modeling and Using Context (Context), International Conference on Conceptual Modelling (ER), ODBase, and National Conference on Artificial Intelligence (AAAI) "AI and the web" track. Jérôme Euzenat has also been programme committee member for the IJCAI workshop "Automated Reasoning about Context and Ontology Evolution" (ARCOE), ER workshop on "Modeling and reasoning for business intelligence" (MoREBI), and IJCAI workshop on "Discovering meaning on the go in large and heterogeneous data".

- Cássia Trojahn dos Santos has been programme committee member for the 2011 issues of the Brazilian Symposium in Information and Human Language Technology (STIL), the International Semantic Web Conference (ISWC), and the Ontology Matching Workshop (OM).

9.3. Conferences, meetings and tutorial organisation

- Jérôme Euzenat has organised (with Pavel Shvaiko, Tom Heath, Christoph Quix, Ming Mao, and Isabel Cruz) the 6th "Ontology matching" workshop of the 10th ISWC, Bonn (DE), 2011 [17].

- Jérôme Euzenat and Cássia Trojahn dos Santos have organised (with many other colleagues) the Ontology Alignment Evaluation Initiative 2011 at the "Ontology matching" workshop of the 10th ISWC, Bonn (DE), 2011 [9].

9.4. Visits

- Cássia Trojahn dos Santos visited the Pontifícia Universidade Católica do Rio Grande do Sul, January, 11–13.

- Renata Viera (Pontifícia Universidade Católica do Rio Grande do Sul) visited *Exmo*, September, 22–30.

- Angela Locoro (Universitá di Genova) visited *Exmo*, October 15–December 15.

9.5. Invited conferences and other talks

- EXMO: Computer-mediated exchange of structured knowledge, Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre (BR), 12/01/2011 (Cássia Trojahn dos Santos)

- Building correspondences between ontologies and lexical resources, Seminar, University of Wolverhampton (UK), 04/02/2011 (Cássia Trojahn dos Santos)

- Interlinking the web of data: challenges and solutions, invited talk, 5th Semantic days, Oslo (NO), 9/06/2011 (Jérôme Euzenat).

9.6. Teaching

- Jérôme Euzenat co-ordinates with Éric Gaussier the "AI and the web" option of the second year of informatics research master, Joseph Fourier university and INP, Grenoble.

- Jérôme Euzenat teaches "Semantic web: from XML to OWL" (with Pierre Genevès, Nabil Layaïda and Marie-Christine Rousset) at the second year of informatics research master, Joseph Fourier university and INP, Grenoble (18h).

- Ontology matching lecture (Jérôme Euzenat, 2h): European Summer School on Ontology Engineering and the Semantic Web, Cercedilla (ES), resp. Mathieu d'Aquin.

9.7. Miscellaneous

- Jérôme Euzenat has been evaluator on EU FP7 projects.
- Jérôme Euzenat has been reviewer on the FCT (PT), SFI and IRCSET (IE) grant proposals.

10. Bibliography

Major publications by the team in recent years

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Publications of the year

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