EXMO

INRIA, Evaluation of Theme Sym C

2003-2005

1 Administrative aspects

Project-team acronym :	**EXMO**
Project-team title :	**Computer-mediated exchange of structured knowledge**
	Échanges de connaissance structurée médiatisés par ordinateur
Scientific leader :	**Jérôme Euzenat**
URL:	**http://www.inrialpes.fr/exmo/**
Research center :	**INRIA Rhône-Alpes (Montbonnot)**
Common project-team with :	none

Personnel (creation date: June 2003)

	Misc.	INRIA	CNRS	University	**Total**
DR(1)/ Professors					
CR(2) / Assistant Professors		2			**2**
Permanent Engineers(3)					
Temporary Engineers(4)		1			**1**
PhD Students				1	**1**
Post-Doc.					
Total		**3**		**1**	**4**
External Collaborators					
Visitors (> 1 month)					

Personnel (November 2005)

	Misc.	INRIA	CNRS	University	**Total**
DR(1)/ Professors		1			**1**
CR(2) / Assistant Professors		1			**1**
Permanent Engineers(3)					
Temporary Engineers(4)					
PhD Students	2	1		1	**4**
Post-Doc.		1			**1**
Total	**2**	**4**		**1**	**7**
External Collaborators					
Visitors (> 1 month)	1				**1**

(1) "Senior Research Scientist (Directeur de Recherche)"

(2) "Junior Research Scientist (Chargé de Recherche)"

(3) "Civil servant (CNRS, INRIA, ...)"

(4) "Associated with a contract (Ingénieur Expert or Ingénieur Associé)"

Changes in staff

DR / Professors CR / Assistant Professors	Misc.	INRIA	CNRS	University	total
Arrival		1DR			1
Leaving		1CR			1

Comment : This is the promotion of Jérôme Euzenat.

Current composition of the project-team (November 2005):

- Jérôme Euzenat, DR2, INRIA
- Jean-François Baget, CR2, INRIA
- Jason Jung, post-doctoral researcher, INRIA (Ministry of Research) (start Sept. 2005)
- Sébastien Laborie, PhD student, University (Ministry of Research)
- Antoine Zimmermann, PhD student, INRIA (Knowledge web)
- Jérôme Pierson, PhD student, France Telecom (CIFRE)
- Faisal Al-Khateeb, PhD student, Jordan government (start Oct. 2005)

Current position of former project-team members (including PhD students during the 2001-2005 period):

- Raphaël Troncy (PhD 2004): post-doctoral researcher at CWI, Amsterdam
- Olivier Brunet (PhD 2002): two-years post-doctoral stay in Leibniz, now High-school teacher (agrégé)
- Pierre-Antoine Champin (PhD 2002): associate professor (maître de conférences) at Université Claude-Bernard Lyon 1

Last INRIA enlistments

- 2004: Jérôme Euzenat promoted as DR2
- 2002: Jean-François Baget hired as CR2

Other comments :

The project has been created in June 2003. However, it was running autonomously since 2000 (with quite some time dedicated to proposing the project). Finally we decided to restrict this report to 2003-2005 as asked.

2 Scientific aspects

2.1 Keywords

- knowledge representation, semantics of knowledge representation, ontologies,
- semantic web, content representation, context,
- knowledge transformation, ontology alignment, property preservation, multimedia document adaptation, semiotics,
- RDF, RDF Path, OWL, XSLT
- Transmorpher, Alignment API, OLA

2.2 Research fields

Exmo develops and applies techniques from Artificial intelligence and more particularly Knowledge representation. The team has experience in the development of knowledge representation languages and tools. However, our specialisation is on relations between multiple representations and our focus is on improving the communication capabilities of the computer.

Exmo contributes to an emerging field called the Semantic web which marries the communication capabilities of the web with knowledge representation. We uses knowledge representation techniques in order to deal with heterogeneity on the semantic web.

2.3 Overall objectives

The goal of Exmo is the development of theoretical and software tools for qualifying the manipulation of knowledge chunks. Exmo is focussed on the transformations that can be applied to knowledge and the properties of these transformations. We are studying structural, semantic and semiotic properties of transformations (like order or consequence preservation). Our emphasis is currently on three topics: semantic properties in knowledge representation language translation, semantic adaptation of multimedia documents and ontology matching for interoperability.

2.4 Scientific foundations

Our work is based on traditional techniques of knowledge representation:

- semantics and especially model theoretic semantics plays a crutial role in our work on analysing the correspondence between representation, demonstrating the relevance of answers to queries and providing new representation formalisms (e.g., for multimedia documents);
- graph theory is used for computing queries as well as for matching ontologies;
- algebra of relations related to our former work on temporal reasoning [9] is used for defining the adaptation of multimedia documents as well as for composing alignments.

as well as modern software engineering techniques.

2.5 Application domains

Exmo ambitions to produce tools for two different application domains: transformation system engineering and the infrastructure of the semantic web. While transformation system engineering was the starting point of our approach, we encountered difficulties in finding the strong industrial partnership we sought in this area. On the contrary, the interest for interoperability problems within the semantic web has been growing to the point we concentrated on this.

2.5.1 Semantic web technologies

Our work deals with heterogeneity in the semantic web. The semantic web idea is essentially based on the notion of ontology (that can be quickly described as conceptual schemes or knowledge bases). Even if a standard knowledge representation language emerges, it will still be necessary to import and exchange ontologies or data in such a way that the semantics of their representation language is taken care of. We work on finding the correspondences between various knowledge representation languages and ontologies in order to

take advantage of them in ontology merging and bridging or message translation. Bringing solutions to this problem is part of the ambition of Exmo.

Our current goal is to put an alignment infrastructure at the center of the semantic web.

2.5.2 Transformation system engineering

In the context of the generalized exchange of structured data (XML) on the web, it seems unavoidable that, in the future, we will have to deal with complex transformation flows automating the combination of transformations, some of which coming from external sources. This will require the global understanding of the behavior of the flow of transformations. This calls for real "transformation system engineering" which should address the following issues:

- the lack of global consideration of transformations: they are processed in relation with other transformations;
- the need to consider the properties of transformations and especially their semantic properties: this will require the semantic analysis of the transformations;
- the design of transformation flows from external resources (as it is in software engineering): this will require the ability to consider the properties of imported transformations.

Transformation system engineering will require tools, methodologies and formal methods. As a matter of fact, it will be necessary to check that a particular transformation system does not export sensitive information or that the transformation process terminates. For that purpose, the transformation flow must be expressed in a parsable way and the expected properties of the flow must be expressed. Exmo is concerned by tools and formal methods and aims at combining them in solutions for transformation flow design environments.

2.6 Main contributions

2.6.1 Semantic framework for multimedia document adaptation

Adaptation of multimedia documents is primarily seen as the application of hand-crafted transformations without any more formal characterization. With our collegues of WAM, we introduced a semantic characterization of the adaptation [21]. This allows us to characterize what should be an adaptation in semantic terms and precisely define the "minimal" adaptation of such a document. We are applying this approach to the SMIL language [40].

2.6.2 RDF inference through graph homomorphism

Graph homomorphism-based entailment mechanisms used, for instance, in conceptual graphs, have been successfully applied to RDF Schema [18, 41], leading to import optimization techniques and polynomial subclasses from various knowledge representation languages (e.g., constraint networks). We have generalized this method to a class of logics caracterized by the possibility to express their semantics through a graph homomorphism [34]. This class covers conceptual graphs, constraint networks, RDF, positive Datalog... This framework has been applied to query answering with RDF, RDF Schema [34] and RDF complemented with regular expressions defining paths.

2.6.3 Ontology distance and distance-based alignment algorithm

Ontology alignment is usually based on some particular features of the ontologies (graph structure, strings, etc.) [5]. Because ontologies are not generally homogeneous, we have designed a distance between the elements of ontologies that take into account all the features of these ontologies. Moreover, these ontologies easily contain cycles that are problems for the direct computation of distances. We reduced the computation of the distance between elements to the optimization of a system of non-linear equations and produced a converging technique for solving this system [33]. These results have been implemented in the OLA system developed with university of Montréal.

2.6.4 Ontology alignment API

There are many algorithms for ontology matching and their results can be used for many different purposes (e.g., merging ontologies, translating messages, transforming knowledge). In order to share and compare the algorithms and to use the same algorithms for several purposes, we designed an API for expressing and manipulating the alignments resulting from matching [28]. This API has been used in a number of systems (see Software) and in the evaluation of ontology alignment evaluations.

2.6.5 Ontology alignment evaluation initiative

Since 2004 and in relation with our activity in the Knowledge web network of excellence we have lauched the Ontology alignment evaluation initiative which goal is the setup of a set of benchmark for ontology alignment algorithms and to organize evaluation campaigns (modelled after TREC). We have run two such campaigns in 2004 (Hiroshima [13]) and 2005 (Banff [14]). The web site (http://oaei.inrialpes.fr) provide the benchmark as well as the results from each campaign.

In order to evaluate the performance of ontology matching algorithms, we have proposed a framework for generalizing precision and recall that takes into account the distance between the found alignment and the expected one [35].

2.6.6 XML Transformation software

In order to prove or check the properties of transformations, it is necessary to have a representation of these transformations. The XSLT language enables the expression of a transformation in XML but is relatively difficult to analyse. In order to overcome this problem, we have designed and developed in collaboration with the Fluxmedia company, the Transmorpher environment for expressing and processing complex transformation flows (involving multiple input/output, recursion, composition). Transmorpher provides a set of abstract elementary transformations (including their execution model) and one default instantiation. Such elementary transformations include external call (e.g. XSLT), dispatcher, serializer, query engine, iterator, merger, generator and rule sets.

2.7 Project-team positioning

The specific standpoint of Exmo is to address the heterogeneity problem at the level of knowledge representation – i.e., considering the semantics of some logic system – and in general – i.e., independently from a particular application (by considering the representation and its manipulation only).

There are very few teams at INRIA concerned with artificial intelligence and knowledge representation. The most closely related teams are WAM, Acacia, Orpailleur and Gémo,

that we know quite well. Exmo works together with the three first ones. With WAM we bring the semantic approach to multimedia documents; with Acacia and Orpailleur we collaborate within the Knowledge web network of excellence and we share views on ontology alignment techniques (Acacia focusses on knowledge acquisition techniques and Orpailleur on Galois lattices). Currently, a salient difference with Gémo is the emphasis on XML versus RDF/OWL. But this difference may vanish in the coming years.

Outside INRIA, Exmo is among the leading teams concerned with ontology reconciliation. Through the Knowledge web network of excellence we are currently organizing the community on ontology matching (in particular through common evaluation which goal is to provoke progress in the field). The specificity of Exmo is its exclusive and restricted focus on heterogeneity and openness: we do not develop our work by reference to one application (web services: U. Innsbruck, p2p network: Galway and Trento, ontology editing: Karlsruhe and Stanford, agent communication: Liverpool and France Telecom, or even database integration: Microsoft, Washington State U.). So we collaborate with a number of these teams in order to push a common view of ontology alignment from which all can benefit.

This general view is an advantage since it allows to share forces among the different use of alignments and to apply results generally. However, this can also be a weakness because some fields may use directly specialized matchers, delivering specialized formats and compromising the integrated semantic web idea.

2.8 Publications

	02	03	04	05
PhD Thesis			1	
H.D.R (*)				
Journal		1	2	1
Conference proceedings		9	8	7
Book chapter		2	1	1
Book (written)				
Book (edited)		2	2	3
Technical report		2		
Deliverable		2	5	2

(*) HDR Habilitation à diriger des Recherches
(**) Conference with a program committee

Indicate five main journals in which scientific staff members publish their results:

1. Journal of Web Semantics
2. Journal on Data Semantics [5]

Indicate a maximum of five principal conferences where scientific staff members published their results on a regular basis:

1. International Semantic Web Conference (ISWC, 22%) [24, 28, 34]
2. International Joint Conference on Artificial Intelligence (IJCAI, 20%) [6]
3. European Conference on Artificial Intelligence (ECAI, 27%) [33]
4. European Semantic Web Conference (ESWC, 32%)
5. Knowledge Representation and Reasoning (KR, 34%) [27]

Selected publications:

[34] Jean-François Baget, **RDF entailment as graph isomorphism**, Proc. 4th International Semantic Web Conference (ISWC), Galway (IE), 2005 to appear.

[33] Jérôme Euzenat, Petko Valtchev, **Similarity-based ontology alignment in OWL-Lite**, in: Ramon López de Mantaras, Lorenza Saitta (eds), Proc. 16th european conference on artificial intelligence (ECAI), Valencia (ES), pp333-337, 2004

[6] Jérôme Euzenat, Nabil Layaïda, Victor Dias, **A semantic framework for multimedia document adaptation**, Proc. 18th International Joint Conference on Artificial Intelligence (IJCAI), Acapulco (MX), pp31-36, 2003

[**?**] Jérôme Euzenat, Laurent Tardif, **XML transformation flow processing**, *Markup languages: theory and practice* 3(3):285-311, 2002

2.9 Software

2.9.1 Advanced software

Transmorpher Transmorpher is a software environment for defining and processing complex transformations of XML documents. Transformation flows are described in XML. Input/output channels carry the information, mainly XML, from one transformation to another. Transformations can be other transformation flows or elementary transformations. Transmorpher provides a set of abstract elementary transformations (including their execution model) and one default instantiation. Such elementary transformations include external call (e.g. XSLT), dispatcher, serializer, query engine, iterator, merger, generator and rule sets.

Transmorpher has been registered by the "Agence de Protection des Programmes" (APP). Since June 2001, it is freely available at http://transmorpher.inrialpes.fr, under the GPL licence. It works correctly but is still subject to improvements.

Alignment API We have designed a format for expressing alignments in a uniform way [28]. The goal of this format is to be able to share on the web the available alignments. 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. We proposed a Java API and an implementation of this API dealing with the format.

The Alignment API has been used for the processing of the EON 2004 Ontology Alignment Contest and Ontology Alignment Evaluation Initiative 2005. It is used in the people's portal alignment tool at DERI Innsbruck and used or output by a number of alignment tools (among which OLA that we develop jointly with the University of Montréal or CMS from University of Southampton). The Alignment API is freely available since December 2003 under the LGPL licence at http://co4.inrialpes.fr/align.

2.9.2 Prototype software

OLA OLA [33] stands for OWL-Lite alignment and is a prototype implementation of our distance based alignment algorithm developed with University of Montréal. It is an implementation of the Alignment API and has been used in the two first ontology alignment evaluations.

OLA is available through anonymous CVS (see http://www.iro.umontreal.ca/~owlola/).

2.10 Collaborations

2.10.1 Collaborations with other INRIA project-teams

WAM (SymC) we collaborate directly on multimedia document adaptation (as well as carrying discussions on XML transformation aspects) [21, 40];

Acacia (SymC) we are part of the Knowledge web network of excellence and have exchanges on knowledge acquisition and ontology alignment [47, 49];

Orpailleur (CogA) we are part of the Knowledge web network of excellence and share views on ontology alignment and galois-lattice based knowledge extraction [47, 2, 4].

2.10.2 Collaborations with French research groups outside INRIA

INA, Bry-sur-Marne collaboration through Raphaël Troncy's thesis on content annotation of audio-visual documents with semantic web languages [7, 24, 23, 25, 1];

France Telecom R&D, Meylan collaboration through Jérôme Pierson's thesis on context modelling and matching for ambient computing;

MAGMA/Leibniz, Grenoble collaboration through Alexandre Viollet's master thesis on agent communication protocol for ontology alignment [50];

LIRMM, Montpellier collaboration on efficient inference with graph homomorphism (related to conceptual graphs);

2.10.3 Collaboration with Foreign research groups

U. Trento, Italy, we work with the team of Fausto Giunchiglia (Pavel Shvaiko and Mikalai Yatsewich) on ontology alignment [47, 48, 5];

U. Karlsruhe, Germany, we work with the team of Rudi Studer, on ontology alignment and more specifically on alignment accuracy measurement (with Marc Ehrig) and categorical characterization of alignment (with Pascal Hitzler and Markus Krötzsch) [47, 46, 35];

U. Liverpool, United Kingdom, we work with the multi-agent team (Valentina Tamma, Loredana Laera) on multi agent negociation and argumentation for aligning ontology [49, 50].

2.11 Specific hardware for experimental purpose

non relevant.

2.12 Specific software for experimental purpose

non relevant.

2.13 Industrial collaborations

Fluxmedia, 2001-2003 Fluxmedia was a small company that invested in the development of Transmorpher (by paying a software engineer). Unfortunately, after several loss of funding opportunity it had to close in 2003.

France Telecom R&D We have currently two distinct collaborations with France telecom R&D. The first one with Meylan is concerned with the thesis of Jérôme Pierson: it has raised a need for us to investigate the interoperability problems in the context of ambient computing (especially when the context is ever changing). We are starting another collaboration with a team in Lannion on heterogenous knowledge exchange in software agents.

2.14 Other funding, public, European, regional...

OntoWeb, EU FP5 thematic network 70 partners, INRIA part of the core group (15 partners) 2001-2004, 60kEuros (shared among Exmo, Aid, Acacia and Orpailleur);

Knowledge Web, EU FP6 network of excellence 18 core partners, Jérôme Euzenat vice scientific director, head of heterogeneity working group, 2004-2007, 445kEuros (for INRIA, 274kEuros for Exmo);

2.15 Teaching

Master research "Information, Interaction, Intelligence", Université Joseph Fourier/INP Grenoble, "Semantics of knowledge representation" lecture (18h per year);

Tutorial on Schema and ontology matching: European Semantic Web Conference - Hersounisous (GR) - 3h- resp. Jos De Bruyn, September 28-29th (Jérôme Euzenat and Pavel Shvaiko);

Web sémantique et pratique documentaire: Séminaire "publier sur Internet", Aix-les-Bains (FR), September 28-29th (Jérôme Euzenat and Raphaël Troncy) [7].

Jérôme Euzenat coordinates the Artificial intelligence profile of the second year of mathematics and informatics master, Intelligence, Interaction, Information track -Joseph Fourier university and INPG - Grenoble - resp. Yves Demazeau

- main doctoral school of involvement: "Mathématiques, Sciences et Technologies de l'Information, Informatique" (Université Joseph Fourier, INP Grenoble);
- Jérôme Euzenat is member of the advisory board of the "Scuola di dottorato internazionale in informatica e telecomunicazioni" of the universitá degli studi di Trento (IT)
- Jérôme Euzenat is responsible for relationship with Doctoral schools at INRIA Rhône-Alpes. Due to that, he is member of the councils of MSTII and "Mathématiques et Informatique fondamentales" (Université Claude Bernard, École National Supérieure, École Centrale, INSA Lyon) doctoral schools.

2.16 Visibility

General chair Jérôme Euzenat has been the general chair of the "European Semantic Web Conference (ESWC)" (Heraklion, GR), May 28th-June 1st, 2005 [15].

Program chair Jérôme Euzenat has been the program chair of the "Langages et modèles à objets (LMO)" conference (Lille), March 15-17th, 2004 [10].

Editorial boards Editorial board of the journal "L'objet", "Journal électronique d'intelligence artificielle (JEDAI)", "Journal of Web Semantics" and "Journal of Data Semantics" (Jérôme Euzenat).

Executive functions Jérôme Euzenat is vice-scientific director of the Knowledge web network of excellence (2004-2007) and coordinator of "Heterogeneity" work package. Jérôme Euzenat was board member and coordinator of "Promoting world-wide collaboration" work package of the OntoWeb thematic network involving 70 teams (2001-2004).

Associations Jérôme Euzenat is elected member of the board of the French artificial intelligence society (AFIA).

Steering committees Jérôme Euzenat is founding member of the "Semantic web science association" (steering committee for the ISWC conference series), member of the steering committee of the LMO conference series and member of the steering committee for the RFIA 2006 conference.

Standardization Jean-François Baget and Jérôme Euzenat have been members of the WebOnt working group of W3C which designed the OWL language [44]. Jean-François Baget is member of the RDF Data Access working group which is designing the SPARQL language.

Workshop organization

- Organizer (with Pavel Shvaiko, Alain Léger, Deborah McGuinness and Holger Wache) of the AAAI-2005 Context and ontologies workshop, Pittsburgh (PA US), 2005 [16].
- Organizer (with Marc Ehrig, Todd Hugues and Heiner Stuckenschmidt) of the "Integrating ontologies" workshop in the 3rd conference on Knowledge Capture (K-Cap), Banff (CA), 2005 [14].
- Organizer (with Mikalai Yatsewitch and Heiner Stuckenschmidt) of the Ontology Alignment Evaluation Initiative 2005 at the "Integrating ontologies" workshop at K-Cap conference 2005, Banff (CA), october 2005 [38].
- Organizer (Antoine Zimmermann) of the SDK Ontology Working Group meeting, 7-8 April 2005 in Grenoble (SDK is the cluster of three FP6 European projects: SEKT, DIP and Knowledge web).
- Organizer of the Ontology Alignment Contest at the EON workshop at ISWC 2004, Hiroshima (JP), november 2004. 40 people (Jérôme Euzenat) [13].
- Organizer for the workshop on "Semantic intelligent middleware for the web and the grid" at ECAI 2004, Valencia (SP), (Jérôme Euzenat) [12].

3 Main evolution of the objectives during the evaluation period

3.1 Planned objectives

For the four years starting 2003, Exmo has been given very precise objectives related to the design of an infrastructure for proved transformations on the web. The project proposal document states:

> *In the framework of this project proposal, it seems that three particular points should retain our attention in order to contribute solving interoperability problems:*
>
> - *the possibility to analyse transformations in units composed by precise operators;*
> - *the study of the behavior of a set of precise properties with regard to these operators;*
> - *the capacity to prove identified semantic properties concerning elementary transformations;*
>
> *We will mainly tackle these three problems in the coming years.*

3.2 Main evolution

Our project proposal had been designed far before 2003, with transformation engineering as its main target. The work on transformation intelligibility was well advanced, but the remainder of the four year programme faced several events:

- the difficulty to have industry interested in transformation engineering (and the additional closing of Fluxmedia);
- the difficulty to hire students able to deal with proof-checking and proof-carrying code;
- the raise of the semantic web as a very busy area in which we were deeply involved;

– the remark (made both by one of the evaluators of the projects and ourselves while designing the Knowledge web network) that instead of starting with transformations, we should rather consider alignments.

As a consequence, we put our strengths on dealing with ontology alignment as a more abstract way to consider transformations. However, our goal is to come back to our initial objectives after this detour. We explain how below.

4 Objectives for the next four years

We plan to implement the infrastructure for safe transformation, replacing transformation by ontology alignments and transformation engineering by the semantic web context.

4.1 Alignment infrastructure

The ontology alignment structure allows to maximize sharing on the semantic web: various algorithms can produce alignments and various use can me made of these alignments.

We are working on an alignment infrastructure that can fulfil the needs of various applications (ontology merging for editors, message translation for agents, mediation for web services, query and peer-to-peer systems). The current alignment API is being extended in order to offer its services to these applications (through agent communication protocols and web service invocation) and generating or processing the various transformations required by the applications. The agent aspect is jointly considered with University of Liverpool and with France Telecom R&D.

We currently investigate two practical applications of such an infrastructure:

– Matching context and needs in ambient computing requires such an infrastructure and would benefit sharing alignments on a large scale. The architecture has been designed as this is the thesis topic of Jérôme Pierson (with France telecom);
– Annotated resource sharing in peer-to-peer architecture requires to query peers with heterogeneous ontologies. The alignment service is used there to infer, edit and store the alignments and provide appropriate mediators for processing the queries. In this application, the alignment infrastructure is also used for building a "knowledge network" paralleling the social network of peers and enabling to expand it.

From the tool viewpoint, this infrastructure should be integrated in the works of the NeOn integrated project dedicated to develop a networked ontology development environment (starting March 2006).

4.2 Alignements, transformations and properties

Such an alignment infrastructure is the occasion to adapt Exmo's objective of providing an environment guaranteeing properties of the transformations. Instead of directly considering the properties of transformations, we would consider those of alignments and generate transformation (or any other kind of mediators) from these alignments.

For that purpose, we are currently studying, in particular through the thesis of Antoine Zimmerman, how alignment properties can be obtained by construction from the type of algorithm used for computing the alignment. We are also developing alignment composition operators that will be inserted in the alignment service. We will have to study how the transformation generators preserve these properties (and what distortion is introduced by these generators).

Another approach is the study of graph homomorphism-preserving transformations. Using the class of self-described logics [34], such transformations directly translate into consequence-preserving transformations on formulas. These transformations are thus an adequate tool to align ontologies written in different languages belonging to that class.

4.3 Other research

In the meantime we will continue to investigate some particular interesting problems in which we can still progress:

- the design and development of efficient alignment algorithms (with University of Montréal);
- the design of semantically grounded alternative to precision and recall for comparing ontology alignments (with Karlsruhe Universität);
- the design of inference and transformation techniques based on graph homomorphism (with LIRMM);
- the semantic (and rhetoric) adaptation of multimedia documents (thesis of Sébastien Laborie, with WAM);

It is clear that Exmo needs reinforcement, both on the infrastructure and on the certification aspects. The NeOn integrated project will offer the opportunity to hire someone for working on the insfrastructure aspect of the project. Exmo still miss some researcher trained to proof checking and proof carrying code techniques to apply and develop them to alignments, transformations and the semantic web technologies.

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