Team: EXMO
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1 General presentation

Scientific and Technological Project

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. The goal of Exmo 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 expressed on the web should be in a single format or by reference to a single vocabulary (or ontology). In order to interoperate, the 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 for 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 can 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.

Our work is naturally applied in several contexts: semantic peer-to-peer systems, dynamic document composition, interoperability in ambient computing, web service composition, semantic social networks and transformation system engineering (when one wants to establish properties of a complex transformation flow). We also investigate more traditional topics such as distributed reasoning with heterogeneous ontologies and expressive query answering.

Team History

Exmo has been created as an INRIA project in 2003. It joined the LIG at its creation.

The initial Exmo topic concerned interoperability on the web in its full generality. During our 2005 INRIA evaluation, this topic has been refocussed on “ontology matching and alignment”.

2 Team Composition

Permanent Researchers				
Name	First name	Institution	Function	Arrival date
Euzenat	Jérôme	INRIA	Research Director	09/1992
David	Jérôme	UPMF	Associate Professor	09/2008

Post-docs, engineers and visitors				
Name	First name	Institution	Function and % of time	Arrival date
Delbru	Renaud	INRIA/NUIG	PhD visitor	various visits
Freitas	Frederico	INRIA/UFPE	invited prof	various visits
Hoffmann	Patrick	INRIA	post-doc	04/2009
Le Duc	Chan	INRIA	Expert engineer	12/2007
Valtchev	Petko	INRIA/UQàM	Invited prof	various visits
Zamazal	Ondřej	INRIA/U.Praha	PhD visitor	03/2009

Doctoral Students					
Name	First name	University	Supervisors	Registration	Funding (sources and dates)
Pierson	Jérôme	UJF	J. Euzenat F. Ramparani (FT)	09/2004	CIFRE (France Telecom) (09/2004-08/2007)
Kramdi	Seif-Eddine	UJF	M.-C. Rousset (Hadas) & J. Euzenat	11/2008	LIG (ANR DataRing) (11/2008-11/2011)

Past team members

Past Members Oct. 2005-Oct. 2009						
Name	First name	Employer	Position	Arrival date	Departure	Current position
Baget	Jean-François	INRIA	Research Scientist	09/2002	03/2007	Sophia-Antipolis

Past Doctoral students						
Name	First name	University	Supervisor	Registration	Departure	Current position
Zimmermann	Antoine	UJF	J. Euzenat	11/2004	11/2008	Post-doc. NUIG Galway
Laborie	Sébastien	UJF	J. Euzenat N. Layaïda (WAM)	07/2004	08/2008	Post-doc. IRIT, Toulouse
Alkhateeb	Faisal	UJF	J. Euzenat J.-F. Baget	10/2005	07/2008	Ass. Prof. Yarmouk U.

Past post-doctoral researchers, engineers and visitors					
Name	First name	Home Institution	Function	Arrival date	Departure
Lee	Seung Keun	Association of Venture Corporations	Post-doc	06/2006	06/2007
Scharffe	François	INRIA	Post-doc	03/2009	12/2009
Jung	Jai Eun	INRIA	Post-doc	09/2005	09/2006
Laera	Loredana	U. Liverpool	Visitor	02/2007	03/2007

Evolution of the team:
There are two sailient features in the evolution of Exmo during the period:

- Jean-François Baget who had joined the team in 2003 left it in 2007. Jérôme David joined the team as Associate professor in 2008[1].
- We did not achieve to have a steady flow of PhD students. Instead we basically had fours students together for 4 years and now the stock is low.

3 Research Themes

3.1 Ontology matching and alignment

We pursue our work on ontology matching and alignment support with basic contributions.

3.1.1 Ontology distances

List of participants: Jérôme David, Jérôme Euzenat, Jason Jung

Scientific issues and positioning of the team: There are many reasons for measuring a distance between ontologies. In particular, it is useful to know quickly if two ontologies are close or remote before deciding to match them. To that extent, a distance between ontologies must be efficiently computable.

Key references: [9]

Major results Oct. 2005-Oct. 2009: We have studied constraints applying to such measures and reviewed several possible ontology distances [69]. Then we evaluated experimentally some of them [9]. We have carried out experiments on 12 measures in the ontology space against 111 ontologies. This allowed us to identify a triple-based distance of our own, associated with a minimum weight maximal graph matching, as the most accurate measure, but measures based on the vector space model of information retrieval as the most efficient measures.

Perspectives: We are developing further our studies of ontology distances with truly original measures based on alignments. This work will be implemented and disseminated in the OntoSim library currently under development.

[1]For those persons and others who were not part of Exmo during the whole evaluated period, we cover here only their activities and publications during their involvement in the team.

Contributors: This work is carried out in cooperation with Open university (Mathieu d'Aquin and Carlo Aloca) in the context of the NeOn project (see §5.1) and Yeungnam university (Jason Jung) in the context of a PHC STAR project (see §5.1).

3.1.2 Distributed system semantics

List of participants: Antoine Zimmermann, Jérôme Euzenat

Scientific issues and positioning of the team: When dealing with alignments, it is important, both for generating them and for using them to know their interpretation. This is even more important when users are dealing with a whole network of ontologies related by alignments. Such a structure composed of a set of ontologies, interconnected with ontology alignments is called a distributed system. A legitimate question is: given the semantics of these ontologies, what are the consequences of a distributed system? The answers were so far provided with distributed description logic or $\mathcal{E}$-connections. We have provided our own semantics that, we think, is more intuitive and allows for accommodating heterogeneous languages.

Key references: [38, 37]

Major results Oct. 2005-Oct. 2009: So far, alignments have been given semantics only related to a precise logical framework, e.g., first-order logic. In the continuation of our work on categorical definition of alignment [38], we aimed at an alignment semantics independent from the ontology semantics.

For that purpose, we have defined a parameterised family of model-theoretic semantics for alignments and knowledge-based distributed systems. This semantics is parameterised by the interpretation of the set of relations it uses and relies transparently on the semantics of the ontologies (which is only supposed to define the consequence relation). This means that the models of an alignment or a distributed system are defined in function of the models of the local ontologies, even when different ontologies are written in different languages.

We have investigated three different variations of this semantics, offering different levels of integration and supporting different paradigms. The three types of semantics use different techniques to obtain commensurate interpretation of formulas: either by constraining interpretations on a common domain, mapping the domains to a common domain or relating the entities of each pair of domains. We studied the semantic properties of ontology alignment composition according to these three variants [37]. It appears that only the first two types of distributed semantics are sound with respect to alignment composition, while the last one, which corresponds to the paradigm of Distributed First Order Logics (DFOL), Distributed Description Logics (DDL) and C-OWL, is not.

Contributors: Part of this work has been carried out in the framework of the Knowledge web network of excellence (see §5.2). In particular, the categorical development is the result of a collaboration with Markus Krötzsch and Pascal Hitzler (Universität Karlsruhe).

Perspectives: This semantics is a major asset of the team which is widely used in many of our other activities (distance, algebra, evaluation measures, modules). We plan to study further what an agent aware of this semantics can do for deciding what it must believe. We also plan to use this semantics, if not to improve it, in future studies of alignment composition and revision.

3.1.3 Alignment languages and algebra

List of participants: Jérôme Euzenat, Antoine Zimmermann, François Scharffe

Scientific issues and positioning of the team: Sharing alignments across the web requires a language to express them. We have been developing the Alignment format for exchanging alignments across applications which is widely used inside and outside Exmo. We use it in the Alignment server, the Alignment API and the OAEI evaluation effort (§3.1.5). Although this format is freely extensible, it is only able to express simple alignments between ontologies.

Key references: [11, 92]

Major results Oct. 2005-Oct. 2009: In order to offer a format which is both expressive and independent from concrete ontology languages we developed the Expressive Alignment Language [92]. The high expressivity of the language allows for expressing complex alignments even if the ontology languages are not themselves expressive. The language independence guarantees that we can define expressive alignments between any languages and provides a declarative definition of the alignments which will be usable in various manners, e.g., ontology merging or data translation. We defined for this language an abstract syntax (used for describing the semantics), an exchange syntax (in RDF/XML) and a more readable surface syntax. We provided a model theoretic semantics for the language which relies upon the semantics of aligned ontologies while remaining independent from their details. We also provided support for this language by combining and extending the API for the Alignment Mapping Language developed at Innsbruck Universität and our Alignment API (see §8).

We also have proposed to use algebra of binary relations instead of the generally used ad hoc relations. The first motivation for this was to be able to express uncertainty in relations between ontology entities, but we have shown that algebras of binary relations are a natural way to represent disjunctions of relations, to agregate matcher results, and to compute composition and granularity change [11].

In addition, once we are able to ascribe a semantics to alignments [74], it is possible to carry out approximate reasoning that does not involve ontologies but alignments alone. This can be exploited for evaluating alignments [10], for checking consistency, or for preprocessing a distributed set of alignments through the computation of its compositional, symmetric and union closure. Algebra of relations are then instrumental for computing composition of alignments [11].

Contributors: This work is carried out in cooperation with Innsbruck Universität (François Scharffe) in the context of the Knowledge web project (see §5.2).

Perspectives: We are currently reengineering our Alignment API (see §8) in order to ground it on these languages and algebra and to demonstrate their benefits. We want to use them in reasoners and in systems for processing alignments. There are currently no standard language and format for alignments, so we are considering submitting the Expressive Alignment Language to W3C.

3.1.4 Ontology modules

List of participants: Jérôme Euzenat, Antoine Zimmermann, Frederico Freitas, Camila Bezerra

Scientific issues and positioning of the team: The goal of the semantic web is to share knowledge. In this context, knowledge is expressed in interlinked chunks rather than large monolitic ontologies. Ontologies can be assembled from ontology modules like programme modules in software engineering.

Key references: [18]

Major results Oct. 2005-Oct. 2009: We have designed a model of modules which combines an interface and an ontology implementation, in which a module can import other modules through alignments with their interface [18, 81]. This is a very natural approach since alignments can be used to adjust the components in the ontologies. We have provided a semantics for such modules which is a combination of ontology semantics and our own alignment semantics.

Contributors: This work is carried out in cooperation with Frederico Freitas (see §5.3) and in the framework of the NeOn project (see §5.1).

Perspectives: Ontology modules are very important for the development of the future semantic web. However, the currently required work on that topic is prominently development of support tool. We will avoid invest our scarce resources in such developments.

3.1.5 Benchmarking

List of participants: Jérôme Euzenat, Jérôme David, Ondřej Zamazal

Scientific issues and positioning of the team: In order to evaluate ontology matching algorithms it is necessary to confront them with test ontologies and to compare the results.

Key references: [17]

Major results Oct. 2005-Oct. 2009: 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 [98, 91, 82]. In 2008, 13 different teams entered the evaluation which consisted of 8 different sets of tests. This is still a very successful and lively event.

On the research side, we have pursued our investigations on generalising precision and recall. We have developed semantic precision and recall measures [17] based on the new semantics of alignments (see §3.1.2). Unfortunately these measures are difficult to compute fairly in extreme cases, hence we have analysed its limits and we proposed two new sets of evaluation measures [10]. The first one is a semantic extension of relaxed precision and recall. The second one consists of bounding the alignment space to make ideal semantic precision and recall applicable.

We also have attempted to go beyond these raw evaluation results and try to provide guidance to users with a specific ontology matching problem to solve. This amounts to characterising matching problems and matching solutions over specific dimensions and requirements, e.g., the kind of input or the properties expected from the output, and applying decision support procedures in order to find the most adapted solutions [35].

Perspectives: This work will be continued in the framework of the SEALS European project. In particular, we plan there to introduce more automation in the evaluation process and to measure the hardness of tests. We will also complete our work on alternative evaluation measures.

3.2 Systems of networked ontologies

Dealing with the semantic web, we are interested in systems of networked ontologies, 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.

3.2.1 Constrained Path RDF as a query language for RDF and RDFS

List of participants: Faisal Alkhateeb, Jean-François Baget, Jérôme Euzenat

Scientific issues and positioning of the team: Though RDF itself can be used as a query language for an RDF knowledge base (using RDF entailment), the need for added expressivity in queries has led to the definition of the SPARQL query language. SPARQL queries are defined on top of graph patterns that are basically RDF (and more precisely GRDF) graphs. Another way to query RDF graphs is to query for paths expressed by regular expressions holding between nodes (the former allows for full graph branching and cycling as queries, the latter allows for indetermined lengths of paths). However, some queries that can be expressed in one approach cannot be expressed in the other: a query whose homomorphic image in the database is not a path cannot be expressed by a regular expression, while RDF semantics is not meant to express paths of unknown length. The two kinds of queries do not identify the same set of queries.

Key references: [72, 1]

Major results Oct. 2005-Oct. 2009: To benefit from both approaches, we have defined PRDF, for Path RDF [89, 51, 72], an extension of RDF that encompasses regular expressions over relations as labels to the arcs of RDF graphs. PRDF can characterise paths of arbitrary length in a query, e.g., "does there exist a trip from town A to town B using only trains and buses?".

In addition, we have extended these PRDF graphs so that they allow for expressing constraints on the nodes, e.g., "Moreover, one of these connections must provide a wireless connection". To express these constraints, we propose an extension of PRDF, called CPRDF (for Constrained Path RDF [88, 7]).

For these two extensions of RDF, we have provided an abstract syntax and an extension of RDF semantics. We characterise query answering (the query is a PRDF or a CPRDF graph, the knowledge base is an RDF graph) as a particular case of PRDF or CPRDF entailment that can be computed using some kind of graph homomorphism. Query answering thus remains an NP-hard problem in all these languages. Finally, we use these PRDF or CPRDF graphs as graph patterns in SPARQL, defining the PSPARQL and CPSPARQL extensions of that query language. We provide the necessary algorithms for computing the answer set to a given PSPARQL or CPSPARQL query and we have implemented them (see §8).

We have also proposed a new approach for evaluating queries over a core fragment of RDFS. This approach mainly relies on rewriting any (CP)SPARQL query q into a semantically equivalent CPSPARQL query q' such that the evaluation of q' over an RDF graph G is equivalent to the evaluation of q over the RDFS closure of G. The efficiency of evaluating queries using this approach has been demonstrated through the use of the Lehigh University Benchmark[2] for generating RDFS graphs.

Finaly, we have proposed to use PSPARQL as a basis for a new language for processing alignments [12, 85]. More precisely, we have proposed that for processing expressive alignments generated by patterns [13], we needed a mix of the rule language SPARQL++ and PSPARQL.

[2] http://swat.cse.lehigh.edu/projects/lubm/

Perspectives: This work has been ahead of the development of SPARQL. There is currently a new W3C working group considering extensions of the current SPARQL language. Among these extensions, as a "to be added if time permits" feature is the addition of regular paths and this work is among its inspiration. We do not plan to invest more on query languages and rather to use those implementing the standards for processing alignments.

3.2.2 Reasoning with distributed systems of networked ontologies

List of participants: Chan Le Duc, Antoine Zimmermann

Scientific issues and positioning of the team: The semantics of networks of aligned ontologies defines the consequences of such a network. A reasoner will compute such consequences when needed. There are very few distributed reasoners, we have developed one of those based on the semantics that we have defined. It has the advantage of processing the alignments independently of the local provers. This provides flexibility, but is computationally expensive.

Key references: [14, 74]

Major results Oct. 2005-Oct. 2009: In order to effectively reason on distributed systems of networked ontologies, we introduced a new kind of distributed logics, namely Integrated Distributed Description Logics (IDDL), where ontologies are represented as description logic knowledge bases and alignments assert cross-ontology concept/role subsumptions or disjunctions, or cross-ontology instance membership. In particular, this formalism is adapted for reasoning with OWL ontologies aligned by automatic ontology matching tools. The semantics of the logic is the one we inroduced (see §3.1.2).

The difference between IDDL [24] and the existing formalisms is that (i) IDDL focuses on alignments by considering them as independent pieces of knowledge, (ii) IDDL does not make any expressiveness assumption on formalisms used in ontologies except for decidability, (iii) IDDL supports distributed reasoning, i.e., all local computing for ontologies can be independently performed by local reasoners.

We have developed an algorithm for consistecy checking in IDDL [87, 14]. The procedure is correct and complete when the correspondences which appear in the alignments only assert cross-ontology subsumption of concepts or roles, or cross-ontology disjointness of concepts. The complexity class of consistency checking is at least NP but depends on the complexity of local reasoners.

This algorithm has beed implemented and a preliminary version of the IDDL reasoner (see §8). First experiments with our prototype show that it answers quickly on several real life cases.

Perspectives: Reasoners for networks of ontologies, either distributed or centralised, are tremendously useful and necessary. We need them, to some extent, in every work which involves our alignment semantics. They can be used in semantic peer-to-peer networks. Developing a reasoner requires very specialised knowledge and promises to be particularly expensive computationally. We could either improve the IDDL reasoner or associate with other partners for continuing this work.

3.2.3 Semantic social networks

List of participants: Jérôme Euzenat, Jason Jung, Antoine Zimmermann

Scientific issues and positioning of the team: Social networks are simply the graph between people along social relations (usually denoting that they know each others). There has been much work on social network analysis for finding central people in a network or connecting efficiently an individual to another.

Key references: [19]

Major results Oct. 2005-Oct. 2009: We introduced the notion of semantic social networks in order to describe networks embedding not only relations between people, but also the ontologies that people use. These ontologies can be used, for instance, in order to annotate resources such as documents, pictures, etc. We proposed an organisation for semantic social networks in three layers: social layer, ontology layer and concept layer. Each layer features a network based on different relations [19].

People in the social network are related to the ontologies they use, and ontologies are related to the concepts they use and they define. However, it may be useful to be able to infer relations between people from the relations between concepts and ontologies. This has the advantage of providing potential proximity relations for people who do not even know each others. Such techniques can be useful for instance, for finding people to which it will be easier to forward a query or group of homogeneous people who will be more prone to design a consensus ontology [20]. We proposed some propagation rules as well as measures for computing network analysis.

Perspectives: We plan to resume this work in collaboration to Yeungnam university. This involves using new distances between ontologies (see §3.1.1) as well as experimenting the whole framework on real world cases.

3.3 Dynamic aspects of alignments

We apply the results obtained on alignments in various contexts where semantic web technologies and alignments are useful.

3.3.1 Context management in pervasive computing

List of participants: Jérôme Pierson, Jérôme Euzenat, Seungkeun Lee, Jason Jung

Scientific issues and positioning of the team: In a pervasive computing environment, the environment itself is the interface between services and users. Using context information coming from sensors, location technologies and aggregation services, applications adapt their run time behaviour to the context in which users evolve, e.g., physical location, social or hierarchical position, current tasks as well as related information. These applications have to deal with the dynamic integration in the environment of new elements (users or devices), and the environment has to provide context information to newly designed applications. We study and develop a dynamic context management system for pervasive applications. It must be flexible enough to be used by heterogeneous applications and to run dynamically with new incoming devices.

Key references: [2]

Major results Oct. 2005-Oct. 2009: We have designed an architecture in which context information is distributed in the environment. Each device or service implements a context management component in charge of maintaining its local context. It can communicate with other context management components: some of them are context information producers, some of them are context information consumers and some of them are both. We have defined a simple protocol to allow a consumer to identify and determine the right producer for the information it needs. Context management components express their context information using an OWL ontology and exchange RDF triples with each other. The openness of ontology description languages makes possible the extension of context descriptions and ontology matching helps dealing with independently developed ontologies. Thus, this architecture allows for introducing new components and new applications without interrupting what is working [53, 28, 42].

We have developed a library to build the distributed context management system. It provides support for most operations of context management, i.e., searching, broadcasting and updating context information.

We have developed the Alignment server [20] and, in particular, the JADE plug-in for communicating with agents which is used in our distributed context management system. The Alignment server allows the context information manager component to find correspondences between various ontologies with which it is confronted and thus to match application needs in terms of context information with the information provided by the other devices.

We have built a complete easily deployable ambient home environment. Our infrastructure manages context information flows from sensors and web services to pervasive application and a dynamic service composition infrastructure. We demonstrated it through several applications composed of a set of potentially interchangeable sensors and actuators. These applications are combined to present an integrated scenario which shows how an ambient home environment can improve the experience of a typical Grenoble resident and helps him to organise his leisure. This environment was showcased at the Ubicomp 2007 conference.

Contributors: This work is developed in collaboration with France Telecom R&D and more specifically Fano Ramparany.

Perspectives: We think that the issue of ontology heterogeneity in ambient computing applications will develop during the years to come. We plan to integrate the proposal that we have made in a broader context involving user intervention. In particular, we think that such applications should not be restricted to work in a particular well identified context, but should be continuously kept in order in uncontrolled contexts. So we plan to push on experimenting and improving our heterogeneous context framework.

3.3.2 Argumentation over ontology alignments

List of participants: Jérôme Euzenat, Loredana Laera

Scientific issues and positioning of the team: When two independently developed agents want to interact they may not share the same ontologies. In order to reconcile their ontologies, they can take advantage of an alignment service which will provide alignments for the two ontologies. But if the obtained alignment does not suits both parties, it is necessary for these parties, if they want to interact, to negotiate the meaning of terms, or, more modestly, to negotiate the correspondences in alignments.

Key references: [34, 23]

Major results Oct. 2005-Oct. 2009: For that purpose, we have introduced a novel argumentation framework for arguing for and against correspondences found in alignments [32, 34, 33, 23]. This framework is based on previous work on argumentation in multi-agent systems, and especially value-based argumentation, but adapts it to the specific case of arguing about alignments and correspondences. It provides a first typology of arguments that can be applied to correspondences between ontology entities (based on the way the correspondences have been obtained). A preference relation among arguments can be defined with regard to this typology. This relation can be different from agent to agent so that they do not all prefer the same arguments. We have used classical multi-agent argumentation theory in order to characterise what is an acceptable argument for an agent as well as the prefered extensions (of a set of arguments) for a set of agents having different preference relations. We also designed an argumentation protocol for reaching these preferred extensions. We provide strategies for evaluating arguments during the unfolding of the negotiation dialogue.

Collaborators: This work is developed in collaboration with the Computer Science Departement of the University of Liverpool and, precisely, Loredana Laera, Valentina Tamma and Trevor Bench-Capon.

Perspectives: This work has been put on hold for some time now. We still hope to be able to resume it with a better proof system and a distributed implementation providing better evaluation.

3.3.3 Semantic adaptation of multimedia documents

List of participants: Sébastien Laborie, Faisal Alkhateeb, Jérôme Euzenat, Jean-François Baget

Scientific issues and positioning of the team: When a multimedia document is played on platforms with limited resources, e.g., a mobile phone that can only display one image at a time or an interactive display without keyboard, it is necessary to adapt the document to the target device. In order to assess the meaning of adaptation, we have defined a semantic approach , which considers a model of a multimedia document as one of its potential executions (an execution satisfying its specification). In a first approximation, adaptation reduces the set of models of a specification by selecting those satisfying the adaptation constraints. Adapting amounts to finding this subset of models or, when it is empty, finding a compatible execution as close as possible to the initial execution.

Key references: [73]

Major results Oct. 2005-Oct. 2009: For that purpose, we have proposed to express the set of possible interpretations by a resolved relation graph. Each relation of this graph can be a temporal, spatial, or spatio-temporal relation. This approach has been applied to the temporal and spatial dimensions based on Allen and RCC algebras respectively [47].

We instantiated this approach on semantic adaptation for the SMIL 2.0 language [55]. We have shown that our adaptation framework is generic, by adapting SMIL documents in the temporal, spatial [44], spatio-temporal [30], hypermedia dimensions and mixed them with the temporal one [31]. Moreover, we have completed preliminary work to include the logical dimension, i.e., group together some objects in one single element. We have extended our adaptation approach with the capability to suppress multimedia objects [21]. For example, a profile may indicate that only a few multimedia objects are allowed in a presentation. When multimedia objects are removed, we forced the adapted document to satisfy properties such as presentation contiguity. Instead of removing multimedia objects, we have considered media adaptation [22]. For that purpose, we propose to adapt media items by replacing incompatible media items by others found on the web. The adapted media items must convey the same message as the original ones, while satisfying the target profile. We have presented a possible architecture to implement this and we have shown that search engines can already do it to a limited extent. Nonetheless, some results are unsatisfactory because media annotations lack semantics, are partial and are heterogeneous. Hence, we have proposed to use semantic web technologies, such as RDF descriptions, ontologies, ontology merging and matching, in order to select better alternatives, thus improving this adaptation framework.

We have implemented this approach in an interactive adaptation system for SMIL documents. Moreover, we have studied the computation time of adaptating solutions. We want to increase the efficiency of this search in order to adapt real SMIL documents, i.e., documents containing many multimedia objects. For this purpose, we have considered relation graphs containing mixed quantitative and qualitative relations. To efficiently check the satisfiability of this kind of temporal constraint network, we have to deal with the infinite domains of variables, which can generate an infinite number of candidates during backtrack. For solving this problem, we rely upon finite partitions of domains using bi-intervals (intervals of intervals) [16]. We have implemented sound and complete backtrack and forward checking algorithms and shown that bi-intervals, used in a hybrid algorithm which also instantiates constraints, improve our backtrack efficiency.

We have also used semantic web technologies in the context of multimedia document adaptation. On one hand, we have proposed an extension to SPARQL for generating any kind of XML documents from multiple RDF data and a given XML template [50]. Thanks to this extension, an XML template can itself contain SPARQL queries that can import template instances. With such an approach, it is possible to reuse templates, divide related information into various templates and avoid templates containing mixed languages. Moreover, reasoning capabilities can be exploited using RDFS, and document adaptation could be achieved using the SPARQL FILTER clause to restrict the answers to the set that satisfies the given profile. On the other hand, we have considered the use of the author discourse in the context of semantic adaptation [73]. We have shown that specifying some rhetorical relations between multimedia objects, such as “examplified”, may in turn identify implicit spatio-temporal relations between these objects. Hence, using the author discourse structure guides the adaptation process by providing adapted documents which are as close as possible from either the explicit document composition or the author discourse structure. Moreover, for SMIL documents, we have shown that this discourse may be specified with RDF triples in the SMIL Metadata Module.

Contributors: This work has been made in collaboration with Nabil Layaïda (WAM).

Perspectives: The work on multimedia document adaptation is currently stopped due to lack of forces. There are, however, interesting perspective in designing adapters closer to the semantics of documents.

4 Application domains and social, economic or interdisciplinary impact

Two application contexts motivate and spur our work: the semantic web infrastructure and transformation system engineering.

4.1 Semantic web technologies

Web technologies support organisations in accessing and sharing knowledge, which is often difficult to access in a documentary form. However, these technologies are facing 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 searches. 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.

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 in such a way that the semantics of their representation language is taken care of. We work on finding correspondences between various knowledge representation languages and ontologies (see §3.1) 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.

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 §3.3.1). 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 inferred from relationships between knowledge they use. In ambient intelligence, applications have to reconcile device and sensor descriptions provided by independent sources.

4.2 Transformation system engineering

Computerisation and networking lead organisations to exchange information in machine-readable form. E-commerce generates a continuous flow of such documents. As transmitted information is neither addressed nor adapted to all the members of an organisation, it is necessary to transform document structure and content. Similarly, web sites are generated from databases or primary sources and e-commerce documents are applied various transformations before goods are shipped. Additionally, the Object Management Group Model-Driven Architecture (MDA) considers that a part of software development can be reduced to the composition of transformations from (platform independent) domain models to other (platform dependent) models in function of platform description models. This is considering any implementation as adaptation.

Interoperability requirements have led to the definition of the structured document representation language XML which helps handling the syntax of documents straightforwardly. Other languages, such as XSLT or Omnimark, enable the implementation of standalone transformations.

However, this view of transformations is only partial and local. 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 behaviour 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, like in transformations workflow languages such as Transmorpher or XProc;
- the need to consider 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.

In the recent years, we turned our interest more specifically towards alignment management [46] which remains tied to transformation system engineering: it is still about composing alignments, satisfying properties and generating transformations from alignments.

It would be presumptuous to judge impact a priori. It seems clear that the potential impact of these application domains on society and economy is important and that the development of applications involved in the first domain will require to work with human and social scientists. However, we are at the beginning of the journey.

5 Contracts and grants

5.1 External contracts and grants (Industry, European, National)

NeOn (Networked ontologies, FP6 IP IST, 2006-2010), 14 partners coordinated by Open university (UK). NeOn is dedicated to the development of an environment covering the whole lifecycle of networked ontologies. Exmo is working on the alignment support aspect of netwoked ontologies. We provide our Alignment server and various means to use it (NeOn toolkit plug-in and Cupboard integration). http://www.neon-project.org

SEALS (Semantic evaluation at large scale, FP6 Infrastructure, 2009-2012), 10 partners coordinated by Universidad Politecnica de Madrid (ES). SEALS develops a lasting reference infrastructure for semantic technology evaluation and organises the continuous evaluation of semantic technologies at a large scale via public world-wide evaluation campaigns. Exmo is in charge of the Ontology matching evaluation work-package and Jérôme Euzenat is vice-project coordinator. http://www.seals-project.eu

WebContent (ANR-RNTL, 2006-2009). Project partners involve INRIA Gemo, LIG Hadas, CEA, EADS, coordinated by CEA. The project is dedicated to the development of an open platform for exploiting semantic web technologies in searching and managing information; We are more specifically in charge of subtask 3.2 dealing with ontology matching. We are integrating the Alignment server and new matching algorithms to the WebContent platform. http://www.webcontent.fr/

STAR (Ontology distances for semantic social networks, PHC STAR, 2009-2011). The project is a cooperatio between Exmo and Yeungnam university (Gyeungsan, South Korea) for designing ontology distances that can be used for computing measures in semantic social networks.

5.2 Research Networks (European, National, Regional, Local)

Knowledge web (FP6 NoE 2004-2008, FP6-507482) Network of excellence on the semantic web. There were 19 partners led by the university of Innsbruck (AT). Exmo was leader of the Heterogeneity work package and served as vice-scientific director (Jérôme Euzenat). This network has structured semantic web research in Europe and for our concern driven the work on ontology matching. http://knowledgeweb.semanticweb.org/

Web Intelligence (Région Rhône-Alpes grant, 2006-2008-2011) Regional research network involving seven Rhône-Alpes laboratories working on Web and artificial intelligence led by LIRIS and École nationale des mines de Saint-Étienne. http://www.web-intelligence-rhone-alpes.org/

5.3 Internal Funding

OntoCompo (cooperation FACEPE-INRIA grant, 2008-2011) designs modular ontology models and software support. It involves Exmo and partners at Universidade Federal de Pernambuco and Universidade Federal de Santa Catarina.

OLA is a matcher developed through a continuous cooperation with Petko Valtchev at Université du Québec à Montréal. This cooperation has benefited from various limited grants from the French consulate in Montréal and INRIA.

6 Principal International collaborations

We work with most of the teams, especially European, in the domain of the semantic web and more specifically on ontology matching. We have had student exchanges during the period with Università degli Studi di Trento, University of Liverpool, Universität Karlsruhe, Universidade Federal de Pernambuco, Prague University of Economics, New Ireland University Galway, and University of Innsbruck.

7 Visibility, Scientific and Public Prominence

7.1 Contribution to the Scientific Community

Managment of Scientific Organisations

- *Semantic Web Science Association* (steering committee for the ISWC conference series), Jérôme Euzenat is founding member, 2001-;
- *Steering committee of the LMO conference series*, Jérôme Euzenat, 2004-;
- *European Academy for Semantic web Education* (EASE), Jérôme Euzenat has been member of the "Scientific advisory board" and a founding member, 2006-2009;
- *Scientific Steering Committee of the "European Semantic Web Conference Series*, Jérôme Euzenat, 2006-2008;
- *Steering committee for the RFIA 2006 conference*, Jérôme Euzenat, 2006;

Editorial Boards

- *Journal of web semantics*, Jérôme Euzenat, 2004-2008
- *Journal on data semantics*, Jérôme Euzenat, 2004-2008

Organisation of Conferences and Workshops

- *European semantic web conference*, Jérôme Euzenat, general chair, 2005;
- *Asian semantic web conference*, Jérôme Euzenat, general chair, 2008;
- *Context and ontologies* workshop, Jérôme Euzenat, 2006, 2007, 2008;
- *Ontology matching* workshop, Jérôme Euzenat, 2006, 2007, 2008, 2009;
- *Ontology Alignment Evaluation Initiative*, Jérôme Euzenat, 2006, 2007, 2008, 2009;
- Atelier *Passage à l'échelle des techniques de découverte de correspondances*, Jérôme Euzenat, 2007;

- Atelier *Intelligence artificielle et web intelligence*, Jérôme Euzenat, 2007;
- *Plate-forme AFIA*, Faisal Alkhteeb, Sébastien Laborie, Antoine Zimmermann, 2007;

Program committee members

- *Artificial intelligence : methodology, systems and applications conference 2006 (AIMSA)*, Jérôme Euzenat, programme chair, 2006;
- *International conference on knowledge engineering and knowledge management (EKAW)*, Jérôme Euzenat, co-programme chair, 2008;
- *International Semantic Web Conference (ISWC)*, Jérôme Euzenat, 2006, 2007, 2008, 2009; Jérôme David, 2009;
- *International Joint Conference on Artificial Intelligence (IJCAI)*, Jérôme Euzenat, 2009;
- *European Semantic Web Conference (ESWC)*, Jérôme Euzenat, 2006, 2007, 2008;
- *European Conference on Artificial Intelligence (ECAI)*, Jérôme Euzenat, 2008;
- *Worldwide Web Conference (WWW)*, Jérôme Euzenat, 2006, 2009;
- *(US) National conference on AI (AAAI)*, Jérôme Euzenat, 2006, 2007, 2008;
- *International Conference on Conceptual Modeling (ER)*, Jérôme Euzenat, 2008;
- *Formal Ontologies for Information Systems (FOIS)*, Jérôme Euzenat, 2006, 2008;
- *International Conference on Artificial Intelligence: Methodology, Systems, Applications (AIMSA)*, Jérôme Euzenat, 2008;
- *International Conference on Semantic and Digital Media Technologies (SAMT)*, Jérôme Euzenat, 2006;
- *International conference on knowledge engineering and knowledge management (EKAW)*, Jérôme Euzenat, 2006;
- *Reconnaissance des Formes et Intelligence Artificielle (RFIA)*, Jérôme Euzenat, 2006, 2008;
- *Langages et Modèles à Objets (LMO)*, Jérôme Euzenat, 2008;

International expertise

- *Evaluator for FP6 European projects, DG INFSO*, Jérôme Euzenat, 2006;
- *Expert on WWTF (AT) grant applications*, Jérôme Euzenat, 2008;
- *Panelist in the European Commission Knowledge and content research unit FP7 brainstorming meeting (Luxembourg, LU)*, Jérôme Euzenat, 2009;
- *Expert for Israel Science Foundation*, Jérôme David, 2009;
- *Expert on NWO (NL) grant applications*, Jérôme Euzenat, 2009;

National expertise

- *AERES visiting committee for LORIA and INRIA Lorraine*, Jérôme Euzenat, 2008;
- *Expert on OSEO grant applications (FR)*, Jérôme Euzenat, 2008;
- *Evaluator on ANR CONTINT grant applications*, Jérôme David, 2009;
- *Recruitment committee Université de Pau* professor position 510, Jérôme Euzenat, 2009;

8 Software and Research Infrastructure

Software Publication

Alignment API and server, Software library and toolbox, the Alignement API and server is composed of a format for expressing alignments, an API for manipulating (generating, parsing, outputing, trimming, evaluating) these alignments, a library implementing this API and a server for sharing and storing alignments on the web. This API provides a high level of interoperability between systems providing and requiring alignments. It has been adopted by many developments around the world, both by team implementing matchers and teams manipulating them[3], and is used in the Ontology Alignment Evaluation Initiative. It is distributed since 2003 under the LGPL license and current version is 3.5. http://alignapi.gforge.inria.fr.

PSPARQL Query evaluator, This query evaluator can parse SPARQL, PSPARQL and CPSPARQL queries, parse RDF documents written in the Turtle language, evaluate the query and then return the answer set. It is a research prototype

[3] See http://alignapi.gforge.inria.fr/impl.html.

showing the possibility of implementing the PSPARQL and CPSPARQL languages that we designed. It can serve as a reference implementation in case these improvements are taken into account for SPARQL 2. License: Cecill-B. http://exmo.inrialpes.fr/software/psparql.

IDDL Reasoner, The IDDL Reasoner is a theorem prover in the distributed description logic IDDL [87]. It takes as input a network of ontologies and can decide if it is consistent; it can also decide if a correspondence is a consequence. It is a research prototype demonstrating our work on IDDL and used in several of our projects (modules, NeOn, etc.). http://iddl.gforge.inria.fr/

Research Infrastructure

NeOn toolkit: http://www.neon-toolkit.org/ is an extensible ontology editor created by the NeOn project. Exmo provides the Alignment plug-in based on the Alignment API and server for the NeOn toolkit. It has been used both inside and outside of the project.

WebContent platform: http://www.webcontent-project.org/ is a software platform integrating tools necessary to exploit the semantic web for market watch. Exmo provides the ontology alignment service of the WebContent platform based on the Alignment API and server.

9 Educational Activities

Supervision of Educational Programs

- Jérôme Euzenat: coordinator of option “intelligence artificielle” of M2R Mathematics and informatics (UJF & INPG, 2005-2006, 2006-2007);
- Jérôme Euzenat: coordinator of option “web intelligence” of M2R Mathematics and informatics (UJF & INPG, 2007-2008);
- Jérôme Euzenat: coordinator, with Éric Gaussier, of option “artificial intelligence and the web” of M2R Mathematics and informatics (UJF & INPG, 2008-2009);

Teaching

Name	Course title (short)	Level	Institution	Hours (eqTD)	Academic Years
Jérôme Euzenat, Jean-François Baget	Technologies du web sémantique	continued	EDF	16	2005-2006
Jérôme Euzenat, Jean-François Baget	Connaissance, web, sémantique	M2R MI	UJF-INPG	24	2006-2007
Jérôme Euzenat	Ontology matching	advanced	UPMadrid	10	2007-2008
Jérôme Euzenat	Ontology matching	advanced	summer school	4	2005-2008
Jérôme Euzenat	Web sémantique	M2R MI	UJF-INPG	9	2008-2009
Jérôme David	Plate-formes de développement Web	M2 DCISS&ICPS	UPMF	30	2008-2009
Jérôme David	Développement Web mobile	M2 DCISS&ICPS	UPMF	30	2008-2009
Jérôme David	Interfaces Homme-Machine	M2 DCISS&ICPS	UPMF	30	2008-2009
Jérôme David	Initiation Informatique	L1 socio.	UPMF	48	2008-2009
Jérôme David	Bases de données relationnelles	L2 MIASS	UPMF	55	2008-2009
Jérôme David	Développement mobile - streaming	Lpro MIAM	UPMF IUT2	20	2008-2009

10 Industrialization, patents and technology transfer

Consulting Activities

- *consulting visitor for the EDGAR project, ISEP, Porto (PT)*, Jérôme Euzenat, 2008;

11 Self-Assessment

We think that Exmo has been successful in shaping the field and leading the work on ontology matching these past years. We have written the reference book on the topic [48], we organise the well-attended OAEI evaluation campaigns, we have papers at the best conferences on the topic (ISWC, IJCAI, AAMAS, ESWC, FOIS), and we develop software which is quite used. We also have good papers out of the field of ontology matching (SPARQL, ambient computing, document adaptation). Globally the team, of only two permanent people, is well regarded and the PhD students that we have trained have reached a good visibility.

We are involved in large European projects (Knowledge web, NeOn, SEALS). This strategy, beside providing resources, allows us to collaborate with very good teams in mid term projects. This also helps to involve our students on the international scene. The constraints and burden associated with such projects are real, but so far, so good.

We faced difficulties for finding adequate people at all levels (PhD students, post-doctoral researchers, professors). This has been slightly better recently with post-doctoral researchers. We do not want to grow in an uncontrolled manner, but we could easily employ a few more members.

At the moment, we are enjoying ourselves and we think that we are producing good results.

12 Perspectives for the research team

Exmo aims at building on its strength in order to increase its contribution and impact to the field of ontology matching and alignment and the semantic web at large. For that purpose, we will investigate the following directions:

Distances between ontologies and their use in ontology matching, semantic peer-to-peer system, ontology search and semantic social network. We are currently developing this work in the direction of measures in the alignment space which take advantage of existing alignments. We would like to better understand the relation between measures and their use. This work will be delivered in a new software library: OntoSim.

Algebraic manipulation of alignments including composition, reasoning and combining alignments. We want to define the possible operations on alignments and their properties. We are currently reengineering our Alignment API so that these operations could be fully integrated. We will then be able to provide support to the other research threads and to improve our support to alignment management [46].

Evaluation of matchers concerns the automation of evaluation as well as the particular evaluation measures. We will take advantage of the other tracks in order to improve matcher evaluation.

Better matchers we want to build better matchers and for this we would like to investigate several paths among which context-based matching in which the matcher takes advantage of resources external to the ontologies, reasoning about alignments for improving them, and pattern-based matchers in which matching patterns are used for guiding matching. We also want to improve our work on argumentative matching in which agents argue about their correspondences (see §3.3.2) and our OLA structural matcher.

Our work belongs to the “Communication” scientific priority of INRIA and more specially the “Ubiquitous information and web of knowledge and services”. It is relevant to the first of the INRIA Grenoble Rhône-Alpes research centre themes: “Maîtriser des ressources dynamiques et hétérogènes (mastering dynamic and heterogeneous resources)”.

On the application side, the semantic web is slowly making progress. We would like to contribute to the adoption and dissemination of semantic web technology more broadly. In fact we would like to deliver it in everybody’s pocket. For that purpose, we are planning to curve Exmo’s trajectory towards ambient intelligent applications that we have already considered (see §3.3.1). This it is directly contributing to the LIG and PILSI objectives on “ambient computing” as well as the INRIA Grenoble Rhône-Alpes research centre sub-domain “Systèmes mobiles and réseaux ambiants (mobile systems and ambient networks)”.

13 Publications

International peer reviewed journal [ACL]

2009

[1] F. Alkhateeb, J.-F. Baget, and J. Euzenat. Extending SPARQL with regular expression patterns (for querying RDF). *Journal of web semantics*, 7(2):57–73, 2009.

2008

[2] J. Euzenat, J. Pierson, and F. Ramparany. Dynamic context management for pervasive applications. *Knowledge engineering review*, 23(1):21–49, 2008.

International peer-reviewed conference proceedings [ACT]

2009

[3] C. Bezerra, F. Freitas, J. Euzenat, and A. Zimmermann. An Approach for Ontology Modularization. In *Proc. Brazil/INRIA colloquium on computation: cooperations, advances and challenges (Colibri), Bento-Conçalves (BR)*, pages 184–189, 2009.

[4] S. Laborie, J. Euzenat, and N. Layaïda. Semantic multimedia document adaptation with functional annotations. In *Proc. 4th international workshop on Semantic Media Adaptation and Personalization (SMAP2009), San Sebastián (ES)*, pages 44–49, 2009.

[5] C. Le Duc. Decidability of SHI with transitive closure of roles. In *Proc. 6th european conference on semantic web (ESWC), Heraklion (GR)*, pages 365–379, 2009.

[6] O. Svab-Zamazal, F. Scharffe, and V. Svátek. Preliminary results of logical ontology pattern detection using SPARQL and lexical heuristics. In *Proc. 1st ISWC 2009 workshop on Ontology pattern (WOP), Chantilly (VA US)*, pages 139–146, 2009.

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[7] F. Alkhateeb, J.-F. Baget, and J. Euzenat. Constrained regular expressions in SPARQL. In H. Arabnia and A. Solo, editors, *Proc. international conference on semantic web and web services (SWWS), Las Vegas (NV US)*, pages 91–99, (US), 2008. CSREA Press.

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[11] J. Euzenat. Algebras of ontology alignment relations. In *Proc. 7th conference on international semantic web conference (ISWC), Karlsruhe (DE)*, pages 387–402, 2008.

[12] J. Euzenat, F. Scharffe, and A. Polleres. Processing ontology alignments with SPARQL (Position paper). In *Proc. IEEE international workshop on Ontology alignment and visualization (OAaV), Barcelona (ES)*, pages 913–917, 2008.

[13] F. Scharffe, D. Fensel, and J. Euzenat. Toward design patterns for ontology alignment. In *Proc. ACM conference (SAC), Fortaleza (BR)*, pages 2321–2325, 2008.

[14] A. Zimmermann and C. Le Duc. Reasoning on a network of aligned ontologies. In *Proc. 2nd International conference on web reasoning and rule systems (RR), Karlsruhe (DE)*, pages 43–57, 2008.

2007

[15] F. Alkhateeb and A. Zimmermann. Query answering in distributed description logics. In *Proc. conference on New technologies, mobility and security (NTMS), Paris (FR)*, pages 523–534, Heildelberg (DE), 2007. Springer Verlag.

[16] J.-F. Baget and S. Laborie. Bi-intervals for backtracking on temporal constraint networks. In *Proc. 14th international conference on temporal representation and reasoning (TIME), Alicante (SP)*, pages 163–168, Los Alamitos (CA US), 2007. IEEE Computer Society.

[17] J. Euzenat. Semantic precision and recall for ontology alignment evaluation. In *Proc. 20th International Joint Conference on Artificial Intelligence (IJCAI), Hyderabad (IN)*, pages 348–353, Menlo Park (CA US), 2007. AAAI Press.

[18] J. Euzenat, A. Zimmermann, and F. Freitas. Alignment-based modules for encapsulating ontologies. In B. Cuenca-Grau, V. Honavar, A. Schlicht, and F. Wolter, editors, *Proc. 2nd workshop on Modular ontologies (WoMO), Whistler (BC CA)*, pages 32–45, 2007.

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2009

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Summary

	2006	2007	2008	2009	**Total**
International peer reviewed journal [ACL]	0	0	1	1	2
International peer-reviewed conference proceedings [ACT]	14	10	8	4	36
Short communications [COM] and posters [AFF] in conferences and workshops	3	1	0	2	6
Scientific books and chapter [OS]	0	1	2	1	4
National peer-reviewed conference proceedings [ACTN]	3	2	2	0	7
Book or Proceedings editing [DO]	3	5	3	2	13
Invited conferences [INV]	0	0	2	0	2
Doctoral Dissertations and Habilitations Theses [TH]	0	0	3	1	4
Other Publications [AP]	2	9	7	6	24
Total	25	28	28	17	98