

This section is devoted to the activities of the Exmo team (2014–2016) and those of the MOEX team (2017–2019). The two teams show both continuity and rupture.

EXMO has been dedicated to the development of the semantic web since 2000. The semantic web blends the communication capabilities of the web with knowledge representation. The goal of EXMO was the development of theoretical, experimental and software tools for communicating formalised knowledge. In particular, we developed a unique expertise on the domain of **ontology matching**, i.e. finding and exploiting relationships between ontological entities. However, we estimate that our contributions to this field are behind ourselves, hence this topic is not any more a MOEX objective. During the period, one important result has been the investigation of the use of algebras of relations for expressing alignments.

On the contrary, since 2010 we have invested in **data interlinking**, i.e. finding links between resources described in the Resource Description Framework (RDF). This activity is continued in MOEX and led to various important results: the investigation of techniques to interlink cross-lingual data sources, the design of probabilistic rule-based methods for data interlinking, the development of a generalisation of keys, link keys, to identify resources.

MOEX addresses the **evolution of knowledge** representations in individuals and populations. We aim at acquiring a precise understanding of knowledge evolution through the consideration of a wide range of situations, representations and adaptation operators. For that purpose, we combine knowledge representation and cultural evolution methods. The former provides formal models of knowledge; the latter provides a well-defined framework for studying situated evolution. We consider knowledge as a culture and study the global properties of local adaptation operators applied by populations of agents by jointly:

- *experimentally* testing the properties of adaptation operators in various situations using experimental cultural evolution, and
- *theoretically* determining such properties by modelling how operators shape knowledge representation.

1.1 Activity profile

The permanent team membership is 2 full-time equivalent researchers. The profile of the team has been reoriented towards more fundamental research. We previously involved a lot of our time transferring knowledge to the semantic web infrastructure and more recently SmartCities. We decided that it was time to go to the drawing board to have something to transfer in the future.

Consequently, we are concentrating more on research, which includes training, and eventually money hunting. We do our share of service to the community (see Appendix) and we recently took the initiative to develop material to explain our work to the general public.

1.2 Recommendation of the previous evaluation

"L'équipe peut déjà compter sur un réseau de collaborations avec des compétences complémentaires. Afin de répondre aux nouveaux défis, ce réseau doit être étendu pour permettre à l'équipe de rester compétitive malgré son effectif restreint."

The MOEX team has now been defined with largely different objectives. This indeed led us to recompose our collaboration network concerning the continuation of activities on data interlinking (we now closely cooperate with colleagues from Nancy and Paris 8: one ANR project and two co-supervised PhD). Moreover, on the application side, we had developed a collaboration with the Bibliothèque Nationale de France.

Concerning the new topic, our collaboration network is less tight at the moment. However, at the occasion of the definition of the MIAI institute proposal, we have been quickly able to ensure the collaboration of colleagues from Liverpool, Barcelona and Trento.

We are open to new collaborations, but remain vigilant on their relevance as they may have a cost for a small team.

2.1 Extracting link keys

The period started with the publication of our initial link key extraction algorithm $[C5^*]$. It introduced a very clean method for efficiently extracting link key candidates and offered new measures to select the best ones, even in non supervised cases. In addition, we showed that it was robust to various forms of alteration (§4.2.4). During the period, we investigated the relationships of this algorithm with formal concept analysis, and we proved their equivalence. We also extended the approach with the help of relational concept analysis. This yields an elegant formulation of extracting link keys in presence of circular dependencies (§4.2.4). This work has been published in *Discrete applied mathematics* [J1*]. It is implemented in our LINKEX prototype which also supports compound link keys and constructed properties (§4.2.4).

2.2 Reasoning with link keys

We also worked of designing a reasoning procedure for reasoning with link keys. For that purpose, we extended the tableau method used with the ALC description logic. We recently showed that this method is sound and complete and that its complexity is 2EXPTIME (§4.2.5).

Another achievement was the grant of the ANR project Elker in which link keys are further developed.

2.3 Revision in network of ontologies

Belief revision is a a well-known operation in logic. We considered it in the context of a network of ontologies connected by alignments (§4.3.1). In networks of ontologies, inconsistency may come from two different sources: local inconsistency in a particular ontology or alignment, and global inconsistency between them. We formulated revision postulates for alignments and networks of ontologies based on an abstraction of existing semantics of networks of ontologies. We showed that revision operators cannot be simply based on local revision operators on both ontologies and alignments. We adapted the partial meet revision framework to networks of ontologies and showed that it indeed satisfies the revision postulates. This work has been published in *Artificial intelligence* $[J2^*]$.

2.4 Cultural alignment repair

Cultural knowledge evolution is a new topic and we wanted to be sure that we would be able to design and run experiments in this field (§4.3.2). To that extent, we chose a topic on which we already had technical mastery: alignment repair. We quickly obtained interesting results with agents able to achieve 100% success in the designed experiments and quality of results which were over known repair methods. We have developed further modalities allowing agents to reach fully correct and nearly complete alignments [C1^{*}]. We also showed that it was possible to reach such results even when agents start without alignments [C10].

2.5 Miscelaneous

Jérôme Euzenat has been elected fellow of the European Coordination Committee for Artificial Intelligence (ECCAI) in 2014.

3.1 Team members

Permanent Members							
Name	Institution	Grade	Date				
Manuel Atencia	UGA	Associate professor	-				
Jérôme David	UGA	Associate professor	_				
Jérôme Euzenat	INRIA	Research director	-				

There is no evolution of the permanent team membership since 2014.

Non Permanent Members						
Name	Status	Date				
Luz Maria Priego-Roche	Post-doctoral researcher	2013-12-01 - 2014-05-30				
Nicolas Guillouet	Engineer	2013-09-02 - 2015-12-31				
Tatiana Lesnikova	Post-doctoral researcher	2016-06-01 - 2016-12-31				
Zhengjie Fan	PhD student	2011-12-01 - 2014-03-30				
Armen Inants	PhD student	2012-12-01 - 2016-04-01				
Tatiana Lesnikova	PhD student	2012-10-01 - 2016-05-30				
Adam Sanchez Ayte	PhD student	2013-12-16 - 2016-12-31				
Khadija Jradeh	PhD student	2018-10-01 -				
Line van den Berg	PhD student	2018-10-01 -				

Concerning non permanent members, we trained relatively few PhD students during the period: besides one student who was finishing, three started at the beginning of the period and two started at the end. This is the result of project funding availability (funding for a PhD requires at least a three years project, and is usually assigned at the start, and given the size of the team we cannot carry out too many such projects at once).

This is unfortunate because the new and ambitious objectives of MOEX would require training more students in this developing phase. We count on the MIAI proposal to improve on this situation.

3.2 Team organization and scientific animation

As can be noted, the team has a relatively small size, hence day-to-day interaction is achieved face-to-face. We occupy a block of facing offices at INRIA Montbonnot. We also have a team mailing list and blog.

Assistant professors also have offices on the campus and teaching duties. However, the small size of the team favours frequent gatherings.

Permanent members follow a yearly personal interview discussing more generally needs and objectives.



3.3 Financial ressources

		2014	2015	:	2016	:	2017	-	2018	2019
			SEALS							
		42	32							-
			Lindicle	e					Elker	
		62	62		62			14	42	21
	Da	ıtalift							MCC	
	9								30	
					Dotatio	'n				
		0	0		0	-	18		6	3
Total (k€):		113	94		62		32		78	24

Financial resources of the team are sketched in the attached table (project resources are smoothed prorata temporis). They cover all resources of the project besides one PhD grant from UGA and a pair of Master indemnities from the Persyval Labex.

They have been declining during the exercise.

We used to rely on European projects (SEALS and Ready4SmartCities were running at the beginning) whose collaboration prospect were very good and the funding adequate. However such projects have become less research-driven at the moment when we turn to more fundamental objectives. In consequences, they have become both less attractive and more difficult to obtain.

We also have relied on ANR funding (Datalift, Lindicle and Elker) which allows to carry out exciting research. However, the main part of their funding is dedicated to fund PhD students with not much accompanying funds.

We did not benefit much from local projects, mostly because they are most of the time oriented towards particular topics and forms of collaboration. We performed, in 2018, two small contracts with the Ministry of Culture and Communication

Hence, the day-to-day funding of our work is based on a small (INRIA) "dotation" which is nowadays insufficient.

3.4 Ethics

The team does not have a specific policy on most of these topics. We tend to follow those of our institutions (INRIA, UGA as well as those of the doctoral schools). Our PhD students are trained to such issues by the doctoral school.

We often have the occasion to raise master students' awareness on issues of scientific integrity. This is part of the training. Some pieces of advice and references on specific topics can be found in our (private) blog.

We try to develop an environment in which the focus is on producing good work and publish it in the venues where they can have most impact, and first of all, visibility. Hence, we do not encourage multiplying papers or favouring some more-or-less valuable categories of support. Although this may have adverse effects, we think that in the long run, this is beneficial to research as a whole and researchers in particular.

Because we are currently developing more experimental work than we used to do, we are putting a strong emphasis on the reproducibility of these experiments. This is work in progress and it would require more resources.

Currently, all our students are females, although all the permanent are males. It is unclear what can be concluded from that, except that we do not have strong prejudices.

We organise this section into three parts:

- Ontology matching and query evaluation (covering exclusively Ехмо, 2014–2016),
- Data interlinking (covering both Ехмо and Моех, 2014–2019), and
- Cultural knowledge evolution (covering exclusively MOEX, 2017-)

More detailed information is available from our web sites https://exmo.inria.fr and https://moex.inria.fr.

4.1 Ontology matching / semantic web

When different representations are used, it is necessary to identify their correspondences. This task is called ontology matching and its result is an alignment [*1]. It can be described as follows: given two ontologies, each describing a set of discrete entities (which can be classes, properties, rules, predicates, etc.), find the relationships, if any, holding between these entities.

An alignment between two ontologies *o* and *o'* is a set of correspondences $\langle e, e', r \rangle$ such that:

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

This definition is extended to networks of ontologies: a collection of ontologies and associated alignments.

As described, we progressively decreased our activity on ontology matching during the period, by phasing out our strong implication in evaluation (\$4.1.1), completed important work on the use of algebras of relations in alignments (\$4.1.2) and contributed on alignment evaluation through querying (\$4.1.3).

4.1.1 Evaluation

Since 2004, we have run the Ontology Alignment Evaluation Initiative (OAEI) which organises evaluation campaigns for assessing the degree of achievement of actual ontology matching algorithms [*5, C17]. In 2015, we handed out the organisation of OAEI to Ernesto Jiménez Ruiz (The Turing institute). We used again our generator for generating new version of benchmarks and the Alignment API was used for manipulating alignments and evaluating results presented at the Ontology matching workshops held in Riva del Garda [C17], Bethleem [C12], Kobe [C11], and Monterey.

More information on OAEI can be found at http://oaei.ontologymatching.org/.

4.1.2 Algebras of alignment relations

Qualitative calculus is the central concept in qualitative binary constraint satisfaction problems. We had previously shown the advantages of using a qualitative calculus for expressing ontology alignment relations between concepts [*7].

All these qualitative calculi share an implicit assumption that the universe is homogeneous, i.e. consists of objects of the same kind. We have tackled the problem of combining two or more calculi over disjoint universes into a single calculus [C15]. The problem is important because ontology matching deals with various kinds of ontological entities: concepts, individuals, properties. We introduced modularity in qualitative calculi and provided a methodology for modeling qualitative calculi with heterogeneous universes [PhD1^{*}]. It allows for combining several qualitative calculi into a single calculus. We defined an operation called combination modulo glue, which combines two or more qualitative calculi over different universes, provided some glue relations between these universes. The framework is general enough to support most



known qualitative spatio-temporal calculi. We have designed an algorithm for combining two homogeneous calculi with different universes into a single calculus.

This has been applied to alignment relations [C15] combining algebras for relations between concepts and individuals.

We also introduced a calculus for weighted ontology alignments $[C3^*]$ provided by an infinite relation-type algebra, the elements of which are weighted taxonomic relations. In addition, it approximates the non-weighted case in a continuous manner.

This work has been part of the PhD of Armen Inants [PhD1*] partially funded by the Lindicle project (§1.1.9).

The proposed algebras of relations and others have been integrated within the Alignment API (§1.1.4).

4.1.3 Evaluation of query transformations without data

Query transformations are ubiquitous in semantic web query processing. For any situation in which transformations are not proved correct by construction, the quality of these transformations has to be evaluated. Usual evaluation measures are either overly syntactic and not very informative —the result being: correct or incorrect— or dependent from the evaluation sources. Moreover, both approaches do not necessarily yield the same result. We proposed to ground the evaluation on query containment [J3]. This allows for a data-independent evaluation that is more informative than the usual syntactic evaluation. In addition, such evaluation modalities may take into account ontologies, alignments or different query languages as soon as they are relevant to query evaluation [C7].

4.2 Data interlinking

Links are important for the publication of RDF data on the web. We call data interlinking the process of generating links identifying the same resource described in two data sets. Data interlinking parallels ontology matching: from two datasets (d and d') it generates a set of links (L).

Data interlinking is usually performed by using a framework, such as SILK [*6], for processing *link specifications* that produce links. Link specifications indicate what are the conditions for two IRIs to be linked.

4.2.1 Interactive learning of interlinking patterns

We proposed an interlinking method which, from class correspondences between data source ontologies, uses k-means or k-medoids clustering to produce property correspondences. It then generates a first link specification which can be transformed into a SILK script for generating an initial link set. A sample of these links are assessed by users as either correct or incorrect. These are taken as positive and negative example by an extension of the disjunctive version space method to find an interlinking pattern, that can justify correct links and incorrect links. Experiments show that, with only 1% of sample links, this method reaches a F-measure over 96% [C21].

This work was part of the PhD of Zhengjie Fan [PhD3^{*}], co-supervised with François Scharffe (LIRMM), and developed in the DATALIFT project (§1.1.9).

4.2.2 An iterative import-by-query approach to data interlinking

We modelled the problem of data interlinking as a reasoning problem on possibly decentralised data. We described an import-by-query algorithm that alternates steps of sub-query rewriting and of tailored querying of data sources $[C4^*]$. It only imports data as specific as possible for inferring or contradicting target owl:sameAs assertions.

Additionally, we have proposed a probabilistic mechanism of trust that allow peers in a semantic peer-to-peer network to select the peers that are better suited to answer their queries, when query reformulation based on alignments may be unsatisfactory due to unsoundness or incompleteness of alignments [J4].

Finally, to effectively deal with incomplete and noisy data and to exploit uncertain knowledge, we introduced a framework based on probabilistic Datalog for modelling uncertain RDF facts and rules. We have designed an algorithm, ProbFR, based on this framework.

Experiments on real-world datasets have shown the usefulness and effectiveness of these approaches for data linkage and disambiguation [C2*].

This work was part of the PhD thesis of Mustafa Al-Bakri, co-supervised with Marie-Christine Rousset (Slide), and developed in the QUALINCA project.

4.2.3 Interlinking cross-lingual RDF data sets

RDF data sets are being published with labels that may be expressed in different languages. Even interlinking systems based on graph structure, ultimately rely on anchors based on language fragments. We proposed a general framework for interlinking RDF data in different languages and implemented two approaches: one approach is based on machine translation, the other one takes advantage of multilingual references, such as BabelNet.

Concerning machine translation for interlinking concepts, we conducted two experiments involving different thesauri in different languages. The first experiment involved concepts from the TheSoz multilingual thesaurus in three languages: English, French and German. The second experiment involved concepts from the EuroVoc and AGROVOC thesauri in English and Chinese respectively. We demonstrated that machine translation is beneficial for cross-lingual thesauri interlinking independently of a dataset structure [C14]. Concerning multilingual references, we found that results were not as good as the translation approach [C16].

This work was part of the PhD of Tatiana Lesnikova [PhD2*] developed in the LINDICLE project (§1.1.9).

4.2.4 Link key extraction

Link keys are linking specifications extending database keys in a way which is more adapted to the context of description logics and the openness of the semantic web. We have introduced the notion of a link key [*1, C5*]. More precisely, a link key is a structure $\langle K^{eq}, K^{in}, C \rangle$ such that:

- *K*^{*eq*} is a set of pairs of property expressions;
- K^{in} is a set of pairs of property expressions;
- *C* is a correspondence between class expressions.

Such a link key holds if and only if for any pair of resources belonging to the classes in correspondence such that the values of their property in K^{eq} are pairwise equal and the values of those in K^{in} pairwise intersect, the resources are the same. Hence, link keys can then be used for finding equal individuals across two data sets and generating the corresponding owl:sameAs links.

Extracting and evaluating link key candidates We designed an algorithm, extending classical key extraction techniques, for extracting weak link keys. It first generates a small set of link key candidates whose quality is assessed with specific measures. Depending on whether some of the, valid or invalid, links are known, we defined supervised and non supervised measures for selecting the appropriate link keys. The supervised measures approximate precision and recall on a sample, while the non supervised measures are the ratio of pairs of entities a link key covers (coverage), and the ratio of entities from the same data set it identifies (discrimination). We have experimented these techniques, showing the accuracy and robustness of both approaches [C5^{*}].

This work has been developed partly in the LINDICLE project (§1.1.9).

Link key extraction and relational concept analysis We first described the extraction approach of §4.2.4 in the framework of formal context analysis (FCA, [*8]) [C19]. We recently showed that link keys extracted by formal concept analysis are equivalent to an extension of those which were extracted by our former algorithm $[C5^*]$.

Furthermore, we used relational concept analysis (RCA, [*2]), an extension of FCA taking relations between concepts into account. We showed that it is possible to encode the link key extraction problem in RCA to extract the optimal link keys even in the presence of cyclic dependencies [J1*]. Moreover, the proposed process does not require information about the alignments of the ontologies to find out from which pairs of classes to extract link keys.

This work has been developed partly in the ELKER project (§1.1.9).

Link key extraction under ontological constraints We investigated the use of link keys taking advantage of ontologies. This can be carried out in two different directions: exploiting the ontologies under which data sets are published, and extracting link keys using ontology constructors for combining attribute and class names.

Following the first approach, we extended our existing algorithms to extract link keys involving inverse (⁻¹), union (\Box), intersection (\Box) and paths (\circ) of properties. This helps providing link keys when it is not possible otherwise (without inverse, there is no possible correspondence if one data set is using parents and the other is using children). We showed how the paths could be normalised to reduce the search space.

We implemented this method in our LINKEX tool (§1.1.5) and evaluated it by running experiments on two real data sets, this resulted in finding the correct link keys that were not found without them.

4.2.5 Reasoning with link keys

Link keys can also be thought of as axioms in a description logic. As such, they can contribute to infer ABox axioms, such as links, terminological axioms, or other link keys. Yet, no reasoning support existed for link keys. We have extended the tableau method designed for the \mathcal{ALC} description logic to support reasoning with link keys in \mathcal{ALC} [C13]. We showed how this extension enables combining link keys with classical terminological reasoning with and without ABox and TBox and generating non-trivial link keys. Since then, we have proven that this method is sound, complete and that it always terminates.

This work has been developed partly in the ELKER project (§1.1.9).

4.3 Knowledge evolution

Data and knowledge have to evolve facing changes in what they represent, changes in the context in which they are used and connections to new data and knowledge sources. We work towards their continuous evolution as it is critical to their sustainability.

We report results along two different approaches.

4.3.1 Revision in networks of ontologies

We reconsidered the belief revision problem in the context of networks of ontologies (§4.1): given a set of ontologies connected by alignments, how to evolve them such that they account for new information. In networks of ontologies, inconsistency may come from two different sources: local inconsistency in a particular ontology or alignment, and global inconsistency between them. Belief revision is well-defined for dealing with ontologies; we have investigated how it can apply to networks of ontologies. We formulated revision postulates for alignments and networks of ontologies based on an abstraction of existing semantics of networks of ontologies. We showed that revision operators cannot be simply based on local revision operators on both ontologies and alignments. We adapted the partial meet revision framework to networks of ontologies and



show that it indeed satisfies the revision postulates $[J2^*]$. Finally, we considered strategies based on network characteristics for designing concrete revision operators.

4.3.2 Cultural knowledge evolution

Cultural knowledge evolution considers knowledge as a culture of a population of agents that evolves though communication with other agents and learning from the environment. It is inspired from cultural language evolution [*3].

Experiments in cultural alignment repair We tested it on alignment repair, i.e. the improvement of incorrect ontology alignments. For that purpose, we performed a series of experiments in which agents react to mistakes in alignments. Agents only know about their ontologies and alignments with others and they act in a fully decentralised way. We showed that cultural repair is able to converge towards successful communication through improving the objective correctness of alignments. Such repair experiments revealed that, by playing simple interaction games, agents can effectively repair random networks of ontologies [Ch1*]. The obtained results are on par with a baseline of state-of-the-art alignment repair algorithms [C20, Ch1*].

Expansion and relaxation We allowed agents to go beyond the initial operators in two ways $[C1^*]$: they can generate new correspondences when they discard incorrect ones, and they can provide less precise answers. The combination of these modalities satisfy the following properties: (1) agents still converge to a state in which no mistake occurs, (2) they achieve results far closer to the correct alignments than previously found, (3) they reach again 100% precision and coherent alignments.

Starting with empty alignments The former results suggest that agents could develop alignments from scratch. We explored the use of expanding repair operators for that purpose. When starting from empty alignments, agents fail to create them as they have nothing to repair. Hence, we introduced the capability for agents to risk adding new correspondences when no existing one is useful [C10]. With it, when starting with empty alignments, alignments reach the same quality level as when starting with random alignments, thus providing a reliable way for agents to build alignment from scratch through communication.

Strengthening Our previous work was still missing some correspondences, and did not achieve 100% recall. We had conjectured that this was due to a phenomenon called reverse shadowing [C1*], avoiding to find specific correspondences.

We introduced a new adaptation modality, strengthening, to test this hypothesis. The strengthening modality replaces a successful correspondence by one of its subsumed correspondences covering the current instance. This modality is different from those developed so far, because it leads agents to adapt their alignment when the game played has been a success (previously, it was always when a failure occurred).

We experimentally showed that, as expected, recall was greatly increased, to the point that some operators achieve 99% F-measure. However, the agents still do not reach 100% recall.

4.3.3 Experiment reproducibility

These experiments have been implemented and performed in our *Lazy lavender* software. This requires care in order for others to be able to repeat them. We developed scripts associated to the *Lazy lavender* software to specify, run, and analyse experiments. In particular, these scripts are able to generate a Docker container specification that can perform experiments in the same conditions or with updated software. The publication of the experiments on our Wiki platform (https://gforge.inria.fr/plugins/mediawiki/wiki/lazylav/index.php/Lazy_Lavender) is also eased by this process.

5) Références bibliographiques

- [*1] Jérôme Euzenat and Pavel Shvaiko. *Ontology matching*. Springer-Verlag, Heidelberg (DE), 2nd edition, 2013.
- [*2] Mohamed Rouane-Hacene, Marianne Huchard, Amedeo Napoli, and Petko Valtchev. Relational concept analysis: mining concept lattices from multi-relational data. *Annals of Mathematics and Artificial Intelligence*, 67(1):81–108, 2013.
- [*3] Luc Steels, editor. *Experiments in cultural language evolution*. John Benjamins, Amsterdam (NL), 2012.
- [*4] Jérôme David, Jérôme Euzenat, François Scharffe, and Cássia Trojahn dos Santos. The Alignment API 4.0. *Semantic web journal*, 2(1):3–10, 2011.
- [*5] Jérôme Euzenat, Christian Meilicke, Pavel Shvaiko, Heiner Stuckenschmidt, and Cássia Trojahn dos Santos. Ontology alignment evaluation initiative: six years of experience. *Journal on data semantics*, XV(6720):158–192, 2011.
- [*6] Julius Volz, Christian Bizer, Martin Gaedke, and Georgi Kobilarov. Silk A link discovery framework for the web of data. In *Proc. WWW Workshop on Linked Data on the Web, LDOW, Madrid (SP)*, volume 538 of *CEUR Workshop Proceedings*. CEUR-WS.org, 2009.
- [*7] Jérôme Euzenat. Algebras of ontology alignment relations. In Amit Sheth, Steffen Staab, Mike Dean, Massimo Paolucci, Diana Maynard, Timothy Finin, and Krishnaprasad Thirunarayan, editors, *Proc.* 7th international semantic web conference (ISWC), Karlsruhe (DE), volume 5318 of Lecture notes in computer science, pages 387–402, 2008.
- [*8] Bernhard Ganter and Rudolf Wille. *Formal concept analysis: mathematical foundations*. Springer, 1999.

Annexe : Scientific and Technological Results

EVALUATION CAMPAIGN 2019-2020 VAGUE A

Name of the team : MOEX Acronym : MOEX

Head of the team for the current contract : Jérôme Euzenat Head of the team for the next contract : Jérôme Euzenat

1.1 Production of knowledge and activities contributing to the influence and scientific attractiveness of the unit

1.1.1 Journal Articles

Scientific articles in English

- [J1*] <u>Manuel</u> <u>Atencia</u>, <u>Jérôme</u> <u>David</u>, <u>Jérôme</u> <u>Euzenat</u>, Amedeo Napoli, and <u>Jérémy</u> <u>Vizzini</u>. Link key candidate extraction with relational concept analysis. *Discrete* <u>applied</u> mathematics, 2019.
- [J2^{*}] <u>Jérôme Euzenat</u>. Revision in networks of ontologies. *Artificial intelligence*, 228:195–216, 2015.
- [J3] Melisachew Wudage Chekol, <u>Jérôme Euzenat</u>, Pierre Genevès, and Nabil Layaïda. SPARQL query containment under schema. *Journal on data semantics*, 7(3):133– 154, 2018.
- [J4] <u>Manuel Atencia</u>, Mustafa Al-Bakri, and Marie-Christine Rousset. Trust in networks of ontologies and alignments. *Knowledge and Information Systems*, 42(2):353–379, 2015.
- [J5] Faisal Alkhateeb and <u>Jérôme Euzenat</u>. Constrained regular expressions for answering RDF-path queries modulo RDFS. *International Journal of Web Information Systems*, 10(1):24–50, 2014.
- [J6] Angela Locoro, Jérôme David, and Jérôme Euzenat. Context-based matching: design of a flexible framework and experiment. *Journal on data semantics*, 3(1):25–46, 2014.

Other articles (professional journals, etc.)

Top 20%

- [P1] Pieter Pauwels, María Poveda Villalón, Alvaro Sicilia, and Jérôme Euzenat. Semantic technologies and interoperability in the built environment. Semantic web journal, 9(6):731–734, 2018.
- [P2] <u>Jérôme Euzenat</u>. De la langue à la connaissance: approche expérimentale de l'évolution culturelle. *Bulletin de l'AFIA*, 100:9–12, 2018.
- [P3] Michelle Cheatham, Isabel Cruz, Jérôme Euzenat, and Catia Pesquita. Special issue on ontology and linked data matching. *Semantic web journal*, 8(2):183–184, 2017.

1.1.2 Books

Management and coordination of scientific books / Scientific book edition Management and coordination of scientific books / Scientific book edition in English or another foreign language

- [E1*] Jérôme Euzenat and François Schwarzentruber, editors. Actes Conférence Nationale d'Intelligence Artificielle et Rencontres Jeunes Chercheurs en Intelligence Artificielle (CNIA+RJCIA), Nancy (FR), 2018.
- [E2*] Michelle Cheatham, Isabel Cruz, Jérôme Euzenat, and Catia Pesquita, editors. Special issue on ontology and linked data matching, volume 8(2) of Semantic web journal, Amsterdam (NL), 2017. IOS Press.
- [E3] Pavel Shvaiko, Jérôme Euzenat, Ernesto Jiménez-Ruiz, Michelle Cheatham, and Oktie Hassanzadeh, editors. Proc. 13th ISWC workshop on ontology matching (OM), Monterey (CA US), 2018.
- [E4] Kemo Adrian, <u>Jérôme Euzenat</u>, and Dagmar Gromann, editors. Proc. 1st JOMO workshop on Interaction-Based Knowledge Sharing (WINKS), Bozen-Bolzano (IT), 2018.
- [E5] Alvaro Sicilia, Pieter Pauwels, Leandro Madrazo, María Poveda Villalón, and Jérôme Euzenat, editors. Special Issue on Semantic Technologies and Interoperability in the Build Environment, volume 9(6) of Semantic web journal, Amsterdam (NL), 2018. IOS Press.
- [E6] Pavel Shvaiko, Jérôme Euzenat, Ernesto Jiménez-Ruiz, Michelle Cheatham, and Oktie Hassanzadeh, editors. Proc. 12th ISWC workshop on ontology matching (OM), Wien (AT), 2017.
- [E7] Pavel Shvaiko, Jérôme Euzenat, Ernesto Jiménez-Ruiz, Michelle Cheatham, and Oktie Hassanzadeh, editors. Proc. 10th ISWC workshop on ontology matching (OM), Bethlehem (PA US), 2016.



Document d'autoévaluation de l'équipe MOEX

- [E8] Pavel Shvaiko, Jérôme Euzenat, Ernesto Jiménez-Ruiz, Michelle Cheatham, Oktie Hassanzadeh, and Ryutaro Ichise, editors. Proc. 11th ISWC workshop on ontology matching (OM), Kobe (JP), 2016.
- [E9] Pavel Shvaiko, Jérôme Euzenat, Ming Mao, Ernesto Jiménez-Ruiz, Juanzi Li, and Axel-Cyrille Ngonga Ngomo, editors. Proc. 9th ISWC workshop on ontology matching (OM), Riva del Garda (IT), 2014.

Book chapters in English or another foreign language

Top 20%

- [Ch1*] Jérôme Euzenat. First experiments in cultural alignment repair (extended version). In Valentina Presutti, Eva Blomqvist, Raphaël Troncy, Harald Sack, Ioannis Papadakis, and Anna Tordai, editors, ESWC 2014 satellite events revised selected papers, pages 115–130. Springer Verlag, Heidelberg (DE), 2014.
- [Ch2] Marie-Christine Rousset, <u>Manuel Atencia</u>, <u>Jérôme David</u>, Fabrice Jouanot, Olivier Palombi, and Federico Ulliana. Datalog revisited for reasoning in linked data. In Giovambattista Ianni, Domenico Lembo, Leopoldo Bertossi, Wolfgang Faber, Birte Glimm, Georg Gottlob, and Steffen Staab, editors, *Proc.* 13th International summer school on reasoning web (RW), London (UK), volume 10370 of Lecture notes in computer science, pages 121–166. 2017.
- [Ch3] Olga Kovalenko and Jérôme Euzenat. Semantic matching of engineering data structures. In Stefan Biffl and Marta Sabou, editors, Semantic web technologies for intelligent engineering applications, chapter 6, pages 137–157. Springer, Heidelberg (DE), 2016.
- [Ch4] Maria Rosoiu, Jérôme David, and Jérôme Euzenat. A linked data framework for Android. In Elena Simperl, Barry Norton, Dunja Mladenic, Emanuele Della Valle, Irini Fundulaki, Alexandre Passant, and Raphaël Troncy, editors, *The Semantic Web:* ESWC 2012 Satellite Events, chapter 15, pages 204–218. Springer Verlag, Heidelberg (DE), 2015.
- [Ch5] Jérôme Euzenat and Marie-Christine Rousset. Web sémantique. In Pierre Marquis, Odile Papini, and Henri Prade, editors, L'IA: frontières et applications, volume 3, chapter 4. Cepadues, Toulouse (FR), 2014.

Edited theses

- [PhD1*] <u>Armen</u> <u>Inants</u>. *Qualitative calculi with heterogeneous universes*. Thèse d'informatique, Université de Grenoble, Grenoble (FR), 2016.
- [PhD2^{*}] <u>Tatiana</u> <u>Lesnikova</u>. *RDF data interlinking: evaluation of cross-lingual methods*. Thèse d'informatique, Université de Grenoble, Grenoble (FR), 2016.

[PhD3^{*}] <u>Zhengjie</u> <u>Fan</u>. *Concise pattern learning for RDF data sets interlinking*. Thèse d'informatique, Université de Grenoble, Grenoble (FR), 2014.

1.1.3 Production in conferences / congresses and research seminars

Meeting abstracts

Top 20%

- [M1*] Jérôme Euzenat. Extraction de clés de liage de données (résumé étendu). In Bruno Crémilleux and Cyril de Runz, editors, Actes 16^e conférence internationale francophone sur extraction et gestion des connaissances (EGC), Reims (FR), volume E30 of Revue des nouvelles technologies de l'information, pages 9–12, 2016.
- [M2] Jérôme David, Jérôme Euzenat, and Jérémy Vizzini. Linkky: Extraction de clés de liage par une adaptation de l'analyse relationnelle de concepts. In Actes 29^e journées francophones sur Ingénierie des connaissances (IC), Nancy (FR), pages 271–274, 2018.
- [M3] Jérôme Euzenat. Knowledge diversity under socio-environmental pressure. In Michael Rovatsos, editor, Investigating diversity in AI: the ESSENCE project, 2013-2017, pages 28–30. 2017.

Articles published in conference proceedings / congress

- [C1*] Jérôme Euzenat. Interaction-based ontology alignment repair with expansion and relaxation. In Proc. 26th International Joint Conference on Artificial Intelligence (IJ-CAI), Melbourne (VIC AU), pages 185–191, Menlo Park (CA US), 2017. AAAI Press.
- [C2*] Mustafa Al-Bakri, <u>Manuel Atencia</u>, <u>Jérôme David</u>, Steffen Lalande, and Marie-Christine Rousset. Uncertainty-sensitive reasoning for inferring sameas facts in linked data. In Gal Kaminka, Maria Fox, Paolo Bouquet, Eyke Hüllermeier, Virginia Dignum, Frank Dignum, and Frank van Harmelen, editors, *Proc. 22nd european conference on artificial intelligence (ECAI)*, Der Haague (NL), pages 698–706, Amsterdam (NL), 2016. IOS press.
- [C3*] <u>Armen Inants, Manuel Atencia, and Jérôme Euzenat</u>. Algebraic calculi for weighted ontology alignments. In Paul Groth, Elena Simperl, Alasdair Gray, Marta Sabou, Markus Krötzsch, Freddy Lécué, Fabian Flöck, and Yolanda Gil, editors, Proc. 15th International semantic web conference (ISWC), Kobe (JP), volume 9981 of Lecture notes in computer science, pages 360–375, 2016.
- [C4*] Mustafa Al-Bakri, <u>Manuel Atencia</u>, Steffen Lalande, and Marie-Christine Rousset. Inferring same-as facts from linked data: an iterative import-by-query approach. In Blai Bonet and Sven Koenig, editors, *Proc. 29th Conference on Artificial Intelli*gence (AAAI), Austin (TX US), pages 9–15, 2015.



- [C5*] <u>Manuel Atencia, Jérôme David, and Jérôme Euzenat</u>. Data interlinking through robust linkkey extraction. In Torsten Schaub, Gerhard Friedrich, and Barry O'Sullivan, editors, Proc. 21st european conference on artificial intelligence (ECAI), Praha (CZ), pages 15–20, Amsterdam (NL), 2014. IOS press.
- [C6] Jomar da Silva, Kate Revoredo, Fernanda Araujo Baião, and Jérôme Euzenat. Interactive ontology matching: using expert feedback to select attribute mappings. In Pavel Shvaiko, Jérôme Euzenat, Ernesto Jiménez-Ruiz, Michelle Cheatham, and Oktie Hassanzadeh, editors, Proc. 13th ISWC workshop on ontology matching (OM), Monterey (CA US), pages 25–36, 2018.
- [C7] Jérôme David, Jérôme Euzenat, Pierre Genevès, and Nabil Layaïda. Evaluation of query transformations without data. In Proc. WWW workshop on Reasoning on Data (RoD), Lyon (FR), pages 1599–1602. ACM Press, 2018.
- [C8] Manel Achichi, Michelle Cheatham, Zlatan Dragisic, Jérôme Euzenat, Daniel Faria, Alfio Ferrara, Giorgos Flouris, Irini Fundulaki, Ian Harrow, Valentina Ivanova, Ernesto Jiménez-Ruiz, Kristian Kolthoff, Elena Kuss, Patrick Lambrix, Henrik Leopold, Huanyu Li, Christian Meilicke, Majid Mohammadi, Stefano Montanelli, Catia Pesquita, Tzanina Saveta, Pavel Shvaiko, Andrea Splendiani, Heiner Stuckenschmidt, Élodie Thiéblin, Konstantin Todorov, Cássia Trojahn dos Santos, and Ondrej Zamazal. Results of the ontology alignment evaluation initiative 2017. In Pavel Shvaiko, Jérôme Euzenat, Ernesto Jiménez-Ruiz, Michelle Cheatham, and Oktie Hassanzadeh, editors, Proc. 12th ISWC workshop on ontology matching (OM), Wien (AT), pages 61–113, 2017.
- [C9] Jomar da Silva, Fernanda Araujo Baião, Kate Revoredo, and Jérôme Euzenat. Semantic interactive ontology matching: synergistic combination of techniques to improve the set of candidate correspondences. In Pavel Shvaiko, Jérôme Euzenat, Ernesto Jiménez-Ruiz, Michelle Cheatham, and Oktie Hassanzadeh, editors, Proc. 12th ISWC workshop on ontology matching (OM), Wien (AT), pages 13–24, 2017.
- [C10] Jérôme Euzenat. Crafting ontology alignments from scratch through agent communication. In Bo An, Ana Bazzan, João Leite, Serena Villata, and Leendert van der Torre, editors, Proc. 20th International Conference on Principles and practice of multi-agent systems (PRIMA), Nice (FR), volume 10621 of Lecture notes in computer science, pages 245–262, 2017.
- [C11] Manel Achichi, Michelle Cheatham, Zlatan Dragisic, Jérôme Euzenat, Daniel Faria, Alfio Ferrara, Giorgos Flouris, Irini Fundulaki, Ian Harrow, Valentina Ivanova, Ernesto Jiménez-Ruiz, Elena Kuss, Patrick Lambrix, Henrik Leopold, Huanyu Li, Christian Meilicke, Stefano Montanelli, Catia Pesquita, Tzanina Saveta, Pavel Shvaiko, Andrea Splendiani, Heiner Stuckenschmidt, Konstantin Todorov, Cássia Trojahn dos Santos, and Ondrej Zamazal. Results of the ontology alignment evaluation initiative 2016. In Pavel Shvaiko, Jérôme Euzenat, Ernesto Jiménez-Ruiz, Michelle Cheatham, Oktie Hassanzadeh, and Ryutaro Ichise, editors, Proc. 11th ISWC workshop on ontology matching (OM), Kobe (JP), pages 73– 129, 2016.
- [C12] Michelle Cheatham, Zlatan Dragisic, Jérôme Euzenat, Daniel Faria, Alfio Ferrara, Giorgos Flouris, Irini Fundulaki, Roger Granada, Valentina Ivanova, Ernesto Jiménez-Ruiz, Patrick Lambrix, Stefano Montanelli, Catia Pesquita, Tzanina

Saveta, Pavel Shvaiko, Alessandro Solimando, Cássia Trojahn dos Santos, and Ondrej Zamazal. Results of the ontology alignment evaluation initiative 2015. In Pavel Shvaiko, Jérôme Euzenat, Ernesto Jiménez-Ruiz, Michelle Cheatham, and Oktie Hassanzadeh, editors, *Proc.* 10th ISWC workshop on ontology matching (OM), Bethlehem (PA US), pages 60–115, 2016.

- [C13] <u>Maroua Gmati, Manuel Atencia, and Jérôme Euzenat</u>. Tableau extensions for reasoning with link keys. In Pavel Shvaiko, Jérôme Euzenat, Ernesto Jiménez-Ruiz, Michelle Cheatham, Oktie Hassanzadeh, and Ryutaro Ichise, editors, Proc. 11th ISWC workshop on ontology matching (OM), Kobe (JP), pages 37–48, 2016.
- [C14] <u>Tatiana Lesnikova, Jérôme David, and Jérôme Euzenat</u>. Cross-lingual RDF thesauri interlinking. In Nicoletta Calzolari, Khalid Choukri, Thierry Declerck, Marko Grobelnik, Bente Maegaard, Joseph Mariani, Asuncion Moreno, Jan Odijk, and Stelios Piperidis, editors, Proc. 10th international conference on Language resources and evaluation (LREC), Portoroz (SI), pages 2442–2449, 2016.
- [C15] <u>Armen Inants</u> and Jérôme Euzenat. An algebra of qualitative taxonomical relations for ontology alignments. In Marcelo Arenas, Óscar Corcho, Elena Simperl, Markus Strohmaier, Mathieu d'Aquin, Kavitha Srinivas, Paul Groth, Michel Dumontier, Jeff Heflin, Krishnaprasad Thirunarayan, and Steffen Staab, editors, *Proc.* 14th International semantic web conference (ISWC), Bethleem (PA US), volume 9366 of Lecture notes in computer science, pages 253–268, 2015.
- [C16] <u>Tatiana Lesnikova, Jérôme David</u>, and Jérôme Euzenat. Interlinking English and Chinese RDF data using BabelNet. In Pierre Genevès and Christine Vanoirbeek, editors, Proc. 15th ACM international symposium on Document engineering (DocEng), Lausanne (CH), pages 39–42, 2015.
- [C17] Zlatan Dragisic, Kai Eckert, Jérôme Euzenat, Daniel Faria, Alfio Ferrara, Roger Granada, Valentina Ivanova, Ernesto Jiménez-Ruiz, Andreas Oskar Kempf, Patrick Lambrix, Stefano Montanelli, Heiko Paulheim, Dominique Ritze, Pavel Shvaiko, Alessandro Solimando, Cássia Trojahn dos Santos, Ondrej Zamazal, and Bernardo Cuenca Grau. Results of the ontology alignment evaluation initiative 2014. In Pavel Shvaiko, Jérôme Euzenat, Ming Mao, Ernesto Jiménez-Ruiz, Juanzi Li, and Axel-Cyrille Ngonga Ngomo, editors, Proc. 9th ISWC workshop on ontology matching (OM), Riva del Garda (IT), pages 61–104, 2014.
- [C18] <u>Manuel Atencia</u>, Michel Chein, Madalina Croitoru, Jérôme David, Michel Leclère, Nathalie Pernelle, Fatiha Saïs, François Scharffe, and Danai Symeonidou. Defining key semantics for the RDF datasets: experiments and evaluations. In Proc. 21st International Conference on Conceptual Structures (ICCS), Iasi (RO), volume 8577 of Lecture notes in artificial intelligence, pages 65–78, 2014.
- [C19] <u>Manuel Atencia, Jérôme David, and Jérôme Euzenat</u>. What can FCA do for database linkkey extraction? In Proc. 3rd ECAI workshop on What can FCA do for Artificial Intelligence? (FCA4AI), Praha (CZ), pages 85–92, 2014.
- [C20] <u>Jérôme Euzenat</u>. First experiments in cultural alignment repair. In *Proc.* 3rd ESWC workshop on Debugging ontologies and ontology mappings (WoDOOM), Hersounisos (GR), pages 3–14, 2014.
- [C21] <u>Zhengjie Fan</u>, Jérôme Euzenat, and François Scharffe. Learning concise pattern for interlinking with extended version space. In Dominik l zak, Hung Son Nguyen,

Marek Reformat, and Eugene Santos, editors, *Proc.* 13th IEEE/WIC/ACM international conference on web intelligence (WI), Warsaw (PL), pages 70–77, Los Alamitos (CA), 2014. IEEE Computer society.

- [C22] <u>Tatiana Lesnikova</u>. Interlinking RDF data in different languages. In Christophe Roche, Rute Costa, and Eva Coudyzer, editors, *Proc.* 4th workshop on Terminology and Ontology: Theories and applications (TOTh), Bruxelles (BE), 2014.
- [C23] <u>Tatiana Lesnikova, Jérôme David</u>, and Jérôme Euzenat. Interlinking English and Chinese RDF data sets using machine translation. In Johanna Völker, Heiko Paulheim, Jens Lehmann, Harald Sack, and Vojtech Svátek, editors, Proc. 3rd ESWC workshop on Knowledge discovery and data mining meets linked open data (Know@LOD), Hersounisos (GR), 2014.

Other products presented in symposia / congress and research seminars

1.1.4 Tools and products

We self-rank our (meaningful) software on the same scale and colour as the other teams:

	Audience	Originality	Maturity	Maintainance	Distribution
Alignment API	4	4	4	4\3	5
Linkex	4	4	3	3	4
Lazy lavender	3	4	4	3	4

Softwares

Alignment API

We have designed a format for expressing alignments in a uniform way [*4]. The goal of this format is to share available alignments on the web. It should help systems using alignments, e.g. mediators, translators, to take advantage of any matching algorithm and it will help matching algorithms to be used in many different tasks. This format is expressed in RDF, so it is freely extensible.

The API itself [*4] is a JAVA description of tools for accessing the common format. We provide an implementation for this API which can be used for producing transformations, rules or bridge axioms independently from the algorithm which produced the alignment.

It further integrates the implementation of link keys in the EDOAL language and their transformations into SPARQL queries (§4.2). Finally, we provided the interface with alignment algebras into the API implementation (§4.1.2).

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

The Alignment API is used in the Ontology Alignment Evaluation Initiative data and result processing (§4.1.1). It is also used by more than 50 other teams worldwide.

The Alignment API is freely available since december 2003, under the LGPL licence, at http: //alignapi.gforge.inria.fr and has been registered by APP.

1.1.5 Instruments and methodology

Prototypes

Linkex

LINKEX is a tool for extracting and evaluating link key candidates from two RDF datasets. It is aimed at integrating our results on the topic (see §4.2). It implements the extraction of candidates with formal concept analysis. It is able to extract candidates with inverse and composed properties and to generate compound link keys.

LINKEX can evaluate link keys candidates using various measures, including our discriminability and coverage. It can also evaluate them according to reference set of links given as input. The set of candidates can be rendered within the Alignment API'S EDOAL language or in dot. The API can generate other formats.

It is available at https://gitlab.inria.fr/moex/linkex.

Lazy lavender

Lazy lavender is a simulation tool for cultural knowledge evolution, i.e. running randomised experiments with agent adjusting their knowledge while attempting to communicate. It is the basis of our work on cultural knowledge evolution.

The web site also features detailed report and data from the performed experiments and directions to repeat them.

It is available at https://gforge.inria.fr/plugins/mediawiki/wiki/lazylav/index.php/Lazy_Lavender.

1.1.6 Other products

1.1.7 Editorial activities

Participation in editorial committees (books, collections, etc.)

- Jérôme Euzenat have been guest editor of a special issue of *Semantic web journal* on "Ontology and linked data matching" (with Michele Cheatham, Isabel Cruz, and Catia Pesquita) [E2*].
- Jérôme Euzenat have been guest editor of a special issue of *Semantic web journal* on "semantic technologies and interoperability in the build environment" (with Álvaro Sicilia, Pieter Pauwels, Leandro Madrazo, and María Poveda-Villalón) [E5].

Collection and series management

- Jérôme Euzenat is editorial board member of *Journal of Web Semantics* (area editor), *Journal on Data Semantics* and *Semantic web journal*.

1.1.8 Reviewing activities

Reviewing of articles

Major programme committee membership

- Manuel Atencia (2015, 2019), Jérôme David (2017–2019) and Jérôme Euzenat (2015, 2017–2019) have been programme committee members of the "International Joint Conference on Artificial Intelligence (IJCAI)".
- Jérôme David and Jérôme Euzenat have been programme committee member of the "National conference on artificial intelligence (AAAI)" 2018
- Manuel Atencia (2014, 2016), Jérôme David (2016) and Jérôme Euzenat (2014, 2016) have been programme committee members of the "European conference on artificial intelligence (ECAI)".
- Jérôme Euzenat has been programme committee member of the "International conference on Knowledge Representation and Reasoning (κR)" 2014 and 2016.
- Manuel Atencia (2018) and Jérôme Euzenat (2017–2019) have been programme committee member of the "Worldwide web Conference (www)".
- Manuel Atencia (2014, 2016–2019), Jérôme David (2017) and Jérôme Euzenat (2014–2019) have been programme committee members of the "International semantic web conference (ISWC)".



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- Manuel Atencia (2015–2016), Jérôme David (2015–2017) and Jérôme Euzenat (2015–2017) have been programme committee members for the "European Semantic Web Conference (Eswc)".
- Jérôme Euzenat has been programme committee member of the "International Conference on Formal Ontologies for Information Systems (FOIS)" 2014, 2016.
- Jérôme Euzenat has been programme committee member of the "International conference on knowledge engineering and knowledge management (ЕКАЖ)" 2018.
- Jérôme Euzenat has been programme committee member of the "International Conference on Semantic Systems (Semantics)" 2017, 2018.
- Jérôme Euzenat has been programme committee member of the "International Conference on Conceptual Structures (ICCS)" 2014, 2016.
- Jérôme Euzenat has been programme committee member of the conference «Reconnaissance des Formes et Intelligence Artificielle (RFIA)» 2014.
- Jérôme David had been programme committee member of the "French national artificial intelligence conference (CNIA)" 2018.
- Manuel Atencia (2014), Jérôme David (2014, 2015, 2017, 2018) and Jérôme Euzenat (2014, 2015) have been programme committee members of the "knowledge engineering (ingénierie des connaissances)" conference.
- Manuel Atencia (2018), Jérôme David (2017, 2018) and Jérôme Euzenat (2017) have been programme committee members of the "French Extraction and gestion des connaissances conference (EGC)".
- Jérôme Euzenat has been programme committee member of the conference "French fundamental artificial intelligence days" (JIAF) 2014, 2016, 2018.

Journal reviewing

- Jérôme Euzenat has been reviewer for the following journals:
 - Journal of Artificial Intelligence Research,
 - Semantic web journal,
 - Journal of the Association for Information Science and Technology,
 - Applied ontologies,
 - ACM transactions on the Web,
 - Mobile information systems,
 - IEEE transactions on knowledge and data engineering,
 - Knowledge and information systems,
 - Artificial intelligence review,
- International journal on metadata, semantics and ontologies.
- Jérôme David has been reviewer for the following journals:
 - Semantic web journal.
 - Artificial intelligence review,
 - Information system journal,
 - Ingénierie des systèmes d'information.
- Manuel Atencia has been reviewer for the following journals:
 - Semantic web journal,
 - ACM transactions on database systems,
 - Knowledge-based systems,
 - VLDB journal,
 - Journal of web semantics,
 - Applied ontology.

Grant evaluation (public or charities)

- Jérôme Euzenat has been evaluator for European projects (FP7, H5: Smart cities and sustainability communication networks, content and technology), 2015
- Jérôme Euzenat had been member of the scientific evaluation committee "CE23: Data, knowledge, big data, multimedia content – artificial intelligence" of the French national research agency (ANR)
- Manuel Atencia had been evaluator for CAPES-COFECUB projects (BR)
- Manuel Atencia had been evaluator for the French national research agency (ANR)

Reviewing of research institutes

- Jérôme Euzenat has been scientific coordinator of the evaluation seminar for the "Data and knowledge representation and processing" theme of INRIA, 2015.

1.1.9 Academic research grants

European (ERC, H2020, etc.) and international (NSF, JSPS, NIH, World Bank, FAO, etc.) grants - partnership

Ready4SmartCities

- Type: CAPACITIES
- Defi: ICT-2013.6.4 Optimising Energy Systems in Smart Cities
- Instrument: Coordination and Support Action
- Project acronym: Ready4SmartCities
- Project title: ICT Roadmap and Data Interoperability for Energy Systems in Smart Cities
- Objectif: Optimising Energy Systems in Smart Cities
- Duration: October 2013 September 2015
- Coordinator: D'appolonia Spa (Italy)
- Other partners: D'appolonia (Italy) Universidad Politecnica de Madrid (Spain) CSTB (France), CERTH (Grèce), VTT (Finland), AIT (Austria), AEC3 (UK), Politecnico di Torino (Italy), Empirica (Germany)
- Înria contact: Jérôme Euzenat
- Participants: Jérôme Euzenat, Luz Maria Priego-Roche, Jérôme David, Adam Sanchez Ayte
- See also: http://www.ready4smartcities.eu
- Abstract: The Ready4SmartCities project aims at increasing awareness and interoperability for the adoption of oct and semantic technologies in energy system to obtain a reduction of energy consumption and co₂ emission at smart cities community level through innovative relying on RTF and innovation outcomes and ICT-based solutions.

National public grants (ANR, PHRC, FUI, INCA, etc.) - coordination

ANR Lindicle

- Program: ANR-Blanc international 2
- Project acronym: LINDICLE
- Project title: Linking data in cross-lingual environment
- Duration: January 2013 December 2016
- Coordinator: INRIA Ехмо/Jérôme David
- Participants: Jérôme Euzenat, Manuel Atencia, Jérôme David, Tatiana Lesnikova, Adam Sanchez Ayte, Armen Inants
- Other partners: Tsinghua university (CN)
- See also: http://lindicle.inrialpes.fr
- Abstract: The LINDICLE project investigates multilingual data interlinking between French, English and Chinese data sources (see §4.2).

ANR Elker

- Program: ANR-PRC
- Project acronym: Elker
- Project title: Extending link keys: extraction and reasoning
- Duration: October 2017 September 2021
- Coordinator: LIG/Manuel Atencia
- Participants: Manuel Atencia, Jérôme David, Jérôme Euzenat, Khadija Jradeh
- Other partners: INRIA Lorraine, Université de Vincennes
- Abstract: The goal of ELKER is to extend the foundations and algorithms of link keys (see §4.2) in two complementary ways: extracting link keys automatically from datasets and reasoning with link keys.



National public grants (ANR, PHRC, FUI, INCA, etc.) - partnership

ANR Datalift

- Program: ANR-ContInt
- Project acronym: Datalift
- Project title: DATALIFT
- Instrument: platform
- Duration: September 2010 March 2014
- Coordinator: INRIA Ехмо/François Scharffe
- Participants: Jérôme Euzenat, Zhengjie Fan, Jérôme David
- See also: http://www.datalift.org
- Abstract: Exmo coordinates with LIRMM the DATALIFT project whose goal is to produce a platform for publishing governmental data as linked data. Exmo is particularly involved in the generation of links between datasets (see §4.2).

1.1.10 Visiting senior scientists and post-doc

Foreign visiting scientists

- Giuseppe Pirrò (Free University of Bozen-Bolzano) visited Ехмо in February 2014 working on web query languages.
- Juanzi Li and Zhigang Wang (Tsinghua university) visited Ехмо in October 2014, working on multilingual data interlinking.
- Kate Revoredo and Frenanda Baião (Federal University of the State of Rio de Janeiro) visited Ехмо in October, 2014 and in May 2015, working on learning to evolve alignments. Kate Revoredo visited Moex again in May 2017.
- Karima Akli (изтнв, Algiers) visited Ехмо in September 2016, working on rough sets for link key extraction.
- Yan Zhang (U. Tsinghua) and Zhichun Wang (Beijing Normal University) visited Ехмо in September 2016 in the framework of the Lindicle project, working cross-lingual data interlinking and query-driven ontology matching.
- Chan Le Duc (U. Paris 8) visited MOEX in January 2019 in the framework of the Elker project, working on reasoning with link keys.

1.1.11 Scientific recognition

Prizes and/or distinctions

Jérôme Euzenat has been elected fellow of the European Coordination Committee for Artificial Intelligence (ECCAI, now EurAI).

Chair of learned and scientific societies

Jérôme Euzenat was member of the executive committee and the scientific council of the CNRS Pre-GDR "Artificial intelligence". Now that the GDR has been created, he is member of the scientific council of the CNRS GDR "Intelligence artificielle".

Invitations to meetings and symposia

- Seminar on "Data integration with ontologies through alignments", Semanco VoCamp, Barcelona (ES), 13/02/2014 (Jérôme Euzenat).
- Invited talk on "Foundations for revising networks of ontologies", WoDOOM workshop, Hersounissos (GR), 26/05/2014 (Jérôme Euzenat).
- Invited talk on "Raisonner avec des réseaux d'ontologies", Journées d'intelligence artificielle fondamentale, Angers (FR), 12/06/2014 (Jérôme Euzenat).
- Invited talk on "Représenter, communiquer, échouer", Journée AFIA de promotion de l'intelligence artificielle, Paris (FR), 2/10/2014 (Jérôme Euzenat).

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- "Extraction de clés de liage de données", Invited talk, 16e conférence internationale francophone sur l'extraction et la gestion des connaissances (EGC), Reims (FR), 2016-01-21 (Jérôme Euzenat).
- Series of four seminars at UniRio, Rio de Janeiro (BR): "Introduction to ontology matching and alignment" 2016-03-11, "Repairing alignments and cultural evolution" 2016-03-17, "Data link key extraction (and relation with Formal concepts analysis)" 2016-03-22, "(Belief) revision in networks of ontologies" 2016-03-30 (Jérôme Euzenat).
- "Introduction to ontology matching and alignment", Seminar івм Research, Rio de Janeiro (BR), 2016-03-23 (Jérôme Euzenat).
- "Semantic web evolution: tectonic quake or gentle drift?", Invited talk, 12th International Conference on Web Information Systems and Technologies (WebIST), Roma (IT), 2016-04-24 (Jérôme Euzenat).
- "Knowledge change, failure, adaptation, and evolution", Invited talk, 2nd Joint ontology workshops (Jowo), Annecy (FR), 2016-07-06 (Jérôme Euzenat).
- "Data interlinking with formal concept analysis and link keys", Invited talk, 13th international conference on concept lattices and applications (CLA), Moskow (RU), 2016-07-19 (Jérôme Euzenat).
- "Fixing knowledge in the distributed age", Invited tutorial, 10th international conference on scalable uncertainty managament (suм), Nice (FR), 2016-09-21 (Jérôme Euzenat).
- "Symbolic methods for RDF data interlinking", Lecture at EGC, Grenoble (FR), 2017-01-23 (Jérôme David)
- "Data interlinking using link keys", Seminar Trinity college, Dublin (IE), 2017-04-13 (Jérôme Euzenat)
- "Cultural knowledge evolution: motivations and experiments", Seminar Trinity college, Dublin (IE), 2017-04-13 (Jérôme Euzenat)
- "Linked data", Tutorial at the 4th Journées du développement logiciel (JDev) 2017, Marseille (FR), 2017-07-06 (Manuel Atencia)
- "Knowledge diversity under socio-environmental pressure", Invited talk, International Conference on Computational Approaches to Diversity in Interaction and Meaning, Venezia (IT), 2017-10-08 (Jérôme Euzenat)
- "Ontology matching, adaptation and evolution", GDRI in Web science Workshop, PUC-Rio, Rio de Janeiro (BR), 2017-12-04 (Jérôme Euzenat, Fernanda Baião, Kate Revoredo)
- "Enhancing Link Keys: Extraction and Reasoning", BNF workshop on "Données liées et données à lier: quels outils pour quels alignements?", Paris (FR), 2018-07-10 (Manuel Atencia)
- "Towards cultural knowledge evolution: experiments with alignments repair", Seminar LIP6, Paris (FR), 2018-10-15 (Jérôme Euzenat)
- "Link key extraction with a variation of relational concept analysis", EKAW workshop on symbolic methods for data interlinking, Nancy (FR), 2018-11-12 (Jérôme Euzenat)

Members' long-term visits abroad

Jérôme Euzenat has benefited from a special visiting researcher grant from the Brazilian Ciência sem Fronteiras program on "Methodology and algorithms for ontology refinement and matching" (2015-2017). He has been working with the team of Fernanda Baião and Kate Revoredo at the Universidade Federal do Estado do Rio de Janeiro (UNIRIO). Together, they investigated methods for evolving ontologies and alignments which involve users and agents. The goal of the project is to design methods and algorithms for both revising ontologies to represent the evolution of knowledge in a reliable manner and obtaining better quality alignments.

- Jérôme Euzenat visited the Universidade Federal do Estado do Rio de Janeiro (UNIRIO) for three months in March and November 2016, and November-December 2017.
- Tatiana Lesnikova and Jérôme Euzenat visited Tsinghua University from March 30 to April 15, 2015 within the LINDICLE project (§1.1.9) on multilingual data interlinking and key extraction.



1.1.12 Scientific animation

Organisations of meetings and symposia

- Jérôme David has been member of the organising committee of the LIG keynote speeches (2014–2018).
- Jérôme Euzenat was organiser of the Ontology matching workshop of the 13th Iswc, Riva del Garda (IT), 2014 (with Pavel Shvaiko, Ming Mao, Ernesto Jiménez-Ruiz, Juanzi Li and Axel Cyrille Ngonga-Ngomo).
- Jérôme Euzenat was organiser of the 10th Ontology matching workshop of the 14th Iswc, Bethleem (US), 2015 (with Pavel Shvaiko, Ernesto Jiménez Ruiz, Oktie Hassanzadeh and Michele Cheatham).
- Jérôme David has been member of the organisation committee of the "Web of data summer school", Saint-Étienne (FR) 2014 and 2015.
- Jérôme Euzenat was organiser of the 11th Ontology matching workshop of the 15th Iswc, Kobe (JP), 2016 (with Pavel Shvaiko, Ernesto Jiménez Ruiz, Michele Cheatham, Oktie Hassanzadeh and Ryutaro Ichise).
- Jérôme Euzenat was organiser of the 12th Ontology matching workshop of the 16th Iswc, Wien (AT), 2017 (with Pavel Shvaiko, Ernesto Jiménez Ruiz, Michele Cheatham and Oktie Hassanzadeh).
- Jérôme Euzenat was organiser of the 1st Workshop on Interaction-Based Knowledge Sharing (WINKS) of the 3rd Joint Ontology Workshop (Jомо), Bozen-Bolzano (IT), 2017 (with Dagmar Gromann and Kemo Adrian).
- Jérôme Euzenat was part of the Ontology alignment evaluation initiative (OAEI) organising team (2006–2017).
- Jérôme David had been organiser of the workshop Symbolic methods for data-interlinking of the 21st EKAW, Nancy (FR), 2018 (with Miguel Couceiro).
- Jérôme Euzenat had been organiser of the 13th Ontology matching workshop of the 18th Iswc, Monterey (CA US), 2018 (with Pavel Shvaiko, Ernesto Jiménez Ruiz, Michele Cheatham and Oktie Hassanzadeh).

Scientific and steering committees

- Jérôme Euzenat is founding member of the "Semantic Web Science Association" (steering committee for the Iswc conference series). Membership ended in 2014.
- Jérôme Euzenat was co-chair with Maria Keet of the "ontologies" area of the programme committee of the "European Semantic Web Conference (Eswc)", 2014
- Jérôme Euzenat had been program chairman of the "French national artificial intelligence conference (CNIA)" [E1*], Nancy (FR), 2018.
- Manuel Atencia had been workshop and tutorial chairman (with Marieke van Erp) of the 21st екаw, Nancy (fr), 2018.

1.2 Interaction of the unit with the non-academic world, impacts on economy, society, culture or health

1.2.1 Socio-economic interactions / Patents

1.2.2 Socio-economic interactions

Industrial and R&D contracts

Ginco V3 (Framework agreement Ministère de la culture et de la communication)

- Program: Framework agreement INRIA-Ministère de la culture et de la communication
- Project acronym: Ginco V3
- Project title: Outil d'aide à l'alignement pour l'élaboration du graphe culture

- Duration: November 2017 December 2018
- Coordinator: Jérôme David
- Participants: Jérôme David, Jérôme Euzenat, Manuel Atencia
- Abstract: The GINCO V3 project aims at extending the GINCO tool with ontology alignment capabilities.

FNE (Framework agreement Ministère de la culture et de la communication)

- Program: Framework agreement INRIA-Ministère de la culture et de la communication
 Project acronym: FNE
- Project title: Álgorithmes d'aide à la définition de clés de liage et d'alignement d'autorités
- Duration: November 2017 December 2018
- Coordinator: Jérôme David
- Participants: Jérôme David, Manuel Atencia, Jérôme Euzenat
- Other partners: Bibliothèque nationale de France
- Abstract: The goal of the FNE cooperation is to evaluate the suitability of link key extraction algorithms to matching authorities from BnF, ABES and the ministry of Culture and to improve such algorithms if necessary.

Start-ups

EXMO collaborated with the *Meaning engine* start-up company (http://www.meaningengines.com/) whose goal is to help improve the knowledge of corporate knowledge, e.g. catalogs, costumer data, through linked data principles (the application of semantic web technology for publishing data). Among their prospective costumers are music aggregators as well as banks. We have benefited from the position of Nicolas Guillouet for developing generic connectors based on our Alignment API. They introduce two novel features: using the notion of link keys to identify identical items in a data flow and performing hybrid integration which either identifies or creates objects from the incoming flows. In fact, hybrid integration is a type of knowledge evolution that provides new interesting research problems.

1.2.3 Expertise

Consulting

- Jérôme David has been consulting for the start-up Budplace.

1.2.4 Public outreach

Journal articles, interviews, book edition, videos, other popularization outputs, debates on science and society, etc.

- Jérôme Euzenat gave a talk to the Canopé network conference cycle on "Communication et adaptation: la fabrique de la communication flexible (communication and adaptation: the making of flexible communication), CROP, Grenoble (FR), 2/04/2014.
- Jérôme Euzenat gave a talk to the 7es journées de l'interopérabilité des applications d'entreprise (JIAE) on "Aligner les ontologies pour communiquer (matching ontologies to communicate)", Saint-Étienne (FR), 16/05/2014.
- Jérôme David participated to the working group "Créer et maintenir une interconnexion sémantique des grands référentiels culturels: le "Graphe Culture" of the ministry of Culture. http://cblog.culture.fr/projet/2013/11/07/groupe-de-travail-metadonnees-culturelles/
- Jérôme Euzenat gave a talk to the Grilog networking business meeting "Big data" on "Publication et exploitation des données avec les technologies sémantiques (Publishing and exploiting data with semantic technologies)", Meylan (FR), 2015-04-28.
- Jérôme Euzenat gave a training conference in computer science for high-school teachers on "Language and semantics", INRIA, Montbonnot (FR), 2016-02-10

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- Jérôme Euzenat gave a talk to the local #FranceIA day "Intelligence artificielle et communication", Grenoble (FR), 2017-03-02
- Manuel Atencia animated the workshop "Modéliser les ontologies: cas d'application d'une ontologie pour l'annotation de photos" at the 4th Journées du développement logiciel (JDEv), Marseille (FR), 2017-07-06
- Jérôme David animated the workshop "Comment faire une application avec des données liées: annotation de photos en utilisant les technos du web sémantique avec Jena" at the 4th Journées du développement logiciel (JDEv), Marseille (FR), 2017-07-06
- Jérôme Euzenat gave an interview "Dans 50 ans, les ordinateurs écriront des succès littéraires?" for the INRIA web site, Montbonnot (FR), 2017-10-24
- Jérôme Euzenat gave a talk on "Artificial intelligence: a broad view" to BEST Spring course, Grenoble (FR), 2018-04-16
- Jérôme Euzenat gave a talk on "mOeX: évolution de la connaissance" INRIA "Mon projet en 180 secondes", Grenoble (FR), 2018-05-29
- Jérôme Euzenat gave a talk on "Evolving knowledge: different facets of Artificial Intelligence" to the French-American Doctoral Exchange (FADEx) seminar, Grenoble (FR), 2018-06-27

1.3 Involvement of the unit and of each team in training through research

1.3.1 Educational outputs

1.3.2 Scientific productions (articles, books, etc.) from theses

The papers are based on results obtained in PhD by our students: Zhengjie Fan [C21], Tatiana Lesnikova [C23, C22, C16, C14], Armen Inants [C15, C3^{*}], Mustafa Al-Bakri [C4^{*}, J4, C2^{*}].

Actually three papers covered results obtained with master students: Maria-Elena Rosoiu [Ch4], Maroua Gmati [C13], Jérémy Vizzini [J1*].

1.3.3 Training

Habilitated (HDR) scientists: 1

HDR obtained during the period: 0

PhD students (total number): 2

- PhD in progress: Khadija Jradeh, "Reasoning with link keys", 2018-10-01 (Manuel Atencia and Chan Le Duc)
- PhD in progress: Line van den Berg, "Knowledge Evolution in Agent Populations", 2018-10-01 (Manuel Atencia and Jérôme Euzenat)

To these can be added the PhD of Nacira Abbas in LORIA co-supervised by Jérôme David:

 PhD in progress: Nacira Abbas, "Link key extraction and relational concept analysis", 2018-10-01 (Jérôme David and Amedeo Napoli)

PhD students benefiting from a specific doctoral contract: 3

Defended PhDs: 3

- PhD: Zhengjie Fan, "Concise Pattern Learning for RDF Data Sets Interlinking", Université de Grenoble, 2014-04-04, supervisors: Jérôme Euzenat and François Scharffe
- PhD: Tatiana Lesnikova, "RDF data interlinking: evaluation of cross-lingual methods", Univ.
 Grenoble Alpes, 2012-10-01–2016-05-04, supervisors: Jérôme Euzenat and Jérôme David
- PhD: Armen Inants, "Qualitative calculi with hererogeneous universes", Univ. Grenoble Alpes, 2012-12-01–2016-04-25, supervisor: Jérôme Euzenat



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To these can be added the PhD of Mustafa Al-Bakri in the Slide team co-supervised by Manuel Atencia:

 PhD: Mustafa Al-Bakri, "Uncertainty-sensitive reasoning over the web of data", Université de Grenoble, 2011-10-01–2014-12-15 (Marie-Christine Rousset and Manuel Atencia)

Mean PhD duration: 42

Internships (M1, M2)

- Mashruf Zaman Chowdhury, Agreement and disagreement between ontologies, M2R Informatics, Univ. Grenoble Alpes, from Feb 2016 until Jun 2016 (Jérôme David and Jérôme Euzenat)
- Irina Dragoste, Ontology evolution through interaction, M2R Informatics, Univ. Grenoble Alpes, from Feb 2016 until Aug 2016 (Manuel Atencia and Jérôme Euzenat)
- Maroua Gmati, Reasoning with link keys, M2R Informatics, Univ. Grenoble Alpes, from Feb 2016 until Jun 2016 (Manuel Atencia and Jérôme Euzenat)
- Jérémy Vizzini, Data interlinking with relational concept analysis, M2R Informatics Data science, Univ. Grenoble Alpes, June 2017 (Jérôme David and Jérôme Euzenat)
- Iris Lohja, "Improving semantic recall of ontology alignments in cultural knowledge evolution", M2R Informatics, Univ. Grenoble Alpes, June 2018 (Manuel Atencia and Jérôme Euzenat)
- Khadija Jradeh, "Link key extraction under ontological constraints", M2R Informatics, Univ. Grenoble Alpes, June 2018 (Jérôme David and Jérôme Euzenat)

People in charge for a mention or a master's degree course (total number)

- Jérôme David has been coordinator, with Benoît Lemaire, of the "Web, Informatique et Connaissance" option of the master "Ingénierie de la Cognition, de la Création, et des Apprentissages" (UPMF, UJF & INPG);
- Jérôme David is coordinator of the master "Mathematiques et informatiques appliquées aux sciences humaines et sociales" (Univ. Grenoble Alpes), since 2015.
- Manuel Atencia has been coordinators of the "Web, Informatique et Connaissance" option of the master M1 "Ingénierie de la Cognition, de la Création, et des Apprentissages" (UPMF, UJF & INPG);
- Manuel Atencia is coordinator of the "Web, Informatique et Connaissance" option of the master M2 "Mathematicques et informatiques appliquées aux sciences humaines et sociales" (Univ. Grenoble Alpes);
- Jérôme Euzenat has been, with Éric Gaussier, then Sihem Amer-Yahia, then Danielle Ziébelin, coordinator of the "AI and the web" option of the M2R in computer science and applied mathematics (UJF & INPG, then Univ. Grenoble Alpes) until 2018.