Activity Report 2015

Project-Team GRAPHIK

GRAPHs for Inferences and Knowledge representation

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Project-Team GRAPHIK

Creation of the Project-Team: 2010 January 01

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Other Research Topics and Application Domains:
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2. Overall Objectives

2.1. Logic and Graph-based KRR

The main research domain of GraphIK is Knowledge Representation and Reasoning (KRR), which studies paradigms and formalisms for representing knowledge and reasoning on these representations. We follow a logic-oriented approach: the different kinds of knowledge have a logical semantics and reasoning mechanisms correspond to inferences in this logic. However, in the field of logic-based KRR, we distinguish ourselves by also using graphs and hypergraphs (in the graph-theoretic sense) as basic objects. Indeed, we view labelled graphs as an *abstract representation* of knowledge that can be expressed in many KRR languages: different kinds of conceptual graphs —historically our main focus—, the Semantic Web language RDFS, expressive rules equivalent to the so-called tuple-generating-dependencies in databases, some description logics dedicated to query answering, etc. For these languages, reasoning can be based on the structure of objects (thus on graph-theoretic notions), with homomorphism as a core notion, while being sound and complete with respect to entailment in the associated logical fragments. An important issue is to study *trade-offs* between the expressivity and computational tractability of (sound and complete) reasoning in these languages.

2.2. From Theory to Applications, and Vice-versa

We study logic- and graph-based KRR formalisms from three perspectives:

- theoretical (structural properties, expressiveness, translations between languages, problem complexity, algorithm design),
- software (developing tools to implement theoretical results),
- applications (which also feed back into theoretical work).

2.3. Main Challenges

GraphIK focuses on some of the main challenges in KRR:

- ontological query answering, *i.e.*, query answering taking an ontology into account, and able to process large datasets;
- reasoning with rule-based languages;
- reasoning with "imperfect knowledge" (*i.e.*, vague, uncertain, partially inconsistent, multi-viewpoints and/or with multi-granularity).

2.4. Scientific Directions

GraphIK has three main scientific directions:

1. **decidability, complexity and algorithms** for problems in languages corresponding to first-order logic fragments;
2. the addition of expressive and **non-classical features** (to the first-order logic languages studied in the first direction) with a good expressivity/efficiency trade-off;
3. the integration of theoretical tools to **real knowledge-based systems**.

From an applicative viewpoint, two themes are currently privileged:

- knowledge representation for agronomy, the final objective being a knowledge-based system to aid decision-making for the quality control in food processing.
- data integration and quality improvement, specifically for document metadata.

3. Research Program

3.1. Logic-based Knowledge Representation and Reasoning

We follow the mainstream *logic-based* approach to the KRR domain. First-order logic (FOL) is the reference logic in KRR and most formalisms in this area can be translated into fragments (i.e., particular subsets) of FOL. A large part of research in this domain can be seen as studying the *trade-off* between the expressivity of languages and the complexity of (sound and complete) reasoning in these languages. The fundamental problem in KRR languages is entailment checking: is a given piece of knowledge entailed by other pieces of knowledge, for instance from a knowledge base (KB)? Another important problem is *consistency* checking: is a set of knowledge pieces (for instance the knowledge base itself) consistent, i.e., is it sure that nothing absurd can be entailed from it? The *ontology-based query answering* problem is a topical problem (see Section 3.3). It asks for the set of answers to a query in the KB. In the case of Boolean queries (i.e., queries with a yes/no answer), it can be recast as entailment checking.

3.2. Graph-based Knowledge Representation and Reasoning

Besides logical foundations, we are interested in KRR formalisms that comply, or aim at complying with the following requirements: to have good *computational* properties and to allow users of knowledge-based systems to have a maximal *understanding and control* over each step of the knowledge base building process and use.

These two requirements are the core motivations for our graph-based approach to KRR. We view labelled graphs as an *abstract representation* of knowledge that can be expressed in many KRR languages (different kinds of conceptual graphs —historically our main focus—, the Semantic Web language RDF (Resource Description Framework), its extension RDFS (RDF Schema), expressive rules equivalent to the so-called tuple-generating-dependencies in databases, some description logics dedicated to query answering, etc.). For these languages, reasoning can be based on the structure of objects, thus based on graph-theoretic notions, while staying logically founded.

More precisely, our basic objects are labelled graphs (or hypergraphs) representing entities and relationships between these entities. These graphs have a natural translation in first-order logic. Our basic reasoning tool is graph homomorphism. The fundamental property is that graph homomorphism is sound and complete with respect to logical entailment *i.e.*, given two (labelled) graphs G and H, there is a homomorphism from G to H *if and only if* the formula assigned to G is entailed by the formula assigned to H. In other words, logical reasoning on these graphs can be performed by graph mechanisms. These knowledge constructs and the associated reasoning mechanisms can be extended (to represent rules for instance) while keeping this fundamental correspondence between graphs and logics.

3.3. Ontology-based Query Answering

Querying knowledge bases has become a central problem in knowledge representation and in databases. A knowledge base (KB) is classically composed of a terminological part (metadata, ontology) and an assertional part (facts, data). Queries are supposed to be at least as expressive as the basic queries in databases, i.e., conjunctive queries, which can be seen as existentially closed conjunctions of atoms or as labelled graphs. The challenge is to define good trade-offs between the expressivity of the ontological language and the complexity of querying data in presence of ontological knowledge. Classical ontogical languages, typically description logics, were not designed for efficient querying. On the other hand, database languages are able to process complex queries on huge databases, but without taking the ontology into account. There is thus a need for new languages and mechanisms, able to cope with the ever growing size of knowledge bases in the Semantic Web or in scientific domains.

This problem is related to two other problems identified as fundamental in KRR:

- *Query-answering with incomplete information.* Incomplete information means that it might be unknown whether a given assertion is true or false. Databases classically make the so-called closed-world assumption: every fact that cannot be retrieved or inferred from the base is assumed to be false. Knowledge bases classically make the open-world assumption: if something cannot be inferred from the base, and neither can its negation, then its truth status is unknown. The need of coping with incomplete information is a distinctive feature of querying knowledge bases with respect to querying classical databases (however, as explained above, this distinction tends to disappear). The presence of incomplete information makes the query answering task much more difficult.

- *Reasoning with rules.* Researching types of rules and adequate manners to process them is a mainstream topic in the Semantic Web, and, more generally a crucial issue for knowledge-based systems. For several years, we have been studying some rules, both in their logical and their graph form, which are syntactically very simple but also very expressive. These rules, known as existential rules or Datalog+, can be seen as an abstraction of ontological knowledge expressed in the main languages used in the context of KB querying. See Section 7.1 for details on the results obtained.

A problem generalizing the above described problems, and particularly relevant in the context of multiple data/metadata sources, is *querying hybrid knowledge bases*. In a hybrid knowledge base, each component may have its own formalism and its own reasoning mechanisms. There may be a common ontology shared by all components, or each component may have its own ontology, with mappings being defined among the ontologies. The question is what kind of interactions between these components and/or what limitations on the languages preserve the decidability of basic problems and if so, a "reasonable" complexity. Note that there are strong connections with the issue of data integration in databases.

3.4. Imperfect Information and Priorities

While classical FOL is the kernel of many KRR languages, to solve real-world problems we often need to consider features that cannot be expressed purely (or not naturally) in classical logic. The logic- and graph-based formalisms used for previous points have thus to be extended with such features. The following requirements have been identified from scenarios in decision making in the agronomy domain (see Section 4.1):

1. to cope with vague and uncertain information and preferences in queries;
2. to cope with multi-granularity knowledge;
3. to take into account different and potentially conflicting viewpoints ;
4. to integrate decision notions (priorities, gravity, risk, benefit);
5. to integrate argumentation-based reasoning.

Although the solutions we develop need to be validated on the applications that motivated them, we also want them to be sufficiently generic to be applied in other contexts. One angle of attack (but not the only possible one) consists in increasing the expressivity of our core languages, while trying to preserve their essential combinatorial properties, so that algorithmic optimizations can be transferred to these extensions. To achieve that goal, our main research directions are: non-monotonic reasoning (see ANR project ASPIQ in Section 9.1), as well as argumentation and preferences (see Section 7.2).

4. Application Domains

4.1. Agronomy

Agronomy is a strong expertise domain in the area of Montpellier. Some INRA researchers (computer scientists) are members of GraphIK, and more generally we closely collaborate with the Montpellier research laboratory IATE, a join unit of INRA and other organisms. A major issue for INRA is modeling agrifood chains (i.e., the chain of all processes leading from the plants to the final products, including waste treatment).

This modeling has several objectives. It provides better understanding of the processes from begin to end, which aids in decision making, with the aim of improving the quality of the products and decreasing the environmental impact. It also facilitates knowledge sharing between researchers, as well as the capitalization of expert knowledge and "know how". This last point is particularly important in areas strongly related to a "terroir" (like in cheese or wine making), where knowledge and "know how" are transmitted by experience, with the risk of non-sustainability of the specific skills. For all these reasons, INRA became very interested in developing knowledge engineering methods.

An agrifood chain analysis is a highly complex procedure since it relies on numerous criteria of various types: environmental, economical, functional, sanitary, etc. Quality objectives imply different stakeholders, technicians, managers, professional organizations, end-users, public organizations, etc. Since the goals of the implied stakeholders may be divergent, decision making raises arbitration issues. In this context, our first investigations led to identify decision support based on argumentation frameworks as a promising topic, as well as the representation and processing of preferences. For the capitalization of expert knowledge and "know how", that often require to handle exceptions, we began to investigate forms of non-monotonic negation.

4.2. Semantic metadata

Semantic metadata (*i.e.,* metadata expressed in terms of a formal ontology) are at the core of the applications we have been working on for several years, with our main partners INA (French Institute for Audiovisual, http://www.ina.fr/) and ABES (French Agency for Academic Libraries, http://www.abes.fr/). Our focus evolved from building semantic annotations and exploiting them to retrieve data, to interlinking problems between individual references in annotations of documents. More specifically, the linkage problem at the core of our current project Qualinca (in Section 9.1) consists in identifying an authority (i.e., an element of a referential described by metadata) to be linked with a reference in a bibliographic notice (i.e., metadata describing a document). This problem is an instance of the intensively studied entity resolution problem. In the Semantic Web, it can be recast as the computation of OWL:sameAs links between two metadata bases, clearly a fundamental problem for the Linked Open Data. We use a knowledge-based approach to solve this problem.

5. Highlights of the Year

5.1. Highlights of the Year

- Michel Chein was nominated at the **Academy of Science and Literature from Montpellier** (Académie des Sciences et des Lettres de Montpellier). It is the first nomination of a computer scientist in this academy.

  http://www.inria.fr/centre/sophia/actualites/michel-chein-elu-membre-de-l-academie-des-sciences-et-lettres-de-montpellier

- By joining the team, Meghyn Bienvenu (CR researcher) brings her deep expertise in description logics and complexity, in particular applied to ontology-based data access, a core focus in GraphIK. She was recently put forward by the national committee of the CNRS ("section 6 du comitée national", http://cn6.fr/) to receive the bronze medal of the CNRS.

6. New Software and Platforms

6.1. DLGP 2.0

- Participants: Jean-François Baget, Michel Chein, Alain Gutierrez, Michel Leclère, Marie-Laure Mugnier, Swan Rocher and Clément Sipieter
- URL: http://graphik-team.github.io/graal/

DLGP (for Datalog+) is our textual format for the existential rules framework. This year, we extended it to ensure compatibility with Semantic Web languages. This required to include web notions such as IRIs and literals. A new parser was implemented, and is used in both Cogui (6.2) and Graal (6.3).

6.2. Cogui

Cogui is a tool for building and verifying knowledge bases. It is a freeware written in Java (version 1.6). Currently, it supports Conceptual Graphs and import/export in RDFS and Datalog+.

- Participants: Alain Gutierrez, Michel Leclère, Michel Chein, Marie-Laure Mugnier and Madalina Croitoru
- Contact: Michel Leclère (scientific contact) and Alain Gutierrez (technical contact)
- URL: http://www.lirmm.fr/cogui/

Objectives: Cogui is a visual tool for building conceptual graph knowledge bases (KB). It allows to create a KB, to edit its structure and content, and to control it. The KB can be serialized in the XML. Imports and exports from and to RDFS are also provided, as well as from and to the *Datalog+ (DLGP)* format that we defined for existential rules. Wizards allow to analyze and check facts with respect to some constraints, as well as to query them while taking into account inferences enabled by the ontology.

Users community:*Research:* MIMOS (National R&D center in information and communication technology, Malaysia http://www.mimos.my/), Defence R&D Canada, our partners in INRA, CIRAD, as well as a new collaboration with the Inria team Imagine. *Education:* Used in knowledge engineering in universities of Nice, Strasbourg, Montpellier, Sheffield, as well as in the engineering school of Tarbes.

Impact: internal use in several EU or National projects. We expect a broader audience by using Cogui as a graphical ontology modeling tool for our other software Graal, the communication being done through our DLGP format http://www.lirmm.fr/~mugnier/graphik/kiabora/downloads/datalog-plus_en.pdf.

State of the art: To the best of our knowledge, Cogui is the only ontology editing tool able to do reasoning with conceptual graph rules (equivalent to existential rules). Many tools exist for DLs and Semantic Web languages (e.g. Protégé http://protege.stanford.edu mainly designed for description logics and TopBraid Composer http://www.topquadrant.com/ designed for RDF and SPIN rules, which are rules without existential variables).

Misc.: Cogui is written in Java and has been part time developed since 2005 by Alain Gutierrez (approx. 50 man months). First developed as an interface communicating with the conceptual graph reasoner Cogitant http://cogitant.sourceforge.net/, it has become a standalone tool, integrating more and more reasoning features.

New features: This year, we mainly focused on improving the compatibility with the semantic web languages. The main improvements are the following:

- integration of the parser using our new textual format DLGP 2.0 (6.1).
- a new repository is available to store the projects. It facilitates collaborative work combined with a version control software (a feature developed for Qualinca combined with GIT).
- ergonomics: rule engine and query assistants have been redesigned, several graphical editor behaviors have been improved.
- A backward chaining rule evaluation algorithm, with lazy computation of rule bodies, has been developed for the kind of Datalog rules used in the system SudoQual.

6.3. GRAAL

In its current state, Graal allows storage of data via a generic interface in different storage paradigms and systems. Currently, the relational database management systems MySQL, PostgreSQL, Sqlite, and InMemory graph and LinkedList structures are implemented. The triple store Jena TDB and the graph database system Sparksee are coming soon. Graal also allows us to query this database taking into account an ontology represented by a set of existential rules. It provides forward chaining and query rewriting algorithms (building up on Mélanie König's PhD thesis) and a tool for the analysis of the properties of a set of rules which is an integration of Swan Rocher's tool Kiabora. The input and output of this software can be expressed in our Datalog-inspired format DLGP 2.0 (6.1), and can be translated from the semantic web language OWL2 or to RuleML. This software is designed in a modular way, hence it is possible to use only a subpart of Graal without embedding it all or to easily replace an implementation of a module by another.

FUNCTIONAL DESCRIPTION

Graal is intended to be a generic platform for ontology-based query answering with existential rules.

- Participants: Clément Sipieter, Swan Rocher, Jean-François Baget, Marie-Laure Mugnier, Michel Leclère

- Partner: LIRMM

- Contact: Marie-Laure Mugnier (scientific contact) and Clément Sipieter (technical contact)

- URL: http://graphik-team.github.io/graal/

Objectives: Graal is a generic platform for query answering under existential rules. It will integrate all algorithms designed in the team, and our ambition is to make it a reference platform in the research community, allowing for the integration of algorithms designed by other teams.

Users community: Graal is intended for use in research and education.

Impact: Due to the recent release of the first stable version, Graal has only been used for now in our projects. A related paper received the RuleML 2015 challenge award http://2015.ruleml.org/.

State of the art: To the best of our knowledge, the only other tool for reasoning with existential rules is Nyaya [1], a joint development from teams in Rome, Oxford, and Milan. It has been renamed IRIS+/- https://bitbucket.org/giorsi/nyaya.

Misc.: Graal is written in Java (around 30k lines of code, 30 man/months effort). It is mainly developed by Clément Sipieter (2 years Inria ADT funding) under the CeCILL licence (GPL compatible, see http://www.cecill.info/licences.fr.html). The development started 1.5 years ago from a prototype realized during Bruno Paiva's PhD thesis, and integrates work carried out by other PhD students (Mélanie König and Swan Rocher). Graal has been first presented at RuleML 2015 [23], [33], where it received a best paper award.

New features: Main features integrated in 2015 are query rewriting algorithms, projection algorithms, and translations to and from other languages (OWL2, RuleML).

Note that we do not detail here other software developments internal to our current projects and not publicly available.

7. New Results

7.1. Ontology-Based Query Answering with Existential Rules

Participants: Jean-François Baget, Meghyn Bienvenu, Fabien Garreau, Michel Leclère, Marie-Laure Mugnier, Swan Rocher, Federico Ulliana.

Since Meghyn Bienvenu joined the team very recently (September 2015), we only include here the work she did in collaboration with GraphIK members.

Ontology-based query answering (and more generally *Ontology-Based Data Access*, *OBDA*) is a new paradigm in data management, which takes into account inferences enabled by an ontology when querying data. In other words, the notion of a database is replaced by that of a knowledge base, composed of data (also called facts) and of an ontology. In this context, *existential rules* (also called Datalog+) have been proposed to represent the ontological component [42], [41]. This expressive formalism generalizes both description logics used in OBDA (such as $\mathcal{EL}$ and DL-Lite), which form the cores of so-called tractable profiles of the Semantic Web ontological language OWL2) and Datalog, the language of deductive databases. Since about five years, we have been studying the theoretical foundations of this framework (mainly concerning decidability and complexity) and developing associated algorithmic techniques. We have started the development of a platform dedicated to OBDA with existential rules (see section 6.3).

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[1] De Virgilio, R.; Orsi, G.; Tanca, L.; Torlone, R., "NYAYA: A System Supporting the Uniform Management of Large Sets of Semantic Data," in Data Engineering (ICDE), 2012 IEEE 28th International Conference on , vol., no., pp.1309-1312, 1-5 April 2012

Before presenting this year' results, we recall the two classical ways of processing rules, namely forward chaining and backward chaining, also known as "materialization" and "query rewriting" in the OBDA setting. In forward chaining, the rules are applied to enrich the initial data and query answering can then be solved solved by evaluating the query against the "saturate" database (as in a classical database system *i.e.*, with forgetting the rules). The backward chaining process can be divided into two steps: first, the initial query is rewritten using the rules into a first-order query (typically a union of conjunctive queries, UCQ); then the rewritten query is evaluated against the initial database (again, as in a classical database system). Since entailment is not decidable with general existential rules, both forward and backwards processes may not halt.

7.1.1. *Embedding transitivity rules.*

In recent years, many classes of existential rules have been exhibited for which CQ entailment is decidable. However, most of these classes cannot express transitivity of binary relations, a frequently used modelling construct. We began to investigate the issue of whether transitivity can be safely combined with decidable classes of existential rules. On the one hand, we obtained negative results, proving that transitivity is incompatible with many classes having finite chase, and with UCQ-reducible classes in general. Second, we showed that transitivity can be safely added to linear rules (a subclass of guarded rules, which generalizes the description logic DL-Lite$_R$) in the case of atomic CQs, and also for general CQs if we place a minor syntactic restriction on the rule set (only needed when predicate arity is strictly greater than 2). Finally, we pinpointed the combined and data complexities of query entailment over linear rules + transitivity.

  ▷ *IJCAI 2015* [22]

7.1.2. *A generic algorithm for query reformulation.*

We first designed and implemented a query reformulation algorithm that takes as input any set of existential rules and a UCQ q, and outputs a sound, minimal and complete UCQ-reformulation of q, whenever such a reformulation exists (i.e., when the set of existential rules is UCQ-reducible). The core operation, unification, relies on a special technique that we first developed for conceptual graphs ("piece-unification"). A noteworthy feature of the implemented unification is that it is able to process rules without decomposing their head into single atoms. Experiments showed that this feature has a very high impact on the efficiency of query reformulation in terms of running time.

This algorithm can be seen as an instantiation of a generic reformulation algorithm, parametrized by a reformulation operator. As a complementary work, we studied the properties that should be fulfilled by any reformulation operator to ensure the correctness and the termination of this generic algorithm and analyzed some known operators with respect to these properties.

  ▷ *Semantic Web Journal 2015* [15]

7.1.3. *Optimization of query reformulation algorithms*

Query reformulation techniques have the advantage of being independent from the data. However, a main bottleneck is that the size of the obtained query can be exponential in the size of the original query, hence the produced reformulation maybe not usable in practice (and the corresponding SQL query may not even be accepted by the RDBMS). To overcome this combinatorial explosion in practice, we made two proposals, which have in common to consider other forms of reformulation, while staying equivalent to UCQs in terms of expressivity.

We defined semi-conjunctive queries (SCQs), which are a syntactical extension of conjunctive queries allowing for internal disjunctions. Briefly, a union of SCQs can be encoded in a more compact form than a UCQ. We designed and implemented an algorithm called Compact, which computes a sound and complete reformulation of a UCQ in the form of a union of SCQs (USCQ). First experiments showed that USCQs are both very efficiently computable and (often) more efficiently evaluable than their equivalent UCQs.

We developed another solution, which starts from a simple observation: in practice, combinatorial explosion is mainly due to some very simple rules, which form the core of any ontology. These rules typically express concept and relation hierarchies, concept properties and relation signatures. We proposed a technique that consists in compiling these rules into a preorder on atoms and embedding this preorder into the reformulation process. This allows us to compute compact reformulations that can be considered as "pivotal" representations, in the sense that they can be easily translated into different kinds of queries that can be evaluated by different kinds of database systems (e.g., unfolded into a classical UCQ or a USCQ, processed as such on data saturated by the compilable rules, or transformed into a Datalog program). Experiments show that this technique leads to substantial gains in the query reformulation process, in terms of size and runtime, it scales on very large ontologies (several ten thousands of rules), and it is competitive w.r.t. other existing tools, including those tailored for more specific rules corresponding to DL-Lite ontologies. This technique has been implemented in the sofware platform Graal.

▷ *IJCAI 2015*[28], *RuleML 2015*[23]

7.1.4. *Ontology-based query answering with Semantic Web languages*

On the one hand, we proposed Deductive RDF Triplestores, which are RDF knowledge bases equipped with Datalog inference rules. This work was developed in the context of the tool MyCorporisFabrica http://www.mycorporisfabrica.org/, an ontology-based tool for querying complex anatomical models.

In particular, we studied how to extract modules from deductive RDF triplestores. Indeed, many ontologies are extremely large, while users often need to reuse only a small part of resources in their work. A module is a Deductive RDF Triplestore entailed from the reference knowledge base, which is defined upon a restricted vocabulary. We proposed a new semantics for bounded-level modules allowing one to control their size, and then presented extraction algorithms compliant with the novel semantics.

▷ *AAAI 2015*[30] and *Journal of Biomedical Semantics* [16]. In collaboration with Marie-Christine Rousset (U. of Grenoble) and MyCorporisFabrica's team.

On the other hand, in the context of the Graal platform, we defined a translation from the Semantic Web Ontological Language OWL 2 to our existential rule format. This gave rise to the definition of the "existential rule" OWL 2 profile, which covers the so-called tractable profiles of OWL 2 (see Section 6.3).

▷ *RuleML challenge*[33] (this paper obtained the RuleML 2015 challenge award)

7.2. Reasoning with Imperfect Information and Priorities

Participants: Abdallah Arioua, Patrice Buche, Madalina Croitoru, Jérôme Fortin, Nouredine Tamani, Rallou Thomopoulos.

This year, we mainly explored the use of argumentation frameworks in practical applications. Indeed, we have been involved in three main projects that have employed argumentation techniques. The projects were all in the context of agronomy where the nature of the problem studies fits well the use of argumentation: (1) the knowledge bases considered to model the domain are inconsistent, (2) the reasoning / decision making has to take into account the inconsistency, (3) the end user is a non-computing expert thus explanation facilities are needed.

We enumerate below the three projects and explain our results:

- Bread Making project (financed by the Food and Bioproducts department at INRA) investigates the possibility of using wholemeal flour in bread as opposed to classic white flour. The main theoretical result that we exploited here was the instantiation work into the existential rule framework done with Srdjan Vesic [43]. We used reverse engineering and the subsequent logic-based argumentation in order to provide the experts with a cartography of possible pros and cons of using one type of flour vs the other.

▷ *Ecological Informatics 2015* [18]

- EcoBioCap (FP7 EU project led by INRA Montpellier, see Section 9.1) investigates the conception of biodegradable packaging for fruits and vegetables. The main theoretical result used here concerns the fuzzy aspects of argumentation but the modeling of the problem using argumentation and subsequent argument elicitation was also a very challenging process.

  ▷ *Computers and Electronics in Agriculture 2015* (2 papers) [14] [17]

- DURDUR (ANR project led by INRA Montpellier, see Section 9.1) investigates the technological itineraries to grow durum wheat for subsequent pasta and couscous making. This ongoing project investigates the use of argumentation for explanation facilities.

  ▷ Initial results have been published in *SUM 2015*[19] and *DEXA 2015* [20].

7.3. Quality and interoperability of large document catalogues

Participants: Michel Chein, Madalina Croitoru, Alain Gutierrez, Michel Leclère, Rallou Thomopoulos.

The work in this research line takes place in the ANR project Qualinca, devoted to methods and tools to repair linkage errors in bibliographical databases (see Qualinca in Section 9.1). Within this project, we specially work with our applicative partner ABES (French Agency for Academic Libraries, http://www.abes.fr/).

ABES manages several catalogues and authority bases, in particular the *Sudoc*, the collective catalogue of French academic libraries. ABES also provides services to libraries and end-users, as well as to other catalogue managers (e.g., OCLC for Worldcat and, in France, Adonis for the Isidore platform).

This year, we devoted most of our research effort to the following aspects in collaboration with ABES:

1. the finalization of a conceptual model of ABES librarian expertise in their linkage activity, and its formalization in our theoretical framework; the formalized model is both logical (the knowledge is expressed by facts, rules and constraints in first-order logic) and numerical (some predicates, which correspond to qualitative criteria, are computed by numerical functions, which themselves take as input the result of logical queries to the knowledge base).

2. the development of a diagnosis prototype, called SudoQual, which implements this model; in brief, SudoQual takes as input a given apellation (i.e., family name and first name), retrieves all references potentially associated with this appellation and outputs *sameAs* and *Different* links between these references. To develop SudoQual, we built an API on top of our tool Cogui.

3. first experiments with SudoQual on the Sudoc base, with the results being checked manually by ABES librarians.

▷ *Research report* [37]

This work required a tight collaboration with ABES (materialized by bimonthly meetings and numerous ponctual exchanges). The first experiments yield extremely satisfactory results, hence ABES is now considering turning SudoQual into a production tool used by librarians in their daily work to validate/correct autority links in the Sudoc catalogue. This requires to define a suitable user-interface, which is an issue we are currently discussing with ABES. We are also preparing experiments at a larger scale on a sample provided by ABES.

Besides, in collaboration with Qualinca partner LRI, we developed a method and a tool to fusion data linked by "same-as" links. More precisely, given an RDF dataset, our tool allows to merge "same as" data, which are often conflictual, into a unified and consistant representation using a multi-criteria decision method. The tool was evaluated on a dataset provided by INA and LIG, two other partners of Qualinca.

▷ *EGC 2015* [32]

Still with the LRI partner, who developed a logic-based decision tool that statuates on the validity of same-as links in RDF data, we investigated the use of argumentation techniques to explain why "same-as" links are invalidated by this tool.

▷ *SUM 2015* [25]

8. Bilateral Contracts and Grants with Industry

8.1. Bilateral Contracts with Industry

8.1.1. CTFC

Participants: Patrice Buche, Jérôme Fortin.

In 2015, we relied on our collaboration with the technical center of Comptois' cheese (CTFC : Centre Technique des Fromages Comtois), initiated in the previous years, to build an enlarged project involving different traditional food chains (CNAOL, Conseil National des Appelations d'Origine Laitière). The aim of this project is to develop a platform that will be used in traditional cheese processing for expert knowledge management. This project was pre-selected by the French Ministry of agriculture but finally not accepted, hence we are working on a new version.

8.1.2. ABES

Participants: Michel Leclère, Michel Chein.

See results in Section 7.3 and the ANR project Qualinca in Section 9.1.

9. Partnerships and Cooperations

9.1. National Initiatives

9.1.1. ANR

9.1.1.1. ASPIQ

Participants: Jean-François Baget, Fabien Garreau, Marie-Laure Mugnier, Jérôme Fortin, Michel Leclère.

ASPIQ (ASP technologIes for Querying large scale multisource heterogeneous web information), is an ANR white project (duration: 4 years) that started in Oct. 2012. It involves partners from CRIL, LERIA and LSIS. The project coordinator is Odile Papini (LSIS). http://aspiq.lsis.org/

The main objective of this project is to propose:

- extensions of standard ASP for representing OWL2 tractable sublanguages;
- new operations for merging conflicting information in this extended ASP;
- the identification of subclasses of this extended ASP allowing for efficient query answering mechanisms;
- an implementation of a prototype reasoning system.
- *See Section 7.1 for this year's results (Extensions of the Framework).*

9.1.1.2. Pagoda

Participants: Meghyn Bienvenu, Jean-François Baget, Marie-Laure Mugnier, Swan Rocher, Federico Ulliana.

Pagoda (Practical Algorithms for Ontology-based Data Access)is an ANR JCJC (young researchers) project that started in Jan. 2013 (duration: 4, extended to August 2017). The project coordinator is Meghyn Bienvenu (initially in LRI, now member of GraphIK). It involves partners from the EPI LEO, the LIG, and the Anatomy Laboratory of Grenoble. http://pagoda.lri.fr/

The primary aim of this project is to address challenges brought by scalability and the handling of data inconsistencies by developing novel OBDA (Ontology Based Data Access) query answering algorithms and practical methods for handling inconsistent data.

- *See Section 7.1 for this year's results.*

9.1.1.3. Qualinca

Participants: Michel Leclère, Michel Chein, Madalina Croitoru, Rallou Thomopoulos, Alain Gutierrez, Swan Rocher, Marie-Laure Mugnier.

Qualinca is an ANR Contint project that started in Apr. 2012 (duration: 4 years, extended to September 2016). The project coordinator is Michel Leclère (GraphIK). It involves partners from LRI, LIG, ABES and INA. http://www.lirmm.fr/qualinca/index8ece.html?q=en/en/home

The main objective is to elaborate mechanisms allowing to:
- evaluate the quality of an existing document base;
- maintain a given level of quality by controlling updating operations;
- increase the quality of a given base;
- develop generic methods that take into account the quality of a given base (for instance for searching documents or interconnecting bases).
- *See Section 7.3 for this year's results.*

9.1.1.4. Dur-Dur

Participants: Abdallah Arioua, Patrice Buche, Madalina Croitoru, Jérôme Fortin, Rallou Thomopoulos.

Dur-Dur (Innovations agronomiques, techniques et organisationnelles pour accroître la DURabilité de la filière blé DUR) is an ANR project that started in March 2014 (duration: 3 years). It is led by IATE Laboratory. http://umr-iate.cirad.fr/projets/dur-dur

The Dur-Dur project develops a systematic approach to investigate the questions related to the management of the nitrogen, energy and contaminants, to guarantee a global quality of products throughout the production and the processing chain. The knowledge representation task of Dur-Dur proposes to map the stakeholders' objectives into a multicriteria cartography, as well as possible means to reach them, and computes the compatibility / incompatibility of these objectives on the basis of argumentation methods. The research methods used are qualitative and based both on argumentation theory and on Social Multi- Criteria Evaluation (SMCE) theory. They will be extended and adapted to the needs of the project to provide a formal framework of assessment of the various orientations considered for the durum wheat chain.

9.2. European Initiatives

9.2.1. FP7 & H2020 Projects

9.2.1.1. EcoBioCap

Participants: Patrice Buche, Madalina Croitoru, Jérôme Fortin, Nouredine Toumani.

EcoBiocap is a FP7-KBEE project that lasted 4 years and ended in March 2015. It was led by INRA (and scientifically managed by Montpellier IATE laboratory). It involved sixteen partners among which Cork University (Ireland), CSIC (Spain), Roma University La Sapienza (Italy), SIK (Sweden). The objective of EcoBioCAP was to "provide the EU food industry with customizable, ecoefficient, biodegradable packaging solutions with direct benefits both for the environment and EU consumers in terms of food quality and safety". The budget was managed by IATE team.
- *See Section 7.2 for this year's results.*

9.2.2. Collaborations with Major European Organizations

- On existential rules, we collaborate with TU Dresden and have scientific contacts with the University of Oxford.
- On description logics, we collaborate with the universities of Bremen, Liverpool, London, Rome and Vienna (new collaborations brought by Meghyn Bienvenu).
- On argumentation, we work with the universities of Aberdeen and Southampton.

9.3. International Research Visitors

Odile Papini, PR Univ. Aix-Marseille, is a visitor from Sept. 2015 (one year CNRS delegation) (see ASPIQ project in Section 9.1).

Pierre Bisquert is currently an international visitor for one year at the University of Amsterdam (from May 2015).

Rallou Thomopoulos is currently a visitor at the University of Quebec for one year (from July 2015).

10. Dissemination

10.1. Promoting Scientific Activities

10.1.1. Scientific events organisation

Madalina Croitoru co-organized the workshop GKR@IJCAI (international workshop on graph structures for knowledge representation and reasoning) co-located with IJCAI 2015. This is the 4th edition of this workshop series, that she initiated for IJCAI 2011. https://www.lirmm.fr/~croitoru/GKR/

Marie-Laure Mugnier co-organized the workshop "Ontologies and logic programming for query answering" co-located with IJCAI 2015. http://iaoa.org/jowo/calls/

10.1.2. Scientific events selection

We are regularly members of the program committees of the main generalist conferences in AI (i.e., IJCAI, AAAI, ECAI) and more specialized conferences and workshops (KR, the main conference in knowledge representation and reasoning, RR —Web reasoning and Rule Systems, SUM — International Conference on Scalable Uncertainty Management, COMMA — International Conference on Computational Models of Argument, Metadata and Semantics Research Conference, etc.)
In 2015, those conferences were:

- AAAI 2015: 1 senior PC member (Marie-Laure Mugnier) and 2 PC members (Federico Ulliana, Jean-François Baget)
- IJCAI 2015: 4 PC members (Jean-François Baget, Madalina Croitoru, Marie-Laure Mugnier, Federico Ulliana)
- KR 2016 (Marie-Laure Mugnier)
- RR 2015: 1 PC member (Marie-Laure Mugnier)
- SUM 2015 (Madalina Croitoru)
- MTSR 2015, special track on Metadata and Semantics for Agriculture, Food & Environment [AgroSEM'15] (Patrice Buche)
- PRIMA 2015 (Pierre Bisquert)

10.1.3. Journal

Madalina Croitoru is member of the editorial board of the International Journal of Conceptual Structures and Smart Applications (IJCSSA).

10.1.4. Invited talks

- 8th International colloquium GeCSO Gestion des connaissances dans la société et les organisations (GECSO 2015), Bordeaux, June 2015, 'Intégration de modèles en ingénierie des connaissances aide à la décision pour le choix d'emballages alimentaires', Patrice Buche
- Seminar INRA DID'IT (Diet impact and determinants), May 2015, Intégration de modèles en ingénierie des connaissances aide à la décision pour le choix d'emballages alimentaires, Patrice Buche
- Building the next generation of sustainable food packaging from the conversion of food wastes: Decision Support System. Milano Expo 2015 – October 2015, Patrice Buche

- Environmental Life Cycle Analysis using knowledge engineering based approach for assessing sustainability of biorefinery systems, GDR CNRS-INRA Symbiose, November 2015, Patrice Buche

- Open data: éléments de contexte, enjeux, initiatives, Séminaire d'automne du département INRA CEPIA, October 2015, Patrice Buche

10.1.5. Leadership within the scientific community

- **Scientific animation at INRA**: Patrice Buche co-animates the national network INRA IN-OVIVE, devoted to methods and tools for big data management in life sciences, agronomy and food processing http://www6.inra.fr/reseau-in-ovive
  In particular, he co-organized three editions of the IN-OVIVE workshop dedicated to heterogeneous data sources integration in life sciences during the French conference IC (ingénierie des connaissances) in 2013, 2014 and 2015 https://colloque.inra.fr/in_ovive_2015
  Patrice Buche is also co-animator (2012-2016) at the national level of the INRA CATI ICAT "Ingénierie des connaissances et analyse textuelle" http://www6.inra.fr/cati-icat/Presentation. Moreover, he co-animates the regional seminar MIAD (Mathematical models for decision making in environment, agronomy and processing of agricultural resources) http://umr-iate.cirad.fr/seminaires/aide-a-la-decision

- **Scientific animation at the national level**: Marie-Laure Mugnier is member of the organizing committee of the workshop "Journées d'Intelligence Artificielle Fondamentale" (JIAF, the annual meeting of the French community on the foundations of AI)
  http://icube-web.unistra.fr/gdri3/index.php/Th%C3%A8me_1_:_Intelligence_Artificielle_Fondamentale
  We will locally organize the next JIAF, which will be held in Montpellier in June 2016, in conjunction with the JFPC, the Journées de Programmation par Contraintes (JFPC), the annual workshop of French researchers on constraint programming. https://www.supagro.fr/jfpc_jiaf_2016/

10.1.6. Scientific expertise

Rallou Thomopoulos and Madalina Croitoru are members of the management committee of the European cooperation network (COST) "Mathematical and Computer Science Methods for Food Science and Industry", accepted in Nov. 2105. http://www.cost.eu/COST_Actions/ca/CA15118 http://www.cost.eu/COST_Actions/ca/CA15118?management

Scientific advisory board of the Food and Bioproducts department (CEPIA) at INRA (Marie-Laure Mugnier, since 2011).

Scientific advisory board of **ABES** (National Bibliographic Agency for Universities), Michel Chein (since 2010)

Participation to the Wheat Data initiative of Research Data Alliance (Patrice Buche from June 2015), whose objective is to propose recommandations for wheat and other cereals data
 http://ist.blogs.inra.fr/wdi/

Punctual expertise tasks: Experts for ANR, INRA and Inria.

10.2. Teaching - Supervision - Juries

10.2.1. Teaching

The next table details the number of lecture hours as well as the number of module responsibilities for each team member.

Name	Position	2014/15	Cursus (*)	Module Resp. (per year)
J.-F. Baget	Research Scientist	40	M (UM2)	1
M. Croitoru	Assistant Prof.	198	L2	2
M. Bienvenu	Research Scientist	15	M(UM2)	no
J. Fortin	Assistant Prof	230	Polytech	2
M. Leclère	Assistant Prof.	196	L and M (UM2)	2
M. -L. Mugnier	Professor	192	L and M (UM2)	3
A. Arioua	PhD	12	L (UM2)	no
F. Ulliana	Assistant Prof.	192	L and M (UM2)	3
N. Patel	PhD	64	L(UM2)	no

(*) L =Licence, M = Master (M1 = first year, M2 = second year), UM2 = Univ. Montpellier 2 (Sciences), IUT = Institute of Technology of UM2 (Licence Cursus), Polytech = Engineering School of UM2, UM3 = Univ. Montpellier 3 (Art and Humanities)

The courses organized by team members are mainly in Logics (in Licence), Artificial Intelligence, Knowledge Representation, Knowledge Engineering, Social and Semantic Web. We are also responsible of modules in Web Technologies (Professional L at IUT).

We have some specific responsibilities in the Computer Science Licence and Master:

- Michel Leclère (Faculty): since Sept. 2015, he is deputy manager of the Computer Science teaching Department from the Science Faculty. Moreover, since 2011, he manages the program "Data, Knowledge and Natural Language Processing" (DECOL), part of the Master of Computer Science (about 30 students).

- Marie-Laure Mugnier (Faculty): since 2011, she is (co)-director of the Master in Computer Science, which gathers 6 programs. She also led the Master project for the next four years (LMD4, from 2015/16 to 2018/2019).

- Madalina Croitoru (IUT): since Sept. 2014, she manages the "année spéciale" (about 25 students).

10.2.2. Supervision

The PhDs in progress are:

Fabien Garreau (ANR ASPIQ grant), Algorithms for stable model semantics and existential rules (ANR ASPIQ, with Univ. of Angers), started Sept. 2012, supervised by Igor Stephan, Jean-François Baget and Laurent Garcia.

Swan Rocher (ANR Qualinca grant), Reasoning with inconsistent knowledge bases in presence of existential rules (ANR Qualinca), started Sept. 2013, supervised by Marie-Laure Mugnier and Jean-François Baget.

Namrata Patel (Univ. Montpellier grant), Preference Handling in Decision Problems (ministry grant), started Oct. 2013, supervised by Souhila Kaci and Roland Ducournau.

Abdallah Arioua (ANR Dur-Dur& INRA Grant), Argumentation Theory and its Application to Knowledge-based Systems, started Nov. 2013, supervised by Patrice Buche, Madalina Croitoru and Jérôme Fortin.

Stathis Delivorias (Univ. Montpellier grant), Module extraction in existential rule knowledge bases, started Oct. 2015, supervised by Federico Ulliana, Michel Leclère and Marie-Laure Mugnier.

Abdelraouf Hecham (Averroes grant), Cognitive biases in argumentation, started Oct. 2015, supervised by Madalina Croitoru.

10.2.3. Juries

HDR reviewer - Freddy Lécué - Scalable Machine Reasoning in the Web of Data - Nov. 2015 - University of Nice (Marie-Laure Mugnier)

PhD jury co-director - Lilia Berrahou - Extraction d'arguments de relations n-aires dans les textes guidée par une Ressource Termino-Ontologique de domaine, application aux domaines de la bioraffinerie des ligno-celluloses et des emballages alimentaires - Sept. 2015 - University of Montpellier (Patrice Buche).

PhD jury member - Zied Bouraroui - Inconsistency and uncertainty handling in lightweight description logics - June 2015 - University of Lens (Marie-Laure Mugnier)

President of a recruitment jury (comité de sélection) for a professorship position at the University of Montpellier - Spring 2015 (Marie-Laure Mugnier)

President of an evaluation jury for INRA IT project managers, Oct. 2015, Patrice Buche.

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