Important
Ce document ne doit pas dépasser 30 pages, dans la mise en page et la typographie fournies par l'ANR. Ce point constitue un critère de recevabilité de la proposition de projet. Les propositions de projet ne satisfaisant pas aux critères de recevabilité ne seront pas évaluées._

Acronyme / Acronym	**ASPIQ**		
Titre du projet	Techniques ASP pour l'interrogation d'informations web hétérogènes multisources à grande échelle		
Proposal title	ASP technologIes for Querying large scale multisource heterogeneous web information		
Comité d'évaluation/Evaluation Committee	SIMI 2		
Type de recherche / Type of research	✙ Recherche Fondamentale / Basic Research		
Coopération internationale (si applicable) / International cooperation (if applicab	X NON		
Aide totale demandée / Grant requested		**Durée du projet / Projet duration**	48 mois

1. RÉSUME DE LA PROPOSITION DE PROJET / EXECUTIVE SUMMARY

The overall objective of the project is to propose new solutions for querying large scale multisource heterogeneous information. These solutions will be validated on two applications where we face large data sets expressed in RDFs and OWL, namely to web linked data and to underwater archaeological surveys. The project is centered on three main requirements:

Processing **multisource** information: The fusion of existing information systems, issued from different sources, is a huge and urgent task in many application areas. This is particularly true for the World-Wide Web applications, where pieces of information are often redundant, heterogeneous and imprecise and having exceptions. In addition, they may be very dynamics and changing over times which often induces uncertainties. Besides, even if the information provided by each source is consistent it is rather unlikely that the union of all information will be consistent too. This project proposes adequate solutions to cope with inconsistent information.

Processing **heterogeneous** information: The information provided by multiple sources is often heterogeneous, i.e., it can be expressed in different languages. This project focuses on web-based languages such as OWL family. OWL2 has been proposed for representing structured and semi-structured information in terms of ontologies and several tractable sublanguages dedicated to query answering have been defined, namely OWL2 EL, OWL2 QL OWL2 RL. Nevertheless, currently available languages do not allow for satisfactory uncertainty and inconsistency handling.

Performing **large scale** reasoning: Effective implementation of huge amount of heterogeneous multi-source items of information requires suitable tools. The Answer Set Programming paradigm (ASP), with the development of more and more efficient solvers, compelled recognition in the last decade as an efficient reasoning tool but also as a very expressive formalism. However, most of the solvers are mainly dedicated to propositional logic, while an extension of ASP is required for querying ontological knowledge represented in OWL2 sublanguages.

The main objective of this project is to propose:

1. Extensions of standard ASP for representing OWL2 tractable sublanguages in order to provide a common representation of the knowledge provided by multiple sources, allowing to deal with inconsistencies, exceptions and uncertainties, while staying compatible with efficiently querying knowledge bases with large amounts of data where generic knowledge is represented in terms of an ontology.

2. New operations for merging information represented in extended ASP, of various reliability and quality with or without uncertainty, according to the commensurability assumption or not. Besides efficient algorithms will be proposed for handling conflicts in extended ASP programs.

3. The identification of subclasses of this extended ASP allowing for an implementation of efficient query answering mechanisms moreover able to order and compute the most relevant answers.

4. An efficient implementation of scalable inconsistency handling, fusion operations, defeasible reasoning like exception handling, possibilistic uncertainty and query answering for multiple knowledge bases. To design a prototype reasoning system capable of managing fusion operations, solving conflicts and query answering for multiple knowledge bases. This prototype will be evaluated on two applications: the first one concerns Web data integration, more precisely the Linked Data issue, which consists of interconnecting web data sources (bibliographic catalogues in our case); this application relies on a collaboration with ABES (http://www.abes.fr). The second application deals with querying information stemming from 3D surveys for helping

archaeologists to study underwater sites, in the following of the European VENUS project (http://sudek.esil.univmed.fr/venus/).

This project is part of different very active research directions at the international level. It highlights methods and technologies for managing uncertainty and inconsistency in a semantically defendable manner while being able to process huge amounts of data.
This project joins four partners together: CRIL, LERIA, LIRMM, LSIS and combines complementary skills in different domains of Artificial Intelligence, more specifically in Knowledge Representation and Reasoning, Logic Programming and the Semantic web. The project participants are particularly well placed in the international community as shown by their recent publications in famous international journals and top-level conferences (IJCAI, AAAI, ECAI, KR, ...).

2. CONTEXTE, POSITIONNEMENT ET OBJECTIFS DE LA PROPOSITION / CONTEXT, POSITION AND OBJECTIVES OF THE PROPOSAL

Our world becomes more and more complex, interconnected and dynamic. We live in an information society in constant development with increasingly large volumes of information, which is distributed among an increasing number of sources.

Since the 80's, efforts from the database and the artificial intelligence communities have led to successfully modelize structured or semi-structured information in various domains (biology, medicine, computer security, …). Generic domain knowledge has been conceptually formalized in terms of ontologies. New representation formalisms, based on first-order logic, namely, description logics (DL), have been defined and extensively used for generic knowledge management. However, the exploitation of ontologies in relation with data has been much more recently addressed. Querying data while taking inferences enabled by ontologies into account has now been identified as a crucial issue. More generally, more and more applications where generic knowledge is expressed in terms of ontologies and dealing with a large amount of data, require to process both data and ontologies. Classical description logics were not designed to face this issue, and, as a matter of fact lead to extremely complex reasoning mechanisms. This gave rise, in the last ten years, to tractable sublanguages of the semantic web ontological language OWL, such as OWL2 EL, OWL2 QL and OWL2 RL.

When dealing with multisource information, pieces of information come from different sources characterized by various degrees of confidence. The methods of acquisition differ and provide data of unequal quality. We face pieces of information of different nature: factual information, observations which reflect how the real world is, or is believed to be, expert knowledge or generic knowledge which describes general properties about the world, goals or preferences which express subjective descriptions, laws and regulations which describe the world as it should be ideally. Most of the time, these items of information are incomplete, uncertain, or inaccurate, and they can conflict. There is thus a well-acknowledged need for representation and reasoning formalisms able to handle inconsistency and uncertainty. However, in the context of large amounts of data, the computational complexity issue is crucial.

The overall objective of the project is to propose new solutions for querying large scale multisource heterogeneous information. The project is centered around three main requirements:

1. Processing *multi-source* information: the variety of sources raises the problem of information integration and fusion. Integration involves combining data residing in different sources and providing users with a unified view of these data while fusion attempts to construct a global point of view exploiting the complementarity between sources, solving different existing conflicts, reducing the possible redundancies. Generally speaking, the information provided by the sources, like for example, information of different nature, can be incomparable. Besides, when the pieces of information are incommensurable, i.e., described with different levels of granularity, for

example in case of geographic information provided by sources that do not use the same scale, the fusion operations used in the commensurable case cannot be used anymore and new operations have to be defined.

2. Processing *heterogeneous* information: The pieces of information provided by the sources are often heterogeneous, in the sense that they can be expressed in different languages. We consider here the tractable fragments of the second version of the web ontology language OWL2, namely OWL2 EL, OWL2 QL OWL2 RL. In order to better take advantage of what is provided by the sources, the definition of a common representation language is necessary.
3. Performing *large scale reasoning*: Effective implementation of reasoning with huge amount of heterogeneous multi-source information items requires suitable tools. The rule-based Answer Set Programming (ASP) paradigm, with the development of more and more efficient solvers compelled recognition, in the last decade, as an efficient reasoning tool but also as a formalism more expressive than other approaches like, for example the ones based on SAT that have been developed to implement reasoning in artificial intelligence. ASP allows for naturally representing exceptions, moreover it is successfully used in order to both represent and implement within an unified formalism, non-monotonic reasoning, defeasible reasoning, like reasoning with exceptions, default reasoning, revision and fusion.

This project is part of different very active research directions at the international level. The effervescence around the new low complexity ontology languages in the international Knowledge Representation and Reasoning community is noticeable (cf. for instance the increasing number of papers dedicated to low description logics within excellent international conferences like KR, AAAI, or IJCAI). Answer Set Programming is a well-established paradigm of declarative programming. More and more efficient ASP solvers are proposed and an annual international competition is organised to compare their performances. Besides, among the various approaches of multisource information merging, symbolic approaches gave rise to increasing interest within the artificial intelligence community in the last decade. Belief bases merging has received much attention and most of the approaches have been defined within the framework of classical logic, more often propositional for flat or stratified belief bases. However, when pieces of information come from various sources of unknown reliability or when they are expressed in different languages, merging such information remains an open research issue.

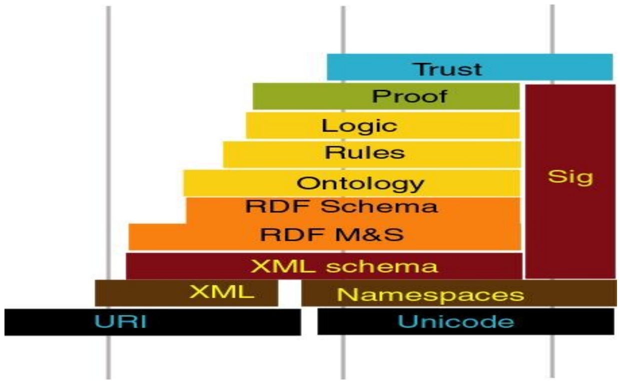
In this international context, our cutting edge will consist in our specific approach: we propose to start from information expressed in low complexity ontology languages (the tractable fragments of OWL2) and to extend ASP to cover these languages, in order to provide a common representation of the knowledge encoded in the sources; the use of ASP allows to deal with exception handling and uncertainty management, thanks to possibilistic logics, while staying compatible with efficiently querying knowledge bases with large amounts of data.

The solutions proposed by this project will take the form of:

- ASP extensions for representing several OWL2 tractable sublanguages, in order to provide a common representation of the knowledge provided by the sources;
- new operations for merging standard ASP logic programs as well as merging logic programs expressed in extended ASP;
- new efficient query answering methods for querying extended ASP logic programs;
- a prototype for scalable inconsistency handling, fusion operations, as well as query answering, on large ASP knowledge bases.

The solutions developed are specially relevant to the Semantic web, even if they are more widely applicable. From a large amount of data distributed on the web, expressed according to different languages, we look for a formalism which allows for representing exceptions in taxonomies and

uncertainty on concepts, to then merge the information represented in this common formalism for providing a global point of view in order to query and obtain more « intelligent » answers, without loosing efficiency.
To situate the proposed solutions more precisely in this context, let us consider the classical "semantic web cake": the project goes beyond the "Ontology" and "Rules" levels to address the "Logic" level.



The proposed solutions will be implemented in a prototype and experimented. We will consider two applications: the first one concerns the management of semantic metadata, and can be placed in the context of the Web of data, more precisely the Linked Data issue, which consists of interconnecting web data sources (bibliographic catalogues in our case); this application relies on a collaboration with ABES (http://www.abes.fr); the second application deals with querying information stemming from 3D surveys for helping archaeologists to study underwater sites, in the following of the European VENUS project (http://sudek.esil.univmed.fr/venus/).

This project joins four partners together: CRIL, LERIA, LIRMM, LSIS and combines complementary skills in different domains of Artificial Intelligence (AI), more specifically in Knowledge Representation and Reasoning, Logic Programming and the semantic web; it federates specialists of formalisms for representing and reasoning with uncertainty, in particular possibility theory, specialists of logic-based formalisms for knowledge representation and reasoning, as well as specialists of reasoning tolerant to inconsistency and exceptions. It should be noted that the project participants are particularly well recognized in the international community as shown by their recent publications both in famous international journals (such as Artificial Intelligence, Journal of Web Semantics, ACM Transactions on Computational Logic, IEEE Transactions on Fuzzy Systems, ...) and top-level conferences (IJCAI, AAAI, ECAI, KR, ...).

Besides, the project will benefit from the collaboration between participants from LIRMM and Karlsruhe Institute of Technology (Sebastian Rudolph) on query answering with existential rules, which is closely related to this project.

Some partners are currently collaborating or have already collaborated. The partners CRIL and LERIA collaborated on propositional belief bases inconsistency handling. The partners CRIL and LSIS have a long standing collaboration on several topics, propositional belief bases revision within the framework of the European project REVIGIS (2000-2004), inference from partially preordered propositional belief bases, causal reasoning within the framework of the pluridisciplinary ANR project MICRAC (Modèles Informatiques et Cognitifs du Raisonnement Causal, 2006-2008).

2.1. CONTEXTE ET ENJEUX ÉCONOMIQUES ET SOCIÉTAUX / CONTEXT, SOCIAL AND ECONOMIC ISSUES

With the increasing development of networks, information is more and more distributed in numerous areas, multi-node computer networks, cooperative systems, multi-agent systems, Internet and more recently with the success of social networks and the development of augmented reality. In most of the applications, generic knowledge is represented in terms of ontologies and information is encoded in ontology languages such as OWL2 family of languages. Query answering, multisource heterogeneous information, requires the development of efficient tools in order to represent and to reason with such information, more specifically in the web context in order to provide more elaborated queries and more « intelligent » answers. Our proposal will be illustrated with and experimented on two real scale applications**.** In both applications we face large data sets expressed in RDFs and OWL.

The first application is within the context of the Web Linked Data initiative, which aims at interconnecting web data coming for various sources. In particular, there are many initiatives to interconnect public bibliographic data, such as the construction of the WorldCat catalog or the Virtual International Authority File (VIAF) Initiative, both led by OCLC (Online Computer Library Center). In this context, ABES (Agence Nationale de l'Enseignement Supérieur) is a major French actor. Involved in both WorldCat and VIAF projects, it will play a key role in building a French hub of bibliographic data. The LIRMM team has initiated a collaboration with ABES on this linked data issue. This project will develop tools for improving the quality of bibliographic catalogues and the links between them. Ontological knowledge is described in OWL2, RDFS, as well as rules and constraints. On the one hand, our tools can be used as complementary tools, allowing to extend rules and constraints to take into account inconsistencies (in the case when the catalogues cannot be repaired) and uncertainty (representing for instance the quality of a given catalogue). On the other hand, our tools can be used to query linked catalogues, while allowing to rank answers according to a preference relation.

The second application is within the context of underwater archaeological surveys, where we deal with knowledge bases consisting of generic knowledge and observations. The generic knowledge takes the form of an application ontology constructed from a domain ontology which describes the vocabulary on the amphorae (the studied artefacts) in terms of typologies and from a task ontology describing the data acquisition process. The observations come from the data acquisition process which provides measures coming from the photogrammetric restitution of surveyed amphorae pictures on the underwater site [Papini et al. 2008], [Hué et al. 2011]. The produced prototype can help the archaeologists for studying underwater sites. Since each observation set is potentially incomplete, merging several observations sets could enrich the description of the measured artefacts. Of course, in case of inconsistency, merging strategies have to be defined. Querying a single artefact allows for identifying from which measurement campaign or series of pictures it comes from. Querying several artefacts allows for analysing the topologic relations between artefacts that can eventually show areas where amphorae belong to the same typology, which is very useful for the study of the shipwreck.

2.2. POSITIONNEMENT DU PROJET / POSITION OF THE PROJECT

In this subsection, we position the project with respect to other groups working on similar issues. Concerning ASP, the leader groups are in Europe. The development of ASP solvers is a main research line in the ASP community. The leading groups are Potsdam Univ. (Potassco project with Clasp Solver), TU Vienna and Calabria Univ.(DLV solver) and Helsinki Univ. of Technology (Smodels solver). These solvers rely on a preprocessing step, which consists of instantiating variables, while our ASPeRiX solver is doing the instantiation gradually and in a limited way. The integration of uncertainty in ASP is not widely used yet and is original. Some groups are working on this feature (Univ. of Gent, Vrije Univ. Brussels, Univ. Politecnic of Catalunya) and we can notice that some of the proposed works are based on, or are evolutions of, works proposed by the LERIA partner of the ASPIQ project. Last, the links between ASP and the semantic web is a new challenging research issue which is growing nowadays (TU Vienna, National Univ. of Ireland, Galway, Vrije Univ. Brussels).
On the other hand, ontology-based data querying is one of the most important challenges currently tackled in knowledge representation, databases and the semantic web. As for ASP, the leader groups on this issue are in Europe, mainly in UK (Oxford University, Birbeck College, Manchester Univ., Liverpool Univ.), Germany (Bremen University, TU Dresden, Karlsruhe IT) and Italy (Free University of Bozen-Bolzano, La Sapienza University), as well as in TU Vienna. While most approaches to

ontology-based data querying are based on description logics (and related to OWL in the context of the semantic web), the use of ASP has been investigated by some of the above groups (most notably TU Vienna). However, existing proposals consist in coupling a DL prover and ASP, whereas we propose to develop a proper extension of ASP that generalizes DLs dedicated to query answering. Besides, ASP has been recently used for both representing and implementing belief change (Potsdam Univ. , TU Vienna, Simon Fraser Univ. Vancouver)

2.3. État de l'art / State of the art

ASP

Answer set programming (ASP) is an appropriate formalism to represent various problems issued from Artificial Intelligence and arising when available information is incomplete as in nonmonotonic reasoning, planning, diagnosis, etc. From a global view, ASP is a general paradigm covering different declarative semantics for different kinds of logic programs. Whatever the precise framework is, information is encoded by logical rules and solutions are obtained by sets of models called stable models. Each model is a minimal set of atoms (or literals) containing sure information (some facts) and deductions are obtained by applying by default some rules. So, conclusions rely on present and absent information, they form a coherent set of hypotheses and represent a rational view on the world described by the rules.

ASP offers both a valid formal model and operational systems. It is also a very convenient framework to encode and solve combinatorial problems since some efficient operational systems are available today to deal with ASP. Smodels [Simons et al. 2002], Clasp [Gebser et al. 2009] and DLV [Leone & Faber 2008] are the most popular one. These solvers take part in ASP competitions (these competitions have been initiated similarly to SAT competitions several years ago and are growing significantly). Moreover, some of these solvers participate in SAT competitions and can obtain better results than SAT solvers. However, these solvers work on propositional rules after a step of variable instantiation. Now, some solvers begin to deal with rules that are not propositional: it is the case of the solver ASPeRiX [Lefèvre & Nicolas, 2009] which works directly on rules with variables and limit the instantiation.

When dealing with information coming from several sources, some contradictions can appear and have to be handled before reasoning. The basic idea of fusion is to avoid some pieces of information to remove all the contradictions but this can lead to loose a large part of information. The use of a nonmonotonic formalism like ASP is then a good way to improve this treatment since it allows to keep the initial information while blocking the use of contradictory rules. Indeed, it is possible to express exceptions in each initial rule, thus to block this rule in some configurations and to allow for its use in some other ones.

Recently, concerning belief change, ASP has been used as a unified formalism for both representing and implementing belief base operations. Delgrande and al. proposed a solution for revising logic programs with stable semantics as well as a semantic approach for merging logic programs with stable semantics [Delgrande et al. 2008, 2009]. Starting from a different viewpoint, Hué et al. proposed a syntactic framework for merging logic programs with stable semantics [Hué et al. 2009].

Morevover, studying the use of ASP for the semantic web is a major subject handled today in ASP community. Some works are focusing on the links between ASP and description logics [Eiter et al. 2008, Heymans and Vermeir 2003, Le Dorze 2010]. These works propose a combination between DL and ASP machineries. They have to manage some kinds of information that lead to hybrid ASP systems (with special atoms for the communication between the two systems) or to huge programs in standard ASP (due to generation of many rules to encode standard DLs). When dealing with programs encoding the information in standard ASP, some aspects of description logics (like existential variables in the head of a rule) are not satisfactory taken into account.

Multi-source fusion

Taking advantage of the different sources of information usually requires performing some combination operation on the pieces of information, and leads to a data fusion problem (e.g., [Gorogiannis and Hunter, 2008] [Konieczny and Pérez 1998] [Konieczny et al. 2004], [Gorogiannis and Hunter, 2008]). Uncertain pieces of information pertaining to numerical parameters, quantifying uncertainties attached to information, are usually represented by set functions, i.e., measures (that may be probability measures, possibility and necessity measures, belief and plausibility measures, according to the considered uncertainty theory). In the literature, many approaches have been proposed to merge these distributions by means of operations, which are in agreement with the uncertainty theory used (e.g.[Dubois & Prade 2004]). However, none of these combination modes is defined on interpretations over ASP languages or interpretations in the sense of description logic languages.

One of the emerging important problems pertaining to data fusion is inconsistency handling [Yahi et al. 2008]. Conflicts often appear when several consistent pieces of information pertaining to the same domain, but coming from different sources, are available. Conflicts may also arise between established knowledge and newly incoming information. This problem is dealt with in belief revision theory [Rott, 2001] [Benferhat et al. 2009a] [Jin and Thielscher, 2007] [Delgrande et al, 2006]. Belief revision [Gärdenfors 1988] [Fermé and Hansson, 2011] completely makes sense in World-Wide Web applications where information always changes over time. Again, existing approaches are mainly defined for propositional logic or weighted set of formulas and to the best of our knowledge there is no conflict management approach defined for possibilistic-based ASP languages.

In the answer set programming framework, two very tentative and preliminary approaches to merging logic programs have been mainly discussed by partners of this project. The first solution, which is depicted in [Delgrande et al. 2009], provides a semantic approach to merging logic programs as the results are the concept of « SE » models which are the closest to the « SE » models of the logic programs to merge. The second solution is based on the Removed Sets Fusion idea [Hué et al. 2008]. It is depicted in [Hué et al. 2009] and is more syntactic oriented providing the result as the union of the logic programs to merge minus some rules. However, none of these two solutions handle the problem of uncertainty associated with information, and they address the problem of conflicting information without taking into account additional information such as source reliability or ordered knowledge bases.

Dealing with heterogeneous data we usually have to cope with distinct data description models used by sources. In particular, sources may not use a common language to describe their information/data and may not use a same uncertainty theory to describe uncertainty associated with pieces of information [Bloch et al., 2001]. Even when they refer to the same uncertainty theory, they often do not share a same meaning of uncertainty scales. Without this commensurability assumption, comparing or combining numerical parameters, uncertainty degrees, does not make sense in the merging process. Besides, in existing merging methods it is often assumed that all sources have a same level of reliability. This assumption may lead to arbitrary results if the source reliabilities are unknown or uncommensurable. In [Benferhat et al. 2009b] solutions have been proposed for ordered propositional knowledge bases, where they consider only one aspect of commensurability related to the uncertainty scale. Our project studies different facets of incommensurability such as the heterogeneity of uncertainty frameworks or the use of granularity languages, and we do not restrict to the propositional logic language but consider richer ASP programs.

Ontological query answering

Nowadays, there are increasingly large amounts of available data, described in relation with representations of knowledge about the modeled domains (i.e., ontologies) [Poggi et al. 2008]. To produce usable information from these data, scalable mechanisms for querying data, while exploiting ontological knowledge into account, are needed. This issue has been recognized as crucial, both in knowledge representation and in database theory. Indeed, classical ontological languages, typically description logics, were not designed for efficient querying. On the other hand, database languages were 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 data, in the semantic web or in scientific domains like medicine, environmental science, life science, or physics.

New description logics dedicated to query answering, less expressive than those considered before, have been designed in the last years, namely the *EL* family [Baader et al. 2005], the DL-Lite family [Calvanese et al. 2007] and the Horn DL family [Grosof et al. 2003] [Krötzsch et al. 2007]; in the context of the semantic web, and the new version OWL2 of the OWL language [OWL2], these DLs have led to three "profiles", namely OWL2 *EL* (based on EL++), OWL2 QL (based on DL-Lite) and OWL RL (based on the Horn DL family). Rules are essential components of knowledge-based systems, however the interaction of classical DLs and rules does not preserve decidability (cf. The pioneer work [Levy & Rousset 1998]). These last years, there have been a lot of proposals aiming at combining rules and description logics (e.g. [Rosati 2005] or Horn description logic programs e.g. [Grosof et al. 2003] [Hustadt et al. 2005]) while ensuring decidability.

Another approach, developed by the LIRMM team, as well as by the data management team led by Gottlob at Oxford university, consists in extending rules to make them more appropriate to the representation of ontological knowledge; in this way, we do not combine rules and DLs but rather *cover* DLs by rules: cf. [Baget et al. 2009, 2010, 2011a, 2011b; Mugnier 2011] for the LIRMM team and [Cali et al. 2008, 2009, 2010] for the Oxford team. This approach will be applied to ASP programs.

2.4. Objectifs et caractère ambitieux/novateur du projet / Objectives, originality and novelty of the project

The overall objective of the project is to propose new solutions for querying large scale multisource heterogeneous information. This ambitious objective is very challenging and faces difficult theoretical problems. We identify 3-ANR lock-outs to overcome.

1. The first lock-out is the extension of ASP that reaches a satisfactory trade-off between expressiveness and computational complexity. Implementing reasoning with non-monotonic features in the framework of low complexity description logics with ASP raises the question of the extension of ASP to first order logic which is very challenging.
2. The second lock-out concerns multisource fusion with incommensurable sources providing information of different nature, expressed in different formalisms. This difficulty leads to two possible approaches. Ontology alignment which is an open issue when considering ontologies with exceptions and incommensurable fusion when knowledge bases are expressed in description logics which is an open problem.
3. The third lock-out is scalable ontological query answering. When dealing with a huge amount of data, the challenge is to define good trade-off between the expressivity of the ontological language and the complexity of querying data in presence of ontological knowledge.

In order to overcome these difficulties, we propose four objectives. These goals will not be easy to reach. They constitute hard challenges as shows the fact that a large international community has confronted or confronts theses issues.

Objective 1: ASP extensions

Even if ASP is known as a formalism offering efficient operational systems, it should be pointed out that these systems only process propositional information (the user can write a program with variables but these variables are instantiated before being processed by the solver). However, for large scale multisource heterogeneous information handling, it is necessary to have a first-order ASP solver able to process, in particular, positive extended rules. That is why we want to extend the solver ASPeRiX, working on rules with variables without a preprocessing phase of grounding (instantiation), by introducing quantifiers. Since current solvers work on propositional information, new efficient algorithms are needed, which will use propagation in an original way as well as dependencies between rules. Moreover, the handling of quantifiers will lead to an extension of ASP (which will be one step more towards first-order ASP) from which the notion of answer set will have to be redefined (particularly by the use of a form of Skolemisation). Moreover, since we want to deal with heterogenous information, we have to introduce some notions like uncertainty in ASP. Uncertainty will be expressed in terms of a qualitative framework. All these characteristics will be added in standard ASP to propose an extended ASP, called ASP+.

Objective 2: Multisource fusion

The integration of existing information systems is a huge and crucial task in many areas such web-based applications. One of the major objectives of this project is to provide methodologies and efficient tools for merging heterogeneous, inconsistent, incommensurable and uncertain multiple-sources information. These pieces of imperfect information are encoded using extended answer set programming paradigm. In particular, we study different genuine fusion operations that take as input data sources encoded in ASP frameworks and provide as output an uncertain-based ASP representing the result of merging. However, since we deal with huge amount of data and the number of sources can be large such a merged knowledge base may not be possible to obtain. A challenge is then to study algorithms that pre-process and reformulate initial queries (defined on merged bases) into an equivalent set of queries that are locally defined on initial knowledge bases. We also study original solutions for different problems raised by merging scalable data sources such as how to analyse redundancy, how to deal with incommensurability of sources (incommensurability with respect to used uncertainty frameworks, used uncertainty scales or used granularity description-languages), how to get rid or live with inconsistency with a particular emphasis on the use of argumentation in alignments of ontologies.

Objective 3: Scalable ontological query answering with rules

Querying data while taking domain knowledge encoded in the ontology into account has been recognized as a major issue. Standard queries are the so-called conjunctive queries in databases (Select-From-Where queries in SQl, or existentially quantified conjunctions of atoms in a logical setting). The challenge is to define *good trade-off* between the expressivity of the ontological language and the complexity of the querying task. There is currently growing interest on how to *conciliate* DLs, which are typically used to represent ontologies, and rule-based languages, which have long been recognized as essential components of knowledge-based systems. To achieve this objective, a frequently used approach consists in combining them into a hybrid language, in which there are two components, a rule-component and a DL-component, with the rule-component making calls to the DL-component. We propose another approach: defining a single rule-based mechanism which covers DLs (more precisely, OWL2 fragments). For that, we rely on recent results by the LIRMM team [Baget et al. 2009-2011] as well as Gottlob's team at Oxford University [Cali et al. 2008-2010], which has led to define a framework based on extended positive rules (called existential rules or Datalog+): in these rules, the head may contain variables that do not appear in the body of the rule, these variables being existentially quantified. This allows to create new unknown individuals, which makes these rules particularly adapted to the representation of ontological knowledge in open-domains, where it cannot be assumed that all individuals are known in advance. Precisely studying how existential rules can cover low complexity DLs will be the first part of our objective. The next step is to support reasoning with incomplete information, i.e., nonmonotonic reasoning, as performed by ASP. We will study the combination of ASP and existential rules, which will lead to ASP+ (cf. Objective 1). Then, the challenge is to identify several fragments, or profiles, of this framework with interesting computational complexity with respect to several parameters, which will allow to define typical uses of these profiles. This family is called ASP+/- in the sequel of this proposal.

Objective 4: Prototype, algorithmic and implementation issues of ASP

Since the structure of extended ASP will be more complex than that of standard AS, we have to deal with the algorithmic aspects of the solver. For instance, since current solvers work on propositional information, new efficient algorithms are needed, which will use propagation in an original way as well as dependencies between rules to deal with first-order programs. New algorithms will also be needed to handle efficiently uncertainty in ASP. Algorithms concerning fusion and querying will also be studied to deal with tractable fragments of ASP+. All these works will lead to an implementation that will take the form of a prototype. This prototype will contain a parser from OWL2 to ASP, a first-order extended ASP solver dealing with uncertainty, a fusion machinery and a query machinery. This prototype will be used to treat two applications: the first one about Web Linked Data and the other one about underwater archaeological surveys.

3. Programme scientifique et technique, organisation du projet / Scientific and technical programme, Project organisation

3.1. Programme scientifique et structuration du projet / Scientific programme, project structure

The first question before querying multisource data is how to perform fusion taking into account the incommensurability, the uncertainty of the sources, handling inconsistency, redundancy and exceptions, in order to provide a global view of the available data.

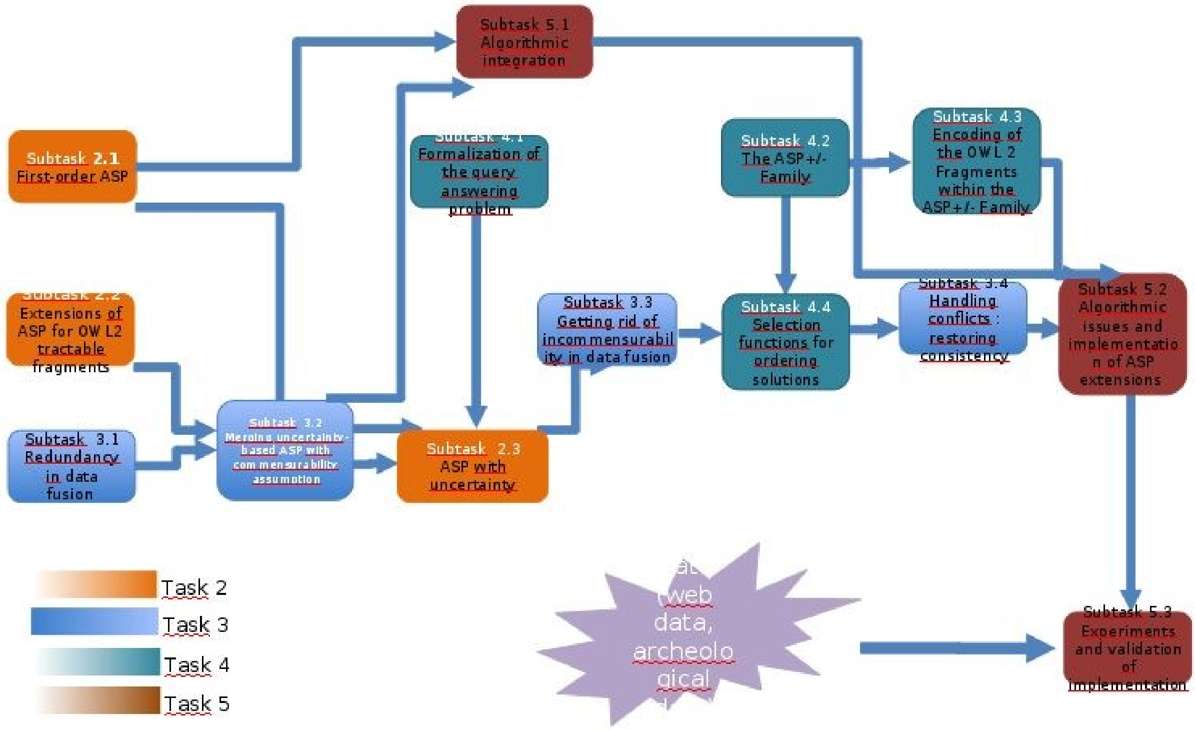
Our approach is to propose an extension of ASP as representation formalism. First, we will define an extension of ASP suitable for representing tractable fragments of OWL2 language. Then, we will extend it again with uncertainty and inconsistency management to efficiently implement reasoning tasks like fusion and query answering.

We will design a prototype with parsing ability from OWL2 to extended ASP and with reasoning capabilities for merging and querying such programs. This prototype will be experimented on two real scale applications: web data integration (related to the Linked Data issue) and querying information from 3D surveys.

In order to achieve the objectives described in section 2.4, besides Task 1 dedicated to the project coordination, the scientific work will be run through 4 tasks:

- **Task 2 (ASP extensions)** is devoted to the extensions of ASP in terms of representation and computation; it will allow to translate each OWL2 source into an ASP+ program (with uncertainty);
- **Task 3 (Fusion of complex and multisource knowledge bases)** deals with fusion of several ASP+ programs, resulting into a single ASP+ program;
- **Task 4 (Scalable ontological query answering)** focuses on querying the merged knowledge bases (i.e., resulting from Task 3);
- **Task 5 (Algorithms, implementation, integration and experimentation)** deals with algorithmic and implementation issues, as well as the validation of the framework on applications.

The following diagram summarizes this scientific organization and emphasizes the interactions between tasks.



3.2. Management du projet / Project management

The project coordination is decomposed into two levels:

Global level: The coordinator (Odile Papini- LSIS) will ensure that all tasks are on schedule and that the different goals are achieved. She will produce a biannual report on progress made in all tasks, results, publications, technical achievements and meetings. She will be responsible for writing the final report.

Task level: The project is divided into 5 tasks. Each task is assigned a coordinator who will prepare a biannual report including a listing of activity performed (results, publications, technical achievements). He will produce the final report corresponding to the task.

Scientific and administrative responsibilities

The project coordinator will be responsible for all liaison with the ANR.

For each participating laboratory, a local coordinator is assigned as follows:

1. CRIL: Salem Benferhat
2. LERIA: Laurent Garcia
3. LIRMM: Marie-Laure Mugnier
4. LSIS: Odile Papini

Each local coordinator has the scientific, technical and administrative responsibility for his/her group. This includes ensuring the quality of scientific work, organizing meetings, in his/her laboratory, the management of the allocated resources and activities related to the dissemination of the results.

Communication within the project
A first plenary meeting will be organized at the start of the project. Such meetings will then be held at least one a year to be attended by all project members.
For each task, at least two meetings are scheduled per year. We will ensure that meetings for each task will be held, as far as possible, on the same site as those for other tasks, in order to facilitate communication within the project.
The project will set up a web site to provide external showcase.

3.3. Description des travaux par Tâche / Description by task

3.3.1 Tâche 1 / Task 1: Scientific coordination

Scientific coordination
The project coordination is described in Section 3.2. It requires 3 Person-Months for LSIS

3.3.2 Tâche 2, Task 2: ASP extensions

Title: ASP extensions			Start Date: T0	Duration: 24
Coordinator Laurent Garcia (LERIA)				
Participants	CRIL	LERIA	LIRMM	LSIS
Person-Months	10	32	12	31
Persons	S. Benferhat F. Cheikh R. Ayachi	L.Garcia C. Lefèvre S. Ngoma I. Stéphan	J.F. Baget J. Fortin M. Leclère M.-L. Mugnier	F. Nouioua O. Papini E. Würbel S. Yahi

The aim of this task is to propose ASP extensions allowing to encode web information by means of:

- developing the first-order ASP solver ASPeRiX
- defining an extension of ASP called ASP+ allowing in particular to encode the pecularities of OWL2 fragments (quantification, cardinality, …)
- proposing ASP extensions integrating priorities upon information.

Subtask 2.1: First-order ASP
Current ASP solvers are based on an instantiation of the initial program that generates a program without variables which is used to compute the solutions. Unfortunately, the instantiation leads to an explosion of the number of rules which is problematic when dealing with large scale information. That's why we propose to handle programs without instantiation. More precisely, the instantiation is done during the exploration of the rules to reduce this explosion. This is the method used by the solver developed at the LERIA and called ASPeRix [Lefèvre & Nicolas 2009].

Subtask 2.2: Extensions of ASP for OWL2 tractable fragments
Since our ASP extension will be able to deal with DL, some of the features of DL representation has to be introduced into ASP formalism. The features will come from the different versions of OWL2 (OWL2-EL, OWL2-QL and OWL2-RL). For instance, we will focus on the treatment of quantifications, particularly when existential quantifiers will take place in the head on a rule. Moreover, when dealing with information coming from the web, we have to discard the Unique Name Assumption and the Close World Assumption.
Dealing with such information will lead to add some functionalities to standard ASP to obtain an ASP+. Let us note that some work dealing with DLs but in standard ASP has started at the LERIA [Le Dorze 2010].

Subtask 2.3: ASP with uncertainty
When dealing with uncertain information and/or pieces of information coming from different sources preference relations have to be represented into logic programs. Since the source provide a huge amount of data, this subtask aims at studying efficient ways for directly representing preference relations into logic programs in order to define preference relations between answer sets and to directly compute the preferred stable models.

The integration of preferences in ASP should use the works realized at the LERIA for the treatment of qualitative uncertainty in ASP with possibilistic stable models [Nicolas et al. 2006]. In the aim to merge several categories of information, we have developed an extension of the Answer Set Programming paradigm, called possibilistic answer set programming for incomplete and uncertain knowledge representation and reasoning. Our framework of possibilistic stable model semantics embeds in a unified way two aspects of common sense reasoning: nonmonotonicity and uncertainty. Each part is underpinned by a well established formalism: stable models semantics and possibility theory.

3.3.3 TÂCHE 3, TASK 3: FUSION OF COMPLEX AND MULTISOURCE KNOWLEDGE BASES

Title: Fusion of complex and multisource knowledge bases		Start Date: T0		Duration: T36
Coordinator: Salem BENFERHAT (CRIL)				
Participants	CRIL	LERIA	LIRMM	LSIS
Person-Monhs	26	6	1	41
Persons	S. Benferhat S. Konieczny S. Lagrue R. Ayachi	L. Garcia S. Loiseau	J.-F. Baget	H.Nguyen F. Nouioua O. Papini V. Risch E. Würbel S. Yahi

The aim of this task is to deal with information fusion from multiple disparate sources (web-resources, web-services, archeological data, etc), in particular, those involving uncertainty. The input of this task is a set of uncertainty-based answer sets logic programs. The uncertainty framework considered in this task is the same as the one of Task 2 and Task 4, namely the possibility theory framework. The output of this task is a knowledge base described in an uncertainty-based answer set programming framework representing the result of merging different available information. The merging task process requires several steps which are described in the following subtasks.

Subtask 3.1: Redundancy in data fusion

Once in Task 2, available information are translated in uncertainty-based answer set programs, it is crucial to know whether sources share some common information and to what extent this represents redundancy. When faced with redundant information, it is important to know if this redundancy is due to a repetition of the same piece of information issued from a same source or if this redundancy brings an additional information in particular about the reliability we can give to this duplicated piece of information. Redundancy is not always a drawback that one should absolutely get rid. In some applications, a fact that is stated several times may be more important than a fact that is only present once in the knowledge base. Besides, a fact that appears in several websites may be considered as more accepted (or more confirmed) than a fact that is only present in one of them. However, a same information stated twice but at two different time points may not be considered as redundancy especially for World-Wide Web applications where such information may change over time.
The work that will be done in this subtask is to investigate methods for detecting redundancy, to discriminate between redundancy to eliminate and the one that represents additional information and to study appropriate fusion modes in both cases.
This pre-processing step of analyzing redundancy is crucial for the definition of merging operations (Subtask 3.2) and also for inconsistency management (Subtask 3.4) since some approaches, like the lexicographic inference, use (implicit and explicit) redundancies as criteria to solve conflicts.

Subtask 3.2: Uncertainty in information fusion: Merging uncertainty-based ASP with commensurability assumption

In this subtask, we assume that sources to merge are commensurable in the sense that they share same meaning of uncertainty scales, use a common language to describe their knowledge and use a same uncertainty theory. The incommensurability case is analysed in SubTask 3.3.
The first objective of this subtask is study semantic combination operations where uncertainty distributions are not defined on a set of interpretations of a propositional logic but are defined on the

set of stable models (in a sense of ASP). The semantic combination are studied in order to select appropriate merging operations on the basis of available information (for instance with respect of the status of redundancy studied in Subtask 3.1).
A second objective of this task is to provide syntactic counterparts of semantics fusion when pieces of information are represented by uncertain answer set programs. Merging logic programs addresses new important issues compared to the propositional case: what is the definition of consistency in this framework? How to measure distances between two programs in ASP representing two OWL concepts?
Lastly, in some applications, the number of data/information sources that can be used for solving problems can be enormous. Hence, in this case constructing one merged uncertain ASP logic program may not be feasible. A last objective of this subtask is to then to study local merging strategies by identifying only relevant sources that can directly contribute to query answering.

Subtask 3.3: Getting rid of incommensurability in data fusion
The aim of this subtask is to propose methods that get rid of incommensurability in order to use merging methods defined in Subtask 2.2 (under commensurability assumptions). Firstly, there is a need for developing methods for conversions of different uncertainty mechanisms when merging information from multiple sources. This will be our first way to get rid of one aspect of incommensurability when sources do not use same uncertainty theories. This step is crucial for Task 2 since it aims in transforming uncertainty framework used by each into the one used in uncertain answer-set programs.
Secondly, this subtask studies methods for solving the problem of incommensurability of uncertainty scales, namely when sources do not share a same meaning of scales. This tasks will explore methods based the notion of compatible scales. A compatible scale is simply a reassignment of « numerical parameters » associated with formulas in bases, such that the original relative ordering between such formula is preserved.
Thirdly, we address the problem of incommensurability associated with the used language. Namely, we are interested in reasoning from uncertain-based answer set programs that use distinct languages having different levels of granularity. Indeed, one main assumption in standard knowledge fusion is the fact that all knowledge bases to merge are defined using a same language. Such assumption is rarely true in practice. Here, we again need to some «taxonomy » or some « compatible languages » to link different concepts. The result of merging depends on the expected level of granularity that may be provided for a given query. We will investigate two kinds of merging: i) abstract merging which aims to map used concept to their abstract level. This has a clear advantage where only few inconsistency may be encountered, or ii) focussed merging where the result of merging should be as precise and detailed as possible. In this case the major risk is that the number of conflicts may significantly increase.

Subtask 3.4: Handling conflicts: restoring consistency
This Subtask investigates methods for coping with conflicts caused by multiple source information. The main difficulty in presence of conflicts is how to select the less relevant pieces of information to be removed in order to restore the consistency. Namely, how to define appropriate criteria which allows to select one subset of consistent sources over another.
The presence of uncertainty formulas in ASP programs will be used to appropriately restore consistency of knowledge bases. We propose in particular to study different strategies for restoring consistency such: the lexicographic inference (where redundancy is viewed as a confirmation) or inclusion-based inference (where redundancy is viewed as a drawback to be eliminated). The solutions that we will propose to study go beyond the ones proposed in propositional logic where a propositional formula is often either accepted or rejected. Here, we take advantage of the use of a richer language such as answer set programming to propose new strategies that proceed to parsimonious changes in knowledge bases (needed to restore consistency).
This will give a richer and an original notion of maximal consistent subbases traditionally used for managing inconsistency in propositional bases. In fact, every stable model of a program can be viewed as the result of the application of a maximal subset of rules that can be « well-chained » and

are not contradictory. Inconsistent programs can be characterized by the fact that they contain at least a subset of rules which are « blocking theirselves ».
It is interesting to define formally this notion of blocking set for ASP framework, to characterize the notion of inconsistency in a normal logic program via a property on his blocking sets and to propose a method for « repairing » inconsistent programs by exploiting the information present in the blocking sets. This treatment of incoherent programs takes place in the optic of integrating imperfect information that are potentially incoherent, these aspects being important for integrating information as described in the tasks.

3.3.4 TÂCHE 4, TASK 4: SCALABLE ONTOLOGICAL QUERY ANSWERING

Title: Scalable ontological query answering			Start Date: T0	Duration: T30
Coordinator Jean-François Baget (LIRMM/INRIA)				
Participants	CRIL	LERIA	LIRMM	LSIS
Person-Months	6	6	12	7
Persons	S. Benferhat S. Lagrue	C.Lefevre L. Garcia	J.-F Baget J. Fortin M. Leclère M. L. Mugnier	F. Nouioua O.Papini

This task is dedicated to the interrogation of ASP+ programs with database-like conjunctive queries of form $ans(x_1, \ldots, x_k) \leftarrow B$ where B is a conjunction of atoms whose variables include $x_1, \ldots, x_k$. The subtasks involved will answer the following questions. What is an answer to a conjunctive query in an ASP+ program? What restrictions on an ASP+ program can ensure decidability of this problem? Are these restrictions sufficient to encode translations of DL ontologies (in particular the considered OWL2 fragments)? And finally, how can we use preferences on extensions to provide preferences on answers?

Subtask 4.1: Formalization of the query answering problem
The first subtask is a preliminary study that will provide the necessary formal definitions and framework for ASP+ query answering. We can consider an extension (in the sense of ASP) in an ASP+ program as a conjunction of atoms, whose instantiation is a database. An answer to a conjunctive query is thus an answer in that database. However, due to the presence of existential variables in the head of ASP+ rules, such an extension can have an infinite size. Looking for all answers can thus be an impossible problem to handle. A solution adopted in DLs is to consider that two answers are different only when there is a variable in $ans(x_1, \ldots, x_k)$ that maps to different initial terms (i.e., terms that have not be created by an application of a rule). This provides a way to define a finite set of different answers in a given extension.
Now our problem is to define the answer set of an ASP+ program from the answer sets of its extensions. In its decision form (is there an answer to the query), the problem can be stated as "is there an answer in one extension" (credulous deduction), or "is there an answer in all extensions" (skeptical deduction). Let us now define credulous answers as the union of the answer sets in all extensions, and skeptical answers as their intersection. Though credulous deduction is equivalent to the credulous answer set being non empty, a similar result does not hold for skeptical deduction (there can be answers in all extensions, but not the same ones). Consequences of this discrepancy between logical deduction and the notion of answers will be evaluated, mainly in the light of our DLs translations into ASP+.

Subtask 4.2: The ASP+/- Family
Due to the existential variables in the head of ASP+ rules, deciding whether a tuple belongs to the answer set of an extension is an undecidable problem. Undecidability does not come from the non-monotonic features of ASP+, but is already present in the Datalog+ language (that can be seen as ASP+ without constraints). Decidable fragments of Datalog+ are now being increasingly studied, and these fragments form the Datalog+/- family. The goal of this subtask is to study which languages of

the Datalog+/- family can be extended to a decidable fragment of ASP+. These fragments will form the ASP+/- family.

Three families of decidable Datalog+ fragment can be identified. The first, called finite expansion sets, rely upon finiteness of the forward chaining (chase) mechanism. The second, called bounded-treewidth sets, rely upon the tree-like structure of the generated atoms. Finally, finite unification sets rely upon the finiteness of rewritten queries. Though finite expansion sets will easily extend to decidable fragments of ASP+, these fragments cannot be considered as fit for our problem, since they do not provide the possibility to represent existential quantification in DLs. Most of the low complexity DLs we are interested in can be translated into Datalog+/- rules that belong to a bounded tree-width set. This family is thus an interesting starting point to define decidable fragments of ASP+. Finally, finite unification sets provide us with a challenging issue: though they are very interesting when working with very large databases (since they do not saturate the database, but rewrite the query), this framework seems to be less adapted to ASP+, whose reasoning heavily relies upon forward chaining.

Subtask 4.3: Encoding OWL 2 Fragments within the ASP+/- Family

The expressivity of the languages of the ASP+/- family must now be evaluated. Let D_1, …, D_k be different description logics. Is there a decidable fragment of ASP+ that contains the ASP+ program obtained from the fusion of ontologies written in each of these languages? What is the complexity of reasoning in that case? On the other hand, if the ASP+ program obtained does not fit into any ASP+/- fragment, can we transform the program without loosing any answer? If still not possible, can we restrict the interactions between the ontologies to obtain decidable program?

This subtask is mainly devoted to complexity results, both in the ASP+ and description logics domains. Specific algorithms that will be implemented in subtask 5.2 will be studied here.

Subtask 4.4: Selection functions for ordering solutions

When querying an ASP+ program resulting from the fusion of heterogeneous ontologies, it can be the case that there is no answer that appears in every extension (no sceptical answer), but that there are many extensions in which answers can appear (lots of credulous answers). The problem here is to provide the end-user with the most relevant credulous answers.

This subtask is devoted to the ordering of answers. The "weight" of an extension, as defined in subtask 2.3, can be used, thanks to an aggregation function, to define the weight of an answer appearing in one or more extensions. This will allow for an ordering of credulous answers that are not sceptical. The main goal here will be to examine if it is possible to generate all "best answers" without having to generate all expansions, according both to the method used to compute the extension "weights" and our aggregation function.

3.2.5 Tâche 5, Task 5: Algorithms, implementation, integration and experimentation

Title: Algorihtms, implementation Integration and experimentation			Start Date: T6	Duration: T36
Coordinator: Igor Stephan (LERIA)				
Participants	CRIL	LERIA	LIRMM	LSIS
Person-Months	12	16	12	18
Persons	F. Cheikh S. Lagrue R. Ayachi	L.Garcia C. Lefèvre S. Loiseau S. Ngoma I. Stéphan	J.-F Baget J. Fortin M. Leclère M. L. Mugnier	P. Drap H.Nguyen O. Papini E. Würbel

The aim of this task is to integrate the results obtained in Tasks 2-4 and to provide an implementation, with experiments and validation:

- choosing the suitable ASP extension for integrating these tasks and developping algorithmic aspects of this suitable ASP extension
- implementing a prototype

- validating this system by characterizing quality criterion and experimenting it on applications.

Subtask 5.1: Algorithmic Integration

The aim of this subtask is to integrate the implemented algorithms in order to provide a pipeline from the data provided in input expressed in OWL2 sublanguages to the ouput which is the result of query answering. It will first prepare the software prototype with all necessary interfaces. It will then integrate the parsers from OWL2 sublangages to extended ASP, the merging algorithms, and finally the query answering implemented in subtask 5.2.

Subtask 5.2: Algorithmic issues and implementation of ASP extensions

This subtask handles the implementation of the frameworks proposed in the other parts of the project. The result will be a prototype used to validate models and algorithms.
In order to reduce risks of failure, each part will be implemented as an independent module, before integrating all propositions:
- implementing a parser for translating bases expressed in description logic into ASP programs as studied in subtask 2.1
- implementing first-order ASP: this implementation will integrate in the ASPeRix solver the extensions studied in the subtask 2.1
- implementing efficient ways for preference handling: this implementation will focus on the handling of possibilistic preferred stable models suggested in 2.3
- implementing fusion and interrogation in standard ASP,
- implementing fusion and interrogation in extended ASP,
- last, implementing ASP prototype integrating all the functionalities.

Subtask 5.3: Experiments and validation of implementation

This subtask is closely linked to the previous one and will be developed in accordance with the evolution of the implementation. Experiments will be mainly performed on two applications, in which some participants of ASPIQ have been involved or are currently involved. The first one is related to the Linked Data issue and the second one to 3D surveys.

1- The LIRMM team is currently involved in a collaboration with ABES (Agence Bibliographique de l'Enseignement Supérieur - National Bibliographic Agency for University Libraries, http://www.abes.fr), which manages a large base of metadata (several millions of notices described with RDFS). Both partners are developing an ontology using RDFS and OWL, as well as existential rules and constraints. This collaboration has been enlarged to a project involving INA (Institut National de l'Audiovisuel). Two issues related to the present proposal are addressed: 1) Base repair: improve the quality and the consistency of the metadata base, which has been manually built (by librarians) in a collaborative way. The aim is to detect duplicate entities as well as incorrect fusions of entities. 2) Record linkage problem: given a semantic annotation referring to several entities, find the corresponding entities in the metadata base; this problem can be seen as a query problem, with the answers being ordered by likelihood level. There are needs for non-monotonic reasoning as well as uncertainty management, these features being not provided by the current tools. We propose to experiment the ASP extensions proposed by ASPIQ within this knowledge base relative to both above mentioned problems.

2- The second application concerns inconsistency handling and fusion of information stemming from 3D surveys, in the following of the European VENUS project (http://sudek.esil.univmed.fr/venus/). In the context of 3D surveys, information comes from several sources which are characterized by a huge amount of data. The generic knowledge concerning the domain of the surveyed data is represented in terms of application ontology which can conflict with the data coming from the surveys leading to inconsistency. Since the application ontology can be encoded in low complexity description logics, this experimental problem constitutes a benchmark for implementing the solution where the Tbox (application ontology) and the Abox (data coming from the 3D survey expressed in a low complexity DL) are translated in an extended ASP. Moreover, in order to test the implementation, it will be also interesting to study and elaborate other benchmarks or more simple examples that could be used to the experiments

- *Validation*

The problem of knowledge bases validation is an important problem, studied for more than thirty years, to ensure system fiability. Three criteria are traditionally used for a such validation: inconsistency, redundancy and incompleteness. Once established a property of validity, an algorithm allowing its treatment should be proposed. When a knowledge base is invalid, a phase for fixing the base is necessary. At the LERIA, several theses concerning validation has been lead upon several formalisms of knowledge bases (production rules, conceptual graphs) and could be adapted for ASP.

3.4. Calendrier des tâches, livrables et jalons / Tasks schedule, deliverables and milestones

Tasks	**Partners**	**Year 1**		**Year 2**		**Year 3**		**Year 4**	
		Sem. 1	**Sem. 2**	**Sem. 3**	**Sem. 4**	**Sem. 5**	**Sem. 6**	**Sem. 7**	**Sem. 8**
Task 1 coordination	**LSIS**	**M**	**M**	**M**	**M**	**M**	**M**	**M**	**M**
		Web site							
Task 2 ASP extensions	**CRIL LERIA LIRMM LSIS**	**Subtask 2.1**							
		Subtask 2.2							
		Subtask 2.3							
Task 3 Fusion of complex and multisource knowledge bases	**CRIL LERIA LIRMM LSIS**	**Subtask 3.1**							
		Subtask 3.2							
				Subtask 3.3					
				Subtask 3.4					
Task 4 Scalable ontological query answering	**CRIL LERIA LIRMM LSIS**	**Subtask 4.1**							
		Subtask 4.2							
				Subtask 4.3					
				Subtask 4.4					
Task 5 Algorithms, implementation integration and experimentation	**CRIL LERIA LIRMM LSIS**			**Subtask 5.1**					
				Subtask 5.2					
						Subtask 5.3			

M: bi-annual plenary meeting

Deliverables

Task 2: ASP extensions

Subtask 2.1: First-order ASP

- research report on first-order ASP (T0 + 9)
- publications on first-order ASP improvements (T0 + 18)

Subtask 2.2: Extensions of ASP for OWL2 tractable fragments

- research report on translation of bases expressed in OWL to ASP program (T0 + 18)
- publications on translation of bases expressed in OWL to ASP program (T0 + 24)

Subtask 2.3: ASP with uncertainty

- research report on ASP with uncertainty (T0 + 18)
- publications on extended ASP (T0 + 36)

Task 3: Fusion of complex and multisource knowledge bases

Subtask 3.1: Redundancy in data fusion

- Research report on analysing of redundancy (T0+12)
- Publication on how to deal with redundancy in uncertainty-based ASP (T0+24)

Subtask 3.2: Uncertainty in information fusion: Merging uncertainty-based ASP with commensurability assumption

- Research report on studying syntactic and semantics merging (T0+12).
- Publication on merging ASP programs (T0+24)

Subtask 3.3: Getting rid of incommensurability in data fusion

- Research report on getting rid of incommensurability of uncertainty scales (T0+24).
- Research report on getting rid of incommensurability of uncertainty frameworks (T0+24).
- Publication on getting rid of incommensurability of languages granularity (T0+36).
- Publication report on getting rid of different forms of incommensurability in merging uncertainty-based DL and uncertainty-based ASP (T0+42).

Subtask 3.4: Handling conflicts: restoring consistency

- Research report on definitions of preferred uncertainty ASP subbases and strategies for relaxing conflicting information (T0+36).
- Publication on lexicographic inference for extended ASP (T0+36)

In addition to research reports and publications, there will be a deliverable under the a form of a program dedicated to the merging of extended ASP programs (T0+42).

Task 4: Scalable ontological query answering

Subtask 4.2: The ASP+/- Family

- research report on Datalog+/- (T0 + 18)
- research report on ASP+/- (T0 + 36)
- Publication on the same topic

Subtask 4.3: Comparison of the OWL 2 Fragments with the ASP+/- Family

- Research Report on ASP+/- (T0 +42)

Subtask 4.4: Selection functions for ordering solutions

- Research Report on Preferred Answers (T0 +42)

Task 5: Algorithms, implementation integration and experimentation

Subtask 5.2: Algorithmic issues and implementation of ASP extensions

- parser for translating bases encoded in OWL to ASP (T0 + 36)
- first version of prototype (T0 + 48)

Subtask 5.3: Experiments and validation of implementation

- research report with results of experiments and validation (T0 + 48)

4. Stratégie de valorisation, de protection et d'exploitation des résultats / Dissemination and exploitation of results. intellectual property

The exploitation of project results will primarily focus on the traditional aspects of academic recognition. In other words, the first goal is to achieve high-level publications. This concerns relevant international journals of the field, but also leading international conferences. Given the extent and the difficulty of the theoretical problems tackled, software devlopment will be limited to a prototype integrating all results. However, we intend this project to be a first step towards a true platform (an open-source software that will fully operationalize extended ASP, whatever its final shape will be, intended for the community of researchers and R&D engineers). Moreover, as explained in the context of this proposal, the potential impact of our results for the logic level of the semantic web is important. We thus plan to pursue this project with a more applied project, which will devoted to the developement of a software platform providing advanced reasoning services in the context of the semantic web.

Concerning dissemination, beside publications themselves, the consortium will organize 2 workshops within the framework of international conferences: the first one at ECSQARU 2013 (European Conferences on Symbolic and Quantitative Approaches to Reasoning with Uncertainty) and the second one at ECAI 2014 (European Conference on Artificial Intelligence). Moreover, a web site will be set up in order to more easily disseminate the results of the ANR project

For a more formal aspect of sharing contributions made during the project, a consortium agreement will be negotiated and signed by the partners during the first year. This agreement will cover the principles of disclosure of results between partners, privacy and intellectual property (IP), and their exploitation . These IP issues will be submitted to an « ad hoc » committee who will review and retain the most appropriate scenario concerning IP. This committee will consist of one representative of each partner. In this regard, the partners place their trust in the competent departments of their research laboratories.

Regarding ownership of results, each party will own knowledge (methods, software, etc) acquired prior to the start of the project but which may be modified or improved during the course of it. The other parties will on request be able to use, without financial contribution such prior knowledge. The specific results obtained during the project by one party and all intellectual property rights attaching thereto are the property of the party who developed these results. Results obtained jointly by different parties will be subject to co-owner-ship in proportion of their respective contributions (financial, material, intellectual, etc).

Regarding the exploitation of the results, each party may freely use the results which it owns. Any exploitation of the results common to several parties will be subject to a prior contract signed between the different parties concerning operating conditions, including fees. The exploitation strategy will be decided by the ad-hoc committee mentioned above. Nevertheless, we have already decided that all the new software tools will be open-source and placed in the public domain and made freely available on the web.

5. Description du partenariat / Consortium description

5.1. Description, adéquation et complémentarité des partenaires / Partners description & relevance, complementarity

The consortium was built to gather all the skills necessary for the success of this project. The objective needs the cooperation of all of them: none of the teams is able to achieve the objective alone, and each of them brings out part of the needed expertise. The project joins 4 partners together: CRIL, LERIA, LIRMM, LSIS and combines complementary skills in different domains of Artificial Intelligence (AI), more specifically in knowledge representation and reasoning, logic programming and semantic web.

The participants from CRIL will build on their results on fusion, inconsistency and uncertainty handling to address the problem of multisource fusion and uncertainty handling. The research interests of participants from LERIA focus on logic programming with stable models semantics, namely ASP, They have developed the ASP solver ASPeRIX. The members of LIRMM bring skills on knowledge bases query answering with logical or graphical languages, more specifically description logics, rules and semantic web languages. The participants from LSIS bring competences in description logics, exception handling, argumentation, revision and fusion with implementation based on standard ASP.

LSIS (Laboratoire des Sciences de l'Information et des Systèmes- UMR 6168 in the Universities of Aix-Marseilles) www.lsis.org chartered in 2002, with more than 100 faculty people in mechanics, control, image processing and computer science, LSIS is one of the France's Computer Science research laboratories offering all the facilities and expertise necessary for this project. In particular the INCA research team is specialized in Artificial Intelligence. INCA team is rated A+ (highest rating) in the latest assessment of the AERES Among its expertises Knowledge Representation and Reasoning constitutes one of the important topics addressed by this team.
Odile Papini and Eric Würbel proposed efficient syntactic methods for revising and merging belief bases and logic progams. They implemented these operations thanks to ASP. Together with Pierre Drap they experimented their approaches on real scale applications on 3D surveys within the framework of the European VENUS project (ECAI 2008, ECSQARU 2009, Applied Intelligence 2010).
Farid Nouioua developed a complete system of causal reasoning about textual descriptions (reports on car-crash accidents) based on nomonotonic inferences and implemented it in ASP (Articial Intelligence Journal 2009, TI ME 2008, SUM 2008). He started recently working with Vincent Risch who has long standing research activity in argumentation, about argumentation theory and its relationship with logic programming (ICTAI 2010, SUM 2011, ICAART 2012). More recently Safa Yahi which research interests are inconsistency handling and inference, knowledge base compilation (IJCAI 2007, KR 2008, JAR 2009) joined LSIS and since her PHD was co-supervised by Salem Benferhat and Sylvain Lagrue she is a natural link between CRIL and LSIS.

CRIL(Centre de Recherche en Informatique de Lens – www.cril.univ-artois.fr).
The CRIL is a research laboratory of the Artois University. It is associated with the CNRS and labeled CNRS UMR 8188. It is composed of more than fifty members (including PhD students). The unifying research theme addressed by the CRIL is symbolic artificial intelligence and its applications. The main research axes are:
* Handling of imperfect, dynamic, contextual and multi-source information (key words: knowledge representation, uncertainty handling, information fusion, belief revision…)
* Algorithms for inference and decision making (key words: satisfiability problems SAT and CSP, search, heuristics…)
The CRIL is rated A+ (highest rating) in the latest assessment of the AERES.
The CRIL members involved in this project have a long experience in development of formal models for reasoning under uncertainty. They have been extensively working in inconsistency handling, data fusion, belief revision with applications of description logics to alert correlation. In particular, CRIL is at the origin of the work on rational postulates for knowledge fusion (Sebastien Konieczny's works). CRIL members (Salem Ben logics for reasoning under incomplete information and deveoping logics for composition of services issued from multiple sources with an anaylsis of their complexity. CRIL members (Salem Benferhat and Sylvain Lagrue) are also experts on reasoning within possibility theory and are the first who proposed solutions for merging uncertain bases when uncertainty scales are incommensurable. The CRIL has also contributed to algorithms for reasoning from weighted logics and proposed solutions for compiling possibilistic logic bases.
The CRIL members (see attached CV) in this project have published in all major international journals and conferences in artificial intelligence (AIJ, AAAI, IJCAI, KR, UAI, ECAI, etc) and served as senior program committee members or program committee members of all main conferences in Artificial Intelligence. They are also PC-chairs of several specialized national conferences (LFA'2008, IAF) or international conferences (Ecsqaru, SUM, NMR, etc).

LERIA / ICLN team
http://www.info.univ-angers.fr/leria/
http://www.info.univ-angers.fr/leria/icln.php
The LERIA (Laboratoire d'Etude et de Recherche en Informatique d'Angers – UPRES EA 2645) gathers all researchers in Computer Science of the Angers university (35 researchers including PhD students). It received an A from the AERES in 2007 and 2011.
ICLN is one of the two teams of LERIA. Mainly works are on knowledge representation and knowledge based system. The team has an important expertise on ASP, QBF, and conceptual graph languages and systems. One important point of the team is to associate theoretical works on formalism and algorithms with practical developments to validate them. Publications take place in high quality journal or conferences of the domain, like Artificial Intelligence journal, AMAI, IJCAI, ECAI, ICTAI.
The project is in line with the goals that the team wants to promote: high quality research on knowledge representation and algorithms, developing collaborations with others teams on related subjects, facing new challenges on knowledge representation and decision. The project will benefit from our expertise on ASP and validation knowledge.
Laurent Garcia, Claire Lefèvre and Igor Stéphan are working on ASP and its extensions. Claire Lefèvre works on the first-order solver ASPeRiX, Laurent Garcia on extensions of ASP (uncertainty) and Igor Stéphan on foundations of logic programming. Stéphane Loiseau works on knowledge validation.

LIRMM/GraphIK team
http://www.lirmm/fr
http://www.lirmm.fr/graphik
The LIRMM (Laboratoire d'Informatique, Robotique et Microélectronique de Montpellier, joint unit of CNRS and University of Montpellier 2 - UMR 5506) gathers all researchers in Computer Science, Robotics and MicroElectronics of the Languedoc-Roussillon Region (more than 320 researchers including PhD students). It received an A+ from the AERES in 2009.
GraphIK team, also common to INRIA and INRA, mainly works in the Knowledge Representation and Reasoning domain, with a strong expertise on languages both based on graphs and logics. One of the research challenges currently addressed by the team, and central in this project, is querying large knowledge bases, while taking ontological knowledge into account. The framework developed by the team and grounded on existential rules has proven to be particularly relevant to this challenge. First results have been published at the highest level in Artificial Intelligence (Artificial Intelligence Journal in 2011, IJCAI'11, KR'10, IJCAI'09 to cite the major venues). The framework has also raised interest in the Database and Semantic Web communities: for instance, Marie-Laure Mugnier has given a keynote talk on this issue at RR'11 (International Conference on Web Reasoning and Rule Systems). The team has an experience in software development (cf. Cogui: http://www.lirmm.fr/cogui and Cogitant: http://http://cogitant.sourceforge.net/).
This proposal is in line with the team main scientific directions. For some aspects (complexity and algorithms for fragments of classical first-order logic), it builds on well-established expertise of the team. For other aspects which correspond to new challenges for the team (extension of these fragments to non-classical features), this project gives it the opportunity of initiating new collaborations with major French teams on these topics.

5.2. Qualification du coordinateur du projet / Qualification of the project coordinator

Odile Papini is professor in computer science since 1999. Member of the IncA team of LSIS (UMR CNRS), her research interests focus on knowledge representation and reasoning in Artificial Intelligence. The works she developed from theory to practice mainly concern the formal definition and study of belief change operations (revision, fusion), the effective implementation within the ASP framework, and experiments with specific application to spatial information, geographic information, archaeological surveys information, biometry. She is involved in research in Artificial Intelligence since more than 15 years and her works are regularly published in national and international conferences and journals in artificial intelligence like KR, IJCAI, ECAI, ... (http://odile.papini.perso.esil.univmed.fr/sources/RECHERCHE/publirec.htm)

She created a research group on the topic « Applying Artificial Intelligence to 3D surveys », LSIS transversal project IA3D in 2006.
She has been involved in several European projects with responsibilities:

- the European REVIGIS project, IST-1999-14189, from 2000-2004, where she was responsible of the Task of "tractability issues".
- the European STREP ``VENUS'' no FP6-2005-IST-5, 2006-2009, Virtual ExploratioN of Underwater Sites. URL: http://sudek.esil.univmed.fr/venus/ where she was responsible of Work Package 3.

She co-managed the Pluridisciplinary Thematic Network (RTP 11) "information and intelligence: reasoning and deciding" of department STIC of CNRS from 2002 to 2004.
She is member of the animation team of the group « Fondamental Artificial Intelligence » of French CNRS GDR I3 from 2006. She co-manages the French group « Spatial and temporal representation and reasoning » of French CNRS GDR I3 from 2004. Odile Papini will be significally involved in the project since she will participate at a rate of 60%.

6. ANNEXES / ANNEXES

6.1. RÉFÉRENCES BIBLIOGRAPHIQUES / REFERENCES

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