Reasoning on Hybrid Ontology Using Extended SWRL Rules

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***Abstract*—In this paper we present the principal steps to create a semantic rule which integrates Object Oriented Techniques to the comportment of the concepts.**

The set of rules obtained from the extension of SWRL rules will be posted to Jess Engine using rewrite meta-rules. The reasoning on this combination allows inferring new knowledge and stores it in the knowledge base. We propose an implementation of the method of extending SWRL rules with the adaptation of the different Object Oriented Techniques. The engine executes the transformation of these techniques to the Jess model. Our demonstration clarifies the importance of this kind of reasoning. We use a case study inherent to interpret a check up in preventive medicine.

***Index Terms*—SWRL rules, Reasoning, Object Oriented Technique, Hybrid Ontology.**

I Introduction

One of SWRL's most useful features is its ability to incorporate uses refined built-in libraries. This extension mechanism provides very powerful means of expanding SWRL's expressiveness and increasing the types of the reasoning information using rules. In particular, this mechanism can be used to tackle the issue of data integration, which is one of the central challenges of the Semantic Web. The ability to meet this challenge requires the development of a variety of mapping technologies to allow interoperation between the various formats that will be encountered when developing Semantic Web applications [1] While we embrace this proposal, we will argue in this paper that it is not sufficiently expressive for our own needs, and we have therefore proposed an extension to SWRL [25]. We have proposed an approach for enriching the comportment (behavior) of the concepts of an ontology with rules [2]. This enrichment is done through the two manners: 1) Binding attributes and roles of concepts with conditions, 2) Creating rules to combine the individuals and the atoms of concepts. The latter is, in a large scale, in literature.

This internal and external enrichment of the concepts of an ontology give rise to hybrid antologies, which permit amelioration of the reasoning results. To clarify the interest of such reasoning, we apply a case study inherent to interpretation of check up in preventive medicine, using the standard and current tools of semantic Web.

In this paper we present a prototypical implementation of our approach which integrates the rules inside a concept using Object Oriented Techniques and the Jess[1] reasoning engine. Our integration allows posing a query to a knowledge base using an nRQL language[26]. We assume that the hybrid ontology which is handled can contain both OWL axioms and SWRL rules and reasoning with extended SWRL rules.

During the development and research process, we have proposed and implemented two main methods of transforming OWL ontologies and SWRL rules into rules expressed in Jess language. In this work, we are focused on the implementation and the evaluation of the latter methods.

The paper is organized as follows. In the next section, we detail the approaches and strategies to combine existing OWL DL with another language rules and gave birth to languages such as SWRL, DLP and some work to combine reasoning about OWL and that on SWRL rules. In Section 3 we present the classification of rules. Section 4 has a discussion about some related work. Proposed process and reasoning methods are provided in Section5. Section 6 provides an example evaluation and application to illustrate the reasoning process. Finally, Section 7 contains concluding remarks and future work plans.

II Approaches of Integration of OWL with Language Web of Rule

In this section, we briefly overview the approaches, both practical and theoretical, for the utilization of onto-

[1] JESS : http://www.jessrules.com/

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logical knowledge in rule engines. More details can be found in the surveys [3][4].

2.1. *Interfacing External Ontology Reasoners with Rule Engines*

In this scenario, the rule engine calls an external OWL reasoner, e.g. a DL reasoner, whenever is needed (“on the fly”). The hybrid approaches can be classified into bidirectional and unidirectional. In unidirectional frameworks, the information goes from the ontology reasoner to the rule engine and thus, the ontology knowledge remains unmodified [5][6][7]. In bidirectional frameworks, the ontology predicates can be used both in the body and in the head of rules and thus, the ontology knowledge may be modified [8][9].

2.2. *Mapping Ontology Reasoners on the Data Model of Rule Engines*

In this case, the results of the external OWL reasoner are mapped to the data model that the rule engine supports, e.g. on triple-based facts [10]. In that way, the rule engine can operate without calling further the ontology reasoned (one-time mapping), since all the ontological knowledge exists in its knowledge base.

2.3. *Strong Coupling of Ontologies and Rules*

In this approach, also known as homogeneous, there is no external OWL reasoning module. The ontology semantics are partially mapped on rule formalism [11], e.g. Datalog, that coexists in the rule base with rule predicates, enhancing the expressivity [12]. Therefore, a new reasoner is needed, able to handle the new homogeneous language that emerges [13][14][15][16].

III CLASSIFICATION OF RULES

The rules are necessary to represent knowledge, which is required for various tasks of reasoning or of meta-reasoning. Classification below is a non thorough classification of the rules according to their use on a conceptual level. They are classified according to the role which they play in the various tasks [21]: deductive rules, meta-reasoning rules, connecting rules, mapping rules, querying rules. [22, 23,24]

3.1. *Deductive Rules*

Are needed for inferences based on dependencies between some ontologies properties, such as the transfer of properties from parts to wholes (e.g. a disease located in an organ part, is located in the organ), For a long time, rule-based expert systems have shown the usefulness of deductive rules in health care e.g. for diagnosis, decision making etc.

3.2. *Connecting Rules*

Aare required for connecting ontology to allow reasoning across several domains such as Genomics, Proteonomics, Pathology, for example when searching for correlations between diseases and the abnormality of a function of a protein coded by a human gene.

3.3. *Mapping Rules*

For mapping ontology in information integration, to allow answering queries over heterogeneous sources e.g., patient data scattered in many Hospital Information Systems.

3.4. *Querying Rules*

Expressing complex queries upon the Web or querying heterogeneous sources.

3.5. *Meta-Reasoning Rules*

Are needed to facilitate meta-reasoning, either to support ontologies engineering e.g., acquisition, validation, maintenance of huge reference ontologies, or control of reasoning.

IV LIMITATIONS OF SWRL

The current SWRL specification omits some typical rule language constructs, sacrificing some expressiveness to ensure decidability and/or efficiency. We have previously identified some limitations and workarounds in writing teaching strategies in SWRL; in this work, we directly address these limitations.

- *Flat list*. A SWRL rule body (or head) is a flat list of atoms. No block structure is supported (as there are no constructs that would need them). Note that either of #E or #F would also entail adding block structure.
- *E. Conjunction only*. Disjunction (E1) and negation (E2) are excluded.
- *F. No quantifiers*. Explicit universal and existential quantifiers are excluded. All atoms are implicitly universally quantified.
- *No user-defined functions*. SWRL provides a library of built-in functions for primitive math, string, and date operations. It doesn’t allow an external function to be defined or called (which fails 1.1#C).
- *Assertions only*. A SWRL rule head “makes” its atoms true; the standard implementation is to add these atoms as new facts to the knowledge base. Existing knowledge cannot be changed.[27]

V RELATED WORK

- DLEJena [17] is inspired from the hybrid and homogeneous approach for the integration of rules and ontologies. The architecture of DLEJena has four modules: the first charges the ontology and separates its terminological and assertional parts. The second reasons on the T.box part, the third reasons on the A.box part and the last one, reasons with the help of the applied rules to T.box and A.box parts.
- In [18], the plugin of SWRL Jess Tab is illustrated on the Family ontology rules to show how certain reasoning could be provided for interoperability between SWRL and OWL.
- In [19], the symbolic knowledge is represented in an ontology of the cortical structures. For the representation standard languages of the semantic Web (OWL, SWRL) are used. In order to enrich ontology, it is ex-

tended by Horn clauses. These rules permit to propagate relations and to infer new facts from those existing.

- Alloy [20] is a system for reasoning on an ontology written in OWL and SWRL or SWRL-Fol. It is based on the transformation of OWL ontology and SWRL rules in a program called Alloy's program and its analysis starts from a charged model to verify automatically its uniformity.

VI Discussion

The study of the previous work shows that there are two different, fundamental approaches. The first approach, called homogenous, where the rules and the individuals of the ontology are compiled without separation between them. This leads to a base of facts, compiled in the same inference engine [20]. The hybrid systems are the second approach. They are made of several subsets, each of them treats a different part of the knowledge base and use new formalisms of representation and specific procedures of reasoning [17, 18, 19]. In such systems, the problem of the complementary in answers is asked. Really, if the inference is executed separately with OWL reasoner and an inference engine, some inferences are evidently missed.

Finally the integration of description logic and logic programming is very difficult because these two paradigms are semantically different. Therefore the interoperability between the SWRL rules and the ontology requires a close integration.

The following table summarizes the characteristics of each use case.

For this reasons, this type of integration has limits such as:

- The inferences of rule are based only on the component of rule, since Tbox is not integrated in the knowledge base of rule (for example Jess). Because the knowledge base Jess is incomplete, some inferences are necessarily missed.
- Language LD and of LP are basically and semantically different.
- A loose interoperability between SWRL rules and ontology (OWL LD) is not satisfied; therefore interoperability between the two components requires a tight integration. And to ensure a decidable reasoning, valid and complete it is necessary to obtain a Web rule language which has a very clear semantics.

In conclusion of these studies, the following table summarizes the characteristics of each use case.

Table 1.
Different types of rules and integration approaches used for each case study

Use Case	**Rule types**	**Integration Approaches**
DLEjena[17]	Meta-reasoning, Deductive	loose (limit of Mapping)
FamilyOntology[18]	Meta-reasoning, Deductive	loose (limit of Mapping)
Medical ontology[19]	Deductive	Extension of OWL LD with rules
Alloy [20]	Deductive, Mapping	Extension of OWL LD with rules

In [2] we are interested in complete answers of a hybrid system by proposing an approach that allows enriching the comportment of concepts. This enrichment is done via rules reasoning on the attributes. Concretely, we propose a complete process of creation a rules base to the terminological part of ontology.

VII Proposed Reasoning Methods

In this paper we will introduce the new extension of SWRL from another angle to illustrate what makes it different, and why we believe that it provides good solutions to many real-world requirements. Our main point is that this extension (it extension and its formal definition in [2]) is borrowing good practices from object-oriented programming and modeling languages and integrates object-oriented techniques with the flexible architecture of Semantic Web to produce a new way of working with linked data.

A key contribution of this new kind of rules is to introduce a mechanism that allows users to organize those SQWRL (Semantic Query Web Rule Language) queries in a natural, object-oriented way. These rules are not just plain lists of rules like in comparable rule languages (SWRL etc). That you can arrange the rules in the class hierarchy where they belong. This follows the Object-Oriented principles of abstraction and encapsulation. Since the rules (and constraints) are attached to classes, any human or agent who looks at the ontology can quickly understand the meaning of the classes and properties. Furthermore, the rules are "scoped" so that tools are better guided when they need to execute the rules and constraints.

Our main goal of this work is to research novel reasoning techniques which allow for efficient reasoning in hybrid ontology. A Hybrid ontology is an ontology enriched by SWRL rules. this enrichment is effected by two ways.

1. Connect the attributes and roles of the concept which rules that adapt the object-oriented programming techniques. At this level we propose to enrich the language SWRL by adding new keywords.

2. Combine individuals with simple SWRL rules.

We have led to the development of highly optimized systems that support efficient reasoning. This novel reasoning methods and techniques which improve the efficient reasoning. It will present in the following architecture.

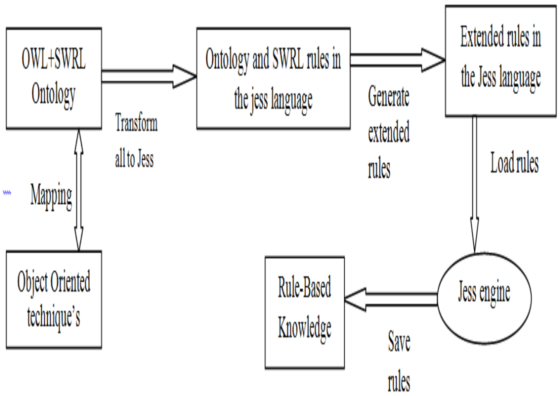

Fig. 1. The Reasoning Process

The Figure 1 concentrated to make clear the reasoning part in the system proposed in [2]; it presents the integration schema of an OWL ontology with SWRL rules, Object Oriented Techniques and the Jess engine. We assume that the ontology is in the Horn SHIQ language and contains SWRL rules (Horn-like clauses). Such OWL+SWRL ontology is transformed into a set of rules in the Jess language. The set of rules is stored as a Jess script file (*.clp). The script is then transformed into a set of extended rules (ExRScript.clp).

Our tool is implemented in Java language; its module provides the following functionalities:

- Reading OWL ontology (and viewing of concepts/roles hierarchies; These hierarchies are calculated by the RACER engine) and Jess scripts, Jess scripts generation (forward and backward chaining, extended rules, Horn-SHIQ transformation) from OWL ontology
- Mapping between ontology concepts/roles and Object Oriented techniques
- Executing a Jess query which consists of the concepts and roles from OWL ontology or templates defined in Jess language,
- Rule-based inquiry answering methods: hybrid and extended rules, Jess engine reasoning management (in forward and backward chaining).

7.1 SWRL extension to Jess Transformation Methods

The proposed tool supports two main methods of transforming OWL ontologies and SWRL rules into rules expressed in Jess language: Simple and Horn-SHIQ.

7.1.1 The Simple Method

This method transforms taxonomies of concepts and roles into Jess rules. These taxonomies are calculated by the RACER engine first. SWRL rules and SWRL extension predicates are also transformed into rules and Jess expressions. The simple transformation can be done in the following modes:

- Jess script assigned to forward chaining.
- Jess script assigned to backward chaining.
- Jess script assigned to forward chaining with extended rules.

7.2.2The Horn-SHIQ Transformation

The Horn-SHIQ transformation method is an extension of the simple one. In this case, additional rules are generated according to OWL axioms. Rather than transforming the semantics of the OWL language into rules we create rules according to this semantics and a given ontology.

VIII EVALUATION EXAMPLE

To validate the preceding methods, we use a preventive medicine domain ontology. In this demo we present an example where we start with a simple ontology (conceptualization steps [2]). It defines a class Person with the following characteristics:

Person is a class that has five properties. The values of Weight, size, sex, age and BMI (Body Mass Index), are specified by the user, and the new SWRL rule is used to compute and calculate the value of the BMI (The Body Mass Index is a measurement tool that compares your height to your weight and gives you an indication of whether you are overweight, underweight or at a healthy weight for your height) property by using the following formula: weight in kilograms divided by height in meters squared (weight (kg) / [height (m)]2). Let's have a look at the rule first. We need to add a new keyword as SWRL rule attached to a class using the CONSTRUCT rule for example to do mathematical calculations.

Whenever someone changes the of values size weight, then the value of BMI will update automatically, as shown with the following figure the editing of rule Construction on Protégé.

Fig. 2. Rule Construction

We use the built-in bridge to create the new concepts (keywords). It provides a mechanism for defining and dynamically loading built-in implementation written in Java [2].

Having edited the rules, we convert the rules to Jess by opening the “rules-only” .owl file. This automatically invokes XSLT, SweetRules, and rule transformations in Jess to achieve the conversion, detects which rules have changed, and updates only those rules in Jess’s working memory.

A key contribution of this new kind of rules is not just plain lists of rules like in comparable rule languages (SWRL etc). That you can arrange the rules in the class hierarchy where they belong. This follows the Object-Oriented principles of abstraction and encapsulation. Since the rules (and constraints) are attached to classes, any human or agent who looks at the ontology can quickly understand the meaning of the classes and properties. Furthermore, the rules are "scoped" so that tools are better guided when they need to execute the rules and constraints.

The use of the Rule Construction is presented in the figure 3.

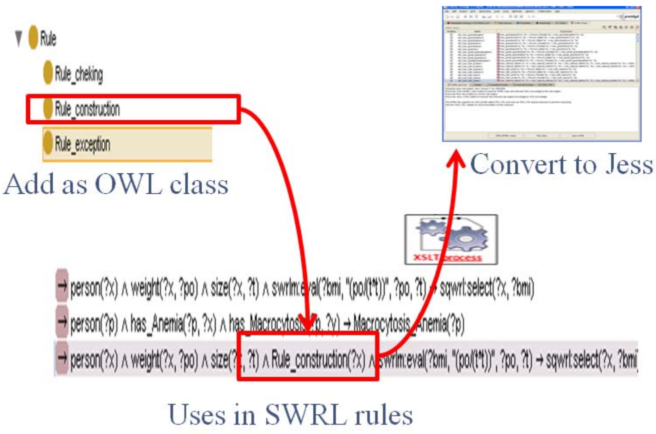

Fig. 3 Using RuleConstruction to Create Datatype Property

In this case we use Jess as our primary inferencing engine. Consequently we need to convert SWRLp rules into Jess syntax. The XSLT script to perform this operation is quite similar to the swrlp2prolog script.

The following is the code for the rule Construction as generated by swlp2jess.xsl:

```
(defrule RuleConstruction
(Patient(Name ?x))
(weight (?x ?w))
(size(?x ?s))
(bind ?s (* ?s ?s))
(bind ?BMI (/ ?W ?s))
 => assert (?BMI (?x ?BMI)))
```

When the system execute the rule construction, the BMI data property well be created in the Person concept, then the reasoning inside the concept we are permitted to create a new data property in the same concept Person.

The Person concept is enriched by the new data property (BMI), which is can be inherited. The following figure represents the BMI calculated for each person.

?x	?bmi
Nassima	40.0
Fateh	19.37716154272828
souad	20.0

Fig.4. Create and Calculate the BMI

Our system comes with a mode in which it does incremental inferencing. This means that whenever someone changes the values of width or size, then the value of BMI will update automatically, as shown with the example instance below:

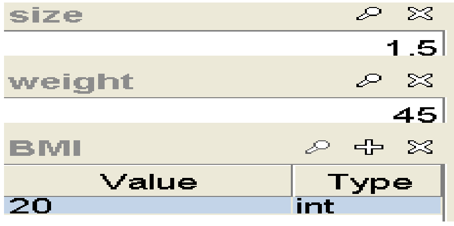

Fig.5. Update Automatically the BMI

To verify user input, and to provide warnings if values violate a constraint; we will add the constraint definitions to the editing tool. These tests can be performed very efficiently, only on the instance that the user is currently looking at.

IX Conclusion and Future Work

The reasoning on ontologies uses simple inference engine. But in view of insufficiencies of the supported languages, ontologies are extended by SWRL rules. We assess that SWRL isn't expressive enough to write rule's sets for inherent to interpretation of check up in preventive medicine. So we have estimated extending SWRL rules. We have also demonstrated a syntax-based extension to SWRL that supports more flexible and expressive rules.

In this paper we have presented a reasoning process, who adapted the proposed reasoning methods witch its goal is to convert SWRLp rules into Jess syntax. We have explained the motivation for this reasoning mechanism, provided an example of its use, offered some cases concerning the XSLT transformation scripts and described the rule construction and rule exception that have been developed thus far.

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