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What reasoning support for Ontology and Rules? the brain anatomy case study

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Abstract. This paper presents a medical case study, which requires reasoning with an OWL ontology extended by rules. The application aims at assisting the labeling of some brain cortex structures identified in MRI images. A simplified example is provided to illustrate the need for supplementing OWL with rules, for reasoning over such hybrid knowledge, and showing potential issues with doing that. Then, we describe some of the available techniques and implementations for reasoning over hybrid systems and discuss potential tools that might be considered for this application.

1 Introduction

As Protégé-OWL has been complemented with a SWRL editor, it permits editing both SWRL rules [12] and OWL ontologies. Hence an important question now arises: what reasoning support should be provided for SWRL+OWL? In some applications, rules are devoted to a specific task, which can be achieved independently of the ontology. In such cases it is possible to use two distinct languages with specific inference engines, one for the structural part (e.g. OWL DL for the ontology) and another one for the rule component (e.g. SWRL or other rule or logic programming language). However, other applications need rules to extend the expressiveness of OWL and require reasoning with rules in *conjunction* with the ontology for problem solving. This case of "hybrid" systems or languages is more complex because of decidability and complexity issues. As mentioned in [12][14], the combination of OWL DL and rules is undecidable. Thus, reasoning support for SWRL+OWL is an important issue, however it is also a difficult problem that should be carefully addressed.

This paper presents a medical case study, which precisely requires reasoning with an OWL ontology complemented with rules. The application aims at assisting the labeling of the brain cortex structures in MRI images. The system being developed

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relies on two components: an ontology for dealing with the structured knowledge i.e. the main brain entities and properties, and a rule base for representing the interdependencies between the properties. After introducing the application (§2), a simple example illustrates the need for supplementing OWL with rules and for reasoning over such hybrid knowledge, showing potential issues with doing that (§3). Section 4 presents some language requirements issued from this case study. Then, we describe some existing techniques and implementations for reasoning over such hybrid knowledge and discuss potential tools that might be considered for it (§5).

2 The application

The general framework is sharing anatomical knowledge (ontology and rules) and tools (services) needed in the context of neuroimaging, applied both to medical practice, i.e. decision support in neurology and neurosurgery, and to research about neurological pathology such as epilepsy, dementia, etc. The application aims at developing new methods for assisting the labeling of the brain cortex structures - sulci and gyri - in MRI images. Indeed, the brain cortex can nowadays be automatically segmented as a whole but the problem remains to identify its various parts. Numerical tools previously developed at IDM provide a list of items corresponding to the gyrus parts and sulcus segments separating them, recognized in the images. Each item is associated with a set of features: (1) attributes depicting intrinsic properties, such as the length and depth of a sulcus segment, or the surface of a gyrus part, (2) binary relationships, such as the neighborhood of two gyrus parts, the connection of two sulcus segments, (3) n-ary relationships such as the separation of two gyrus parts by a sulcus segment. However, as they are generated by numerical tools, such items are unlabelled. The approach proposed to assist their labeling relies on a brain ontology (§ 2.1) storing the a priori "canonical" knowledge [20] about the most important sulci and gyri, and on a rule base (§ 2.2) describing the dependencies between the properties of the brain cortex structures. Documentation about the ontology and the rules was prepared for the W3C Workshop on Rule Languages for Interoperability [9] and is available at http://idm.univ-rennes1.fr/~obierlai/anatomy/annexes/index.html.

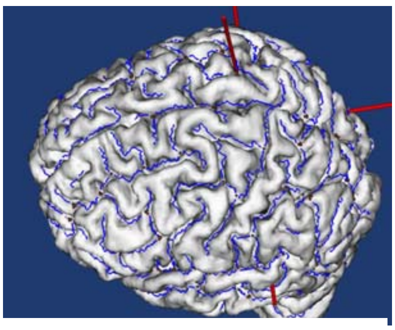

Figure 1 a view of the brain surface, reconstructed from MRI images ; the external traces of brain sulci are represented in blue

2.1 Ontology of brain cortex anatomy

The main entities in brain anatomy are "material entity" and "sulcal folds", and the main relations are "part of" and "bounded by". Material entities are composed of several parts, separated by sulcal folds or other lines. For example, the brain is

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composed of two “hemispheres”, separated by a deep fissure called “longitudinal fissure”. Each hemisphere is divided into several “lobes” separated either by fissures named “sulci” or conventional lines. For instance, the Central Sulcus separates the Frontal Lobe and the Parietal Lobe. Each lobe is composed of gyri bounded by sulci. A gyrus may be composed of parts, called “pars”, also separated by sulci. For instance, the Inferior Frontal Gyrus is composed of Pars Opercularis, Pars Triangularis and Pars Orbitalis. There are different types of connections between gyri: conventional separation, pli de passage, and operculum. An informal ontology of the brain cortex anatomy has been achieved by O. Dameron at IDM [3] to capture this structured knowledge about the entities and their properties. An HTML document providing its description is publicly available[1]. The classes and properties of the ontology are defined as follows:

Classes: the root is the primitive class `AnatomicalEntity` (AE) from which stem two subtrees: `MaterialAnatomicalEntity` (MAE) denoting brain entities made of material such as gyri, opposed to `NonMaterialAnatomicalEntity` (NMAE). MAE includes several subclasses representing the main material anatomical entities: `Hemisphere`, `Gyrus`, `Lobe`, `Pars`. NMAE includes `SulcalFold` (SF) denoting sulcal folds between material entities such as sulci, `GyriConnection` denoting a connection between two gyri such as `ConventionalSeparation`, and `SulciConnection`. All siblings classes such as `Gyrus`, `Lobe`, `Hemisphere`, etc. are disjoint. In addition to these general domain entities, a specific class named “Patch” is defined for the application so as to represent the parts of gyri isolated in the images.

Properties: in addition to the subsumption relation, mereological and topological properties are defined in the ontology. Mereological properties concern part-whole relations between anatomical entities. Topological properties concern neighborhood relations. For each property, e.g. `hasAnatomicalPart`, its domain range, inverse or equivalent relation if given, its logical characteristics: transitive and symmetric, its global cardinality: functional and inversefunctional are specified.

For several reasons, mainly needs of reusability by several applications and of sharing it, this ontology is being extended and migrated from its XML representation to OWL-DL. Taking advantage of the DL powerful inference services is

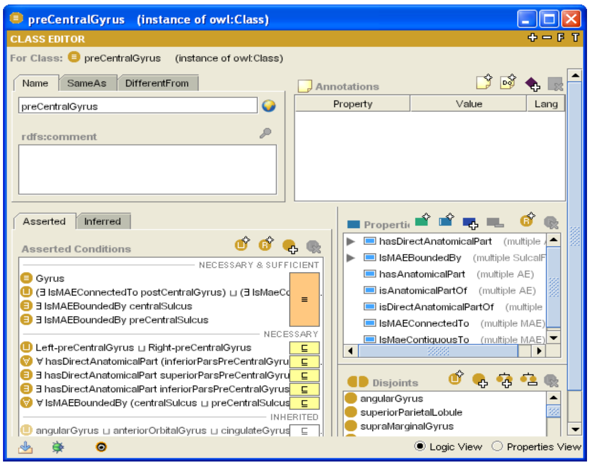

Figure 2: OWL definition of PreCentralGyrus

[1] http://idm.univ-rennes1.fr/~odameron/anatomy/abstractModel/index.html

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another strong ground. Migrating the Brain ontology to OWL DL will surely provide the same benefits of DL reasoning services as those already obtained in converting the FMA into OWL DL [8], in particular for reclassifying classes, checking consistency or completing the ontology.
The recurrent issue is to decide how to enrich the ontology with logical axioms, and in particular what class descriptions to specify for the *defined classes*. Defined classes may have several necessary and sufficient conditions, and privileging some classes equivalent definitions may depend on the reasoning required for each application [8]. In this particular one, due to the nature of the queries and of the facts extracted from the MRI images, which concern topological rather than mereological relations, it seems more relevant to define the classes of the gyrus subtree from their boundaries: each gyrus class definition is based on the restrictions of topological properties, such as `isBoundedBy, isConnectedTo` (Figure 2). But other applications may have advantage to use other definitions, for example defining a gyrus from its direct anatomical parts (pars).

2.2 Rules

For assisting the labeling of sulci and gyri identified in the MRI images, an OWL ontology alone is not enough. Indeed, rules are needed to express:
- *Dependencies between ontology properties*. Rules are required to capture the relationships between the mereological and topological properties, for example to express that two entities are connected when they have a common boundary (ex. R1).
- *Dependencies between ontology and other domain predicate*. Rules are required to capture relationships not only between ontology properties, but also relationships to other domain properties. For example, a rule is useful to express the continuity (contiguity) of two entities from a connection or separation relationship (R2-R3). Propagation of a property along another is also often needed: part-whole relations play a central role in anatomy and are crucial for this application. Different part-whole relations are involved, e.g. `hasAnatomicalPart, hasSegment` which have different semantics. Depending on the part-whole relation and on the considered property, some properties are inherited through the part-whole relation, under particular conditions. Rules play the role of axioms providing the semantics of the part-whole relations related to the topological propagation (R4).

Examples

1. A rule is needed for expressing the relationship between the two ontology properties `isMAEConnectedTo` and `isMAEBoundedBy`:
   Two MAE entities having a shared boundary are connected.
   R1: `isMAEConnectedTo(?x1,?x2) ← isMAEBoundedBy(?x1,?x3)`
   `∧ isMAEBoundedBy(?x2,?x3) ∧ MAE(?x1) ∧ MAE(?x2)`
   `∧ GyriConnection(?x3)`

2. A rule is needed for representing the relationship between the ternary predicate `connectsMAE` and the ontology property `isMAEConnectedTo`:

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Two MAE entities having a shared connection are connected
R2: `isMAEConnectedTo(?x1,?x2) ← connectsMAE(?x3,?x1,?x2) ∧ MAE(?x1) ∧ MAE(?x2) ∧ GyriConnection(?x3)`

3. Expressing symmetry in the ternary predicate `connects` also requires a rule:
An entity connecting two entities x1 and x2, connects x2 and x1
R3: `connects(?x3, ?x2, ?x1) ← connects(?x3,?x1,?x2) ∧ AE(?x1) ∧ AE(?x2) ∧ AE(?x3)`

4. A rule is needed for expressing the propagation of a separation along part-whole relationship:
A sulcus having a segment separating two material entities separates them too
R4: `separatesMAE(?x1, ?x2, ?x3) ← separatesMAE(?y,?x2,?x3) ∧hasSegment(?x1,?y)∧Sulcus(?x1)∧MAE(?x2)∧MAE(?x3)∧SF(?y)`

- *Queries*. Rules are also useful to express queries. Queries consist in finding, for given parts m_i of gyri of a region under study, all the possible instances of gyri they are part of (with eventual additional constraints):

$$Q\ (?x_1,\ \ldots,\ ?x_n\ ) \leftarrow \bigwedge_{i=1\ to\ n} AE(?x_i) \wedge hasPart(?x_i, m_i)$$

Some of these rules, e.g. R1, can be represented in SWRL and vizualized with the SWRL Editor (Figure 3), but other ones cannot, e.g. R2, R3, R4, since they involve non DL predicates.

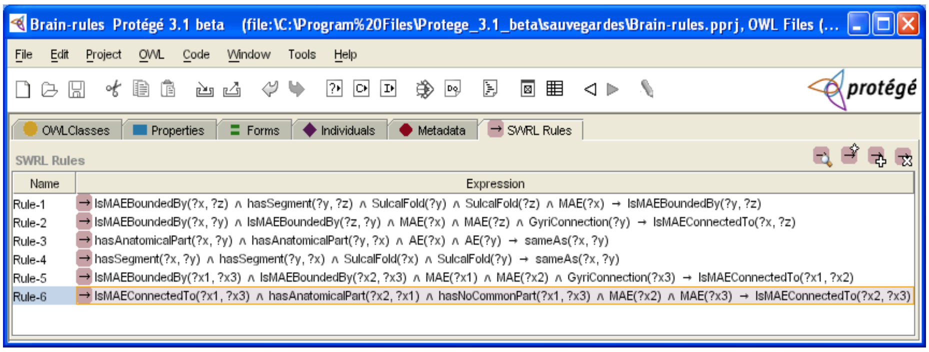

Figure 3: SWRL Rules

3 Example of reasoning

The simplified example below is proposed to give a flavor of how problem solving might be obtained in reasoning with the rules and the ontology. Let be m1 and m2 two “patchs” of the region under study, i.e. two gyrus parts to be labeled. Assume that at the current step of resolution we know that m1 is bounded by the Central Sulcus, the

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PreCentral Sulcus and that there is a connection between three items: `m2`, a gyri connection `op`, and the PostCentral Gyrus. The instances of the anatomical structures specific to the brain image under study are denoted by mark 0, for example the particular instance of `CentralSulcus` for the considered image is respectively `cs0`, of `PostCentralGyrus` is `pcg0`, of `PreCentralGyrus` is `g0` etc. The current facts are initial facts asserted by the user or facts derived at the current step of the resolution and facts issued from the ontology:

- Current facts $\mathscr{F}$

```
F1.   hasPart(g1,m1), gyrus(g1)
F2.   hasPart(g1, m2)
F3.   isBoundedBy(m1,cs0)
F4.   isBoundedBy(m1,pcs0)
F5.   connects(op,m2,pcg0)
F6.   centralSulcus(cs0)
F7.   preCentralSulcus(pcs0)
F8.   postCentralGyrus(pcg0)
F9.   gyriConnection(op)
F10.  all other individuals and
      relations of the ontolgy O e.g.
      preCentralGyrus(g0)
```

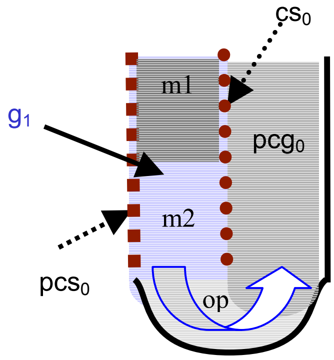

Figure 4 Case under study

- Query

Let be the query "find all the possible instances of gyrus which m_1 and m_2 can be part of " expressed by the rule:
$Q(?x_1) \leftarrow Gyrus\ (?x_1\ ) \wedge hasPart\ (?x_1, m_1) \wedge hasPart\ (?x_1, m2)$

- Knowledge base

(1) Rule base $\mathscr{R}$	(2) Ontology $\mathscr{O}$
R1:isBoundedBy(?x,?y) ← hasPart(?x,?z) ∧ isBoundedBy(?z,?y) R2:isConnectedTo(?x,?y) ← hasPart(?x,?z) ∧ isConnectedTo(?z,?y) R3:isConnectedTo(?x,?y) ← connects(?z,?x,?y)	PreCentralGyrus ≡ Gyrus ⊓ (= 1 isBoundedBy CentralSulcus) ⊓ (= 1 isBoundedBy PreCentralSulcus) ⊓ (= 1 isConnectedTo PostCentralGyrus) ⊓ (∀ isBoundedBy CentralSulcus ⊔ PreCentralSulcus) ⊓ …

Figure 5: Rules and ontology

The knowledge base is composed of two parts, rules and ontology (Figure 5). The deduction process relies on rules inferences combined with ontology inferences, as described below. First, from the facts $\mathscr{F}$ the rules $\mathscr{R}$ derive new facts: rule R1 propagates boundaries from part to whole, R2 propagates connection, R3 enables to deduce connected entities. For example, rule R1 entails `isBoundedBy(g1,cs0)` from facts F1, F3 (resp. `isBoundedBy(g1,pcs0)` from facts F1, F4). Thus, $\mathscr{F} \cup \mathscr{R}$ entails

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$$\begin{cases} \texttt{gyrus}(g_1) & \\ \texttt{isBoundedBy}(g_1, cs_0) & [R1] \\ \texttt{isBoundedBy}\ (g_1, pcs_0) & [R1] \\ \texttt{isConnectedTo}(g_1,\ pcg_0) & [R2,\ R3] \end{cases}$$

Then, reasoning with the ontology $\mathcal{O}$ enables to identify which class g_1 is an instance of. As gyrus(g_1) ∧ isBoundedBy(g_1,cs_0) ∧ isBoundedBy (g_1,pcs_0) ∧ isConnectedTo(g_1, pcg_0) is verified, the sufficient condition to be a PreCentralGyrus is satisfied. Hence preCentralGyrus(g_1) is derived. In conclusion, $\mathcal{F} \cup \mathcal{R} \cup \mathcal{O}$ entails preCentralGyrus(g_1) and it is possible to answer the query from the rules and the ontology.

This example was voluntarily adapted for illustrating how the solution can be obtained in computing the consequences from the knowledge base. A named individual g1 was introduced for representing the gyrus having part m1, i.e. the facts gyrus(g_1), hasPart(g_1,m_1) have been added, where g_1 is one among the 100 known individuals of Gyrus in $\mathcal{O}$[2]. It is precisely these facts that permit to apply the rules. But in fact, the exact information extracted from the image is only the presence of a patch m_1, that is a part of some gyrus (to be identified). This should be represented in extending the ontology by a class Patch defined by Patch ≡ MAE ⊓ (∃ isAnatomicalPartOf Gyrus) with an instance m_1 of Patch (or adding a rule with an existential in head). Besides, the PreCentralGyrus definition is also simplified. Indeed, its third restriction (∃ isConnectedTo PostCentralGyrus) is true only in 75% cases, and should be replaced by a disjunction (∃ isConnectedTo PostCentralGyrus) ⊔ (∃ isContiguousTo PostCentralGyrus). Thus in reality, existential and disjunction occur in the class equivalent definitions of the ontology. Let be $\mathcal{O}'$ the ontology added with the Patch definition and $\mathcal{F}'$ the same facts as $\mathcal{F}$ apart F1 which is replaced by Patch(m_1). Then, although $\mathcal{F}' \cup \mathcal{R} \cup \mathcal{O}'$ also entails the expected result, computing ontology inferences and applying the rules *separately* as before, will not produce it, since the rules could not be fired from the facts explicitly known. This is a well-known problem, clearly identified by [4] [17] and [15] who explains why usual inference mechanisms are inadequate for hybrid languages: “a KB may entail the antecedent of a rule without the antecedent being instantiated in the KB”, which is precisely the case here. Second, “a KB may entail the disjunction of antecedents of two rules without entailing either of them”.

[2] ignoring laterality, in fact 200 for the entire brain

4 Language requirements

We need for this application an Ontology language that offers OWL DL expressiveness, extended by qualified cardinality constraints. OWL DL expressiveness is at least needed (∃ and ⊔ occur in class definition). OWL DL was selected, as said earlier (§2.1) to benefit of DL reasoning services (consistency checking and automatic classification) and because OWL DL reasoners are available e.g. Racer [11], Pellet[3]. But as already exhibited with brain examples [6] and more recently with the FMA migration to OWL DL [8], its extension by qualified cardinality constraints would be particularly useful in anatomy for defining structures from their parts, or from their boundaries, or combinations of both. For example, they are needed to represent in OWL-DL an 'hemisphere' as an anatomical entity whose direct parts are lobes, each part being of a distinct type (i.e. frontal lobe, parietal lobe, occipital lobe, limbic lobe, temporal lobe), or similarly to express that a precentral gyrus is bounded by exactly one precentral sulcus, one central sulcus, and is connected or contiguous to one postcentral gyrus. Additionally, we need OWL DL to be extended by a Web rule language that offers at least Datalog rules. DL extensions such as $\mathcal{SHIQ}$ added with Role Inference Axioms [13] limited to the form $P \circ Q \subset P$, are not sufficient for this application. For example, the "triangle" rule R1 (§2.2) `isMAEBoundedBy(?x, ?y) ∧ isMAEBoundedBy(?z, ?y) ∧ MAE(?x) ∧ MAE(?z) ∧ GyriConnection(?y) → isMAEConnectedTo(?x, ?z)` cannot be represented in DL. An extension with some form of rules is required. Moreover, "ordinary" relations not defined in the ontology, also called "non DL" predicates [17] are needed. They occur in rules e.g. R2, R3, R4, queries, or facts, e.g. the ternary predicate `connects`, or the binary predicate `hasNoCommonPart` etc. (cf. online Documentation). Ternary predicates are specially useful for representing the ground facts issued from the information extracted by the numerical tools, e.g. the initial fact `F5 separates(s,m1,m2)` captures the separation relation between a sulcus segment `s` and two gyrus parts `m1 and m2`, or `connectsMAE(op,m,g)` expresses the connection between three anatomical entities. Although it is possible to express a n-ary relationship with unary and binary predicates thanks reification, arbitrary arity is preferred. Hence, SWRL [12] extension is not enough. OWL DL should be extended by a Datalog language supporting ontology concepts and roles in rule bodies or head as unary or binary predicates, and also non DL predicates, in particular n-ary predicates in body and head atoms, and negation in body atoms.

5 Support for reasoning

Hybrid systems are not a new idea. Rules have been earlier added to DL, e.g. in Classic [1] [2]. DL reasoner have been combined with Datalog reasoner, e.g. AL-log [4] [5], Carin [15]. But a particular recrudescence of interest is now noted in the context of the Semantic Web, related to interoperating between rules and the OWL

[3] http://www.mindswap.org/2003/pellet/index.shtml

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standard. Alternative approaches and tools are investigated, including SweetRules[4], OWL2Jess and SWRL2Jess[5] or ROWL[6] translators, SWRL with HOOLET[7], KAON2[8].

A first direction favors decidability through a restriction on the sublanguages or a safe interaction constraint. SweetRules[4] proposes hybrid reasoning with ontologies and rules, based on the DLP fragment of FOL [10]. Defined as the intersection of DL and Horn logic programming, DLP is a decidable language. Several translators are proposed to merge the ontology and the rules within the same programming framework, e.g. Jena 2, Jess etc. For example SweetOnto permits to convert DLP OWL ontologies with RDF facts into SWRL, SweetJena translates the set of all the resulting SWRL rules into Jena 2, which is then executed. The main drawback of DLP is the restriction in the form of axioms: DLP does not support existential quantifier, disjunction, negation in the axiom consequent. According to DLP authors, “extensions to DLP, including extension that treats existential, have already been worked out in a DLP 2 version, based on skolemization.”[9]
Other recent techniques suggest solutions retaining decidability in extending DL with rules, by imposing a “safe” interaction between the DL and rule components, instead of restricting the languages (see [19] for a survey). [17] proposes a decidable extension of OWL-DL with so-called “DL-safe” rules, that is, rules where each rule variable occurs in a non-DL atom of its body. This approach is implemented in KAON2. KAON2 supports the $\mathcal{SHIQ}(\mathcal{D})$ subset of OWL-DL (all features of OWL-DL apart from enumerated classes) and the DL-safe subset of SWRL. Its hybrid reasoner is based on reduction of a $\mathcal{SHIQ}(\mathcal{D})$ knowledge base to a disjunctive datalog program.

A different direction is suggested with SWRL [14], privileging a DL extension with no restriction on the languages nor on their integration, at the price to be no longer decidable. OWL DL is extended by unary/binary datalog rules which atoms are all DL atoms. Reasoning is achieved by a first-order theorem prover. Hoolet supports such an extension and uses Vampire for reasoning.

Meanwhile, other works investigate practical tools based on Jess for reasoning with SWRL. The SWRL editor, associated to the Protégé OWL plugin, has recently been integrated with the Jess rule engine [18]. Sharing some features with the previous SWRJessTab plugin [7], this tool adds new very interesting developments: its interactive editor with a visual interface and the use of the SWRL factory Java API, which makes its integration with Java rule engines easier. But, it also exhibits some limitations. The translation from OWL to Jess is limited, and does not handle all the constructors. Managing conflicts and iterating between Racer and Jess is left to the user. [16] suggests a practical way to extend the translation to all the OWL DL

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[4] http://sweetrules.projects.semwebcentral.org/
[5] http://www.inf.fu-berlin.de/inst/ag-nbi/research/owltrans/
[6] http://mycampus.sadehlab.cs.cmu.edu/public_pages/ROWL/ROWL.html
[7] http://owl.man.ac.uk/hoolet/
[8] http://kaon2.semanticweb.org/
[9] B.Grosof personal communication

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and SWRL constructors. The XSLT OWL2Jess.xsl transforms ontologies from OWL to Jess, SWRL2Jess.xsl translates rules from SWRL to Jess. But, since basically all the OWL constructors, e.g. existential in consequent, *cannot* be translated by Jess rules, these cases are handled by Jess rules asserting caution or error messages. Doing so, as the authors say, their inference service is neither complete nor sound. For example, suppose the ontology has a class A= ∃ `hasChild. Man` and the relation hasChild is verified for some individuals, but no one is asserted to be a man in the KB, then a Jess rule asserts a new fact, which may be false, since based on the Jess random process. In fact, all these tools share a common drawback due to the basic difference of expressiveness of OWL DL and Jess rules. As they are based on explicit facts and an incomplete representation of the ontology in Jess, they may provide wrong answers, as already pointed out. For example for $\mathcal{F}'$ and $\mathcal{O}'$, even after iterations, the output reported by Jess may be failure, although a solution exists (§4).

Several options might be considered for our brain application. A first one would be to transform the original ontology as done in the example, in defining for each patch m_i an explicit individual g_i representing the gyrus of which m_i is part, adding facts hasPart(g_i, m_i), gyrus(g_i) instead of fact patch(m_i), and similar facts for other existential in rhs[10] (for SulcusSegment) and also reifying the n-ary predicates. Remaining in DLP, different tools, e.g. a rule engine like Jess, might be considered. DL-safe Datalog rules and using KAON2 needs further investigation, but may probably be possible too. Another option would be the extension of SWRL-FOL[11] to non DL predicates with arbitrary arity, and to use a FOL reasoner. The applicability of these techniques to our case and the availability of the corresponding reasoners have to be better investigated. We also need to edit our rules. At the moment, the Protégé editor supports SWRL. So we extended the representation of SWRL in Protégé OWL to function-free FOL, introducing the relevant OWL classes according to the SWRL FOL proposal extending SWRL to function-free unary/binary first-order formula, added with non DL predicates of arbitrary arity n (that should be interpreted in the usual manner by relations of arity n over the domain of interpretation). A class NonDLRelation has been defined for non DL predicates, and two disjoint subclasses of Atom, swrl:Atom and NonDLAtom, respectively for DL and non DL atoms. The brain non DL predicates are imported, from an external BrainRelations ontology similar to the built-ins ontology swrlb.owl. Instances of Non DL relations are stored in external files (database or XML file). Extending the present SWRL Editor and the SWRL Factory to handle FOL formula would allow different third-party rule engines to be integrated to the rule editor. If a rule species validation facility was offered to determine the rule language used, then a compliant reasoner. The FOL sublanguage then used would imply a suitable reasoner in each case

[10] which lead to about 100*50 = 5000 combinations

[11] http://www.w3.org/Submission/2005/SUBM-SWRL-FOL-20050411/

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6 Conclusion

As it is impossible to have at the same time, decidability, soundness, completeness, and expressivity, the properties required of the application have to be carefully evaluated, with regards to the guarantees or limitations of the reasoning method, so as to determine the best language to be selected. It would be useful to clarify for the users what properties can be expected under DLP restrictions, when a production rule engine e.g. Jess and a DL reasoner e.g. Racer are used separately. If DLP is not satisfying and OWL DL expressiveness is needed, an OWL DL extension with safe Datalog $^{(\neg\vee)}$ rules, SWRL, or FOL, depending on the expressiveness and computational properties expected, seems to be good options, at that time. It is worthwhile studying which increasingly expressive FOL sublanguages, DLP [10], OWL DL extensions such as safe Datalog [17], SWRL[12], or FOL, and the safe Datalog$^{\neg\vee}$ extension [19] would be the most relevant to be offered to the users. For the brain application, it is perhaps a safe Datalog$^{(\neg)}$ extension.

7 References

1. A.Borgida and P.F. Patel-Schneider. A semantics and complete algorithm for subsumption in the CLASSIC description logic.J.of Artificial Intelligence Research 1:277–308,1994.
2. Brachman, McGuinness et al. Ronald J. Brachman, Deborah L. McGuinness, Peter F. Patel-Schneider, Lori A. Resnick Living with classic: When and how to use a kl-one-like language, 1991
3. Dameron O, Modélisation, représentation et partage de connaissances anatomiques sur le cortex cérébral, Thèse de doctorat d'Université, Université de Rennes 1, 2003.
4. F. M. Donini, M. Lenzerini, D. Nardi, A., Schaerf, A Hybrid System with Datalog and Concept Languages, 1991.
5. F.M. Donini, M. Lenzerini, et al AL-log: Integrating Datalog and Description Logics., Journal of Intelligent Information Systems, 1998
6. Golbreich C, Dameron O, Gibaud B, Burgun A, Web ontology language requirements w.r.t expressiveness of taxononomy and axioms in medecine, 2nd International Semantic Web Conference, ISWC 2003, Sanibel Island, Florida, October 2003, LNCS 2870, Springer. 2003.
7. Golbreich C., Combining Rule and Ontology Reasoners for the Semantic Web, Invited talk, Rules and Rule Markup Languages for the Semantic Web, Hiroshima, Japan, G. Antoniou, H. Boley Editors, LNCS 3323, Springer, 2004.
8. Golbreich C, Zhang S., Bodenreider O. Migrating the FMA from Protégé to OWL, Proc. of the 8th International Protégé Conference, 2005, Madrid, Spain.
9. Golbreich, C., Bierlaire O., Dameron O., Gibaud, B., Use Case: Ontology with Rules for identifying brain anatomical structures, W3C Workshop on Rule Languages for Interoperability, April 27–28, 2005, Washington, D.C., USA.

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10. Grosof B., Horrocks I., Volz R., and Decker S., Description Logic Programs: Combining Logic Programs with Description Logic In: Proc. 12th Intl. Conf. on the World Wide Web (WWW-2003), Budapest, Hungary, May 20-23, 2003.
11. Haarslev V., Möller R. : Description of the RACER System and its Applications. Description Logics 2001
12. Horrocks, I., Patel-Schneider, P., Harold, B., Tabet, S., Grosof, B., Dean, M.: SWRL: A Semantic Web Rule Language Combining OWL and RuleML. Version 0.5 Nov. 2003
13. Horrocks, I, Sattler U., Decidability of SHIQ with Complex Role Inclusion Axioms, Artificial Intelligence Vol 160, Issues 1-2 , Dec 2004, Pages 79-104
14. Horrocks, I., Patel-Schneider P. F., Bechhofer S., and Tsarkov D. OWL rules: A proposal and prototype implementation. Journal of Web Semantics, 2005.
15. Levy A. Y. and Rousset M.-C.. Combining Horn rules and description logics in CARIN. Artificial Intelligence, 104 (1-2):165–209, 1998.
16. Mei, J., Paslaru Bontas, E., Reasoning Paradigms for SWRL-enabled Ontologies, Protégé With Rules Workshop, Madrid, 2005.
17. Motik B., Sattler U. , and Studer R. Query Answering for OWL-DL with Rules, ISWC 2004, LNCS 3298 Springer.
18. O'Connor, M., Knublauch, H., Samson, T., Musen, M. Writing Rules for the Semantic Web Using SWRL and Jess. Protégé With Rules WS, Madrid, 2005.
19. Rosati, R., On the decidability and complexity of integrating ontologies and rules, Journal of Web Semantics, 2005. To appear.
20. Rosse C, Mejino JL, Jr. A reference ontology for biomedical informatics: the Foundational Model of Anatomy. J Biomedical Informatics 2003; 36(6):478-500.