Rules for Transforming OWL 2 Ontology into SBVR

Gintare Krisciuniene[1], Lina Nemuraite[1], Rita Butkiene[1] and Bronius Paradauskas[2]
[1]*Departament of Information Systems, Kaunas University of Technology, Studentu st.50-309, Kaunas, Lithuania*
[2] *Centre of Information Systems Design Technologies,*
Kaunas University of Technology, Studentu st.50-313, Kaunas, Lithuania

Keywords: Ontology, Business Concepts, Business Rules, Representation, Meaning, SBVR, OWL 2, Transformation.

Abstract: Our research is concentrated on defining transformation rules from OWL 2 ontologies into SBVR vocabularies and rules without a loss of information and the expressive power, characteristic for ontologies, overcoming the fact that some ontology-specific concepts have no direct representation in SBVR. Our focus is on generic transformation rules, but the particular attention is devoted to ontologies and vocabularies related with semantic search in Lithuanian Internet corpus. Therefore, we consider some particular constructs related with our application domain, including the idea of creating domain-specific lexical ontologies, related with domain ontologies and capable to support semantic annotating and search.

1 INTRODUCTION

Web Ontology Language OWL 2 (W3C, 2012) is a knowledge representation language, used for sharing a common understanding of a certain domain among computer systems and human experts, and having capabilities for reasoning and querying semantic specifications. OWL 2 is not easily understood by every user. Semantics of Business Vocabulary and Business Rules (SBVR) (OMG, 2013) provides opportunity to describe business concepts and business rules in the structured language, similar to natural language and understandable for human. SBVR is based on formal logics and can be applied for computer processing, but it cannot be directly used in semantic technologies.

Both languages, OWL 2 and SBVR, are created for expressing semantics of the domain, but the development of these languages was inspired by different issues. In result, we have two different metamodels and different sets of tools for semantic processing. The semantically overlapping concepts of both knowledge models has encouraged investigating a possibility of transforming SBVR into OWL 2 and vice versa. The transformation of SBVR to OWL 2 will allow business users to describe domain ontologies using human-understandable language, to prove consistency of business vocabularies and rules by using OWL 2 reasoners, etc. The reverse transformation will allow business users to have a human-friendly interface to ontologies, considering them in business applications (Ghali, 2012) and in semantic search, where SBVR questions in structured language are transformed into SPARQL queries (Sukys, 2012a; 2012b). SBVR to OWL 2 transformation was considered in several works, of which the transformation of (Karpovic et al., 2011; 2012) seems the most comprehensive and suitable for further investigation.

The goal of current paper is to present rules for transforming OWL 2 ontologies into SBVR, compatible with SBVR to OWL 2 transformation (Karpovic, 2012). Both these transformations should be mutually reversible and lossless, and compatible with SBVR to SPARQL transformation, because in semantic search SBVR questions are transformed into SPARQL queries, which are executed in the source ontology (Sukys, 2012a).

Semantic search in our research is directed towards better facilitation of people and organizations to use natural Lithuanian language in the virtual space in their professional and personal activities. Natural language technologies require sophisticated processing algorithms and vast amounts of resources. In the world practice, lexical resources as WordNet, VerbNet, FrameNet, or PropBank are used for relating senses of ontology elements with their verbal representations in semantic annotating and search. The representation

Krisciuniene G., Nemuraite L., Butkiene R. and Paradauskas B..
Rules for Transforming OWL 2 Ontology into SBVR.
DOI: 10.5220/0005076902560263
In *Proceedings of the International Conference on Knowledge Engineering and Ontology Development* (KEOD-2014), pages 256-263
ISBN: 978-989-758-049-9

part of SBVR is similar to what is encompassed by WordNet and other lexical ontologies where various syntactic forms are related to meaning. We had made an assumption (Bernotaityte, 2013; Krisciuniene, 2014) that the lexical ontology for Lithuanian language can be based on SBVR representations and related to SBVR based domain ontology thus making it possible to accelerate the task of creating the lexical resources required for embodying the semantic search techniques for Lithuanian language.

The rest of the paper is structured as follows. Section 2 analyses related work. Section 3 presents a domain ontology example. Section 4 describes rules for transforming OWL 2 ontologies into SBVR. Section 5 presents initial experiments for checking their applicability. Section 6 summarizes conclusions and envisages future research.

2 RELATED WORKS

Currently, there are several research works and prototypes aiming at transforming SBVR business vocabulary and business rules into ontologies (ONTORule, 2009; Karpovic, 2011, 2012; Kendall, 2013; Reynares, 2013); some informal mappings between SBVR and OWL 2 concepts are given in SBVR specification (OMG, 2013). The transformations described in (Karpovic, 2011, 2012) are the most appropriate for our purpose as they are not only comprehensive, bet also take into account aspects specific for our joint research. SBVR to OWL 2 transformations often are defined from the SBVR side: what constructs of SBVR can be represented in OWL 2. Our research needs not only making the SBVR – OWL 2 transformations mutually reversible but also to reflect ontology advantages in SBVR specifications.

The result of SBVR to OWL 2 transformation (Karpovic, 2011, 2012) is the domain ontology based on preferred representations of SBVR concepts. This transformation does not involve synonyms and synonymous forms except a single synonymous form for each verb concept wording, if it is required for specifying business rules and obtaining the corresponding inverse object property. SBVR metamodel does not give possibility for specifying desirable inverse verb concept wordings. For solving this and other similar problems, additional concept types (e.g., inverse verb concept) are described in the special SBVR for OWL 2 vocabulary, which can be incorporated into SBVR vocabularies for transforming them into OWL 2.

(Kendall and Linehan, 2013) define the solid reversible SBVR to OWL 2 transformation without loss of semantic information but the result of reverse transformation does not guarantee an identical original representation, because they transform SBVR synonyms and synonymous forms into OWL 2 annotations. The reverse transformation from OWL 2 into SBVR is not capable to recover the original vocabulary and rules although they remain semantically equivalent. For solving this problem, we propose separating SBVR synonyms and synonymous forms from the domain ontology and creating the lexical ontology based on SBVR representations (Krisciuniene, 2014). Other analysed SBVR to OWL 2 transformations were superficial, e.g., (Reynares, 2013), but the author's idea for preserving information about SBVR partitive verb concepts in ontology is noteworthy, and we are willing to borrow it with the reference to the authors. There was found only one (except our) work dealing with transformation from ontologies to SBVR (Gailly, 2013), however, it was in an initial stage and did not propose some special ideas or experience.

The novelty of our work is that we are aiming at creating SBVR vocabularies by building them upon existing or designed ontologies, and considering creating lexical ontologies, based on SBVR representations, for the complete correspondence and transformation between the transformable subsets of SBVR and OWL 2 elements. Also, we use a few SBVR and OWL 2 extensions for obtaining the reversible and lossless OWL 2 – SBVR transformations.

3 EXAMPLE OF ONTOLOGY FOR SEMANTIC SEARCH

The excerpt from the OWL 2 ontology for Semantic Search in Lithuanian Internet Corpus is presented in Figure 1. The ontology is built on the base of SBVR knowledge model, which presents the metamodel and principles for creating domain specific conceptual schemas (i.e., domain ontologies). The top construct is the abstract "object", which may be any concept, having occurrence in the corpus under investigation. More specific concepts are the agent, location, time and "state of affairs", which, following the SBVR, may be an event, state, activity, circumstance, etc. We focus on the generic model of events, which may be related with an agent, time, location, target and the event type that

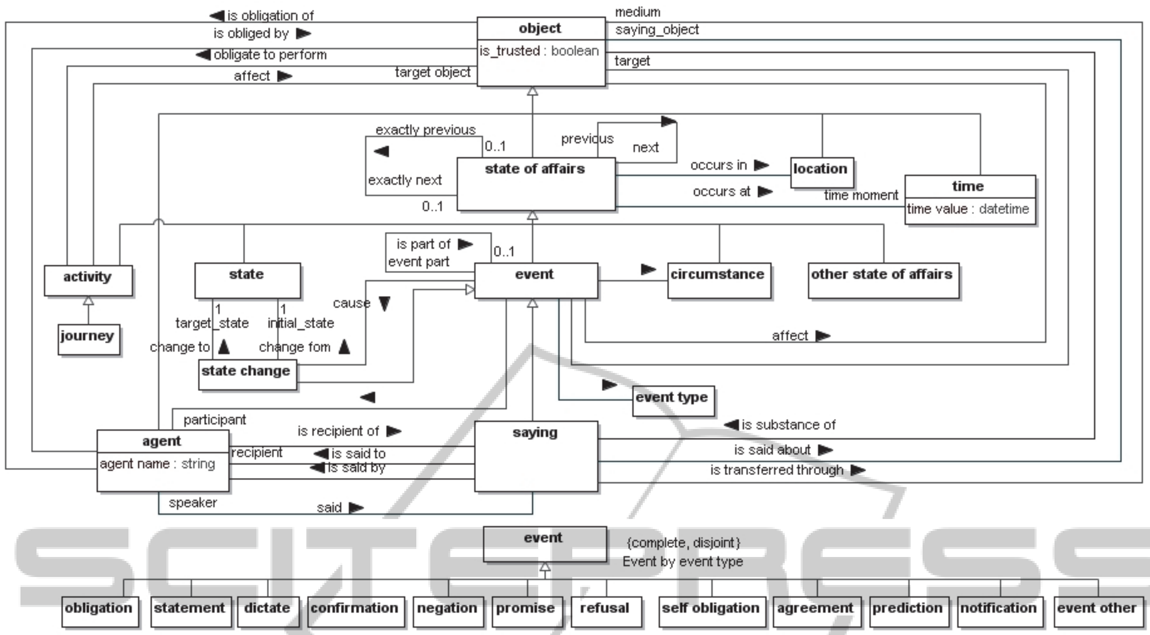

Figure 1: Excerpt from domain ontology for "saying" events (represented as UML class diagram).

allows the multiple categorizations of events, which sometimes is required instead of assigning the unique category. The event is the problematic concept. In a natural language, events are usually expressed by verbs; majority of events represent n-ary relations. SBVR allows describing n-ary relations; however, the OWL 2 is limited to binary ones. For describing n-ary relations in OWL 2, we define the event class (SBVR general concept) objectifying the n-ary relation (SBVR verb concept) and having n relations with other classes (agent, time, location, etc.). The number of roles may vary depending on the type of the event and on completeness of information we have. In our research, SBVR models are limited to binary relations due to difficulties of representing such relations in software models and implementing in CASE tools, SBVR and ontology editors, etc.

There are many ontologies and research works devoted to event models, e.g., (Kaneiwa, 2007), (Scherp, 2009), which describe temporal, spatial, instance, participation, causality, mereology, correlation, documentation, interpretation and other event categories. The event (as well as other objects) may be identified in many Web documents and is important for semantic search. We concentrate on "saying" event, as it is one of the most frequently occurring events in Lithuanian Internet corpus. It is related with speech acts, defined by Winograd and Flores, which mean actions expressed by saying, e.g., obligation, confirmation, agreement, etc. Therefore, we suppose that "saying" is worth for the primary attention in semantic annotating and search, and, therefore, should be analysed first.

4 ONTOLOGY CONCEPTS AND RULES FOR TRANSFORMING THEM INTO SBVR

Main concepts of the OWL 2 are axioms and entities (classes, object properties, data properties, data types and named individuals) (Figure 2). Main SBVR concepts are presented in Figure 3. For SBVR structured language specifications, we use the SBVR style of terms, *verbs*, Names and keywords (OMG, 2013), where terms represent noun concepts (general concepts, roles and verb concept roles); verbs represent symbols used in verb concept wordings (meaning verb concepts) and in statements meaning propositions (facts). Vocabulary entries introduce the primary forms (preferred representations) of SBVR concepts, and can have captioned details, e.g., General concept, Concept type, Synonym or Synonymous form, etc. SBVR vocabulary can be obtained from the OWL 2 ontology, and defined as the individual concept of the general concept "vocabulary". Vocabulary name, namespace and language can be obtained from the ontology name, namespace and language. OWL 2 Annotations can be used to specify additional information in ontology, e.g., comments. We use standard annotation property "label" for human readability of entity names in a vocabulary language (e.g., English, as in the following example, or Lithuanian), and the additional annotation properties, e.g., "vocabularyURI"; "label_sbvr", etc., for specifying entity names in SBVR style that would be useful for transforming OWL 2 ontology into SBVR.

OWL 2 Entities define named elements of the OWL 2 ontology, uniquely identified by their IRIs and declared by the Declaration axioms. OWL 2 Class is transformed into SBVR general concept, ObjectProperty with its domain and range – into verb concept; OWL 2 DataProperty corresponds to the SBVR role, except DataProperty with DataRange 'boolean', which corresponds to SBVR unary verb concept (characteristic).

OWL 2 has a rich set of data types including RDFS Literals, RDF DataTypes, XSD DataTypes and Plain Literals (W3C, 2012). SBVR has just a few elementary concepts (text, URI, number, integer, nonnegative integer, positive integer) that can be used for representing the corresponding OWL 2 data types. However, the SBVR allows extensions. SBVR extension for Data and Time (OMG, 2011) defines various extensions of SBVR elementary concepts for representing dates and time durations. For the OWL 2 – SBVR transformation, we have introduced into SBVR boolean and date_time as the most necessary elementary concepts. Further extensions can be added as necessary.

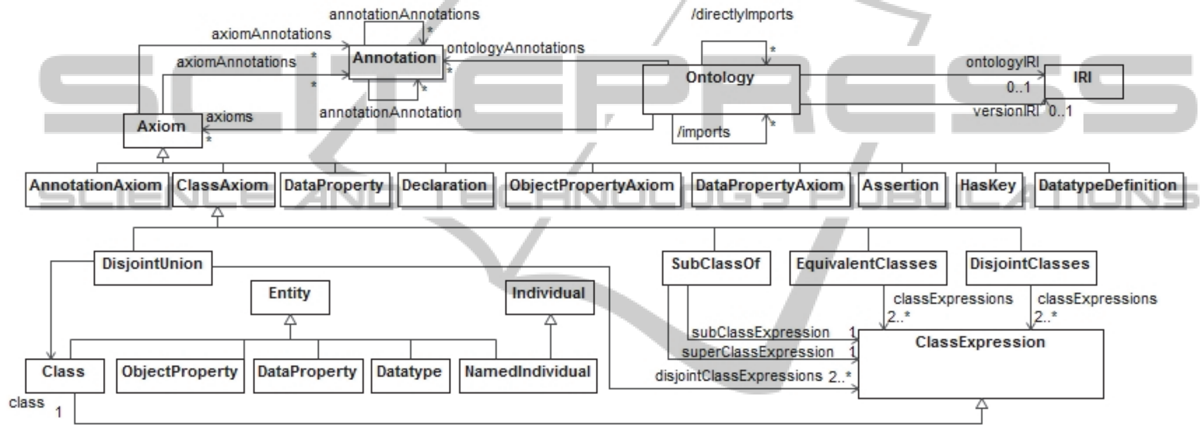

Figure 2: Main concepts of OWL 2 (some class axioms are shown in more detail).

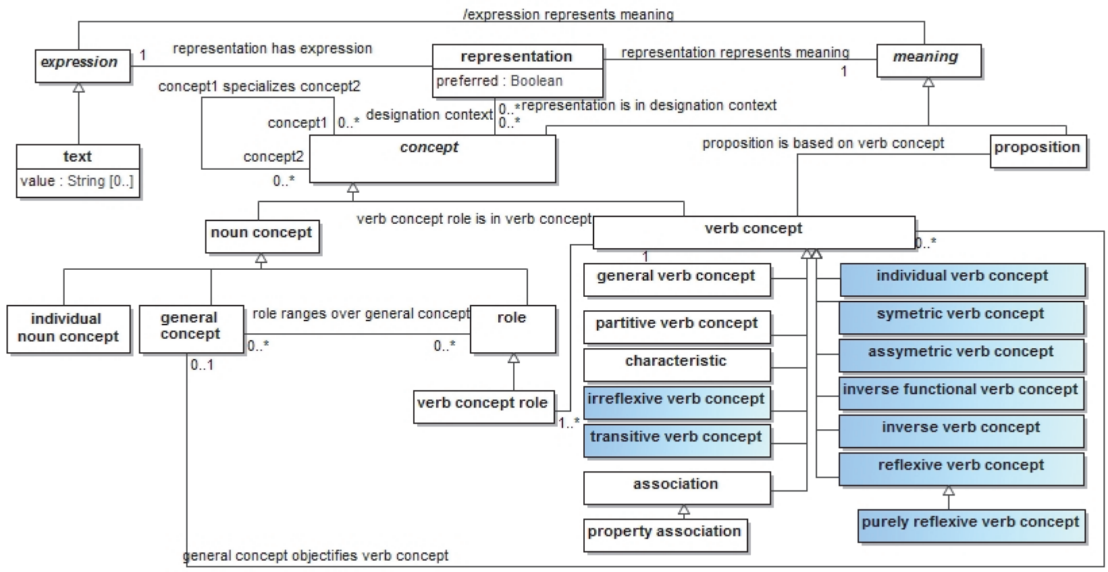

Figure 3: Main concepts of SBVR meaning extended with concepts for reflecting advanced features of OWL 2.

OWL 2 Class Axioms and Class Expressions. SubClassOf class axiom provides possibility to create class specialization hierarchies by defining the subsumption dependency between classes. Such axiom can be transformed to SBVR categorization:

```
OWL: SubClassOf(saying event) →
SBVR: event
     saying
       General concept: event
```

OWL 2 SubclassOf axioms are formulated along with many other OWL 2 axioms and restrictions: AllValuesFrom, SomeValuesFrom, ObjectHasSelf, ObjectHasValue, cardinality restrictions, etc.; in such cases, SubclassOf axioms are not transformed.

Class expression AllValuesFrom, defining universal quantifications on object properties or data properties, can be transformed to SBVR necessity statements scoping over universal quantifications and atomic formulations, which use more general verb concepts for defining specific general concepts as players of more general roles:

```
OWL: SubClassOf(journey (ObjectAllValuesFrom
     (has__target_object location)) →
SBVR: It is necessary that journey
     has_target_object that is location
```

Class expressions SomeValuesFrom, defining existential quantifiers on object properties or data properties, are transformed to SBVR necessity statements scoping over existential quantifications and atomic formulations based on binary verb concepts, e.g.:

```
OWL: SubClassOf(saying ObjectSomeValuesFrom
     (is_said_about saying_object))→
SBVR: It is necessary that saying is_said_about
     saying_object at least 1 saying_object
```

OWL 2 EquivalentClasses axiom denotes the equivalence of class expressions. This axiom between single classes is transformed into SBVR verb concept concept1 *is_coextensive_with* concept2. The axiom between a single class and a class expression, which defines how this class is derived, is transformed to the SBVR definition.

Class disjointness in the OWL 2 means that an individual I can be an instance of the only one class (class expression) CEi from the set of disjoint classes. DisjointClasses can be transformed to SBVR impossibility statements, or necessity statements with nor formulations.

DisjointUnion (C,CE_1, …, CE_n), n≥2, states that a class C is the disjoint union of classes CE_1, …, CE_n, which are pairwise disjoint. DisjointUnionOf axiom can be transformed to SBVR disjunction accompanied with impossibility statement or nor formulation, e.g.:

```
OWL: SubClassOf(person, agent)
     SubClassOf(organization, agent)
     DisjointClasses(person, organization) →
SBVR: agent
        Definition: person or organization
     person
       General concept: agent
     organization
       General concept: agent
It is impossible that person is organization
```

The ObjectUnionOf, ObjectIntersectionOf, and ObjectComplementOf class expressions can be transformed to SBVR logical operations with the closed logical formulations, e.g.:

```
OWL: EquivalentClasses(person
     ObjectIntersectionOf (ObjectComplementOf
      (organization) agent)) →
   SBVR: person
     Definition: agent that is not organization
```

The OWL 2 ObjectHasValue class expression allows expressing object properties of individuals. In the SBVR, such expression can be specified as a fact, based on the verb concept, in which one role is played by an individual verb concept.

OWL 2 ObjectPropertyExpressions and ObjectPropertyAxioms.

OWL 2 InverseObjectProperties axiom denotes that two object properties OP_1 and OP_2 are pair-wise inverse, e.g.:

```
OWL: InverseObjectProperties(said__saying
     is_said_by__speaker)→
SBVR: speaker said saying
       Synonymous_form: saying said_by speaker
     saying said_by speaker
         Concept type: inverse verb concept
```

Transformation rules for the SubObjectProperty, DisjointObject Properties, EquivalentObjectProperties axioms are similar to the transformation rules of SubclassOf, DisjointClasses and EquivalentClasses axioms.

ObjectPropertyChain is the more complex SubObjectPropertyAxiom. It states that if an individual I_1 is connected by a chain of object property expressions with an individual I_2, then I_1 is also connected with I_2 by the derivable object property expression OPE. ObjectPropertyChain can be transformed to the SBVR necessity statement formulated by the implication formulation, which has the antecedent restricted by one or more projecting formulations, and the second role of its consequent coincides with the second verb concept role of the last verb concept in the projecting formulations' chain, e.g.:

```
OWL: SubObjectPropertyOf(ObjectPropertyChain
  (said__saying is_part_of__event)
  is_participant_of__event))→
SBVR: It is necessary that agent
     is_participant_of event if agent said
     saying that is_part_of event
```

ObjectHasSelf axiom allows specifying the object property that is pure reflexive in ORM2 terms (Halpin, 2005).

FunctionalObjectProperty can be transformed to the SBVR at most one quantification, e.g.:

```
OWL:FunctionalObjectProperty(occurs_in_location)
SBVR: It is necessary that event occurs_in
      at most 1 location
```

The Inverse Functional Property cannot be directly specified in SBVR. Besides this, there is a set of OWL 2 Object Property Axioms that come from ORM2 (Halpin, 2005) and are important for inference: Reflexive, Irreflexive, Symmetric, Assymetric, and Transitive object properties that do not have corresponding characteristics in SBVR metamodel, though the latter also is based on ORM2 (Halpin, 2011). For solving this problem, we extended the SBVR binary verb concept similarly as in the case of inverse object property (Figure 3). Transformation of characteristics of OWL 2 object properties to concept types of SBVR verb concepts is straightforward, e.g.:

```
OWL: TransitiveObjectProperty
       (is_part_of__event) →
SBVR: event part is_part_of event
       Concept type: transitive verb concept
```

Transformations of OWL 2 Cardinality Restrictions also are straightforward, as they have their direct equivalents in SBVR, except DataExactCardinality '1' on Data Properties having DataRange 'boolean'. These restrictions are transformed to metamodel level statements of the type 'concept incorporates characteristic', e.g.:

```
OWL: SubClassOf(object (DataExactCardinality
    (1 is_trusted xsd:boolean))→
SBVR: object incorporates characteristic
      'is_trusted'
```

Transformation rules for OWL 2 DataProperty axioms and restrictions, ObjectPropertyAssertions and DataPropertyAssertions are defined in a similar way. The short summary of OWL 2 to SBVR transformation rules is given in Table 1.

5 EXPERIMENTAL APPROVAL

Two experiments were conducted for transforming OWL 2 ontologies into SBVR vocabularies. For evaluating the suitability of defined transformations for existing ontologies, the OWL2SBVR prototype has been implemented using ASP.NET technologies (the final implementation is under development in ATL transformation language as an integral part of the overall framework for the semantic search). Also, the purpose of the experiment was to find the unexpected problems, which could remain unknown from the context of theoretical models.

For the first experiment, three ontologies from internet (SIOC, Wine and GoodRelations) were chosen and used without any preparation for obtaining comprehensible vocabularies. Names of vocabulary entries were obtained from labels (or names, if labels were missing) of ontology entities. Names of classes, individuals and data properties, consisting of several words, were reconstructed into SBVR style (in ontologies, they usually are constructed using camel style). Names of verb concepts were constructed from names of domain classes, object properties and range classes.

The experiment has shown that almost all simple elements (classes, properties, class hierarchies) can be transferred to the SBVR vocabulary. All classes of SIOC, Wine and GoodRelations were transferred. The problems have arisen with transformation of properties. In the worst case, only 48.2% of object properties and 70% of data properties were transformed from SIOC ontology. The semantics of properties was often questionable, and could not be automatically ensured.

Several problems were identified during the first experiment. Object properties sometimes have no domain and range specified. In such cases, the "thing" class may be assigned as a domain or range by default, but it would not be a right solution in all cases. Object properties often are named by nouns that have meaning of roles; or they present junctions of relations and roles, which are expressed by phrases, consisting from several words. Camel style does not help to recognize such constructions. Moreover, object properties can have several domains or ranges, or have excess information, as in the labels (e.g., "type of good (1..1)"@en)) of Good Relations ontology.

In general, there is no rational way to automatically recognize roles in OWL 2 ontologies. Other problems have arisen with multiple categorizations when the same concept belongs to several subsumption hierarchies. While SBVR

Table 1: The short summary of rules for transforming OWL 2 constructs into SBVR.

OWL 2 Entities	
OWL 2	**SBVR**
EntityIRI	NameSpace URI
Class	general concept
NamedIndividual	individual concept
ClassAssertion	classification
string, boolean, integer, nonnegative integer, possitiveInteger, dateTime	text, boolean, integer, nonnegative integer, positive integer, number, date time
ObjectProperty	association
ObjectProperty, SubObjectPropertyOf (ObjectProperty Partitive object property)	partitive verb concept
DataProperty, DataPropertyDomain, DataPropertyRange	property association|characteristic
OWL 2 Class expressions and axioms	
SubClassOf	categorization
ObjectAllValuesFrom|DataAllValuesFrom	necessity statement with universal quantification
ObjectSomeValuesFrom]DataSomeValuesFrom	necessity statement with existential quantification
SubClassOf, DataSomeValuesFrom for DataRange 'boolean'	concept *incorporates* characteristic
EquivalentClasses for single classes	association 'concept$_1$ *is coextensive with* concept$_2$'
EquivalentClasses between a class and axiom	definition
EquivalentClasses, SubClassOf hierarchy, DisjointUnion	segmentation
EquivalentClasses, SubClassOf hierarchy	ccategorization scheme
DisjointClasses	impossibility statement|necessity statement with nor formulation
ObjectUnionOf, ObjectIntersectionOf, ObjectComplementOf, ObjectOneOf, ObjectHasSelf, ObjectHasValue	disjunction, conjunction, logical negation, definition with conjunction of Individual concepts, purely reflexive verb concept fact with Individual concept
CardinalityRstriction	quantification
OWL 2 Property Expressions and Axioms	
ObjectProperty, InverseObjectProperties	verb concept, inverse verb concept
SubObjectProperty, SubDataProperty	categorization of verb concepts
DisjointObjectProperties, DisjointDataProperties	impossibility statement for verb concepts
EquivalentObjectProperties, EquivalentDataProperties	association 'concept$_1$ *is coextensive with* concept$_2$'
ObjectPropertyChain	necessity statement with implication formulation and projecting formulation chain
FunctionalObjectProperty, FunctionalDataProperty	at most one quantification
InverseFunctionalObjectProperty	at most one quantification for inverse verb concept
(Transitive|Reflexive|Irreflexive|Symmetric|Assymetric ObjectProperty)	(transitive|reflexive|irreflexive|symmetric|assymetric verb concept)

supports multiple categorizations, such cases should have a special structure leading to categorization schemes or segmentations. According ontology normalisation requirements, multiple categorizations are allowable in OWL 2 ontologies in the form of derivable classes. Existing ontologies may not fulfil such requirements.

The second experiment was performed with ontologies of three domains related with semantic search (politics; business and economy, and public administration). These ontologies were developed in accordance with the rules of the normalization and other requirements for ontologies intended to be used for creating SBVR vocabularies. These ontologies had dedicated annotations "label_sbvr", specified using SBVR style in the Lithuanian language.

The experiment has shown, that it is possible to correctly reflect the semantics of ontologies via concepts of SBVR business vocabulary and business rules if these ontologies follow the normalisation rules and are provided with the desired representations, especially for specifying verb concept roles in ontology properties. Existing ontologies can be prepared for creating SBVR vocabularies in any language as in our framework for semantic search transformations are language-independent.

6 CONCLUSIONS AND FUTURE WORKS

The paper presents the rules for transforming OWL 2 ontologies into SBVR business vocabularies and business rules, which are intended for using interlinked SBVR vocabularies and ontologies in semantic search or other business applications. Particularly, we are interested in semantic search in Lithuanian Internet corpus; therefore, ontologies reused or developed for that purpose should be extended with specific labels allowing specifying Lithuanian words and word phrases for naming entities of the domain ontologies in the spoken language and the style of SBVR. The experiments have shown that freely chosen ontologies could require some preparation before transforming them to SBVR vocabularies: providing special labels, ensuring ontology normalisation, supplementing them with semantics of part-whole relations, etc.

The performed analysis has inspired extensions of SBVR required for transforming inverse object properties and characteristics of object properties. It still remains a problem to transform OWL 2 object properties without domains and ranges specified. Sometimes, domains and ranges may be inferred from property subsumption hierarchies or inverse object properties. Also, we yet have not considered complex domain and range specifications and other advanced features that would require additional efforts as well as the wider experimental investigation of the proposed transformations.

ACKNOWLEDGEMENTS

The work is supported by the project VP1-3.1-ŠMM-10-V-02-008 "Integration of Business Processes and Business Rules on the Basis of Business Semantics" (2013–2015), which is funded by the European Social Fund (ESF).

REFERENCES

Bernotaityte, G., Nemuraite, L., Butkiene, R., Paradauskas, B., 2013. Developing SBVR vocabularies and business rules from OWL2 ontologies. In *ICIST 2013, CCIS, vol. 319*. Springer, Heidelberg, 134–145.

Gailly, F., 2013. Transforming Enterprise Ontologies into SBVR formalizations. In *Proceedings of the CAiSE'13 Forum*. Valencia, Spain, pp. 122–129.

Ghali, A.E., Chniti, A., Citeau, H., 2012. Bringing OWL ontologies to the Business Rules Users, In *RuleML 2012 Proceedings*. Montpellier, pp. 62–76.

Halpin, T., 2005. *ORM 2 Graphical Notation*. Neumont University, Technical Report ORM2-01.

Halpin, T., Curland, M., 2011. Enriched Support for Ring Constraints. In *On the Move to Meaningful Internet Systems: OTM 2011 Workshops. LNCS, 7046*. Springer: Berlin, Heidelberg, pp. 309–318.

Kaneiwa, K., Iwazyme, M., Fukuda, K., 2007. An upper ontology for event classifications and relations. In *AI 2007. LNAI 4830*. Springer, Heidelberg, pp. 394-403.

Karpovic, J., Nemuraite, L., 2011. Transforming SBVR business semantics into Web ontology language OWL2: main concepts. In *Information Technologies' 2011*. Kaunas, Lithuania, pp. 231–238.

Karpovic, J., Nemuraite, L., Stankeviciene, M., 2012. Requirements for Semantic Business Vocabularies and Rules for Transforming them into Consistent OWL2 Ontologies. In *ICIST 2012, CCIS, vol. 319*. Springer, Heidelberg, pp. 420–435.

Kendall, E., Linehan, M. H., 2013. *Mapping SBVR to OWL2*. IBM Research Report, RC25363 (WAT1303-040).

Krisciuniene, G., Nemuraite, L., Butkiene, R., Paradauskas, B., 2014. Lexical Ontology Model Based on SBVR Representations. In Computing, Communication and Information Technology (CCIT 2014), London, UK, pp.77-81

OMG, 2011. *Date-Time Vocabulary (Date-Time)*. Version 1.0. OMG Document bmi/2011-08-01.

OMG, 2013. *Semantics of Business Vocabulary and Business Rules (SBVR)*. Version 1.2. OMG Document Number: formal/2013-11-05.

ONTORule Project, 2009. *ONTOlogies meet Business RULEs*. ILOG/IBM, http://ontorule-project.eu/.

Reynares, E., Caliusco, M.L., Galli, M.R., 2013. An Automatable Approach for SBVR to OWL 2 Mappings. In *XVI Ibero-American Conference on Software Engineering CIbSE 2013*. Montevideo, Uruguay, pp. 201–214.

Scherp, A., Franz, T., Saathoff, C., Staab, S., 2009. F-A Model of Events based on the Foundational Ontology DOLCE+DnS Ultralite. In *K-CAP 2009*. California, pp. 137–144.

Sukys, A., Nemuraite, L., Paradauskas, B., Sinkevičius, E., 2012a. Transformation framework for SBVR based semantic queries in business information systems. In *Bustech 2012*. Nice, France, IARIA, pp. 1–6.

Sukys, A., Nemuraite, L., Paradauskas, B., 2012b. Representing and transforming SBVR question patterns into SPARQL. In *ICIST 2012, CCIS 319*. Springer, Heidelberg, pp. 436–451.

W3C, 2012. *OWL 2 Web Ontology Language Structural Specification and Functional-Style Syntax* (Second Edition). W3C Recommendation 11 December 2012.