Towards Lexical Meaning Formal Representation by virtue of the NL-DL Definition Transformation Method

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Abstract

The paper represents a part of an extensive study devoted to the issues of lexical meaning formal representation in OWL 2 DL notation. Both theoretical and methodological aspects of lexical meaning formalization within the framework of an ontology are observed in the paper. Model-theoretic semantics paradigm and Kripke model are considered to form a theoretical background for formalization of lexical meaning, whereas the NL-DL definition transformation method is investigated as a method designed to provide us with acceptable formal definitions in OWL 2 DL notation with natural language definitions given at the input. A brief critical study of the method has allowed to reveal particular problematic cases of the method application, which arise due to syntactic peculiarities of natural language definitions given at the input.

1. Introduction

The technology of lexical meaning formal representation is supposed to play the key role within the Semantic Web development since the latter is aimed to extend current Web search engines with applications able to conduct Web content and query analysis based on word meaning processing (Berners-Lee, 2001; Horrocks, 2008; Yu, 2014). In order to reason about the meaning a user renders by a sentence, an inference engine has to use a specific knowledge base – an ontology that represents a scope of formal definitions of domain terms written in a formal language (Horrocks et al., 2007; Ding, 2010). OWL 2 is currently used for that purpose as a formal language, which is expressive enough to give an extensive and accurate specification of lexical meanings of terms representing ontology classes (Hitzler et al., 2012). In the current study the OWL 2 DL extension corresponding to the Description Logic SROIQ is observed (Hitzler et al., 2009).

In OWL 2 DL notation formal definitions of domain terms are given in a form of class descriptions, which are currently derived from natural language texts by means of the transformation method which takes a parsed natural language definition at the input and produces a formal definition in OWL 2 DL corresponding SROIQ notation. The method of NL-DL definition transformation is subjected to a brief critical review, the problematic cases which arise during the method implementation are exemplified with DL-definitions of sociolinguistic terms. The review is preceded by a brief description of theoretical and methodological grounds for lexical meaning formal representation and SROIQ syntax toolkit used for that purpose.

2. Lexical meaning formalization within the model-theoretic semantics paradigm

OWL 2 DL, a DL compatible syntactic fragment of OWL 2, standardized by the World Wide Web Consortium in 2009, is provided semantics within the framework of model-theoretic semantics (Motik et al., 2012; Krötzsch et at., 2014). Model-theoretic semantics allows to ascribe an axiom defining meaning of a natural language expression a set-theoretic interpretation on a domain existing in a set of

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possible worlds (Farrugia, 2003). The cornerstone of lexical meaning representation within the model-theoretic semantics paradigm was laid by R. Carnap. R. Carnap made a contribution by specifying the Frege's vague sense to reference dichotomy, which was used to distinguish a denoted object and a mode of reflection of the object in a description and to define the semantic difference between two expressions designating the same thing. The notion of intension that exhibits sense is opposed to extension denoting the scope of a lexeme's referents feasible in a domain, which is observed in a scope of states of affairs. The idea of possible states was used by R. Carnap to define an intension as a semantic feature that provides an identity of a lexeme's extension in all observed states of affairs (Carnap, 1947).

The notion of intension as proposed by R. Carnap was formalized within the framework of possible world semantics, which is considered as an extension of standard model-theoretic semantics devised for predicate logic by A. Tarsky to ascribe each formula a set-theoretic interpretation on a domain of reference (Menzel, 2017). Within the current study we use the four-part Kripke model M <*W*, *R*, *D*, *I*>, where W is a non-empty set of possible worlds, R is a binary relation on W binding possible worlds $w \in W$ and $w' \in W$ as alternative realities, D is a non-empty object domain considered as a scope of observed objects bound with a number of n-ary relations and represented in a scope of possible worlds, and I is a function from a set of possible worlds to a set of all n-ary relations on a domain, which assigns each vocabulary unit a referent on D: $I_V: W \to D^n$ (Lindström, 2001; Fitting, 2015).

As long as a lexeme is considered to acquire a specific logical type in accordance with its reference, a lexeme denoting an n-ary relation on a domain should be represented by a predicate symbol in an atomic formula $P(x_1,\ldots,x_n)$, whereas if a lexeme's extension is represented by a member of an n-ary relation on a domain, the lexeme is supposed to act as a constant symbol substituting a variable in an argument position (Trentelman, 2009). In order to describe an intension of a lexeme functionally, i.e. as a referential function of a lexeme that it takes in a set of possible worlds on a non-empty object domain, we have to take into account that a predicate is supposed to be mapped to a set of homogeneous n-ary relations in all possible worlds, whereas a constant symbol should denote the same entity in all possible worlds. On occasion we equate lexical meaning to intension of a lexeme, lexical meaning of a vocabulary unit should be understood as a function from a set of possible worlds to a set of all subsets of homogeneous n-ary relations on a domain: $Int_V: W \to 2^{D^n}$, this way of lexical meaning comprehension is extensively shared in theoretical papers on ontologies (Guarino, 1998; Guizzardi, 2005; Gritz, 2017).

An intension of a lexeme might be defined conceptually as proposed by R. Carnap: '*the general conditions which an object must fulfill in order to be denoted by (that) word*' (cit. ex. Gasparri and Marconi, 2016). Hence, in order to compile a formal definition of lexical meaning, the indispensable attributes of a lexeme's referent should be described by means of a formal language, which is understood as a set of strings formed by means of a finite set of syntactic rules and a set of symbols that make up an alphabet. In the current study the strings are given interpretation within the framework of model-theoretic semantics by means of the four-part Kripke model *M* <*W*, *R*, *D*, *I*> described above, therefore the strings should be formed by means of the first-order modal logic. Within the current study we concentrate our attention on intension and extension of predicate symbols, consequently a simplified signature of the first-order modal logic is implemented: functional and constant symbols are excluded from consideration. An extension is ascribed to a predicate symbol in accordance with the following set of rules defining truth values, where P is a predicate symbol and x is a variable, and $P(x_1,\ldots,x_n)$ is an atomic formula. Atomic formulas are combined in a string with the connectives: $\neg$, $\wedge$, $\vee$, $\rightarrow$; the quantifiers: $\exists$, $\forall$; and modal operators: $\Box$, $\Diamond$ used to denote necessity and possibility, *m* and *n* are variable assignment functions mapping each variable to an entity on a domain which disagree only on the variable x in some cases:

$$M, w \vDash_m P(x_1, \ldots, x_n) \Leftrightarrow (m(x_1), \ldots, m(x_n)) \in I(P, w),$$

$$M, w \vDash_m \neg\alpha \Leftrightarrow not\ M, w \vDash_m \alpha,$$

$$M, w \vDash_m \alpha \wedge \beta \Leftrightarrow M, w \vDash_m \alpha\ and\ M, w \vDash_m \beta,$$

$$M, w \vDash_m \alpha \vee \beta \Leftrightarrow M, w \vDash_m \alpha\ or\ M, w \vDash_m \beta,$$

$$M, w \vDash_m \alpha \rightarrow \beta \Leftrightarrow not\ M, w \vDash_m \alpha\ or\ M, w \vDash_m \beta,$$

$M, w \vDash_m \forall x.\alpha \Leftrightarrow M, w \vDash_n \alpha$ *for all* x *variants* n *of* m,

$M, w \vDash_m \exists x.\alpha \Leftrightarrow M, w \vDash_n \alpha$ *for some* x *variant* n *of* m,

$M, w \vDash_m \Diamond \alpha \Leftrightarrow M, w' \vDash_m \alpha$ *for some* w' *such that* $R(w, w')$,

$M, w \vDash_m \Box\alpha \Leftrightarrow M, w' \vDash_m \alpha$ *for all* w' *such that* $R(w, w')$.

One should distinguish the statements $\Diamond\alpha$, which are true under particular interpretation only in some of the possible worlds under consideration, and the statements $\Box\alpha$, which are true under particular interpretation in all the possible worlds under consideration. A borderline between these two kinds of statements was drawn by R. Carnap (1947, 1952) and by W. V. O. Quine (1951), who distinguished the statements which exhibit synthetic truth, that depends on a particular state of affairs, and analytic truth, or L-truth in terminology by R. Carnap, that holds in all possible worlds and depends on meanings of words.

For instance, referring to the John Smith's enterprise as to a single possible world we can make the following true statement revealing attributes a referent of the lexeme 'employee' possesses on a domain in a particular state of affairs:

$$\Diamond \forall x(Employee(x) \rightarrow Male(x) \land Engineer(x)).$$

On the contrary, one can formulate a statement that describes referents of the lexeme 'employee' in the scope of all possible worlds one might imagine to exist in 2018 or in the scope of possible worlds where both people and sensible robots – androids are employed that can be conceived to take shape in a century:

$$\Box \forall x(Employee(x) \rightarrow Person(x)),$$

$$\Box \forall x(Employee(x) \rightarrow Person(x) \land Android(x)).$$

One could define all individuals who are employees in all existing possible worlds assigning values to variables within the following meaning postulate, which states the meaning of the lexeme 'employee':

$$\Box \forall x \exists y(Employee(x) \rightarrow Person(x) \land has\_Job(x, y) \land is\_paid\_for(x, y)).$$

For this reason, within the practice of lexical meaning formal representation the statements of the type $\Box\alpha$ referred to as meaning postulates are proposed to define an intension of a predicate symbol representing a common noun, a verb, or an adjective within the framework of model-theoretic semantics (Carnap, 1952; Montague, 1973). Even though meaning postulates have been subjected to wide criticism (Quine, 1951; Katz, 1982), the point of implementing meaning postulates is still advocated (Horsey, 2000; Wechsler, 2015). One of the reasons for implementing meaning postulates is that they represent semantics ignoring cognitively problematic hierarchy of concepts arranged by compositional complexity and associated with individual words, which is proposed by decompositional approach to lexical semantics (Chierchia and McConnell-Ginet, 2000). We suppose that meaning postulates are able to serve as a basis for formal definitions development provided that the basic problems of lexical meaning formal representation have been solved:

- a correlation between a data unit retrieved by virtue of NL text analysis and a type of a formal language symbol should be found,
- the data retrieved by virtue of NL text analysis should be expressed by means of the strings formed in accordance with syntactic rules of a formal language applied for the purpose of formalization.

3. Formal representation of lexical meaning within an ontology

An ontology is a knowledge base which provides a formal specification of a vocabulary that represents a scope of entities of a domain together with entity bounding n-ary relations defined on the domain which is observed in a set of possible worlds (Gruber, 1993; Guarino, 1998). The knowledge base is comprised of assertional axioms, which describe individuals; terminological and relational axioms, which describe features of classes and object properties accordingly, all axioms being written by means of a particular formal language. Hence, within an ontology structure three basic types of units should be distinguished: individuals (also referred to as instances), which represent single entities of a domain;

classes (also referred to as concepts), which represent subsets of entities of a domain and are instantiated by members of the subsets; object properties[1] (also referred to as roles), which denote binary relations that bind single entities of a domain (Krötzsch et at., 2014).

Assertional, terminological and relational axioms, which compose an ontology as a knowledge base, are currently written by means of a standard formal language known as OWL 2 DL, which exploits the expressive power of the Description Logic titled as SROIQ (Lehmann, 2010). The signature of SROIQ contains non-logical symbols forming a triple $<O, \mathcal{C}, \mathcal{Q}>$. Each vocabulary unit is assigned an interpretation function I, which maps each individual $a \in O$ to an entity on a domain $a^I \in \Delta^I$, which maps each concept $C \in \mathcal{C}$ to a subset of a domain $C^I \subseteq \Delta^I$, which maps each role $Q \in \mathcal{Q}$ to a binary relation on a domain $Q^I \subseteq \Delta^I \times \Delta^I$ (Leinberger et al., 2016). The signature includes a top-concept $\top$, which can be instantiated by every individual; bottom concept $\bot$, which denotes an empty set; nominals $\{a\}$, which denote sets with a single member; and a universal relation U, which is associated with a universal binary relation on a domain $\Delta^I \times \Delta^I$ (Horrocks et al., 2006; Krötzsch et at., 2014). Assertional axioms define features of individuals by relating them to each other by means of individual equality (inequality) assertions: $a \equiv b$ ($a \not\equiv b$), to concepts by means of concept assertions: $a{:}C$, to roles by means of role assertions: $(a, b){:}\, Q$, $(a, b){:}\, \neg Q$. Terminological axioms describe concept inclusion: $C \sqsubseteq D$, whenever C is subsumed by D, and concept equivalence: $C \equiv D$, whenever C and D share the same instances (Krötzsch et at., 2014). Relational axioms are not considered in this paper. Terminological axioms of both types might be expanded to form complex class descriptions by means of specific concept constructors. The concept constructors allowed by SROIQ, and consequently by OWL 2 DL, to define ontology class features within terminological axioms are given in the Table 1 (Horrocks et al., 2006; Hitzler et al., 2012; Motik et al., 2012).

Concept Constructor	**OWL 2 DL Syntax**	**SROIQ Syntax**	**Semantics**
Complement	<owl:complementOf rdf:resource="#C"/>	$\neg C$	$\Delta^I \backslash C^I$
Intersection	<owl:intersectionOf rdf:parseType="Collection"> <owl:Class rdf:resource="#C"/> <owl:Class rdf:resource="#D"/> </owl:intersectionOf>	$C \sqcap D$	$C^I \cap D^I$
Union	<owl:unionOf rdf:parseType="Collection"> <owl:Class rdf:resource="#C"/> <owl:Class rdf:resource="#D"/> </owl:unionOf>	$C \sqcup D$	$C^I \cup D^I$
Universal restriction	<owl:Restriction> <owl:onProperty rdf:resource="#Q"/> <owl:allValuesFrom rdf:resource="#C"/> </owl:Restriction>	$\forall Q.C$	$\left\{x \in \Delta^I \middle\vert \forall y.(x, y) \in Q^I \rightarrow y \in C^I\right\}$
Existential restriction	<owl:Restriction> <owl:onProperty rdf:resource="#Q"/> <owl:someValuesFrom rdf:resource="#C"/> </owl:Restriction>	$\exists Q.C$	$\left\{x \in \Delta^I \middle\vert \exists y.(x, y) \in Q^I \wedge y \in C^I\right\}$
Qualified cardinality restriction (at-least restriction)	<owl:Restriction> <owl:onProperty rdf:resource="#Q"/> <owl:onClass rdf:resource="#C"/> <owl:minQualifiedCardinality rdf:datatype=	$\geq nQ.C$	$\left\{x \in \Delta^I \middle\vert \left\vert\left\{y \middle\vert (x, y) \in Q^I \wedge y \in C^I\right\}\right\vert \geq n\right\}$

[1] Datatype properties, which assign an individual a data value, are not considered in this paper.

	"&xsd;nonNegativeInteger">n </owl:minQualifiedCardinality> </owl:Restriction>		
Qualified cardinality restriction (at-most restriction)	<owl:Restriction> <owl:onProperty rdf:resource="#Q"/> <owl:onClass rdf:resource="#C"/> <owl:maxQualifiedCardinality rdf:datatype= "&xsd;nonNegativeInteger">n </owl:maxQualifiedCardinality> </owl:Restriction>	$\leq nQ.C$	$\left\{ x \in \Delta^I \middle\| \left\| \left\{ y \middle\| \begin{matrix} (x,y) \in Q^I \\ \wedge\, y \in C^I \end{matrix} \right\} \right\| \leq n \right\}$
Local reflexivity	<owl:Restriction> <owl:onProperty rdf:resource="#Q"/> <owl:hasSelf rdf:datatype="&xsd;boolean"> true </owl:hasSelf> </owl:Restriction>	$\exists Q.Self$	$\{x \in \Delta^I \mid (x,x) \in Q^I\}$
Enumeration	<owl:oneOf rdf:parseType="Collection"> <rdf:Description rdf:resource="#o$_1$"/> … <rdf:Description rdf:resource="#o$_n$"/> </owl:oneOf>	$\{o_1\} \sqcup, \ldots,$ $\sqcup \{o_n\}$	$\{o_1^I, \ldots, o_n^I\} \subseteq \Delta^I$

Table 1: Concept constructors used to enable class defining axioms formation
by means of the syntax of OWL 2 DL and the syntax of SROIQ

As long as OWL 2 DL is considered to be a fragment of the first-order logic, the semantics of OWL 2 DL statements is regarded within the framework of the four-part Kripke model *M* <*W*, *R*, *D*, *I*> discussed above. It should be considered that whereas assertional axioms are supposed to state something true about relations on a domain at least in a single possible world, i.e. to state synthetic truth, terminological axioms are presumed to state something true about relations on a domain in every possible world under consideration, i.e. to state analytic truth. Therefore we put forward a hypothesis that terminological axioms defining ontology class features form meaning postulates referred to as class descriptions that reveal lexical meanings of the terms representing ontology classes. Since we define an ontology class as a formal concept in the following way: '*<A, B> is a formal concept if and only if A contains just objects sharing all attributes from B and B contains just attributes shared by all objects from A*' (Belohlávek, 2008: 7), class descriptions should include all the attributes from *B*, i.e. all features of the class, which distinguish it from any other class in the ontology.

Class descriptions are derived in the process of ontology learning. Ontology learning techniques allow to retrieve ontology units from structured data (databases), semi-structured data (HTML or XML documents, Wordnet), and unstructured data (unannotated text documents) (Biemann, 2005). Specific ontology learning techniques are implemented to define classes and object properties in an unannotated natural language text: term and synonym extraction techniques, conceptual clustering (Cimiano et al., 2009), association discovery algorithms (Mädche and Staab, 2000), dependency relation analysis (Schutz and Buitelaar, 2005), and noun phrase analysis (Hearst, 1992).

4. An outline of the NL-DL definition transformation method

In order to generate ontology class descriptions systematically, LExO approach has been proposed to derive terminological axioms through transformation of syntactically parsed natural language definitions of class representing lexemes into OWL corresponding DL-statements (Völker et al., 2007; Völker et al., 2008). The method underlying LExO as well as later developments such as ACE and TEDEI (Mathews and Kumar, 2017) includes three main steps of natural language material processing:

syntactic parsing, omission/concatenation and transformation (Azevedo et al., 2014). LExO has been devised to transform natural language sentences into SHOIN axioms, which are transferrable into OWL 1 DL (Völker et al., 2008), while TEDEI has introduced the rules for OWL 2 DL axioms formation (Mathews and Kumar, 2017). Since OWL 2 syntax has been developed on the basis of OWL 1 syntax, the set of transformation rules proposed by LExO has been enhanced by TEDEI recommendations developed specifically for OWL 2 DL (see Table 2), omission and concatenation rules proposed by ACE are also taken into account.

For the purpose of natural language text syntactic analysis an off-the-shelf parser is used. For instance, Völker et al. (2007) have proposed to use the MINIPAR parser, following Azevedo et al. (2014) we use the Stanford parser, the version accessible online[2]. It is common practice to associate all noun phrases containing common nouns with ontology classes, whereas verb phrases are supposed to introduce object properties. Following LExO approach we omit subjective adjectives attached by common nouns, intersective adjectives are considered to represent ontology classes (see rule 4), whereas privative adjectives are supposed to indicate complement (see rule 5). Following LExO and ACE the prepositions attaching noun phrases as prepositional complements are subjected to concatenation (see rules 11, 12), determiners should be omitted, nominal collocations used as terms, adverbs, and modal verbs undergo concatenation (Völker et al., 2008; Mathews and Kumar, 2017). We refer to TEDEI to obtain lexical and grammatical indicators of specific OWL 2 DL constructors: qualified cardinality restriction (see rule 13); universal and existential restriction and local reflexivity (see rules 8, 11, 12) (Mathews and Kumar, 2017). The set of transformation rules provides a roadmap for mapping phrase structures to DL constructs and a scheme for development of unfold terminological axioms according to the principle of compositionality. The terminological axioms recognized as DL-definitions state concept equivalence between an atomic concept and a complex description which defines a set of referents denoted by the atomic concept. Therefore in order to provide an account on lexical meaning of a term, a DL-definition should be coherent in terms of set theory based interpretation on a domain of reference.

	Transformation rule	**NL syntax**	**DL syntax**
(1)	Copula	NP_0 is/are NP_1	$NP_0 \equiv NP_1$
(2)	Conjunction	NP_0 and NP_1	$NP_0 \sqcap NP_1$
(3)	Disjunction	NP_0 or NP_1	$NP_0 \sqcup NP_1$
(4)	Intersective adjective	Adj_0 NP_0	$Adj_0 \sqcap NP_0$
(5)	Privative adjective	Adj_0 NP_0	$\neg NP_0$
(6)	Negation (not)	not V_0 NP_0	$\neg\exists V_0.NP_0$
(7)	Negation (without)	NP_0 without $NP(pcomp\text{-}n)_1$	$NP_0 \sqcap \neg\exists with.NP_1$
(8)	Transitive verb phrase	V_0 $NP(obj)_0$	$\exists V_0.NP_0/\forall V_0.NP_0/\exists V_0.Self$
(9)	Relative clause	NP_0 $C(rel)$ VP_0	$NP_0 \sqcap VP_0$
(10)	Participle	NP_0 $VP(vrel)_0$	$NP_0 \sqcap VP_0$
(11)	Verb with prepositional complement	V_0 $Prep_0$ $NP(pcomp\text{-}n)_0$	$\exists V_0\_Prep_0.NP_0/$ $\forall V_0\_Prep_0.NP_0$
(12)	Noun with prepositional complement	NP_0 $Prep_0$ $NP(pcomp\text{-}n)_1$	$NP_0 \sqcap \exists NP_0\_Prep_0.NP_1/$ $NP_0 \sqcap \forall NP_0\_Prep_0.NP_1$
(13)	Number restriction	V_0 Num $NP(obj)_0$	$\geq nV_0.NP_0/\leq nV_0.NP_0$

Table 2: The basic transformation rules used for the purpose of DL-definitions formation

5. Problematic cases of the NL-DL definition transformation method application

The data for the NL-DL definition transformation method critical study has been derived from a Dictionary of Linguistics and Phonetics (Crystal, 2008) and Routledge Dictionary of Language and Linguistics (Bussmann, 1996). Pairs of alternative natural language definitions of 50 randomly selected sociolinguistic terms retrieved from the two dictionaries were parsed and transformed into DL-definitions of ontology class representing terms using the described method of transformation. The left

[2] http://nlp.stanford.edu:8080/parser/index.jsp

part of a DL-definition includes an ontology class bearing a role of definiendum, whereas the right part of the definition contains syntactically bound definiens – distinctive ontology classes and object properties. Whenever ontology classes act as definiens of the boundaries of a subset denoted by an ontology class being described, the classes undergo intersection, union, and complement. Whenever an object property acts as definiens of the boundaries of a subset denoted by an ontology class being described, the object property is ascribed a range with a universal, existential, or cardinality restriction imposed on it. Whether ontology classes or object properties act as definiens, certain problems arise in the process of transformation mainly due to the fact that natural language syntax is undoubtedly far more expressive than the syntax of SROIQ, and natural language syntax peculiarities need to be taken into account.

One problem we have discovered is the formation of intersections between disjoint ontology classes, which arises as a result of relative clause transformation being conducted in case a relative pronoun, which is coreferential with the modified noun, acts not as a nominal subject, but as a nominal modifier in relation to a predicate of the relative clause. For instance, within the NL-definition of the term ‘archistratum’ a relative pronoun, which is coreferential with the modified noun ‘variety’, acts as a nominal modifier of the relative clause’s predicate, whereas the noun ‘community’ takes the role of a nominal subject. An attempt to obtain a formal class description from this NL syntactic material results in an inadmissible DL-axiom describing the intersection of disjoint sets of privileged varieties of a language and communities (see Table 4). However, this is not the case in a DL-definition of the term ‘divergence’ since the modified nominal collocation ‘process of dialect change’ denotes a set of events, whereas the relative clause ‘in which the dialects become less like each other’ describes a subset of the set of events that could be defined as a process of dialect change. Consequently, if a noun or a nominal collocation modified by a relative clause designates a set of objects, not a set of events, a relative pronoun should act as a nominal subject in relation to a predicate of the relative clause for the NL-definition to be transferrable into DL-definition by virtue of the NL-DL transformation method. A good example of a suitable NL-definition is a definition of the term ‘standard’: ‘*Standard is a prestige variety of language used within a speech community, which cuts across regional differences and provides unified means of communication and an institutionalized norm, which can be used in the mass media and teaching*’, where in both relative clauses the relative pronouns are found in the syntactic role of a nominal subject.

Structurally the right part of a DL-definition might be represented as a chain of classes undergoing intersection. Each class obtains a description, which involves other classes and object properties, some of the classes’ names occur twice or more times in different links of the chain, the term ‘language’ in DL-definitions of terms ‘non-native variety’, ‘interference’, and ‘adstratum’ is among them. The issue of coreference between the recurred names should be resolved, otherwise nonsensical DL-statements emerge, one of them advocates that non-native varieties emerge in societies where speakers do not have a mother tongue at all (see Table 4). Since determiners are subjected to omission during the NL-DL transformation, in order obtain a correct DL-definition of a term, one should expand the DL-definition with information on whether the same or different subsets of a named set are bound in different links of the chain. In order to improve otherwise improper DL-definitions, one should annotate recurred names or use a local reflexivity constructor to characterize an object property as reflexive or irreflexive in case the same class name is used to characterize both domain and range of the object property (see Table 3).

DL-definitions with annotation of recurred names	**DL-definitions with a local reflexivity constructor introduced**
$Adstratum$ $\equiv Scope \sqcap \exists scope\_of.(Feature$ $\sqcap \exists features\_in.\boldsymbol{Language_0}$ $\sqcap \exists have\_resulted\_from.(Contact$ $\sqcap \exists contact\_with.(Neighbouring$ $\sqcap \boldsymbol{Language_0})))$	$Divergence$ $\equiv Process \sqcap \exists process\_of.(Dialect$ $\sqcap Change) \sqcap (Dialect$ $\sqcap \exists become\_less\_like.Dialect$ $\sqcap \neg\exists \boldsymbol{become\_less\_like.Self})$

$Interference$ $\equiv Scope \sqcap \exists scope\_of.(Error \sqcap (Speaker$ $\sqcap \exists introduces\_into.\boldsymbol{Language_0}$ $\sqcap \exists introduces\_as\_a\_result\_of.(Contact$ $\sqcap \exists contact\_with.\boldsymbol{Language_1})))$	$Isolect$ $\equiv Linguistic \sqcap (Variety$ $\sqcap \exists differs\_minimally\_from.Variety$ $\sqcap \neg\exists \boldsymbol{differs\_minimally\_from.Self})$
$Language\_shift$ $\equiv (Gradual \sqcup Sudden) \sqcap (Move$ $\sqcap \exists move\_from.(Use \sqcap \exists use\_of.\boldsymbol{Language_0})$ $\sqcap \exists move\_to.(Use \sqcap \exists use\_of.\boldsymbol{Language_1})$ $\sqcap \exists move\_by.(Individual \sqcup Group))$	$Convergence$ $\equiv Process \sqcap \exists process\_of.(Dialect$ $\sqcap Change) \sqcap (Dialect$ $\sqcap \exists become\_more\_like.Dialect$ $\sqcap \neg\exists \boldsymbol{become\_more\_like.Self})$

Table 3: The improvements proposed to enhance otherwise improper DL-definitions

Another problem arises as soon as we adopt the rule which states the conversion of a privative adjective ‘former’ into complement since the adjective denotes the absence of an attribute in the present and at the same time states its presence in the past. For this reason, the DL-definition of the term ‘creole’ fails to express an essential attribute of creole languages – the fact that all creole languages evolve from pidgins. Even the possibility to define adjectives as an intersective on a reasonable basis does not make things easier since many of them have wide meanings, the adjectives ‘cultured’ and ‘intellectual’ derived from the definition of the term ‘archistratum’ are good examples. As a result, the inclusion of the ontology classes represented by intersective adjectives in a taxonomy might be a challenging task.

The method also ignores the cases of an adjective acquiring a function of a predicate and representing an object property. A definition of the term ‘variable’: ‘*Variables are the units in a language which are most subject to social or stylistic variation, and thus most susceptible to change in the long term*’, clearly illustrates the use of two adjectives ‘subject’ and ‘susceptible’ in the role of a predicate. Both adjectives attach noun phrases as prepositional complements, yet the proposed list of transformation rules is limited to solutions for formal representation of noun phrases and verb phrases with prepositional complements.

NL-definitions	**DL-definitions**
Adstratum is a scope of features in a language which have resulted from contact with a neighbouring language.	$Adstratum$ $\equiv Scope \sqcap \exists scope\_of.(Feature$ $\sqcap \exists features\_in.Language$ $\sqcap \exists have\_resulted\_from.(Contact$ $\sqcap \exists contact\_with.(Neighbouring \sqcap Language)))$
Archistratum is a privileged variety of a language from which a community draws its cultured or intellectual vocabulary.	$Archistratum$ $\equiv (Privileged \sqcap Variety$ $\sqcap \exists variety\_of.Language) \sqcap (Community$ $\sqcap \exists draws.((Cultured \sqcup Intellectual)$ $\sqcap Vocabulary) \sqcap \exists draws\_from.Language)$
Change from below is the scope of the alterations that people make in their speech below the level of their conscious awareness.	$Change\_from\_below$ $\equiv Scope \sqcap \exists scope\_of.(Alteration \sqcap (People$ $\sqcap \exists make\_in.Speech \sqcap \exists make\_below.(Level$ $\sqcap \exists level\_of.(Conscious \sqcap Awareness))))$
Convergence is a process of dialect change in which the dialects become more like each other.	$Convergence$ $\equiv Process \sqcap \exists process\_of.(Dialect \sqcap Change)$ $\sqcap (Dialect \sqcap \exists become\_more\_like.Dialect)$
Creole is a former pidgin whose functional and grammatical limitations and simplification have been eliminated and which now functions as a full-fledged, standardized native language.	$Creole$ $\equiv \neg Pidgin$ $\sqcap \forall have\_been\_eliminated.(((Functional$ $\sqcap Grammatical) \sqcap Limitation)$ $\sqcap Simplification) \sqcap \exists now\_functions\_as.((Full$ $- fledged \sqcap Standardized)$ $\sqcap Native\_language)$

Divergence is a process of dialect change in which the dialects become less like each other.	$Divergence$ $\equiv Process \sqcap \exists process\_of.(Dialect \sqcap Change)$ $\sqcap (Dialect \sqcap \exists become\_less\_like.Dialect)$
Interference is a scope of the errors a speaker introduces into one language as a result of contact with another language	$Interference$ $\equiv Scope \sqcap \exists scope\_of.(Error \sqcap (Speaker$ $\sqcap \exists introduces\_into.Language$ $\sqcap \exists introduces\_as\_a\_result\_of.(Contact$ $\sqcap \exists contact\_with.Language)))$
Isolect is a linguistic variety which differs minimally from another variety.	$Isolect$ $\equiv Linguistic \sqcap (Variety$ $\sqcap \exists differs\_minimally\_from.Variety)$
Language shift is the gradual or sudden move from the use of one language to another, either by an individual or by a group.	$Language\_shift$ $\equiv (Gradual \sqcup Sudden) \sqcap (Move$ $\sqcap \exists move\_from.(Use \sqcap \exists use\_of.Language)$ $\sqcap \exists move\_to.(Use \sqcap \exists use\_of.Language)$ $\sqcap \exists move\_by.(Individual \sqcup Group))$
Network is the set of linguistic interactions that a speaker has with others.	$Network$ $\equiv Set \sqcap \exists set\_of.((Linguistic \sqcap Interaction)$ $\sqcap Speaker \sqcap \exists has\_with.Speaker)$
Non-native variety is a variety of a language which has emerged in a speech community in which most speakers do not have the language as a mother tongue.	$Non-native\_variety$ $\equiv (Variety \sqcap \exists variety\_of.Language)$ $\sqcap \exists has\_emerged\_in.(Speech\_community$ $\sqcap (Speaker \sqcap \neg\exists have.(Language$ $\sqcap \exists language\_as.Mother\_tongue)))$

Table 4: The samples of unacceptable definitions obtained by means of the NL-DL definition transformation method

6. Conclusion

The brief critical study of the NL-DL definition transformation method has revealed the fact that the method proposes a reasonable solution to the basic problems of lexical meaning formal representation that have been outlined in the current article. First of all, the correlation between syntactic categories and types of OWL 2 symbols and conforming DL symbols has been set. Secondly, the transformation rules propose a working algorithm which allows to transfer the natural language phrase combinations revealed via parsing techniques into DL-axioms which compose ontology class descriptions. Hence, the DL-NL definition transformation method should be considered as a theoretically appropriate solution to the problem of lexical meaning formal representation within the framework of an ontology.

On the other hand, the method obviously does not involve the formal analysis of syntactic dependencies connecting phrase units, which leads to the problem of semantic correlation between the definiendum and definiens in a DL-definition. The extensive practice of omission of determiners resulting in the unresolved issue of coreference between recurred names poses additional challenges towards formation of DL-definitions that could cover the whole scope of class representing term's referents on a domain.

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