XXX. ON REPRESENTATION LEVELS, CONCEPTS AND THEIR INSTANCES IN LINGUISTIC MODELING

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A DESCRIPTION OF LINGUISTIC STRUCTURES in terms of autonomous representation levels lacks phenomenological and psychological validity, and does not provide a computational advantage. Modularization that is required for a scientific description may be achieved using another computational model, namely, a hierarchy of classes, which properties may concern several levels, for example, both semantic structures and their syntactic realizations. However, application of the traditional OO-methodology to linguistics shows a problem of handling a contextual dependency of linguistic meanings. A way to overcome this problem is hinted by Husserl's model of correlation between noema and noesis.

1. LEVELS IN LINGUISTIC REPRESENTATIONS

Chomskian revolution in theoretical linguistics restricted its field to language as a system for generation of correct utterances. This led introduction of the principle of the autonomy of syntax. Because the system of language expresses meanings by a linear sequence of characters, the alleged autonomous syntactic level serves as an interface between phonological and semantic (or logical-form) levels. Further development of this schema introduces a set of levels, for example, surface-morphological, deep-morphological, surface-syntactic, deep-syntactic and semantic representations in Mel'čuk's "Meaning-Text" Theory (Mel'čuk, 1974; Steele, 1990). Each level also keeps an autonomy because it is described in terms of its own features. For example, a surface-syntactic representation is a tree of constituents or a tree of surface-syntactic relations which connects lexemes (in Mel'čuk's dependency model), while a deep-morphological representation is a linear sequence of strings which correspond to lexemes and bear morphological tags. Rules for transition between levels are necessarily defined in terms of two adjacent levels (investigations are mostly confined to the pairs of the deep-morphological and surface-syntactic or surface- and deep-syntactic levels).

However, the model of representation levels which are translated to one another lacks psychological and phenomenological corroboration. This model also does not provide a significant computational advantage. Phenomenological inadequacy of the level model is evident, when structures from distant levels influence one another, but are not represented at intermediate levels. One example of this is representation of the discourse structure. A discourse status which is assigned to information units (not necessarily to words or noun groups) is hardly represented in the syntactic level, this concerns such features as identifiability, thematic or emphatic markedness, significance, status of the author with respect to an event, for example, whether he/she acts, observes an event or conveys a second-hand information, and so on. While these features are defined at the level higher than the syntactic one, information units are realized through different structures. This is often achieved at the level below syntactic representation, for example, this can be achieved by the word order or by introduction of special features in the deep-morphological or phonetic representation. Another recalcitrant phenomenon is the lexical choice, which is usually assigned to the transition from the semantic representation level to the deep-syntactic one, but also depends on surface-syntactic and combinatorial features of chosen words.

Psychological adequacy of the level model is confronted with multiple psycholinguistic experiments, the review on this topic is provided in (Bierwisch, 1983). Though Chomsky declares that compliance of a linguistic model with real mental processes is the basic motivation for the generative grammar (Chomsky, 1986), the level-based model is designed as an abstract theoretical construct that is checked only for internal consistency—the need for the autonomy of syntax is grounded in purity of the theoretical model, while the deep syntactic level was introduced for an identical representation of similar, but different expressions, for example, sentences in the active and passive voice. While the human experience about phenomena and the theoretical model may be expressed in different terms (like in the case of mechanics), natural language has evolved from communication between humans, so a psychological faithfulness of a theoretical model should be taken into account.

Experience in development of applied NLU systems also shows the possibility for direct mapping of a text into a predicate-argument structure without an additional level of syntactic structure (Narin'yani, 1980), (Schank, 1975), (Wilks, 1968). A semantic representation in this approach is constructed using rules for combinations of semantic information that is stored in lexical items. This shows the optional nature of an additional syntactic level from the practical viewpoint. Linguistic theory regards this approach as a "partisan" one,[1] because it lacks the notion of a domain-independent grammar. However, the semantic-oriented approach does not deny syntactic structures. They are used inside analysis which is governed by semantic features (an example is shown below).

2. ENCAPSULATION INSTEAD OF A SET OF LEVELS

It is often argued that since "divide and conquer" methodology proved to be useful in computer science, levels are necessary for separation of linguistic structures into independent modules, which may be implemented by corresponding subroutines, for example, units for morphological or syntactic analysis or for semantic interpretation. However, such software architecture is inadequate for modern modularization techniques, which treat modules as sets of *resources* organized around a relatively coherent set of goals. According to the object-oriented programming paradigm (OOP), the fine-grained modularization is achieved by encapsulation of all properties of an object into its class, which belongs to the inheritance network. This modularization method has introduced a new computational model into the linguistic theory: instead of the separation of linguistic structures into levels that are processed by subroutines, linguistic structures are described as instances (objects, in OOP terms) of classes. Properties of a particular class describe various linguistic phenomena that are relevant for its instances. This makes it possible to design rules that simultaneously use discourse, semantic, syntactic and phonetic properties. Such parallelism in use of linguistic resources also fits psycholinguistic data.

Among several theories that introduce class hierarchies of linguistic descriptions, this section discusses:

- the grammar theory of HPSG (Pollard, Sag, 1994);
- the UM—the Penman Upper Model (Bateman et al, 1996), which is based on systemic-functional linguistics, SFL (Halliday, Matthiessen, 1999);
- SNOOP—a formalism that integrates several knowledge representation methods tailored for processing of linguistic structures (Sharoff, 1993). The formalism was used in the design of semantic-oriented grammars (Kononenko, Sharoff, 1996).

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[1] Gazdar and Mellish (1985) attribute this remark to McCawley (1968).

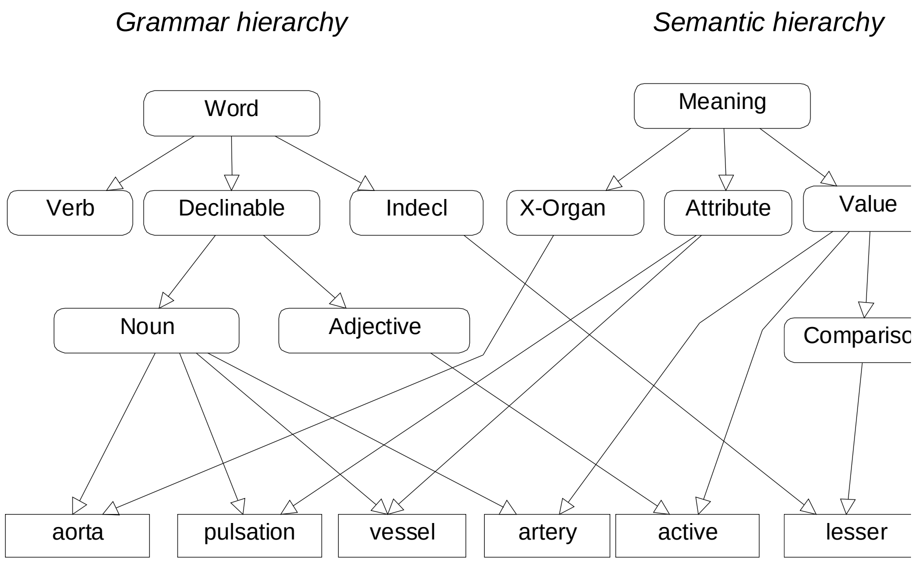

FIGURE XXX.1. *Multiple inheritance*

These theories differ in their status: HPSG is a grammar theory, the UM is an ontology that exists inside a larger theory, SNOOP is a theory-neutral knowledge-representation language for linguistic descriptions. However, they are comparable with respect to ways for employing a class hierarchy, in some sense they show a spectrum of such ways. Different views on the nature of language employed in these theories lead to different structures of class hierarchies. HPSG is mainly concerned with the grammar system *per se* (this attitude follows the Chomskian paradigm), it classifies lexical data in order to reflect syntactic constructions, for example, verb predicates are classified according to their valency frames, though the theory admits that some discourse characteristics may be relevant for transformations of valency frames (for example, diathesis transformations). In contrast to the formalist approach of HPSG, the UM inherits from systemic linguistics an attention to ways how meanings function in language, so the UM involves a semantic classification which is based on means for expression of author's goals. For example, verbal predicates are classified as message-oriented (*say, demonstrate*), addressee-oriented (*tell, inform*), non-message / non-addressee oriented (*complain, confide*). The difference that is detected at the semantic level is manifested in the grammar by different possibilities in referring to an addressee and to a message content (Bateman, et al, 1996).

This way of modularization may be further developed by classification of independent properties using separate class hierarchies. For example, the semantic-oriented model based on SNOOP uses three types of hierarchies (cf. FIGURE XXX.1):

- a semantic hierarchy (for example, Attribute, Value),
- a grammar hierarchy (for example, Noun, Adjective), and
- a textual hierarchy (Fragment, Fragment-Boundary, Topic).

The semantic hierarchy is based on statements expressed in terms of Attributes and their Values. In the problem domain of medical descriptions of X-ray films of the thorax organs (X-texts), four subclasses of attributes are distinguished—Localizers (represented by such words as *field, component, valve*), Parameters (*pulse, size, shape*), Intensity and Modality (names of these attributes are not expressed in texts). Corresponding values are divided into four subclasses as well: Loc-values (*periphery, vascular, mitral*), P-values (*active, enlarge, calcification*), I-values (*moderate, substantially, signs*) and M-values (*suspect, supposedly*)[2].

There is a difference between a class hierarchy which represent extralinguistic meanings of a problem domain and a class hierarchy of semantic units used in the same domain. For example, X-texts define specific language-dependent classes, including X-organs, which nomenclature and set of attributes may differ from real organs of the human body. Attributes and properties of such semantic classes as used in semantic modeling correspond to expressions found in texts, which often preserve some real characteristics of the thorax (for example, its topology), but they are described through interaction of their instances (words, collocations, propositions) with other instances in texts. For example, in X-texts, doctors often use words corresponding to organs of the body as attributes of X-organs, so the word *arteries* in the sentence:

(1) *On the left the pulmonary pattern is substantially intensified — vascular (arteries) and interstitial components*

refers to a visible deviation within the pulmonary pattern. The word *arteries* (in plural) is used, as if it were a Value of the Component attribute of an X-organ, which name is ‘Pulmonary Pattern’. Arteries in X-texts are not individuated as organs, as it should be in a domain model based on the human anatomy. Instead, X-texts describe visibility of arteries within the pulmo-

[2] Specific subclasses of Attributes and Values are not shown in FIGURE XXX.1.

nary pattern, also there is no an organ like 'Pulmonary Pattern', this is the shadow of lungs on an X-ray film. The properties of this usage are reflected both in the vocabulary, where the word *artery* is an instance of P-Values, and in the output formal specification for the example (1):

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Abs1: X-organ = Pulmonary Pattern;
  Loc1: Field = left
      Component = {vessels / arteries /, interstitial}
  Eval: State = increased
      Intensity = high
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The semantic and grammar hierarchies are intersected at the level of concrete words, so that their properties are described from two viewpoints with respect to their semantic or grammatical properties. If necessary, both viewpoints may be addressed in a single description rule. For example, dependency relations, which are defined in terms of grammatical elements (for example, a nominal group or a simple clause), help in determination of information units corresponding to semantic elements (an actant or a proposition). This provides a possibility to determine the scope of semantic operations (such as negation or comparison).

The Fragment class from the textual hierarchy corresponds to a single proposition about some state in the problem domain. For example, in the problem domain of X-texts there are absolute statements:

(2) *On the left the pulmonary pattern is intensified*

and comparisons, cf. the second proposition in

(3) *The ventricles are enlarged, the right one substantially prevailing*

Thus, we distinguish two subclasses of Fragments: absolute and comparative fragments, which methods provide different ways for arrangement of information in clauses. Analysis in terms of information fragments is extended to inter-fragment relations, for example, a Topic of a sequence of fragments provides information for disambiguation of elements within the fragments or for ellipsis resolution.

3. PROBLEMS WITH THE OO-MODEL FOR LINGUISTIC MODELING

While disadvantages of the level-based model may be overcome by encapsulation of properties of an instance in terms of its class, the OO-model also has its own limitations in representation of linguistic phenomena. The classic OO-model involves a strict separation of an ontology, which defines the behavior of classes, from instances of these classes (as demonstrated by

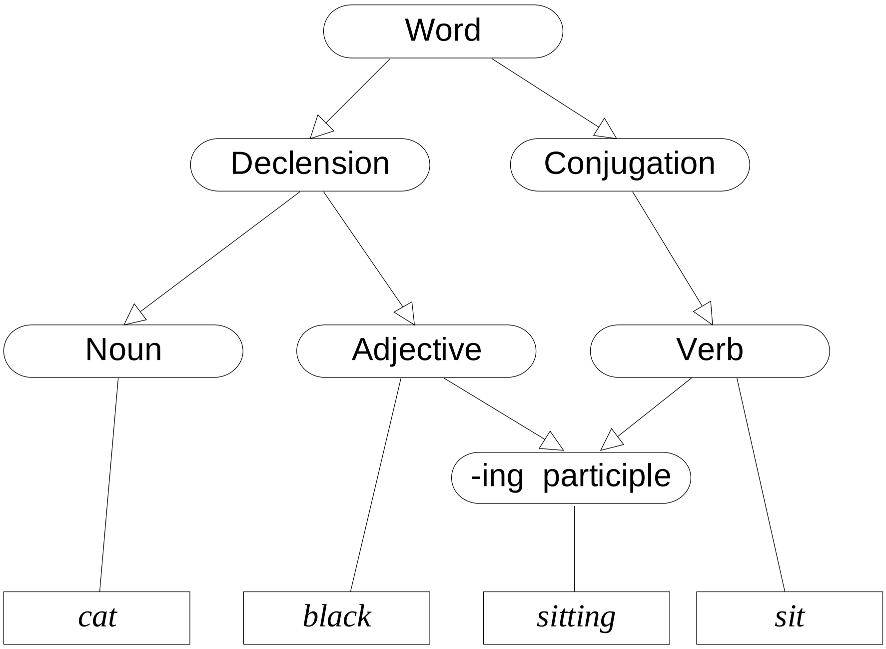

FIGURE XXX.*2. A static classification.*

SNOOP hierarchies). A class is the basic locus of the meaning for a linguistic unit (a word or a grammatical constituent). Classes encode both denotational and connotational meanings, as well as rules according to which a unit interacts with other units. At the same time, instances of classes store instance-specific data, but exhibit no instance-specific behavior. However, in linguistic modeling there is a problem with creation of instances. In the case of models pertaining to speech production, we may posit a free choice of linguistic classes, which express the target ideas in signs with physically perceptible features (phonemes, letters, ideograms). In the opposite case, when the goal is to understand a sequence of such signs, we are confronted only with physically perceptible features, while meanings of signs, i.e. their classes, should be detected in the process of analysis.

A typical “transducer” for such detection is provided by a dictionary, which maps words to instances of classes as a matter of definition. However, the meaning of a word or a grammatical construction depends on its contribution into the structure of a respective sentence and the discourse in general, but the meaning is unknown at the moment of instantiation. Even in the very simple case of structural units, like parts of speech (cf. FIGURE XXX.2), the class of a word depends on its functions within the syntactic structure of a sentence; for example, an adjective can be used instead of a noun, if the meaning of the latter can be inferred; this happens particularly often in Russian, though English also has a way to use adjectives in a syntactic position of nouns (*Make a left at the next corner*). In other words, although an instance has been created as an adjective due to the vocabulary association, it should endowed with properties of a noun during analysis of the sentence. In the same way, assignment of *arteries* to the P-Value class facilitates processing of the majority of X-texts, but hinders understanding of expressions, in which arteries are discussed as organs with their own attributes. In other words, functions of an instance in a context conform to conditions which are partly determined by this context and not only by the class it receives, when it is created.

A similar remark about the difference between form and function is made by Halliday, who distinguishes permanent classes that are assigned to a linguistic unit on formal grounds from functions that the unit performs in a clause (Halliday, 1985: 30). In utterances, functions are realized by respective classes of parts of speech, for example, in the nominal group *a black sitting cat,* the Thing function is realized by *cat,* while two other functions Epithet and Classifier are realized by *black* and *sitting*, respectively (Halliday, 1985: 164). However, this treatment works only for the generation perspective, in which the goal is to express an available configuration of meanings, while understanding requires reconstruction of the configuration and invokes contextual flexibility of functions, for example, in distinguishing Epithets from Classifiers, which cannot be detected using a single definite formal feature, such as information about a lexical item or word order. Physically perceptible features are akin to medical symptoms, which by themselves do no denote a decease, however, specific configurations of symptoms and some additional knowledge help in its diagnosis (from an example by Jakobson).

Another type of flexibility meanings concerns the relationship between the vocabulary definition of semantics of a lexical item and its function in concrete utterances. For example, the UM comprises processes of Happening, which is a subclass of material processes, and processes of Existence, which is a subclass of relational processes (Bateman, et al, 1996). There are good grammatical reasons for separating material processes expressed by typical verbs from relational processes expressed primarily by *be* and *have* and their respective equivalents in other languages. However, instances of

Happening processes that lead to appearance of their participants can be easily treated as processes of Existence, since the participants are brought into existence (or perception) by the effect of these processes. The Russian verb *появиться* expresses features of the both process types, for example[3]:

(4) *На экране появится окно AutoCAD Text Window.*
On screen-loc appears window-nom AutoCAD Text Window
The AutoCAD Text Window appears.

(5) *После регистрации у вас появится право на техническую поддержку.*
After registration by you-gen *appears right*-nom *for technical support*-acc
Register now to have access to technical support.

(6) *В настоящей версии программы появились гиперссылки для…*
In current version-loc program-gen appeared hyperlinks-nom for…
Hyperlinks, which are available in the new version, provide a better alternative…

The examples present a standard Happening rendered in the English original by the verb *appear* (4), a Happening that results in possessing of a property (5), and an Existence of a feature that was not present in the previous version of software (6). Halliday and Matthiessen (1999) refer to such cases as a *cline*, which offers a gradient scale of class membership. However, the simple statement of a similarity between classes provides no formal mechanism for describing instances, so computational versions of SFL, such as the UM, also define a hierarchy of classes, for example, material/ happening/ ambient processes, and use the traditional notions of class membership.

In short, meanings of the classic OO-model are defined as instances of pre-existing classes, which completely define their behavior, so that instances exhibit only their identity. This line of thought follows the Kantian ontological model in which perception is treated as a classification in terms of universal or stipulated categories. The position stems even to Aristotle according to which a category is defined by necessary and sufficient conditions for membership in the category. However, this approach assumes a strong ontological commitment, namely, that all categories exist prior and independently from communication acts. An opposing line of thought is presented by the Husserlian theory of intentionality as a tripartite arc consisting of an object being experienced, its noema (a phenomenal experience of the object) and noesis (a mode this phenomenon is experienced). In linguistic terms, an object is a physically perceptible sign, its noema can be inter-

[3] All examples are taken from user's manuals for Windows software in Russian and English.

preted as a linguistic meaning and noesis as its context (McIntyre, Smith, 1982). Husserl considered both perception and language understanding as a series of meaning-endowing acts which result in the dynamic correlation between noema and noesis: noesis provides the context for constitution of noemata, but is itself constituted by them. Several researchers, for example, (Dreyfus, 1982), (Münch, 1993) even claim that Husserl is a founder of the modern cognitive science due to his project of phenomenology as a rigorous research of the human mind. This is true with respect to the intent of Husserl's research, however, a lot of crucial phenomenological ideas are waiting to be interpreted in cognitive science and linguistics[4].

A Husserl-inspired mechanism for description of constitution of meanings can be based on typed feature structures (TFSs), cf. (Zajac, 1992). The proposed interpretation is cognate to attempts to bridge SFL with the unification paradigm, for example, (Bateman, et al, 1992), though the latter work concerned only mapping of the systemic-functional formalism into the TFS representation without considering problems in the relationship between meanings and signs within the SFL model. The proposed mechanism involves a decomposition of large-scale classes into a *manifold* of distinguishing features which are designed as microclasses. Larger classes are detected by configurations of distinguishing features which are defined by constraints on combination of distinguishing features. Recognition of a larger class also serves as a distinguishing feature for detection of other classes. So, predefined classes provide only resources for combination of linguistic elements into a structure corresponding to a specific communicative act, but do not define. The behavior of a word or a linguistic structure is determined by the way in which its manifold of classification features is organized in specific contextual conditions, i.e. a set of classification features which describe other aspects of the situation at question. In this model, a class is treated not as a meaning, but as a constraint on an instance, so that it can be considered from different aspects. For example, some features of the Intensive function that relates Element and its Quality (SFL terms) can be described in a uniform way both at the Clause level, for example, *The book is red,* and at the nominal group level *The red book*, as in (1).

The Element and Quality are also constrained by respective typed-feature structures Unlike the classic OO approach, such structure does not directly denote an instance. It specifies constraints, which are realized by the Intensive relation in clauses and nominal groups: the attribute carrier is expressed

[4] The range of possible impacts of the phenomenological movement on cognitive science is discussed, for example, in (Sharoff, 1995).

by an Element, its attribute by a Quality, and in Russian their features of gender, number and case are in agreement (*Agree* is a macro that specifies these constraints). Other constraints may be added to instances from the viewpoint of other TFSs specifying relational clauses or nominal groups.

Class inheritance is another example of problems caused by the fact that the functionality of an instance is defined by its class. For example, a Russian verb in the past tense has a gender feature and agrees in gender with the subject, while normally verbs lack a gender characterization. This adds a new feature into the structure of an instance of verbs. However, in the traditional OO-model it is difficult to represent past-tense verbs as a subclass of general verbs, because respective lexical items are assigned to the class of verbs according to the dictionary, but the class alters, when a new value of its Tense attribute is specified. On the other hand, instances with specific feature values are not treated as subclasses in the traditional OO-model, while from the linguistic viewpoint, it is advisable to have a description of meanings pertaining to specific values, for example, meanings of nominal groups in the instrumental case. Also, participles are not simply mixins of adjectives and verbs; in some cases they develop more features of adjectives (*a black sitting cat*), in some — verbs (*A cat sitting on the desk purrs*). The treatment of Russian participles in TFS terms is as follows.

(1) $$_{INTENSIVE}\begin{bmatrix} \text{carrier } \boxed{1} \in \text{Element} \\ \text{attribute } \boxed{2} \in \text{Quality} \\ Agree(\boxed{1}, \boxed{2}) \end{bmatrix}$$

(2) $$_{PROCESS}\begin{bmatrix} \text{actor} \in \text{Element} \\ *\,\text{circumstance} \in \text{Circumstance} \\ \text{tense} \in \{\text{past}, \text{present}, \text{future}\} \\ \text{phase} \in \text{Phase} \end{bmatrix}$$

(3) $$_{DIRECTED-PROCESS}[\text{actee} \in \text{Element}]$$

(4) $$PROCESS > DIRECTED-PROCESS$$

(5) $$PHASE = \{\text{continuation, repetition, result, limit}\}$$

(6) $$_{PROCESS}\begin{bmatrix} \text{tense} = \text{present} \\ \text{phase} \in \{\text{continuation, repetition}\} \end{bmatrix}$$

(7) $$_{DIRECTED-PROCESS}\begin{bmatrix} \text{actor} \mid \text{case} = \text{instr} \\ \text{actee} \in \text{Element} \\ \text{form} = \text{passive} \end{bmatrix}$$

(8) $$_{SCALABLE-QUALITY}[\text{scale} \in \text{Scale}]$$

(9) $$_{FEATURE-QUALITY}[\text{sign} \in \{+, -\}]$$

A participle combines properties of a verb (a process, from the semantic viewpoint) and an adjective (a quality). Thus, from the viewpoint of a process, a participle defines Participants and Circumstances of a process and some speech act properties (tense and aspect), but it lacks properties corresponding to a process included in a proposition, like mood and modality. From the viewpoint of an adjective, a participle defines a quality of an object (Element in Halliday's terminology). In its instance in text, a participle realizes some properties of the process stance, when a participial clause is a condensed version of a relative subordinate clause, and some properties of the quality stance, when a participle is used in a sequence of other qualities.

The said functional features are detected on the basis of respective distinguishing formal features: agreement in gender, number and case for qualities and setting tense, aspect and voice for processes. Some functional constraints correspond to formal features, for example, passive participles exist only for transitive verbs, because of a functional constraint on the actee of directed processes. Also, present tense participles are possible only for verbs with the imperfective aspect, because a perfective verb cannot express duration; the formal restriction is expressed in (6).

4. CONCLUSIONS

It is widely accepted across modern linguistic theories that the methodology that uses classes with their hierarchies and properties provides a convenient formal tool for representation of various linguistic phenomena. It is also tacitly assumed that a pre-defined set of classes defines meanings of linguistic units. However, the meaning of a word or a grammatical construction is not directly given in text or speech as an instance of a class (the same concerns our perception of objects of the world). Its meaning (Husserl's noema) depends on various contextual conditions (noesis), including its contribution to the meaning of a larger unit and the discourse, in general, and intentions of the speech producer and recipient. Moreover, new words are regularly coined, and usage of existing words or constructions changes, thus a predefined set of classes as the repository of all meanings is rendered useless. By this reason, the paper argues for a difference between a *potential* of lexicogrammatical possibilities for expression of meanings by linguistic signs and *realization* of the potential in the discourse. Realization of the potential results in dynamic constitution of meanings, which are not instances of classes, though instantiated meanings are subjected to constraints imposed by the interpretation potential. In the proposed model, meanings are represented in the form of attribute-value matrices, which terminal values are physically perceptible distinguishing features. At the same time, the proposed model is limited in two respects. Firstly, it also does not describe acquisition of new linguistic knowledge that enriches or alters the potential of possibilities (either about new words or usages). Secondly, it does not specify a relation between the lexicogrammatical potential and communicative needs to be expressed via the potential.

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