Syntactic Disambiguation in Constructions with Attachment Ambiguity with Adjuncts by Means of Ontological Semantics

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Abstract

The article describes a pilot study of a method of syntactic disambiguation in constructions with attachment ambiguity by means of ontological semantics on the basis of the AIIRE (Artificial Intelligence Information Retrieval Engine) universal linguistic processor.
Four types of ambiguous constructions with adjuncts are identified and corresponding search queries are compiled into National Corpus of the Russian language (NKRYA). The result is the list of 200 ambiguous constructions. Ambiguity in constructions is eliminated by performing automatic parsing and further manual selection of correct parsing variants. However, at this stage, the following problems are possible: parsing tree gaps within the constructions that prevent parsing and also large amount of parsing versions. These problems are solved by means of such AIIRE tools as Ontohelper and ontology. Ontology is used to process language data and understood as a set of lexical meanings and relations between them. Ontohelper is the auxiliary tool with editing interface, where the valencies of verbs and verbal nouns can be modeled and prescribed through ontological relations.
As the result of this paper 66/200 constructions are disambiguated and it is proved that accuracy of syntactic disambiguation directly depends on fine-tuning ontological concepts.

Keywords: Ontology, Ambiguity, Attachment ambiguity, Valencies of verbs, Parsing

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Introduction

Syntactic analysis is the important stage of linguistic analysis of a text, since at this step the structure of the sentence is analyzed. In some cases, several versions for the structure of a single sentence are possible. Such phenomenon is called syntactic ambiguity. The main problem associated with this phenomenon is combinatorial explosion, when the number of versions increases exponentially depending on the size of the analyzed text. As the result of this problem machine resources may not be enough to build and store all versions. In addition, more than one or two sentences can be parsed in this way and therefore, the performance of the parser will decrease and directly affect the overall result of processing text data.

Syntactic ambiguity and its related problems are sometimes solved by means of machine learning methods, which can be statistical or based on neural networks, such as, for example, Syntaxnet or Gate. Such approaches may not involve a linguist in determining the methodology that guides the system in resolving ambiguity, and therefore, do not allow the linguist to correct it. Alternative methods are those of computer linguistics. They assume the presence of semantic dictionary, ontology, knowledge base or any other linguistic supportions used by a semantic

component system with the semantic analysis and, in particular, provide a choice of semantically valid parsing versions. The methods of computer linguistics in this problem are in demand due to the need to take into account all correct versions of parsing in a number of tasks of automatic understanding of texts, which include multivariate machine translation, semantic search, extraction of factual information and opinions (opinion mining) mathematical linguistics as machine translation, speech recognition, thematic analysis, as well as even some fields of psycholinguistics (cf. [1]) or in the field of syntax, where various methods of resolving syntactic ambiguity are considered [2]. Moreover, the task of syntactic disambiguation is still only partially solved [3].

The relevance of the topic of this research is determined by the fact that studies related to syntactic ambiguity resolution arouse keen interest among researchers. For instance, in [4] there is a review of existing approaches to disambiguation by means of ontology with the following conclusions about advantages and usefulness of this topic. Musken's Logical Description Grammar (LDG) approach is used in [5] to solve the problem in question. Furthermore there is a method of joint analyses proposed by [6].

This paper deals with one of the most common types of syntactic ambiguity – attachment ambiguity in constructions with adjuncts. The purpose of this paper is to determine the possibilities of ontological semantics in resolving syntactic ambiguity in constructions with adjuncts by experimental research on the material of a syntactically marked corpus of texts in Russian language. The problem is solved on the basis of the AIIRE universal linguistic processor, the ontology built into it and its editing tools.

The essence of the method of ontological semantics is that it is supposed to use ontology for modeling in it the concepts corresponding to lexical units, their meanings and valencies. Due to the fact that the valencies of concepts are deduced in the ontology, it is possible to limit the number of combinatorial options for parsing the interpretation of relationships within a sentence or phrase. In particular, it is thus possible to prescribe optional valencies, that is, to determine which host the adjunct really belongs to and, therefore, to resolve the ambiguity caused by the optionalness of the adjunct, provided that the ambiguity can be resolved.

Based on the results obtained, it is determined whether it is possible to completely eliminate the selected kind of ambiguity using the available means of ontological semantics.

There are five sections in this article. The review of current studies in the field of syntactic disambiguation is presented in the Related work section. In the Data Collection section there is information about the corpus of constructions which were to be processed. The Approach section describes the present method of disambiguation. In the Results section there are examples of disambiguated constructions. In the Conclusions and Further Work section provides the conclusions drawn up by the presented results and the description of the further planned work.

1. Related work

There are several ways of resolving syntactic ambiguity.

In [4], there is a review of existing approaches to ambiguity resolution by means of ontology and without it. There are syntactic parsers, especially single-objective parsers, like DictaScope, STAGE-3, StanfordNLP, RASP, OpenNLP which perform parsing, but do not guarantee correct versions; moreover, as they are single-objective, they return only the most probable version. The main conclusion of this paper is that one of the most effective ways to achieve the most effective solution to the problem of disambiguation is the use of special complex systems based on a complete description of language. One kind of these systems are those based on parsing and performing semantic analysis with ontologies, since it is possible to effectively solve the problem of syntactic ambiguity using other levels of a linguistic analysis, in particular semantics and sometimes pragmatics.

There are various examples of resolving syntactic ambiguity by means of other levels of linguistic analysis using ontology. For example, in [7], the multi-agent system is presented

in which agents resolve ambiguities by calculating the power of their context and the strength of evidence. The authors argue that this information system can be used to solve the lexical ambiguity and that it is also the basis for the approach to the removal of syntactic ambiguities, which depends on the context. In [8] the main idea was as follows: «The algorithm is based on a parallel parser which ranks constructions for access, and interpretations for disambiguation, by their conditional probability» [8, pp. 137-194], thus the less probable constructions are not taken into account and [9], where «the system relies on a syntactic and a semantic subcomponent» [9, pp. 183-187], and it was also proved that «integration of syntactic and semantic analysis is beneficial for both of them».

In [5], there is another method of resolving syntactic ambiguity. Authors state that in order to cope with the syntactic ambiguity it is effective to use packed parse forests to represent sets of grammatical representations and statistical algorithms that also allow putting probabilistic weights on analyses. The authors use Musken's Logical Description Grammar (LDG) approach; they extend this model by including lexical or ontological information and show how this extension can be applied to the underspecification and resolution of lexical ambiguities.

In addition to the works, in which syntactic disambiguation is carried out, it is also necessary to mention those, in which word-sense disambiguation is performed using parsing and semantic interpretation of syntactic structures. Thus, in [10] a procedure was proposed for estimating the level of «nearness» of two words in a semantic net- work dictionary. In some cases, resolving the ambiguity using only syntax is not possible. Taking this into account, the author suggests calculating the paths between words in the semantic dictionary: if some word x can be recognized as a subordinate of the word n, as well as the subordinate of the word m, then it is necessary to calculate the path from n to x and from m to x and choose the least long way as a solution.

There is another example of performing syntactic disambiguation by using the level of semantics. In [6], where the method of joint analyses is used, the author suggests that in some cases it is difficult to resolve syntactic ambiguity "without utilizing our full knowledge of the situation" and represents a method combining parsing and semantic analysis, in which the results of the latter directly affect the results of the former.

Last but not least example is AIIRE that is «the project dedicated to the development of a computer technology stack for semantic processing of unstructured or weakly structured data in a natural language». The AIIRE linguistic processor is an implementation of the full-scale Natural Language Understanding (NLU) process based on the inter-level interaction method and the rule-based ambiguity resolution.

The method of inter-level interaction is to get rid of the artificial separation of the levels of linguistic analysis and to analyze morphology, syntax and semantics at the same time. This principle helps to minimize the problem of combinatorial explosion, which is very important for NLP software and the current method of analysis implies resolving ambiguity at lower levels using the upper-level rules immediately after ambiguity occurs at lower levels, rather than after analyzing the entire text (or sentence) at these levels [11]. The method is implemented using the built-in linguistic ontology where it is possible to prescribe the valences of the words. Moreover, there is a special tool for prescribing valences of verbs, i.e. Ontohelper. Thus, the connections between words are established only within the framework of the prescribed rules and the number of possible versions of parsing is accordingly reduced. Tools of the linguistic processor are closed internal resources and are not accessible to ordinary users. However, for a scientific research, access can be obtained.

Resources for the Russian language such as YARN, RussNet cannot be effective for they do not provide any sufficient for the purpose of this study information about valences.

In publications on the RussNet project, information is mentioned that during development the valencies of the verbs were taken into account and registered: «When constructing thesaurus, we took into account the laws of morphological-syntactic design of contexts for different meanings of significant words, primarily verbs. Of particular importance here is the implementation

of verbal valencies characteristic of the Russian language through prepositional constructions. In RussNet thesaurus, synsets are supplemented with a lexical and grammatical description of valencies – statistically stable parameters of corpus contexts, including combinations with prepositions» [12]. The project website says that «partly synsets are provided with contextual information in the form of valency frames; the format of their description is not yet complete». XML is used as the presentation format, but a significant part of the data prepared earlier requires verification and conversion to the current format. Examples of synsets are also given in the RussNet Synsets section, one of which can be downloaded. However, the site does not provide any information on how to access the whole thesaurus. On the WordNet site, there were links to downloading Russian WordNet1.7.1 databases and Russian WordNet 3.0 databases for the Russian language, with which it was proposed to download WordNet itself. The latter could not be downloaded due to the «Page not found» error. The link was sent by the reviewer of the CompLing2020 conference.

In addition to RussNet, there is YARN (Yet Another RussNet). On the YARN page it is indicated that «Work on the project has been discontinued since 2018», and YARN itself can be downloaded either in xml file format or in csv format file. Trying to download an xml file, an error occurs and the page crashes. The csv file contains synsets, sometimes half-tagged, but there is no valency information there.

It is also worth mentioning that English sources like SUMO, OpenCyc, WordNet were not taken into consideration under this work, for these projects were made namely for English language, whereas this study deals with Russian language.

2. Data collection

2.1. The concept of ambiguous syntactic construction

Syntactic structures created in the process of Syntactic Analysis represent the object of processing during semantic analysis. Automatic semantic analysis of a text is a procedure of constructing a semantic representation of a possible meaning of the text by processing the syntactic trees.

There are three approaches to the analysis of the syntactic structure: the structure of the immediate components, which is usually used for languages with strict word order and deals with immediate blocks of words, the structure of dependencies, which is usually used when working with Russian as it allows establishing connections between words and the combined approach. The latter allows one to take into account both the relationship between words (by analogy with the structure of dependencies), and the relationship between the individual immediate components. A combined approach was chosen for this study, because when resolving arrow homonymy in constructions with adjuncts, it is necessary to take into account the connections of the adjunct with a possible host, as well as take into account the connections between words within the entire ambiguous construction.

As the minimum components of sentence, we will consider word forms. Grammatical relations arising between the elements of a sentence are denoted by edges connecting the main word (master) and the dependent word (subordinate). Ambiguous structures arise from the fact that not all connections in the sentence are established unequivocally. Thus, the same «subordinate» can be attributed to different «masters».

(1) Детективы схватили Гулю в постели
Detectives caught Gulya in bed,
«Detectives caught Gulya in bed»,

The prepositional phrase «in bed» in (1) can join both the verb «caught» and the noun «Gulya». Then there are two options for parsing and, accordingly, two syntactic trees. In the first version, the interpretation is that detectives caught a girl named Gulya, and this situation took place in her bed, and in the second version, detectives caught Gulya, and Gulya was located

inside or dressed in her bed. Connections that are ambiguously defined for competing structures will be called homonymous links, and further we will consider the so-called attachment ambiguity.

2.2. Attachment ambiguity and its types

The most common case of attachment ambiguity of this type is that some syntactic group is “rearranged ” when it moves from one structure to another, that is, it changes the master [13].The most common types of rearranged syntactic group are the following: prepositional or coordinate structure group consisting of prepositional groups. In this case, the verb and the noun or two nouns most often compete.

(2) чтобы управлять разнообразными химическими реакциями в клетках
to control various chemical reactions in cells
«to control various chemical reactions in cells»

In (2) the group «in cells» can be attached both to the verb control and to the noun reactions. Other pairs of competing masters are possible: a participle – a noun.

(3) источающий свет на основе открытого заряда
emitting light from open charge,
«emitting light from an open charge»

In (3) something either emits light and does it being based on a charge (and there PP group is adjunct), or something emits light, and the light itself is turned on charge basis.

The other type is that the adjunct is adverb or coordinate structure group of adverbs and the masters are the same. The competing masters are the same: a verb and a noun.

(4) девочка вытерла тщательно вымытую посуду
girl wiped thoroughly cleaned dishes
«The girl wiped the dishes thoroughly cleaned»

In (4) the girl either thoroughly wiped the dishes after washing, or she wiped the dishes she had thoroughly washed before;

The last type is that the adjunct is verbal participle or verbal circulation and the masters are the same.

(5) директор распорядился продолжать работу, не обращая внимания на протесты
director ordered to continue work, ignoring protests
«The director ordered to continue the work, ignoring the protests»

In (5) the director was either ignoring the protests while ordering to continue the work, or the work should be continued no matter if there any protests or not.

2.3. Data collection based on NKRYA

Search for usage examples of the constructions was carried out in the NKRYA (URL: http://www.ruscorpora.ru/new/search-main.html access date: 14.09.2019) by grammatical features (tags and grammatical characteristics). This corpus was chosen for it is the publicly available and well-known syntactically labeled representative corpus of Russian texts with clear and accessible documentation. Necessary constructions were prepositional and nominal groups. Word that is a possible master: noun or verb. Query schemes are as following: verb + noun + prep+ noun, this scheme reflects (2) example where the competing hosts are noun and verb. Two queries were made, where the adjunct submits first to one host, and then to another.

In order to reproduce the structure corresponding to examples (3) and (5), verbs in the corresponding participle or infinitive forms were added to the parameters of the search query:

verb in infinitive form + noun + prep+ noun and verb in participle form + noun + prep+ noun. The last scheme is that one that reflects (4) example: verb+ adverb+ verb in participle form+ noun. There also were two queries for each of the last three types.

Among the search results for each query, examples of ambiguous constructions were manually selected. The number of selected examples was approximately the same for each query

in order to ensure sample representativeness. As a result, a list of 200 ambiguous constructions of the types mentioned above was compiled.

3. Resolving syntactic ambiguity by means of ontological semantics

3.1. The method of ontological semantics

«Ontological semantics is a theory of meaning in natural language and approaches to the analysis of natural language, which uses a constructed model of the world or ontology as the main resource for extracting and representing the meaning of texts, building a logical inference for knowledge derived from texts, as well as for generating texts based on from the presentation of their meaning» [14].

As mentioned earlier, to solve the problem, one must take into account the valencies of words that are implemented in the ontology as the concepts corresponding to lexical units. The method of ontological semantics is to provide semantic relationships between concepts by modeling the corresponding relationships. Based on what was said above, we can conclude that one of the important criteria for choosing a resource for automatically resolving arrow homonymy with adjuncts is the presence of a detailed description of valencies, since it is with their help that the chosen method is implemented. In addition, it is necessary to have links of higher levels with lower ones, so that the restrictions formulated once at the upper level are then applied to the lower ones. To perform this work, the linguistic processor AIIRE and the ontology built into it were chosen because this resource meets the above requirements. Further, this method implemented in the ontology of AIIRE will be described.

The selected ontology makes it possible not only to establish relationships such as synonymy, hyperonymy, etc., but also to specify semantic valencies of the meanings of the verbs, which are necessary to solve the problem in question, as they allow to have strict rules about possible connections between word meanings, hence there is no need in counting paths like it was done in [10]. In addition, the selected resource implements a combined approach to the analysis of the syntactic structure, which was previously chosen for the research.

According to A.V. Dobrov ontologies consist of concepts and the relationships between them. Concepts are formal (mathematical, computer) models of concepts behind the meanings of lexical units [11], which include“ attributes” and are interconnected by relationships. The latter represent a class of meaningful connections between the concepts of the two classes. All relations in themselves are concepts and, like all concepts, can be denoted by specific expressions (prepositions, conjunctions, verbs, complex names of relations) [11]. The concepts involved in the relationship are called the subject and object of the relationship.

Modeling in the ontology of concepts takes place in accordance with the rules of conventions and methods for working with ontology: words are distinguished from ambiguous constructions and then the corresponding to them concepts are manually modeled, that is, their meanings are written. For example, for the word «man» there is the meaning «a specific individual of the form homo sapiens». It represents the class «homo sapiens», which has generalized attributes common to all its representatives, for example, the ability to communicate through language. The following attribute inherits from its hyperonym «man (a specific individual of the form homo)»: the relation «to manufacture (produce a product)» with the object of the relation «tool of labor (an object used by a person to carry out some kind of activity)». Moreover, this concept under consideration also has the attribute «live (carry out vital activity)», which it inherits from the concept of «organism (living being)». Through hyperonyms, «man» inherits connections with basic concepts, such as, for example, «living creature». Using attributes, possible valencies for a given concept are formulated. So, «man» is the subject of the relationship «participation in the role of the subject of action», that is, it can be the bearer of an action and do something. This is a direct binary relation, who corresponds to the inverse relationship «possess the subject of the action», that is, any action can be performed by a «person». Thus, due to the fact that such

an attitude is written in the ontology, it will be recognized during the automatic processing of a sentence or phrase, which refers to a person who performs some action.

After modeling the values, one can load the entire structure into the manager body, which allows downloading texts for their further automatic marking, which reflects the structures of the direct components and dependencies. They will be automatically processed by the linguistic processor based on the rules prescribed in the ontology.

3.2. Data processing tools and the algorithm of the work

The algorithm of the work was as follows:

- To collect examples of ambiguous constructions, load them into the AIIRE corpus manager. After loading, structures are processed by the linguistic processor. Further it will be seen if the structures are recognized correctly. Their parsing depends on it;
- If constructions are not fully recognized, there are gaps between the syntactic trees that should be eliminated with the help of ontology. This part is done manually by viewing the list of already processed constructions, checking if there is a gap sign and then prescribing all the necessary relationships in ontology and filling out all the necessary valencies in Ontohelper;
- After eliminating the gaps, parsing is performed automatically and as a result we get the generated syntax trees and the corresponding semantic graphs;
- Syntactic connections between words are represented in the trees, and corresponding semantic relations between concepts are represented in semantic graphs. To understand, which versions are correct and which are wrong, it is necessary to look through and compare them with each other and to eliminate the erroneous ones by fine-tuning the concepts by means of Ontohelper and ontology editing interface.

3.2.1. Ontohelper

An auxiliary tool for working with ontology is Ontohelper, in the interface of which the meanings and relationships of specific verbs are modeled in order to simplify the procedure for writing down their meanings and relationships. The remaining parts of speech are modeled in the ontology interface. It is possible for them to create auxiliary interfaces in the near future.

The idea of Ontohelper is based on the hypothesis that any (subject, object, dative, prepositional) valency of any verb meaning can be: expressed as one and only one base class of ontological concepts for the meanings of nouns, independently sets one and only one base class of ontological concepts for verb meanings.

In general terms, this hypothesis defines any valencies as the relationship between the base classes of ontology.

There is an example of the work of ontology editing tools:

Consider an ambiguous construction:

(6) выяснение [разрыв] отношений в
Clarification [gap] of relations in leadership.
«clarification [gap] of relations in leadership».

It is necessary to make so that relations could be established, that is, the verb has to be connected with the corresponding object. Gap means there is no connection between them. Ontohelper allows selecting this verb in the desired meaning, if there is no such meaning, it can be added to the list of available meanings. Further fields are filled in:

- «Corresponding perfect-aspect verb»;
- «Processual noun corresponding to the given verb»;
- Now the subject and object of action or state are selected. Presumptive result is: the verb has an appropriate object of action or state and, therefore, this action is a concept in the ontology and will be correctly processed;

– In the ontology editing interface, it is checked whether the concepts we need exist and whether the necessary meanings of these concepts exist, as well as whether the concepts have the necessary relationships.

3.3. Disambiguation reprocessing in AIIRE ontology

After eliminating the gaps between the syntactic trees, the parsing is done and we get the syntax trees and the corresponding semantic graphs. The amount of parsing results can be large. To understand, which versions are correct and which are wrong, they need to be compared with each other.

The most frequent case of the emergence of several variants for parsing is the presence of several meanings in one or more lexical units. Then it is necessarily to check whether those meanings are presented in the semantic graph. After selecting the most correct meanings for a construction, it is also important to check the relationships between its elements, which can also be different. “Unnecessary” and inappropriate relations are revealed in accordance with logic and linguistic material by fine-tuning concepts in the ontology editing interface and Ontohelper, where only the correct relations are established.

(7) участие иудеев в делах
participation Judaists in deeds
«participation of the Judaists in deeds»

In (7) 4 variants of analysis were originally obtained. In two of them, the lexical units «participation» and «Judaists» were with a genitive relation: «Judaists» had the property «participation», and did not participate in anything. To eliminate this error, it was necessary to use the ontology editing interface, select the proper meaning of the noun participation: «engagement in any activity», to add the relationship «correspondence of the process to the action» and indicate the object of this relationship «to participate». After that, the concept of «Judaists» was refined: the hyperonym «follower» was added, which, in turn, is associated with the basic concept of «someone». The latter was needed to fine-tune the meaning of the verb to participate in Ontohelper, where the correct subject («someone») and the preposition «in» were chosen in the necessary meaning «(about participation) to refer to an object or process». At the end, after the fine-tuning, only two correct variants of participation of the «Judaists» in deeds were obtained, where the «Judaists» take part in the process.

4. Results

The total number of approved concepts in ontology – 82841; the total number of concepts approved during the course of the study – 909. Currently, as a result of processing and fine-tuning ontological concepts needed for that, gaps were eliminated in 66 structures out of 200 and 66 correct parsing versions were obtained with ambiguity resolved. Only in isolated cases such as «the participation of the Judaists in deeds» it was necessary to further fine-tune the ontological models for the concepts after the gaps were eliminated. This preliminary result suggests, in fact, in cases where the ontology is fine-tuned, the attachment ambiguity was resolved without any additional actions, and then, in 66 cases out of 66, one correct set of versions was obtained (the adjuncts are attached to one word in all versions). Then, it can be predicted that in the remaining 134 sample constructions the result will be comparable; evidence of this assumption will be presented in following parts of the research. Therefore, the main task is to eliminate the gaps (to establish ontological relations needed to do so), to introduce new concepts into the ontology, to enlarge the amount of constructions.

Conclusions and further work

According with the results of this work, it became obvious that the main task is to eliminate the gaps between syntactic trees and to introduce new concepts into ontology, to improve queries

and to increase the number of constructions being disambiguated. To implement this strategy, it is necessary:

- to fine-tune the requests by extending and concretizing them in order to receive more ambiguous constructions;
- to find constructions with attachment ambiguity on the given queries in the National Corpus of the Russian Language syntactic subcorpus for it contains parsing trees with which the results can be lately compared to see and to estimate the difference. In this case, requests should be formulated so that the result is exactly homonymous constructions, i.e. a preposition related to noun stood after that noun;
- to download these constructions automatically, so that there will be faster and there will be more examples, then in the current study; to create a corpus of constructions found;
- to upload these constructions to the AIIRE corpus manager and to provide the absence of the syntactic tree gaps;
- to provide resolution of attachment ambiguity;
- to compare the result for each disambiguated construction with that in Syntax subcorpus and check the correctness of the results obtained.

The results of this work will be presented in subsequent articles.

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