**IRSTI 20.23.17; 20.23.21**
**UDC 004.421, 004.912**

# THE DECISION AMBIGUITY PROBLEMS FOR THE KAZAKH LANGUAGE

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**Abstract**. For the Turkic languages, including the Kazakh language, there are many applications that are not allowed. Recently, the study of the problems of ambiguity in natural language processing is relevant. This problem occurs in various intelligent information systems, such as information search, machine translation, text and speech analysis, etc. There are various approaches to solving this problem. But for the application of the Kazakh language, taking into account its features, there were difficulties. This article discusses the problems of ambiguity of the word for the Kazakh language. Based on the proposed technology, the process of solving the problem of ambiguity for the Kazakh language in the machine translation system for Kazakh-English and Kazakh - Russian pairs (and Vice versa) is described. The proposed technology includes a restriction grammar model and a maximum entropy model for a more effective solution to the problem of lexical selection for the Kazakh language. The results are presented by comparing the two technologies separately and together.

**Keywords:** ambiguity, technology, Kazakh language.

## Introduction

Automatic detection of the correct translation of words that depend on the context is a very difficult task. The solution of lexical polysemy is perceived as the main task, the solution of which will allow achieving an almost perfect machine translation. Machine translation has two main problems in text processing. First of it is lexical selection, which connected with problem of choosing corresponded translation by context. Second problem of a lexical words is order. Later consider the task of words order in sentence of target language. In word processing the main problem is lexical selection, which leads to disambiguation task.

The work of the translator's program is carried out in several stages. The development of algorithms that allow us to recreate the human ability to understand and choose the right meaning of a word is a difficult task. It consists in choosing the most suitable translation in the context under consideration from all possible translations. The solution of the problem involves finding the probable meanings of words, determining the relationships between these values and the context in which the words were used.

The scientific novelty of paper is in developing combined technology of lexical polysemy (selection) based on the constraint grammar model and maximum entropy model and them sequence applying to Kazakh language as source and target language in translation pairs Kazakh-English and Kazakh-Russian (and vice versa).

## Related works

Scientific research on a word sense disambiguation has long-term history. With a current of years the number of the proposed solutions and their efficiency steadily grew, but the task hasn't received the full decision yet. A large number of methods have been investigated: from the methods based on knowledge, rules, lexicographic sources, training with the teacher at corpus to training methods without teacher, clustering words on the basis of meaning. Among listed, today, training methods with the teacher have shown the best efficiency.

The problem of resolving ambiguity as a separate problem was formulated in the middle of 20th century, almost simultaneously with the advent of machine translation. Since that time, many methods of solving this problem have been developed, but it is still actual.

M. Tyers, Felipe S´anchez-Mart´ınez, Mikel L. Forcada in [1] uses the maximum entropy model for performing lexical selection in machine-based translation systems based on rules to English-Basque, English-Catalan. As a learning method, the method of teaching without the teacher (unsupervised methods) is used, which does not require an annotated corpus. The system uses the maximum entropy formalism for lexical selection as in Berger [2] and Marecˇek (2010) [3], but instead of counting the actual lexical selection event in the annotated corpus, they consider fractional occurrences of these events according to the model of the target language.  David Marecˇek, Martin Popel, Zdeneˇk Zˇabokrtsky in [3] showed the model of the maximum entropy of translation in machine translation based on dependencies, which allows to develop a large number of features of functions in order to obtain more accurate translations. Francis Morton Tyers in [4] the general method of teaching rules for the module is described. Monolingual and bilingual corpora can be used for the method. For learning a monolingual corpus the method without the teacher (unsupervised method) is used. Also weighting method is described, based on the principle of maximum entropy. This method allows to take into account all the rules without having to choose between conflicting and overlapping rules.

Rule-based approaches in lexical selection not cover all possible translation of source language. Since it is not always possible to take into account all rules. In the statistical approach, lexical choice also does not guarantee for the correctness of the translation in context. Analyzing both approaches, we came to the conclusion about the development of technology combining the two approaches mentioned above with solutions to lexical selection problems for the Kazakh language in Apertium systems.

## Technology of lexical selection

The technology for solving the problem of lexical selection we propose consists of two models: the model of production rules (constraint grammar) and the maximum entropy models (fig. 1).

In the process of translating a lexically ambiguous word, the system first solves the problem using the model of production rules. The model of production rules gives a good result, but does not completely solve the task. Because rules are not cover all cases of ambiguity of a certain word in any context. A word can have a different senses, and can be used with different other words in a context. And there can be many such combinations. And writing the rules can take a lot of time. Therefore, for the case when there is no written rule for some case, the selection of translation is solved by using data in semantic cube based on parallel corpora processed by statistical model. So, the ambiguous word is processed using the statistical part of the module.

The models of combined technology performed sequentially. Firstly is used the model of production rules and then maximum entropy model.

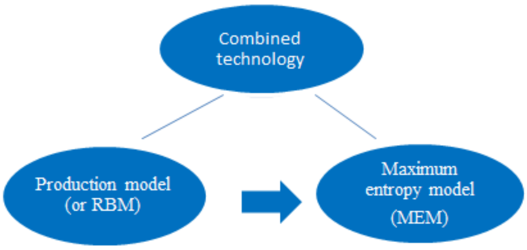


**Figure 1** – The models of combined technology

The technology of combined technology was introduced in the Apertium [5]. In the aperture, divide into two parts the lexical selection and lexical choice based (fig. 2) on the semantic cube.

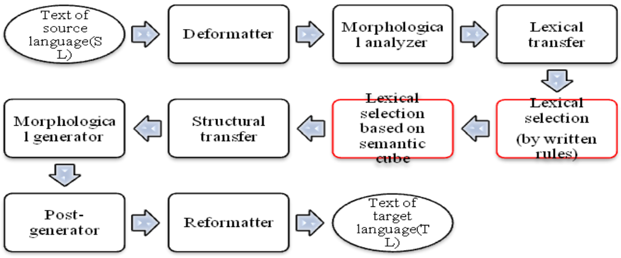

Text of source language(SL)
Deformatter
Morphological analyzer
Lexical transfer
Lexical selection (by written rules)
Lexical selection based on semantic cube
Structural transfer
Morphological generator
Post-generator
Reformatter
Text of target language(TL)

**Figure 2** – The technology in Apertium work pipeline

### Model of production rules

In the Apertium system, the lexical selection (polysemy) problem is solved by writing the rules manually in the lexical selection module using the Constraints Grammar, which has the form of product rules.

The model of product rules is a rule-based model, where knowledge is shown in the form "if (condition), then (action)". The product model can be represented in the following form:

$$i = \langle S, L, A \rightarrow B, T \rangle$$

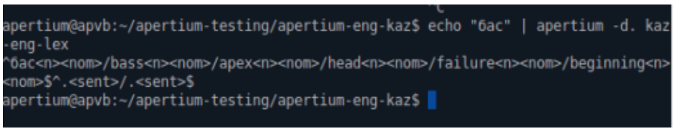
where $S$ is a case, $L$ is translation, $A \rightarrow B$ is productivity kernel, $T$ is a postcondition of the production rule.

The rules of lexical selection are written in the file "apertium-eng-kaz.eng-kaz.lrx" for the English-Kazakh and in the file "apertium-eng-kaz.eng-kaz.lrx" for Kazakh-English pair of languages. All rules are written in XML format. The format of lexical rules is based on the technology of patterns. This module is used to select a translation when the meaning of ambiguous word refers to one part of the speech. For example, the word "year" is more often translated as "жыл"[zhyl], and the phrase "five years old" is translated as "бес жаста"[bes zhasta], that is, it indicates the age of a person. For this case the following rule is written:

```
<rule> <match lemma="year" tags="n.pl.*">
          <select lemma="жас" tags="n.*"/>
</match> <match lemma="old" tags="adj.*"/></rule>
```

The meaning of the rule: if after the noun "year" is an adjective "old", then the translation "жас"[zhas] is chosen.

For example word “бас”[bas] has various translation(fig. 3):



```
apertium@apvb:~/apertium-testing/apertium-eng-kaz$ echo "бас" | apertium -d. kaz
-eng-lex
^бас<n><nom>/bass<n><nom>/apex<n><nom>/head<n><nom>/failure<n><nom>/beginning<n>
<nom>$^.<sent>/.<sent>$
apertium@apvb:~/apertium-testing/apertium-eng-kaz$
```

**Figure 3** – The translations of word “Бас” in bilingual dictionary of English

The figures below show lexical units to word “бас(bas)”. As you see given words have 4 translations.

```
<rule><match lemma= “адам” tags=n.*”/>
  <match lemma= “бас” tags=”n.*”>
<select lemma=”head” tags=”n.*”/></match></rule>
<rule>
  <match lemma="фильм” tags= “n.*”/>
```

<match lemma= “бас” tags= “n.*”><select lemma= “beginning” tags= “n.*”/></match></rule>

The meaning of the rule: if word “бас”[bas] comes after word “адам”[adam], the translation will be as “head”, whereas when it comes after with “фильм” [film] it translated as “beginning”

The model of production rules gives a good result, but does not completely solve the task. Because rules are not cover all cases of ambiguity of a certain word in any context. Kazakh-English language pairs in Apertium currently have 98 and 75 lexical selection rules respectively. And Kazakh-Russian language pairs in Apertium currently have 76 and 59 lexical selection rules respectively. A word can have a different senses, and can be used with different other words in a context; and there can be many such combinations. And writing the rules also depending of knowledge level of developer. The lexical selection rules are written to the various part of speech, namely to noun, verb, adjective, adverb, preposition and etc. Therefore, for the case when there is no written rule for some case, the selection of translation is solved by using statistics the maximum entropy model.

## Maximum entropy model

Lexical selection maximum entropy model includes a set of binary functions and appropriate weights for each function [4]. The feature is defined as $h^s(t,c)$ in equation (1), where t is a translation and c is a source language context for each source word s:

$$h^s(t,c)=\begin{cases}1, c\_the\_value\_of\_tunder\_the\_condition\_c\\ 0, other\end{cases} \quad (1)$$

During the learning process each function is assigned a weight $\lambda^s$, and combining the weights as in Equation (2) gives the probability of a translation t for word s in context c.

$$p_s(t\mid c)=\frac{1}{Z}\exp\sum_{k=1}^{n_F}\lambda_k^s h_k^s(t,c) \quad (2)$$

where Z is a normalizing constant, $n_F$ – numbers of features for $s$. Thus, the most probable translation can be found using equation (3)

$$\hat{t}=\arg\max\ p_s(t\mid c)=\arg\max\sum_{k=1}^{n_F}\lambda_k^s h_k^s(t,c) \quad (3)$$

where $t\in T_s$, $T_s$ are all possible translations for $s$ source word, $\lambda$ is weight of known translation.

It is important to note that the rules for the function $h^s(t,c)$ will be different depending on the language pair. Consider an example: 'Mark is a bass player. He fried the bass'. In these sentences the word bass is ambiguous. In the first sentence, the sentence is translated into Kazakh as a "bass guitar", and in the second as a type of fish "алабұға" [alabuga]. Then the function has the form

$$h^s(t,c)=\begin{cases}1, if\_t='бас-гитара'\_and\_'player'\_after\_bass\\ 0, in\_other\_clases\end{cases}$$

In combined technology the maximum entropy model is realized through the construction of a semantic cube.

## Algorithms of semantic cube

The algorithm for implementation consists of the following steps:

Step 1. Create a frequency list of words.

First, to build a cube, we create a frequency list and a list of ambiguous words. The frequency list is a list of the most often met words in the corpus.

Step 2. Create a list of ambiguous words.

After composing the frequency list, it is necessary to find among them ambiguous ones, namely, the lexical ambiguity is taken into account, that is, when possible translations of the required word belong to one part of the speech (tab. 1).

**Table 1.** Example of ambiguous words.

| Ambiguous words | Part of speech | Sense 1 | Sense 2 | Sense 3 |
|---|---|---|---|---|
| String | Noun | жол | Жіп | ішек |
| Order | Noun | рет | жарлық | орден |
| Part | Noun | бөлік | партия | дене |
| Small | Adjective | кішкентай | Ұсақ | шағын |
| Thing | Noun | зат | Нәрсе | дүние |
| Discover | Verb | байқау | Ашу | табу |
| Information | Noun | ақпарат | Хабар | мәлімет |

Step 3. Prepare bilingual parallel corpus.

Next, we prepare a bilingual corpus. Each statistic machine translation consist the greater number of text array. These arrays named as corpora. The word "prepare" means that "unnecessary" words or stop words are deleted, which have a special effect in calculating probabilities, as well as choosing the sense of the word. Such words, for example, articles like the, a, an, numbers, punctuation marks, etc. It is also necessary to bring all the words from the context to the basics, that is, to the initial form of the word. This completes the preparation of the corpus.

Step 4. "Training" / "Machine learning" stage. Semantic cube building.

The result of applying the maximum entropy model to solving the problem of lexical selection is the construction of a "semantic cube". At first the statistical system passes a stage of "training" at which statistical data on the translation of separate words and phrases from source language on target language are taken. The maximum entropy model is trained on a pre-prepared parallel bilingual corpus [8]. On the basis of this stage the cube is formed. The cube represents a three-dimensional set of tables. The tables contain the senses of ambiguous words, the context, the meanings of the probabilities of the senses (translations) of ambiguous words that depend on words from the context.

There two variables can be denote as a linear releationship:

$$amb_{word} : t_i \rightarrow f_i \in C$$

Choosing or finding word’s translation basically depends on two main variables - translation and context.

The semantic cube model determines the translation by weight of word’s context in parallel corpora. The model gives information about frequency and probability to determined words and his neighbourhood words. The frequency of a translation is determined by the number of occurrences of the features, and when the known features are repeated, the number increases to 1.

The probability of translation calculated by next formula (4):

$$P_{amb\_word}\left(v_{f_{ij}} \mid f_n\right) = \frac{v_{f_{ij}}}{\sum_{i=1}^{n} f_n} \tag{4}$$

where, $v_{f_{ij}}$ is the frequence of a word with a certain translation, $\sum_{i=1}^{n} f_n$ is total amount of features in corpora for a particular translation.

The found probability gives the weight of a specific word translation. The model of semantic cube chooses the translation from the corresponding set of tables of multivalued words maximizing their frequency and probability (formula 5):

$$\tilde{t} = \arg\max_{t \in c} \sum_{i=1}^{n} P_{amb_{word}}\left(t_i \mid f_n\right) \tag{5}$$

The advantages of this model it works with parallel corpora.

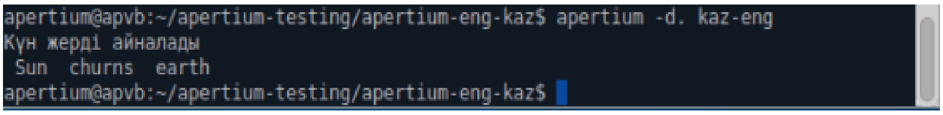
Step 5. "Testing" stage.

Next is the "testing" stage which is made on another separate text, consisted of sentences, in which there are ambiguous words. During the translation process, this system calculates the most likely translation of the source sentence based on the data obtained during training. By comparing probabilities, as a translation for ambiguous word is selected the sense which has higher probability. It should be noted that the larger the volume of the corpus, the higher the quality of translation.

There are three outputs of the result for this technology. In the first case, when the system recognizes that there is an (lexical) ambiguous word in the sentence, then the word goes into the lexical selection module. First, the ambiguity is solved by using the model of product rules. If there is a written rule in the file for the required ambiguous word, then the translation for the word is selected based on this rule. In the second case, if there is no such rule, then a transition to the next stage occurs, where the problem is solved using the maximum entropy model. In this case, the translation for the required word will be that sense, which probability is higher. In the third case, when the translation cannot be found using the product rules model, or the maximum entropy model, as the default translation selects the meaning that is first specified in the bilingual dictionary.

Compared with other works of Berger(1996)[2] and Dell Pietra(1997) [6], our model differs in that the whole sentence is used as a context. Sanchez-Martinez and Tyers (2015) [7] use monolingual corpora; we use bilingual parallel corpora and a frequency list of ambiguous words with certain senses. Tyers uses a monolingual corpus of the source language and a statistical model of the target language. In his model the volume of context for an ambiguous word is four words, two on each side. We have the context of all the words included in the sentence, with the ambiguous word.

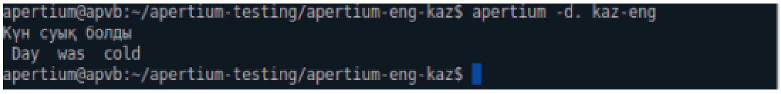
In the below figures the results of combined technology are presented (fig. 4):



```
apertium@apvb:~/apertium-testing/apertium-eng-kaz$ apertium -d. kaz-eng
Күн жердi айналады
 Sun  churns  earth
apertium@apvb:~/apertium-testing/apertium-eng-kaz$
```

**Figure 4** – The results to word “күн”[kun] with combined technology

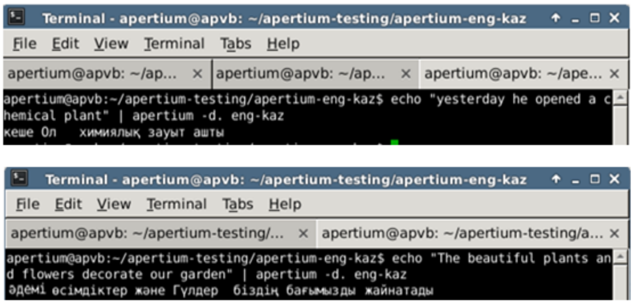
At the fig. 4 Kazakh word “күн”[kun] depending of context is translated as “sun”.



```
apertium@apvb:~/apertium-testing/apertium-eng-kaz$ apertium -d. kaz-eng
Күн суық болды
 Day  was  cold
apertium@apvb:~/apertium-testing/apertium-eng-kaz$
```

**Figure 5** – The translation’s results to word “күн”[kun] with combined technology

At the fig. 5 Kazakh word “күн”[kun] depending of context is translated as “day”.


Terminal - apertium@apvb: ~/apertium-testing/apertium-eng-kaz
File Edit View Terminal Tabs Help
apertium@apvb: ~/ap...
apertium@apvb: ~/ap...
apertium@apvb: ~/ape...
Terminal - apertium@apvb: ~/apertium-testing/apertium-eng-kaz
File Edit View Terminal Tabs Help
apertium@apvb: ~/apertium-testing/...
apertium@apvb: ~/apertium-testing/a...

```
apertium@apvb:~/apertium-testing/apertium-eng-kaz$ echo "yesterday he opened a c
hemical plant" | apertium -d. eng-kaz
кеше Ол   химиялық зауыт ашты
```

```
apertium@apvb:~/apertium-testing/apertium-eng-kaz$ echo "The beautiful plants an
d flowers decorate our garden" | apertium -d. eng-kaz
әдемі өсімдіктер және Гүлдер  біздің бағымызды жайнатады
```

**Figure 6** – The translation results for word “plant” with combined technology

In fig. 6 is given examples for English-Kazakh language pair. The word “plant” is ambiguous word can be translated into Kazakh as “зауыт”[zauyt]-“factory” and “өсімдіктер”[osimdikter]-“herb”. In both situations combined technology model chose right senses, for the first “зауыт”[zauyt] and for the second “өсімдіктер”[osimdikter].

For realization of the combined technology the rules and parallel corpora are used to determine the context. By using corpora for training and testing we distinguish context for ambiguous word. To resolving the task of lexical selection we collect and use parallel corpora [8, 9] taken from different sources such as texts in electronic form from various famous literary novels, fairy tales, open Internet resources, news portals.

We have collected the English-Kazakh parallel corpus of ~30000 sentences, the Kazakh-Russian parallel corpus of ~26 000 sentences.

## Experiments results

In experiment for determining the translation were estimated in modes of checking productive rules, maximum entropy model and proposed combined technology in two direction of translation: Kazakh-English and Kazakh-Russian. Results are given in tab. 2.

**Table 2.** Results of experiments on corpora

| Language pair | Total number of sentences | Produc | Maximumen | Combined technolog |
|---|---|---|---|---|

| | | tive rule model, % | tropy model, % | y, % |
|---|---|---|---|---|
| Kazakh-English | 26078 | 52 | 72 | 87 |
| English-Kazakh | 26078 | 48 | 65 | 78 |
| Kazakh-Russian | 22053 | 53 | 64 | 68 |
| Russian-Kazakh | 22053 | 62 | 68 | 70 |

By the results we can see that the proposed combined technology works better.

## Conclusion and future work

In this paper was performed a combined technology uniting the model of productive rules and maximum entropy model for solving the problem of lexical selection for English-Kazakh and Kazakh-English language pairs. Also parallel bilingual English-Kazakh corpus has been developed with ~30000 sentences, Kazakh-Russian corpus has been developed with ~26 000 sentences. Experiments of checking productive rules, maximum entropy model and proposed combined technology in two direction of translation: Kazakh-English and Russian-Kazakh shows better results of proposed combined technology of lexical selection.

In future work we plan to increase the volume of parallel corpora for receiving more exactly results in solving of lexical selection.

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