The methodology of semantic analysis for extracting physical effects

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Abstract. The paper represents new methodology of semantic analysis for physical effects extracting. This methodology is based on the Tuzov ontology that formally describes the Russian language. In this paper, semantic patterns were described to extract structural physical information in the form of physical effects. A new algorithm of text analysis was described.

1. Introduction

Nowadays, the semantic analysis is one of the most topical and growing areas in computer science. In this work, the semantic analysis is considered as a tool for extracting structured physical information in the form of physical effects (PE). Today the task of identifying PE descriptions in the science texts to supplement the database of PE is the information basis for the new technical solutions development. It is an important and actual task. Today, there is the system of identifying PE descriptions. It was realized using the semantic analyzer “Semantix” [1]. The system and the semantic analyzer that are described in this work were realized using the Tuzov ontology.

2. Program systems and tools for semantic analysis

Analysis of the effectiveness of software systems for semantic analysis is shown in Table 1, Table 2.

| Program system | An algorithm of target entities identifying | The system's flexibility (the ability to customize settings, adding new entities) | License | Accuracy extracting (1 - 75% 2 - 65 - 75%, 3 - 65% less) | Completeness (1- more than 60%, 2 – less than 60%) |
|----------------|---------------------------------------------|--------------------------------------------------------------------------------|---------|----------------------------------------------------------|--------------------------------------------------|
| Extracting facts from the text files, RCO [2] | Patterns search | The parameters are hard-coded | Close | 1 | 2 |
| Attensity Text Analytics [3] | Neural network technology | The parameters are hard-coded | Close | 2 | 1 |
| NetOwl Extractor [4] | Neural network technology | The ability to add new entities | Close | 1 | 1 |
| IOFFE [1] | Patterns | The ability to add new | Open | 3 | 2 |

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search patterns

Table 2. Semantic analysis systems

| Software             | Russian support | License | Base technology                  | Flexibility (focus on the subject area, the ability to customize, code availability) |
|----------------------|------------------|---------|----------------------------------|----------------------------------------------------------------------------------|
| Stanford nlp [5]     | No               | Open    | Machine Learning Technologies    | No                                                                                |
| Malt parser [6]      | Yes              | Open    | Machine Learning Technologies    | No                                                                                |
| Link grammar parser  | No               | Open    | Relations grammar                | No                                                                                |
| AGFL [8]             | Yes              | Open    | AGFL-grammar                     | No                                                                                |
| Tomita parser [9]    | Yes              | Open    | CF-grammar and key words         | dictionaries                                                                     |

As is seen from the tables, most of the systems are flexible enough for adjustment to the subject area. It is necessary to create a new approach to work with the physical science text.

3. Semantic analyses for extracting structured physical knowledge in the form of physical effects of the Tuzov ontology

Ontology of the Russian language [10] is a formal description of the Russian language proposed by V.A. Tuzov (semantic roles are defined on the basis of semantic classes and morphological information). The base of computer semantics uses the functional model of the language:

1) the language is an algebraic system \{f_1, f_2, ..., f_n, M\}, where \( f_i \) - basic functions of a language and \( M \) - the structure of a language, which is a set of basic concepts \( m_1, ..., m_r \) and their hierarchy;

2) each language sentence can be represented as the superposition of basic functions \( f_i \), and every word of the language is expressed by these functions. The exception - basic concepts \( m_j \), belonging to \( M \);

3) grammar is inextricably linked with the language semantics, which basis is the semantic dictionary that describes more than one hundred thousand lexical units (words and phrases), and each word is described as a semantic formula consisting of basic functions.

Table 3. Some basic functions

| Function | Description |
|----------|-------------|
| Caus (x,y) | x is the reason y |
| Loc(x,y)  | x is in y    |

The dictionary entry contains a header word and its interpretation in the semantic language:

EXPOSURE $15142 (\text{Caus}_{o} (\text{AGENT:} \text{SOMETHING} \;\$\; 1 \rightarrow \text{Gen, Lab} \;\text{OBJECT:}! \text{Acc, LOCATION:} \;\text{Prep})))$

3.1. Physical Effect

There is a formal description of a physical effect [11]. It consists of the following structure \((A, B_1, B_2, C)\): \( A \) - an input stream of matter, energy or signals; \( B_1 \) - the initial state of a physical object \( B \); \( B_2 \) - the final state of the physical object \( B \); \( C \) - the flow of matter, energy or signals; At the department, CAD, of Volgograd State Technical University, the physical effects fund was established. This fund has more than 1,200 PE descriptions.

3.2. The model of structured physical information representation in natural language texts

The model of structured physical information representation in natural language texts was created to retrieve descriptions of physical effects [12]:

\[ M_{PE} = \langle C, D, B, R_C, R_D \rangle, \]

where \( C \) - the set of predicates (relations), to describe the PEs in the text, \( c_e \in C \);
D - semantic roles and case arguments in predicates \( D_i \subset D \) - a list of roles / arguments of cases agreed with predicate \( c_i \); 

\( d_j \in D \); 

- \( B \) - a number of elements to describe PE (A, B, C), \( B_k \in B \), 

where \( B_k \in \{ \text{input (A), output (C), object (B)} \} \); 

\( \text{def} \) - the operator that is associated with the role / case of the \( d_j \) argument at the \( c_i \) predicate; 

- \( R_C \) - the relationship on \( C \times D \), pair \((c_i,d_j) \in R_C\) uniquely identifies the item of the PE description, consistent with the role of predicate / case \( d_j \); 

- \( R_B \) - the relationship at \( R_C \times B \), pair \(((c_i,d_j),B_k) \in R_B\) defines a set of concepts corresponding to the element of PE description \( b_k \), \( b_k \in B_k \).

3.3. The algorithm of semantic analysis for extracting the semantic roles

The algorithm of semantic analysis for extracting the semantic roles of Agent, Object, Place arguments is shown in Figure 1.

As a result of domain analysis, we can see the presence of semantic ambiguity. Semantic ambiguity arises because sometimes it is possible to match one semantic role of the Tuzov ontology (role "Agent", "Object", "Place") and several elements of the physical effect description ("Input", "Output", "Object" of physical effect).

To remove this kind of semantic ambiguity, one software module was developed. It is required for matching the existing descriptions of physical effects and semantic roles described in the templates on the basis of the Tuzov ontology.

The approach is to compare the semantic roles, elements of the physical effects descriptions and specific words, which may show the ambiguity. It was realized using the field (PE Description in the natural text) in the database of physical effects [13].

- \(<\text{Semantic role}> - <\text{Item of PE description}>\). 

- On the basis of statistics of this bunch, a template for the PE extracting is formed for each predicate.

The algorithm for constructing correspondences of semantic roles in the ontology and elements of the PE descriptions for the subject area of the predicates is shown in Figure 2. Thus, the overall physical effects extraction algorithm is shown in Figure 3.

4. Results

The main performance indicators are the accuracy and completeness of extraction.

Accuracy is characterized by the number of correctly retrieved elements from the total number of elements of PE description.

\[
P = \frac{N_k}{N_n} \tag{2}\]

\( P \) - extraction accuracy of the PE, \( N_k \) number of correctly retrieved elements, \( N_n \) - the number of elements found in the text.

Completeness of the PE elements extraction indicates the amount of elements relative to the total number of PE elements in the text descriptions.

\[
R = \frac{N_k}{N} \tag{3}\]

\( R \) - completeness of extraction, \( N_n \) - the number of PE elements found in the text. \( N \) - a total number of elements of the PE elements in the text.

F-measure is calculated as 4:

\[
F = \frac{(\beta^2 + 1)PR}{\beta^2P + R} \tag{4}\]

\[
\beta^2 = \frac{1 - \alpha}{\alpha} \tag{5}\]

where \( \alpha = 0.3 \).
Tokenization

Morphological analysis

Lemmatization

Extraction domain predicates

For all predicates

Finding the predicate in the sentence

Extract the pattern corresponding the predicate from the patterns based on the ontology

Extract the nouns corresponding the arguments of Agent Object Place of the PE based on the ontology pattern

For every argument corresponding the semantic role

Extract the nouns and adjectives connected by cases

For every PE description

Extract the Input, Output and Object of PE from the corresponding fields

For all predicates of the subject area

Find the Predicate in the PE description

Extract the arguments of the Agent, Object and Place roles from the Tuzov ontology

PE formation of their compliance for the predicate

**Figure 2.** The algorithm for constructing correspondences of semantic roles in the ontology and elements of the PE descriptions for the subject area of the predicates.

For every predicate of the subject area

Find the predicate in the text

Find the arguments corresponding the semantic roles in the pattern based on the Tuzov ontology

Comparison the arguments to the PE element description based on the corresponding patterns

Elimination the semantic ambiguity by check for the presence of the argument in the thesaurus

**Figure 3.** The extraction algorithm of overall physical effects.

**Figure 1.** The algorithm of semantic analysis for extracting the semantic roles of Agent, Object, Place arguments.
Tests were carried out on the basis of the database of physical effects developed at the department of VSTU. 100 physical effects were selected. Tests were conducted on the base of physical effects descriptions in the database and compared with the fields “Input”, “Output” and “Object” of the physical effects. Tests were also conducted by the example of 31 patent documents (field “description”).

The results were compared with the results of program IOFFE [1] on the basis of the semantic analyzer “Semantix”.

The results of the effectiveness comparing are shown in Tables 4 and 5.

| Table 4. Analysis of efficiency using the PE database |
|-----------------------------------------------|
| Accuracy (%) | Completeness (%) | F-measure |
|----------------|------------------|-----------|
| Our system    | 68               | 59        | 61.5 |
| IOFFE         | 57               | 53        | 54.14|

| Table 5. Analysis of the effectiveness using the patent array |
|-----------------------------------------------|
| Accuracy (%) | Completeness (%) | F-measure |
|----------------|------------------|-----------|
| Our system    | 53               | 46        | 47.9 |
| IOFFE         | 46               | 41        | 42.38|

Efficiency Analysis showed that the developed system improves the efficiency to 4% for accuracy and completeness – to 7%.

Sample. Patent description: “The photoelectric conversion element may be a photodiode having a p-n junction or a pin junction, a phototransistor, or the like. When the incident light hits the semiconductor junction of the cell, this light leads to the appearance of the photoelectric effect, in which electric charges arise.” [14]

PE Input: “Light, any other electromagnetic radiation (energy - eV)”.  
PE Output: “The electric charge (electron emission), (J)”.  
PE Object: “Photoconductive material (photoconductor)”.

The results of the program show the results of the physical effect elements extraction:  
PE Input: “Light”. PE Output: “electric charge”. PE Object: “phototransistor”.

5. Conclusion

The method described in this article allowed increasing efficiency of the PE elements extracting. The semantic analyzer based on the Tuzov ontology was created to increase the accuracy and completeness of the method. The approach was tested on the PE database and the patent array.

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