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AUTOMATION OF SEARCHING FOR TERMS IN THE EXPLANATORY DICTIONARY

О.Б. Кунгурцев, Н.О. Новікова, М.Г. Кожушан. **Автоматизація пошуку термінів в тлумачному словнику.** В роботі запропонований спосіб автоматизації пошуку тлумачень термінів в залежності від розглянутої предметної області в раніше підключених словниках і в Інтернеті. Розроблено математичну модель тлумачного словника на основі аналізу структури словникових статей. Розроблено методику налаштування аналізатора словникової статті для певного словника, який раніше не використовувався. Розроблено методику автоматизованого пошуку однослівних і багатослівних термінів в електронних словниках шляхом сканування словникових статей на наявність пошукових термінів за допомогою регуляторних виразів. Реалізовано пошук в Інтернет-ресурсі завдяки інструменту для автоматизації дій веббраузера Selenium. Розроблено дві методики автоматизованого аналізу результатів пошуку відповідно до предметної області. При наявності в структурі словникової статті помітки стилістичної зони, яка вказує на область вживання терміну, результати коректуються шляхом відсіювання невідповідних їй тлумачень багатозначних термінів. При відсутності цієї позначки результати пошуку коригуються шляхом аналізу числа входжень пошукових термінів в тлумачення. Запропоновано створення банку словників для накопичення налаштованих для пошуку електронних словників. Розроблено програмний продукт, який дозволяє організувати пошук в підключених і вбудованих електронних тлумачних словниках і в Інтернет-ресурсі. Робота з програмою вимагає залучення експерта для коригування та верифікації результатів. Ефективність способу підтверджена експериментально. В експериментах були використані терміни російського, українського, англійської мов з різних предметних областей. Запропоновано формули розрахунку витраченого на пошук часу для оцінки ефективності реалізованих методик. Результати продемонстрували скорочення часу на пошук в автоматизованому режимі в порівнянні з ручним приблизно в 5 разів. Показано, що при підключенні тлумачного словника спеціалізованої предметної області, результати пошуку найбільш влучно розкривають поняття термінів.

Ключові слова: тлумачення терміну, електронний словник, система поміток, математична модель тлумачного словника, словник предметної області

O. Kungurtsev, N. Novikova, M. Kozhushan. **Automation of searching for terms in the explanatory dictionary.** In this paper, an approach for automating the search for interpretations of terms for a specific domain in explanatory dictionary and on the Internet is proposed. A mathematical model of the explanatory dictionary is developed. It bases on the structure of the dictionary entry. The methodology for setting up an analyzer of a dictionary entry in a dictionary that has not been used before is developed. A methodology for automated search for one-word and multiword terms in electronic dictionaries has been developed. It bases on scanning dictionary entries in search for term using *Regular Expressions*. The automation of searching on the Internet resource using a browser automation tool Selenium is proposed. Automated analysis of search results in according to subject area have been developed in two methods. If there is a stylistic label in the structure of a dictionary entry, which indicates the area of the polysemantic term using, the results are corrected by filtering out definitions that do not correspond to this subject area. If there is no stylistic label, the search results are filtering out in the way of screening out definitions for occurrence of search terms. The creation of Dictionary bank for storing set-up to search electronic dictionaries is proposed. The program product, which allows search organizing in added and built-in electronic dictionaries and on the Internet resource, was developed. Using the program requires involvement of an expert to correct and verify the results. Working with the program requires the involvement of an expert to correct and verify the results. The effectiveness of the approach is confirmed experimentally. Groups of English, Russian and Ukrainian terms from different subject areas were used in the experiments. Formulas to determine the time spent on searching are proposed to assess the effectiveness of the implementation of the developed methods. The results showed a reduce of the time spent on search in the automated mode in about 5 times compared to the manual one. It is shown that adding an explanatory dictionary of a specialized subject area gives the most certain definition of terms in search process.

Keywords: interpretation of the term, electronic dictionary, system of labels, mathematical model of the explanatory dictionary, dictionary of the subject area

Introduction

For the formation of dictionaries of the subject area (SA), thesauruses, creation of user interfaces, work with various documents it becomes necessary to get the interpretation of some terms. There are many general-purpose [1, 2, 3] and specialized [4, 5, 6] online dictionaries. Each of them has a specific structure of dictionary entries. Usually it takes 5 to 10 minutes to find an appropriate dictionary,

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study its structure and find the correct interpretation. When dictionary is often used, for example, for translating or editing texts in narrow SA, studying documentation and formulating requirements for a software product such a search can significantly reduce the efficiency of an expert. Consequently, there is a problem of spending a lot of time searching for interpretations of terms.

Analysis of the Literature Data and Formulation of the Problem

To create a dictionary of some SA, it is necessary to select terms from the documents of this SA and find their interpretation. By a term we mean one word or a collocation that has a certain meaning in some SA.

The papers [7, 8] focus on the automated selection of multiword expressions [9, p. 166] from documents in a specific domain. In paper [10] a method of choosing a correct interpretation for a term from a dictionary entry is proposed. It bases on the use of entering into the interpretation of previously defined terms. However, the problem of searching for correct interpretation in a dictionary entry was not solved completely, but only for some specific dictionaries.

In the Interpretatio program [11] it is possible to search for a term in many dictionaries, but there are no multiple search function, i.e. search for all selected terms at the same time, and search for multiword expressions is also not implemented. Analysis of the dictionary entries structure in explanatory dictionaries showed an important role of the “Label system” [12] in search organizing for a correct interpretation of a term.

The dictionary entries define many interpretations of the term, as well as inter-word relations, in which the given term has a variety of shades of meaning. This capacity is called polysemy [13, p. 8]. Modern lexicology sees in the polysemy of words their ability of semantic variation, in other words, to change the meaning depending on the context. The most polysemantic of the independent parts of speech in Russian, Ukrainian and English are verbs. [9, p. 139]. The verb “to go” in Russian is a record holder for polysemy. It has 26 meanings in Ozhegov's dictionary, but we do not perceive them out of context. In English, the verb “run” has 645 meanings! The number of different relations that prepositions can express is also impressive. If these relations are equated to meanings, then, for example, the preposition “to” has 61 meanings, the preposition “by” and “in” – 32, the preposition “with” – 49, “for” has 28 meanings.

Considering the term from various typological features of linguistic dictionaries, its meanings can reach thousands! The search for an interpretation of such a term may continue for a long time and does not guarantee the correct result.

Thus, there is a problem of high cost of time for searching for interpretations of terms while working with unfamiliar terminology of documents and, in particular, while formation of dictionaries in the narrow SA for developing software products “by order”.

To solve the problem, the following tasks have been formulated:

– develop a mathematical model of an explanatory dictionary;
– develop a methodology for setting up an analyzer of specific dictionary entry;
– develop a methodology for automated search for the interpretation of the term;
– develop a methodology for the automated analysis of search results according to SA;
– create a Dictionary bank and Internet-resource links.

Some of tasks require an involvement of the expert in the SA. The expert verifies and corrects the results obtained in an automated mode. The following subsections provide detailed explanations on each task of the approach.

Mathematical model of an explanatory dictionary

Let us present the explanatory dictionary Dg in the form of:

$$Dg =< dt,\ mDe,\ sp >,$$

where dt − dictionary title;

mDe − multiple dictionary entries;

sp – dictionary entries separator.

Each dictionary entry is a tuple:

$$De =< tr, dl, Ti >,$$

where tr – term;

dl − delimiter, that separates the term from interpretation;

Ti − interpretation of the term.

Let's present the interpretation of the term in the form of :

$$Ti =< Df, Lt, Rl >,$$

where Df − definition, set of statements of the meaning of a term.

$$Df = \{tt_1, tt_2, ..., tt_n\},$$

where tt_i – one of the interpretations, n – number of interpretations;

Lt − linguistic labels, characteristics of the term, can be represented as:

$$Lt =< ge, sz, tu >,$$

where ge − grammatical labels (kind, number, etc.);

sz − stylistic labels indicating the SA of the word;

tu − topic labels, indicating the correct use of the term.

Rl – relator.

Relator – a symbol or system of symbols used to separate the meanings of a polysemantic term. Let us present it in the form of:

$$Rl =< vr, cr >,$$

where vr – variable relator;

cr – constant relator.

Methodology for setting up a dictionary entry analyzer

For each specific dictionary, parameters of the mathematical model may have different values.

Considering a structure of selected dictionary, methodology of setting up a dictionary entry analyzer has been developed into a setting function.

The setting function runs only one time for each new dictionary. It includes the following steps.

1. Formation of the title of the dictionary dt.

2. Definition the structure of the dictionary.

3. Definition the "Label system" for further work with the dictionary. The function setups on this step:

$$fSetup(dt, sp, dl, vr, cr, sz),$$

where dt − title of the added dictionary;

sp − dictionary entries separator;

dl − delimiter that separates the term from interpretation;

vr − variable relator of polysemantic interpretations;

cr − constant relator of polysemantic interpretations;

sz − stylistic labels, which helps to select correct interpretation of the term. Not all dictionaries contain it.

4. After adding a new dictionary, work with it continues as with a built-in one.

As an example, the analysis of a dictionary entry $De =< tr, dl, gr, vr, cr, tt, sz >$ from **"**Oxford Dictionary of English" [3].

*Magistrate n. 1 civil officer administering the law. 2 official conducting a court for minor cases and preliminary hearings. [latin: related to *master]*

Magma n. (pl. -s) molten rock under the earth's crust, from which igneous rock is formed by cooling. [greek masso knead]

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dt – *"Oxford Dictionary of English"*,
sp – *"empty line"*,
dl – *' '*,
vr – *"1234567890"*,
cr – *' '*,
sz – *"no"*.

fSetup(Oxford Dictionary of English,empty line, ,1234567890, ,no) .

Methodology for automated search for the interpretation of the term

In accordance with inputted parameters of the mathematical model of the dictionary, algorithm to find the definition of terms were developed (Fig. 1):

1. Reading terms set-in by users. Dictionary selection by title *dt* .

2. Search for the interpretation of each term. Scanning dictionary and dictionary entries in search for term and subterms (in case of multiword term) using *Regular Expressions* [14]. *Regular Expressions* use complex yet powerful query syntax to define search terms precisely.

3. Analysis of search results. If the term is not found in selected dictionary, the search starts in other built-in dictionaries from the Dictionary Bank.

4. If the term is found, the dictionary entry *De* of the term is selected by separator *sp* . Separating the term from the interpretation with a delimiter *dl* . Splitting dictionary entry into definitions by entering the relator $Rl =< vr, cr >$ into the search pattern of the regulatory expression.

5. Repeating steps 2 – 4 until the end of the term list.

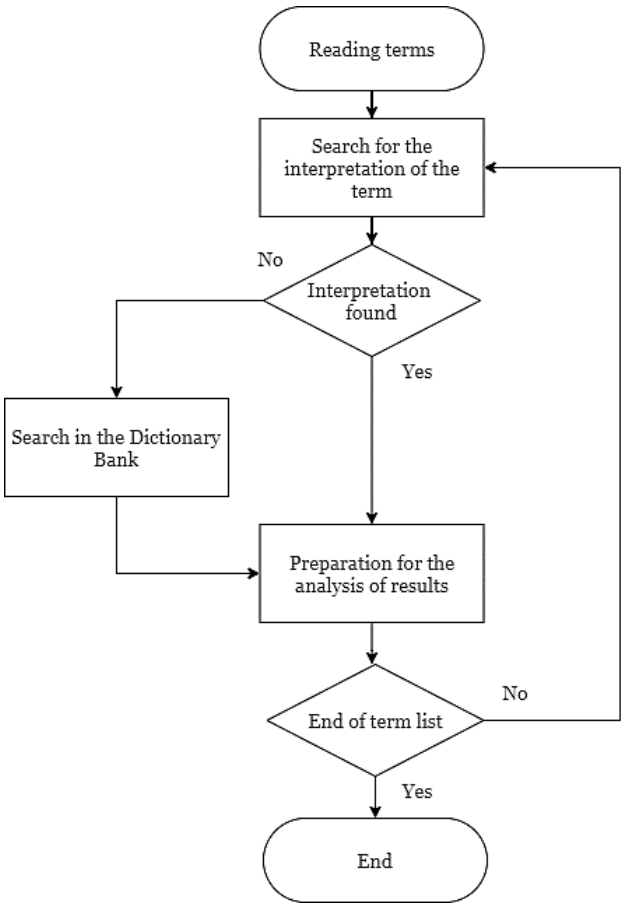

Fig. 1. Automated search in the electronic dictionary

In accordance with the above, it is proposed to present the algorithm in the form of search function for a term: $Ti = fSearch(tr)$.

This function is called for each term tr to find its interpretation in a selected dictionary.

Methodology for the automated analysis of search results according to SA

In case if, $n > 1$, where n is number of found definitions of the term $Df = \{tt_1, tt_2, ..., tt_n\}$, starts the process of screening out definitions that do not correspond to the SA. This process can be implemented in two automated methods:

1. Analysis of stylistic labels of the definition.
2. Analysis of the number of occurrences of search terms in the definition.

The first method implements if the dictionary contains a stylistic label sz. For example, most of the term interpretations contain stylistic label *medicine*, then the definition with the stylistic label *economy* or any other labels will be removed.

The second method implements for those dictionaries that have no a stylistic label sz. The process of screening out definitions that do not correspond to the SA is shown with following algorithm:

1. Terms decomposition into subterms.
2. Determination of the word roots of all provided terms and subterms, by removing suffixes (depending on the language). The root word is a generic part of related words, which carries main semantic meaning [13, p. 88].
3. Search for obtained lexical units in definitions. Counting the number of found lexical units. Ordering definitions by this number.
4. Removing definitions with the lowest number.
5. Saving the results for further verification by an expert.

The definitions analysis provides to user an interpretation that is most close to the studied subject area. Verification and correction of obtained results require involvement of the expert.

The use of Dictionary bank

Searching for interpretations in explanatory dictionaries is preferable to searching on the Internet. The Internet has a huge coverage and easy access, but search engines do not analyze or process information, they just provide everything they find. The lexicographer, while creating a dictionary, processes a lot of information, separates random or old data from correct and new. The Internet traces the frequency of requests, the more often something is encountered, the easier to find it. The dictionary, in turn, defines the norm, the use of words in accordance with their meaning. Therefore, it is proposed to use created by a lexicographer dictionaries with wide search capabilities that exist in electronic form and describe the language as a system.

The bank contains several built-in general-purpose explanatory dictionaries of Russian, Ukrainian and English. If there is no acceptable dictionary among the built-in ones, or searching is in a narrow SA, a new dictionary can be added by entering the parameters for the analyzer in the user interface. Each adding replenishes the total number of set-up dictionaries for search - the Dictionary Bank. Due to the collecting electronic dictionaries, the search area is expanding, which reduces the possibility of not found interpretation of the term.

Dictionary bank is represented as:

$$Db =< mEd >,$$

where Db − Dictionary bank,

mEd − multiple electronic dictionaries, which, in turn, present in the form of:

$$Ed =< Dg, Tp \mid Tp \in \{Sp \vee Gp\} >,$$

where first component Dg − explanatory dictionary, and the second Tp shows the type of the dictionary:

Sp − specialized dictionary of narrow SA;

Gp − general-purpose dictionary of a specific language;

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$$Sp =< po >;$$

po − marker for a SA of the dictionary;

$$Gp =< \lg >;$$

$\lg$ − language of the general-purpose dictionary.

Sorting added dictionaries by type Tp and thematic category (po or $\lg$) simplifies choosing a dictionary for future searches. The dictionary is added one time. The type of dictionary is select on a stage of adding.

If there is no acceptable dictionary among the built-in ones and no dictionary that could be added, then search on Internet resource is called. It includes one built-in website, and has not the option to connect a new Internet resource.

The selected resource is:

Academic.ru [15] – internet-service for searching information in the database of dictionaries and encyclopedias. The search query processes queries in many languages and provides interpretations in all found dictionaries. The multiword terms search, as well as advanced search (by partial occurrence of lexical units of the term) has been implemented.

The automation of searching on the Internet resource was provide using a browser automation tool Selenium [16].

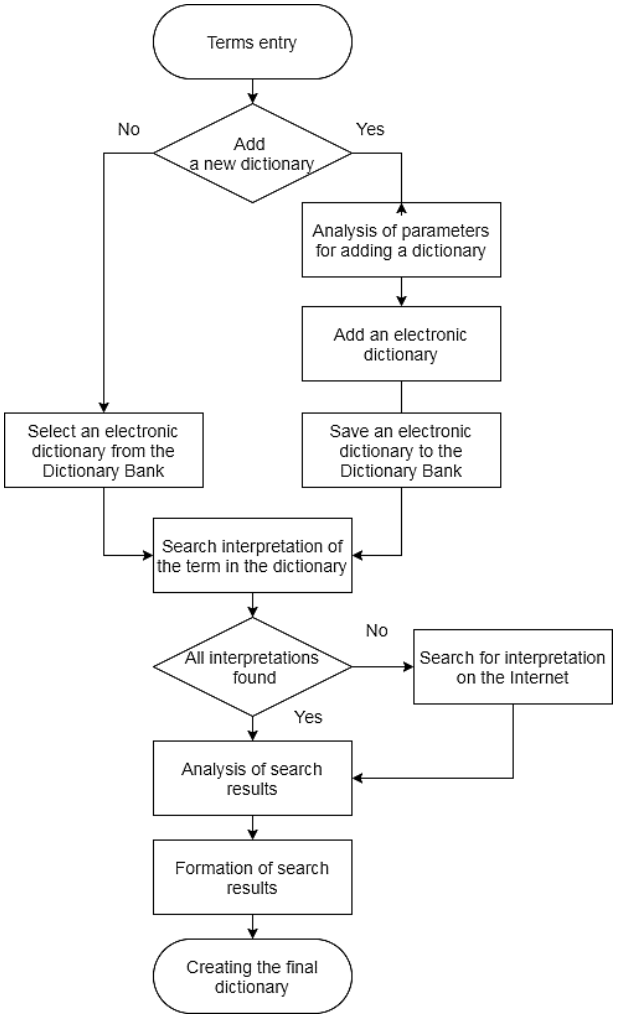

Fig. 2. Schema of program product work

Methodology Implementation

In accordance with the proposed models and methods, the program product DictionaryOfInterpretations was developed.

On Fig. 2 given schema of program product work:

1. Entering terms to search.
2. Adding a dictionary or selecting from the Dictionary Bank:

Adding a new dictionary requires the involvement of an expert to analyze dictionary parameters; saving a new dictionary to the Dictionary Bank.

3. Automated search for interpretations in the electronic dictionary.
4. Searching for terms, which interpretation has not been found, on the Internet resource.
5. Analysis of search results, filtering definitions that do not correspond to SA.
6. Formation of search results. Results verification and correction by an expert.
7. Creation and saving of the final dictionary.

Evaluation of the Effectiveness of the Methodologies and Program Product

To analyze the effectiveness of the program product based on previous methodologies, formulas to determine the required time t are proposed.

Manual term search, when the expert had to find and edit the definition of the term using online dictionaries:

$$t = t_{cd} + (t_{sm} + t_{an}) \cdot n ,$$

where t_{cd} – time of familiarization with the list of terms and selecting a dictionary for search by the expert;

t_{sm} – time of manual search for the interpretation of the term;

t_{an} – time of search results editing according to SA;

n – number of terms to search;

Automated search in built-in dictionaries:

$$t = t_{cd} + (t_{sd} + t_{an}) \cdot n + t_{al} ,$$

where t_{sd} – time of search in an electronic dictionary;

t_{al} – time of analyzer operating;

Automated search with adding a new dictionary:

$$t = t_{cd} + t_{st} + (t_{sd} + t_{an}) \cdot n + t_{al} ,$$

where t_{st} – time of "Label system" analysis and inputting parameters into the program by an expert.

Automated search on the Internet:

$$t = t_{cd} + t_{si} \cdot m + t_{an} \cdot n + t_{al} ,$$

where t_{si} – time of search on Internet;

m – number of terms to search on Internet.

The purpose of the test was verification of a search correctness in different languages and effectiveness of the SA analyzer. The "Number of errors" was considered as the number of interpretations that are incompatible with the term or their absence. "Number of definitions" was define as a number of interpretations of the term selected by the analyzer.

For the experiment were selected groups of 10 terms from 6 different subject areas (medicine, history, economics, physics, law, biotechnology) in explanatory dictionaries of 3 languages (English, Russian and Ukrainian). Examples of them are shown in Table 1. Tests were carried out in 4 modes: in Manual mode, Automated search in built-in dictionaries, Automated search with adding a new dictionary and Automated search on the Internet.

Table 1

Input data

Language	SA	Terms
Russian	Medicine	Akinez, Raduzhka, Resnichnoye telo, Sosudistaya obolochka glaza, Utomleniye, Khrustalik, Fotopsiya, Eydetizm, Veki, Gabitus
	History	Burzhuaziya, Imperiya, Industrial'naya revolyutsiya, Matriarkhat, Plebistsit, Gil'diya kupecheskaya, Vassal, Despotiya, Dogmaty, Lyumpeny
Ukrainian	Economics	Stahnatsiya, Rentabel'nist', Reval'vatsiya valyuty, Forfeytynh, Valyutna interventsiya, Valovyy vnutrishniy produkt, Aktsept oferty, Abandon, Monetaryzm
	Physics	Anamorfuvannya, Zond, Zakon zberezhennya, Velychyna vektorna, Vyprominyuvannya, Induktyvnist', Atomna elektrostantsiya, Shkala absolyutna termodynamichna, Ionizatsiya, Radiolokator
English	Law	Duty of care, Complex rights, Appeal, Priority claim, Interrogatories, Petition, Witness, Court reporter, Parole, Concurrent sentence
	Biotechnology	Transgenic organism, Selective breeding, Allergen, Agronomic trait, Molecular markers, Marker gene, Genomics, Organic agriculture, Phenotype, Chromosome

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As a result, the average search time in automated modes is 0.3978 seconds. The search time in manual mode is about two minutes. Table 2 shows average time for each parameter.

Table 2

Time to find the interpretation of terms in minutes

Search mode	t_{cd}	t_{sm}	t_{sd}	t_{si}	t_{st}	t_{al}	t_{an}
Manual	2	2	–	–	–	–	3
Automated search in built-in dictionaries	2	–	$5{\cdot}10^{-3}$	–	–	$2{\cdot}10^{-3}$	2
Automated search with adding a new dictionary	2	–	$5{\cdot}10^{-3}$	–	5	$1{\cdot}10^{-3}$	1
Automated search on the Internet	1	–	–	$6{\cdot}10^{-2}$	–	$1{\cdot}10^{-3}$	1

Research results

Fig. 3 illustrates the results of the experiment. The manual search method gave definite interpretation of the term, but the process required a lot of time. As the number of search terms increases, the time spent on their search will increases as well.

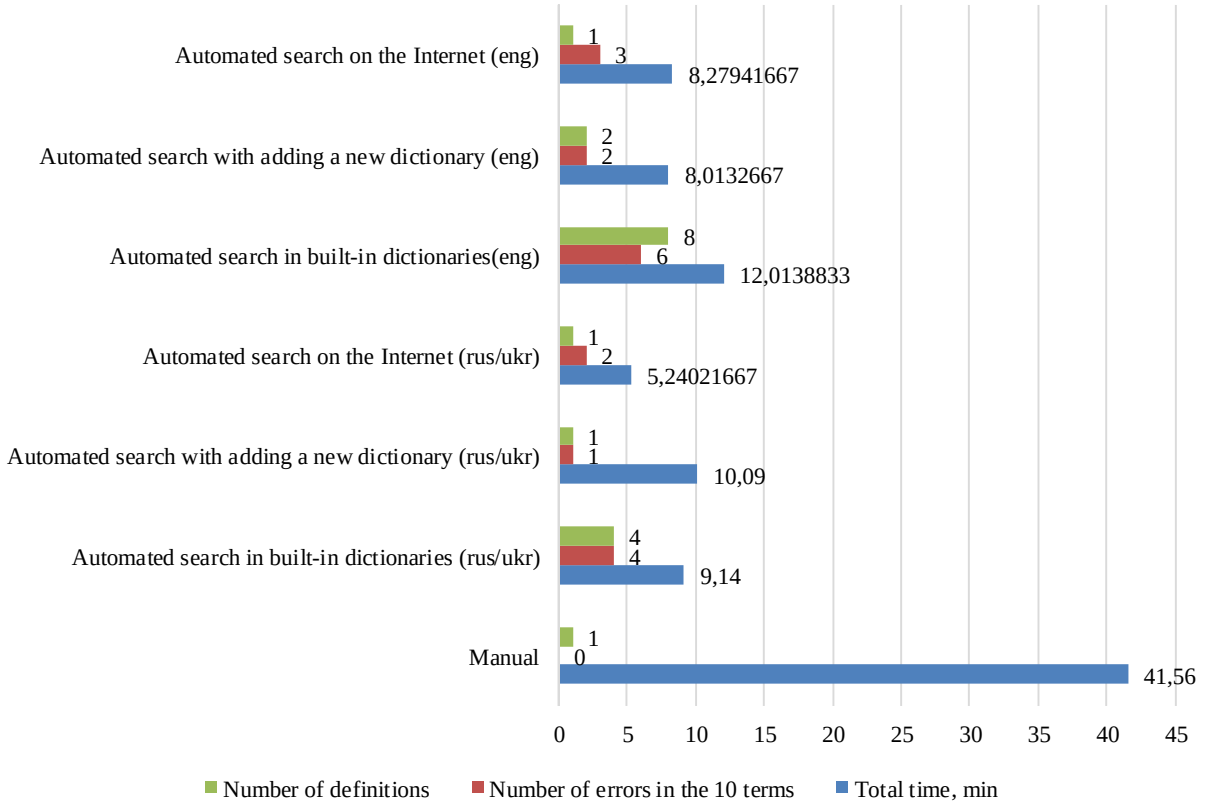

Fig. 3. Diagram – Average research results

Automated search was better in that regard. Search with adding a new dictionary gave a more correct result than search in built-in dictionaries of general-purpose. Most of the total time spent on this search is devoted to adding the dictionary. Further, the dictionary is saved in the Dictionary bank and does not require adding any more. Less time is spent to analyze the results by an expert, since interpretations are certain. Accordingly, further increase in the number of terms, will not follow significant changes in the time.

Internet search depends directly on the user's connection speed. The resulting interpretation were certain, but in some cases did not accord the SA.

Thus, the best option for automatic search is a search in added domain dictionary of studied SA. It allows to reduce the time spent on search in 5 times compared to a manual search. Internet search methods and automated search using the built-in dictionary gave quick results, but not all interpretations accord to subject area. Such methods are most suitable to search for interpretations of common use terms.

The research was conducted with terms in the languages, for which the concept of a multiword term and a lexical unit such as a root of word can be applied. For this reason, developed methodologies do not apply to a number of Oriental languages (Chinese, Korean, Japanese and other similar).

The drawbacks of the study are involving an expert to analyze the parameters of the dictionary. Automation of this process requires syntax analysis of the dictionary macrostructure and the structure of the dictionary entry. This task is the subject of further research.

Conclusions

A mathematical model of the explanatory dictionary is developed. It bases on the structure of the dictionary entry. Dictionary entry analyzer for a specific dictionary is created; Dictionary bank for further use and the option to search on Internet have been implemented;

A methodology for automated search for terms and multiword terms (which are decomposed into simple lexical units) in electronic dictionaries and on Internet resource have been developed;

Automated analysis of search results in according to subject area have been developed in two methods. The first one analyzes stylistic labels of the definition. The second based on screening out definitions for occurrence of search terms.

A developed program product implements all the above-mentioned, which allows to improve user's productivity by automating the processes of searching and of screening out interpretations of the terms in electronic dictionaries.

The results of the study can be used for acceleration of creating dictionaries of the subject domain and thesauruses, creation of user interfaces, studding documentation that reflects activity of some organizational system.

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