The Five-Level Structure of Soft Computing in an Intelligent System with Direct Imposition of Knowledge

Gennady Bronfeld[a] and Dmitrii Kirov[a]

[a] *Nizhny Novgorod State Technical University, Minin St. 24, Nizhny Novgorod, 603950, Russian Federation*

Abstract

An intellectual system based on the technology of direct imposition of knowledge using a five-level system for handling the fuzziness of the natural language, the relativity of knowledge and the inaccuracy of the logical conclusions used is considered. Special knowledge models – molingas – with confidence factors are used to account for the ambiguity of the natural language. A two-level inference system for decision making on knowledge bases based on molingas is described.

Keywords 1

Text, molinga, fuzziness, elinga

1. Introduction

The problem of fuzziness has always been one of the main ones in the field of creation of intelligent systems (IS), starting with expert systems (ES) [1]. Of course, at the source were the fuzziness of the human natural language (NL) [2], the fuzziness of human thinking and the lacking knowledge of people about the world around them [3, 4].

Here we'll talk about IS based on technology of "direct imposition" of knowledge (TDIK) [5, 6, 7, 8, 9, 10, 11]. There are several problems that this technology solves in a certain way to overcome the situation with "fuzziness".

The first problem is the need to relatively objectively reflect human knowledge as it is, since the known models of knowledge are production models, semantic networks, frames, ontologies [1, 12] distort the semantic essence of the modeled object / knowledge.

The second problem is in accounting for the reliability of the modeled knowledge [13].

The third problem is the fuzziness of the NL. There are quite a few ways to take this situation into account [1, 14].

The fourth problem is in question: how to obtain at least a satisfactory result in terms of reliability using fuzzy knowledge in the process of logical inference (LI), especially on a knowledge base (KB) of significant volume. Zadeh's approach here finds itself in a difficult situation [1, 14].

The fifth problem is in finding a satisfactory solution for the user [15, 16]. So far, almost all known approaches got "stumped" by this problem, both within the framework of traditional IT technologies (Internet) and IS - IHS Goldfire [17], Watson [18], OSTIS [19].

2. Applied modelling base of knowledge

The considered IS on the basis of TDIK has a knowledge base and an inference engine that provide solutions in fuzzy conditions. But the knowledge modeling process can be surprisingly complicated. It is well known that "a simple sentence ... remains the basic unit of text syntax ..." [20]. Simple sentences of the text (complex ones are broken down into simple ones) are represented by a small semantic network with the compilation of dictionaries of terms, relationships, qualitative,

Russian Advances in Fuzzy Systems and Soft Computing: selected contributions to the 8-th International Conference on Fuzzy Systems, Soft Computing and Intelligent Technologies (FSSCIT-2020), June 29 – July 1, 2020, Smolensk, Russia
EMAIL: stolem1985@gmail.com; tmdagger2000@gmail.com

quantitative and linguistic features. Excessive emotions are removed from sentences, they are simplified with preservation of the semantic meaning [21] and become the basis of the molingas. Molingas have the following form [6, 7, 10]

$$D; P; Z; K; F; N \tag{1}$$

Here D is a set of identifiers. The identifier is a composite number, including the number of the reference to the text, the chapter number, the paragraph number, the section number of the paragraph, the indent-section number and the sentence number in this indent-section of the text. Every identifier for this molinga from all texts T_i is provided, for every case where contents of molinga occurred. There can be many texts within supertext [22] with i = 1,2,…,n. The sameness in the semantic sense of sentences and formation of the same molingas are ensured by the expert editor when he introduces semi-automatically (knowledge editor is already developed) the molingas into the IS knowledge base.

The expert editor himself, as before for ES [1], determines the semantic meaning of the input. Only now there is no need for further debugging of the LI results to ensure the reliability of the results obtained during the operation of the ES. It is by introducing molingas with the participation of a specialist that the first problem is solved - the need to objectively reflect human knowledge as it is, which has already been tested in theory and practice of ES.

The element P is the condition for the applicability of the molinga's core. The main element of the molinga is the core Z - a simulated simple sentence, although it can be complex sentence too (if necessity arises). In K is the code sequence of the numbered dictionaries that affix the position of words within the core of the molinga, these words being present in corresponding dictionaries.

F contains the confidence levels of the molinga in the form of confidence factors (CFs) f_j (j – index of molinga in the KB), as applied once in the ES MYCIN with an indication of the confidence range from -1 (absolute false) to +1 (absolute true) [1]. This proven method solves the second problem of accounting for the reliability of the modeled knowledge. Element N is the postconditions of the molinga that are in effect if the molinga's core is realized. They describe the actions and procedures to be performed, such as showing figures, tables or calculating formulas.

The KB becomes a set of short semantic networks that are externally readable as short sentences [5, 6, 7, 10]. Along the way, molingas solve the problems of synonyms, homonyms, dialect words, etc. by modeling knowledge by an expert editor when creating an IS knowledge base. This allows you to insert into the knowledge base the understanding and meaning of the knowledge contained in the texts. This also has to do with the solution of the third problem - NL fuzziness. A special dictionary of interpretations is introduced, including the variants of the semantic meaning of a particular word, phraseological unit, metaphor and their definitions used in the knowledge base. For example, this concerns the term bow, which has different semantic meanings will be defined as bow1, another - bow2, the third - bow3, etc.

The next question is how to organize the knowledge contained in supertexts, which are inevitably utilized in many ISs [17, 18, 19]?

The integration of knowledge quickly became the main one, which developed on the basis of different approaches. The first was the use of unified knowledge bases for ES. This succeeds for a limited number of tasks with a limited amount of information and knowledge. Another approach is modeling individual texts with knowledge models, and then deriving solutions based on them [23, 24]. The general drawback of this approach is the endless enumeration of solution options, an attempt to restrict it by heuristic methods leads to too approximate (imprecise) solutions. It received the most serious development in the Watson IS [18], in which the initial sources are automatically modeled, and in the LI process, to obtain an adequate answer, multivariate analysis and synthesis is carried out on the basis of a powerful computing complex, which boils down to a shortened search for suitable answers among the practically infinite number of options.

But there is also a completely different version of knowledge integration called TDIK [5, 7, 9]. The first time such a thing was used by J. Gray [25, 26] for data processing in the creation of a virtual astronomical observatory. Other groups of specialists are approaching a similar solution, for example [13, 27].

It is well known that texts have the property of intertextuality [28]; the texts contain a part of other texts - by other authors.

The TDIK is implemented as follows. The texts are broken down into simple sentences and calculation models and visual and graphic images attached to them through postconditions. These simple sentences are transformed into molingas by an expert editor, with encoding of the word order in the molinga's cores with the entry of words into the appropriate dictionaries and the assessment of the confidence level of the moling in the form of a CF value f_j. If molinga cores happen to be the same or semantically identical to those molinga cores that are already in the IS knowledge base, their identifiers are added to existing set of molinga's identifiers. A feature of this approach is a significantly smaller volume of knowledge base of supertexts in comparison with other methods of obtaining a knowledge base [7].

The third aspect of the situation is how to find solutions using IS?

In most ISs, the well-known LI methods are used to work on knowledge bases and supertexts [1, 18, 29] and intelligent information retrieval and its integration [16, 30]. The key problem here is that since knowledge models are built on the basis of terms extracted from the source texts, they are combined again when outputting into some texts that are understandable to the user and which would have a sufficiently reasonable meaning. This is due to the extreme semantic complexity of words (and word order) within the sentences of text [2, 20, 30]. Sentences in texts are also semantically related, but in simpler manner [28]. Many ISs use these capabilities poorly. The proposed technology uses a two-stage scheme. First, in accordance with the task of the decision-maker (DM), on the basis of the LI on the knowledge base of the IS, the answer options are built according to the degree of reduction of the CF, and then, in the process of the dialogue-associative search, the DM finds solutions as a result of the discourse with the IS [6, 7, 31]. Here we come to the fifth problem, but have not yet analyzed the solution to the fourth problem and have not talked more specifically about the IS itself.

3. Various IS options for working with KB in TDIK mode

The IS with knowledge base based on TDIK can be: a mass production model for an individual consumer in the form of an intelligent electronic book - elinga [5, 6, 7], in an individual version for a separate enterprise - an analytical knowledge management system (AKMS) [5, 7] and for general use by a mass consumer in the form of a library for analytical accumulation of knowledge (LAAK) [8, 31]. Let's take a closer look at the example of elinga as a basic technology.

Elingas will allow: to enter a large amount of knowledge into them; for decision makers to receive an answer quickly by asking questions to elinga; to be purchased at low cost; the user to work in a wide subject area; the user to gradually receive results at the level of the best specialists in the world and above. For the consumer, Elinga acts as a "bearer of knowledge" [6], or in other words, a local library of knowledge in a specific subject area. Elinga creates its own special environment for finding rational solutions quickly and efficiently.

The elinga includes Figure 1 [5, 6, 7]: software that implements the LI machine, an intelligent interface, knowledge base and auxiliary programs. Knowledge base includes - dictionaries of terms, relationships and their equivalents, knowledge itself, in the form of molingas, calculation models (subroutines), visual and graphic images.

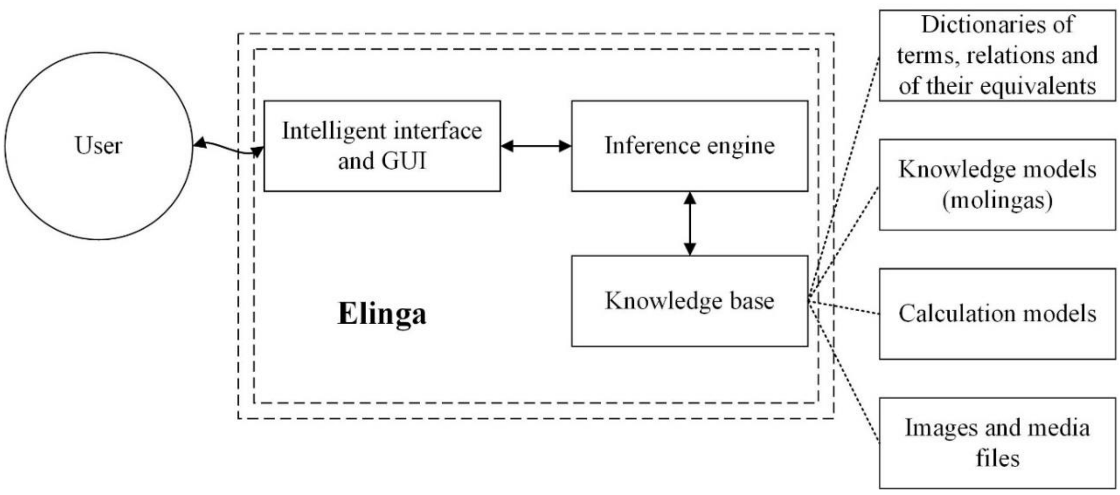

Figure 1: Structure of Elinga

The main modes of elinga operation include [9]: a separate mode for inputting knowledge and operating modes - a mode of working with a dialogue, an LI mode, a mode for outputting source texts and a cohesion mode. The operating modes are used either to simply find information in the process of dialogue with the knowledge base of the elinga, or requests are set to find a solution in some situation that interests the decision maker. To search for simple information, the text output mode is suitable, either completely, close to the original, or, partially, in the cohesion mode [28].

The LI mode is implemented by a separate program - an inference engine with the participation of the KB block and the dialogue block. The program is based on well-known principles [1, 31, 32], only the results of working with knowledge base with new knowledge models are somewhat unusual.

LI, in general, can be represented as [31, 32]:

$$\frac{F_1, F_2, \cdots, F_p}{G}(R) \tag{2}$$

where $F_1, F_2, \cdots, F_p, G$ are formulas of some theory Γ, i.e. $F_1, F_2, \cdots, F_p, G \in \Gamma$.

Here $F_1, F_2, \cdots, F_p$ are suppositions, *G* – conclusion, while *R* – denotes the inference rule.

It should be noted that in the elinga, at every stage of the dialogue-associative search, the search for different variants of LI-chains between two user-specified terms (expression) is considered, i.e. F_1 and *G*. But these chains can be many and can have different levels of reliability.

In our situation, the connection between some $\Phi_{i_1}, \Phi_{j_1} \in \{F_1, F_2, \cdots, F_p, G\}$ with indexes $i_1, j_1 \in \{1,2, \cdots, p\}$ is based on the rule from the classical mathematical logic *modus ponens* – "if it is known that the statement Φ_{i_1} is true and the rule "IF Φ_{i_1} THEN Φ_{j_1}" is true, then the statement Φ_{j_1} is also true." I.e.:

$$\frac{\Phi_{i_1}, \Phi_{j_1}}{\Phi_{j_1}} \to T \tag{3}$$

And so on, along the chain, a connection is sequentially found between the user-specified F_1 and *G*.

4. Implementation of dialogue-associative search

In elinga / AKMS / LAAK, the role of LI is different from that in [16, 17, 18]. There answers are usually received automatically. In elinga, they are of an auxiliary nature for the dialogue-associative search. In process, the decision maker himself chooses the appropriate answers obtained in the LI process, and can change the modes, for example, turn on the modes of cohesion or output of source texts (fragments of interest for user).

The initial level of reliability is determined by the initial CFs specified in the KB of IS and gradually refined in the process of filling up the elinga knowledge base [6, 7]. However, the LI chain usually contains several molingas with no more than six intermediate terms, as ordained in Karaulov's "six steps" rule [28].

In general, the confidence level of the molinga sequence f_{seq} calculated on the basis of the development of the theory of CF [1] using the Larsen rule, similar to the fuzzy inference [14] with a sequence of implications as follows.

Let f_t be the confidence level in the form of CF in the range from -1 to 1 for the initial t-th molinga (where $1 \leq t \leq \Omega$);

f_{t+k} be the confidence level in the form of CF in the range from -1 to 1 for some intermediary t+k -th molinga (where $1 \leq k \leq \Omega$);

f_{t+k+r} be the confidence level in the form of FU in the range from -1 to 1 for some final t + k + r -th molding (where t + k <r <Ω - (t + k)). Then

$$f_{seq} = \prod f_t \times \cdots \times f_{t+k} \times \cdots \times f_{t+k+r}, \tag{4}$$

if all of $f_t, f_{t+k}, f_{t+k+r} > 0;\ 1 \leq t \leq \Omega;\ 1 < k < \Omega;\ t + k < r < \Omega - (t + k)$.

If any of the values f_t, f_{t+k}, f_{t+k+r} turns out to be ≤ 0, then the whole value f_{seq} is assumed to be = 0 without need for calculations.

So, the decision maker asks the system in the form of a pair of the first terms of interest (Figure 2) - Term1, Term2, and it gives answers in the form of blocks of molinga's nuclei (simple sentences) Gr 1 ... Gr h ... Gr 20 (20 groups of molinga nuclei) based on LI - through the connection of concepts based on abductive inference [31, 32] using the modified modus ponens rules applied to the KB of molingas. Moreover, the blocks are issued as the CF decreases (the calculation is carried out according to (4)). I.e. first, as a rule, there are separate sentences, where both terms meet, then, two sentences (where the given terms and one intermediate connecting them, then follow three sentences (where there are already two connecting terms), etc. In contrast to the increase in variants of combinations of molingas when specifying even simple queries, a traditional heuristic search algorithm with an evaluation function is used [1], which limits the number of options to be searched.

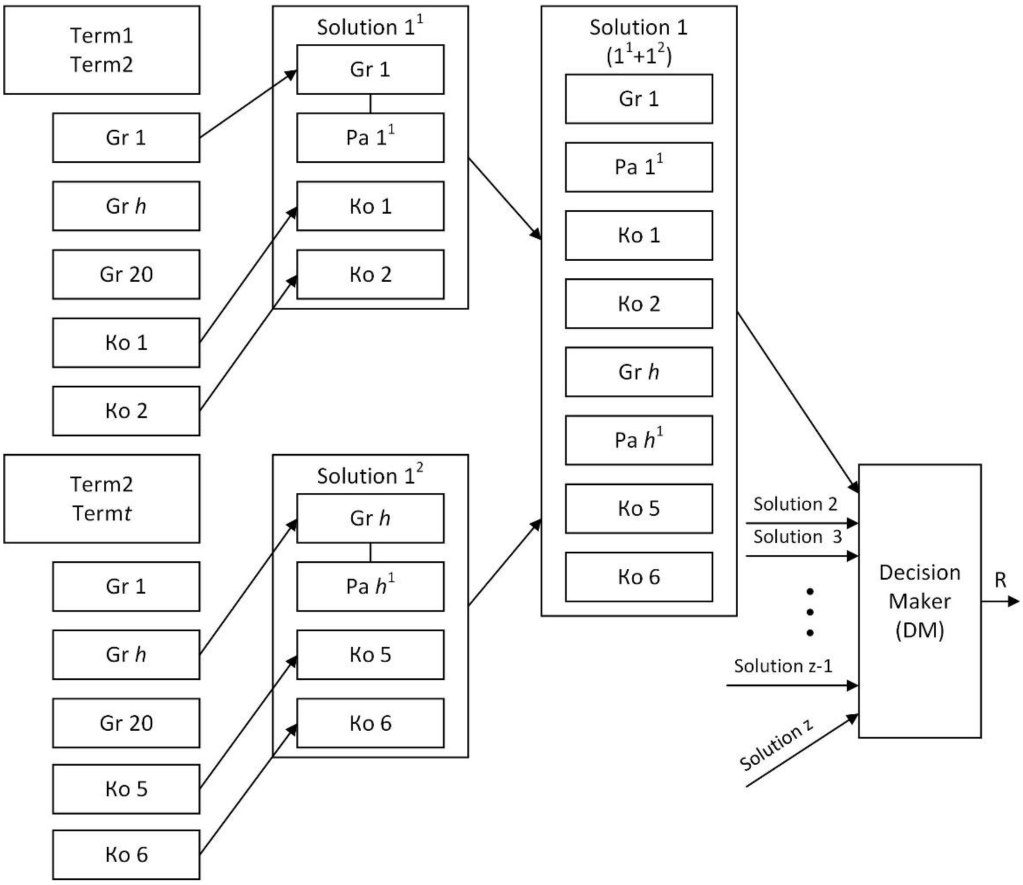

Figure 2: Decision-making procedure for dialogue-associative search

Finally, the fifth problem is finding a satisfactory solution to the decision maker.

The most "successfully" it is done in the ES, - the solution is obtained at the level of an experienced expert. Well, what if you don't understand something? Or if you want to take a look at some alternatives? You find yourself in a "dead end". In addition, the problem may change over the course of the solution [33, 34]. This is understandable for the decision maker, but in many existing IS [18] he cannot interfere in the process of finding a solution. It is known that the procedure for human understanding of meaning is very complex [35]. It turns out that everything is much more complicated and difficult than it seems, and a different path is needed for active advancement. In particular, technologies such as "brainstorming" and TRIZ are already known for an intensive search for new solutions.

An avalanche-like increase in the volume of LI results usually occurs at three or more steps. From a practical point of view, in a dialogue-associative search, decision makers need only the first few options in order to quickly reach the final result. At the same time, with a more complete acquaintance with the problem under study, incl. through refinement of queries, the user will still reach the required "depth" of relationships. The decision maker, looking through the contents in the sequences of molinga cores (in fact, a group of sequences of sentences, semantically related to each other [7, 28]), decides whether this result satisfies him or not, selects and fixes it in the program memory, and continues the search from new starting positions.

If the answer is not satisfactory, the decision maker either re-launches the LI mode with new requests or, according to the selected molinga core, applies the cohesion mode (inference based on the local cohesion of the text relative to a specific molinga from the knowledge base corresponding to a paragraph of the original text) [28] or the output of a part of the original text for clarification of the context and meaning of the embedded in the simulated sentence.

In Figure 2, these are the responses to the new query Term2, Termt and responses Gr 1 ... Gr h ... Gr 20. Additionally, the decision maker adds small parts of the text of cohesion output in the first request Ko1, Ko2, in the second request, say Ko5, Ko6.

All this is memorized in the elinga report field at first as parts of the solution $Sol1^1$, then as $Sol1^2$. Additionally, he can perform the necessary calculations through postconditions and save the necessary graphs and figures that they contain. Then, as a result of purely editorial revisions, the decision maker receives Solution 1. If it does not suit him, then he gets Solution 2, ... Solution z-1, Solutionz. Among them, a certain methodology (also from the knowledge base) can be applied to assess the results. As a result, the decision maker can quickly get a solution R.

5. Implementation in the IS prototype with TDIK

Here is a brief description of the prototype IS with TDIK in the elinga variant. Figure 3 shows the main window of the elinga prototype. On the left, a glossary of terms is displayed, choosing from which you can compose queries / questions for the IS. The modes can be different – search for any of chosen terms, for presence of all the chosen terms and the LI between two specified terms. The first version of the elinga prototype, capable of working with a freely written question, has already been tested, but for now we are describing the original version.

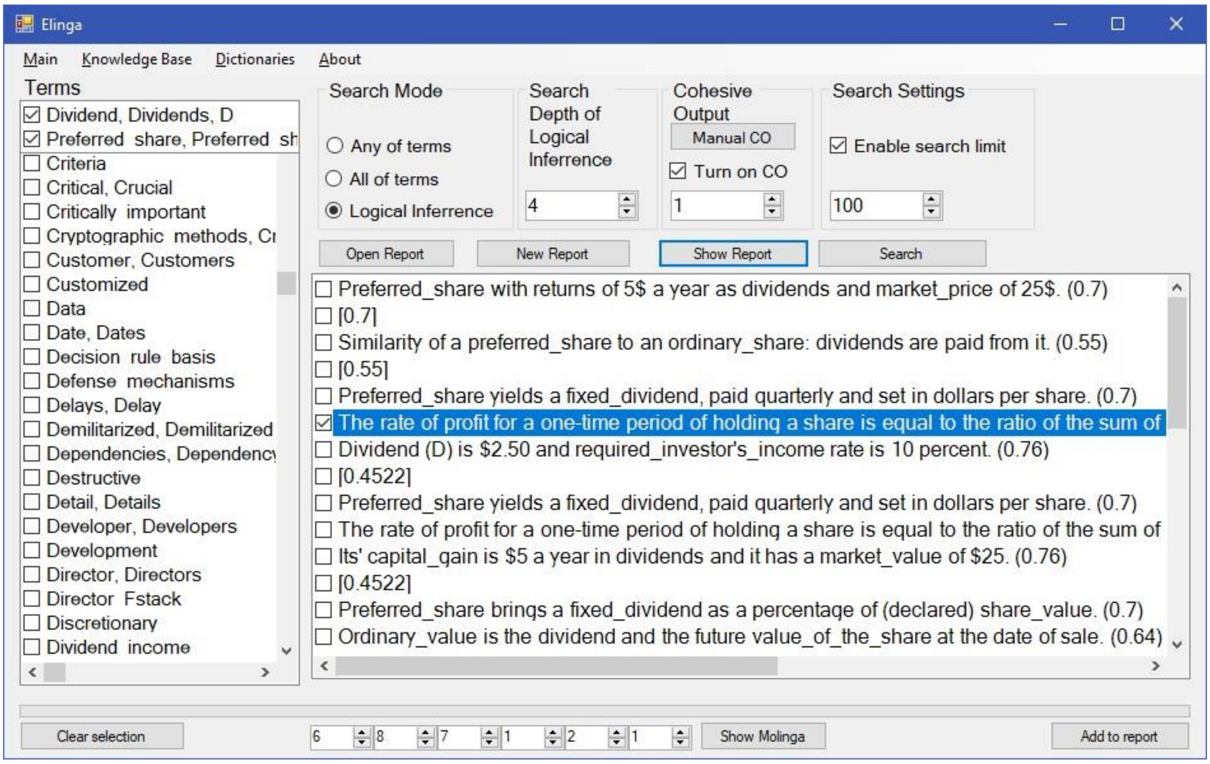

Figure 3: Main window of the prototype in LI-mode

The decision maker poses a question to the system in the form of a pair of the first terms of interest, and it gives answers in the form of blocks of molinga cores (simple sentences) based on different principles, including with LI - through the connection of concepts based on abductive inference [31, 32] using modified modus ponens rules, applied to KB of molingas. From the point of view of linguistics, this is already the output of coherent text [28].

The knowledge base can be filled with molingas in the following way: select “Add molding” in the “Knowledge base” menu. After that, a window will open in which you must enter the molingas’ parameters, including the postcondition, if needed. The postcondition can be an executable program with a formula or a media file.

The postconditions output is implemented as well. In the event that a molinga with a postcondition was found among the search results, you can select the line with the molinga and press the "Show" button. This will open a new window. In this window, you can view the image attached to the molding, or perform a calculation using a formula with arbitrary initial data. For the convenience of the decision maker, the results of work with postconditions can be saved in the general report on work-session with elinga.

To work with images, click on the button with an image icon in the window for working with postconditions. This action will copy the image to the clipboard. Then you can go to the main window, click on the "View report" button and add an image to the opened report file by pressing the Crtl + V key combination.

There is also a clipboard file for calculation results. The user can freely edit its’ contents and commit the selected sections to report file using the “Add to report” button. To make sure that the data was actually recorded, you can open the report again through the main window and see the newly added contents.

In addition to postconditions, a decision maker can fill the report in the cohesive output mode. For example, adding an indent-span / paragraph / chapter in which the selected molinga is located. This can be done either using manual cohesion (button in the main program window), where you need to explicitly specify the range of molinga identifiers that will be added to the report, or in automatic mode, by selecting the cohesion depth level in the main window and adding a molinga (and nearby text of source) to the report.

Here on the capabilities of dialogue-associative search come into play [5, 6, 7, 9, 11], which provides a solution to the fifth problem – of finding a satisfactory solution of interest to the decision maker in the face of fuzzy human thinking and peoples’ lack of knowledge about the world around them. The decision maker can refine his request once again, based on the previous responses received and continue his search, going deeper into the details, or applying calculations through the issued postconditions. At the same time, remaining in the group of the most reliable results based on CF. He can enter intermediate results of interest in the final report. In Figure 4 an example of result of using the above functions is displayed.

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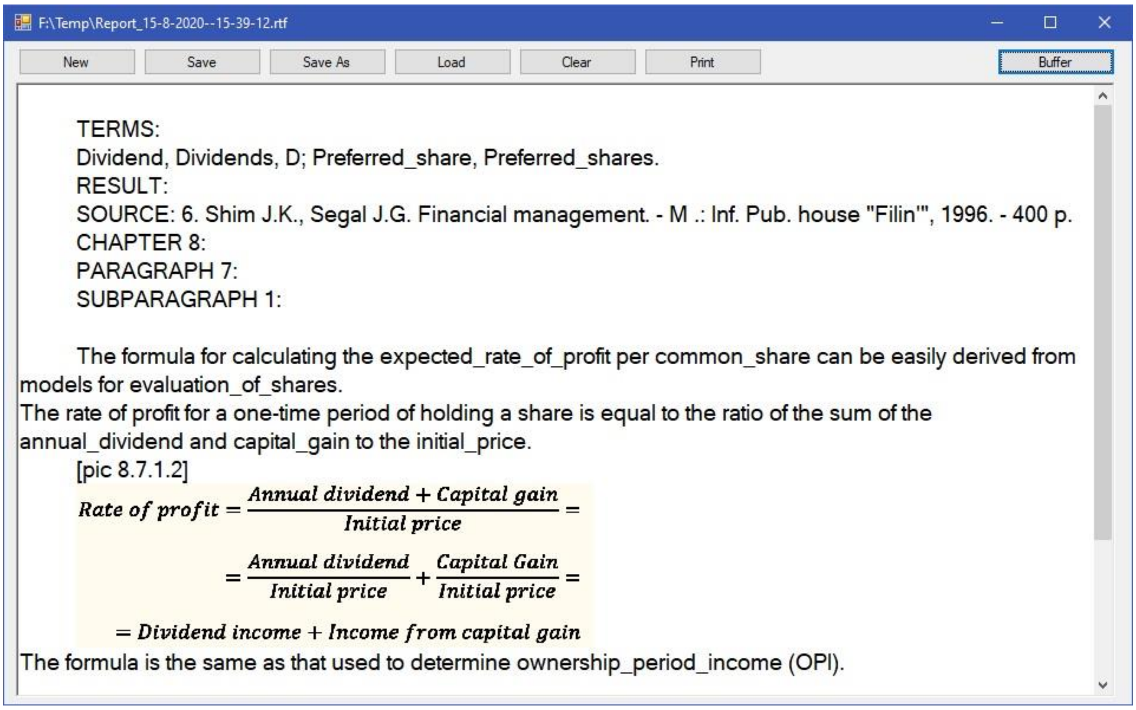

F:\Temp\Report_15-8-2020--15-39-12.rtf

New | Save | Save As | Load | Clear | Print | Buffer

TERMS:
Dividend, Dividends, D; Preferred_share, Preferred_shares.
RESULT:
SOURCE: 6. Shim J.K., Segal J.G. Financial management. - M .: Inf. Pub. house "Filin'", 1996. - 400 p.
CHAPTER 8:
PARAGRAPH 7:
SUBPARAGRAPH 1:

The formula for calculating the expected_rate_of_profit per common_share can be easily derived from models for evaluation_of_shares.
The rate of profit for a one-time period of holding a share is equal to the ratio of the sum of the annual_dividend and capital_gain to the initial_price.
[pic 8.7.1.2]

$$\textit{Rate of profit} = \frac{\textit{Annual dividend} + \textit{Capital gain}}{\textit{Initial price}} =$$

$$= \frac{\textit{Annual dividend}}{\textit{Initial price}} + \frac{\textit{Capital Gain}}{\textit{Initial price}} =$$

$$= \textit{Dividend income} + \textit{Income from capital gain}$$

The formula is the same as that used to determine ownership_period_income (OPI).

Figure 4: An example of the reconstructed text in the report file

The window for working with the report (Figure 4) is the main result of the dialog-associative search, where the main solution of the elinga is formed. This window provides the following options: manual content editing; saving the current contents to file; creation of a new report file, access to inbuilt clipboard, printing of contents.

Here, just like in case of TRIZ and “brainstorming” conditions for the emergence of associations in decision makers mind are created, leading to finding solutions with high originality and efficiency. And, one of the main features – very rapidly, because you do not need to reference - neither the other books, nor other libraries, nor other specialists. And, in fact, solving problems with fuzziness is an intermediate, albeit important process, since more and more important and complex problems of rapid finding of a solution among a large set of options, most of which are false or ineffective, are solved.

The very style of dialogue of the decision maker and the computer has the character of a discourse, moreover, in a conversational style, which allows you to quickly come to the solution the user needs, to receive high-quality answers to the questions posed, even in large knowledge base.

6. Conclusion

The considered technology serves as an "intellectual assistant" of a person, which sharply enhances his capabilities in conditions of fuzziness. The use of a conversational style makes it possible to increase the efficiency of finding a solution in the process of dialogue of a person (DM) and a computer.

A prototype of an elinga has been created, in particular for management, in which the user can pose a question to the system and receive a chain of answers in the form of blocks of interrelated text based on different principles, including through LI - through the connection of concepts or the use of the immanent properties of source texts - cohesion and coherence, as well as postconditions in the form of calculation formulas or media files. Moreover, the process of obtaining a coherent text in responses of IS rests upon the basis of natural principles inherent in human thinking, and not artificial, like in almost all other ISs.

7. References

[1] J. F. Luger, Artificial Intelligence. Strategies and methods solving complex problems, Publishing house “Williams”, Moscow, M, 2003.

[2] A. B. Solomonik, Language as a sign system, Publishing house “LIBROKOM”, Moscow, M, 2016.

[3] A. T. Ishmuratov, Logical analysis of practical reasoning, Naukova Dumka, Kiev, K, 1987.

[4] D. A. Pospelov, Modeling of reasoning. Experience in the analysis of mental acts, Radio and Communication, Moscow, M, 1984.

[5] G. B. Bronfeld, Direct imposition of knowledge and some of its’ features, in: Proceedings of the Russian conference “Technical and software means of control, monitoring and measurement systems”, UKI-10, IPU n.a. V.A. Trapeznikov RAS, 2010, 201-211.

[6] G. B. Bronfeld, System for working with intelligent e-book – elinga, Filed June 21, 2440610 (2012), Issued Jan. 20 (2010).

[7] G. B. Bronfeld, Fundamentals of Artificial Intelligence, NSTU n.a. R.E. Alekseev, Nizhny Novgorod, NN, 2014.

[8] G. B. Bronfeld, The new technology of work with knowledge-based elinga, in: Proceedings of the 12th International Forum on Knowledge Asset Dynamics “Knowledge Management in the 21stCentury: Resilience, Creativity and Co-creation”, St. Petersburg, 2017, 851-863.

[9] G. B. Bronfeld, D. I. Kirov, V. V. Kondratyev, Intelligent e-book prototype using technologies of direct imposition of knowledge, Software products and systems, 3 (2019) 403-410.

[10] G. B. Bronfeld, D. I. Kirov, Molingas - new model representation for working with knowledge, Proceedings of the VII international conference “Knowledge-Ontology-Theory”, ZONT-19, Novosibirsk, 2019, 73-82.

[11] G. B. Bronfeld, D. I. Kirov, Application of soft computing in an intelligent system with direct imposition of knowledge, Proceedings of the VIII International Scientific and Practical

Conference “Fuzzy Systems and Soft Computing and Intelligent Technologies”, NSMVIT-2020, Smolensk, 1 (2020) 231-240.
[12] T. A. Gavrilova, D. V. Kudryavtsev, D. I. Muromtsev, Knowledge engineering. Models and methods, Publishing house “Lan”, St. Petersburg, SPb, 2016.
[13] V. P. Ivashenko, Models and algorithms for integration of knowledge based on homogeneous semantic networks, Proceedings of the V International Scientific and Technical Conference “Open Semantic Technologies for the design of Intelligent Systems”, OSTIS-2015, BSUIR, Minsk, 2015, 111-132.
[14] V. V. Borisov, V. V. Kruglov, A. S. Fedulov, Fuzzy models and networks, Hotline-Telecom, Moscow, M, 2007.
[15] D. Ferrucci, J. Dunietz, G. Burnman, A. Bharadwaj, O. Rambow, J. Chu-Carroll, Test Machine Comprehension, Start by Defining Comprehension, Cornell University, 2020. arXiv:2005.01525v1 [cs.CL] 4 may 2020.
[16] E. Ovchinnikova, Integration of World Knowledge for Natural Language Understanding, Atlantis Thinking Machines 3, Atlantis Press, 2012.
[17] IHS Goldfire. Accelerating Decisions. Powering Innovation, White Paper, IHS Inc., 2013.
[18] R. High, The Age of Cognitive Systems: How IBM has Built and Operated Watson, 2013. URL: http://www.olap.ru/home.asp?artId=2507.
[19] V. V. Golenkov, N. A. Gulyakina, An open project aimed at creating a technology for the component design of intelligent systems, Proceedings of the III International Scientific and Technical Conference “Open Semantic Technologies for the design of Intelligent Systems”, OSTIS-2013, BSUIR, Minsk, 2013, 55-78.
[20] E. I. Dibrova, L. L. Kasatkin, N. A. Nikolina, I. I. Scheboleva, Modern Russian language. Theory. Analysis of linguistic units. In 2 parts, Publishing center “Academy”, Moscow, M, 2008.
[21] V. Ya. Tsvetkov, Semantic Information Units as L. Florodi’s Ideas Development, European Researcher 25, 7(2012) 1036-1041.
[22] M. N. Kozhina (Ed.), Stylistic Encyclopedic Dictionary of the Russian Language, Flinta: Nauka, Moscow, M, 2006.
[23] E. H. Tyugu, Knowledge integration, Bulletin of the USSR Academy of Sciences: Technical cybernetics 5 (1989) 3-13.
[24] C. Dulin, I. Kisele, Intellectual system of organization of multilevel interconnected knowledge base, Software products and systems 4 (2002), 19-22.
[25] T. Hay (Ed.), S. Tansley (Ed.), C. Tolle (Ed.), The fourth paradigm. Scientific research using large amounts of data, Microsoft Research, 2014.
[26] J. Gray, A. Czalay, The World – Wide Telescope, an Archetype for Online Science, 2002.
[27] F. Hakimpour, A. Geppert, Resolution of Semantic Heterogeneity in Database Schema Integration Using Formal Ontologies, Information Technology and Management 6 (2005) 97-122.
[28] V. A. Lukin, Fiction Text: Fundamentals of Linguistic Theory. Analytical Minimum, Publishing house “Os’”, Moscow, M, 2009.
[29] R. Schenk, Processing of conceptual information, Energia, Moscow, M, 1980.
[30] I. S. Nickolaev, I.S. Nickolaeva (Ed.), O.I. Mitrenina (Ed.), T.M. Lando (Ed.), Applied and Computational Linguistics, Lenangrad, Moscow, M, 2016.
[31] G. B. Bronfeld, The logical inference in the intellectual system based on the knowledge base of molingas, Economics and management of systems management 22.4 (2016) 64-74.
[32] V. N. Vagin, E. Yu. Golovina, A. A. Zagoryanskaya, M. V. Fomina, Reliable and plausible inference in intelligent systems, Fizmatlit, Moscow, M, 2004.
[33] F. P. Brooks Jr., The Design the Design: Essays from a Computer Scientist, LLC “I.D. Williams”, Moscow, M, 2013.
[34] S. V. Mikouni, Multi-criteria choice on a finite set of alternatives: A Study Guide, Publishing house “Lan”, St. Petersburg, SPb, 2009.
[35] V. F. Spiridonov, Psychology of Thinking: Problem Solving and problems, Genesis, Moscow, M, 2006.