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HEURISTIC EVALUATION OF VISUALIZATION IN THE SEMANTIC SEARCHING FOR ECONOMIC INFORMATION. PRELIMINARY ANALYSIS OF THE RESEARCH RESULT

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Economic indicators provide much information concerning the functioning of an enterprise. Their usefulness depends also on decision-makers' comprehension of structural and semantic connections existing between indicators. Visualization of a semantic network in the topic map allows users to more swiftly notice and understand various relations. The main goal of this paper is to discuss the research on heuristic evaluation of visualization in the semantic searching for economic information. This study consists of three experiments with the participants. We used the two author's applications of the ontologies for return on investment indicator and for early warning system. In this paper we analyze and compare the results of these experiments.

Keywords: visualization, system usability, ontology, topic map, economic indicators

1. Introduction

To make optimal decisions, managers need very specific information. They must analyse various economic indicators assessing the functioning of an enterprise. Data for these analyses are taken from different analytical applications. To interpret an economic indicator, a manager should analyze relations between indicators and economic data which have influence on its value. However, available information systems concentrate mainly on providing information reflecting hierar-

chic relations between examined indicators. Decision-makers expect also possibilities of inspecting rates on account of semantic associations existing between them. Such an analysis of indicators can potentially ease and shorten the time needed, inter alia, to identify chances of advancement and threats of breakdown related to carrying out an activity.

In order to solve this problem we propose the usage of the topic map (TM) as a model of knowledge about the analysis of economic indicators and the usage of the topic map as a visual method which allows searching for economic information based on the semantic network. The topic map standard [ISO/IEC 13250:2000] enables the representation of complex structures of knowledge bases [3], and the delivery of a useful model of knowledge representation [11, p. 174], where multiple contextual indexing can be used. TM is a relatively new form of the knowledge presentation (see [2]; [12, p. 30]). TM is a kind of combination of subject indexing and semantic network knowledge representation [7] which contains a set of topics and a set of associations between topics. The topic maps standard provides different ways to show various connections (including semantic). It allows displaying the whole a semantic network (topics and associations) efficiently, as it is essential to select the relevant information. Thanks to the visualization users can more quickly notice and understand different structural and semantic relations. The semantic search is more efficient than that based on the basic hierarchic structure [18, p. 1899] and the search for information basing on semantic connections in the topic map has a positive influence on discovering information [16, p. 301]. TM can be one of various tools for information visualization, which allows to search for information for decision-makers or by decision-makers.

This is our proposal of supporting the process of analysis of economic indicators:

1) to use the topic map which shows taxonomic and semantic relationships existing between economic indicators,
2) to use visualization searching based on a semantic network.

Our research concentrates on two essential issues: knowledge representation in an information system, which would also enable to change tacit knowledge into explicit knowledge, and the usage of visualization methods in searching information basing on a semantic network. The use of visualization techniques can help to solve the problem, because "visualization offers a link between the human eye and the computer, helping to identify patterns and to extract insights from large amounts of information" (see [19, p. 139]). In the visualization, human factors (e.g. interaction, cognition, perception) play a key role in the communication between a human and a computer and therefore contribute significantly to the visualization process (see [9, p. 50]). Fundamental factors for a good visualization interface of

the application of the topic map are: the overview of the structure for the global understanding of the structure and of the relationships within the hierarchy; the ability to zoom and to select some nodes; and the possibility to use dynamic requests in order to filter the data in real time [8].

In this paper we discuss the research on evaluation of visualization in the semantic searching for economic information. The paper is structured as follows: in the next section the visualization of a semantic network for searching information is shortly described. In section 3, the design of the research is presented. In section 4, assumptions of the experiments are described. In section 5, the analysis of the results of the research and conclusions are presented. Finally, in the last section we give a summary of the work and indicate future research prospects.

2. The visualization of a semantic network for searching information

The issues of searching an information basing on a semantic network technologies is the subject of many studies and concerns various fields (see inter alia [1], [17], [18]). It is caused by the users' need to search information also on account of contextual connections. In this approach the attention is paid on the role of the visualization of a semantic network which is not only a tool for presenting data, but also provides an interface allowing interactive visual searching information (see inter alia [8]).

One of the methods enabling visualization of a semantic network is the topic map, which is a semantic graph that contains definitions of a set of topics and a set of association between topics (Figure 1). Visualization in TM allows navigation from topic to topic in a highly interactive manner: interesting nodes can be put in the foreground with zooms, translations and rotations. Users can delete inapplicable branches of the tree or expand interesting ones.

TM is a relatively new visualization form of the presentation of knowledge, which puts emphasis on the data semantics and ease of finding desired information. In this interactive visual process, an user is able to subsequently concentrate on the interesting data elements by filtering uninteresting data, and focusing (zooming in) on the interesting elements, until final details are available for an interesting subset of the analyzed elements (see also [4, p. 1756]). Important stage in this process is use of appropriate solutions, which allow to filter and zoom in (zoom out). The topic maps can be easily used to represent financial knowledge about financial measures, where graphical expressions can assure semantic information search and interpretation for non-technically-minded users.

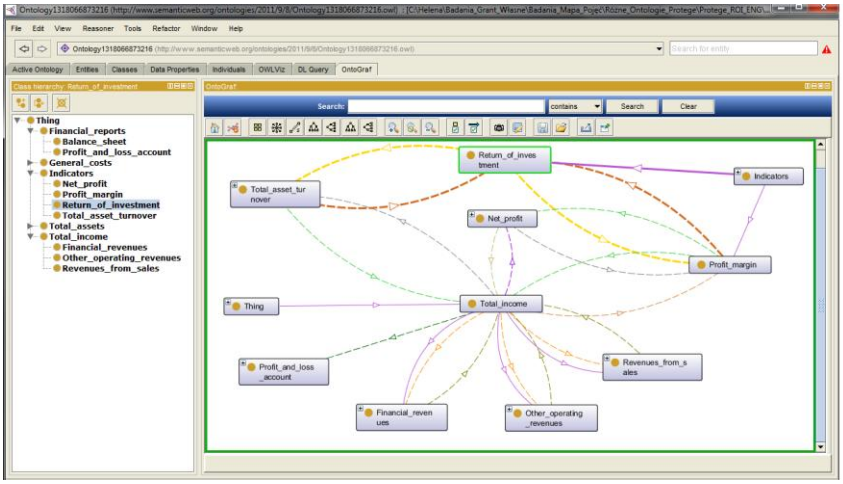

Figure 1. An example of visualization of a semantic network of the system to analyze economic indicators

3. The design of the research

The topic map application may be a useful tool in the visual searching for information for decision-makers. However, it requires carrying out a research. This is our method of research, which consists of two phases and five stages (Figure 2).
Proposed procedure consists of the following main phases (see also [5, 132-134]):

1. Phase 1: Conceptualization of the ontology of economic indicators and creating TM application. The goal of this study is verifying the concept of using TM standard for the model of knowledge about analysis economic indicators. This phase consists of the three stages. The results of this work are inter alia the following: the creation of the ontology for the selected analysis of economic indicators; the creation of TM application for a specific field of analysis of economic indicators; and the verification of the visualization of a semantic network in TM for searching and acquiring unique information on economic indicators.
2. Phase 2: Research on the usability of the visualization in economic information retrieval in TM application. The goal of this study is verifying the usability of applying the visualization of a semantic network in TM in searching and acquiring unique information in the analysis of economic indicators. This phase consists of two stages. The results of this work are inter alia the following: the evaluation of the usability of visualizing a semantic network based on TM; solving the problem of a large number of topics in using TM as a tool enabling

a visual exploration of a huge, complex and multidimensional data set. The research in this phase is carried out on the basis of the model proposed by E. Brangier (the usage – adaptation – re-engineering cycle), "which highlights how human adaptations (of the users) are a source of innovation to design new uses" [6]. These studies enable to identify users' needs precisely and may contribute to the development of innovations.

Between phases of proposed research method there is a feedback, i.e. conclusions from the second phase influence both improvement of created a topic map application as well as procedure of creating the ontology and TM for the analysis of economic indicators. The results of this work are as follows:

1) creation of the ontology for the selected analysis economic indicators;
2) creation of TM application;
3) creation of the procedure of building TM applications for the ontology of the analysis of economic indicators;
4) verification of the visualization of a semantic network in TM for searching information on economic indicators.

In this paper we focus on the presentation of the research conducted in the second phase (stage 4). In literature many methods of research and evaluation of the system usability and human-computer interaction are described (see inter alia [10]; [13]; [14]; [15]). The study of a prototype is conducted with the experts' participation (e.g. heuristic evaluation, inspections, reviews, checklists) and/or users (e.g. usability tests, eye tracking, evaluation by observation). We suggest two research methods on the usability of the visualization of a semantic network in searching for economic information. These are usability tests and heuristic evaluation.

Research according to presented research method was carried out thrice: twice for the ontology for return on investment (ROI) indicator, then for the ontology for early warning system. Conclusions from the first phase of the first research for ROI indicator were used in creating the ontology and application of the ontology for an early warning system, whereas the data obtained from the second phase of this research were verified by carrying out studies for ROI indicator and for the ontology for an early warning system. The applications created for built ontologies differ in scale of solution, which is important in verifying the usage of TM as a visual tool in searching for information on account of semantic connections. In case of the ontology for ROI indicator 44 topics, 6 taxonomic classes with relation of Subclass-Of type and 13 binary relations, whereas in the ontology for an early warning system 142 topics, 23 classes with relation of Subclass-Of type and 20 binary relations were defined.

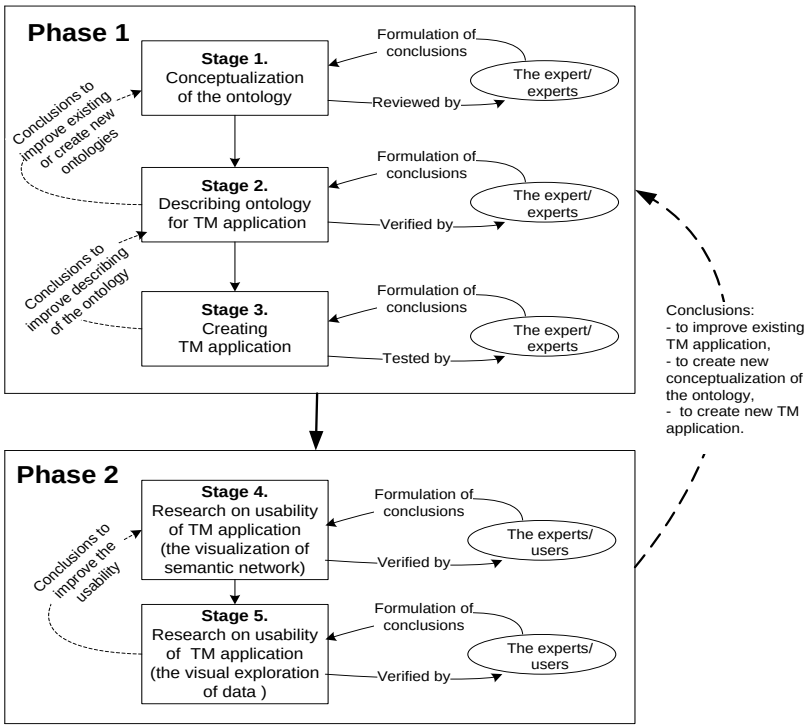

Figure 2. Scheme of the design of the research on the visual exploration of information using the semantic searching based on the applications of TM
Source: [5, p. 132]

4. Assumptions of the experiments

Before starting the research on system utility we created an ontology for economic indicators, built TM application in TM4L software and tested visual searching information. Setting about research with participants we decided to create an application in Protégé 4.1 beta for ROI indicator and for early warning system, because there were many difficulties with correct executing TM4L software in operation system MS Windows 7. In Protégé 4.1 beta, there is the module OntoGraf which turned out to be sufficient to carry out the initial research, the aim of which was to verify the usefulness of visual a semantic network in searching for economic information.

The aim of the research presented in this paper is heuristic evaluation of using visualization in semantic searching for economic information.

Three experiments were carried out:

1) test 1 – for the application of an ontology for ROI indicator (so called: preliminary study),
2) test 2 – for the application of an ontology for ROI indicator,
3) test 3 – for the application of an ontology for an early warning system.

In the research (test 1, test 2 and test 3) potential users participate. The selection of the participants cannot be random, as they are to fulfil a double role. The first one is to be a typical user, performing specific tasks in a topic map application for ontology indicators (research using the usability testing technique). The second role is to be an expert evaluating the usability of applied interface (research using heuristic evaluation of user interface). None of them either searched information basing on the visualization of ontology before or was familiar with the program Protégé.

In the first research 42 persons aged from 23 to 30 years, who had various experience and knowledge concerning economy and analysis of economic indicators as well as systems and information technology, that is with only computer education, computer science and econometrics education, economic education or non-computer education, took part. In the second and the third research 14 and 46 persons, respectively, took part. In these two experiments the participants were 20-23 years old and had similar knowledge both of economic terms and computer systems. For the comparison and verification of the results of this study we have decided to conduct two tests for two different TM applications.

In these three experiments the duration of the introduction to performing tasks by participants was similar (about 20-30 minutes), but the introduction differed in content. The observation of users during the first test and analysis of the realization of usability tests caused a modification of training and used vocabulary before the next experiments. The second test was realized with lower number of participants, because it was to be preparation for the test 3, in which participants were using more complex application of the ontology for an early warning system. This experiment was to answer the question whether the training was substantially well prepared and whether modification of phrasing in tasks improved finding correct information. Such realization of experiments resulted from the proposed research method.

In the research we used questionnaires which consisted of three parts:

1) tasks which participants of this study were to do,
2) criteria of an interface evaluation,
3) list of potential problems.

Used questionnaires differed only in the first part (i.e. task to be done), whereas in the second and third parts they were the same.

5. Preliminary analysis of the research result

The results of the study may be divided into two groups. First group comes from the research using the usability testing technique. It concerns the correctness of performing tasks by users and the evaluation of easiness of searching information basing on the visualization of the semantic network. These are the data obtained from the first part of the questionnaire. The second part of the results comes from the research using the heuristic evaluation of user interface. These are the data obtained from the second and third parts of the questionnaire. In this paper we will analyze the data acquired from the second group, which concern:

- evaluation of interface usability,
- identification of potential difficulties connected with used human-computer interaction.

In Appendix Table 1 there is data obtained from the research carried out so far (test 1, test 2 and test 3). In the columns data in per cent were put for the following number of research participants:

1) $N = 102$ – data involving all experiments;
2) $N = 42$ – test 1;
3) $N = 14$ – test 2;
4) $N = 46$ – test 3.

The data presented in the table shows that comparing to the test 1, in the other two tests visual searching for information was much better evaluated. In the first research ($N = 42$), according to the criterion B, the dominant mark is *unsatisfactory* (40%), and in case of criterion A – *average* (31%). There was also high percentage of the answer *unsatisfactory* for the criterion C (26%) and D (33%). Significantly better results were obtained in the second and third tests. In the second experiment for criteria A, C and D there were no negative marks. In case of the third experiment for any of criteria there was no answer *very unsatisfactory*, and in case of mark *unsatisfactory* for criteria A, C and D there were only 2% of such answers, whereas for criterion B – none. Setting about the second and the third experiments, we changed only the wording of the tasks (without changing their difficulty) and the content of training for participants that preceded the realization of the tasks. These changes were the consequence of both the results obtained from the first test and observing participants performing tasks.

In conclusion, the second and the third studies' participants much better evaluated adopted solution according to the four criteria. For all four criteria the dominant mark is satisfactory. We can notice the same by analyzing the column of all participants. Looking at this data, this is important information, that there is very small percentage of negative marks: unsatisfactory and very unsatisfactory. Two conclusions result from this data. Firstly, the proposed way of searching for information can be a useful solution for decision-makers carrying out an analysis of

economic indicators. Secondly, we should focus more on preparing better content of training.

In Appendix Table 2 the data concerning identification of potential difficulties connected to human-computer interaction is presented. Its initial analysis confirms conclusions formulated basing on the analysis of the data contained in Table 1. The modification of only the training and wording of tasks (they were clearer for research participants) significantly improved the evaluation of potential difficulties. In case of test 1 (N = 42) for four difficulties (i.e. no. 1, 2, 3 and 4) the dominant answer is*: a small problem*, whereas in case of test 2 (N = 14) in all seven difficulties considerably dominant answer is: *no problem*. In case of the third test (N = 46) only for two difficulties (no. 2 and 3) there is similar number of marks *no problem* and marks *a small problem*. In the other five difficulties the dominant answer is: *no problem*. The positive information from the analysis of data for all the participants (N = 102), as well as for the test 2 and test 3 is significantly small percentage of the answer *an important problem*.

Summing up, we can make the same conclusion as from the previous table. Participants of the second and the third studies evaluated interface much better than participants of the first study.

Results obtained from the research are quite promising in the context of using a topic map to:

- present knowledge on economic indicators,
- search for information basing on the visualization of various semantic relations between indicators.

The research should be continued both on creating a topic map application for analysis of economic indicators, as well as on evaluation of usability of such system.

6. Conclusions and future work

In this paper we discussed the results of the research on heuristic evaluation of the visualization in the semantic searching for economic information. The results of the research can be found quite significant. They characterize the usability assessment of applying the visualization of the ontology of chosen economic indicator as interface user – system in searching information with regard to contextual connections. An attention should be paid to the fact that before the second stage of experiment we modified only the wording of tasks (which did not change their difficulty) and the content of the training preceding performing tasks by research participants. These modifications resulted in much better evaluation of the application in the following two experiments.

The research will be continued in order to verify the creating of the ontology in formal and substantive respect, by testing created applications. Then we will verify the usefulness of applying the topic map standard as an interface for visual exploration of data concerning indicators of assessment of functioning of an enterprise and usefulness of the topic map application in analysis of economic indicators.

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APPENDIX

Table 1. The heuristic evaluation of the visualization in searching for economic information in economic analysis indicators

The criteria for assessment	Scale of usability interface evaluation	Breakdown of accomplishment of tasks (%)			
		All participants *N* = 102	Test 1 *N* = 42	Test 2 *N* = 14	Test 3 *N* = 46
A. How would you rate the system in terms of visual clarity?	highly satisfactory	9	17	0	4
	satisfactory	**48**	29	**71**	**59**
	average	32	**31**	29	35
	unsatisfactory	10	21	0	2
	very unsatisfactory	1	2	0	0
B. How would you rate the system in terms of its functionality (in the context of searching information)?	highly satisfactory	13	7	21	15
	satisfactory	**43**	33	**43**	**52**
	average	25	14	29	33
	unsatisfactory	18	**40**	7	0
	very unsatisfactory	2	5	0	0
C. How would you rate the system in terms of flexibility of its structure and the presentation of information?	highly satisfactory	8	10	0	9
	satisfactory	**49**	**33**	**79**	**54**
	average	31	31	21	35
	unsatisfactory	12	26	0	2
	very unsatisfactory	0	0	0	0
D. How would you rate the way of searching information that bases on the visualization of a semantic network?	highly satisfactory	8	7	7	9
	satisfactory	**47**	**36**	**86**	**46**
	average	30	24	7	43
	unsatisfactory	15	33	0	2
	very unsatisfactory	0	0	0	0

Table 2. The evaluation of the potential problems with the usage of the visualization of the semantic network in searching for economic information

The list of the problems	Scale of the problem evaluation	Breakdown of accomplishment of tasks (%)			
		All participants *N* = 102	Test 1 *N* = 42	Test 2 *N* = 14	Test 3 *N* = 46
1. Understanding how to navigate the OntoGraf	no problem	**56**	33	**79**	**70**
	a small problem	39	**57**	21	28
	an important problem	5	10	0	2
2. Understanding how to execute tasks	no problem	45	38	**64**	46
	a small problem	**51**	**55**	36	**52**
	an important problem	4	7	0	2
3. Understanding the relation between information on the screen and the executed operation	no problem	34	26	14	**48**
	a small problem	**56**	**57**	**79**	**48**
	an important problem	10	17	7	4
4. Finding necessary information	no problem	**51**	26	**57**	**72**
	a small problem	41	**60**	43	24
	an important problem	8	14	0	4
5. The difficulty in reading information on the screen	no problem	**56**	**45**	**57**	**65**
	a small problem	36	43	29	33
	an important problem	8	12	14	2
6. Too many colors on the screen	no problem	**64**	**60**	**64**	**67**
	a small problem	26	24	29	28
	an important problem	10	17	7	4
7. The necessity to memorize too much information during execution of the task	no problem	**64**	**55**	**71**	**70**
	a small problem	32	36	29	30
	an important problem	4	10	0	0