INFORMATION
SYSTEMS IN
MANAGEMENT

Information Systems in Management (2013) Vol. 2 (3) 194–206

HEURISTIC EVALUATION OF VISUALIZATION OF THE SEMANTIC SEARCHING ECONOMIC INFORMATION THE COMPARATIVE ANALYSIS OF FOUR EXPERIMENTS

HELENA DUDYCZ

Department of Information Technology, Wrocław University of Economics

The main goal of this paper is to discuss the research on heuristic evaluation of visualization in the semantic search of economic information. It is already the fourth experiment with participants. This time in the research we used two applications built in Protégé 4.1: for analysis of Return on Investment (ROI) indicator according to Du Pont model and for multidimensional early warning system. In the article we briefly described semantic networks as visual interface and premises of conducted study. Then we analysed and compared results of these experiments. Finally, we presented conclusions.

Keywords: interface, visual interface, visualization of semantic network, evaluation of usability of visualizing in searching information, ontology

1. Introduction

Issues of information search based on semantic network technologies is a subject of many studies and concerns various fields (see inter alia [1]; [2]; [16], [18], [19]). In this approach special 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 [2], [8], [16]). The combination of data visualization in the form of semantic web and personal navigation can become an effective and efficient tool to perform various analyses, including economic data. The interface is described as good because

it has the proper presentation and efficient navigation allowing users to quickly access the information they need. (see: [9]). Used presentation of data has a major impact on the way in which for example decision–makers interpret the data and assess the usefulness of the system. For users the presentation layer is the most critical element of information and analytical system because it largely shapes the understanding of the basic data on the computer screen. (see: [17]).

Our research concentrates on the usage of visualization methods in searching information basing on semantic network. In this article we discuss four experiments from research on evaluation of visualization in the semantic search of economic information. The paper is structured as follows: in the next section we present shortly semantic networks as a visual interface. In section 3, assumptions of the experiments and the analysis of the results of the research and conclusions are described. Finally, in the last section we give a summary of this work and indicate future research prospects.

2. Semantic networks as a visual interface

One of ideas of collecting and searching data is semantic network, which besides the data themselves contains also information on relations between them, which are encoded in text format (as a metadata). There are many open formats of metadata. These are inter alia computer languages, so called web ontology languages, such as XML, RDF, OWL i SPARQ basing on natural language (see [7]; [16]). The basis of creating semantic network is worked out ontology that defines objects from some field of knowledge and relations between them. In this approach the special 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], [16]).

In semantic search visualization is essential, as it allows users to easier notice and understand various both semantic and structural dependences between topics. Basing on displayed semantic structure of topics it is possible to interactively choose analyzed topics or relations, changing area of presented details and obtaining source data. As empiric research carried out by S. Falconer indicates, visualization enhances understanding ontology, making users faster realize conceptual tasks requiring understanding and describing semantic of particular topic [6].

Interactive visualisation allows to actively include user in process of finding information, enabling him to build more accurate queries for specific set (see [13, p. 316]) and facilitating noticing relations between analyzed data. Presentation of data with the use of graphic method supports innovative look at them by user (i.e. decision –makers), allowing him to formulate new hypotheses and their validation. Such approach to visualization of information search is promising solution, because graphical methods and techniques can increase effectiveness of used au-

tomated exploration data methods by using perception and user's general knowledge [10, p. 1767]). Visual information search consists in using graphic methods, allowing interactive browsing, analyzing and obtaining needed data with user's active participation.

Using ontologies and semantic networks for visual interface supporting information search in information-analytic tools may solve following solutions [2, p. 216]:

- lack of support in defining business rules for getting proactive information and consulting in the process of decision making;
- lack of semantic layer describing relations between different economic topics;
- lack of support in in presenting information on account of different users (employees) and their individual needs;
- difficulty in fast modification of existing databases and data factories in the enterprise in case of new analytic requirements.

Information search based on semantic network requires use of advances graphic interfaces, in which visual navigation in order to obtain needed information is essential.

3. Usability of visualization in the semantic searching economic information – research design

3.1. Assumptions of the research

The aim of the research is inter alia to verify the usability of visualization in the semantic searching economic information in the analysis of economic ratios.

In this article we concentrated on discussing four experiments, which used two applications built in Protégé 4.1: for analysis of Return on Investment (ROI) indicator according to Du Pont model and for multidimensional early warning system (MEWS). 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 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.

Study on evaluation of semantic network visualization in information search on account of contextual dependences was conducted using OntoGraf module in program Protégé 4.1 beta. The aim of module OntoGraf, which turned out to be sufficient to carry out the initial research, was to verify the usefulness of visual

semantic network in searching economical information that is contextually connected.

In literature many methods of research and evaluation of human-computer interaction are described (see inter alia [14]; [15]). The research of a prototype can be conducted with the experts' participation (e.g. heuristic evaluation of user interface) and/or users (e.g. user testing, usability testing, eye tracking). It was decided to carry out a research with the participation of users. In the all of four experiments of the heuristic evaluation of visualization in searching economic information we applied a combination of two methods of evaluating interface enabling human-computer interaction, that is heuristic evaluation and usability tests. In literature there are described many procedures using these methods. The research with the use of these two methods is realized according to the following plan (see also [2, pp. 177-178]):

1. Creating test task for the usability testing and questionnaire of heuristic evaluation.
2. Study with participation of users:
   2.1. Selection of research participants.
   2.2. Carrying out study.
3. Data analysis on account of the following criterions:
   — correctness of performing tasks,
   — evaluation of easiness of finding information,
   — evaluation of interface usability,
   — identification of potential difficulties connected with used human-computer interaction.
4. Discussion of results and conclusions.

Presented procedure contains both tasks to be performed by research participants and heuristic evaluation of visual searching information. All four experiments were conducted according to this plan, but they differed in:

— application, that was used by participants during study,
— the tasks to be performed (without changing the context of implementation),
— time and content of training provided prior to the realization of commands.

In the first 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 experiment was realized with lower number of participants, because it was to be preparation for the experiment 3, in which participants were using more complex application of the ontology for an early warning system. This research was to answer the question whether the training was

substantially well prepared and whether modification of phrasing in tasks improved finding correct information.

Analysis of the data from the previous three experiments resulted (described in [2]) in the making the following assumptions for the experiment no. 4:

— each participant performs firstly tasks using the application for the ROI indicator, then the MEWS;
— knowledge of the participants differ in terms of both use of information systems and economics;
— introduction to the study takes about 10-15 minutes and it mainly discusses issues related to Protégé 4.1 beta (as in experiment no. 1);
— participants receive a prepared help on a paper (the identical as in experiment no. 2 and no. 3).

Such realization of four experiments resulted from the proposed research method (see [2]; [4]) and the model proposed by E. Brangier (see [5]). These studies enable to identify users' needs precisely and may contribute to the development of innovations. The important element of the experiments are elaborated questionnaires.

3.2. Scope of questionnaires

According to the presented research plan, the first step was to develop questionnaires covering tasks to be performed using the application for the ontology of ROI indicator and for MEWS ontology as well as heuristic evaluation of the applied interface. To create them we used the conclusions from previous experiments. In the present study the structure of questionnaire is as follows:

- Part no. 1. User profile significantly expanded compared to experiment no. 1. In addition to questions related to personal data, there were also questions concerning used computer equipment.
- Part no. 2. Tasks to be performed in application for ROI indicator. That part of questionnaire consists of list of commands, where study participant records responses –found information. Furthermore in each task there is a table, in which after the execution of instruction the participant evaluates the difficulty of finding information. In the questionnaire five-grade scale was used: *very easily (quickly)*, *easily (quickly)*, *average*, *hard (long)*, *very hard (long*). In case of study on application for ROI indicator, the six tasks were formulated, where several tasks are identical (as to the context and manner of performance) with instructions from experiment no. 1 and no. 2.
- Part no. 3. Tasks to be performed in application for MEWS. Same as in part 2, the commands were placed but in this case with use of application for ontology MEWS and assessment of ease of finding information. There are 7 tasks, most of them repeated questionnaire from experiment no. 3.

- Part no. 4. Criteria of an interface evaluation. This fragment of questionnaire is identical as part 2 in the experiments no. 1, no. 2 and no. 3. There were used four criteria for assessment. Each of these criterions is assessed by a user according to five-grade scale, i.e.: *highly satisfactory*, *satisfactory*, *average*, *unsatisfactory*, *and very unsatisfactory*.
- Part no. 5. List of potential problems. This part of the questionnaire concerns identification and evaluation of potential difficulties in using the system. This part of the questionnaire is identical as in part 3 in the experiment no 3, which differs by one additional position in relation to the experiment no. 1 and no. 2. Participants of the research choose one of the following answers: *no problem*, *a small problem*, *an important problem.*

The data obtained from the questionnaires used in the experiments can be divided in four main groups that concern:

— correctness of performing tasks,
— evaluation of easiness of finding information,
— evaluation of interface usability,
— identification of potential difficulties connected with used human-computer interaction.

Additionally in the experiment no. 4 the data might be analyze due to the profile of the participants involved in study e.g. their knowledge, gender, owned computer hardware.

3.3. Participants of the research

After the development of questionnaires the research was carried out. In the research (experiment no. 1, experiment no. 2 and experiment no. 3) potential users of topic maps participated. 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 the fourth research 41 persons aged from 23 to 27 years, who had various experience and knowledge concerning economy and analysis of economic indicators as well as systems and information technology (similarly as in the first research). In addition, they indicated in the questionnaire whether their current interest is more toward information technology issues, economic or both. Among those with informatics secondary education three people indicated information technology and one - both. In the case of economic-informatics secondary education all (100%) highlighted: information technology and economic issues. However, the greatest diversity was among those included in the group of non-informatics education (mainly economic education in this group), where economic issues indicated four people, information technology issues chose three people, and the same number chose both, while one person answered "*I do not know*".

3.4. Analysis of the results

In the present paper we will focus on analyzing the results of the fourth experiment in comparison with previous studies concerning:

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

Introduction to the experiment no. 4 took about 10-15 minutes, during which we mainly discussed issues related to Protégé 4.1 beta (as in experiment no. 1). In this study each participant firstly performed tasks using the application for the ROI indicator, and then the MEWS. Although the application for the ROI indicator is smaller and as such theoretically easier than the MEWS, success rate of the task was significantly smaller. In the case of the application for the ROI indicator the correct performance of 6 tasks (which consists of searching for proper information) is shaped in the range of 32% to 95%. However, for the application for MEWS, where participants performed seven tasks, is in the range of 90% to 100% (results of this part of the experiment no.4 described in [3]). Analysis of these data allows to tell that only minimal use of the Semantic Web visualization, without time-consuming long training is sufficient to understand the idea of action as a semantic network visualization interface.

In Appendix Table 1 there is data obtained from the research carried out so far (experiment no. 1, experiment no. 2, experiment no. 3 and experiment no. 4). In the columns percentages were calculated for the following number of research participants:

1) $N = 42$ – experiment no. 1;
2) $N = 14$ – experiment no. 2;
3) $N = 46$ – experiment no. 3,
4) $N = 41$ – experiment no. 4.

Data presented in the table shows that comparing to the experiment no. 1, in the other three experiments visual information search was much better evaluated. 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. The number of participation in the experiment no. 2 was smaller than other experiments, because the main aim of this test was verification of preparation of the content of training.

Although in the experiment no. 4, there was the same introduction to the tasks as in the experiment no. 1, but the user ratings are much better (comparable to the experiment no 2 and no. 3). Providing a short but useful help on the handout could have significant importance for faster understanding of the functionality of the tool.

In conclusion, except for the first experiment, participants much better evaluated adopted solution according to the first three criteria. For these three criteria the dominant mark is satisfactory. Looking at this data on the Table 1, this is important information, that there is very small percentage of negative marks: *unsatisfactory* and *very unsatisfactory*. Three 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 ratios. Secondly, we should focus more on preparing better content of training. Thirdly, user relatively quickly and easily learns the idea of information search based on visualization of semantic network.

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 experiment no. 1 for four difficulties (i.e. no. 1, no. 2, no. 3 and no. 4) the dominant answer is*: a small problem*, whereas in case of experiment no. 2 in all seven difficulties considerably dominant answer is: *no problem*. In case of the third and fourth experiments only for two difficulties (no. 2 and no. 3) there is similar number of marks *no problem* and marks *a small problem*. In the other five difficulties (no. 1, no. 4, no. 5, no. 6 and no.7) the dominant answer is: *no problem*. In the experiment no. 3 and no. 4 an additional question in the questionnaire was introduced (no. 8). The dominant response in both experiments is: *a small problem*.

Summing up, we can make the same conclusion as from the previous table. Participants of the second, the third and the fourth studies evaluated interface much better than participants of the first study. Results obtained from the research are quite promising in the context of using visualization in the semantic searching economic information to present knowledge on economic indicators.

4. Conclusions and future work

In this article we discussed the results of the research on heuristic evaluation of the visualization in the semantic searching for economic information. We shortly described the proposed research method. We presented the research carried out and discussed the obtained results. An attention should be paid to the fact that in spite of the fact that in the experiment no. 4 we adopted a rule not to explain to participants of the study how to search for information using the Semantic Web visualization, in a relatively short period of time they "discovered" the idea of that interface. Also in the context of the assumptions, the results of the study: evaluation of interface usability and potential difficulties connected with used human-computer interaction are optimistic.

In the research we used heuristic methods of evaluation of human-computer interaction. Obtained data are presented in tables containing percentages of given event. In this research it is essential to get answers to the following questions:

— is it possible to use visualization in the semantic search of economic information as a useful interface in information systems for managers;
— how much time is needed to teach users of system to use visualization of semantic network as interface for searching needed economic information;
— what should be the scope of training to minimize time needed to teach users to use visualization of semantic network.

The essential factors of carried out experiments are inter alia: economic and computer knowledge and experience, duration of training and its content. Therefore analysis of obtained data from these experiments will be continued - multidimensional analysis with the use of statistical measures will be carried out.

The research will be continued in order to verify the creating of the ontology in formal and substantive respect, by testing created applications. At present research on evaluation of visualization in the semantic searching for economic information will be conducted within the project InKoM (described in: [11]; [12]).

REFERENCES

[1] Andaroodi E., Andres F., Ono K., Lebigre P. (2004) *Developing a Visual Lexical Model for Semantic Management of Architectural Visual Data*, Design of Spatial Ontology for Caravanserais of Silk Roads, Journal of Digital Information Management (JDIM), vol.2, no. 4, December, pp. 151-160.

[2] Dudycz H. (2013) *Mapa pojęć jako wizualna reprezentacja wiedzy ekonomicznej*, Wydawnictwo Uniwersytetu Ekonomicznego we Wrocławiu, Wrocław.

[3] Dudycz H. (2013) *Badanie i ocena wyszukiwania informacji w analizie wskaźników ekonomicznych z użyciem sieci semantycznej jako wizualnego interfejsu*, [in:] “Infor-

matyka & Przyszłość", Wydawnictwo Naukowe Wydziału Zarządzania Uniwersytetu Warszawskiego, Warszawa (in print)

[4] Dudycz H. (2012) *An Attempt of the Heuristic Evaluation of Visualization in Searching Economic Information in Topic Maps*, [in:] CAiSE 2012 International Workshops Gdańsk, Poland, June 2012 Proceedings, M. Bajec, J. Eder, eds., Lecture Notes in Business Information Processing 112, Springer-Verlag Berlin Heidelberg, pp. 130-142.

[5] Eilrich L., Andres F., Sillaume G., Backes M. (2009) *Fostering User Experience in Order to Improve the Quality of a Digital Library*, Workshop on Advanced Technologies for Digital Libraries, http://www.cacaoproject.eu/fileadmin/media/AT4DL/paper-04.pdf.

[6] Falconer S. M. (2009) *Cognitive Support for Semi-Automatic Ontology Mapping*, dissertation, Department of Computer Science, University of Victoria, Canada.

[7] Goczyła K. (2011), Ontologie w systemach informatycznych. Akademicka Oficyna Wydawnicza EXIT, Warszawa.

[8] Grand B.L., Soto M. (2010) *Topic Maps, RDF Graphs, and Ontologies Visualization*, [in:] Visualizing the Semantic Web. XML-Based Internet and Information Visualization, V. Geroimenko, C. Chen (red.), Springer-Verlag, London, pp. 59-79.

[9] Hunting S., Park J. (2002) *XML Topic Maps: Creating and Using Topic Maps for the Web*, Addison-Wesley Professional.

[10] Keim D. A., Schneidewind J. (2005) *Scalable Visual Data Exploration of Large Data Sets via MultiResolution*, "Journal of Universal Computer Science", 2005, vol. 11, no. 11, pp. 1766-1779.

[11] Korczak J., Dudycz H, Dyczkowski M. (2013) *Design of Financial Knowledge in Dashboard for SME Managers*, in: Proceedings of the 2013 Federated Conference on Computer Science and Information Systems (FedCSIS). M. Ganzha, L. Maciaszek, M. Paprzycki, Eds. Polskie Towarzystwo Informatyczne, IEEE Computer Society Press, Warsaw, Los Alamitos, CA 2013, pp. 1123–1130.

[12] Korczak J., Dudycz H., Dyczkowski M. (2012) *Intelligent Dashboard for SME Managers. Architecture and Functions*, [in:] Proceedings of the Federated Conference on Computer Science and Information Systems FedCSIS 2012, M. Ganzha, L. Maciaszek, M. Paprzycki, Eds. Polskie Towarzystwo Informatyczne, IEEE Computer Society Press, Warsaw, Los Alamitos, CA 2012, pp. 1003–1007.

[13] Lopes A. A., Pinho R., Paulovich F. V., Minghim R. (2007),Visual Text Mining using Association Rules, Computer & Graphics, no. 31, pp. 316-326

[14] Sikorski M. (2012) *User-System Interaction Design in IT Projects*, Gdansk University of Technology, Gdańsk.

[15] Tullis T., Albert B. (2008) *Measuring the Use Experience. Collecting, Analyzing, and Presenting Usability Metrics*, Morgan Kaufmann Publishers.

[16] Wienhofen L. W. M. (2010), Using Graphically Represented Ontologies for searching Content on the Semantic Web, [in:] Visualizing the Semantic Web. XML-Based

Internet and Information Visualization, V. Geroimenko, C. Chen (red.), Springer-Verlag London, pp. 137-153.

[17] Wise L. (2008), The Emerging Importance of Data Visualization, October 29, 2008, http://www.dashboardinsight.com/articles/business-performance-management/the-emerging-importance-of-data-visualization-part-1.aspx

[18] Wurzer J., Smolnik S. (2008), Twards an automatic semantic integration of information, [w:] Subject-centric computing. Fourth International Conference on Topic Maps Research and Applications, TMRA 2008, L. Maicher, L. M. Garshol (red.), Leipziger Beiträge zur Informatik: Band XII, Leipzig, pp. 169-179.

[19] Yi M. (2008) *Information organization and retrieval using a topic maps-based ontology: Results of a task-based evaluation*, Journal of the American Society for Information Science and Technology, vol. 59, no. 12, pp. 1898-1911.

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 (%)			
		Test 1 *N* = 42	Test 2 *N* = 14	Test 3 *N* = 46	Test 4 *N = 41*
A. How would you rate the system in terms of visual clarity?	highly satisfactory	17	0	4	5
	satisfactory	29	**71**	**59**	**49**
	average	**31**	29	35	37
	unsatisfactory	21	0	2	7
	very unsatisfactory	2	0	0	2
B. How would you rate the system in terms of its functionality (in the context of searching information)?	highly satisfactory	7	21	15	12
	satisfactory	33	**43**	**52**	**56**
	average	14	29	33	27
	unsatisfactory	**40**	7	0	5
	very unsatisfactory	5	0	0	0
C. How would you rate the system in terms of flexibility of its structure and the presentation of information?	highly satisfactory	10	0	9	15
	satisfactory	**33**	**79**	**54**	**39**
	average	31	21	35	27
	unsatisfactory	26	0	2	19
	very unsatisfactory	0	0	0	0
D. How would you rate the way of searching information that bases on the visualization of semantic network?	highly satisfactory	7	7	9	17
	satisfactory	**36**	**86**	**46**	34
	average	24	7	43	**44**
	unsatisfactory	33	0	2	5
	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 (%)			
		Test 1 *N* = 42	Test 2 *N* = 14	Test 3 *N* = 46	Test 4 *N* = 41
1. Understanding how to navigate the OntoGraf	no problem	33	**79**	**70**	**71**
	a small problem	**57**	21	28	22
	an important problem	10	0	2	7
2. Understanding how to execute tasks	no problem	38	**64**	46	44
	a small problem	**55**	36	**52**	**49**
	an important problem	7	0	2	7
3. Understanding the relation between information on the screen and the executed operation	no problem	26	14	**48**	46
	a small problem	**57**	**79**	**48**	**49**
	an important problem	17	7	4	5
4. Finding necessary information	no problem	26	**57**	**72**	**54**
	a small problem	**60**	43	24	39
	an important problem	14	0	4	17
5. The difficulty in reading information on the screen	no problem	**45**	**57**	**65**	**44**
	a small problem	43	29	33	39
	an important problem	12	14	2	17
6. Too many colors on the screen	no problem	**60**	**64**	**67**	**73**
	a small problem	24	29	28	17
	an important problem	17	7	4	10
7. The necessity to memorize too much information during execution of the task	no problem	**55**	**71**	**70**	**63**
	a small problem	36	29	30	32
	an important problem	10	0	0	5
8. Understanding names of relations between topics	no problem	---	---	37	37
	a small problem	---	---	**54**	**39**
	an important problem	---	---	9	24