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WHICH TECHNIQUE TO USE WHEN ELICITING KNOWLEDGE FROM AN EXPERT

Sandra Lovrenčić, Božidar Kliček
University of Zagreb,
Faculty of Organization and Informatics, Varaždin, CROATIA
{sandra.lovrencic, bozidar.klicek}@foi.hr

Abstract: A *knowledge elicitation technique selection for a knowledge elicitation from an expert still represents a problem in a KBS development. In this paper is presented an original computer program for technique selection and a changed program that was aimed at improving the selection. Both programs use certain factor values as a starting point, but the first program is based on a technique grading and the second on decision trees. Comparison and testing results for both programs are presented.*

Keywords: ***k**nowledge elicitation, knowledge elicitation techniques, knowledge-based systems.*

1. INTRODUCTION

A knowledge acquisition (KA) and a knowledge elicitation (KEL), as its part, had been for years and still are the "critical bottleneck" of the expert systems development [6,7,8,13,14,17,20,23,24,29] and various authors still mention it as a large problem in this process. Most of authors are nowadays occupied with automated knowledge acquisition and data mining and those approaches solved many problems of acquiring and representing knowledge. However, there is always a certain amount of knowledge that needs to be elicited from a domain expert, because there are no data or only a human possesses needed knowledge. In that part of the knowledge elicitation, among other factors, also exists a problem of psychological factors that are involved on expert and knowledge engineer's side. The most discussed psychological problem is expert's tacit knowledge, which an expert can not at all or can only partially express [6,8,9,13,15,34]. To solve problems in that part of KEL is more important than ever [1], because, if done properly, it is one of ensuring factors that the expert system development process will continue successfully.

Most of books regarding the KEL were published in late 1980's and early 1990's [3,6,13,8,31]. They covered the subject generally, mostly concentrating on an interview and giving common guidelines about the elicitation process and when to use which technique. Articles published in last 15 years covered different aspects of the KEL: a KEL technique classification [6,13,3,8,5,18,2,21], a comparison of KEL techniques [34,23,24,4,16] and various KEL tools [13,3,10,11,5,33,19,12,1,35,29,30]. Of course, concerning the problem of gaining knowledge from information systems or documentation, there is various

software for automatic data collection and data mining. For solving the problem of eliciting knowledge from experts, there are computer-based knowledge elicitation techniques, either for initial development of expert systems, such as multimedia polls [27] and knowledge acquisition systems [10,11], or also additionally for the maintenance of developed expert systems that need an update of the knowledge base [29]. Different frameworks for knowledge modeling [32] are being developed and new methods of the knowledge elicitation [9] are being proposed. The problem of the selection of the appropriate knowledge elicitation technique, as a part of the knowledge elicitation problem, has also been an object of exploration. Authors are mostly concentrated on the analysis of several techniques according to few factors [16], on the combination of several techniques [11] or/and the combination of one or more elicitation techniques with knowledge acquisition programs [10].

Several authors gave general directions about the usage of techniques [6,8,13,31], but over years a special consideration was also given to the KEL technique selection [2,6,16,21,22,28], covering different techniques and different influence factors. This article tries to unite the most often used techniques (sixteen of them) with eleven influence factors that the author already suggested in prior work [26]. Most factors are well known, as knowledge type, and are combined with psychological factors, as expert's verbal expression.

2. INFLUENCE FACTORS AND KEL TECHNIQUES

Proposed factors that influence on the KEL technique selection are divided into three groups. References that mention all or some parts of that factor are also given.

2.1. FACTORS RELATED TO THE PROBLEM DOMAIN

The problem domain and its knowledge have a great influence on the KEL technique selection. Three factors in this group are: a knowledge type [2,5,6,21,23,24,28,34,35], a domain width [5,21] and a knowledge scope [5,6,8,34].

The knowledge type is a factor according to which is most often selected a KEL technique. Knowledge can be divided into procedural, declarative and a combination of those two types. The applicability of a certain technique also often depends on the domain width. Some techniques can become too complex in domains that have many concepts and relations among them. The domain width can be narrow, medium or broad. The knowledge scope usually depends on the KEL stage. Since it is divided into common and special knowledge and their combination, it is obvious that in the first stage more common knowledge will be required and that in later stages knowledge will be more specific.

2.2. FACTORS RELATED TO PARTICIPANTS IN THE ELICITATION PROCESS

When selecting a technique for the KEL, a knowledge engineer (KE) must also take into consideration some expert's and his/her own characteristics. Therefore, factors that belong to this group are: an expert type [2,5,6,8], an expert's availability [5], relations between a KE and an expert [5], a KE's experience [5] and KE's knowledge of the problem domain [5,6,24].

Psychological factors, especially tacit knowledge, are already mentioned as a large problem for eliciting desired knowledge. The first factor in this group, the expert type, refers exactly to tacit knowledge and denotes an expert as verbal, non-verbal or "in between" type. The expert's availability also often represents an obstacle for a KE, since

experts are of vital meaning for their company and very occupied. This factor can have values good, medium and bad. Relations between a KE and an expert are usually established at their first meeting, but can also depend on expert's feelings about the elicitation process, such as distrust and fear. A KE's experience in the KEL can have big influence on overcoming those problems and can also affect his success in usage of more complex techniques. The final factor, KE's knowledge of the problem domain is connected with the knowledge scope, but it also includes familiarity with domain processes and concepts independently of the current problem that is being solved with the KBS. All those factors also have values of good, medium and bad.

2.3. FACTORS RELATED TO ELICITATION TECHNIQUES

Last group factors are connected with time needed for the KEL process. The time is divided into a preparation time [5], a training time [5] and an elicitation realization time [5,6,21].

The preparation time comprises time needed that a KE prepares everything for the KEL process, including necessary equipment and a technique study. The training time refers to the time that an expert can separate for the KEL preparation, especially to get acquainted with the technique that will be used. And final time factor is the elicitation realization time. Duration of the elicitation with a certain technique also depends on other factors, such as the domain width and the knowledge scope. All those three factors can have values of short, medium and long.

2.4. KEL TECHNIQUES

Techniques that are considered for selection for a certain KEL stage are those most commonly used [2,5,6,21]:

- unstructured interview
- semi-structured interview
- structured interview
- focused discussion
- laddering
- twenty questions
- teach back
- critique
- construct elicitation (Repertory Grid Analysis)
- card sorting
- matrices
- verbal real-time protocols
- non-verbal real-time protocols
- retrospective protocols
- role playing
- simulation

They are listed here according to their prevailing characteristic. First eight are more of verbal type, next three are multidimensional techniques and last five are more connected with the procedural knowledge.

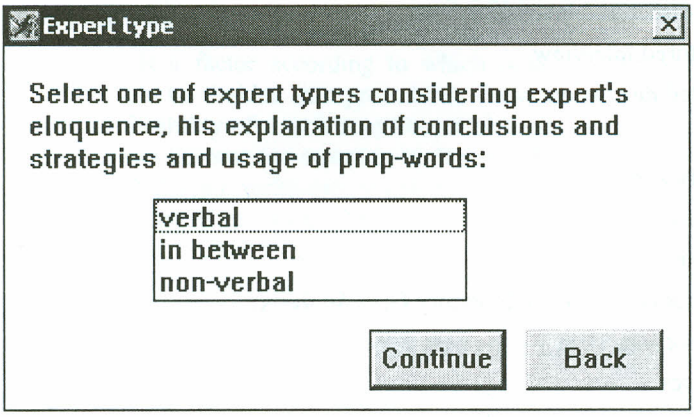
3. THE PROGRAM FOR THE KEL TECHNIQUE SELECTION

3.1. THE ORIGINAL PROGRAM

The program was made in XpertRule 3.72 tool [36]. This tool enables conclusions according to decision trees obtained by induction either from examples or exception trees, or created directly and conclusions according to directly created rules with or without uncertainty. All goals, as are techniques to be selected, are represented as tasks. Our task is actually a logical list type task containing sixteen possible outcomes – technique names, which means that all techniques are included in the solution.

Each of eleven factors represents a logical attribute with three possible values. Therefore, there are thirty-three rules (one for each factor value) and their only function is to, when activated, start the procedure that adds points to each of techniques. Points for third group of factors are multiplied by 0,5 so that their lesser influence would be denoted. Factor values are entered by user, according to his/her estimation. A graphical dialog for entering a value for the expert type factor can be seen in Picture 1.

Since there are no formal propositions in form of rules or formulas about the usage of techniques, technique points are proposed according to excerpts from texts that give advices about the technique usage. Each factor can at the same time have only one value, meaning that only eleven rules will be executed in one consultation. The program executes rules, ads points to techniques and divides final points by ten. At the end, techniques are sorted according to final grades. Their names and grades rounded on two decimal places are listed as a solution. Picture 2 shows an example of the solution.



Picture 1: A graphical dialog for the expert type factor

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The application offered the following solution:

 Structured interview              7.45
 Unstructured interview            6.70
 Semi-structured interview         6.65
 Focused discusion                 6.65
 Simulation                        6.45
 Non-verbal real-time protocol     6.20
 Twenty questions                  6.10
 Laddering                         6.00
 Teach back                        5.70
 Matrices                          5.70
 Card sorting                      5.55
 Retrospective protocol            5.30
 Verbal real-time protocol         5.25
 Critique                          5.20
 Role playing                      5.15
 Construct elicitation             5.00
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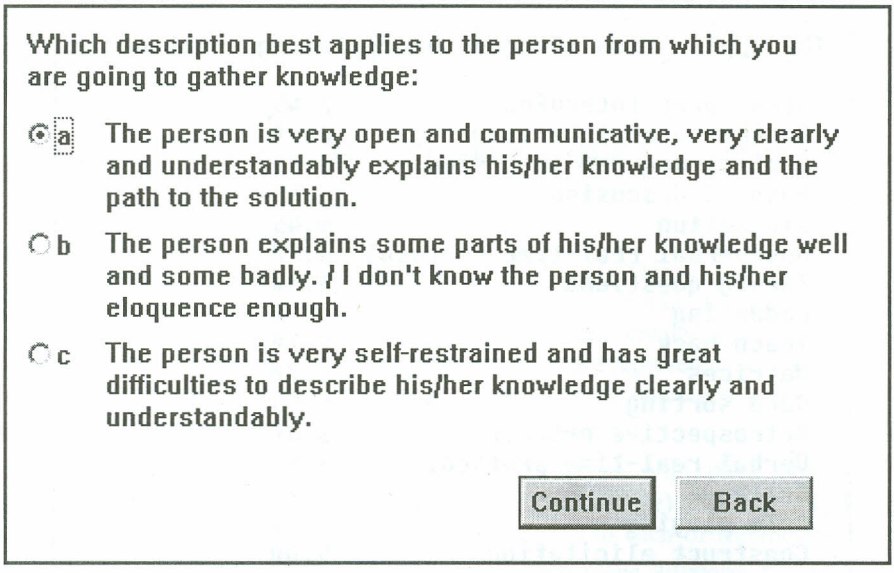
Picture 2: An example of the result output

3.2. CHANGES IN THE PROGRAM

Three types of changes were made in the program, considering:

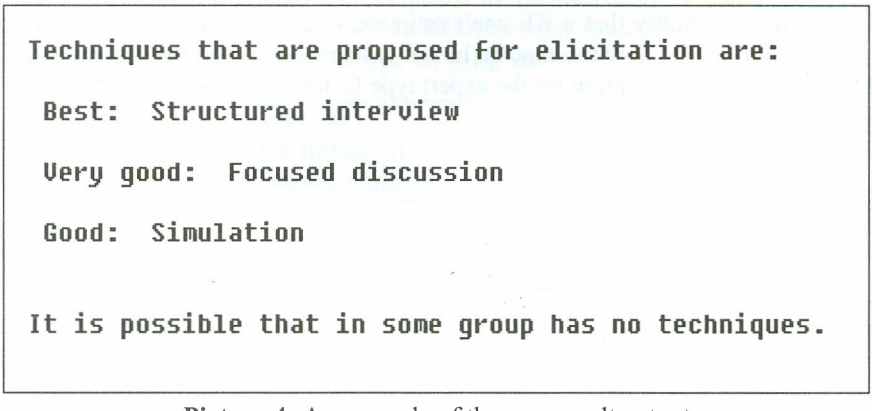
- factor values input,
- selection process,
- results output.

In the original program the user was offered three values for each factor by their names and he/she had to choose one of them. If the user, actually a KE, isn't experienced enough, it might be easier for him if he is offered with a description of the meaning of each factor value. Also, the possibility that a KE can't estimate values of some factors is added (for example, he/she doesn't know the expert). In that case, medium factor values are suggested. An example of such a description for the expert type factor can be seen in Picture 3.



Picture 3: A new graphical dialog for the expert type factor

The selection of KEL techniques was originally made "in a classical way", according to points that each technique gathered. This whole concept was changed. New program includes a knowledge-based reasoning according to factor values. For each group of factors a task is made that as an output has a list of techniques that satisfy the decision tree induced from examples, which were made according to excerpts from texts and points from prior program version. The second group of factors is divided into two groups, one more related to an expert (the expert type and the availability), and the other more related to a KE. An output of a decision tree can have more values, but it doesn't have to contain all techniques. Next step includes the grading of techniques. Each appearance of a certain technique in one of output lists is counted and sum represents a grade for that technique. Therefore, each technique can at the most have four points.



Picture 4: An example of the new result output

The output of the results is also changed. Techniques are grouped according to points into three groups: techniques that best satisfy a certain KEL problem (four points), those that satisfy it very well (three points) and those that are good for it (two points). Techniques

are in that way presented to the user. Groups can contain one or more techniques, but it is also possible that some group doesn't contain any technique. Picture 4 shows an example of the result.

4. RESEARCH

The aim of the research was to prove by seven hypotheses that changes in the program will lead to better results than those gained by the original program. Those hypotheses are made according to seven criteria that will be described below. The research was conducted at University of Zagreb, Faculty of organization and informatics in Varaždin, among third year students in November of 2001 and June of 2002.

4.1. EVALUATION OF THE ORIGINAL PROGRAM

In November of 2001, third grade students that had lesson in knowledge elicitation as a normal part of their course in KBS received additional materials to study for a week. After that they were tested with two ten-question tests, one about influence factors and the other about some additional elements that may affect factors value. 60 students had 50% or more accurate answers on test (58, so two students with 45% accurate answers were added randomly) and represented evaluation subjects. Tests and reasons for rounding up to 60 students can be found in [25]. The group consisted of 47 male and 13 female subjects. The average test grade for the group was 6,25 of 10 as a maximum grade.

Evaluation subjects were asked to read two KEL problems. The first problem was the appropriate wine selection for a certain meal and the second one was a diagnosis of a cardiac infarct. In both problem descriptions information about all factors was incorporated. After that, lists of techniques and their grades for both problems, which were obtained by the original program, were presented to the group. Evaluation subjects had to grade those lists according to following seven criteria:

- the knowledge type,
- the domain width,
- the knowledge scope (with KE's knowledge of the problem domain),
- the expert type,
- relations and a KE's experience,
- time limits (expert's availability, preparation, training and elicitation realization time),
- a combination of all criteria.

Evaluation subjects had to grade both problems technique lists for each criterion according to one-to-five Likert-type scale. The grading form can be seen in Picture 5.

Please grade proposed solution with grades from 1 to 5 (1 - it doesn't satisfy at all, 5 - completely satisfies) according to how it satisfies following characteristics of the problem (circle only 1 number):

Characteristics	Solution
1. knowledge type (concepts, procedures, strategies)	1 2 3 4 5
2. domain width (subdomains, solutions)	1 2 3 4 5
3. knowledge scope (general, special, concepts, procedures)	1 2 3 4 5
4. expert type (eloquence, prop-words, stammer)	1 2 3 4 5
5. relations and experience (cooperation, successfully used techniques)	1 2 3 4 5
6. time limits (preparation, training, KEL)	1 2 3 4 5
7. all characteristics together	1 2 3 4 5

Picture 5: The grading form

Since students as a normal part of their course in KBS have to develop demo-versions of a KBS, they were also asked to estimate factor values for their own KEL problems, enter them into program and to grade results they obtained according to same seven criteria.

This original program was also used in another research, where it was proven (according to same seven criteria) that the program gives better results than KE's if they would select techniques according to their knowledge [25].

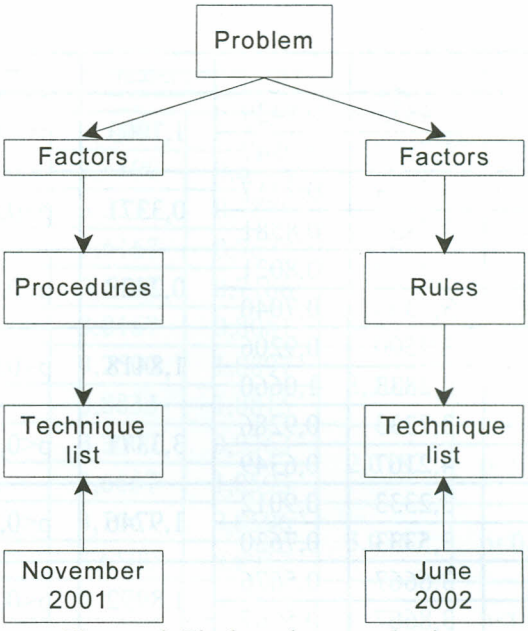
4.2. EVALUATION OF THE CHANGED PROGRAM

In June of 2002, when changes in the program were made, same 60 students were presented with same two elicitation problems as about six and a half months ago. They also received lists of techniques and their grades for both problems, which were obtained by the changed program. They had to grade those lists according to same seven criteria as before. They were once again asked to enter factor values for their own KEL problems into program and to grade those results.

Evaluation subjects were also asked three additional questions related to programs:

5. Do you consider a changed way of entering data into the program, as a difference from prior (direct entering of factor values) as: a) better, b) worse, c) the same?
6. Do you consider an output of fewer number of techniques in solution, and not of all (as in prior program) as: a) more clear, b) less clear, c) the same?
7. Do you consider a grouping of solutions as: a) good, b) bad, c) all the same?

After those two evaluations, information for testing hypotheses was gathered. The process of the each hypothesis evaluation is shown in Picture 6.



Picture 6: The hypotheses evaluation

4.3. RESULTS

Research hypotheses were that changes in the program would lead to better results according to:

- the knowledge type of a certain KEL problem,
- the domain width,
- the knowledge scope and KE's knowledge of the problem domain,
- the expert type,
- relations and a KE's experience,
- time limits.

The final hypothesis was that changed program would generally give better results than the original.

If we denote the average knowledge subjects' grade of the list obtained by the original program as $\overline{X}_{OA}$ and the average grade of the list obtained by the changed program as $\overline{X}_{CA}$, for each of hypotheses additional hypotheses can be made:

$$H_0 ... \overline{X}_{CA} \leq \overline{X}_{OA}$$

$$H_1 ... \overline{X}_{CA} > \overline{X}_{OA}$$

The testing of hypotheses was made at 5% ($\alpha_{.05}$) confidence level with one-tailed z-test. Results for the problem one are shown in Table 1, for the problem two in Table 2 and for students KEL problems in Table 3.

Table 1: Testing results for problem 1

Hypothesis	Solution	$\overline{X}$	δ	z-test	p
Knowledge type	1	3,4333	0,8439	1,7003	p<0,05
	2	3,7167	0,9847		
Domain width	1	3,7333	0,7717	0,3371	p>0,05
	2	3,7833	0,8581		
Knowledge scope	1	3,7000	0,8021	0,2428	p>0,05
	2	3,7333	0,7040		
Expert type	1	3,9500	0,9206	1,8418	p<0,05
	2	4,2833	1,0660		
Relations & experience	1	3,7333	0,9286	3,3371	p<0,05
	2	4,2167	0,6349		
Time	1	3,2333	0,9012	1,9746	p<0,05
	2	3,5333	0,7630		
All criteria	1	3,6667	0,5676	1,8992	p<0,05
	2	3,8667	0,5907		

Table 2: Testing results for problem 2

Hypothesis	Solution	$\overline{X}$	δ	z-test	p
Knowledge type	1	3,3833	0,9503	1,7812	p<0,05
	2	3,7000	1,0050		
Domain width	1	3,5667	0,8239	0,3391	p>0,05
	2	3,6167	0,7977		
Knowledge scope	1	3,4833	0,8849	0,3249	p>0,05
	2	3,5333	0,8055		
Expert type	1	3,1833	1,0246	2,0711	p<0,05
	2	3,6167	1,2661		
Relations & experience	1	3,2333	0,7824	2,3416	p<0,05
	2	3,6000	0,9345		
Time	1	3,3000	0,9183	1,7371	p<0,05
	2	3,6167	1,0815		
All criteria	1	3,5000	0,6191	2,4934	p<0,05
	2	3,8000	0,7024		

Table 3: Testing results for students' problems

Hypothesis	Solution	$\overline{X}$	δ	z-test	p
Knowledge type	1	3,3000	1,0050	2,2412	p<0,05
	2	3,6500	0,6788		
Domain width	1	3,3333	0,7888	1,7667	p<0,05
	2	3,6167	0,9677		
Knowledge scope	1	3,5167	0,7186	2,1618	p<0,05
	2	3,8167	0,8061		
Expert type	1	3,2500	1,0897	3,2083	p<0,05
	2	3,8833	1,0815		
Relations & experience	1	3,3000	0,9363	2,0182	p<0,05
	2	3,6667	1,0593		
Time	1	3,1667	0,8596	3,0367	p<0,05
	2	3,6500	0,8912		
All criteria	1	3,5500	0,6934	1,7202	p<0,05
	2	3,7667	0,6920		

As it can be seen in results, the average grade for the technique list obtained by the changed program is significantly greater than the average grade of the technique list obtained by the original program according to all seven criteria for students' KEL problems. For problems one and two changed program was better according to five criteria. Therefore, H_0 should be rejected and H_1 accepted for all hypotheses except 2 and 3 and they are fully proven. To prove whether original program gives better results than the changed for hypotheses 2 and 3, hypotheses should be set up in reversed order. Calculations are the same, which means that original program also doesn't give better results.

Analysis of three additional questions showed that at least three quarters of students think that the changed way of entering data into the program is better, that a new output is more clear and that grouping of solutions is good (one subject didn't answer). Results are shown in Table 4.

Table 4: Results of additional questioning

Question / Answer	Number of answers			Average values		
	1	2	3	1	2	3
a	45	47	49	76,2712	79,6610	83,0508
b	3	2	3	5,0847	3,3898	5,0847
c	11	10	7	18,6441	16,9492	11,8644
Total	59	59	59	100,0000	100,0000	100,0000

5. CONCLUSION

As it can be seen from various literature mentioned in the introduction, the knowledge elicitation from a domain expert still represents an obstacle in the KBS development process. One of factors that influence on the elicitation success is also the usage of the appropriate technique. After gathering information about the domain and the expert, a KE has to make the decision which technique he would use. It is possible that he will not know all information about all techniques. Exploration of various literatures can take time; therefore, the original program was aimed at making the selection process faster and accurate by including various factors that influence on the selection.

Prior research [25] has shown that the program represents a better solution for the KEL technique selection. Some additional changes are made to improve the selection and to make the program friendlier to the user. It is proven in five of seven hypotheses that those improvements positively affect the selection process and that by two criteria they didn't have any affect. Further research could show reasons for such result and more fine-tuning of the program could make the improvement. For example, a help feature with each factor or concrete examples might lead to better results.

Factors related to the domain, to participants in the elicitation process and to elicitation techniques, if taken altogether, provide a wide view to the problem. A formalization of their influence using rules is an attempt to clearly define the impact of each factor value on the knowledge elicitation technique selection. Using the given method implemented in the program, proposed techniques will represent a good line of the direction when selecting the appropriate knowledge elicitation technique for the real KBS development problem.

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