DEVELOPING ALGORITHMS OF TERNARY GRID TECHNIQUE FOR OPTIMIZING EXPERT SYSTEM'S KNOWLEDGE BASE

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ABSTRACT

The quality and the error possibility of knowledge in the expert system's knowledge base depend directly on the knowledge acquisition process from the expert. Knowledge acquisition is therefore still the most difficult and error-prone task for knowledge engineer while building an expert system. The Ternary Grid technique has potentiality to achieve the above mentioned performance. It is a new technique for knowledge elicitation/acquisition. The Ternary Grid knowledge acquisition is convenient for improving the knowledge performance.

To realize the concepts and to bring its influences into the knowledge base optimization, some algorithms of the Ternary Grid technique have been developed. This paper describes the optimization process of knowledge base and the development process of mentioned algorithms.

Keywords: *technic, intelligence systems, expert system, knowledge acquisition*

1. INTRODUCTION

In most rule-based expert system, building of rules can easily be done. Knowledge engineer does not have to do any work specifying rules and how they are linked to each other. Sometime the knowledge engineer can reference rules or facts that have not yet been created. It seems to be a simple and an instant work. The problem due to the performance of the knowledge will not occur until the number of rules is getting higher. Some problem may appear in the form of inconsistent rules, unreachable rules, redundant rule and closed rule chain of rules.

Knowledge acquisition is still the most difficult and error-prone task for knowledge engineer while building an expert system [5]. One of the most fundamental and still unsolved problems in knowledge acquisition goes by the name of knowledge acquisition bottleneck which is coined by [6]. [7] noted that this was because knowledge acquisition involves communications between people with completely different backgrounds, human experts and knowledge engineers, who must formulate the concepts, relations and control mechanisms needed for the expert system.

The difficulties of knowledge acquisition can appear during transferring the knowledge from human expert into the computer or machine and structuring the knowledge [8]. The reasons conduct to that difficulties are:

- Experts may lack time or knowledge,
- Testing and refining knowledge is complicated,
- Poorly defined method for knowledge elicitation
- The knowledge maybe incomplete,
- Difficult to recognized specific knowledge when mixed with irrelevant data.

In the connection to expert system, the difficulties of knowledge acquisition system influence the development process of expert system. [9] attempted through surveys to demonstrate why the vast majority of expert systems fail. Some of the reasons noted by him and others include:

- The lack of user participation in design [10].
- The lack of structure and organization of knowledge acquisition [11].
- Communication problems between the knowledge engineer and the domain expert [9].
- Failure in identifying the right candidates for knowledge acquisition [12].
- Failure of verification and validation.

Many various techniques for knowledge acquisition do not consider the quality of the knowledge itself, even though there are possible lacks of knowledge that can decrease the knowledge's usability or the performance of the inference machine. There are some reasons are considered as causations for these lacks:

- Expert may lack in know-how technique
- Expert is unable to verbalize the knowledge
- Expert may provide irrelevant, incomplete, incorrect, inconsistent and redundant knowledge.

This paper describes the concept of the Ternary Grid technique in optimizing the expert system's knowledge base and the development of its algorithms. Ternary Grid technique is a new technique for knowledge elicitation/acquisition [1]. The Ternary Grid knowledge acquisition and model are convenient for improving the knowledge performance [2] [3]. The goal of this technique is to guarantee a good quality of the acquired knowledge and to reduce or avoid the error possibility of knowledge that influence the whole performance of an expert system The Ternary Grid is a model of rule-based knowledge in a grid format where every field represents the relation between a rule and a fact. The fields of the grid can only contain ternary value i.e. “0”, “1” or “2”. The rule-based knowledge is represented in the IF-THEN format.

The idea of this work is inspired and can be traced back to knowledge acquisition systems using grid- or matrix-based technique, like the Repertory Grid Analysis [13], Repertory Grid [14], the Formal Concept Analysis (FCA) [15], Multiple Classification Ripple Down Rules (MCRDR) [16], Knowledge Acquisition Tool based on Personal Construct Psychology [17], WebGrid [18], Troika [19].

The expert system as our vehicle for applying this developed knowledge acquisition system has been CongaXpert [4]. It is a web-based expert system that is used for consultation system in academic area in the University of Duisburg-Essen, Germany

2. TERNARY GRID STRUCTURE

The type of knowledge used for this acquisition technique is the production rule. The term production rule is derived from the production system as it was developed by [20]. A production system is a model of cognitive processing, consisting of a collection of rules (called *production rules*, or just *productions*).

The organization of production rule can be easily represented in a Ternary Grid that has the structure in Figure 1. Ternary Grid is also considered as a matrix.

	$F1$	$F2$	...	Fj
$R1$	a_{11}	a_{12}		a_{1j}
...				
Ri	a_{i1}	a_{i2}		a_{ij}

Figure 1. Ternary Grid as

Ri: Rule i (i is the number of rule)
Fj: Fact j or logical term (j is the number of fact)

$$i = \{1,2,3,\dots,I\}$$
$$j = \{1,2,3,\dots,J\}$$
$$J > I + 1$$

The Value of every grid box is 0, 1 or 2
0 = unused, is represented by empty grid box.
1 = Fact Fm belongs to the condition part of rule Rn (LHS= Left Hand Side).
2 = Fact Fm is part of the conclusion part of Rn (RHS = Right-Hand Side).

$$a_{ij} = \{0,1,2\}$$

3. OPTIMIZING CONCEPT

In designing expert systems, the process of eliciting information has been termed knowledge acquisition. According to [21], knowledge acquisition, also known as knowledge elicitation, involves extracting problem-solving expertise from knowledge sources, which are usually domain experts. [22] defines knowledge acquisition as the process of extracting, structuring and organizing knowledge from several sources, usually human domain experts, so it can be used in a program. [22] noted that knowledge acquisition involves the elicitation of data from the expert, interpretation of the data to deduce the underlying knowledge and creation of a model of the expert's knowledge in terms of the most appropriate knowledge representation.

The concept of developed knowledge acquisition system should help the expert or knowledge engineer to maintain the perspective and focus of attentions, which are needed to complete a thorough and consistent knowledge base or expert system application. The approach of acquisition process involves following phases:

- designing knowledge (top-down) and
- implementing the designed knowledge into knowledge base (bottom-up)
- optimizing knowledge

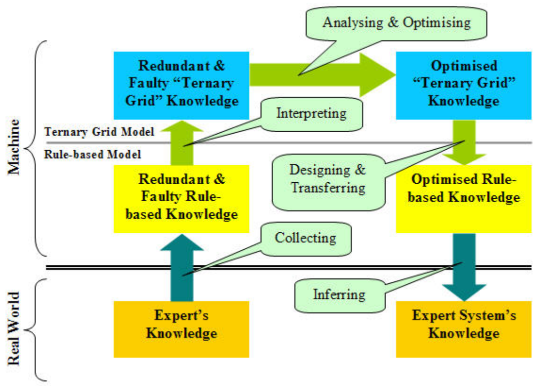

Figure 2. Expert system optimization concept

In the designing phase the expert defines the tasks knowledge. In the implementation phase the expert creates the designed knowledge by using developed knowledge acquisition tools named KASTerGrid (Knowledge Acquisition System using Ternary Grid). The final phase of acquisition process is optimization phase that deals with knowledge optimization. The mentioned knowledge optimization concept can be shown in Figure 2.

Collecting expert’s knowledge; this step requires extracting knowledge from the expert. This extraction is mainly done through conducting interviews with the experts. Interpreting deals with reviewing collected information, picking out relevant information and storing information in Ternary Grid. Analyzing and optimizing: the concept describes how the knowledge is organized and formed into optimal content and structure in the form of Ternary Grid. Designing and transferring knowledge provide support for further problem-solving strategies. An appropriate knowledge structure in the form of Rule-based knowledge is designed and the contents of knowledge in previous structure are transferred into new structure. Furthermore the inference engine of expert system processes this Rule-based knowledge and provides expert system's knowledge to the user.

To explain the process of knowledge optimization, some knowledge (as example) is collected from the expert. It is shown in Figure 3.

No.	Requirement to Student	Result
1	GPA >= 2,75 AND language test passed	Allowed to do selection test
2	Allowed to do selection test	Pre-Selection passed
3	Pre-Selection passed AND Selection test passed	Get admission to study
4	TOEFL >= 550 (paper base) AND Valid Duration <= 2 years	Language test passed
5	TOEFL >= 550 (paper base) AND Valid Duration <= 2 years AND English course duration >= 2 year	language test passed
6	GPA between 2,5 and 2,75 AND Language test passed AND Mathematic score >= B	Language test passed
7	GRE >= 900 (paper base) AND Valid Duration <= 5 years	Language test passed
8	GPA >= 2,75 AND language test passed	Allowed to take preparation courses for study
9	Selection test passed AND Pre-Selection passed	Get admission to study

Figure 3. Collected expert's knowledge

No.	IF	THEN
1	F1 AND F2	F3
2	F3	F4
3	F4 AND F5	F6
4	F7 AND F8	F2
5	F7 AND F8 AND F9	F2
6	F10 AND F2 AND F11	F2
7	F12 AND F13	F2
8	F1 AND F2	F14
9	F4 AND F5	F6

Figure 4. Expert's knowledge in simplified notation

Knowledge engineer reviews collected information and identification of key pieces of knowledge. This yields 14 factual knowledge or facts. The collected expert's knowledge is converted to simplified rule notation. It is shown in Figure 4.

The Knowledge engineer interprets those rules as Ternary Grid knowledge as it is shown in Figure 5. All facts that are elements of a condition part are represented by the value "1" whereas all elements of a conclusion part are represented by the value "2". If an element is part of a condition part as well as of a conclusion part, the value is summed up and yields the value "3". The Value "0" which is represented as an empty box means that there is no relation between the rule Rn and the fact Fm.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
R1	1	1	2											
R2			1	2										
R3				1	1	2								
R4		2					1	1						
R5		2					1	1	1					
R6		3								1	1			
R7		2										1	1	
R8	1	1												2
R9				1	1	2								

Figure 5. Filled Ternary Grid

The Knowledge engineer analyses the organization of knowledge and forms it into an optimal structure. The optimization process deals with the following works:

- Elimination of redundancy due to repeating rules, rule with unnecessary condition and repeating rules.
- Investigation of error possibility due to inconsistent rule and closed rule chain

This paper shows only one case concerning the elimination of redundancy in the form of repeating rules.

4. DEVELOPING ALGORITHM

Repeating rule is a rule that is identical with another existing rule. Figure 6 shows a repeating rule. Using Ternary Grid, a repeating rule can easily be recognized by evaluating the rows that has the same value.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	F13	F14
R1	1	1	2											
R2			1	2										
R3				1	1	2								
R4		2					1	1						
R5		2					1	1	1					
R6														
R7		2										1	1	
R8	1	1												2
R9				1	1	2								

Figure 6. Repeating rule

The following mathematical equations explain how the repeating rule can be recognized:

- Find row in column j, where value 2 appears more than once.

$$Bj = \left\{ b \mid b \in Fj2, |Fj2| \geq 2 \right\} \quad (1)$$

- Find pairs of rows for comparison, which has the same number of logic term in condition part.

$$Cj = \left\{ (p,q) \mid p \in Bj, q \in Bj, p < q, |Bj| > 0, |Rp1| = |Rq1| \right\} \quad (2)$$

- Remove duplication of row pairs

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$$C = \bigcup_{j \in N} Cj \tag{3}$$

- Find pairs of rows, which have the same condition part.

$$D = \left\{ (p,q) \,\middle|\, (p,q) \in C, Rp1 = Rq1 \right\} \tag{4}$$

One of every pair in D can now be eliminated or removed.

To apply the mathematical equation above into software program, the following algorithm has been developed:

For each number in column, starting with the first and ending with the last column.

1. *For each number in row, starting with the first row and ending with the second last row.*
   - 1.1. *Look at the grid value; Find value 2; Let R1 be the row number; Let X1 be number of value 1.*
   - 1.2. *For each number in row, starting with the second row and ending with the last row.*
     - 1.2.1. *Look at the next grid value; Find the value 2; Let R2 be the row number; Let X2 be number of value 1.*
     - 1.2.2. *Compare X1 with X2.*
     - 1.2.3. *If X1 = X2, then compare every value 1 in R1 with every value 1 in R2.*
     - 1.2.4. *If (R1 is identical with R2), then compare every value 2 in R1 with every value 2 in R2. Let Y be number of found value. Let Y1 be number of value 2 in R1; Let Y2 be number of value 2 in R2.*
     - 1.2.5. *If (Y = Y1) and (Y2 > Y), then remove R1.*
     - 1.2.6. *Else If (Y = Y1) and (Y = Y2), then remove R2.*
     - 1.2.7. *Else If (Y = Y2) and (Y1 > Y), then remove R2*

5. EXPERIMENTAL RESULT

The purpose of the experiments, which have been carried out in this research work, is to examine the consistency between the concept and implementation that is discussed in chapter 4. The result of experiments will confirm the ability of the knowledge acquisition system whether the system is able to deliver reliable performance of knowledge or not.

For these experiments we have selected some example rules that can control the conditions, which are used to examine the validity of our hypothesis. We have also developed a tool to implement the whole concept. This tool is named KASTerGrid (Knowledge Acquisition System using Ternary Grid Technique).

Elimination of Repeating Rules

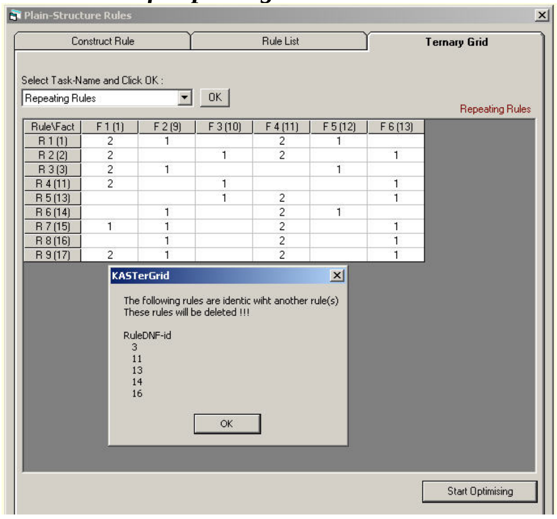

Figure 7. Elimination of repeating rules

The experiment deals with the investigation and elimination of repeating rules. The result of this experiment confirms whether the system can remove repeating rules or not. For this testing, the some rules that contain repeating rules are given in the form of Ternary Grid. It is shown in Figure 7.

Figure 7 shows that the system can remove rules, which are identical with other rules. The numbers that are shows in the figure (3, 11, 13, 14, 16) are the number of rule identity number (rule-id). These numbers represent the row R3, R4, R5, R6 and R8.

6. CONCLUSION

The representation of knowledge in Ternary Grid can be viewed as mathematical object in the form of matrix or sets and enables handling and processing knowledge using mathematical approach.

The results of experiments confirm the capability of the concept and algorithms. They enable not only the optimization of logical terms within a rule but also optimization of logical relations between rules. Due to the role of rules in expert systems, this optimization involves the optimization of expert system knowledge base.

According to existing knowledge acquisition techniques, the developed algorithms for solving knowledge optimization problem in Ternary Grid have potentiality to be novel algorithms and to give a new contribution in developing expert systems.

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