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Human Expert Knowledge Acquisition Using Ternary Grid

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Abstrak

Pada kebanyakan Sistim Basis Pengetahuan (Sistim Pakar) yang berbasis aturan, pembuatan aturan (Rule) dapat dilakukan dengan cepat tanpa harus memikirkan spesifikasi aturan dan bagaimana aturan tersebut terhubung satu sama lainnya. Seringkali seorang expert mereferensikan pengetahuannya kepada aturan atau fakta yang sama sekali belum dibuat. Pekerjaan tersebut tampaknya mudah dan sederhana. Permasalah akan timbul apabila jumlah aturan menjadi banyak. Beberapa masalah dapat timbul dalam bentuk aturan yang tidak konsisten, aturan yang tidak pernah bisa diraih, aturan redundan, aturan melingkar dan lain-lain. Dalam rangka menyelesaikan masalah tersebut dan mendapatkan kinerja yang dimaksud, maka dikembangkanlah sebuah sistem akuisisi pengetahuan berbasis aturan menggunakan Ternary Grid. Sistem ini akan mengakuisisi pengetahuan pakar manusia dan mengolahnya dengan grid atau matrik. Ternary Grid merepresentasikan sebuah pengetahuan berbasis aturan dalam bentuk grid atau matrik.

Kata kunci: *Sistem pakar, pengakuisisian pengetahuan dan aplikasi grid*

Abstract

In most rule-based expert system, building of rules can easily be done. Knowledge engineer or expert does not have to do any work specifying rules and how they are linked to each other. Sometime the knowledge engineer or expert 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 rotating chain of rules. In order to solve that problem and to achieve that mentioned performance, a rule-based knowledge acquisition system using Ternary Grid is developed. This system acquires knowledge from human expert using grid or matrix system. Ternary Grid represents a model of rule-based knowledge in a grid or matrix format.

Keywords: *Expert system, knowledge acquisition and grid application*

1. Introduction

1.1. Problem Situation

The term "knowledge" has been the motto of most Artificial Intelligence researchers since the 1970s. Philosopher, writer, book have attempted to answer the question *"what is knowledge?"* 0 suggest clarifying this that knowledge is *not* synonymous with information. Rather, knowledge is information that has been interpreted, categorized, applied and revised.0 reported that knowledge can be exemplified by concept, constraint, and heuristic method for using probabilistic data, and principles that governs domain-specific operations. 0 contends that domain knowledge consists of descriptions, relationships, and procedures. More specifically, knowledge consists of symbolic description of definitions, symbolic description of relationships, and procedures to manipulate both type of descriptions.

Machines can not think. Machine can deal only with zeros and ones. Only natural things such as human experts can posses

intelligence and understand the world view. We must understand what human experts know so that we can emulate some aspect of their performance on a machine. The machine does not need an entire world view, life experience, or even all expert specific knowledge. It performs a given task, within constraints, for a given purpose. Nor does the machine need to carry out the task in exactly the same way experts do as long as it simulates a degree of accuracy agreed by those concerned.

Knowledge acquisition is a task in Artificial Intelligence (AI) concerned with eliciting and representing knowledge of human experts. Knowledge Acquisition is the transfer and transformation of potential problem solving expertise from some knowledge source to a program. Knowledge acquisition is phases of expert systems development that progress virtually together 0. These are basic for the development of an integrated rule base of the expert system to be built. Many professionals on this field have exposed a common view of that knowledge acquisition is an extremely hard task to accomplish.

The acquisition of knowledge is a major and critical phase in the development of expert systems and is still the most difficult and error-prone task that knowledge engineer does while building a knowledge-based system or an expert system. 0 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. One of the most fundamental and still unsolved problems in knowledge acquisition goes by the name of knowledge acquisition bottleneck which is coined by 0 and 0.

The term *"knowledge acquisition bottleneck"* constricts the building of an expert system like an ordinary bottleneck constricts fluid flow into a bottle. It's a hard work (long and difficult) for an expert to explain (all) his knowledge and reasoning used to solve problems in a specific domain, and then code all this knowledge into facts and rules. Several techniques were developed in order to achieve this task, but no one can really explain all the knowledge used by the expert to solve a problem. Human reasoning is a complex task and we need to take into consideration that all knowledge - even though related to a very small problem - can't be obtained and/or may not be available from the expert, due to common sense, particular cases, implicit context relations, etc.

The problem of knowledge acquisition and knowledge representation are vital to the integrity of the rule base for the expert system to be constructed. Knowledge Acquisition can be extremely frustrated as well as time consuming. It has been stated by many Knowledge Engineers as the bottleneck of expert systems development. Because this phase is intimately related to domain experts, it involves all the problems of dealing with people. How does one best elicit the facts and rules within the human expert's knowledge base? The conclusion is that this process is mainly an art rather than a science 0.

The need to overcome the knowledge acquisition bottleneck is also recognized beyond the knowledge acquisition community 0. For example DARPA's funding the Rapid Knowledge Formation (RFK) initiative seeks to address precisely this issues. The central objective of this Program is to enable experts to enter and modify knowledge directly and easily, without the need for specialized training in knowledge representation, acquisition, or manipulation. The resulting knowledge bases will be available to provide specific answers to questions and could be applied in many different problem-solving situations.

This paper describes some of the advantages than can be gained by rule-based knowledge acquisition with Ternary Grid elicitation technique 0. The term "Ternary Grid" comes from the combination of words "ternary" and "grid" that represent the model of rule-based knowledge structure in grid format 0. The grid has two axes. Vertical Axis represents the rule and

horizontal axis represents the fact. The value of the grid can only contain ternary value i.e. "0", "1" or "2". Value "1" represents the condition part of the rule. Value "2" represents the conclusion part of the rule. Value "0" means, neither condition nor conclusion part of the rule is represented. Every appeared value maps the relation between the fact and the rule. The rule-based knowledge is represented in the IF-THEN format 0.

1.2. Related Works

The idea of this work is inspired and can be traced back to knowledge acquisition systems using grid- or matrix-based technique, like Repertory Grid Analysis 0 , Repertory Grid 0, Formal Concept Analysis (FCA), it is a mathematically based method of finding, ordering and displaying formal concepts assification Ripple Down Rules (MCRDR) 0, Knowledge Acquisition Tool based on Personal Construct Psychology 0, Epistemic Matrix-based Technique 0 and Troika 0.

The experience of knowledge acquisition systems above suggested that grid or matrix technique and representation are convenient for processing the knowledge. In the past, knowledge engineer believed that rule-based knowledge could be acquired relative easily and applied into expert system immediately. In practice, they often found significant mismatches between the acquired knowledge and the knowledge needed for required purpose. This occurs when the number of knowledge is getting higher. The tracking of the rule becomes more complicated. Sometime some situations can miss and not covered by existing rules or conflict with another situation. The developed Ternary Grid techniques should be able to overcome from these problems. Furthermore the problem solving or reasoning method can be developed and implemented using this Ternary Grid.

The Repertory Grid is a simple knowledge elicitation technique devised by clinical psychologists 0. After identifying a small set of *elements* (objects, entities), the user is asked to define some *constructs* (attributes, slots), which characterise those elements. Construct values can be given for each element on a limited scale between two range end-points (the left and right *poles*).

Said that The Formal Concept Analysis (FCA) project was born around when a research group in Darmstadt Germany begun to systematically develop a frame work for lattice theory applications. It was first presented to the mathematical public in a programmatic lecture given at the 1981 Banff conference on Ordered Sets. Since then, several hundred articles have been published including a textbook on the mathematical foundations. The Darmstadt group alone has participated in more than a hundred application cooperation projects Former members of that team have founded a small firm and now make their living from such applications 0.

Furthermore 0 explain that the sophisticated name of "Formal Concept Analysis" needs to be explained The method is mainly used for the analysis of data, i.e. for investigating and processing explicitly given information Such data will be structured into units which are formal abstractions of concepts of human thought allowing meaningful and comprehensible interpretation. 0 uses the prefix formal to emphasize that these formal concepts are mathematical entities and must not be identified with concepts of the mind. The same prefix indicates that the basic data format that of a formal context is merely a formalization that encodes only a small portion of what is usually referred to as a "context".

In the Linear Algebra a Matrix is a composition of numerical values (but also other objects such as operators) in tabular form. One speaks of the columns and lines of the matrix, and calls also vectors (i.e. line vectors and column vectors). One calls the objects, which are arranged in the matrix, components or elements of the matrix. The Designation "Matrix" is introduced by an English Mathematician names James Joseph Sylvester in 1850.

Sylvester did important work on matrix theory. In 1851 he discovered the

Discriminant of a cubic equation and first used the name "Discriminant" for such expressions of quadratic equations and those of higher order. He used matrix theory to study higher dimensional geometry. He also contributed to the creation of the theory of elementary divisors of lambda matrices.

Matrix is proved to be very useful in solving scientific problems. The specialty of the Matrix is the connection to linear illustrations. Each linear illustration can be assigned a Matrix and each Matrix corresponds to a linear illustration. One calls this connection also as Homeomorphism. Homeomorphism is an illustration between two structures; by which the parts of a structure is clearly illustrated on the same sense parts of the other structure.

Between the quantity of the linear Matrix and the quantity of the linear illustrations exists a Bijection. A bijective function is a function that illustrates different elements of its definition range on different elements of the range of values (injective) and arises for each additional element of the range of values as image (surjective). A bijective function has therefore always a completely defined inverse function.

Matrix-based techniques involve the construction of grids indicating such things as problems encountered against possible solutions. Important types include the use of frames for representing the properties of concepts and the repertory grid technique used to elicit, rate, analyze and categorize the properties of concepts 0.

These techniques involve the construction and filling-in of a 2-dimensional matrix (grid, table). Useful examples are:

- Concepts v Properties (attributes and values)
- Problems v Solutions
- Hypotheses v Diagnostic techniques
- Tasks v Resources

The elements within the matrix can contain:

- Symbols (ticks, crosses, question marks)
- Colors
- Numbers
- Text

2. Related Theory

The research area of the Artificial Intelligence deals with computer engineering for solving problems that requires obviously human's intelligence for its accomplishment. Artificial Intelligence is a technique of the data processing which deals with the process of logical thinking, learning and perception.

Artificial intelligence (AI) is a broad field, and means different things to different people. It is concerned with getting computers to do tasks that require human intelligence. However, having said that, there are many tasks which we might reasonably think require intelligence - such as complex arithmetic - which computers can do very easily. Conversely, there are many tasks that people do without even thinking - such as recognizing a face - which are extremely complex to automate. AI is concerned with these difficult tasks, which seem to require complex and sophisticated reasoning processes and knowledge 0.

Expert system is a part of Artificial Intelligence and contains set of programs that manipulate encoded knowledge to solve problems in a specialized domain that normally requires human expertise. An expert system's knowledge is obtained from expert sources and coded in a form suitable for the system to use in its inference or reasoning processes. The expert knowledge must be obtained from specialist or other sources of expertise, such as texts, journal, articles, and database. This type of knowledge usually requires much training and experience in some specialized field such as medicine, geology, system configuration, or engineering design. Once a sufficient body of expert knowledge has been acquired, it must be encoded in some form, loaded into a knowledge base, then tested, and refined continually throughout the life of the system.
There is no official definition for the term of expert system but there are some

descriptions for it created by people working in the field of expert system. "*Expert Systems are computer programs that are derived from a branch of computer science research called Artificial Intelligence (AI). AI's scientific goal is to understand intelligence by building computer programs that exhibit intelligent behaviour. It is concerned with the concepts and methods of symbolic inference, or reasoning, by a computer, and how the knowledge used to make those inferences will be represented inside the machine* 0".

Stated that "*Expert System is a system that employs human knowledge captured in a computer to solve problems that ordinarily require human expertise. Well designed systems imitate the reasoning processes experts use to solve specific problems.*" [17]

The term expert systems are reserved for programs whose knowledge base contains the knowledge used by human experts, in contrast to knowledge gathered from textbooks or non-experts. More often than not, the two terms, expert systems and KBS, are used synonymously. Taken together, they represent the most widespread type of AI application 0.

3. Method and Design

Key to the success of the design and development of the expert system is the choice of the correct or suitable technique for knowledge acquisition. Much research is available discussing the various techniques 0. Several knowledge acquisition techniques include structured and unstructured interviews. 0 list includes observation of the expert in action, unstructured elicitation which corresponds to unstructured interviews.

The process of capturing knowledge is defined as the collection, organization, evaluation, and incorporation of knowledge within a working expert system 0. In designing expert systems, the process of eliciting information has been termed knowledge acquisition. According to 0, knowledge acquisition, also known as knowledge elicitation, involves extracting problem-solving expertise from knowledge sources, which are usually domain experts. 0 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. 0 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. This knowledge acquisition process involves one or more knowledge engineers interacting with one or more domain experts, each of which brings a certain set of attributes to this interaction with the goal of developing a shared representation or model of the expert's problem solving processes 0. 0 noted that knowledge acquisition process consists of the process of identifying, obtaining, and organizing the knowledge that is to be incorporated into an expert system and knowledge elicitation.

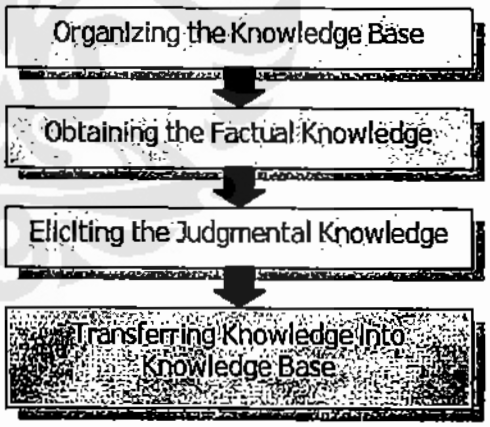

Figure 1.
Knowledge Acquisition Method

Refer to the statements above and consider the character of Ternary Grid elicitation technique I have defined the methodology for knowledge acquisition system that is developed here into:

- Organizing the knowledge base
- Obtaining the factual knowledge
- Eliciting the judgmental knowledge

- Transferring the knowledge into knowledge base

Knowledge base organization deals with the structure organization or representation of knowledge that is stored in knowledge base after acquisition process and used for expert system.

Obtaining the knowledge is the step to get information in the form of factual knowledge from the expert. It has an important role in knowledge acquisition process. In this work, obtain the knowledge concerns with defining and collecting the factual knowledge from the expert, processing and transforming the knowledge into logical entity for supporting knowledge elicitation process using Ternary Grid.

Knowledge Elicitation is the process of obtaining knowledge from a domain expert that describes how they perform a specific task and/or describes what general knowledge they have about the domain. More specifically, KE refers to obtaining knowledge from a person in order to transfer it to a computer program 0. The methods of Knowledge Elicitation are mainly ad hoc and non-scientific. Knowledge engineers are computer specialist's people without adequate training in various psychological techniques, thus contributing to the fact why these methods are vague and instated 0.

The last process of knowledge acquisition is to transfer the knowledge into knowledge base after elicitation process. It concerns with the encoding and storing the knowledge into knowledge base. The system should be able to transfer knowledge into Ternary Grid Knowledge Base or other formatted knowledge base by using Knowledge Transformer. The storage organization that is used for the knowledge base is facilitated by a database.

The concept of knowledge acquisition system that is implemented in KasTerGrid 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:

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

The following diagram explains the mentioned approach.

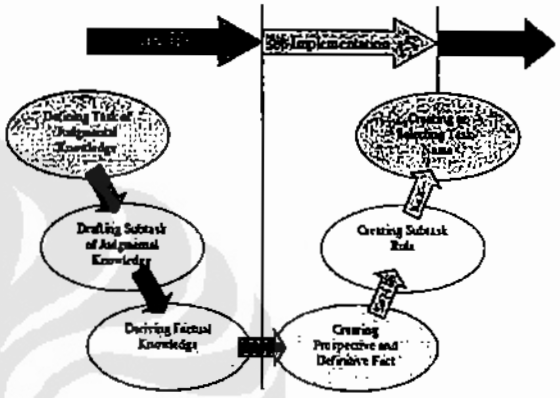

Figure 1.
Acquisition Process

The knowledge optimization stages are illustrated in Figure 3. 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.

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 0. A production system is a model of cognitive processing, consisting of a collection of rules (called *production rules*, or just *productions*).

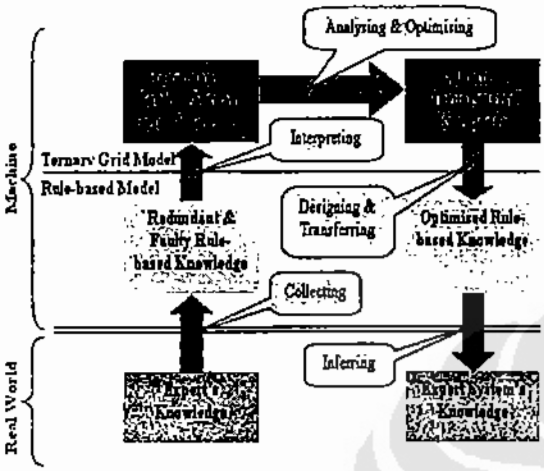

Figure 3.
Optimization Stages

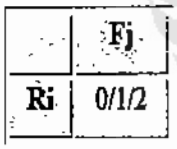

Figure 4.
Ternary Grid Basic Structure

The organisation of production rule can be easily represented in a Ternary Grid that has the following structure in
Figure 4.
Ri: Rule i (i is the number of rule)
Fj: Fact j or logical term (j is the number of fact)

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

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).

Ternary Grid can be considered as matrix. It is shown in the
Figure 5.

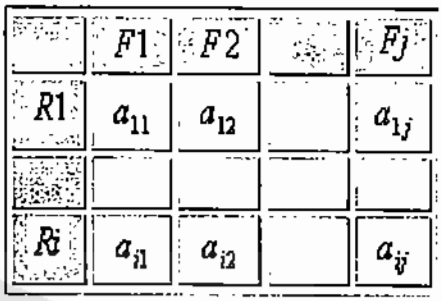

Figure 5.
Ternary Grid as Matrix $a_{ij} = \{0,1,2\}$

Value 0 is represented by empty matrix cell. The following value sets are needed for knowledge optimisation process:

- The set of condition parts in row i is determined as follows:

$$Ri1 = \{ j \mid a_{ij} = 1 \} \quad (1)$$

- The set of conclusion parts in row i is determined as follows:

$$Ri2 = \{ j \mid a_{ij} = 2 \} \quad (2)$$

- The set of condition parts in column j is determined as follows:

$$Fj1 = \{ i \mid a_{ij} = 1 \} \quad (3)$$

- The set of conclusion parts in column j is determined as follows:

$$Fj2 = \{ i \mid a_{ij} = 2 \}$$

4. Results and Discussion

To explain the process of knowledge optimisation, some knowledge (as example) is collected from the expert. It is shown in Figure 6.

Knowledge engineer reviews of collected information and identification of key pieces of knowledge. This yields 14 factual knowledge or facts as shown in Figure 7. One can see that there is not duplicate fact.

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 6.
Collected Expert's Knowledge

Verbal Expression	Fact
GPA >= 2,75	F1
Language test passed	F2
Allowed to do selection test	F3
Pre-Selection passed	F4
Selection test passed	F5
Get admission to study	F6
TOEFL >= 550 (paper base)	F7
Valid Duration <= 2 years	F8
English course duration >= 2 year	F9
GPA between 2,5 and 2,75	F10
Mathematic score >= B	F11
GRE >= 900 (paper base) AND	F12
Valid Duration <= 5 years	F13
Allowed to take preparation courses for study	F14

Figure 7.
Set of Factual Knowledge or Fact

The collected expert's knowledge from Figure 6 is converted to simplified rule notation. It is shown in Figure 8.

The Knowledge engineer interprets those rules as Ternary Grid knowledge as it is shown in Figure 8. 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.

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 8.
Expert's Knowledge in Simplified Notation

	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		1								1	1			
R7		2										1	1	
R8	1	1												2
R9				1	1	2								

Figure 8.
Filled Ternary Grid

The Knowledge engineer analyses the organisation of knowledge and forms it into an optimal structure. The optimisation 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.

Algorithm for Eliminating Repeating Rules

Repeating rule is a rule that is identical with another existing rule. Figure 9 shows a repeating rule.

Using Ternary Grid, a repeating rule can easily be recognised by evaluating the rows that has the same value.

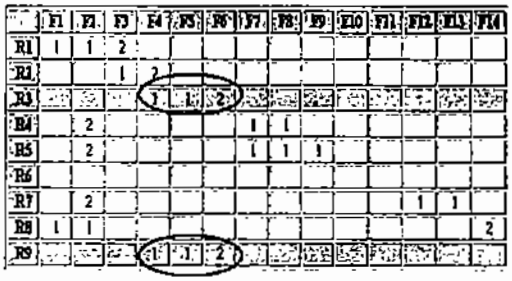

Figure 9.
Repeating Rule

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

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

$$Bj = \left\{ b \,\middle|\, b \in Fj2, |Fj2| \geq 2 \right\} \quad (4)$$

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

$$Cj = \left\{ (p,q) \,\middle|\, p \in Bj, q \in Bj, p < q, |Bj| > 0, |Rp1| = |Rq1| \right\} \quad (5)$$

- Remove duplication of row pairs

$$C = \bigcup_{j \in N} Cj \quad (6)$$

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

$$D = \left\{ (p,q) \,\middle|\, (p,q) \in C, Rp1 = Rq1 \right\} \quad (7)$$

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

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 10.

Figure 10 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.

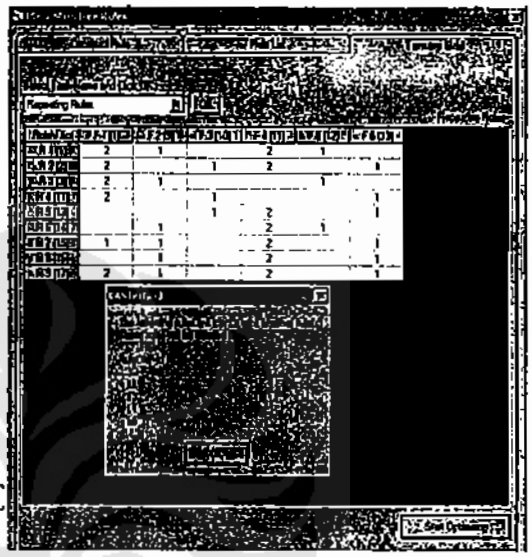

Figure 10.
Elimination of Repeating Rules

5. Contribution

This section lists those ideas developed in this research which are believed to contribute to a general understanding of how to apply practically knowledge engineering, which deals with knowledge acquisition system from human experts. The primary idea of using Ternary Grid for knowledge acquisition system is novel, while other ideas also results in the performance improvement of existing ideas or else new applications of old ideas.

The thesis makes three primary ideas that can be considered as contributions to field of knowledge engineering. First, a novel way for acquiring knowledge from human expert is presented. The acquisition approach is decomposed into set of tasks that provide solution to problems encountered during acquisition process. Dividing factual knowledge into prospective

and definitive facts avoids factual knowledge errors. Method for avoiding factual knowledge duplication optimises the content of knowledge. Elicitation method, which is followed by knowledge optimisation and validation, is the core idea for this approach. It improves the performance of knowledge concerning quality of information and reduces error possibility. The role of developed algorithms is keys to the success of concept implementation. Structured acquisition process guides the expert in creating knowledge step by step.

A second primary contribution of the work, a software application for Knowledge Acquisition System using Ternary Grid (KasTerGrid) has been developed. The user interface for obtaining factual knowledge is designed to give view of knowledge structure to the expert. Syntax validation system, which is applied in rule editor, controls the accuracy of input streams for creating judgmental knowledge. DNF-converter provides required knowledge format for Ternary Grid. Integration of knowledge-base and database provides persistent knowledge. User interface for database connection provides flexible option for choosing type of connection.

A third primary contribution of the work, Ternary Grid presents new approach to knowledge representation. It represents a structure in which knowledge can be stored in a way that allows the system to understand the relationships among pieces of knowledge and to manipulate those relationships.

6. Conclusion

The Ternary Grid technique and representation are convenient for processing the knowledge. They may be directly viewed as task domain and production rule structure or as intermediate stage of optimisation. This technique can optimize not only logical terms within a rule but also logical relations between rules. The grid has elements as *problem-solving domains* which can be derived into sub domains or group of rules, rows as *rules*, columns as *facts* and values as *IF-THEN syntax*.

The Ternary Grid elicitation works in a model domain using concept matrix and logical operation. The organisation and logical content of expert knowledge in Ternary Grid can be easily inspected and analysed. Completion and recognition of patterns which consists of "0 or empty", "1", "2"values in the grid are facilitated by the structure and relative compactness of the matrix representation.

Ternary Grid is position independent, which means that any composition of some factual knowledge as input stream in judgmental knowledge will always be ordered in a specific way by the grid column and it can be considered as mathematical or statistical combinations.

Representation in the Ternary Grid facilitates optimising and testing for conditions of ambiguity, redundancy, completeness 0 and correctness. It will contribute in achieving the performance of the knowledge due to the quality of information and the reduction of error possibility. Implication of that achieved performance is reduction of large body of knowledge and reduction of accessing time of inference engine.

Ternary Grid knowledge acquisition system will encourage the expert to make clear the distinctions he uses in applying his expertise. This system will help him also to structure his knowledge and identify and formalise his concept.

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