Teaching Repertory Grid Concepts for Knowledge Acquisition in Expert Systems: An Interactive Approach

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Abstract

This paper details the theoretical foundations of a system for teaching repertory grid concepts and the practical approach for its implementation. This will involve a discussion of the development of the production program for KAGES (Knowledge Acquisition for Geographic Expert Systems) and the enhancements necessary to make it an effective teaching tool. Initial student reaction to the method will also be presented.

The traditional approach to knowledge acquisition for expert systems has been via interview. However deeper knowledge can be elicited using repertory grid techniques which get domain experts to rank objects against concepts. The technique based on Kelly's Personal Construct Theory has been well proven by Boose et. al (1987). The current study grew out of the development of a repertory grid program, developed for the KAGES toolkit, which will consist of several knowledge acquisition tools for use in the development of spatial expert systems. By expanding the system to show intermediate workings and grids it was found that the system was a good method of explaining repertory grid techniques and the associated hierarchical clustering which is very difficult to demonstrate using traditional techniques.

The system initially interacts with the student over a chosen domain (which does not have to be geographic) to elicit a series of objects or classifications to create a grid. The domain can be either of the student's or the facilitator's choice. The student is then stepped through the various manipulations of the grid. These grids are then subject to hierarchical cluster analysis which the student is also stepped through until a hierarchy chart showing clustering is produced.

Keywords

repertory grids, knowledge acquisition, personal construct theory

1. Introduction

Repertory grids are used as knowledge acquisition tools in the development of expert systems. They can be either drawn by hand or elicited using a computer program. KAGES (Knowledge Acquisition for Geographic Expert Systems) is a knowledge engineering toolkit which is currently under development to acquire knowledge for use in spatial expert systems, especially SPARTEX (Williams *et al.*, 1994). One of the tools which has been developed is based on repertory grids. During its development a series of debugging lines were included to help correct some problems in the code. These lines displayed the grids as they were being developed and analyzed giving a step by step view during execution.

Teaching repertory grids by the traditional ‘chalk and talk’ technique has not been satisfactory with students having difficulty following the development and analysis of examples. This problem has been overcome by using the development version of the KAGES repertory grid tool analyzing a series of easy to understand data sets.

2. Repertory Grid

One of the most popular indirect knowledge acquisition techniques is the repertory grid, which is a knowledge analysis technique derived from Kelly’s (1955) personal construct theory. It is the basis of several computer assisted knowledge acquisition tools including AQUINAS (Boose and Bradshaw, 1987).

2.1 Personal Construct Theory

The theory of personal constructs was proposed in the context of psychotherapy. In terms of clinical psychology a patient’s personal-social behavior is influenced by their internal representation of their feelings towards other individuals who play an important role in their life. These feelings are developed based on past interactions, experiences and perceptions. These internal representations were elicited by Kelly using repertory grid techniques, with treatment being based on the results. (Garg-Janardan and Savendy, 1990).

Perceptions are represented by what Kelly called constructs. Constructs are bi-polar concepts which can be used to discriminate between events. That is, similarity or lack of similarity can be represented. These events are called elements and can be objects, situations or even individuals. With a group of elements, inter-element similarities and differences are perceived. Based on past experiences new or current elements are rated according to the constructs. Constructs themselves are interrelated and may be represented by hierarchies or networks.

This theory has been validated by several researchers including Mair(1966) and it has been concluded that:

- Individuals do represent their environment using constructs;
- Constructs are organized in interrelated structures which change from time to time;
- The repertory grid technique elicits these constructs accurately and reflects the changes in an individuals construct system over time;
- The grid technique elicits the true structure and organization of the individual’s construct system.

2.2 Personal Constructs And Expert Knowledge Acquisition

For use in expert system construction experts are required to identify discrete classifications (elements) which become the column headings of the grid. Groups of three of these are then taken and the expert is asked to identify what differentiates one from the other two elements. These differentiates are known as constructs. All elements are then rated against the construct as either totally belonging or not belonging to groups on a scale of 1 to 5. This construct then becomes the label for a row of the grid. Cluster analysis (such as Johnson Hierarchical Clustering) is used on the two dimensional grid which results. Patterns and associations of the elements and constructs are identified and rules are generated.

```
apples
|   pears
|   |   oranges
|   |   |   bananas
|   |   |   |   melons
|   |   |   |   |   lemons
|   |   |   |   |   |   peaches
|   |   |   |   |   |   |   apricots
|   |   |   |   |   |   |   |   nectarines
|   |   |   |   |   |   |   |   |   plums
3   3   3   2   5   2   2   1   2   2   big
3   3   4   2   5   1   4   3   5   4   sweet
5   1   4   1   1   1   3   3   4   5   red
1   1   1   1   1   1   5   5   5   5   stones
5   5   5   4   1   5   5   5   5   5   tree_fruit
5   5   5   2   1   5   1   1   1   1   keeps_well
5   5   2   5   1   1   5   5   5   5   bruises
1   1   2   3   3   5   3   3   3   2   early
1   1   2   2   4   2   2   2   3   2   matures_quickly
1   1   4   5   4   1   1   1   1   1   tropical
```

Figure 1. Repertory grid comparing various fruit

Figure 1 shows a typical repertory grid which has been built using the repertory grid tool in KAGES. It is a simple demonstration set which shows how an ‘expert’ may discriminate between various fruit (the elements). The criteria used are listed against the rows. A 1 in the grid indicates an element does not exhibit that criteria while at the other end of the scale a 5 represents it is typical of the criteria.

Rules can be generated by concentrating on extremes of rating in grids. For example, with a grid based on a bi-polar rating of 1 to 5 rules would concentrate on concepts which were at the extremes. These can be refined by finding the concepts which are best at differentiating between elements. To this end the between concepts and between elements matrices are of use. Elements which are very dissimilar are easy to distinguish between. Elements which are very similar on the other hand are more difficult. Hence although a computerized system can automatically generate initial rules, there is still the need for a human expert to refine these rules.

The analyzed grids can be looked at and new concepts generated for concepts which are similar. For example with two (or more) concepts at a very high level of similarity as distinguished by cluster analysis, the expert could be asked to name a new concept which incorporates those being grouped. Once this has been done more rules can be generated to better reflect the experts reasoning.

It should be realized that the grids generated are dynamic and it should be possible for a domain expert to add both new concepts and elements. It should also be possible to combine the knowledge of several domain experts held in several grids into a single grid. This can be done by identifying similarities and differences between experts' grids.

3. Traditional Teaching Of Repertory Grid Analysis

Before the development of the KAGES tool, repertory grid techniques were taught using what was effectively a chalk and talk method based on a series of simple examples. This method had several major problems:

- Calculations although simple are numerous and prone to error;
- Numerous reworkings during analysis of grids is tedious and error prone;
- Showing the effect of a minor change in a rating is excessively time consuming;
- Many students have difficulty grasping the concepts; and
- Knowledge to be analyzed tends to be fixed.

4. Computer Assisted Tuition

4.1 Overview

The KAGES system is being developed in Borland Turbo C++ for use on a IBM PC system. Part of the concept and element identification functions of the repertory grid tool were based on the work of Graham and Llewelyn-Jones (1988). The final production system is to be implemented on an IBM Thinkpad system (or similar) for portability during knowledge engineering sessions (Kendall and Senjen, 1993) and as such it is very suitable for use in lecture as well as tutorial situations. The system uses simple text files for storing its data sets which even for large domains tend to be small. Since the teaching version of the repertory grid tool is essentially the same as the production system, it runs on a similar platform.

4.2 Data Sets

The system allows for both the use of pre-written data sets or for students to develop their own in a knowledge domain with which they are familiar. At a basic level, one of the data sets provided is the fruit identification knowledge base shown at figure 1. More complex grids can be provided, tailored to the domain of expertise that is being studied. For example there is one for identifying geographic features in Antarctica.

The system also allows students to build their own grids in a domain of their own choice. To do this the system enters into a dialog with the students eliciting elements then concepts using the triad method. The following is a slightly edited consultation from the program.

system: How many items are there?
student: 4
system :Enter each item's name when you are asked. The order is not important.
Please enter the name of item 1.
student : bananas
system : Please enter the name of item 2.
student: melons

system : Please enter the name of item 3.
student : apples
system: Please enter the name of item 4.
student: pears
system: You will now be prompted to enter a very short (one word is best) description of what discriminates between the items you entered.

bananas   melons   apples
Please enter a quality that two of these items have but the other lacks.
student: tropical

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Following the identification of the concepts students then rank each of the elements against each of the concepts on a scale of 1 (does not exhibit any of the concept) to 5 (exhibits concept completely). The data set so developed can then be immediately analyzed or saved.

4.3 Analysis

The most difficult concept for students is the analysis of grids using Johnson Hierarchical Clustering Techniques (Olson and Rueter, 1987). In an operational system this part of the program is hidden from users with only a final clustering graph being displayed (Waters, 1989). This graph becomes the basis of further discussions with domain experts.

In this system however each stage of the clustering is displayed with students able to watch the recalculation of the grid at each iteration. In Figure 2 the first grid is the result of calculating the relationship between concepts using the data from Figure 1. For example the difference between scores in ‘big’ and ‘sweet’ for all objects is

(big - sweet) = 0 + 0 + 1 + 0 + 0 +1 + 2 + 2 + 3 + 2 = 11.

The values for ‘sweet’ are then flipped (a score of 1 becomes 5, of 2 becomes 4) to allow for concepts with inverted scales. The procedure is repeated:

(big - sweet’) = 0 + 0 + 1 + 2 + 4 + 3 + 0 + 2 + 1 + 0 = 13

The lowest value, 11, is placed in the between concepts grid.

The second grid shows the result after the first iteration where the concepts which are most alike have been combined. In this case a search through the grid finds a 7 at the intersection of the row ‘big’ and column ‘early’. These are combined and the concept ‘early’ set to 0 to denote its combination with ‘big’.

```
big
|   sweet
|   |   red
|   |   |   stones
|   |   |   |   tree_fruit
|   |   |   |   |   keeps_well
|   |   |   |   |   |   bruises
|   |   |   |   |   |   |   early
|   |   |   |   |   |   |   |   matures_quickly
|   |   |   |   |   |   |   |   |   tropical
tropical
0  11  17  17  22  16  24  _7   8  13    big
```

```
big
|   sweet
|   |   red
|   |   |   stones
|   |   |   |   tree_fruit
|   |   |   |   |   keeps_well
|   |   |   |   |   |   bruises
        |   |   |   |   |   |   |   early
|   |   |   |   |   |   |   |   matures_quickly
        |   |   |   |   |   |   |   |   |
0  11  17  17  22  16  24   0   7  12    big
```

0	0	12	16	11	13	15	**14**	15	20	sweet
0	0	0	12	17	15	13	**18**	17	20	red
0	0	0	0	19	**7**	13	**18**	17	12	stones
0	0	0	0	0	18	8	**23**	26	25	tree_fruit
0	0	0	0	0	0	20	**17**	12	19	keeps_well
0	0	0	0	0	0	0	**25**	26	25	bruises
0	0	0	0	0	0	0	0	**7**	**12**	**early**
0	0	0	0	0	0	0	0	0	11	matures_quickly
0	0	0	0	0	0	0	0	0	0	tropical

0	0	12	16	11	13	15	0	15	20	sweet
0	0	0	12	17	15	13	0	17	20	red
0	0	0	0	19	**7**	13	0	17	12	stones
0	0	0	0	0	18	8	0	26	25	tree_fruit
0	0	0	0	0	0	20	0	12	19	keeps_well
0	0	0	0	0	0	0	0	26	25	bruises
0	0	0	0	0	0	0	0	0	0	early
0	0	0	0	0	0	0	0	0	11	matures_quickly
0	0	0	0	0	0	0	0	0	0	tropical

Figure 2. Between concepts grid before and after the combination of concepts ‘big’ and ‘early’ which cluster at a level of 7.

Continuation of the analysis would see ‘matures_quickly’ being clustered with ‘big’ and ‘early’ as it has the same minimum value in the partially clustered grid. The concepts ‘stones’ and ‘keeps_well’ also cluster at a level of 7 but don’t cluster with ‘big’, ‘early’ and ‘matures_quickly’. The process continues until all concepts have been clustered. The final results are displayed in a table like that shown in figure 3 which is then used to display the results graphically (figure 4). The analysis is then repeated for the elements. After the initial analysis of the grid, students can modify their ratings of elements and see the effects on clustering. All grids can be saved at any time.

minimum	12	12	11	11	11	8	7	7	7
row	0	0	0	0	0	4	3	0	0
col	3	2	9	4	1	6	5	8	7

0 = big 1 = sweet 2 = red 3 = stones 4 = tree_fruit
5 = keeps_well 6 = bruises 7 = early 8 = matures_quickly 9 = tropical

Figure 3. The clustering data derived from an analysis of the between concepts grid

5. Results

Before the use of the KAGES development tool, students had considerable difficulty with the repertory grid part of the course ‘Advanced Expert Systems’, generally showing only superficial understanding in assignment tasks and avoiding where possible examination questions on the topic.

A survey of students from past classes where the traditional method of teaching was used indicated that this was one of the most difficult topics in the course. They were then introduced to the computerized model. The general comments have been that if this tool had been available during the course, they would have gained a much better understanding of repertory grid analysis. The tool will be introduced into the course the next time it is offered which will be in 1996.

6. Conclusions

Repertory grid tools used in the development of expert systems are for the most part computerized because of the number of tedious calculations that need to be made. It is not unreasonable to introduce students to such a tool. However most of these tools generate the final result without giving an indication of how the result was arrived at. Hence they are deficient in showing students principles and process concentrating on results. This deficiency can be overcome by using a traditional teaching technique, but this also is not satisfactory being very inflexible. By modifying the electronic tool to show the intermediate steps which are normally hidden and also by providing suitable annotation, students can develop their own grids and follow through the analysis of these grids in a practical session.

7. References

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8. Acknowledgments

The expert system development work reported in this paper has been supported by an Antarctic Science Advisory Committee Research Grant. We would also like to thank Steve Pendlebury (Bureau of Meteorology, Hobart), Bernard Walker and Andy Warner (North Forests, Burnie), Dr Robert Massom and Dr Kelvin Micheal (Antarctic CRC, Hobart) for their assistance in providing glaciological and forestry knowledge which is currently being incorporated into the SPARTEX system.