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A KNOWLEDGE BASED SYSTEM TO SUPPORT REASONING BY ANALOGY FOR BUSINESS SIMULATION GAMING

T.M. Rajkurnar, Texas Tech University
Richard F. Barton, Texas Tech University

ABSTRACT

Reasoning by analogy is a standard technique for alternative generation in decision making. Requirements for support of this type of reasoning in a simulation gaming environment are stated. A knowledge based implementation is described.

INTRODUCTION

In business simulation gaming, players face complex decision tasks. Typically, players are organized into teams, each team managing a firm within an industry that is simulated by a computer model. Teams make decisions, receive reports of consequences, and make subsequent decisions based on those consequences for a number of simulated time periods. A decision for one time period may contain up to 100 or more elements, depending on the simulation model used. Complexity arises from the interactions among the decision elements themselves and from interactions among the decisions of the teams managing firms within the simulated industry, plus any random effects built into the game model. Thus, there are many combinatorial possibilities of decision elements and their consequences, including the unknown decisions being simultaneously made by uncontrolled competing firms. These conditions create a lack of structure in the player's decision environments, although there are usually aspects of business simulation game play that are highly structured as well.

Decision support systems (DSS's), both in real firms and in simulation gaming, have evolved to aid this kind of unstructured decision activity of managers (and business game players). Presumably the use of a DSS enhances the decision making capabilities of managers (and players). The bask service provided by most DSS's enables "what if" experimentation with hypothesized decisions and conditions of uncontrollables and then running out the consequences of the hypotheses. This service Is intended to enhance the rationality of managerial decision making (Barton, 1986; Miths and Callen, 1984; Schellenberger, 1983; Fritzsche et al., 1981).

Recently, there has been criticism of these forms of DSS's in that they do not support the problem diagnosis and understanding phases of decision making because, as stated by Keen (1987), looking at more alternatives is not a causal force for improving decision making. One should not expect managers to make better decisions just because they look at more bad options more quickly.

In answer to these criticisms, knowledge based systems are appearing which can help managers identify problems and assist in many phases of problem solving. The key difference lies in that the system now contains a knowledge of the problem domain and reasoning facilities on that knowledge. In addition, explanation facilities are provided to allow the user of a knowledge base to find out the reasoning processes and to get justifications for conclusions reached by the system (Mylopoloris, 1986), This paper describes an effort to provide knowledge based assistance for decision making player teams in a simulation game.

KNOWLEDGE BASED SYSTEMS

Bonzcek, Holsapple and Whinston (1981) state that a DSS is of little practical value unless the system contains some knowledge about the problem domain. A knowledge based component expands the factual database contained in a DSS to provide representations for qualitative and symbolic processing of data. Typically in knowledge based systems, much like expert systems, the knowledge of the problem domain may be encoded as production rules (rule based systems) or as frame based systems. Powerful tools like Automated Reasoning Tool (ART, 1988) and Knowledge Engineering Environment (Knnz 1984) exist to help develop rules and frames for knowledge based systems in a variety of domains. However these tools are oriented towards building expert systems (Harmon and King, 1985). An expert system (Buchanan and Duda, 1982) is a computer program that provides expert level solutions to important problems and has the following characteristics:

- heuristic: i.e. the system reasons with judgmental knowledge as well as with formal knowledge of established theories.
- transparent: i.e. the system provides explanations of its line of reasoning and answers to queries about its knowledge.
- flexible: i.e. the system integrates new knowledge incrementally into its existing store of knowledge.

Expert systems by their very nature are useful in domains which are narrow and well defined. They are much more difficult to develop for unstructured managerial and strategic decision making.

One difficulty in building an expert system is dependence on an expert being present and on the ability of the knowledge engineer to elicit the correct rules and information that the expert would use in any given situation so that they can be coded into the expert system. Unfortunately, in complex managerial situations and business simulation games it is extremely difficult to derive heuristics due to interaction effects among decision elements. For each decision situation, a multitude of possibilities exists. Hence traditional knowledge based systems such as the typical expert system are not suitable. Dorrough (1986) has argued that analogies are a priori requirements for deep expert system applications. Deep knowledge is time set of principles and general theories which an expert falls back on when laced with unmanageable problems. A special system that makes use of analogies, called a Reasoning by Analogy (RBA) system (Sullivan and Yates, 1988) has been developed For business gaming environments. This RBA system is described in this paper.

ANALOGIES

Analogies help in gaining new perspectives on a problem by freeing thinking from familiar patterns. One type of analogy is direct analogy in which comparisons are made to partially similar objects or processes (Taylor, 1984). Sullivan and Yates (1988) state that the success of well structured idea generation techniques such as brainstorming may really lie in their ability to generate examples to which managers can relate. The example may be from an entirely different industry, or it may bee several years old, but as managers hear about how one firm resolved a problem, they can then explore

whether a similar solution can he applied in their own situation. Thus, analogies help managers in generating alternatives and in making choices among them.

Reasoning by Analogy (RBA) Systems

RBA systems contain structures to aid rather than hinder the process of learning from the experiences of others (Sullivan and Yates, 1988). The objective of these systems is to infuse thinking with a wealth of fresh ideas from the analogies. RBA systems to aid strategic thinking in business should contain the following components (Sullivan and Yates, 1988):

- A good knowledge base encompassing a range of firms and industries and extending beyond the well known success stories.
- Each analogy should contain the underlying environment, competitors' situations, management priorities, experiences and value systems that allowed a certain strategy to succeed.
- The system should also contain a profile of the firm doing the strategic planning, documenting in a comparable way its competitive situation the environment, management values, and other details of the decision situation.
- The system should provide a methodology to quickly assist the managers in their analogical reasoning by being able to identify an appropriate analogical firm. The system should point out both the similarities and dissimilarities between the user manager's firm and the analogical firm.

Since there are no clear cut rules for finding an analogical firm, search strategies for finding analogical Firms in an automated system use some heuristic techniques to emulate planning analysts who would judiciously search the knowledge base. Therefore, artificial intelligence techniques are necessary to guide the search process (Sullivan and Yates, 1988).

RBA in Business Simulation Gaming

The above requirements have been stated for analogical reasoning based on business case histories developed in the style of Porter's (1983) Cases in Competitive Strategies In a business game situation, these requirements can be met in a different fashion. A knowledge base of the game can he built up using time decisions, outcomes, and environments of past plays. Thus the equivalent of Porter's cases can be met in the gaming situation. For example, the details of the analogical firm can be made identical to those of the user firm by using the game computer model itself in the RBA system. The search for the analogical firm in the knowledge base can now be driven based on queries of the user stated in his own terms. For example, in a business simulation game, teams that run out of cash can search for an analogical firm in the knowledge base simply by querying on the condition of cash and find analogical firms from past plays of the game.

This kind of reasoning by analogy is a kind of expert system because it contains the decisions of the experts (the winning teams) in each industry encoded in the knowledge base. However, unlike traditional expert systems, there is no explanation of the reasoning behind the decisions. On the other hand the player user can get a better comprehension of the similar environments because complete details of competing firms in the knowledge base, which are normally not seen in live play, are exposed to the user. The player user because of this additional information, can fully study the interactions among the historical decisions. RBA can also help players in the choice generation phase by letting them see and then try out past decisions of successful teams for the comparable time period in their current gaming DSS.

IMPLEMENTATION

This implementational uses two semesters of data generated by past plays, which provided data for 12 industries and 42 firms. The knowledge base, contains a) the decisions of all firms for all periods of play b) the corresponding output (income statement, balance sheet, and complete industry environment generated by the game model for each decision) c) the environment of each team when the decisions were made (i.e. the previous period output). The RBA system for business simulation gaining described in this paper was built for The IMAGINIT Management Game and its accompanying DSS (Barton, 1981).

The knowledge base is contained in master files for all twelve industries. These are stored on disks and all are uploaded into the computer memory when the user logs onto the system. Current implementation is on the same VAX 11-750 that supports IMAGINIT and its DSS. Terminals are everywhere in the building A separate terminal must be used for the RBA system. Hence, playing teams now use two terminals at once, one for IMAGINIT simulations of the simulation and official decision recording, the other for the RBA system.

Queries on this knowledge base are run from a main menu. Queries are allowed on various aspects of the game such as cash, strikes dividends, bonds, market quote, market share and others, for a total of 42 different "single-condition" queries. Following each query, a list of firms in the knowledge base meeting the query condition is provided. These firms are possible analogical firms for the user. The user can retrieve full details of the analogical firms and their industries for the time period of interest. The system presents information in an identical format Lo the regular simulation game (i.e. the decisions made by the analogical firm and full disclosure of the industry output from these decisions). If the user wants another analogy, he can see complete information for the other firms meeting the conditions of the query, if any. The main menu is shown in Figure 1. A response to a query on cash is shown in Figure 2. When an analogical firm is chosen, the decisions and company and industry reports for the period of inquiry are shown on the screen. If desired, the user can exercise an option to see the same information for the competing firms of the analogical firm.

Not only are individual queries possible, but t queries which combine (ANDing) two or three of these query conditions are possible from the combination queries menu (Figure 3). With combination conditions, the total possible number of query types on which a search for an analogical firm can he made amounts to more than 800 possibilities. It is not necessary that a firm exist in the knowledge base that meets all conditions of a combination query. For example, if the user hooking for a firm that had the conditions of zero cash and took a strike in a particular period, there may he no firms that had both conditions and the system would retrieve no firms, but it would list the firms which met the two conditions individually. This would let the user see Firms that came closest to the analogy sought. A sample query for the combinations of zero probability of strike, six high dividends to date, and increased market quotes is shown in Figure 4.

The system also aids in the marketing strategy formulation ob the user by letting the user retrieve the analogical firms That follow a specified marketing strategy. In IMAGINIT, market strategy is controlled by four decision elements, namely price, research and development, advertising, and material inputs. For each product in the game, the entire realm of 16 marketing strategies can be searched for analogical firms by choosing the marketing strategy query (option 15 on the main menu) amid specifying the product of interest. The marketing strategy menu is shown in Figure 5. A sample query for marketing strategy and the analogical firms it retrieves is shown in Figure 6.

FIGURE 1
MAIN MENU

```
FOR THE INQUIRY PERIOD YEAR 1 QUARTER 0 MONTH 0 , MY INTEREST IS :
1) CASH, EMERGENCY LOANS
2) STRIKES
3) PRODUCTS
4) DIVIDENDS
5) MARKET SHARES
6) BONDS
7) COMMON SHARES
8) INVENTORIES
9) REVENUES
10) EARNINGS, STOCKHOLDERS EQUITIES
11) MARKET QUOTE
12) SEE A PARTICULAR FIRM
13) CHANGE INQUIRY PERIOD
14) COMBINATION QUERIES
15) MARKETING STRATEGY
16) SHIFTS,OVERTIME
Enter Zero - (the number 0) to QUIT the expert system
```

MAIN MENU

FIGURE 2
RETRIEVAL OF FIRMS ON CASH

```
FIRMS WITH ZERO CASH AND HENCE EMERGENCY LOANS
 13  17  23  26  27  41  43  46
 48  58  62  63  66  67  68  69
 71

SIX FIRMS WITH HIGHEST CASH
 38  64  31  72  33  61


CHOOSE FIRM TO VIEW ON SCREEN
CHOOSE ZERO TO RETURN TO MAIN MENU
```

CASH MENU year 1 qtr 0 month 0

FIGURE 3
COMBINATION QUERY SUB MENU

Choose 2 or 3 Combinations - Write Numbers separated by spaces or commas
TO return to Main Menu enter 00 as the first choice

CASH	1) zero	2) 6 high firms	
STRIKE	3)took one	4) zero prob	
FRINGE BENEFITS	5)6 high	6) six low firms	
PRODUCT	7) A2 firms	8) B firms	9) A2 and Bfirms
DIVIDEND	10)inc too low	11) 6 high to date	12) pershare
MKT SHARE	13)inc A	14) inc PROD B	
MKT SHARE	15)6 high A	16) 6 high PROD B	
BONDS	17)issued	18) redeemed	19) 6 high to date
COMMON SHARES	20)sell shares	21) 6 high to date	
DIST. CHAN. INV.	22)stockout A	23) 6 high A	
FIN. GOODS	24)stockout A	25) stockout PROD B	
FIN. GOODS	26)6 high A	27) 6 high PROD B	
MATLS ON HAND	28)stockout A	29) stockout PROD B	
MATLS ON HAND	30)6 high A	31) 6 high PROD B	
INC. REVENUES	32)PROD A	33) PROD B	34)6 high total rev.
6 HIGHEST	35)NET EARNING	36) CHANGE IN EQUITY	
MARKET QUOTES	37)increased	38) six highest	39)six lowest
SHIFTS	40)increased	41)decreased	42)6 high overtime

COMBINATION QUERY MENU year 2 qtr 0 month 0

'The authors would like to thank Mr. Jon Randolph for his assistance in various phases of the implementation of this software.

FIGURE 4
RETRIEVAL OF FIRMS ON A THREE CONDITION COMBINATION

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FIRMS MEETING CONDITIONS
  ZERO PROBABILITY OF A STRIKE
  16  33  38  43  64  66  74
  SIX HIGHEST DIVIDENDS TO DATE
  16  47  58  66  73  74
  INCREASED MARKET QUOTES
  11  12  13  16  17  18  21  22
  23  24  26  27  28  29  31  33
  36  38  43  46  47  48  56  57
  61  62  63  64  66  68  69  71
  72  73  74
AND MEETING ALL CONDITIONS
  16  66  74
CHOOSE FIRM TO VIEW ON SCREEN
You may view a firm even if it does not meet all the conditions
but is on one of the lists
CHOOSE ZERO TO RETURN TO COMBINATION QUERY
MENU
JOINT RESULT MENU                                  year 2 qtr 0 month 0
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FIGURE 5
MARKETING STRATEGY SUB MENU

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Choose strategy of interest - enter Numbers
TO return to STRATEGY Menu enter zero (0)
     MATL INPUT   ADVERTG   PRICE   CUMULATIVE R & D
1)   HIGH         HIGH      HIGH    HIGH
2)   HIGH         HIGH      HIGH    LOW
3)   HIGH         HIGH      LOW     HIGH
4)   HIGH         HIGH      LOW     LOW
5)   HIGH         LOW       HIGH    HIGH
6)   HIGH         LOW       HIGH    LOW
7)   HIGH         LOW       LOW     HIGH
8)   HIGH         LOW       LOW     LOW
9)   LOW          HIGH      HIGH    HIGH
10)  LOW          HIGH      HIGH    LOW
11)  LOW          HIGH      LOW     HIGH
12)  LOW          HIGH      LOW     LOW
13)  LOW          LOW       HIGH    HIGH
14)  LOW          LOW       HIGH    LOW
15)  LOW          LOW       LOW     HIGH
16)  LOW          LOW       LOW     LOW
NOTE HIGH MEANS SIX HIGHEST FIRMS
LOW - SIX LOWEST FIRMS IN THAT CATEGORY
PRODUCT A-1 MARKET STRATEGY CHOICE MENU            year 2 qtr 0 month 0
Please enter number of strategy of interest
```

FIGURE 6
RETRIEVAL OF FIRMS ON MARKETING STRATEGY QUERY

```
FIRMS WITH A STRATEGY OF
  MATERIAL INPUT LOW
  18  33  42  47  48  66
  ADVERTISING HIGH
  31  47  66  67  68  69
  PRICE HIGH
  37  38  46  48  66  67
  CUMULATIVE RESEARCH AND DEVELOPMENT HIGH
  Firm no        42            33            66            27            56            22
  R&D        $ 6000000     $ 6000000     $ 4500000     $ 4000000     $ 4000000     $ 4000000
COMMON firms in the above is
  66
CHOOSE FIRM TO VIEW ON SCREEN
You may choose a firm if it appears in any of the lists
even if it is absent from the common list

CHOOSE ZERO TO RETURN TO STRATEGY CHOICE MENU
PRODUCT A-1 MARKET STRATEGY RESULT MENU            year 2 qtr 0 month 0
```

Once the user runs a query and has seen one analogous firm, the user can choose to see another analogous firm. This is achieved by going back to the screen the user saw prior to his choosing the current firm. In addition the user can make a query for any time period, and if so desired the user can trace the entire play of the historical game for any firm in the knowledge base. This is done by simply resetting the inquiry period repeatedly. The system is entirely menu driven and online help screens are available for all features of the system.

Weaknesses as an RBA System

Not captured in this system is the reasoning behind the teams decisions in the knowledge base, hence there is a lack of explanation for the decisions. This is partially mitigated by giving exposure to variables not seen in the regular game, for example a competitor's entire decision set, leading to a better understanding of the past situations than is possible for the current play.

The system as implemented currently is a stand alone system and does not interact with the DSS of IMAGINIT. Thus, it is not capable of selecting an analogical firm automatically without having the user enter queries. The inability to interact is due to technicalities and may be removed later. To enable the system to automatically generate the analogical firm without any user input requires statistical routines such as clustering. What is conceptually difficult is the generation of a similarity measures i.e., the quantitative scale on which to measure the analogy or similarity between the firms. This is because of the multivariate nature of the decision elements and the environment elements on which similarities may be desired. In addition, extensive statistical routines may need to be run at the time of an automated search, which may increase the response time for the user.

Since the analogical firms are not chosen automatically, and the user is thrown open to a plethora of information and a multitude of query possibilities, there may be an information overload that actually hinders the user. One possible result is that a user may not be able to differentiate between a good decision and a bad decision among those available in the knowledge base and may decide to replicate a Firm which had a bad decision. This is an inherent weakness for which there is currently no solution. however, the system does allow investigating historical firms that succeeded in subsequent game periods simply by providing queries on the success criterion (for IMAGINIT, the simulated stock market quotation) for any future period.

Advantages

The system as presently implemented provides:

- enhanced understanding of the problem environment.
- expanded idea generation.
- direct analogies, by duplicating the existing game output format. This enables the user to relate to the analogy very easily.
- details normally hidden to the user (e.g. competitor's production, overtime, research and development, and complete decisions). This enables users to think about possibil ties and dimensions of the game which they might miss in normal play.
- retrieval of not only success Firms, but also failure firms, that is those firms which came in low on the success criterion of the game. This suggests a basis fnr dialectical inquiry by allowing users to look at both success firms and failure firms. Use of a dialectical inquiry system counteracts the tendency of decision makers to avoid information that may contradict their positions (Taylor, 1984).
- use of multiple experts (many analogical firms), and hence generates many alternative solutions and strategies for consideration.

Comparison With Existing Systems

A historical base of the past decisions has been used in a system described by Sherrell et al. (1986) to enable users to learn marketing strategy Their system however confines itself to the marketing strategy concept, and users have to search using their own DSS (by downloading the information into Lotus) and then search for trends and successful strategies. This does not let them see a direct analogy, neither does it make them aware of all possible strategies in the same environment since the entire search is at the hands of the user. Moreover, for pedagogical reasons of their own, information in the historical knowledge base is left incomplete and must be specifically asked for by the users prior to their first gaming decision. In contrast, the system described here provides the entire information for any analogy at the user's fingertips. In addition, the historical knowledge base is provided for all gaming periods. Efforts by other authors include the development of an expert system to help formulate strategic scenarios (Sackson and Varanelli, 1988; Varanelli et al., 1987). However the emphasis of their system is not on providing assistance to game players but on computerization of a simulated player that would perform as a human expert. The RBA system described in this paper, in conjunction with the gaming DSS, provides an array of capabilities so far not found in other existing systems to assist the user to make better decisions.

RESEARCH QUESTIONS

A number of research questions fall out of this implementation. Currently experiments are being run to measure the use of the RBA system, to find the features of the system which arc most useful to the teams, to find the impact of the system on problem understanding and decision performance. As the experiments are running at the time of writing this paper, there are no results to he reported. However tentative results may be available at the time of the conference.

SUMMARY

A reasoning by analogy (RBA) system for a simulation game has been described. Its potential uses, features and drawbacks have been discussed. In spite of some weaknesses in the system it is hoped advantages far outweigh its disadvantages. The success and popularity of this RBA system will be known when the current experiments are completed.

REFERENCES

ART (1988), Automated Reasoning Tool Reference Manual, Los Angeles: Inference Corporation.

Barton, R.F. (1978), The IMAGINIT Management Came, Lubbock, Tx: Active Learning.

Barton, R.F. (1981), "Simulating the Simulation for Enhanced Player Rationality", ty", Proceedings, Eighth ABSEL Conference, 269-272.

Bonzcek, R.H., C. W. Holsapple, and A. B. Whinston, (1981), Foundations of Decision Support Systems, New York: Academic Press.

Buchanan, B. and R. Duda (1982), "Principles of Rule Based Expert System", in Advances in Computers, Yovits, M. C. ed,, 22, 164-216, New York: Academic Press.

Dorrough, D.C. (1986),"Analogy: A Priori Requirements for Deep Expert System Applications", in Kowalik, J. S., ed., Knowledge Based Problem Solving, 112-165, Englewood Cliffs, NJ: Prentice Hall.

Fritzsche, D. J., G. W. Rodich, and R.V. Cotter (1987), "Integrating Decision Support Systems and Business Games", Proceedings, Fourteenth ABSEL Conference, 63-66.

Harmon, P., and D. King (1985), Expert Systems, New York: John Wiley.

Kunz, J. C., T. P. Kehler, and M. D. Williams (1984), "Applications Development Using a Hybrid AI Development System", AI Magazine, 5. (No. 3).

Keen, P. G. W. (1987), "Decision support systems: The next decade", Decision Support Systems, 3, 253-265.

Muhs, W. F. and R. Callen (1981), "Incorporating Decision Support Systems into Management Simulation Games: A Model and Methodology", Proceedings, Eleventh ABSEL Conference, 261-266.

Mylopoulos, J. (1988), "On Knowledge Base Management Systems", in Brodie, M.L. and Mylopolous J., eds, On Knowledge Base Management Systems, 3-8, New York: Springer-Verlag.

Porter, M. E. (1983), Cases in Competitive Strategy, New York: Free Press.

Schellenberger, R. E. (1983), "MANSYM III Decision Support System Demonstration", Proceedings, Tenth ABSEL Conference, 69.

Sherrell D. L., K. R. Russ, and A. C. Burns (1986), "Enhancing Mainframe Simulations via Microcomputers: Designing Decision Support Systems", Proceedings, Thirteenth ABSEL Conference, 207-211.

Sullivan, C. H. and C. E. Yates (1988), "Reasoning By Analogy: A Tool for Business Planning", Sloan Management Review, Spring, 650-656.

Sackson, M. and A. Varanelli (1988), "The Use of an Expert System to Develop Strategic Scenarios", Proceedings, Fifteenth Annual Conference, 106-112.

Taylor, R. N. (1984), Behavioral Decision Making, Glenview, Il: Scott, Foresman and Company.

Varanelli, A., M. Sackson, D. Cronin, and C. L. Dulberg (1987), "The Use of Expert Systems to Develop Strategic Scenarios: An Experiment Using a Simulated Marketing Environment", Proceedings, Fourteenth ABSEL Conference, 208-213.