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Knowledge acquisition for marketing expert systems based upon marketing problem domain characteristics

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Abstract

Purpose – The purpose of this paper is to present various knowledge-acquisition methods and to show how existing empirical research can be used for mapping between marketing problem domains and knowledge acquisition techniques. The key to doing this is to create a taxonomy of marketing problem domains.

Design/methodology/approach – This paper combines a thorough literature review with prima facie conceptualization to map a generic problem domain, and thereby provide guidance in the choice of knowledge-acquisition technique for developers of expert systems in the field of marketing.

Findings – Recent empirical research in the field of expert systems shows that certain knowledge-acquisition techniques are significantly more efficient than others for the extraction of certain types of knowledge within specific problem domains. It is found that protocol analysis, while fairly commonly used, is relatively inefficient for analytic problems. In the synthetic problem domain, interviewing proves to perform better for simple problems and worse for more difficult-to-model synthetic domains.

Research limitations/implications – The findings suggest that it may be worth exploring some of the non-traditional knowledge-acquisition techniques when working on some types of applications. Further research could offer guidance in choosing the appropriate technique, with the aim of improving the quality, efficiency and development of the resulting system.

Practical implications – Designers of expert systems for marketing should consider interviewing and card sorting as the main means of knowledge acquisition for analytic problem domains, rather than protocol analysis as the main knowledge-acquisition technique for analytic problem domains.

Originality/value – This paper is the first to suggest mapping between knowledge-acquisition research and marketing problem domains.

Keywords Marketing planning, Experts, Knowledge management, Information systems

Paper type Conceptual paper

Introduction

The application of expert systems technology to marketing problems has been steadily increasing within the industry. The most commonly cited problems in developing these systems are the unavailability of both experts and knowledge engineers, and difficulties with the rule-extraction process (Hoffman, 1987). Within the field of artificial intelligence, this has been called the "knowledge acquisition" problem and has been identified as the greatest bottleneck in the expert system development process (Beveran, 2003; Boose, 1989). Simply stated, the problem is how to acquire the specific

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knowledge for a well-defined problem domain from one or more experts and represent it in the appropriate computer format, efficiently.

Given the "paradox of expertise" (Hoffman, 1987), the experts in question have often focused on procedures to the point that they have difficulty in explaining exactly what they know and how they know it. However, new empirical research in the field of expert systems reveals that certain knowledge-acquisition techniques are significantly more efficient than others in different domains and scenarios (Wagner *et al.*, 2003). Adelman (1989), one of the first to design experiments to objectively compare the effectiveness of different techniques, identified five determinants of the quality of the resulting knowledge base:

- domain experts;
- knowledge engineers;
- knowledge representation schemes;
- knowledge elicitation methods; and
- problem domains.

This paper presents the results of mapping between the body of empirical studies and the different problem domains, within the field of marketing, with the aim of guiding developers of marketing expert systems in their choice of knowledge-acquisition techniques.

A generic problem domain taxonomy

Research in the field of knowledge acquisition has focused on several dimensions of the problem as determining factors. One primary determinant of the knowledge-acquisition technique used to develop an expert system is the problem domain. To enhance research in the field, generic problem domain taxonomies have been developed that cut across functional areas. The most commonly used breaks problems into general categories of analysis, synthesis, and those that combine analysis and synthesis (Waterman and Lenat, 1982; Clancy, 1985; Boose, 1989). This is reproduced in Table I.

Table I. Generic problem domain taxonomy

Analysis problems	Classification – categorizing based on observables Debugging – prescribing remedies for malfunctions Diagnosis – inferring system malfunctions from observables Interpretation – inferring situation descriptions from sensor data
Synthesis problems	Configuration – configuring collections of objects under constraints in relatively small search spaces Design – configuration collections of objects under constrains in relatively large search spaces Planning – designing actions Scheduling – planning with strong time and/or space constraints
Problems combining analysis and synthesis	Command and control – ordering and governing overall system control Instruction – diagnosing, debugging, and repairing student behaviour Monitoring – comparing observations to expected outcomes Prediction – inferring likely consequences of given situations Repair – executing plans to administer prescribed remedies

Source: Clancy, (1985)

Proposed mapping of marketing expert system tasks to a generic problem domain
Table II shows how generic task domains can be mapped into specific marketing task domains, with selected examples of marketing expert systems. To do the mapping, a survey of marketing expert system case studies was systematically carried out. It was evident that a wide variety of problems have been addressed with expert systems with varying levels of success. These include such problems as forecasting demand to analyzing advertising campaigns and promotions. The most common applications were in the domains of pricing, media planning and scheduling, with no clear example of a system in the "repair" domain. These tasks were then placed in the generic taxonomy based upon the generic task descriptions.

In addition, the process of mapping specific functions to the more abstract categories of analysis, synthesis, and the combination of the two reveals some

Generic task domains	Marketing task domains	Some examples of marketing expert systems
Analysis		
Classification	Sales prospect qualification, market targeting	Ainscough and Leigh (1996); AMOS Levin *et al.* (1995)
Debugging	Discount evaluation	Ebersold (1991)
Diagnosis	Promotion evaluation system	PROMOTER (Abraham and Lodish, 1987)
Interpretation	Evaluating potential distributors strategic analysis	DISTEVAL (Cavusgil *et al.*, 1995); Business Insights (McNeilly and Gessner, 1993)
Synthesis		
Configuration	Pricing, on-site price quotes; retail space allocation	PRICER (Bernstein, 1989); IBM system (Campanelli, 1994); Resource-Opt (Singh *et al.*, 1988)
Design	Advertising design, on-site product design, process design	ADCAD (Burke *et al.*, 1990); IBM system (Campanelli, 1994); Marra, 1997)
Planning	Strategic planning, market segmentation, planning, media planning	HYMS (Duan and Burrell, 1995); (Eisenhart, 1988); TIMES (Girod *et al.*, 1989); COMSTRAT (Moutinho *et al.*, 1993)
Scheduling	Sales scheduling system, schedule ad spots, order scheduling	(Ainscough *et al.*, 1996); ExpertRule (Heichler, 1993); Logix (Mentzer and Gandhi, 1993); DOLRS (Robins, 1992)
Combination		
Command and control	Market entry, joint partner selection, marketing budget evaluation	Country Consultant (Cavusgil *et al.*, 1992); PARTNER (Cavusgil, 1995); ADVISOR (Lilien and Kijewski, 1987)
Instruction	Consumer product advising	Product Advisor (Bernstein, 1989)
Monitoring	Competitor pricing analysis, monitor advertising campaign	CompShop (Fox, 1992); Gambon, 1995)
Prediction	Forecasting, customer retention, intl negotiations	Hi-Track (Kestelyn, 1991); NEGOTEX (Rangswamy et al., 1989)
Repair	Maintenance	No examples found

Table II. Marketing task domains and expert systems interesting characteristics of marketing problems. Looking at the marketing tasks that fall within the analytic category shows that all of these tasks involve taking a set of data inputs and identifying patterns in them. In contrast, the synthetic problems require that solutions be generated based upon the more general goals of the system and involve the search of a much larger set of potential solutions. Combinations of the two are typically the most ambitious types of expert systems in that they must perform in-depth analysis of large amounts of diverse input data, identify the problems and causes and design a possible solution. The difficulty in this may be the fundamental reason that so few of these types of expert systems have been attempted in the marketing field (Eom, 1996). These categories are meant to serve as a guide to begin thinking about which knowledge acquisition technique might be the most appropriate for the different problem domains within marketing.

Knowledge acquisition techniques

Many different techniques have been developed specifically for knowledge engineers in these different situations, or have been drawn from existing research in fields such as psychology, and several researchers have described these in detail (Boose, 1989; McGraw and Harbison-Briggs, 1989; Tuthill, 1990; Hoffman, 1987; Kim and Courtney, 1988). A brief overview of some of the most commonly used varieties is given here. Of these techniques, it should not be surprising that a survey (Cullen and Bryman, 1988) found that the most commonly used knowledge elicitation technique was the "unstructured interview", in which the knowledge engineer asks general questions and just hopes for the best. However, each technique requires different abilities from the knowledge engineer and the knowledge source, and allows a different set of knowledge representations used.

The knowledge acquisition techniques described here are certainly not without their problems. Not only do they require an enormous amount of time and labour on the part of both the knowledge engineer and the domain expert but they require the knowledge engineer to have an unusually wide variety of interviewing and knowledge representation skills in order for them to be successful. Unfortunately, this has been shown to be a time-consuming and inefficient process (Cooke and McDonald, 1987; Burton *et al.*, 1987; Hoffman, 1987) and can offend the expert as being a "waste of time" (Forsythe and Buchanon, 1989). The difficulties of the unstructured interview become apparent when one views a sample from an actual interview and sees how inefficient it can be.

Recognizing that unstructured interviews are very inefficient, researchers in the area of psychotherapy have been developing structured interviewing techniques for many years (Merton *et al.*, 1956). Basically, they provided structure by coming up with a carefully pre-planned series of questions, and their order. From this work, psychologists developed other interviewing techniques and tools, which were designed to structure the interview process and have been in turn, generally applied to the knowledge elicitation problem. These techniques can often be applied to situations where the expert is being interviewed while actually performing a task or where the task is simulated or reconstructed by case studies or scenarios or simply from the expert's own past experience. Elicitation techniques most commonly discussed in the literature include protocol analysis (Cullen and Bryman, 1988; Hart, 1985; Lewis, 1981; Newell and Simon, 1972), repertory grids (Boose and Bradshaw, 1999; Boose, 1989), prototyping (Grabowski, 1988; Waterman, 1986; Davis et al., 1981), multidimensional scaling (Boose, 1989; Elliot, 1986), cluster analysis (Cooke and McDonald, 1986), discourse analysis (Belkin et al., 1986), card sorting (Burton *et al.*, 1987), and even recall (Hoffman, 1989).

Protocol analysis is one of the most frequently mentioned elicitation techniques in the knowledge acquisition literature. Cullen and Bryman (1988) found it to be second only to unstructured interviews in actual usage. It was suggested (Newell and Simon, 1972) that subjects are asked to "think aloud" while solving a problem or making a decision. These verbalizations are usually taped and then transcribed and the transcription is analyzed using a particular coding scheme. The transcript itself is termed a "protocol" and may be used to refer to a word-for-word record or a summary of the major points. Whatever the form of the protocol, it should enable the knowledge engineer to access index- and code-specific pieces of information easily.

Protocol analysis has become popular as an elicitation tool because it forces the expert to focus on a specific task or problem without interruptions from the knowledge engineer. It forces the expert to consciously consider the problem-solving process and so may be a source of new self-understanding. It is also very flexible in that many different types of tasks (simulations, special cases, etc.) may serve as a basis for the protocol. Having a record encourages the knowledge engineer to identify specific topics and also missing steps in the process. It has been successfully applied to developing expert systems (Hoffman, 1987) and early results of comparative experiments show that it is more efficient than unstructured interviewing (Burton *et al.*, 1987), although the same set of experiments shows clearly that it is less efficient than other non-traditional knowledge acquisition methods such as card-sorting and goal decomposition. Also, on a practical level, protocol analysis requires little equipment or special training for the knowledge engineer.

The main disadvantage of protocol analysis is the very necessity of forcing the expert to express actions in words. It is often the case that experts have concentrated to such an extent on procedures that they are either unable to express their expertise or are completely unaware of it. This phenomenon is more commonly referred to as the paradox of expertise (Hoffman, 1987), and is one of the major motivations for research in the field of knowledge acquisition. Not only may they be unaware of their problem-solving methods, but they may actually verbalize them incorrectly and thus introduce error or bias into the resulting system. Thus, the appropriateness of protocol analysis may depend heavily on the type of task being studied and the personality and ability of the expert to be introspective and verbalize thought processes. Protocols can also be very time-consuming to generate and may result in more data than the knowledge engineer can efficiently handle; especially true of larger knowledge acquisition tasks.

Card or concept sorting techniques are also used to help structure an expert's knowledge. As the names imply, these procedures involve the knowledge engineer in writing the names of previously identified objects, experiences and rules on cards which the expert is asked to sort into groups. The expert describes for the knowledge engineer what each group has in common and the groups can then be organized to form a hierarchy. Some empirical research (Burton *et al.*, 1987) suggests that card sorting, like multidimensional scaling, may be a more efficient elicitation technique than some of the more traditional techniques such as protocol analysis or interviewing.

It has been used with some success to develop applications described in the literature (Cairo, 1998; Chi *et al.*, 1981; Gammack and Young, 1985). It has also been suggested that it is a tool which could be easily implemented on a computer as an automated knowledge acquisition tool (McGraw and Harbison-Briggs, 1989).

Empirical research on knowledge acquisition techniques

Work on the knowledge acquisition problem currently follows along three major interlocking lines. We describe these as technique-oriented, empirical studies, and conceptual research. As has been noted in the literature (Dhaliwal and Benbasat, 1990; Boose, 1989), the primary emphasis to date has been on developing new knowledge acquisition tools and methods. This paper focuses on examining the impact of recent empirical work.

A review of the relavant literature shows that both conceptual and empirical research has lagged behind technique-oriented research. Experiments and case studies have focused on comparing and evaluating knowledge acquisition techniques. However, the empirical work has suffered from a general lack of control precision (Dhaliwal and Benbasat, 1990).

There have been a few recent efforts to test the usability of different knowledge acquisition tools and techniques empirically. The ability of various knowledge elicitation methods were tested (Burton *et al.*, 1987) to elicit knowledge about classifying different rocks, and the relative efficiency of several automated knowledge acquisition tools was compared (Kitto, 1988). Such research is important because it serves to break new ground, but it needs to be conducted in a more systematic and rigorous manner (Holsapple et al., 1991).

Previous researchers have recognized the need for sound empirical research to compare the effectiveness and efficiency of knowledge-acquisition tools and methods. It was concluded (Fellers, 1987) that more research was needed to answer the questions:

- Is there one best elicitation technique for knowledge acquisition?
- If not, what is the best combination of techniques?
- Which techniques are most suitable under which circumstances?
- What skills are required in order to utilize each of these techniques?

One knowledge acquisition researcher (Grabowski, 1988) designed an experiment to test the ability of three different knowledge-acquisition methodologies to elicit different types of heuristics. The three methods tested were scenarios simulated different tasks, and actual familiar tasks. Heuristics were divided into two categories: those that all subjects identified regardless of knowledge acquisition method, and those that only individual subjects identified. These were further broken down into conceptual, operational, and logistical categories. Overall, she found a 30 per cent overlap in those generated by each of the knowledge acquisition methods she tested. Of those that did not overlap, she identified conceptual, logistical, and operational heuristics that were distinct to each method. But given that, the task studied was operational in nature (piloting a boat in a harbour), her results were not surprising.

In an experiment to discover the source of the greatest variation in the knowledge acquisition process, Adelman (1989) identified five determinants of knowledge base quality:

- domain experts;
- knowledge engineers;
- knowledge representation schemes;
- knowledge elicitation methods; and
- problem domains.

The domain experts, elicitation methods and knowledge engineers were varied, in an attempt to see which if any had the greatest effect on the quality of knowledge base. Five of the six knowledge engineers had doctorates and one had studied at high postgraduate level, while all had extensive training in both top-down and bottom-up elicitation techniques. The relative accuracy of each was compared to a "golden mean" rule set derived prior to the elicitation sessions. Although a long line of psychological research has been devoted to describing interviewer effects which are analogous to the potential effects of a knowledge engineer (Hammond, 1948), no significant effects were observed in this set of experiments. Interestingly, the only significant source of variation came from the domain experts themselves.

The best-known experimental research on knowledge-acquisition methods is that of Burton *et al.* (1987). By varying the different knowledge acquisition techniques among different groups of experts, each of whom was tested for cognitive style, they discovered several specific things. Among their findings was that protocol analysis took the most time and elicited less knowledge than the other three techniques they tested (interviewing, card sorting, and goal decomposition). Not surprisingly, they also found that introverts needed longer interview sessions but generated more knowledge than extroverts. Interestingly, the rarely used techniques of goal decomposition and card sorting proved to be as efficient as the more common interviewing technique and more efficient than the commonly used protocol analysis.

This experiment was criticized somewhat for its lack of rigour (Holsapple et al., 1992; Dhaliwal and Benbasat, 1990). One measure of technique efficiency was the time it took to code the transcripts into pseudo-rules while the number of rules or clauses was taken as a measure of acquired knowledge. Coding time does not fully account for temporal differences among methods and there are also serious drawbacks to using the number of coded rules as a measure (Dhaliwal and Benbasat, 1990; Holsapple and Whinston, 1987). The results may also have been confounded by unmeasured differences among the experts and the knowledge engineers.

These various experimental studies are symptomatic of a recognized need empirical investigation of knowledge-acquisition phenomena. The small number of such studies is at least in part, indicative of the difficulty in conducting them. The few pioneer studies are typified by confusing terminology, conflicting operationalizations, and the proliferation of *ad hoc* taxonomies. In addition, results are conflicting and no clear pattern has emerged. There are problems controlling for effects of moderator variables and in operationalizing the measurement of dependent variables. In light of these problems, it was concluded (Dhaliwal and Benbasat, 1990) that empirical work should concentrate on case studies rather than experiments, at least in the near term. A strategy for addressing some of these experimental obstacles has also been proposed (Holsapple et al., 1992).

Table III summarises eight empirical research studies investigating the use of knoweldege-acquisition techniques.

Table III. Summary of empirical knowledge-acquisition research

Studies	KA techniques	Mod. Vars.	PDomain	Dep.Vars	Results
Michalski and Chilausky (1980)	Interviewing Inductive learning	Not considered	Diagnosis	Percentage of correct diagnosis generated	Inductive learning performed better than interviewing
Hart (1985)	ID 3 Induction and interviews	Not considered	Diagnosis	Comparison to know cased	Induction performed much better than interviewing
Messier and Hansen (1987)	Interviews Protocol analysis Expert Walk-throughs	Human vs. reconstructed knowledge sources	Interpretation	KE's opinion of the quality of K acquired	Protocol analysis has limited usefulness for certain types of K
Holsapple and Raj (1994)	Interviews Protocol analysis Goal Decomposition Card-sorting multi-dimensional scaling	Introvert v. Extrovert; cognitive styles	Classification	Time taken for capturing K; time for coding into rules; number of rule clauses; completeness Of rule set	Protocol and takes longer and yields less K; Introverts need longer interview but generate more K than extroverts;
Holsapple and Raj (1994)	Interviewing & Protocol analysis	Domain complexity	Planning	Efficiency and quality of K as measured by number of nodes and arcs and their accuracy.	Interviewing is more efficient and accurate for simple cases but protocol is more efficient for complex cases
Burton *et al.* (1990)	Structured interviews, Protocol analysis, Card sorting, Laddered grids	Expert v. Non-expert; two classification domains	Classification	Efficiency of process	Protocol analysis performed poorly in classification domain; card sorting and grids performed better than interviewing; external validation of experts important
Grabowski (1988)	Scenarios, simulated different tasks, and actual familiar tasks	Not considered	Command and control	Overlap of heuristics	Found 30 percent overlap between heuristics elicited by the three different methods
Adelman (1989)	Top-down vs. bottom-up interviewing	Knowledge engineer, and domain expert	Command and control	Accuracy of elicited rules as compared to "golden mean" set	Found no sig. Variation except for that due to domain expert

Source: Dhaliwal and Benbasat (1990)

Conclusions

From this examination of the different knowledge acquisition techniques used in expert systems development and of the results of recent empirical studies, we can begin to make some more specific conclusions.

First, though the problem domains studied are generally drawn from problems in the classification or command and control type, it would appear that protocol analysis does not perform as well as other less traditional techniques, such as card sorting. The fact that four of the seven studies use tasks from analytic domains suggests that these are the most common type of expert system application domains. Being data-given tasks, the use of inductive techniques seems more likely to perform well than interviewing techniques. Where induction cannot be used, techniques for organizing highly structured interviews, such as card sorting, seem to work better than interviewing. In either case, well structured knowledge-acquisition techniques seem to work best in analytic problem domains and protocol analysis performs poorly in all of the comparative studies.

These results are less supported in the one experiment conducted in what we have described as a synthetic problem domain (Holsapple and Raj, 1994). They found that interviewing performed better than protocol analysis for simple problems whereas the reverse was true for complex problems. This suggests the possibility that, as we move into the more difficult-to-model synthetic domains such as design and planning techniques or protocol analysis may be more appropriate. It would seem that the difficulty in modelling these less structured domains might be one reason there are relatively few comparative studies of knowledge acquisition in the synthetic and combined synthetic/analytic domains. The two studies in the command and control domain do not offer much guidance as to which techniques work best. The fact that Adelman (1989) found no significant effect when he varied the technique may indicate that the choice may not matter as much for problem domains that combine both analytic and synthetic aspects.

Implications for developing marketing expert systems

The application of empirical knowledge-acquisition research to the problem of choosing an appropriate technique for developing an expert system application in the field of marketing suggests several directions.

First, if the task at hand is an analytic problem domain, such as evaluating a promotional campaign or qualifying potential sales prospects, techniques that provide a high degree of structure to the interviewing process seem to work best. Protocol analysis, though fairly commonly used, is relatively inefficient for analytic problems while the most popular technique of using an unstructured interviewing is one of the least efficient and least satisfying from the standpoint of the expert. So it may be worth exploring some of the non-traditional techniques when working on these type applications.

For the more difficult synthetic and combination problem domains the evidence is not as clear. However, the Holsapple and Raj (1994) study seems to indicate that problem complexity may be one determinant of the appropriate technique to choose. If a highly robust expert system for market entry or joint partner selection were to be developed, then we might suppose that protocol analysis would be more efficient than interviewing. The fact that interviewing is more efficient for simple domains may imply that it is best used for initial knowledge-acquisition sessions, when the problem complexity is not yet developed clearly.

For those studies that did consider the effect of moderator variables, it seems clear that no matter what type of problem domain, developers of expert systems in the field of marketing should consider their potential impact. The impact of the cognitive style of the expert, domain complexity, along with other attributes of the domain expert all seem to be important factors in the quality of an expert system regardless of the problem domain. It is clear that some guidance in choosing the appropriate knowledge-acquisition technique can have a significant impact on the quality of the resulting system and the efficiency of its development. It is hoped that further research will clarify some of the issues raised here particularly with respect to the effect of moderator variables and problem domains.

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