Pragmatic considerations for effective knowledge acquisition: The case of business expert systems

Angeliki Poulymenakou, Tony Cornford, Edgar A. Whitley
Information Systems Department
London School of Economics
and Political Science
Houghton Street
London WC2A 2AE
United Kingdom

Abstract
Current knowledge acquisition practices place undue restrictions on the issues placed under consideration when they are applied in an organisational context. This paper reviews a number of such techniques and explores their limitations for many `real world' business problems. Managerial and administrative problem solving, in particular, predicate a less obtrusive and more interpretive methodology of knowledge acquisition. This needs to be established around realistic objectives that are compatible with business strategy and managerial requirements. This paper argues that the future for knowledge acquisition therefore lies in a shift of focus from narrow conceptions of technique, structure and models to a broader understanding of what contributes to the effectiveness of business expert systems.

Keywords: Expert systems, knowledge acquisition, business strategy, organisational analysis, business analysis.

Introduction

In the context of building an expert system, knowledge acquisition is the activity related to the identification, formalisation and representation of knowledge in the system. `Knowledge' in this context is data, retrieved mainly from human experts and refers to their problem solving behaviour in the domain under study. Other data related to problem solving tasks can also be retrieved from other sources (i.e. statistics, manuals, textbooks, seminars, journals etc.). Knowledge acquisition is viewed as a critical activity in the expert system life cycle mainly because of the role that the deliverables of the knowledge acquisition play in the performance of the system.

There are various approaches proposed for knowledge acquisition. Most of them centre around the interaction of a specialised analyst (**knowledge engineer**) with a human expert in the domain of the system. The activity can be complemented and in some occasions substituted by the retrieval of data from other sources of knowledge mentioned above. In the early days of expert systems, knowledge acquisition was basically carried out manually. Currently, there is an increasing number of tools developed to support the process. These tools vary greatly in terms of scope (i.e. domains of application, phases of knowledge acquisition that they support and functionalities). Knowledge acquisition as a part of the expert system development life cycle is commonly seen to fall into three broad stages. Obviously these vary widely according to the nature and size of the project undertaken and different sources use different names for the three stages. Their underlying aims, however, are generally the same.

Stages of knowledge acquisition

The first stage corresponds to the initial orientation of the project. During this stage the `problem' is selected and described. Any preliminary organisation is also performed at this time. This may include identifying suitable experts and ensuring their co-operation, specifying the objectives and scope of the project, and setting up project management activities.

The second stage encompasses the main knowledge acquisition activity; it is during this often iterative stage that the necessary knowledge is obtained. The final stage, knowledge representation, is the most technical. This is sometimes considered to be beyond the scope of knowledge acquisition and instead forms part of the subsequent stages of the expert system life cycle.

The next section reviews the existing approaches for knowledge acquisition emphasising their conceptions of technique, structure and models. The third section examines the effectiveness of these techniques when they are applied to the development of business expert systems. The fourth section then suggests an alternative approach to knowledge acquisition which is more amenable to the real world of business problem solving. The final section summarises the main points presented in this paper.

Current approaches to knowledge acquisition

Many techniques are used within knowledge acquisition, partly as a result of the observation that knowledge requires many different representational forms, that experts do not all respond in the same way to a given stimulus and that the nature of the task of knowledge acquisition changes as the activity progresses. The main distinction, however, is between interview based techniques and observational techniques. Interviews may be open-ended and unstructured at the start of the knowledge acquisition process and then become highly structured as in-depth investigation into particular aspects of the domain are examined. Documented interviewing techniques include case and example based elicitation, multi-dimensional scaling techniques such as the repertory grid, and teach back interviews where the knowledge engineer attempts to teach the subject back to the expert to show that it has been properly understood. Observation techniques are often followed by an analysis of the protocols obtained from them and may need to be complemented by interview based techniques to clarify points that arise in the protocols.

Comparative studies have tried mapping elicitation techniques against a variety of concepts; some have linked them to types of knowledge, others to task taxonomies or problems solving methods (Gammack and Young 1984, LaFrance 1989). Other studies have attempted to compare the efficiency of various techniques within a given domain (Burton *et al.* 1987). Selecting the most appropriate elicitation techniques is still a task lacking rigorous guidance but it is currently the focus of considerable research interest within Europe. The European Community is partially funding a number of ESPRIT 2 projects such as KEW (Shadbolt *et al.* 1990) and VITAL (Motta *et al.* 1990) which are looking into this area.

Although different approaches make use of these common techniques, the theory underlying their use varies quite considerably and influences the manner in which they are used. This section reviews the three most common approaches to knowledge acquisition. Each approach is briefly summarised and its key features, underlying assumptions and advantages are discussed.

Modelling

The basic assumption underlying modelling approaches to knowledge acquisition, which are also known as `top down' approaches, is that an expert's problem solving behaviour can be `described by' or fits a model. By taking this approach the common advantages of top down design, namely modularity, testability and the ability to defer design/implementation decisions are achieved. The models used are usually **problem-solving-task specific** but are **application independent**. The variations to this approach converge on the use of problem solving tasks as representational primitives. By using these primitives, such as selection, diagnosis and design, a formal description of the expert's behaviour can be obtained in a manner that relates directly to the problem at hand. The generic nature of these problem solving tasks means that the models can be easily transformed into code. Modelling approaches include KADS (Breuker *et al.* 1989, Shadbolt *et al.* 1990), generic tasks (Chandrasekaran 1986, 1989), conceptual modelling (Musen 1988, 1989) and problem-solving methods (Markus 1988, McDermott 1988). These methods are reviewed in more detail by Karbach *et al.* 1990).

Modelling techniques guide the knowledge elicitation process and structure the knowledge that is obtained and the three stages of knowledge acquisition can be seen to correspond to an initial identification of suitable tasks performed by the expert, task structuring to produce a model of the problem solving in the domain and detailed knowledge elicitation to populate the selected model.

The modelling approach has provided knowledge engineering with rigorous tools for investigating the content, structure and control of human problem solving in a variety of problem domains. One of the most significant advantages of this approach is the `sense of purpose' it brings to the activity of knowledge acquisition. The objectives of each iteration in the process are clearly defined and guidance and control measures can be included easily. Poulymenakou (1990) reports that the structured approach to knowledge acquisition, as embodied by the modelling approach, has appealing features for managers of expert systems projects since it makes the process visible and controllable, and the generic character of modelling allows the transfer of the results of knowledge acquisition across applications. On the other hand, the approach requires a clear consensus on the problem to be tackled, and rapidly constrains the knowledge engineering architecture.

Prototyping

This second approach to knowledge acquisition can be seen as `bottom up' and corresponds closely to the prototyping approach to building expert systems in general which has been predominant in the field of expert systems since the first systems were developed. Prototyping is usually initiated with only a vague or imprecise understanding of the required knowledge. Prototyping then takes this coarse definition of knowledge and processes and through successive iterations of an operational schema develops a more detailed version. At any time a paper representation or actual system may be given to the expert to evaluate and improve. This cycle is repeated until a sufficient level of performance is achieved. This, in general, also results in increasingly fine knowledge structures.

The prototyping approach to knowledge acquisition is a popular, fast, and often effective way to deliver results. Its success depends, however, on the close collaboration and commitment of an acknowledged domain expert who is willing not only to help in the project but who is also sufficiently aware of the content and boundaries of typical problem solving activities. Monitoring and controlling this approach is often extremely difficult. Prototyping lacks predefined control points and the activity often proceeds on a trial and error basis. It must be noted, however, that pre-prototypes have proved to be a very effective vehicles for communicating and exchanging ideas and information with interested parties during knowledge acquisition activities (Poulymenakou 1990).

Computer aided approaches

In common with many areas of information systems, considerable interest has been shown in using computers to assist with the task of knowledge acquisition. At the most basic level computer aided approaches are simply automated tools that assist in the knowledge acquisition approaches outlined above. The type and degree of support varies considerably but the computer aided approaches all seem to help with the direct elicitation of knowledge as well as the administration and management of the approaches (Boose 1989). As such, these tools face similar difficulties to the approaches they aim to support, but can be a significant aid to the management of a knowledge acquisition project.

Some knowledge acquisition tools have been developed that seem to go beyond assisting a human directed knowledge engineering process and dispense with the human knowledge engineer entirely. Boose (1989) describes tools that implement machine learning methods such as analogy and apprenticeship. They may involve rule induction from large sets of examples, learning from explanations or analyzing text or natural language. The machine learning approach at present requires a very restricted problem domain with considerable assistance from the knowledge engineer in providing `suitable' inputs to the programs. None the less, significant research is under way in many centres.

Characteristics of business decision making

The knowledge acquisition approaches described above operate under a basic assumption that there exists a defined, specified and described **problem** and that the appropriate domain expert can find **the solution** to it. This emphasises two factors; firstly a uniform perception of the problem in the situation and secondly that an individual is capable of solving it alone.

In business environments, however, things are not so simple. Identifying the problem is often one of the most important and time consuming tasks as problems rarely come `neatly packaged' (Keen and Scott-Morton 1978). Different individuals, different groups and different business units may perceive the same situation in widely varying ways. For example, what is considered as a building varies between the accounting function valuing net assets, the staffing office trying to locate staff and the internal mail system delivering letters (Kent 1978). The possible acquisition of a new building will have different implications, and hence cause different problems, for each of these groups. Even when some consensus exists as to the organisational perception of what the problem is, individuals responsible for resolving it may consider different courses of action to achieve `the same end' or evaluate them differently against different criteria.

The context within which these `expert' actions are performed also influence the decisions made. Knowledge about the nature of the business, the structure of the organisation, the conditions that lead to the emergence and recognition of the problem and the repercussions of any decisions taken must be unveiled before any steps are taken.

The extent of contextual considerations means in most cases group decision making is the norm. It is not realistic to expect individuals to conceptualise and analyze a problem situation in its totality. It is even less realistic to expect them to possess sufficient background information to resolve the issue themselves. Group decision making also leads to shared responsibility and increases legitimacy for any resulting actions.

Organisational requirements for business expert systems

The limitations observed with current knowledge acquisition practices that arise from the nature of decision making in business environments are only part of the difficulties facing the development of business expert systems. The organisational requirements placed on business expert systems also influence the course that knowledge acquisition has to follow.

When new business expert systems are commissioned there is often a heightened expectation of impressive improvements in business performance. Being a new technology, expert systems are often exploited as much for their contribution to a company's image as to its accounts. Unlike traditional data processing applications, expert systems are not expected to take a back seat role in the organisation. For example, the United Airlines Expert Gate Assignment Display System is the primary tool used by controllers to map airplanes, people and luggage into gates in real time. The system started to help gate allocation in O'Hare Chicago, one of the world's busiest airports, and is now used in other United Airlines operated terminals. The system is also fully integrated with United's real time scheduling and flight arrival systems.

The emergence of systems with operational or strategic / competitive roles, makes managers in industry and commerce expect similar leverage from their business expert systems. Managers often initiate searches for their own `wonderful saviour' which will provide a similar benefit for their own enterprise without considering the business and organisational implications of doing so.

Technical feasibility, although important, is not enough to determine whether managerial expectations will be fulfilled (Poulymenakou 1990). A technical feasibility study will discuss design requirements and approaches to knowledge acquisition that enable the investigation and formalisation of knowledge and tasks linked to problem solving. The objective of knowledge acquisition in this context is to produce a specification of domain knowledge and knowledge processes that can be subsequently `operationalised'. Technical considerations, however, do not deal with questions of how a particular application should be selected and what constitutes proper justification for the need to develop it. Organisational and business feasibility studies are therefore required to complement the technical study so that the picture of the viability of the project is complete. Business feasibility requires that the application addresses a real business need and meets it with a suitable level of performance that adheres to the standards and goals of the business. Knowledge acquisition in this context will need to analyze and discuss managerial activities in order to determine managerial needs and problems. Organisational feasibility deals with the issues of embedding the system into the structure of the organisation establishing how and by whom the system is to be used, who will be responsible for its operation and maintenance and the impact the system is going to have. In this area knowledge acquisition will benefit from looking into users' skills, tasks and needs.

Furthermore, the innovative role of expert systems technology not withstanding, business expert systems need to interact with the existing information systems of an organisation. At the simplest level this involves the sharing of data between knowledge based and data based applications. There are many ways that this can be performed, from intelligent database systems through to loosely coupled expert system applications requesting data from a remote database. Knowledge acquisition will therefore need to consider issues related to the existing systems, i.e. data structures, processes, design models and existing interfaces. It will also need to evaluate how these combinations of these systems are used for managerial problem solving.

Operational information systems in an organisation point to the existence of a discipline related to systems development, i.e. methods for systems analysis and design as well as techniques and tools to support them. Many large organisations have their own in house methodologies guiding their developers through the software development life cycle (e.g. Arthur Andersen's Method 1™). Others rely on widely endorsed methods such as the British Government's SSADM™ development methodology. System development support environments, such as EXCELERATOR™, may also play a central role. The existence of such methods and tools should alert knowledge engineers to the fact that a culture related to system development practices probably exists in the organisation. In particular, management will be accustomed to reviewing, monitoring, evaluating and controlling the progress of system development in a particular way. Reporting styles and content, feedback loops and quality assurance may all have been normalised within the organisation. Similarly system users will be familiar with a certain type of collaboration with systems analysts, for example, through user requirements specification activities. In each of these cases, current knowledge acquisition practices are likely to prove alien and obtrusive. The introduction of idiosyncratic and esoteric knowledge acquisition practices will not be warmly received within and outside the project team. As Gary Curtis of AMS Inc. says: "today, any of us who cannot describe what we do and how, should be shown the door".

Pragmatic considerations for effective knowledge acquisition

From the discussion of existing approaches to knowledge acquisition it becomes apparent that knowledge acquisition needs to work more in the `front end' (Woodward 1990) where the main issue to be addressed is what is relevant to the situation under investigation and why. An investigation that, in contrast to the approaches described above, starts `from the beginning' of the expert system life cycle, incorporating business and organisational considerations in addition to technical ones. The arguments presented in this paper predicate a less obtrusive approach to knowledge acquisition which expands and shifts current practices in the field towards a more interpretive activity. In doing so it will address the basis of business problems and will allow the development of successful, operational business expert systems.

Whilst it is true that current knowledge acquisition practices have come a long way towards maintaining consistency between what has been retrieved and what is implemented in a system the objective too often remains to obtain and encode knowledge from a mixture of text books and a single human expert. Moreover in an organisational environment neither what constitutes a problem nor what needs to be designed can be defined a priori. Knowledge acquisition needs to focus more on the stage of problem identification. In the analysis of the characteristics of business decision making various **stakeholders** participate in and are influenced by the problem situation. In this context the identity of the experts may need to be **negotiated** together with the managers, users and developers who will be affected by the project. There is not only one expert and there is not one type of user (Diaper 1989). The combination of these different agents will affect the objectives formulated for knowledge acquisition and hence the processes followed.

Knowledge acquisition needs to consider business issues before and in parallel with technical ones. It therefore needs to be business driven before it becomes problem or data driven. These considerations suggest that knowledge acquisition can benefit from and should work in collaboration with existing business analysis techniques already applied by the organisation. At the start of the knowledge acquisition activity it should look outside the project area to collect knowledge on the nature of the organisation, its mission, strategies and goals and also the situations under which problems emerge, problems which may be tackled with an expert system or may be better approached by other routes.

A knowledge acquisition activity that is not initially coupled with a specific application can concentrate on the perceptions of current and future business needs expressed by all stakeholders and should employ investigation techniques based on principles that are already familiar to them. The different focus that knowledge acquisition has in this role suggests the use of techniques such as Decision Conferencing (Phillips 1989) and Naturalistic Knowledge Engineering (Hardiman 1989). Since such analysis is initially application independent benefits outside the scope of building an expert system may be realised.

Once an expert systems project has been selected, knowledge acquisition needs to aim beyond producing technically sound and usable systems to systems that are **acceptable** and **sustainable** within a given organisation. This can be done by investigating the group processes people participate in, the goals they set and the perceptions they hold. We need also to know the role that stakeholders have in the organisation, i.e. their tasks and responsibilities. This should be done in a manner that is compatible with existing managerial styles and contexts. A useful method for this approach is Human Factors (Mantei *et al.* 1989) which incorporates the estimation of people's feelings about existing systems, product acceptance analysis through feedback on demonstrations, users' task analysis, user interface tests for acceptability and product surveys. Group decision making techniques such as consensus decision making (for conflict resolution), brainstorming, nominal voting and the Delphi method (Liou *et al.* 1990) can also prove useful in this role.

As knowledge acquisition shifts from techniques for `acquiring knowledge' to techniques for `investigating problems' the context in which decisions are meaningful will need to be established. Constructive Interaction (Gammack and Anderson 1990) is a technique that understands the subjective nature of decisions, views them as a result of a consensus between participating agents and focuses on the creation of a localised common ground of understanding.

One further benefit may be to use knowledge acquisition as a means of bringing together expert systems and information systems development activities. It is only when we see the seamless synthesis of information systems and expert systems, co-operating throughout their development and use, that true maturity in the area of business expert systems will be achieved.

Coda

In a sense, all knowledge acquisition methods ultimately aim to provide the open-ended, flexible and organisationally sustainable approaches advocated in this paper, yet none does. The questions that therefore need to be asked are: Why this is so? Is the task simply too difficult? Are there other issues that have yet to be uncovered? Is our agenda proposed here just too large? Poulymenakou (1990) has interviewed over thirty people, acting as different stakeholders in a number of organisations that make use of expert systems technology and supply expert systems products and services. The initial findings from this research show that the issues addressed in this paper are the real concerns of business expert system developers, managers and users.

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