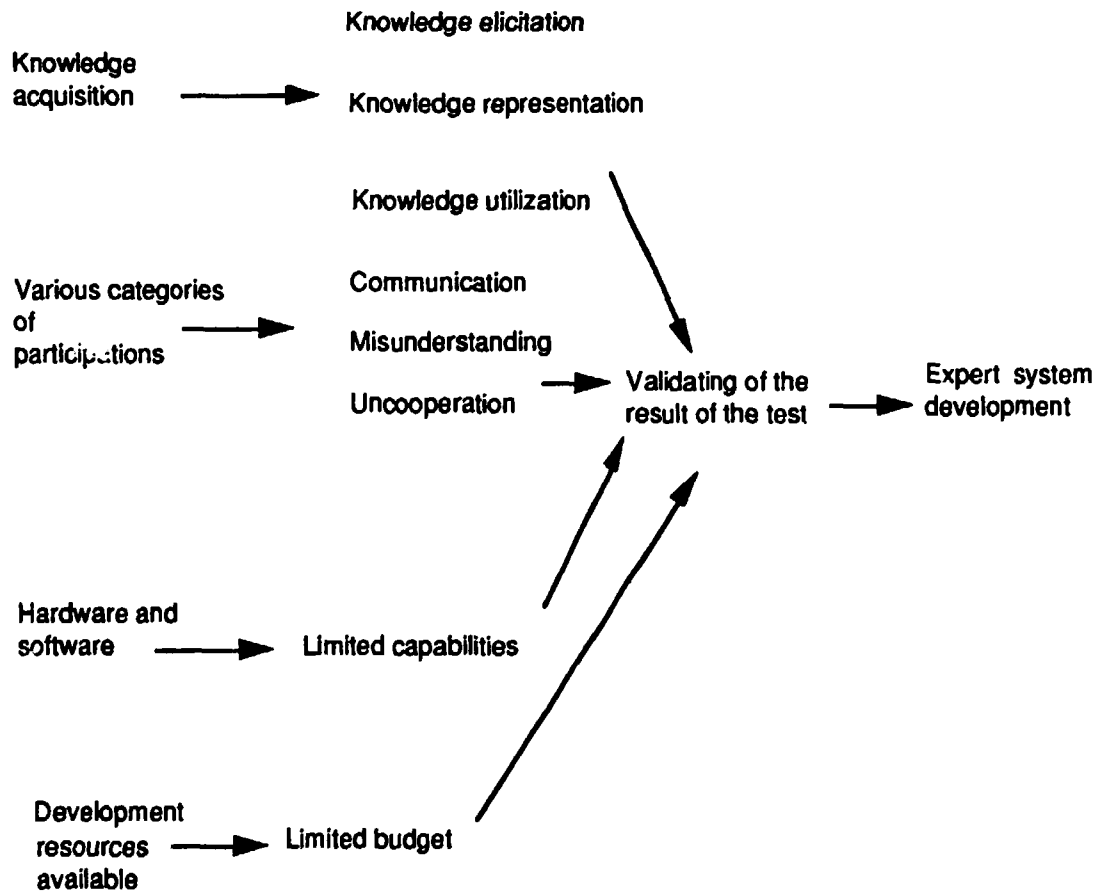LU SADG - SAIP -- 93 -1007.

EXPERT SYSTEMS DEVELOPMENT: SOME PROBLEMS, MOTIVES AND ISSUES IN AN EXPLORATORY STUDY

by

MEHDI SAGHEB-TEHRANI

Knowledge elicitation

Knowledge acquisition ⟶ Knowledge representation

Knowledge utilization

Various categories of participations ⟶ Communication

Misunderstanding

Uncooperation ⟶ Validating of the result of the test ⟶ Expert system development

Hardware and software ⟶ Limited capabilities

Development resources available ⟶ Limited budget

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Title and subtitle

Expert Systems Development: Some Problems
Motives And Issues In An Exploratory Study

Abstract

Even though expert systems (ES) have been in use since the early eighties, there is a remarkable lack of a strong theoretical base for handling expert systems development problems. There is a requirement in the ES field for theories or explanatory models to formulate propositions, to conduct research and interpret findings in a coherent way.

This work presents an exploratory investigation designed to identify some problems, motives and issues associated with developing expert systems. Twenty-three Swedish organizations which studied the potential of expert systems were included in the investigation. Totally, twenty-five expert systems were developed by various organizations which participated in the study.

The study attempts to provide evidence that either supports or refutes the anecdotes, gossips and speculations currently being spread through the academic journals dealing with the expert systems development in organizations. This study provides evidence that knowledge acquisition is indeed the "bottleneck" of expert systems development. It also points out that most expert systems are still in the prototype stage, and that current expert systems are mostly used for aiding the decision making of less skilled domain personnel and to a lesser extent for advice to experts. The rationale behind these uses seems to be the search by organizations for better decision making in the hope of improving competitiveness.

A conceptual model of expert systems development is introduced based upon theoretical studies and the findings of this study from which some hypotheses are drawn. The main objective of the model is to contribute to a larger theoretical framework. Another aim is to create a broader theoretical framework for expert systems development in order to implement such systems more successfully. The results of the study confirm that the linkages of various concepts involved in the expert systems development process are very important for the design of a successful expert system project.

Key words

Expert systems (ES), Expert systems development (ESD) Knowledge acquisitions (KA), Knowledge elicitation (KE), Knowledge engineer(KEN), Knowledge engineering (KENG)

EXPERT SYSTEMS DEVELOPMENT: SOME PROBLEMS, MOTIVES AND ISSUES IN AN EXPLORATORY STUDY

by

MEHDI SAGHEB-TEHRANI

MSc. in Information & Computer Science

Doctoral Dissertation

Dedication

This work is dedicated to my sons,
Mazdak and Sina, and my wife Hamideh.

Into this universe, and, why not knowing,
Nor whence, like water willy-nilly flowing:
And out of it, as wind along the Waste,
I know not whither, willy-nilly blowing.

Omar Khayam, p.64

Source: Rubaiyyat of Hakim Omar Khayam,
Second-Edition. Published by Amir-Kabir, Tehran.

PRELUDE

The purpose of this thesis is to contribute to the understanding of expert systems development. I propose to look at this aspect in a broader perspective. The study presented here is the result of research on expert systems development that I started in the beginning of 1988. Almost all the contents of the chapters (directly or indirectly) of the study were published in 15 various international conference proceedings and journals. I refer to them in the text. Many difficulties arose in the process of this work (i.e, some people particularly played, the unpleasant role of "devil's advocate"), but I have had the benefit of relying on many people, and they are too many for me to be able to mention them all here by name. My thanks to all the respondents (both in the interview cases and questionnaire investigations) who made the empirical parts of this study possible. As I have promised them to remain anonymous, I can only thank them collectively. My thanks to the staff and some of the researchers of the Information & Computer Sciences (new name "Informatics" from Aug. 1993) department at Lund University, notably, S.Friis, G.Dahlman, G.A.Sigbo, E.G Bulow, H.U Karlen, and O.Lanner.

I am very grateful to Prof. G.B Davis (Minnesota University) for his valuable comments on the proposal of this thesis. My sincere thanks to Prof. R.Gustavsson (At SICS, Stockholm), Dr. E. Astor (Lund University, Dep. of Computer Science), Prof. A.A.V. Stuart (Leiden University, Dep. of Comp.), Prof. C.Lucas (Tehran University, Dep. of Elec. Engineering), and M.Petersson (Telelogic, Malmö) for providing me with useful comments and valuable discussions.

Also, I am very much grateful to my supervisor Prof. Pelle Ehn (Lund University, Dept. of Informatics) he has been an indispensable sources of intellectual support for this work. Without his supports, I could not surely conduct this work. Ehn's dissertation has given me some ideas to digest the Dreyfus & Dreyfus skill acquisition model (from my point of view) which I used here. Furthermore, we had a number of valuable discussions.

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PART I: RESEARCH FRAMEWORK

1. THE PROBLEM

1.1 Introduction

Artificial Intelligence (AI)[1] in computer science has interested many computer specialists in recent years. Expert systems development is one of the branches of AI [Rauch-Hindin 1986, Harmon & King 1985], i.e. expert systems development is the most practical application of AI technology [Liebowitz 1989, Harmon & King 1985, Fehsenfeld 1988, Wiig 1988]. Expert systems (ES) are knowledge based-systems that handle real-world problems requiring expertise, when solved by a human [Feigenbaum & McCordouck 1984, Wielinga et al 1988][2]. Successful applications result in numerous benefits such as: reduced decision-making time, consistency in decision-making, improved service levels and better use of human expert time [Duchessi & O'Keefe 1992, Sagheb-Tehrani 19990a].

The objective of this study is to identify some problems, motives and issues of expert systems development. It is also intended to bridge the gap[3] (see Fig. 2.1) between the existing knowledge of expert systems development and the knowledge of knowledge engineers. Moreover, from the result of my earlier study [Sagheb-Tehrani 1990a] and relevant literature studied , it has become apparent to me that there exists another gap- namely the gap in

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[1] For an introduction to AI please see Chapter 3.

[2] This matter is further discussed in Chapter 3. More, as the empirical part of the study reveals the implementers or users of ES in various organizations had different view about the definition of expert system. Put differently, in the context of the study, ES are systems which were labeled as ES by their implementers or users in various organizations.

[3] More discussion of the gap is presented in Section 2.

conceiving expert systems development. Another aim of this study therefore became an attempt to create a broader theoretical framework for conceiving expert systems development. Thus, parts of this study are devoted to delineating relevant conceptual models which may contribute to a larger theoretical framework.

1.2 To whom do I address this study

The outcome of this work may interest disparate categories of readers and organizations, such as:
-The organizations which developed/are developing expert systems
-The organizations which sell/supply expert systems
-The organizations which educate/train people in this field
- The community of AI researchers
- The people who are interested in this field (Students, teachers)
- The knowledge engineers, experts and users of expert systems.

For the researchers, this work is intended as a piece of research work in its own right, which may open some avenues for further research in the field, and identify a number of open issues on which further research is clearly needed. Furthermore, the researcher may be motivated to expand or modify the models presented in this study.

For the practitioners, this work is intended to indicate the problems, motives and issues of developing expert systems. By doing so, it is hoped that the practitioners will obtain a broader understanding of expert systems development in order to develop such systems more successfully.

For others interested in this field (such as teachers, students and so on), this work provides a broader understanding of expert systems development. Some background knowledge may be assumed, prior to using this study. This broader understanding of expert systems development is felt to be necessary for any graduate students who may wish to practice. The study may provide a rich reference list for further readings in the field.

1.3 The incitements for undertaking this study

Why study expert systems development (ESD) problems, motives and their issues. This question may be answered in many ways as far as I am concerned. My foremost motive was the perceived lack of knowledge regarding problems and issues of the expert systems development. The second motive was to examine what lies behind a company that starts to develop an expert system. Another important motive was the need for a systematic analysis of large-scale expert systems. Thus, this study as a whole is intended to provide at least an indication of the potential value of such systematic analyses. A broader motive of this study was to contribute to the knowledge of relevant theories.

1.4 Perspective

All researchers have a perspective of some kind, conscious or unconscious. The process of research can be influenced by this perspective. A broader purpose of any research should be to contribute to both theory and practice. A research study should thus aim both at developing new theory which guides practices and guide new research and theories [Lawler et al. 1985]. All social scientists approach their subject via explicit or implicit assumptions about the nature of the social world and the way in which it can be investigated [Burrell & Morgan 1979].

The discipline of expert systems development falls within the social sciences. Thus, when looking for a theoretical perspective, from which I may understand the grounds of knowledge (about how I might begin to understand the world and communicate this as knowledge to others) in the work presented here, I have looked to the social sciences as described by Burrell & Morgan [1979]. Below, I endeavour to explain very briefly my perspective for this study.

There are many ways to look upon theories of social sciences. One is to place them according to two dimensions obtaining four paradigms. One dimension focuses between two extremes called the subjectivist and the objectivist. The other dimension focuses on dynamic or static aspects of societies ranging between two extremes called the sociology of radical changes and the sociology of regulation [Burrell & Morgan 1979]. Burrell and Morgan also discuss the relationships between the two dimensions and develop a scheme for the analysis of social theories[4], see the following figure.
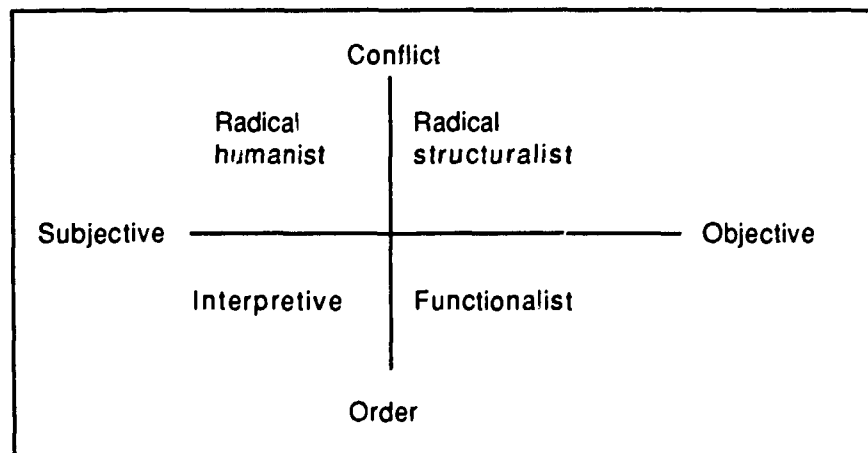
Fig. 1.1: Four paradigms[5] for the analysis of social theories, adapted from [Burrell & Morgan 1979], p. 22.

However, it is difficult to place a specific research into one of the paradigms. Hirshheim and Klein [1989] claim that most IS research may be found mainly in the functionalist sociology paradigm. Considering the first dimension, I belong to the objectivist, i.e, I treat the social world and natural world as being real and external to individuals (myself). To put it

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[4] The above mentioned view by Burrell and Morgan is not without its critics. Numerous writers have criticized this view for being oversimplified [Chua 1986, Hooper & Powell 1985]. There are other views for classifying social science research [Gutting 1980, Reason & Rowan 1985]. But none is as representative of the information system development domain as [Hirschheim & Klein 1989].

[5] For the concept of paradigm, please see [Kuhn 1962].

differently, the "reality" is not the product of my consciousness but my consciousness is the product of the "reality". The research presented here draws upon social system theory in the functionalist sociology defined by Burrell and Morgan [1979]. This paradigm has provided the dominant framework for the study of organizations. It approaches its subject matter from an objectivist perspective. It is characterized by a concern for providing explanations of the status que. The study endeavours to explain the concept of expert systems development by defining various important concepts and their relationships involved in its process. The conceptual model presented in the study is based on the "holistic view" school (social system theory). This view is explained in Chapter 5. In my research approach there exists a mutual relationship between me and my research topic. Thus, the approach requires that my activity should not be accomplished in an isolated situation, i.e. I should be aware of creating a sort of cooperative supporting group which is somehow involved in my research. This cooperative, supporting group comprises various people such as, my supervisors, the organizations who took part in this study, other researchers who were interested in this study and those who assisted me. I am also aware that my research could either interest or irritate various people, because research can never be neutral. Since research always supports or questions social forces, it has effects and side-effects which may interest or irritate people [Reason & Rowan 1985]. In order to recognize this aspect one must depart from the traditional way of thinking and realize that social systems or biological organisms are dependent on their external environment [Katz & kahn 1978].

1.5 Delimitation of this study

This study like any other, has limitations that need to be discussed. Some delimitations have already been introduced. The reason for restriction was to identify the available relevant resources and time within the framework of the study in order to accomplish the study. Furthermore, by limiting the study, I hope to limit various interpretations of the study. Below, an attempt is made to mention the delimitation of this study which may lead to a better conception of this work. The concepts included in the study and items in the questionnaire reflect my views. The literature was thoroughly examined in each area and the questionnaire was criticized by other knowledge engineers and MIS researchers. Naturally, there is no claim here that my views are perfect and absolutely true. Perhaps the following Sufi story can provide readers with a better guidance to the difference between truth and perspective.

Mulla Nasrudin was on trial for his life. He was accused of no less a crime than treason. These charges had been brought by the sages who were ministers to the king charged with advising thɔ king on matters of great importance. Nasrudin was charged with going from village to village inciting the people by saying "the king's wise men do not speak truth. They do not even know what truth is. They are confused." Nasrudin was brought before the king and the court. "How do you plead, guilty or not guilty?"
"I am both guilty and not guilty", replied Nasrudin.
"What, then, is your defense?"
Nasrudin turned and pointed to the nine wise men who were assembled in the court. "Have each Sage write an answer to the following question: What is water?" The king commanded the Sages to do as they were asked. The answers were handed to the king who read to the court what each Sage had written.
The first wrote: "Water is to remove thirst".
The second: "It is the essence of life".
The third: "Rain".
The fourth: "A clear, liquid substance".
The fifth: "A compound of hydrogen and oxygen".

The sixth: "Water was given to us by God to use in cleansing and purifying ourselves before prayer".
The seventh: "It is many different things-rivers, wells, ice, lakes, so it depends".
The eight: "A marvelous mystery that defies definition".
The ninth: "The poor man's wine".
Nasrudin turned to the court and the king, " I am guilty of saying that the wise men are confused. I am not, however, guilty of treason, because, as you see, the wise men are confused. How can they know if I have committed treason if they cannot even decide what water is? If the Sages cannot agree on the truth about water, something which they consume every day, how can one expect that they can know the truth about other things?" The king ordered that Nasrudin be set free. Source, Patton [1980], p.274.

Another limitation is the sample itself. The questionnaires were mailed to 23 organizations. The criterion for selecting a company for inclusion in the study is explained in Section 2.5. The main impetus of this study is a complementary study to my previous work [Sagheb-Tehrani 1990a] to study expert systems development problems and their issues. The characteristics of the study were exploratory which by provision of material and examination of some arguments intended to contribute to the formulation of some hypotheses. This study is concerned with expert systems development and their use[6].

1.6 Importance of the research

A number of Swedish industrial companies have developed expert systems according to my previous study [Sagheb-Tehrani 1990a]. In that study an attempt was made to identify some problems, motives and issues with developing expert systems in some Swedish industrial companies which studied the potentials of

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[6] As Balley et al. [Balley et al. 1977] point out that any information system must achieve both "technical" and "psychological" success. Psychological success refers to the degree to which the end user has confidence in the system, while technical success refers to the actual performance of the system which matches its specifications. One can say, the objective of this study is concerned with the former.

such systems as early as 1984. This study is a complementary of the above mentioned study, in which I identified some problems, motives and issues in a number of administrative Swedish organizations which have studied the potentials of such systems. Thus, by undertaking this research as complementary to my previous study, I hope to contribute to the knowledge of expert systems development in practice, since there exists a lack of knowledge concerning expert systems development and their use.

1.7 Significant prior research

The major preceding research apart from my previous study [Sagheb-Tehrani 1990a], is S. Hägglund's report [Hägglund 1986]. In his report he mentioned the characteristics of expert systems building tools, their suppliers and names of some Swedish companies which developed expert systems in Sweden. In my previous study [Sagheb-Tehrani 1990a], I went further and examined some problems and motives of expert systems development in Sweden, among those companies which were included in the above mentioned report. Furthermore, in that study I presented a number of hypotheses which may contribute to the knowledge of expert systems development. For a brief explanation of the study see [Sagheb-Tehrani 1990a].

1.8 The structure of the study

In Chapters 1 and 2 the motives, perspective, and delimitations of the study , as well as the importance of research, the research questions, the research process and the research method are discussed. In Chapters 3 and 4 some important concepts are discussed and developed. In Chapter 5 some contributions with respect to the matter of system thinking are discussed. In Chapter 6 various models based on the literature study and my previous work are presented. In Chapter 7 the empirical part of my previous study is presented. In Chapter 8 findings of the empirical investigation of this study are presented. In Chapter 9 the findings are analyzed and a summary of the research results is provided. Finally, Chapter 10, (in a postscript) predictions and criticisms of expert systems development are reviewed. Almost,

all the contents of the chapters of this study have been published in 15 various international conference proceedings and journals. I could not include them in the study, because space and cost considerations. I have therefore referred to them in the text in order to support the objective of the study. See Fig. 2.3 in the next section for a better understanding of the research process.

1.9 Summary

In this chapter, the aims of the study and its motives were discussed. Further, the perspective and limitation of the study were explained, and the importance of the research and its prior research were discussed. Finally, the structure of the study was presented. In other words, the chapter represents an overall picture of this study.

2. RESEARCH APPROACH AND METHODOLOGY

2.1 Research problems

To my knowledge, there is really no study which has attempted to investigate some of the problems and issues regarding expert systems development in Sweden. Such an investigation should achieve more than a mere description of disappointment with the shortcomings of such existing systems. That is to say, such investigation should, in my opinion, address the major fundamental problems, motives and issues of expert systems development. A systematic investigation of expert systems development should aim to identify the factors of the current characteristics of expert systems in Sweden. These ideas and the results of my previous investigations [Sagheb-Tehrani1990a,b,c] provide the main background for the formulation of the following main research question.

There exists a gap between the knowledge of knowledge engineers and the existing knowledge of expert systems development. One can say that the existing knowledge of expert systems development is produced/contributed to by various researchers/practitioners in the field, and relevant literature. Understanding this existing knowledge depends upon one's situation and other factors. In another words, the understanding of expert systems varies from person to person (See the following figure). For instance, in my earlier study [Sagheb-Tehrani 1990a], the findings showed that the main motive for developing an expert system was to test new possibilities for such systems. However, the existing knowledge of expert systems development may suggest that the main motive for developing an expert system is to reduce costs by using expert systems. Consider another example: the existing knowledge of expert system development does not give a clear understanding of the knowledge acquisition (KA) process, i.e, what is the main drawback in the KA process? Furthermore, the findings of my earlier study [Sagheb-Tehrani 1990a] also showed that all the

respondents of the questionnaire investigation had different views about what an expert system is. Thus, the existing knowledge of expert systems development does not meet the requirements of the knowledge of knowledge engineers to conceive and implement an expert system project more successfully. Therefore, one may say, this lack of knowledge of expert systems development (or lack of a coherent relevant theory) is caused by this gap or vice versa. This study as a whole is aimed at taking an initial step towards bridging this gap. In order to accomplish it, the study deals with the following sub-questions:

1-What are the reasons for selecting an expert system solution to the problem?

2-What are the most common problem domains and the characteristics addressed by them?

3-How did the organizations decide to develop expert systems?

4-What are the problems of designing expert systems in practice?

5-What are the issues of expert systems after developing?

6-What is the role of expert systems with respect to the user?

The elucidation of concepts in the theoretical part, design of questions in the questionnaires and analyses of the findings of the study are based upon the above mentioned research questions.
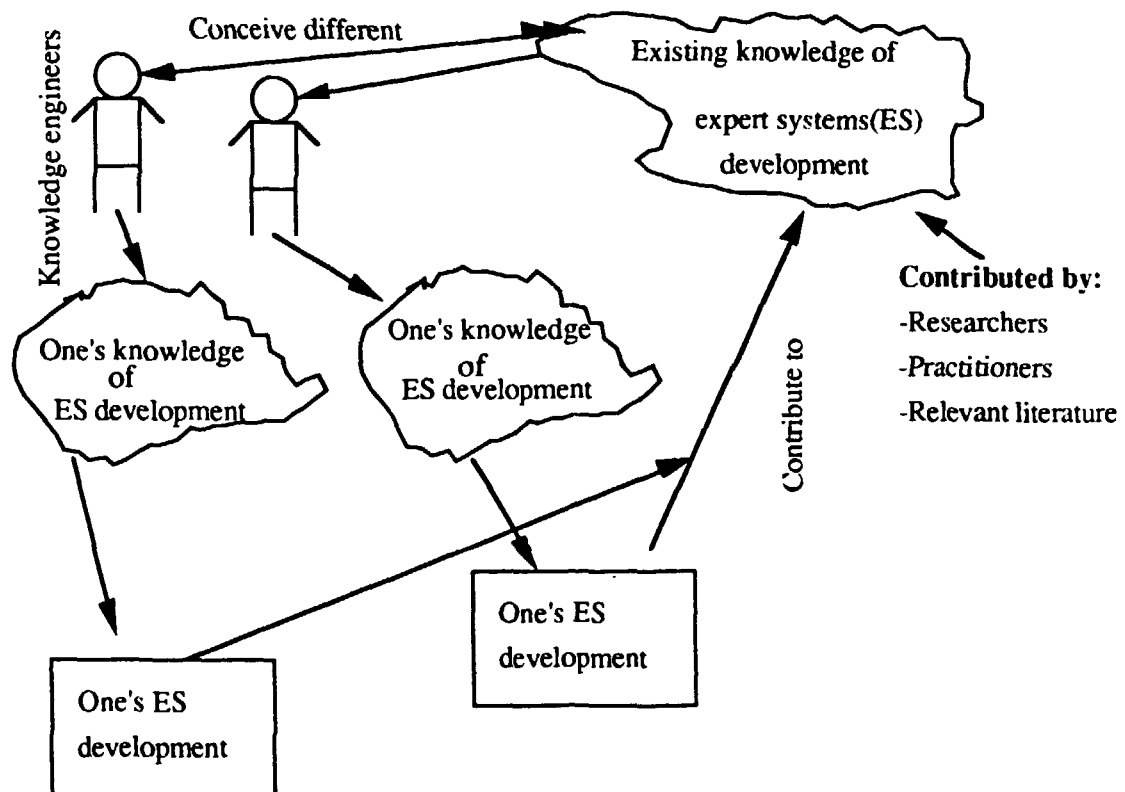
Fig. 2.1: The gap between the knowledge engineers and the existing knowledge of expert systems development

2.2 Research method: The exploratory approach

The main objective of a research methodology lies in seeking answers to how we can find true and useful information about a particular domain of phenomena in our universe. The "truth" about the real world is seen as an interpretation by means of our perceptual and general theoretical outlook (consider the Sufi story in previous section). In other words, one's understanding of the real world depends upon one's perspective. As I defined my path for this study in previous section, the study approaches its subject matter from an objective perspective. Thus, the study methodology emphasizes the nomothetic approach. This approach emphasizes the research on systematic protocol and technique. It focuses on the process of the study and uses both qualitative and quantitative techniques for analysis of data. Surveys and questionnaires are prominent among the tools in nomothetic

methodology [Burrell & Morgan 1979]. The nomothetic approach has its own significance for the way in which I attempt to investigate and obtain relevant knowledge about expert systems development. As I mentioned before, I treat the social world as an external, objective reality, then I endeavour to focus upon an analysis of relationships and regularities between the various elements which it comprises in the concept of expert systems development. The concern, therefore, is with the identification and definition of these elements involved in the concept of expert systems development.

Research methods include collecting and choosing the relevant objects for investigation, analysing and presenting the obtained data with respect to ones perspective. Any research requires an appropriate method and this means that I should be aware of the various relevant methods for accomplishing this research [Mumford 1985, Jenkings 1984 , Kapland 1963]. The objective of this study was to form a set of hypotheses from two empirical studies (my earlier study [Sagheb-Tehrani 1990a] and the present study and other similar studies), therefore the research has been designed within a framework of an exploratory study. Thus, I used an exploratory research design in order to understand the particular phenomena of this study. The exploratory research invites the chance of discovery, i.e. by using exploratory research, one can obtain findings that may contribute to the formulation of some relevant hypotheses. These hypotheses can be verified by further work which may result in building up a relevant theory as shown in the following figure.

External reality
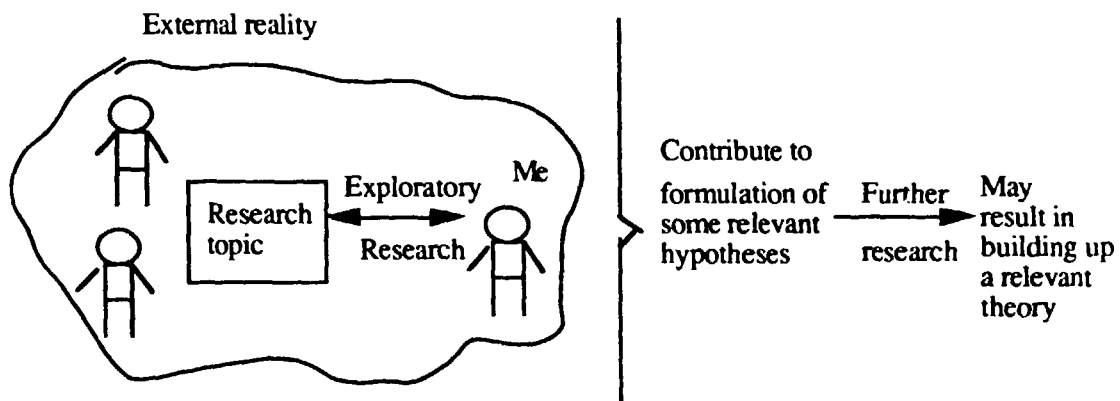
Fig. 2.2: The research method

2.3 Research process

The entire research process consists of two main activities, the theoretical and empirical studies. The main objective of the theoretical studies was to improve the theoretical background of this study by studying selected literature. The purpose of the empirical investigation was to collect and analyse data relevant to exploring the research questions mentioned before. The findings were analyzed and compared with issues drawn from the theoretical part with my previous study as the main background. Together, the above mentioned activities resulted in the formulation of a set of hypotheses. These are described in Chapter 9. The following figure depicts the research process.
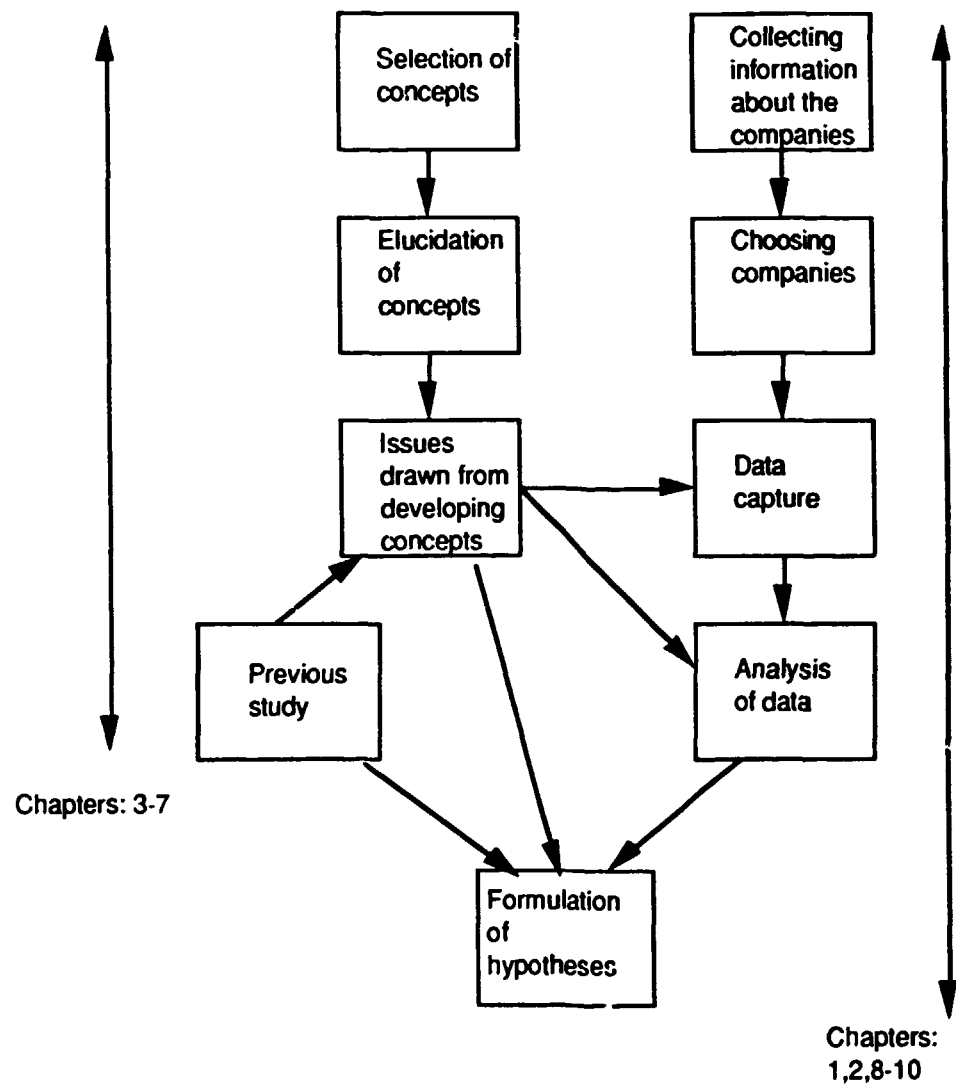
Fig. 2.3: The research process of this study

A short descriptions of each chapter of the study is presented in Section 1.8.

2.4 The possible research instrument and its validity

Organizational study may be approached in many ways, such as surveys, experiments[1] and case-studies[2]. I believe that to evaluate one's research method is a difficult task. It depends upon one's perspective. The term validation is used in a variety of ways in literature [Fitzgerald 1991]. From my point of view, the term validation means the justification of the technique in relation to its objective from a holistic view point. To put it differently, one should validate the entire process in relation to its objective, not just the end result. It is however useful to demonstrate various relevant strengths and weaknesses of techniques. Below, I endeavour to outline briefly the strengths and weaknesses of the above mentioned approaches of organizational study. A common approach to information systems research is the case study approach. Case studies are essentially a means of describing the relationships that exist in a specific situation. The main purposes of case studies are explanation, description and hypothesis generation [Wynekoop & Conger 1991, Galliers 1991]. There is some debate as to whether case study should be under the "scientific" banner or should be under the "interpretivist" category [Vikers 1980, Simon 1978]. The major drawbacks of case studies are high cost, time, difficulty in generalizability of the findings, lack of control variable and different interpretations of events by individual researchers. The strength of the case study approach is that changes and processes over time can be analysed [Wynekoop & Conger 1991, Galliers 1991]. The laboratory experiments approach is the identification of the precise relationships between variables in a designed, controlled environment using analytical techniques, with a view to making generalizable statements applicable to real world situations. The major advantage is the ability of the researcher

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[1] For a basic description see [Stone 1978, Dunnette 1976, Lawler 1977].

[2] For a good description of this methodology see [Stone 1978, Leenders & Erskine 1978].

to isolate and control a small number of variables which may then be studied intensively. The main weakness is the limited extent to which identified relationships exist in the real world due to isolation and simplification of the experimental situation. Field experiments are extensions of laboratory experiments and have the same strengths and weaknesses [Wynekoop & Conger 1991, Galliers 1991]. Surveys use information from a known population systematically gathered by questionnaires or interviews. Responses are collected from respondents and assumed to be unaffected by context. A survey is a better means of looking at a large number of variables than for example in a case study or an experimental approach. Thus, it provides a reasonably accurate description of real world situations from different view points. The advantages of survey research are collection of large amounts of data cheaply and in a shorter time. The proper chosen samples can reduce bias and allow for generalization of results.

As the study was exploratory and its objective was to form a set of hypotheses, choosing an appropriate technique within the context of this study was important. Also, the intention was to elucidate both quantitative and qualitative aspects and gather the appropriate data within a given period of time and cost. The questionnaire technique was chosen for this study. Moreover, using a questionnaire technique allows the researcher to gather beliefs, attitudes, behaviour and attributes from several key persons in an organization[3] [Kendall & Kendall 1988]. Furthermore, the intention also was to cover a large number of facts or variances and with due regard to the foregoing advantages and disadvantages of organizational study approaches, the questionnaire technique was adapted for this study to gather the relevant data. Before sending the questionnaire, a kind of pretest was done, i.e. in order to approve the questionnaire, my supervisor and a number of knowledge engineers and myself very carefully examined each question in the questionnaire. This process took more time than I expected. In designing the

[3] For further basic description see [Carson 1973, Belson 1981, Patton 1980].

questions of questionnaires some principles were considered in order to arrive at a better validation of data collection. After I had determined what I wanted to find out, I considered particular fundamental design strategies. Both open-ended and structured questions were designed. Moreover, some cross controls were designed in the questionnaire in order to obtain quantitative and secure data. (For example, consider question 14 in the questionnaire. If the answer was that KA was a problem, then question 15 had to be answered as well) Thus, there were such cross controls as well, regarding the validity of data collection. The other criterion for validity testing was the comparison of the results with other similar studies in other countries such as USA, England, Germany and Japan. This matter is also considered in Chapter 9. In addition, within the framework of the study, I selected two organizations from 23 which were located near me for interviewing after almost eight months from the date of sending the questionnaire to them. The reason was that I wanted to find out about their processes of ESD over the time. More details of the interviews are explained in Chapter 8. The method of administering the questionnaire can vary from one to another. The questionnaires were mailed to the relevant person in each company supplied with a deadline time, instructions and return address. Before sending the questionnaires, I personally contacted the respondents of the questionnaires in various organizations.

2.5 Source of material

2.5.1 Selection of organizations

In order to collect suitable organizations a number of sources were utilized. One main source was used in this study[4]. In Appendix 3 of the confidential report, the names of various organizations, names of contact persons and their telephone numbers are mentioned. Moreover, the organizations are

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[4] A part of a confidential report was obtained through an uncompleted project which I and Jörgen Lindh undertook during 1988.

classified according to their activities:

* Industrial engineering
* Industrial processing companies
* Banks
* Insurance companies
* Finance companies
* Data/Computer companies
* Medical companies
* Commercial and wholesale companies
* Miscellaneous

The first and second categories of the above mentioned organizations were included in my previous research [Sagheb-Tehrani 1990a]. Some organizations from the above mentioned categories are included in this study. The primary criterion for selecting a company for inclusion in the study was that it had at least one expert system in use or under development. More details of the participants are presented in Chapter 8.

2.5.2 Data collection

Quantitative data consists of detailed descriptions of situations and events from people about their experiences. Qualitative data provide detail and depth. The extent of detail will vary in any research, depending upon the objective of the study. One way of achieving this is from responses to open-ended questions in a questionnaire [Patton 1980], as is done in this study, where the designs of questionnaire and interviews were based on open-ended questions. In the social sciences, there exist problems about gathering qualitative data [Sandström 1991]. One problem regarding collection of data for this study was to make the chosen companies and persons take part in the research process. To achieve this I personally contacted the respondents of the questionnaire in advance by telephone explaining the objective of my research. After convincing the respondents to participate in this study, a letter with a questionnaire was mailed to them. The

motives of the respondents for taking part in this study can vary from one to another. One may simply wish to contribute to this study by participating. One may wish to discuss one's expert systems development problems and so on. One can say that several sources were utilized in collecting data for this study. The main one was by questionnaire. Some telephone conversations were also utilized.

2.6 Analysis of data

The data generated by questionnaires and interviews were voluminous. Sitting down to make sense out of pages of data could be overwhelming. Dealing with all those pieces of papers looked like an impossible task. The first thing I did, was to make sure that it was all there, and all the field notes had been completed before beginning the analyses. I started by reading through all the questionnaires and interview notes and made comments on attached pieces of paper. The process of labeling the different kinds of data and establishing a data index was a first step in content analysis. The content of the data was classified. This classification was critical, because without this there would be chaos. This contributed to simplifying the complexity of reality into some manageable form of analysis. The analysis of qualitative data was a creative process. It was also a process of intellectual rigour and required much hard work. One may manage this hard work in various ways, and there is no right way to go about organizing, analysing and interpreting data [Patton 1980]. Therefore, my description of how I worked was not meant to be prescriptive. With regards to its approach, the work was carried out according to the objective of the study . The first step of the analysis involved classifying the companies according to their activities. The next step involved specifying the working unit for the empirical part. The next stage of analysis involved structuring various tables based on the research questions, the issues drawn from the theoretical part and my previous study [Sagheb-Tehrani 1990a] and then putting the relevant data into disparate tables in order to define and analyze characteristics

and problems of expert systems development. Then, a set of were hypotheses formulated regarding the links between obtained data and issues drawn from the study of relevant literature.

2.7 Presentation of data and results

The empirical part of my previous study [Sagheb-Tehrani 1990a] is presented in Chapter 7. The empirical part of this study is presented in Chapter 8. Brief descriptions of the questionnaire investigations are provided in each respective chapter. The questionnaires are presented in the appendices. The names of the companies which participated in both studies have not been revealed. The results of the research are summarized in Chapter 9 and the hypotheses formulated are listed both in Chapter 9 and below.

Hypothesis 1:Successful implementation of an expert system project depends very strongly on motivation.

Hypothesis 2:The present (1992) common motive for developing expert systems is not to save money.

Hypothesis 3:The management must support the development of expert systems in their organizations.

Hypothesis 4:The development of expert systems is usually performed by DP experts.

Hypothesis 5:The knowledge acquisition process is the main drawback in the process of developing expert systems, and various approaches to knowledge acquisition have their own problems.

Hypothesis 6:A knowledge engineer should have a holistic view when developing expert system projects.

Hypothesis 7:It is important that a knowledge engineer differentiates between the various roles of an expert system at the outset of developing expert systems.

Hypothesis 8:The present trends of developing expert systems are towards aiding better decision-making or advising.

2.8 Summary

The research questions and the research method used in the empirical work were discussed in this chapter. The process of the research and the technique used for collecting data were also discussed. Further, the source of material, analysis of data and presentation were explained. This chapter is intended to give the reader a better understanding of the empirical part of the study.

PART II: THEORETICAL FRAMEWORK

3. ELUCIDATION OF CONCEPTS

In this chapter, my understanding of some concepts involved in expert systems development (ESD) are described. These concepts are based on my understanding from literature studies and my earlier investigation [Sagheb-Tehrani 1990a]. I believe that the following concepts can contribute to a better understanding of ESD. Naturally, this aspect should be considered in relation to other parts of the study.

3.1 Introduction to artificial intelligence (AI)

The Japanese are claiming that they are planning to produce a very new product. In late 1978, the Japanese Ministry of International Trade and Industry gave the Electrical Laboratory a project in order to give the world the next generation of computer called the "Fifth Generation". In 1981 Japan announced this project to the world for the first time. The project formally started in 1982. The Japanese decided to spend about $450 Million and assign several hundred top scientists to the project. Their objective was to develop computer systems for the 1990s. This new generation of computer systems will be oriented toward knowledge processing. According to the Japanese, the Fifth generation computer will be able to communicate with people in a natural language and conceive pictures and everyday language. Input to such a system will be in a natural language, pictures, images and etc. The suggested speed for such a machine is 1000 000 000 logical inferences per second [Feigenbaum & McCorduck 1984, Brooking 1985, Feigenbaum et al. 1988]. (See Fig. 3.1.)
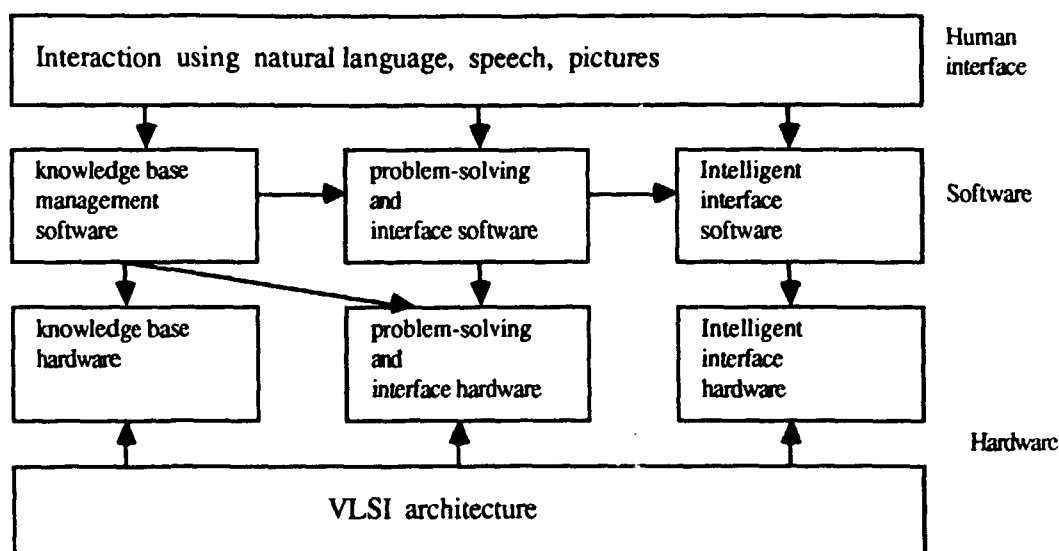
Fig. 3.1: Fifth generation computer system, source [Feigenbaum & McCorduck 1984], p.146.

Thus, the japanese programme of the Fifth Generation computers challenged the USA and Europe in the field, i.e. the USA programme and Europe were stimulated directly by the Japanese Fifth generation programme [Arnold et al. 1989]. In other words, the United States, Great Britain, France and other countries have various research groups in the AI field in to expand computer processing capability and develop more complex applications [Behshtian et al. 1988]. See Table 3.1. Thus, due to the Japanese project, an area of computer science which absorbed many computer specialists in recent years is Artificial Intelligence (AI)[1]. The Alvey programme started in 1983 and finished in

[1] I do not claim that AI research started in 1982. After the Second World War computer specialists have tried to develop techniques that enable computers to perform tasks earlier believed to require humans. In the 1950s, AI practitioners endeavoured to build intelligent machines by imitating the brain. One of the systems was called PERCEPTORN. This work was done by [Rosenblatt 1957]. In the 1960s, GPS was designed by [Newell & Simon 1969]. The central idea to their approach was the heuristic search. In the1970s Feigenbaum E, saying knowledge is power, pioneered expert systems with (DENDRAL). In the 1980s, Machine learning is gaining importance.

1988. During its five-year lifetime at a cost of £350 million, Alvey spawned a new information technology community that has become an integral part of Britain's national Science and Technology policy. It is very difficult task to evaluate such a complex undertaking. Evaluation of research programmes requires truly independent people, people with the experience and knowledge of an evaluation process [Oakely & Owen 1989]. They [Oakley & Owen 1989] point out that there may be two lessons to be learned from the Alvey experiment. First, cooperation can be made to work beneficially for all involved, provided the correct steps are taken to choose partners and programmes with an eye to the long-term outcome.

Secondly, government has a role to play, not just setting the detailed agenda for industrial and academic affairs but in serving as an active intelligent catalyst to ends that are difficult for industry. Furthermore, they [Oakley & Owen 1989] p.294, say,

"If the Alvey age however imperfect it was in conception and execution, was a form of Camelot to those of us who have long believed that cooperation is an outstanding goal for civilized man, then we must believe that, like Camelot, the age of cooperation will come again. Maybe next time it will take the form of a truly international attack on the immense intellectual and practical problems we face before we can claim to have harnessed artificial intelligence for the good of all society."

To my knowledge there is no particular published material regarding evaluation of the Alvey programme. There are conference proceedings of the Sprit programme [Esprit 89, Esprit 90], consisting of many articles regarding various projects in the Esprit programme. Among those articles, there is no study of expert systems development.

Country	Research Establishment	Year Begun	Horizon (Years)	Major Research Areas
USA	MCC	1984	10	Software technology CAD for VLSI Advanced data base architectures Artificial intelligence Human interfaces Parallel processing Semiconductor packaging
England	ALVEY	1983	5 - 6	VLSI design Software engineering Man-machine interfaces Intelligent Knowledge based Systems
Europe	ESPRIT	1982	10	Advanced microelectronics Software technology Advanced information processing Office systems Computer Integrated Manufacturing
Japan	ICOT	1981	10	Development of the Fifth generation computers Database machine, inference machine, human interface, intelligent programming

Table 3.1: Fifth generation research projects, Adapted from [Behshtian et al.1988], p.184.

3.1.1 The concept of AI

According to [Boden 1989], artificial intelligence (AI) is a revolution. It will change our everyday life as much as the Industrial Revolution did, and it will change our views about the human mind as much as the Freudian revolution did. AI is almost completely misunderstood by individuals outside the field. Even AI's specialists are confused about what AI really is [Dale 1987, Schank 1987]. Many of the uncertainties about the exact nature of AI are consequences of the fact that it is a science which does not quite fit in with the other categories of science [Campbell 1986]. Many AI practitioners regard AI as multi-disciplinary [Nilsson 1985, Sloman 1985]. Unfortunately, nobody really knows what intelligence is, or how to be sure when someone is behaving intelligently. In other words, there exists very little consent about what precisely constitutes intelligence[2] [Keller 1987, Dale 1987, Hart 1986, Schank 1987]. I keep returning to the question, what is AI? For the present, it is hard to find one answer to this question [Keller 1987, Dennett 1988, Turkle 1988, Schank 1987, McCarthy 1988, Rada 1984, Yazdani 1984, Cohen & Feigenbaum 1982, Narayanan 1986]. This is partly because of the different objectives of AI practitioners and ongoing development of AI. All disparate conceptions of AI may vanish when a machine can do what AI claims[3]! Narayanan [1986] answers this question this way, unless AI is provided with a proper theoretical basis and methodology one can say anything about AI and not be contradicted.

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[2] The matter of "artificial" has been defined as things made by humans which are imitations of things in nature. It lies outside the scope of this study to discuss the matter of "artificial". Readers who are interested in deep discussion of this matter are referred to [Simon 1982, Sokolowski 1988].

[3] It is not the purpose of this study to specify what is AI. This concept requires a separate research in itself. My intention was to provide a very brief explanation of this concept, because this study (expert systems development) is a branch of AI.

3.1.2 Aims

For the time being, I personally, agree with two main objectives of AI. The first is to create an intelligent machine. The second is to investigate the nature of intelligence which cognitive scientists are mostly interested in. Most AI specialists agree on the above mentioned aims [Schank 1987, Dale 1987, McCorduck 1988, Michalski et al. 1983, Charniak & McDermott 1985, Feigenbaum et al. 1988]. This study is directed mostly towards the first objective of AI mentioned above. As indeed Newell [Newell 1985a, p.390], says,

"I think the consolidation of expert systems into the mainstream of AI will be the central line of progress. By this I do not mean that expert systems are somehow to one side of the main stream. Rather, expert systems will acquire all the mechanisms for intelligence that are currently understood, and so will become indistinguishable from the best intelligent systems AI can build........"

One cannot really separate these two objectives from each other. There is an interplay between them such that achievement in one of them contributes positively to the achievement of the other.

3.1.3 Branches of AI

AI can be briefly subdivided into three relatively independent research areas: expert systems, natural languages and robotics [Rauch-Hindin 1986, Harmon & King 1985, Charniak & McDermott 1985]. See Fig. 3.2.
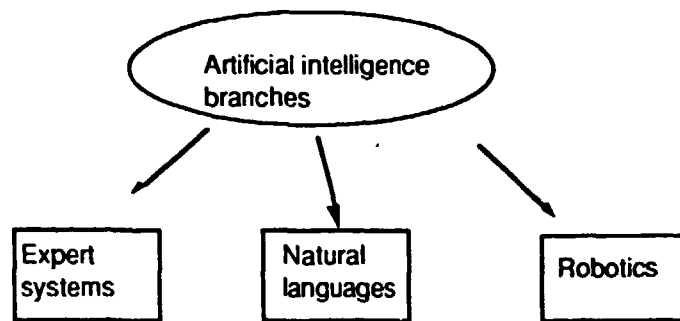
Fig. 3.2: Three main branches of AI

In the first branch of AI mentioned above, AI researchers are concerned with developing programs which use symbolic knowledge to simulate human expertise [Harmon & King 1985]. (The development of expert systems is discussed in more detail in the next section). This study falls within this branch.

In the field of natural languages, AI researchers are concerned with developing programs which can read, speak, and understand languages as people do in everyday life. In other words, the aim of this branch of AI is to develop integrated systems of hardware and software which allow the usage of natural languages in the communication with data base and machinery[4] [Harmon & King 1985, McRobbie & Siekmann 1988].

In robotics, AI researchers are concerned with developing smart robots[5]. The basic research in the field started 15 years ago in the USA but European industry ignored it. Today, there exist more than 15,000 industrial robots in use in Japan. It is generally

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[4] An example of this is [Winograd 1972]. In that system, users can conduct a very natural dialogue with a "hand-eye" robot, i.e. one with a mechanical arm and visual sensor both linked to a computer. More examples:HMRPM [Von Hahn & Wahlster 1979] and GUS [Bobrow et al. 1977].

[5]The early examples are: the robot FREDDY [Ambler et al. 1975] developed at Edinburgh university and robot SHAKEY, described in [Rapheal 1976], developed at Stanford university. Sweden also makes robots.

accepted that the low level of competitiveness of European industry is due to this fact that robot technology research was recognized too late in Europe [MacRobbie & Siekmann 1988]. From my point of view, achievements in any one of the above mentioned fields contributes to the others.

3.2 Expert systems: An attempt at definition

Let's not annoy the reader with the 1672 definitions of expert systems [Bachmann 1988, Gill 1991]. One way of conceiving expert systems[6] is to examine its root. The root of expert systems is AI. In the previous section, a brief history of AI, its aims and its three main branches were discussed (see Fig. 3.3). Further, an explanation of expert systems requires some specialized concepts. An attempt is made to familiarize one with some of these concepts and terminologies in the following sections. A glossary is also provided in the appendix of this work.

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[6] These systems have been called "expert systems (ES)"; "knowledge systems (KS)"; "Knowledge based systems (KBS)" or "intelligent knowledge based systems (IKBS)". Although people have tried to distinguish between these terms to indicate different levels of complexity. The distinction between these terms is not deeply discussed in A' literature. KBS are defined as systems which use knowledge about the domain for solving problems [Feigenbaum & McCordouck 1984, Waterman 1986, Wielinga et al. 1988]. Expert systems are knowledge based systems that handle real-world problems which require expertise when solved by a human [Wielinga et al. 1988 and Feigenbaum & McCordouck 1984]. Thus, all KBS are not necessarily expert systems but all expert systems are KBS, i.e., expert systems are a kind of KBS. In other words, any system which can conceive speech or images requires a large knowledge base in order to achieve this conception, but it doesn't necessarily require any human expertise. Therefore a KBS can not really be considered as an expert system unless its knowledge has reached a human expert status. Rauch-Hindin [1986], on p.67, draws a good figure which distinguishes between the ES and KS. Fig.3.3, also distinguishes between those terms.
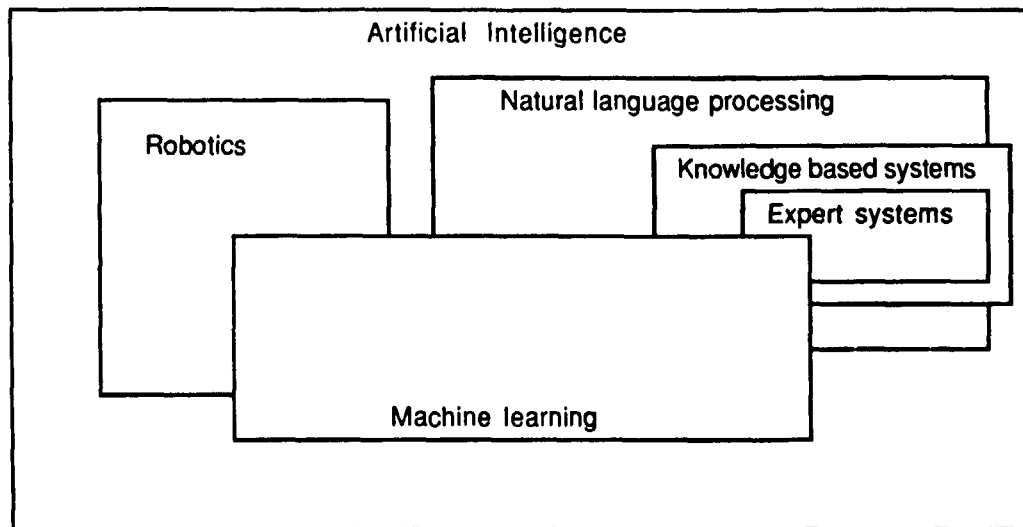
Fig.3.3:The artificial intelligence arena, source [De Salvo 1989], p.334.

From my points of view, expert systems development is a significant branch of AI and expert systems probably are the most practical application of AI which has interested a lot of computer specialists. This is also supported by [Harmon & King 1985, Liebowitz 1989b, Rauch-Hindin 1986, Boden 1989]. As indeed Newell [1985b], p.385, says,

"There is no doubt, as far as I am concerned, that the development of expert systems is the major advance in the field during the last decade.......It makes no difference that these systems are extremely limited in many ways and do not incorporate much that is known in AI. Science advances by a sequence of approximating steps, and the important thing is that a next step gets taken, not how limited each step is in itself.....".

Various research groups in AI have developed highly specialized expert systems for various problems. Many existing expert systems represent research; prototype efforts or are operational. The following figure provides a tabular view of some expert systems and the domains in which they operate[7].

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[7] For further examples of expert systems, please see [Feigenbaum & McCorduck 1984, Hays-Roth et al. 1983, Michie 1979, Waterman 1986, Weiss & Kulikowski

Expert systems	Developed by	Application area
MYCIN	Shortliffe,1976	Medicine
ACE	Vesonder,1983	Electronic
AIRPLAN	Masui,1983	Military science
PROJCON	Underwood,1981 Summerville	Information management
IMACS	O'Connor,1984	Manufacturing
LDS	Waterman,1980 Peterson	Law
SPERIL-II	Ogawa,1984	Engineering

Fig. 3.4: Typical expert systems and their applications area

The field of AI is a young discipline in which there has not been enough time for defining the exact concepts [Sell 1986, Wielinga et al. 1988]. Thus, no widely accepted definition of expert systems has evolved [Walter & Nielsen 1988].

Expert systems are programs that handle real-world problems requiring expertise, i.e. expert systems utilize "humanlike" reasoning processes rather than computational techniques to solve a specific problem domain [Rauch-Hindin 1986, Weiss & Kulikowski 1984]. Expert systems depend on knowledge that has been acquired from human experts. This is the reason that they are called knowledge-based systems. This approach to systems design has been called the knowledge based approach [Forsyth 1986, Mumford & Macdonald 1988]. More discussion of knowledge is presented in Chapter 4.

1984, Feigenbaum et al. 1988].

3.3 Elements of an expert system

In my view, an expert system[8] consists of eight key parts: A data base, a knowledge base, a knowledge acquisition module, an inference engine, an interface, a user, a human expert and a knowledge engineer.

The following figure shows the basic structure of an expert system.
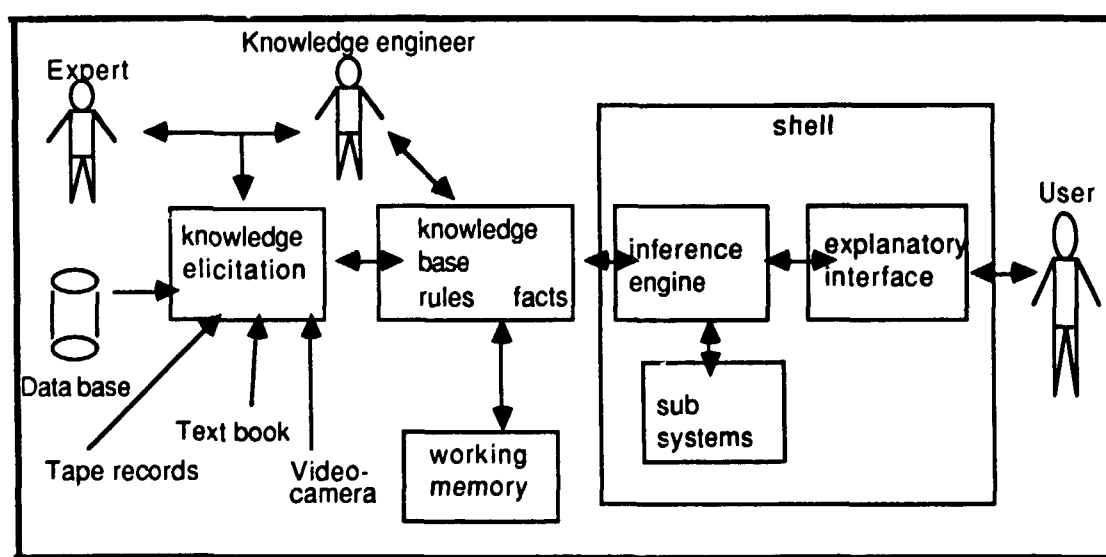
Fig. 3.5: The basic structure of an expert system, adapted from [Sagheb-Tehrani 1990a], p.14

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[8] There are various opinions about the elements of an expert system. Some people view it as two main parts (i.e., Knowledge base and inference engine) [Waterman 1986, Harmon & King 1985]. Others view an expert system as comprising four components (i.e., Expert, KA module, shell and user) [Forsyth 1984]. Feigenbaum et al. [1988] and Weiss & Kulkowski [1984], view an expert system as having eight major elements while Bratko [1986], Hart [1986] and Anderson's [1989] view of an expert system consists of three key areas (i.e. KB, inference engine and user interface). Finally, Hayes-Roth et al. [1983] consider that an ideal expert system has seven components (i.e. User, language processor, blackboard, KB, interpreter, scheduler, consistency enforcer).

According to the structure shown above, the roles of knowledge engineer , human expert and user are included. This aspect is not covered by all authors. The knowledge engineer and human expert are vital elements of an expert system, because one major distinction between the knowledge based approach and conventional data base methodology is that the data base is not usually creative. A conventional data base can contain either complete or incomplete data, whereas a knowledge base is rather active and endeavours to complete missing or uncompleted information via an interface to a user. Hence a knowledge engineer, domain expert and user are necessary components of an expert system during its continuous development process. The qualitative and quantitative knowledge of a human expert improves continuously, and therefore this aspect should be taken into account in the development and age of an expert system. As Nii [Nii 1988] points out, an expert system is developed incrementally, evolving over time with continuous involvement of the human expert (who often represents the end user) and the knowledge engineers. To be able to do this, knowledge engineer, domain expert and user are permanent and vital elements of the development of an expert system.

3.3.1 Knowledge engineer

One should differentiate between knowledge engineering and knowledge engineers. Knowledge engineering is the act of designing and building expert system. Knowledge engineers are the practitioners of the knowledge engineering [Feigenbaum et al. 1988]. The concept of knowledge engineering shall be discussed in more details in Chapter 4. A knowledge engineer is the individual responsible for constructing an expert system. There are perspectives on the qualifications and responsibilities of the knowledge engineers [McGraw & Harbison 1989]. One explanation of this diversity is that a knowledge engineer's job is complex and consists of various tasks. Some people may consider that a programmer could act as the knowledge engineer. Feigenbaum and McCorduck [Feigenbaum & McCorduck1984] and Welbank

[Welbank1983] say that a knowledge engineer should have the following skill[9]:

- Good communication skill
- Intelligence
- Tact and diplomacy
- Empathy and patience
- Persistence
- Logicality
- Versatility and inventiveness
- Self confidence
- Domain knowledge
- Programming knowledge.

It is unlikely that a knowledge engineer has all the above mentioned inter-personal skills. In most expert systems development cases, knowledge engineers are often sought from existing staff with no experience in the AI field. Management information systems people do not have sufficient understanding of the expert system technology to feel comfortable with it [Nii 1988]. This is also supported in my previous study [Sagheb-Tehrani 1990a], where internal specialists were responsible for developing expert systems in most cases. This causes the problem of incompetent knowledge engineers in some cases. However, it is also certain that the selection of a qualified knowledge engineer will have a crucial effect on the success of expert systems development. There is still a shortage of qualified knowledge engineers and applied AI practitioners [Wiig 1988]. This aspect should be considered by universities and other educational organizations in providing the relevant education and training qualified knowledge engineers for this new requirement of society. The role of a knowledge engineer is shown in Fig. 3.5.

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[9] For a brief description of these, see [Hart 1986], p.39.

3.3.2 Human expert

Certain people are called as experts. A human expert or domain expert is expert at something, but not everything. In other words, a human expert is a person who has become highly skilled at problem solving in a particular domain through years of experience. Since knowledge is the key to expert system functionality, in most cases the source of this knowledge is human expertise. Many facets determine the qualifications of a human expert, such as whether he/she is currently active in the domain and has intelligent behaviour [Hart 1988, McGraw & Harbison 1989]. We all recognize that intelligence is difficult to define. Hofstadter [Hofstadter 1979] defines intelligent behaviour in terms of the following abilities:

- Make flexible responses
- Take advantage of fortuitous circumstances
- Make sense from ambiguity and contradiction
- Assess relative importance
- Find similarities
- Draw distinctions
- Form new concepts from old ones
- Formulate new ideas.

To the above mentioned abilities I add the following ones as well:
- Ability in communication[10]
- Ability of carying out goal-driven activity.

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[10] Personally, I believe that this aspect is very vital for an intelligent object, because without a good ability to communicate with people, an intelligent object cannot conceive the specific situation or problem. This may lead to a disaster (consider the case of a doctor). The reason that I emphasis this aspect is, in a course discussion, there was the opposite view of this aspect. In other words, some people believe that an intelligent object should be unsociable and aggressive. It is outside the scope of this paper to discuss this matter further. My intention was briefly to point out the opposite view which I came across.

These qualities enable a human expert to solve problems in a particular domain. An expert may not have all the above mentioned qualities. Selecting a qualified expert to develop a successful expert system is crucial, because an expert system project requires dedication and long term commitment of a human expert. An expert who is not strongly interested or qualified in the problem is not the best choice [Bobrow 1986]. The following definition of an expert has been given by [Johnson 1983] :

> " An expert is a person who, because of training and experience, is able to do things the rest of us cannot; experts are not only proficient but also smooth and efficient in the actions they take. Experts know a great many things and have tricks and caveats for applying what they know to problems and tasks; they are also good at plowing through irrelevant information in order to get at basic issues, and they are good at recognizing problems they face as instances of types with which they are familiar. Underlying the behaviour of experts is the body of operative knowledge we have termed expertise. It is reasonable to suppose, therefore, that experts are the ones to ask when we wish to represent the expertise that makes their behaviour possible."

Gill [Gill 1991] says, human expertise may be seen as a function of its environment. A person is not considered to be an "expert" by his ability to formulate and/or manipulate complex rule systems, but as a consequence of a process of social interaction which accords "expert" status.

Usually, when one needs to consult a human expert in a specific domain it is because one requires some information in order to solve one's specific problem. Thus, a good human expert can provide an acceptable solution by using his/her expertise. One may ask why an expert who has expertise, for example in medicine, cannot do the job of a knowledge engineer. According to Hart [Hart 1986], there are two reasons why an expert cannot play the role of knowledge engineer:

1- Because he/she has not enough knowledge about
programming and expert systems techniques.

2- Because he/she has difficulty in expressing his/her
knowledge completely and correctly.

Regarding the second reason, there are different perspectives for epistemological assumptions. This matter is discussed in Section 4.8.

3.3.3 User

Anyone who interacts with a system is called a user. There are various categories of users. Here, I differentiate between primary and secondary users. Primary users use the expert system directly in order to make a relevant decision. In this case users can be human experts as well. Secondary users, such as people who input data into the system are those who use the expert system indirectly. Regardless of the ways in which users are categorized, user involvement throughout the system project is critical to the successful development of expert systems [Kendall & Kendall 1988, Mumford & Macdonald 1988]. A well performing expert system will still be useless if it is not accepted by the users. In order for the users to accept the system, they must feel that they are helped in their job by the system and the system should gain the user's confidence. The system has to convince the users that its advice is right and its rate of errors is low. Involving the users in the development of systems and considering their requirements can dramatically affect the time required to develop an expert system [Walters & Nielsen 1988].

3.3.4 Interface

Since the purpose of expert systems is to act, at least in some respect, as an intelligent agent, it is important to pay attention to the user interface [Young 1989, Anderson 1989, Oakley 1988]. This is also known as explanatory interface or explanation facility [Waterman 1986, Young 1989, Forsyth 1986]. With this facility the user can ask why and how the system has made its

reasoning. The enquirer can have an almost intelligent explanation facility depending upon various software and hardware support systems. The importance of explanation capabilities is recognized by knowledge engineers. These capabilities are very important for example in a medical expert system specially in consultations. According to Wallis and Shortliffe [Wallis & Shortliffe 1985], good explanations serve four functions in a consultation system:

1-They provide a method for examining the program's reasoning, if errors arise when the system is being built.

2-They assure users that the reasoning is logical, thereby increasing user acceptance of the system.

3-They may persuade users that unexpected advice is appropriate.

4-They can educate users in areas where a user's knowledge may be weak.

Furthermore, Shneiderman [Shneiderman 1987, pp.61-62], points out the following eight rules of dialogue design. Regarding a user interface, these rules or something similar should always be borne in mind when building an expert system:

1-Strive for consistency.

2-Enable frequent users to use shortcuts.

3-Offer informative feedback.

4-Design dialogues to yield closure.

5-Offer simple error handling.

6-Permit easy reversal of actions.

7-Support user control.

8-Reduce working memory load.

Thus, a requirement for a good explanation in consultation with users in an expert system is vital. One of the most common kind of explanation mechanism is retrospective reasoning. In this mechanism, how and why the system reached a particular state is explained. Another type is known as hypothetical reasoning. In this case the system explains what would have happened if a specific fact or rule had been different. In counterfactual reasoning, the system explains why an expected conclusion was not reached[11] [Waterman 1986].

3.3.5 Inference engine

An expert system also requires an inference engine by which inferences to be obtained. Actually, every computer system has a control structure (inference engine) even the traditional ones[12]. The control structure can be simple or complex. How complex it has to be depends on the inherent complexity of the problem treated. With respect to the problem, the simplest possible control structure should be chosen. Such a choice helps the end user to more easily follow the line of reasoning which may lead to greater trust on the part of the user for the reasoning of the system. There are various forms of reasoning [Feigenbaum & McCordock 1984] (problem solving strategy [Bratko 1986, Harmon & King 1985]), such as: backward chaining (goal-directed or top-down), forward chaining (data-driven; antecedent reasoning or bottom up) or a mixture of these. In backward chaining and forward chaining approaches an attempt is made to find a path from an initial state to a goal state. In a backward chaining approach the search starts from the goal and moves to the initial state, whereas in a forward chaining approach the search moves in the opposite direction. When the search space is large, one approach is to search both from the initial state and from the goal and utilize a type approach to match the solutions at an intermediate point. This approach is also useful when the search space can be divided hierarchically, thus both backward and forward search can be combined. This combined search may be best applicable to complex problems.

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[11] For an example see [Waterman 1986].

[12] In a conventional COBOL program the control structure is represented by those parts of the program code which determine in what sequence the various procedures are performed. The conventional programming has a limited capability and well-determining built-in relationship between the facts in its data base. One good text on this subject is Naylor [1984] .

There are several search strategies which are used in various forms of reasoning such as: depth-first search, breadth-first search and heuristics [Bratko 1986]. These search strategies consider the order in search space and how these various forms of reasoning should be employed[13].

In expert systems, there is a number of inference strategies used, for example, modus pones and management of uncertainty. There exist many theories for dealing with uncertainty, for instance, fuzzy logic, certainty factors, probability theory and so on[14]. It falls outside the scope of this paper to discuss the terms just mentioned (reasoning forms, search strategies and inference strategies). Thus, two major tasks are performed by an inference engine. First, it checks upon rules and facts. Second, it decides the order in which inferences are done. To be able to do this, it performs consultations with the user [Harmon & King 1985].

3.3.6 Knowledge base and data base

One of the most important aspects of a knowledge base is that the contents of a knowledge base and data base must be related to the purpose of the system, not just a recording of a large amount of scientific data and recognized terminology [Anderson 1989]. There exist various models of structuring knowledge. This is known as knowledge representation. This is explained in Chapter 4. Data bases are not the same as knowledge bases. A data base is a set of data about objects and events which the knowledge base will work on in order to achieve a desired result. A knowledge base contains facts, rules and heuristic knowledge. Facts are known as short-term information which can change from time to

[13] There are many texts about problem solving methods and search strategies. Almost any AI text explains these subjects. For examples [Barr et. al. 1981, Bratko 1986, Rich 1983, Nilsson 1987, Winston 1979].

[14] Among good texts about inference strategies is [Chang & Lee 1973]. About fuzzy logic is [Zadeh 1965].

time. Maybe the best way to describe the distinction between a data base and a knowledge base is by analogy. Suppose you are a television repair man and you have a TV in front of you for repairing. Your data base in this case is the TV's record, including its history, model, replaced parts and so on. Concerning the problem in hand, you must interpret this data for diagnosis. To be able to do that you must use your technical knowledge. The knowledge base which you use has this and you have learned this from your training courses, books and years of practicing. The following figure depicts the distinction between data base and knowledge base in the context of this study.

Data base   Knowledge base

Name of TV: Sony   Facts:
Type: Colour
Model: ST 555   The TV does not work at all.
Year: 1989
Replaced parts: ....
.....
                             Rules:

                             If TV does not work and
                             there is no indication of
                             power at all then check the
                             fuse.

                             ....
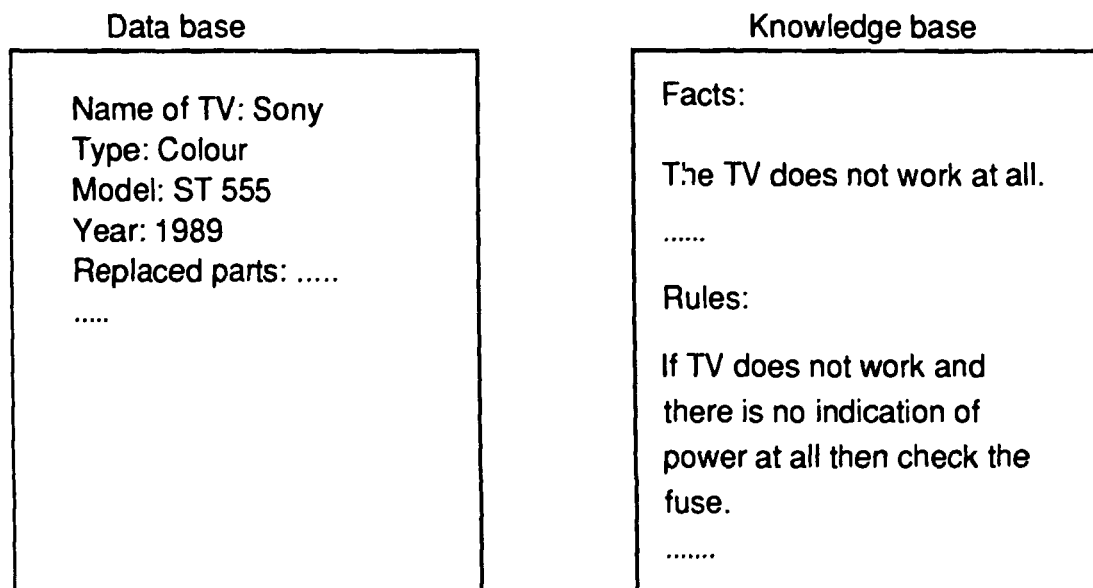
Fig. 3.6: A data base and a knowledge base

3.4 Tools

There are two ways of constructing expert systems. Expert systems can be built from scratch or built on a shell [Feigenbaum et al. 1988]. Expert systems building tools (shells) are programs that make the job of building expert systems easier. Thus, tools are those programs which aid you to develop your own AI application. It has been claimed that these tools perform the development of expert systems in less time. In other words, a tool is an expert system shell but it is not an expert system. An expert systems building tool is a high-level language which permits the user to develop expert systems. The user enters facts and rules in expert systems instead of numbers or formulas as in conventional programming. Expert systems building tools can be classified in different ways. We can classify them on the bases of the type of machines which they can run on. We can also classify them on the ground of the knowledge representation techniques available in a tool. The other possibility of expert systems building tools taxamony is the application's type which itself can be categorized in a number of ways. The following classification is based on the type of tool the computer subsystems contain. According to Waterman [Waterman 1986] there are four main types of tools available for building expert systems (I added the last one to his taxamony):

1. Knowledge engineering languages.
2. Programming languages.
3. Software tools (System-building aids).
4. Support facilities.
5. Hardware support.
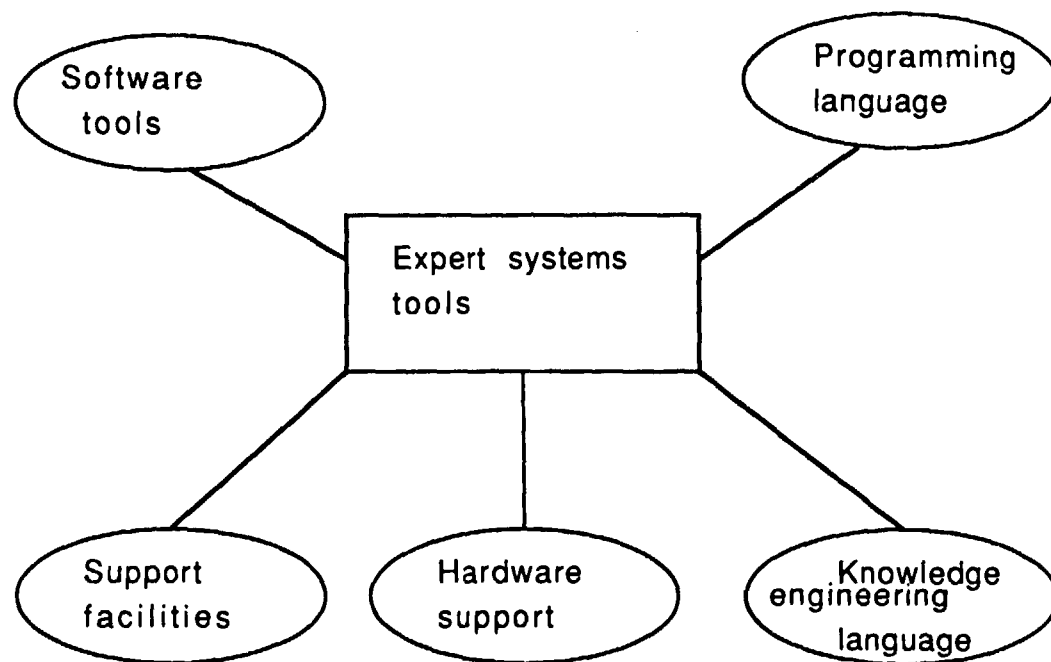
Fig. 3.7: Depicts expert systems main tools

3.4.1 Knowledge engineering languages

These programs vary from low-level programming languages to high-level programming languages. There exist differences between knowledge engineering languages and programming languages. According to Hayes-Roth et al. [Hayes-Roth et al. 1983] knowledge engineering languages can be either skeletal systems or general purpose systems. A skeletal language is an expert system with an empty knowledge base, having the inference engine with its subsystems, such as EMYCIN [Melle et al. 1980] which is derived from MYCIN[15] [Shortliffe 1976] with empty knowledge base [Jackson 1986], see the following figure.

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[15] A very good diagram [Buchanan & Shortliffe 1985, p.11] shows a review of the history of the work on MYCIN and related projects.

MYCIN

Knowledge base expertise knowledge	Inference engine	Sub-systems	

EMYCIN

Knowledge base empty	Inference engine	Sub-systems	
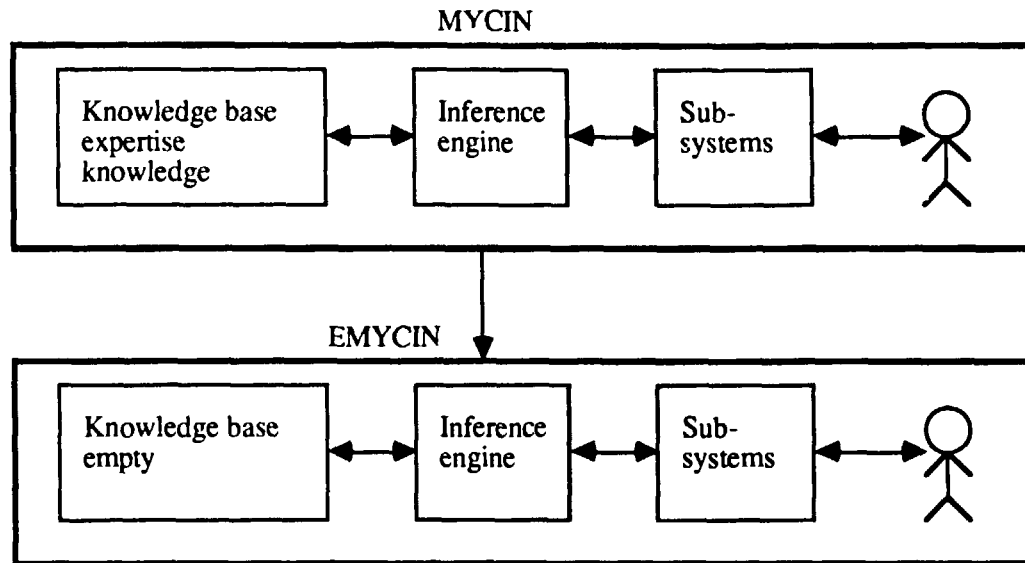
Fig. 3.8: Shows EMYCIN derived from MYCIN with empty knowledge base

The general purpose knowledge engineering language permits a wider problem domain and types. It can provide more control over data access and search. Naturally, it is more difficult to use. An example of this tool is RLL [Greiner et al. 1980]. However, there is the view which considers that many knowledge bases with one shell (general purpose expert system) in practice does not work as well as it claims unless the domain applications are very alike [Frost 1986].

3.4.2 Programming languages

The programming languages which are used for expert systems are either symbolic programming such as Lisp, Prolog and object-oriented languages like Smalltalk or problem oriented such as Pascal, Basic and so on [Watterman 1986]. Object-oriented programming is a term for programming with inheritable abstract data types [Walter 1987]. Smalltalk was developed at a major AI research center called Xerox Palo Alto Research centers. Smalltalk main objective is to develop user-friendly programming environments. But it has also been used to develop

expert systems. Most of the expert systems applications in U.S.A use Lisp as the programming language while Japan and some European countries use Prolog. As previously mentioned the symbolic programming languages are more appropriate for AI applications. At present, it seems that most AI languages are sold to universities and development organizations.

3.4.3 Software tools (System building aids)

The system building aids include programs that help to design expert systems, acquire and represent knowledge. There are not many system building tools. Most of them which exist are at research level. For example AGE [Aiello & Nii 1981] provide design aids and TEIRESIAS [Davis 1979] provide knowledge acquisition aid[16].

3.4.4 Support facilities

Support facilities includes a number of tools for aiding the programming. These tools generally should be consisted in the knowledge engineering language. There are five major kinds of support facilities as follows [Harmon et al. 1988, Waterman 1986, William 1987]:
   1. I/O facilities.
   2. Explanation facilities.
   3. Knowledge-base creation.
   4. Debugging tools.
   5. Training.

For the purpose of brevity, I shall not explain them further. Readers interested in the support facilities are referred to [Harmon et al. 1988, Waterman 1986, and William 1987].

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[16] For more examples of tools regarding knowledge acquisition see [Anjewierden 1987, Bahill et al. 1987]. In addition, for an assessment of tools regarding expert systems development, see [Mettrey 1987].

3.4.5 Hardware support

Hardware support refers to the computer on which the tool runs. Naturally, the size of a tool plays a major role in choosing the appropriate machine. A very vital aspect of selecting the relevant machine is its cost. The types of computers that a tool can be run on are for example: PC, Workstation, Mainframes, and others. Capabilities of expert systems building tools vary from one tool to another. Therefore it is a very difficult job to select an appropriate tool. There is no agreement about how one chooses a shell to use for a given application [Feigenbaum et al. 1988]. The successful use of expert systems building tools lies in choosing the right tool for a problem. This field also needs further research[17]. It requires a practical search of different tools in use and analysis of both tools characteristics and problem domain features.

3.5 Different types of expert systems

Most of the basic expert applications are classified into types as summarized in Table 3.1. An interpretation system analyses data in order to determine its meaning. An interpretation system typically uses sensor data e.g. a chemical interpretation system [Waterman 1986]. Prediction systems induce likely issues of a given situation for example weather forecasting, traffic predictions and so on [Hays-Roth et al. 1983]. Diagnosis systems involve fault finding. This type comprises software, mechanical, medical diagnosis and so on. Design systems develop configurations of objects under a set of problem constraints, e.g. VAX configuration system [Waterman 1986]. Planning systems create a plan of action. They regard designing and scheduling the development of a process or product. For example, creating an air strike plan [Waterman 1986]. Monitoring systems specify vulnerabilities, for example several systems used to monitor

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[17] Two reports in Swedish about the features of various tools and potential use expert systems in different organizations in Sweden are [Hägglund 1986, 1987].

hospital patients. These systems operate as diagnosis, running until they indicate an alarm (warning situation) [Waterman 1986]. Debugging systems describe remedies for fault functions. For example, choosing a type of maintenance to repair telephone cables [Waterman 1986]. Repair systems follow a plan to administer some prescribed remedy. Very few systems of this type have been developed. An example is tuning a mass spectrometer [Waterman 1986]. Problems addressed by instruction systems are diagnosing and debugging. Examples are various teaching systems [Waterman 1986]. Control systems control the overall behaviour of a system, e.g., managing the manufacturing [Waterman 1986]. The above mentioned types are summarized in the following table.

Category	Problem Addressed
Interpretation	Inferring situation descriptions from sensor data
Prediction	Inferring likely consequences of given situations
Diagnosis	Inferring system malfunctions from observables
Design	Configuring objects under constraints
Planning	Designing actions
Monitoring	Comparing observations to plan vulnerabilities
Debugging	Prescribing remedies for malfunctions
Repair	Executing a plan to administer a prescribed remedy
Instruction	Diagnosing,debugging, & repairing student behaviour
Control	Interpreting, predicting, repairing, & monitoring system behaviours

Table 3.1: Various types of tasks carried out by expert systems. Quoted from [Hays-Roth et al. 1983], p. 14.

Some of the expert systems that have been developed in these categories include the following[18] [Waterman 1986, Buchanan 1986, Smart & Knudsen 1986]:

Interpretation
PUFF [HPP 1980]- Interprets pulmonary function tests.

Prediction
PLANT/CD [Boulanger 1983]- Predicts the damage to corn due to the black cutworm.

Diagnosis
MYCIN [Shortliffe 1976]- Diagnoses bacterial infections in the blood.

Design
PEACE [Stefik et al. 1982]- Assists engineers in the design of electronic circuits.

Planning
CSS - Aids in planning the relocation, reinstallation and rearrangement of IBM mainframes.
GIMS [Fox 1983]- Manufacturing industry; performs project management, scheduling simulation and other management functions.

Monitoring
YES/MVS [Griesmer et al. 1984]- Monitors the IBM MVS operating system.

Debugging
BUGGY - Debugs student's subtraction errors.
FALOSY [Sedlmeyer et al. 1983]- Computer programming; fault-finding in computer programs, implemented for master file update programs.

Repair
SECOFOR - Advises on drill-bit sticking problems in oil wells.
IDT [Shubin & Ulrich 1982]- Computer repair; diagnosis of faults in PDP 11/03 computers.

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18 For more examples of expert systems with their applications and functions, please see [Waterman 1986, Smart & knudsen 1986].

Instruction

TVX - Tutors users in operating systems.

Control

PTRANS [Haley et al. 1983]- Helps control manufacture and distribution of Digital Equipment Corporation's Computer Systems.

The problem with the above mentioned categories is, an expert system may perform more than one task. For example, an instruction system often comprises diagnosing, debugging and repairing. Thus, one may find it useful to classify expert systems by their application area. The following table summarizes some of the domains for expert systems.

Domain	Domain
Accountancy	Law
Agriculture	Medicine
Aircraft	Military
Bioengineering	Physics
Chemistry	Pumps
Computer systems	Resource exploration
Consultancy	Telephones
Credit systems	....
Education	.....
Electronics	
Energy	
Engineering	
Geology	
Information management	

Table 3.2: Some domains for expert systems[19]

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[19] Adapted from [Waterman 1986 and Feigenbaum & McCordouck 1984]. Furthermore, some applications are added to Table 3.2, according to the findings of my earlier investigation, the empirical part presented in Chapter 7.

Obviously there can be other ways in which expert systems could be categorized. The above mentioned classifications are probably the most popular and important ones.

3.6 Expert systems characteristics

There are disparate views about the features of expert systems. One may view the possibility of replacing the human expert by expert systems, in which case one can specify various characteristics of such systems. That is, the basic feature of human experts must be matched by expert systems. AI specialists are still discussing what features a system should have in order to be considered an expert system. Some AI practitioners view a number of features as not essential but rather ideal or desirable [Sell1986, Johnson 1989, Hays-Roth et al.1983]. There are several characteristics that an expert system must exhibit. First, an expert system must be capable of updating its knowledge easily [Rauch-Hindin 1986]. The very vital characteristic of an expert system is, the ability to solve real problems which require human expertise. An expert system is required to be capable of explaining why and how it came to a specific solution in a way understandable to its users. Therefore an expert system must have a friendly user-interaction capability . An expert system should be able to deal with uncertainty and incompleteness [Bratko 1986, Rauch-Hindin 1986, Sell 1986, Forsyth 1984, 1986, Waterman 1986]. One cannot really define a set of fixed features of an expert system, because there is no agreement on expert systems. How far can they go? What are their fundamental limits [Davis 1989]? The above mentioned characteristics are the basic ones and presently the most important features of expert systems, see the following figure. Expert systems that seek to achieve these desired features have not yet been created [Anderson 1989].
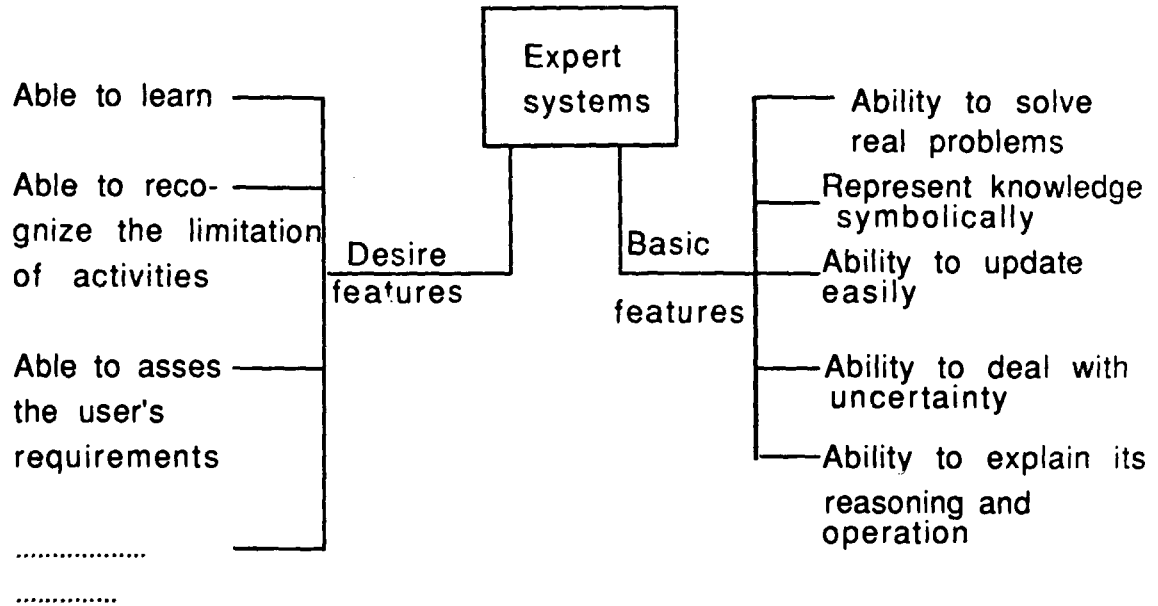
Fig. 3.9: Some basic and desired features of an expert system

3.7 Perceived requirement for expert systems

To build an expert system, certain prerequisites regarding the involvement of human beings, management support, adequate resources and problem characteristics must be met. For example, prerequisite conditions regarding knowledge engineers require that there be at least one knowledge engineer to build the expert system. Moreover, there should be at least one human expert to perform his/her task. The expert must be able to articulate his/her knowledge and explain how to apply that knowledge to a particular task. Defining users of the system and their requirements is an important aspect. This is necessary, if one wants the users to accept the system. Adequate resources such as sufficient budget, relevant hardware and software supports should be provided. Prerequisite conditions regarding problem characteristics require that the application be well bounded. The problem chosen for expert systems application should be solvable by human experts within a specific period of time [Rauch-Hindin 1986], see the following figure.

Some require-
ments for
developing an
expert system

— Applications are bounded

— Chosen problem should be
  solvable by human expert

— Adequate resources

  Have a qualified knowledge
  engineer

— Have a qualified human expert

— Specify user requirements and
  goal/s of the system
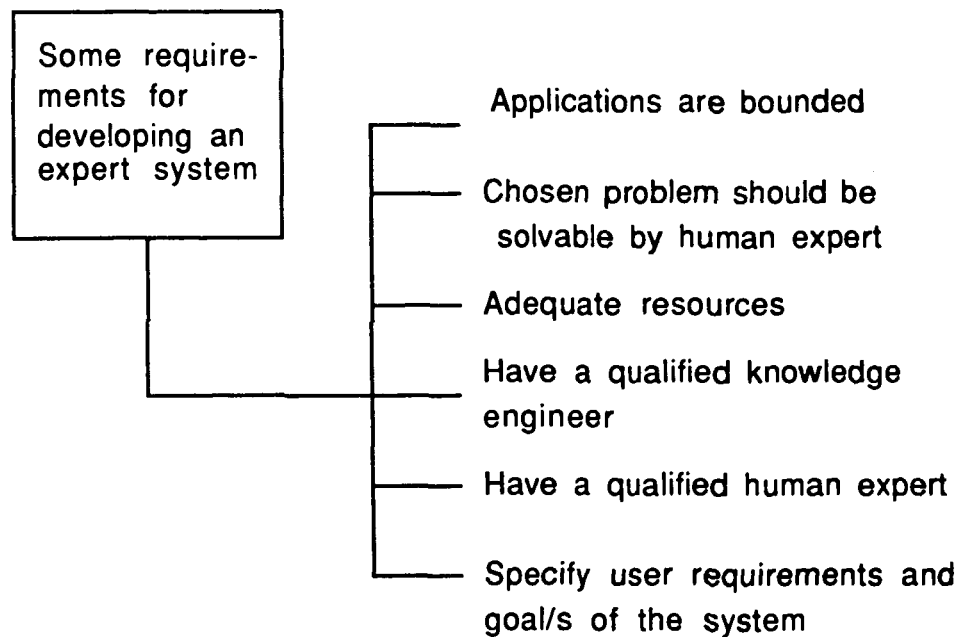
Fig. 3.10: Some requirements for building an expert system

3.8 The role of an expert system

Expert systems can play various roles, both for the user and the
organization. However, the expert system is meant to serve as a
consultant either to help solve problems or to give advice. There
are three possible ways to accomplish this. It is vital to
differentiate between the disparate roles that an expert system
can play [Young 1989, Frost 1986]. One way of describing the
possible roles of an expert system is by analogy with the roles
played by people. For example, is the relationship between user
and system like a relation between boss and secretary; teacher
and student; client and financial advisor or patient and doctor? A
study by Pollack et al. [Pollak et al. 1982] regarding consultation,
points out that most of the expert's effort is directed towards
encouraging the client to reconstruct the question or persuading
them to accept the advice offered by an expert.

Frost [Frost 1986] defines the following three roles[20] an expert system can play:

1- The expert system is considered a 'slave' to the human user. In this case the expert system carries out tasks under the control of the user.

2- The expert system is regarded as the 'controller' and the user as the slave. For example the user provides results as requested by the system then the system gives decisions which may be put into practice by the user.

3- The expert system is considered to be a 'colleague', for example a consultant by the user.

Young [Young 1989] points out that the question of the role an expert system plays is not often asked, but it should be. Because it affects such things as :

- Who controls the dialogue?
- Who takes the initiative, the user or the system?
- Who decides what gets done next?

The following figure depicts the above mentioned three roles of an expert system.

(A) ES as slave   ES ◄─────────── User

(B) User as slave   ES ───────────► User

(C) ES as a colleague   ES ◄──────────► User
        of user
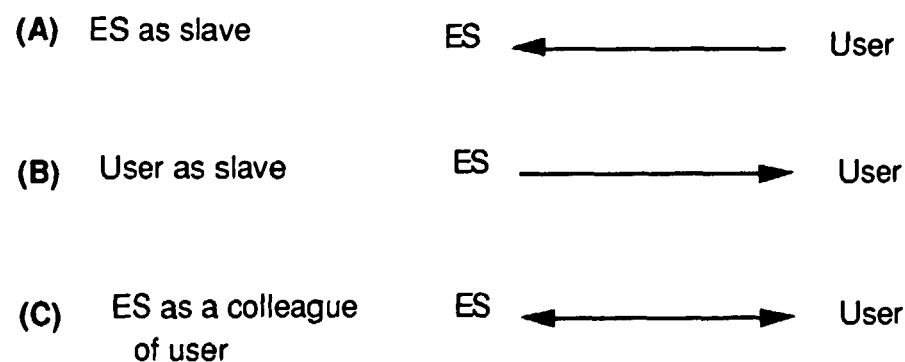
Fig. 3.11: Shows three roles of an expert system (ES), Adapted from [Sagheb-Tehrani 1993g].

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[20] These different roles are comparable with different perspectives in the literature of Human-Computer Interactions (HCI) such as, tool perspective, media perspective, dialogue perspective and system perspective.

The third role of an expert system is difficult to obtain, because the expert system must be capable of 'empathizing' with the user, and having some model of the user's knowledge, capabilities, etc. [Frost 1986].

3.9 Responsibilities of expert systems

The responsibility of those concerned with the development and use of expert systems needs more attention [Baker 1988]. A human expert is responsible for his/her judgement. He or she will stand by the decision they made and suffer the penalties if negligence is shown in their decision. For example the doctor is responsible for the diagnosis given [Newman 1988]. This aspect is important in developing an expert system. In other words, who is responsible: the system designer or the expert for mistakes made by the system? Inevitably a system will sometimes make the wrong conclusion. Therefore, there is a requirement for the consequences of such conclusion [Baker 1988]. The responsibility for expert systems varies from one system to another. An expert system in the case of status "a" in Fig. 3.11, may give the responsibility to the user. In the case "b" in Fig. 3.11, the responsibility may be given to the creator of the system. In the case of "c" in the same figure, the responsibility may be given both to the creator of the system and the user. Roedler [Roedler 1988] says that in the use of expert systems, the system itself should not be responsible alone. A human, one who can test the plausibility of the result must always stand between the decision taken by the system. This is supported in my earlier study [Sagheb-Tehrani 1990b]. Without this test, the human being is dependent upon expert systems, see the following figure.
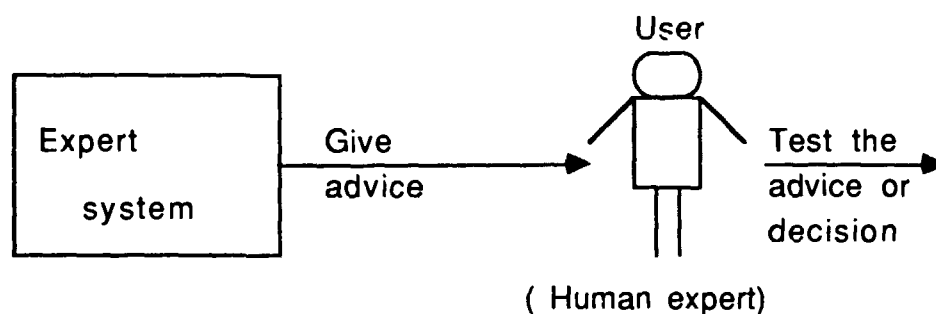
Fig. 3.12: Shows the responsibilities of advice given by expert system, Adapted from [Sagheb-Tehrani 1993g]

Buchanan et al. [Buchanan et al. 1983] refer to this stage of expert systems development as validating or testing. The terms validation and evaluation are used interchangeably [O'Leary et al. 1990]. Balci and Sargent [Balci & Sargent 1984] point out that there is no standard definition regarding validation, evaluation and verification. In the context of this study, validation refers to the process of specifying that an expert system accurately represents an expert's knowledge in a specific problem domain. This definition of validation focuses on the expert system and the expert, whereas evaluation refers to the process of examining an expert system's ability to solve "real-world" problems in a specific problem domain. This focuses on the expert system and the real world[21] [O'Leary et al. 1990].

3.10 Motivation for developing an expert system

The successful implementation of an expert system depends very strongly on motivation. Along with the corporate goals of the company, motivation is the most vital factor [Fehsanfeld 1988]. Before the start of expert systems one could obtain expert advice in two ways.

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[21] For a deeper discussion, please see [O'Leary et al. 1990].

In the first case, one could directly consult an expert. This process is expensive, if the expert is a professional person, such as a tax consultant; lawyer or a doctor. Furthermore, this means travelling to the expert and making an appointment which is not often easy. Sometimes people do not feel comfortable when discussing their personal problems with experts. There are exceptions, but this is the trend of public perception before people discuss their problem with an expert.

In the second way, one could read the relevant books and articles, usually written by experts. This approach is not without its problems. It is time consuming to find the relevant books and articles. Moreover, it takes quite a long time to understand various concepts and find the particular part of the book which is relevant to ones specific problem. Also, this approach is relatively suitable for a small part of the population which is really literate [Oakley 1988].

Therefore, the most obvious reasons for building expert systems are, scare human experts and the high cost of consulting them [Waterman 1986, Weiss & Kulikowski 1984]. The cost of developing an expert system is also high at the beginning, but in the long term it would be bearable compared with the growing cost of human expert employment. This is also supported in my earlier study [Sagheb-Tehrani 1990b]. Human experts are not always within reach compared with expert systems. Furthermore, expert systems make it possible to computerize existing empirical knowledge within a company. This knowledge is available at anytime, anywhere, at constant quality [Waterman 1986, Weiss & Kulikowski 1984, Fehsenfeld 1988]. Human experts are very expensive, and become more expensive as they specialize within narrow domains. Thus, transferring knowledge to lower-skilled people in organizations also implies that cheaper personnel can do the tasks [Klien & Methlie 1990][22]. This

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[22] An example of this aspect is found in Coopers & Lybrand, an international audit and accounting firm. This firm decided to develop Expertax, an expert system which enables less-skilled personnel to handle the simple tax problems, letting the human

common (shared) knowledge base of an expert system could provide consistency in decision making [Weiss & Kulikowski 1984]. A human expert may make different decisions in the same situation due to emotional factors [Waterman 1986]. Thus, by combining various expert knowledge in a narrow problem domain, we shall have an alternative to various opinions of human experts. There are other motives for developing expert systems, such as, simply testing new possibilities of expert systems or dissatisfaction with human experts and so on. This is also supported by the findings of my earlier study [Sagheb-Tehrani 1990b]. A human expert is still more flexible than any expert system of today. One does not expect human experts to be replaced by expert systems in all application areas. In other words, for the time being, it is better to think of an expert system as an intelligent assistant than as a replacement for a human expert [Keller 1987]. For example, the general conception in medical literature is that expert systems must only be utilized as an advisory system [Newman 1988]. Expert systems can be regarded as interactive intelligent problem-solving and advisory systems which increase the capability of the decision maker [Weiss & Kulikowski 1984, Wielinga et al. 1988]. At present, expert systems are utilized for aiding decision making or advising. This trend seems to be the aim in almost all domains. This is also supported in my previous study [Sagheb-Tehrani 1990b]. See the following figure for the above mentioned motives regarding the building of an expert system.

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experts concentrate on the difficult problems where their specialist knowledge is of most value. The less-skilled personnel can now advise on the simpler tax problems, without having to refer them to the tax expert. The benefits are reduced time and costs.

```
┌──────────────┐        ┌──Scarce human experts
│ Some         │        │
│ motivations  │        ├──High cost of human experts
│ for developing│       │
│ an expert    │        ├──Difficult access to human experts
│ system       │        │
└──────────────┘        ├──Inconsistency in human decision
         │              │  making
         │              │
         └──────────────┼──Expert knowledge available anywhere,
                        │  anytime
                        │
                        ├──Easy to reproduce expert knowledge
                        │
                        ├──Testing the new possibility of
                        │  expert systems
                        │
                        └──Dissatisfaction with hum.in expert
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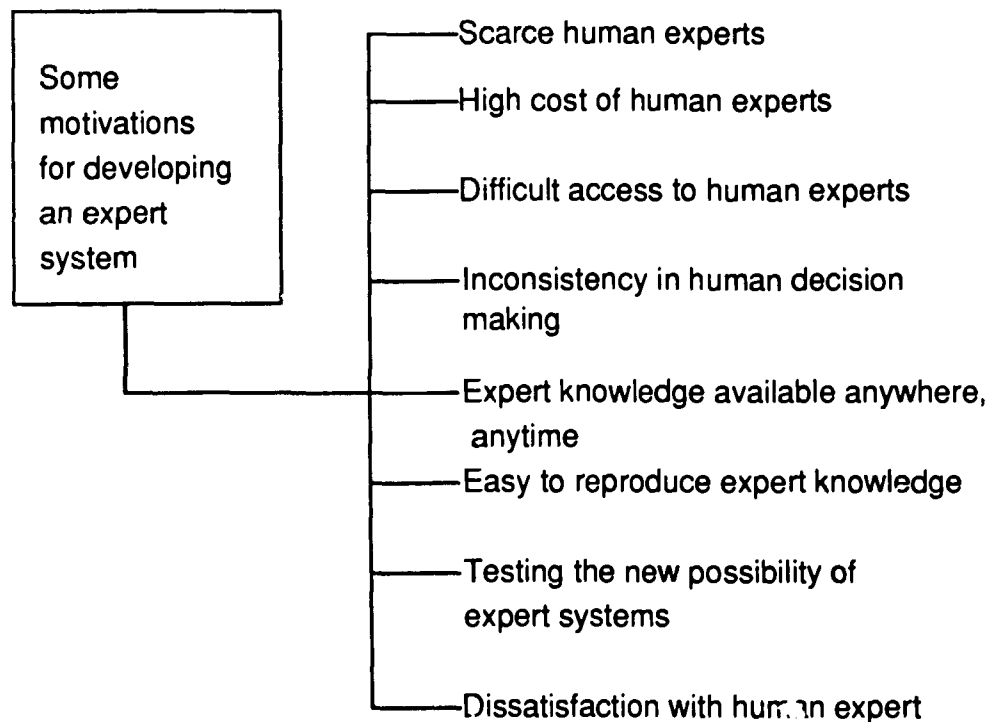
Fig. 3.13: Some motivations for developing an expert system

3.11 Validation

In this section, I take up validation of expert systems development (ESD). The success of ES is often claimed after non-rigorous testing or validation. Validation is not a new subject in computer science. The term validation has different meanings in different contexts. Adrian et al. [1982] define software validation as the determination of the correctness of a program with respect to user needs and requirements. From my point of view, there are differences between expert systems development and conventional computer based systems. These differences have made me consider validation of expert systems as somehow different from conventional computer based systems. An expert system has different components and extra participants compared with conventional computer based systems. These components (for example knowledge base, inference engine) may require their own method of validation, see [Meseguer 1992, Powell 1992, Duchessi & O'keefe 1992, Grogono et al. 1991, Green 1987].

Furthermore, consider the task of knowledge engineering compared with software engineering. The process of knowledge engineering requires its own validation method. Different knowledge engineers may have different views of the life-cycle steps of ESD. From my point of view, a knowledge engineer should consider, requirement validation, knowledge acquisition validation, validation of expert systems architecture, implementation validation (for example, validation of expert system behaviour) and maintenance validation. For instance, validation of ES behavior is normally made by testing [Meseguer 1992]. This testing can be against a set of historical data; specific data or in confrontation with a human expert. However, some validation methods developed for softwar· engineering may be improved for adaptation in knowledge engineering. This matter falls outside the scope of this work. It requires its own research. My intention was to emphasize validation at the outset of an ES project.

3.12 Summary

The main goal of this chapter was to develop some concepts relating to expert systems development. The concept of AI, and its three main branches were discussed. An attempt was made to specify a definition for expert systems. Further, the elements of an expert system, its roles, its responsibility, various kinds of expert systems, expert systems tools, some motivations for developing an expert system and its validation were discussed.

4. EXPERT SYSTEMS DEVELOPMENT (ESD)

This chapter discusses the ESD process from my point of view. Furthermore, an attempt is made to explain the terms: data, information and knowledge in the context of this study. Another attempt is made to explain my conception of the KA process. By doing this, I hope that a better understanding of the KA process with its problems can be obtained.

4.1 Introduction: A very brief background

The first step in developing an expert system is to select a problem, specify the expert system aim(s), and identify the sources of knowledge. Further, there must be at least one human expert and a knowledge engineer willing to develop the expert system. When due attention is paid to the requirement of adequate resources, the process of knowledge acquisition takes place.

4.2 Categories of information systems and problems

Information systems (IS) can be divided into five types [Beulens & Nunen 1988]:
- Operation Information Systems (OIS)
- Management Information System (MIS)
- Management Science or Operational Research System (MS/OR)
- Decision Support Systems (DSS) and Expert system (ES).

See Table 4.1 for the trend of IS development and its application area.

Period	IS type	Functions
1950s	DP	Data and transaction processing
1960s	MIS	Decision making in routine, structured areas
1970s	DSS	Decision making in semi-structured areas
1980s	ES	Decision making in ill-structured specialized areas of narrow domain

Table 4.1: Information systems development and their applications area, adapted from [Yick & Phuong 1990], p.196.

According to Anthony [Anthony 1965], there are three types of management tasks[1]:
- Strategic planning
- Management control
- Operational control.

Each of the above mentioned tasks may require a specific information system (IS) that supports these tasks [Beulens & Nunen 1988]. Operational Information Systems (OIS) are for conducting transaction processes, accurate registration of important activities, events and states of the object system of interest. OIS are primarily used on the operational level. Management Information Systems (MIS) are aimed at the analysis and report of the states and events in the object system which supports planning and control. MIS are mainly utilized on the management control level. Management Science or Operational Research Systems (MS/OR) are mainly utilized for solving structured problems that managers are faced with. They are used both in management control or operational control level. Decision support systems (DSS) are aimed at solving semi/ill-structured problems which management are faced with. DSS are mainly utilized in the management control and strategic planning level. Expert systems (ES) deal with heuristics and ill-structured problems. They support users at any level in an organization. They perform tasks that requires expert knowledge and facts about a problem domain [Yick & Phoung 1990, Beulens & Nunen 1988]. The following table shows the above mentioned IS types and various management tasks.

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[1] Davis & Olson [1985], p.48, draw a good figure which shows the various management tasks as a pyramid.

IS / types	Strategic planning	Management control	Operational control
OIS			X
MIS		X	
MS/OR		X	X
DSS	X	X	
ES	X	X	X

Table 4.2: Types of IS and management tasks, adapted from [Sagheb-Tehrani 1993a]

4.3 Problem selection

Problem selection is a critical step in the development process of an expert system. The success of an expert system development process depends upon an appropriate selection of application [Prerau 1985, Liebowitz 1989]. There are disparate techniques and methodologies for selecting an expert system problem. For example a technique for selecting an expert system problem is to have a checklist of important problem criteria and check how many of the criteria fit the problem. This approach is not very complex, but it may be the most common approach used by knowledge engineers [Liebowitz 1989]. For example, Satty [1980,1982a,b] developed a methodology called Analytic Hierarchy Process (AHP) which can help the knowledge engineer in selecting and scooping a problem. AHP divides a problem into various parts and then calls for only simple pairwise comparison judgments to develop priorities in each hierarchy[2] [Satty

[2] The various steps included in AHP are as follows [1980]:

1-The problem is defined.

2-The hierarchy is structured from the top level to the lowest level.

3-A set of pairwise comparison matrices is constructed for each of the lower levels- one matrix for each element in the level immediately above.

4-After all the pairwise comparisons have been made and the data entered, the consistency of the judgments is determined using eigenvalue.

5-Steps 3 and 4 performed for all levels in the hierarchy.

6-The hierarchical composition is now used to weight the eigenvectors by the weights of the criteria, and the sum is taken over all weighted eigenvector

1980]. A knowledge engineer should consider the following criteria[3] for selecting an appropriate kind of problem to work on [Harmon & King 1985, Waterman 1986, Liebowitz 1988, Buchanan 1986, Perau 1985, 1987, Bobrow et al. 1986]:

- The task may require decisions that are based on incomplete or uncertain information
- The task requires mainly symbolic reasoning
- The task requires the use of heuristics
- The task does not require knowledge from a very large number of areas
- The task is defined very clearly
- A good set of test cases exists
- The domain is one where expertise is generally unavailable, rare, or expensive
- The task doesn't depend heavily on ccmmon sense
- The task has outcomes that can be evaluated
- The task is decomposable, allowing for small rapid prototyping and then slow expansion for the entire task
- The task is neither too easy nor too difficult
- The number of rules should be limited to no more than several hundred.
- The task is narrow domain
- The domain is characterized by the use of human expert knowledge
- Conventional programming approaches are not satisfactory for the task
- There are human experts that can solve the problem

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entries corresponding to those in the next lower level of the hierarchy.

7-The consistency of the entire hierarchy is found by multiplying each consistency indexed by the priority of the corresponding criterion and adding them together.For deeper discussion of the AHP methodology, please see [Satty 1980, 1982a, 1982b and Liebowitz 1989a].

[3] The mentioned criteria may not represent a complete list of criteria for selecting an appropriate problem. But these may represent the basic criteria to the knowledge engineer for selecting an appropriate kind of problem to work on. For example some criteria relating to the domain area personnel that may be utilized in selecting a problem mentioned by Preau [1985].

-The completed system is expected to have a significant payoff for the organization

-At the beginning of the project, the human expert is able to define many of the important concepts relating to the domain

-Management is willing to commit adequate resources.

4.4 Approaches and methodologies

There are various approaches for designing a computer system[4]. Expert systems are often developed using the "middle-out" design approach[5]. The middle-out design philosophy suggests starting with a prototype and then gradually expanding the system to meet the requirements [Hurst 1983], see the following figure.

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[4] For example see Boguslaw [1965], he points out four different approaches to system design. Further, see Bally et al.[1977] for four various information system development strategies. See also Brown [1984] for three different approaches to expert systems development: the low road, the middle road and the high road. The low road involves direct symbolic programming, usually in Prolog or Lisp programming language. This give the advantages of low cost AI machines with a flexible programming environment. For example, DENDRAL [Lindsay et al. 1985] is an early expert system in which the low road was used [Bobrow et al. 1986]. The high road involves building a system which contains explicit representation of a deep knowledge for more than one purpose. An example of this is Sophie [Brown et al. 1975]. The middle road involves explicit representation of knowledge and some direct programming may be used as well. A key feature of middle road systems is that they are focused on a single task. A well- known example of this is MYCIN [Shortliffe 1976].

[5] Waterman [1986] and Hart [1988], refer to this as incremental approach. Waterman says, as soon as builders acquire enough knowledge to construct even a very simple system, they do so and use feedback from the running model to complete the system.
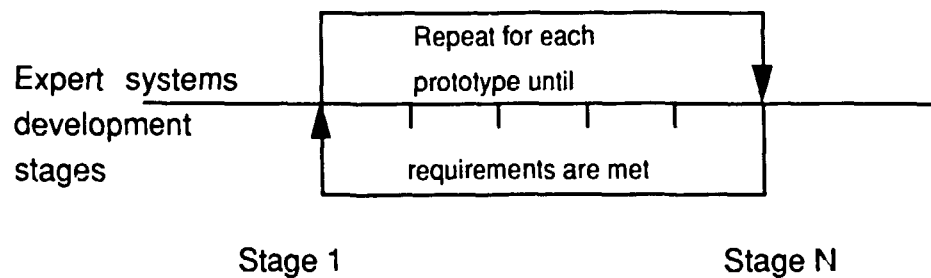
Fig. 4 1: The "middle-out" approach for developing an expert
system

Developing an expert system relies upon the techniques and tools developed in the AI field. The field of AI is still young and requires more research. Most of the current methodologies for developing expert systems are based on the traditional computer based systems approach [Hart 1986, Wielinga et al. 1988]. According to Wielinga et al.[Wielinga et al. 1988], the experimental approach for developing expert systems is useful in a research area, but is less accepted in commercial areas. This is because, it is expensive, hardly manageable and does not cope with the careful life-cycling of traditional software engineering practice. Moreover, traditional software engineering techniques (life-cycle models) do not fit the domain of knowledge engineering, since developing an expert system has to do with knowledge. So, software engineering methodologies have no techniques and tools to uncover knowledge and reasoning. For example, Keller [Keller 1987], recommends structure analysis for developing an expert system. Rapid prototyping obtained wide acceptance as system development technique for expert systems [De salvo et al. 1989, Wielinga et al. 1988, Hart 1988, Harmon & king 1985]. One advantage of using prototyping is that the expert or management who may initially be sceptical about the idea of developing an expert system, will be convinced of the effectiveness of the enterprise [Wielinga et al. 1985]. In prototyping approach a simplified prototype version of the system is designed, implemented and tested. See the following figure.
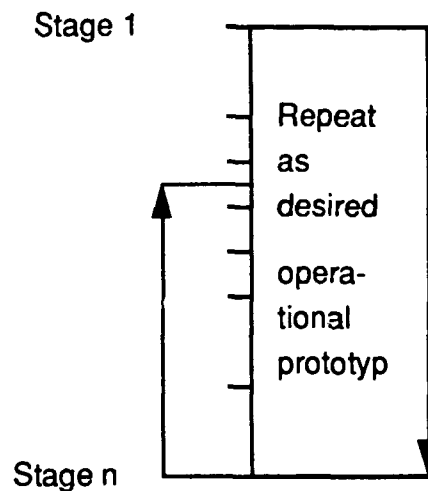
Fig. 4.2: The prototype approach

Most AI practitioners who used a traditional approach for developing an expert system have disparate views. For example, according to Bahill et al.[1987], there are many steps in the process of developing an expert system:

-Identifying an appropriate problem domain.
-Specifying the input-output performance criteria.
-Selecting a good expert.
-Selecting an expert system shell.
-Extracting knowledge from the expert for encoding it in the knowledge base.
-Debugging the knowledge base.
-Making the system user friendly.
-Testing the system.
-Validating the system.
-Updating and maintaining the system.
-Replacing the system.

According to Hart [Hart 1988], the following stages are involved in developing an expert system:

-Select problem
-Elicit preliminary knowledge
-Build prototype
-Run
-Get user/expert comments and amend prototype.

Currently the development of expert systems is rather experimental and non-structured, characterized by an incremental and ad-hoc analysis of the domain. In other words, currently the development of expert systems is based upon traditional approaches. This is also supported by the findings of my earlier study [Sagheb-Tehrani 1990a]. Most AI literature, regarding knowledge acquisition as the key, asserts the lack of a development model for expert systems.

4.5 Data, information, knowledge: An attempt to explain them

Fundamental to the design of expert systems is the conception of knowledge and its categories. In the following section an attempt is made to explain the distinction between data, information and knowledge in the context of this study.

One important point which should be considered here is the distinction between data, information and knowledge. However these terms have been used interchangeably. My intention is not to put forward any exact definition for each of the above mentioned terms, because, firstly, it is not in the scope of this paper to put forward an exact definition of the above mentioned terms without presenting sufficient grounds. Secondly, definitions may be taken seriously by various people in a study such as this. Therefore, in the following I shall present an analogy of my conception of data, information and knowledge in the context of this study.

Imagine you have a thermometer which is placed outside your kitchen window. You are almost ready to leave your home to go work. You look at the thermometer, it shows $-10^{\circ}C$, as the following figure shows.
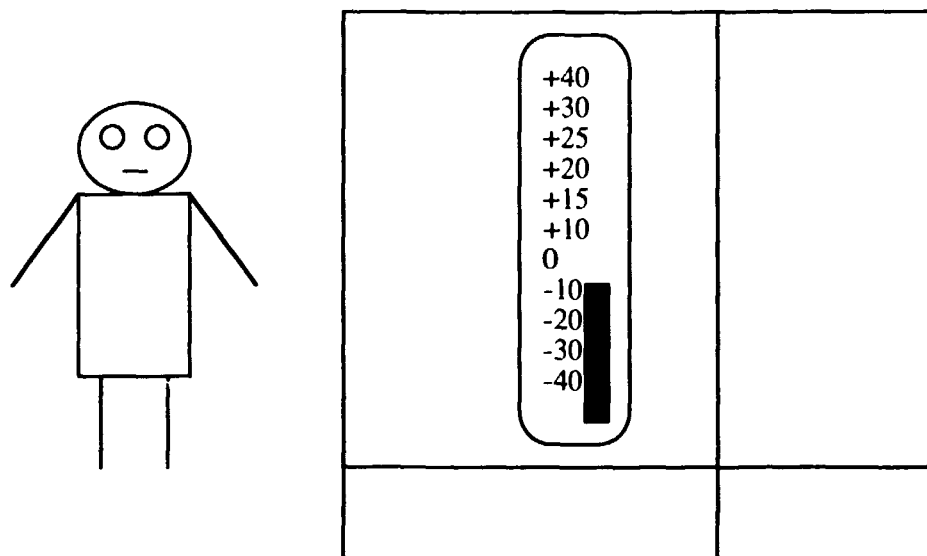
Fig. 4.3: A thermometer which shows -10°c

The interesting question here is , what are data, information and knowledge in this case, if one wants to formalize the relevant knowledge into a system. One may have various perception upon this matter. My conception of data, information and knowledge with regard to the context of this study and the above mentioned example is as follows:

The numbers which are written on the thermometer, I call data.

The temperature which is shown by the thermometer, in this case -10°C, I call information.

My awareness of the fact that by putting on warm clothes I can avoid catching a cold or freezing, I call knowledge.

According to Pritchard [Pritchard 1988], information includes data, facts upon which a decision is to be based; and knowledge-the sum of what is known about a subject (see Fig. 4.4). In order to appreciate this better, we may consider the previous example of data base and knowledge base in Section 3.3.6. In that case we have the following:

Data: Model: ST555
    Name: Sony

    ....

    ....

Information: The TV does not work at all.

Knowledge: If the TV does not work and there is no indication of power at all then check the fuse.

Further, Stonier [Stonier 1984], makes the following analogy between information and the textile industry, in order to distinguish data, information and knowledge.

" The raw fleece is equivalent to data, it may be spun into yarn which represents information. The yarn, in turn, may be woven into cloth just as patterns of information may be woven into knowledge. A loom can weave strands of yarn into patterns of cloth. Similarly, a computer can weave strands of information into patterns of knowledge." p.211.

Information systems

↑

Information

Data   Knowledge

↑   ↑

DP systems   Knowledge
        base systems
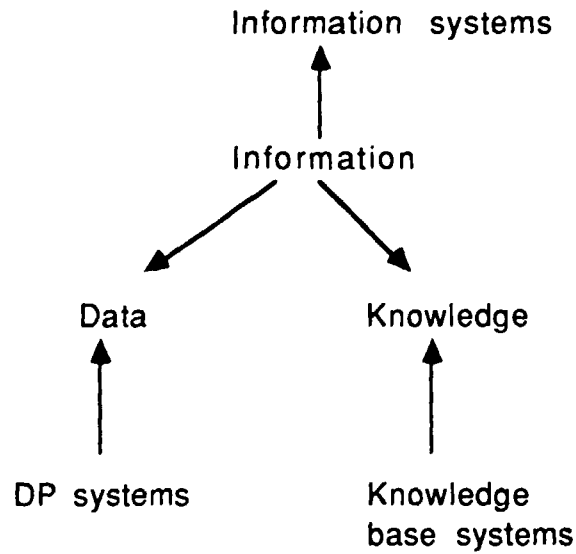
Fig. 4.4: Information, data and knowledge, Adapted from [Pritchard 1988], p.116.

4.6 Classification of knowledge

The other matter relevant to knowledge is its classification. The classification of knowledge can be carried out in many ways[6]. From my point of view, the most relevant are two major types of knowledge in any special domain. They are known as shared (common, formal) and private (informal) knowledge [Alty & Coombs 1984, Hays-Roth et al. 1983, Pritchard 1988]. Feigenbaum and McCorduck [1984] say that, specialized knowledge is of two types: the first type is the facts of the domain- the widely shared knowledge...that is written in textbooks and journals of the field...Equally important to the practice of the field is the second type of knowledge called heuristic knowledge, which is the knowledge of good practice and good judgment in a field. It is experiential knowledge, the "art of good guessing" that a human expert acquires over years of work. Shared knowledge is that knowledge which everybody has access to, such as published facts, concepts and theories. Private knowledge refers to that knowledge which is possessed by private sectors (persons). Human experts' knowledge is placed in the second category. They own private (informal) knowledge that others do not have easy access to. Private knowledge in the context of expertise may use rules of thumb which are known as heuristics[7]. These enable an expert to make relevant intelligent decisions or give advice, see the following figure.

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[6] Many books and articles have been written about the taxonomies of knowledge, for example: Newell [1982], Machlup [1962] and Göranzon[1988]. Further reading about the theory of knowledge [Chisholm 1989].

[7] From a Greek word " heuriskein " means to discover, invent by oneself or to find. Source: TAHDEL [1976]. Furthermore, Polya G [1945], p. 102, says

"Heuristic, or heuretic, or "ars inveniendi" was the name of a certain branch of study, not very clearly circumscribed, belonging to logic, or to philosophy, or to psychology, often outlined, seldom presented in detail, and as good as forgotten today. The aim of heuristic is to study the methods and rules of discovery and invention...."

```
                        Knowledge
                           /\
                          /  \
                         /    \
                        v      v

Shared (formal)          Private (informal)
knowledge                knowledge

   |                        |
   |                        |
   v                        v

Mass-media               Heuristic
                         knowledge
```
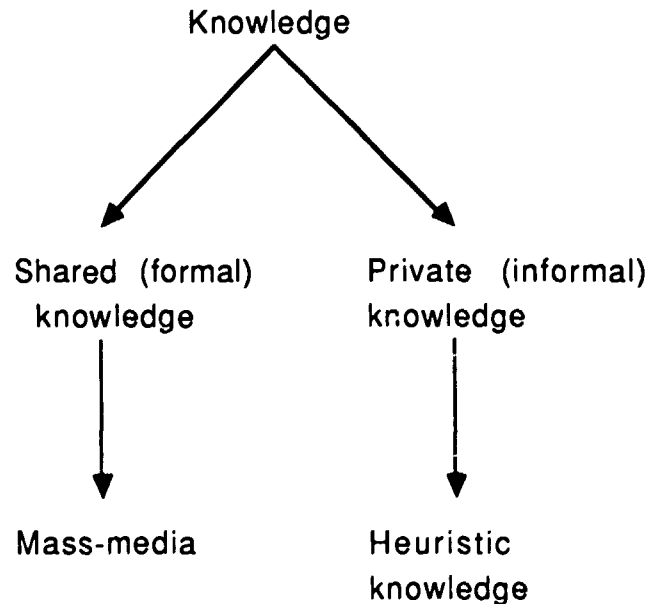
Fig. 4.5: A classification of knowledge

4.7 A view of the knowledge acquisition (KA) process

4.7.1 Knowledge acquisition in general: An attempt at definition

Knowledge acquisition (KA) is a crucial stage in the expert systems development process. To put it in other words, knowledge acquisition is an important and time consuming obstacle to the construction of expert systems [Cullen & Bryman 1988, Kidd 1987, Kim & Courtney 1988, Shadbolt & Burton 1989, Hoffman 1987]. Knowledge acquisition (KA) is the process of eliciting, structuring and representing (formalizing) knowledge from some knowledge source to build an expert system. Shadbolt and Burton [Shadbolt & Burton 1989] have described knowledge acquisition as follows:

"We follow the general convention of referring to the task of gathering information from any source as knowledge acquisition, and the sub-task of gathering knowledge from the expert as knowledge elicitation or KE.", (p.15).

On the contrary, Michalski et al. [Michalski et al. 1983] refer to knowledge acquisition as a process of learning. Considering Michalski's definition, one can say that a human expert becomes an expert during his/her life through elicitation, structuring and interpreting the relevant knowledge. One cannot be an expert only by gathering knowledge [Sagheb-Tehrani 1991b,c]. The other significant point is that some people refer to some tasks of KA as knowledge engineering (KENG). That is correct. But KENG is the art of designing and building expert systems [Feigenbaum & McCordouck 1984]. Therefore, KENG refers not only to some tasks or all tasks which are involved in the knowledge acquisition process, but also involves more than the KA process. In order to understand this better, let's regard Rauch-Hindin's definition [Rauch-Hindin 1986], p.142, in which he refers to knowledge engineering (KENG) as the process of acquiring knowledge and representing it for the computer. According to Feigenbaum's [Feigenbaum 1984] definition, knowledge engineering is more complicated than just the process of acquiring knowledge and representing it. As indeed Gruber & Cohen [Gruber & Cohen 1987] say, knowledge acquisition is a part of the knowledge engineering process which comprises defining a problem, designing an architecture, building a knowledge base and testing and refining the program. Regarding the above discussion, it is important to have a clear distinction between these terms. This leads us to better understand the expert systems development problem [Sagheb-Tehrani 1991b,c]. Furthermore, this gives a better picture of the knowledge engineering process which may provide the concept of various branches of expertise for knowledge engineers (KEN). A KEN may be good at eliciting expert knowledge; another may be good at representing knowledge in computer systems; another may be good at building inference engines or yet another may be good at designing ES and so on. It falls beyond the scope of this paper to discuss these concepts in more detail. My intention was to comments upon these concepts and provide a background for a better understanding of the concept of knowledge elicitation (KE).

Knowledge acquisition comprises the problems: deciding what knowledge is needed, how it is to be used (knowledge utilization), the elicitation of knowledge from human experts and how to represent it (see Fig. 4.6) [Sagheb-Tehrani 1991c]. This process is technically challenging and time consuming [Gruber 1989]. Furthermore, in this process one of the objectives of th. knowledge engineer (KEN) is to change human know-how n. "say-how" through a process of articulation [Lavrace & Mozetic 1989].

```
┌─────────────┐
│Some problems│
│             │
│of KA        │
└──────┬──────┘
       │
       │        ┌────Deciding wh. knowledge
       │        │    is needed
       └────────┤
                ├────Knowledge  elicitation
                │
                ├────Knowledge  representation
                │
                └────Knowledge  utilization
```
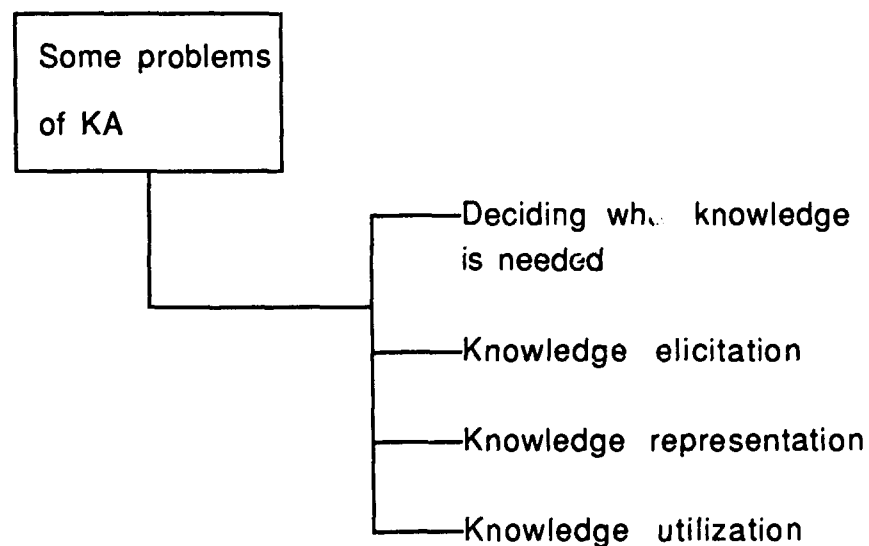
Fig. 4.6: Some problems of knowledge acquisition

4.7.2 Approaches to KA process

As described by Hayes-Roth et al.[Hayes-Roth et al. 1983], the process of knowledge acquisition can be carried out in various ways. At present, the most common practiced is knowledge acquisition by means of a knowledge engineer (knowledge engineer-driven KA), (see Fig. 4.7, a). In this approach, the knowledge engineer extracts knowledge from experts, structures and represents it in a knowledge base. Here, the knowledge engineer is often compared with a system analysts in conventional computer systems development. However, the knowledge acquisition process is a much more complex activity than systems analysis. Knowledge engineers deals with knowledge rather than procedures. A knowledge engineer's task is relatively ill-defined compared to a system analyst's task, so a new set of problems arises in this process [Kim & Courtney 1988]. Some of these problems were explained in the previous section.

It has long been recognized that the development of expert systems may be expedited if the experts themselves could put their knowledge into computers without relying on knowledge engineers as intermediaries [Davis 1976]. In knowledge editing (expert-driven KA), (see Fig.4.7, b), the expert himself puts the knowledge in the expert system by utilizing an editing program. The scope of this approach is limited, particularly, when the structure of knowledge base is predefined and the inference engine is fixed [Wielinga et al. 1988]. This approach has some advantages. First, there is "less noise" introduced in the represented knowledge. Second, the knowledge engineer need not spend time learning domain concepts and particular languages [Kim § Courtney 1988]. The following two problems should be addressed in this approach[8] [Eshelman et al. 1987]. First, indeterminateness, i.e., the expert is likely be vague about the nature of relationships between events. Second, incompleteness, i.e., the expert may forget to specify certain pieces of knowledge.

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[8] For more discussion please see [Eshelman et al. 1987, Kim & Courtney 1988].

The third approach which is not used so often at present is called knowledge induction (machine-driven KA), (see Fig. 4.7, c). A computer program is used to generate the knowledge. It examines the generalities of input which can be utilized in the knowledge base. This approach is recommended for a situation in which a large amount of data or cases must be examined in order to generate the contents of a knowledge base [Wielinga et al. 1988]. This approach has some advantages as well. It is "objective, repeatable, indefatigable, consistent, and easy to understand." [Hart 1985a]. The main advantage of this approach is that the expert finds it easier to give examples of decision cases compared to explain the decision-making process itself. To put it in another way, the expert can describe "what" rather than "how" [Kim & Courtney 1988]. Moreover, the quality of induced results depends both upon the algorithms used and the set of examples. A poor set of examples, attributes, and algorithm results in a poor set of rules. Furthermore, one cannot judge the quality of examples and attributes in advance, because the results of induction are unknown in the early stages [Hart 1985b, 1986]. Finally, In the learning approach (Machine-driven KA), (see Fig. 4.7, d) a learning program may be utilized. In this approach a computer program consults the expert, or is provided with examples or textual materials. On the basis of this interaction, it refines the expert system. The potential use of this approach in commercial applications is presently far from practical [Wielinga et al. 1988].

a- Knowledge engineering
(knowledge engineer-driven KA)

b-Knowledge editing by expert
(expert-driven KA)

Expert

↓

KEN

IE   KB

Expert

↓

Knowledge
editor

IE   KB

c- Knowledge induction
(machine-driven KA)

d- Learning
(machine-driven)

Expert

↓

Induction

program

IE   KB

Text   Examples   Advice

Learning

program

IE   KB
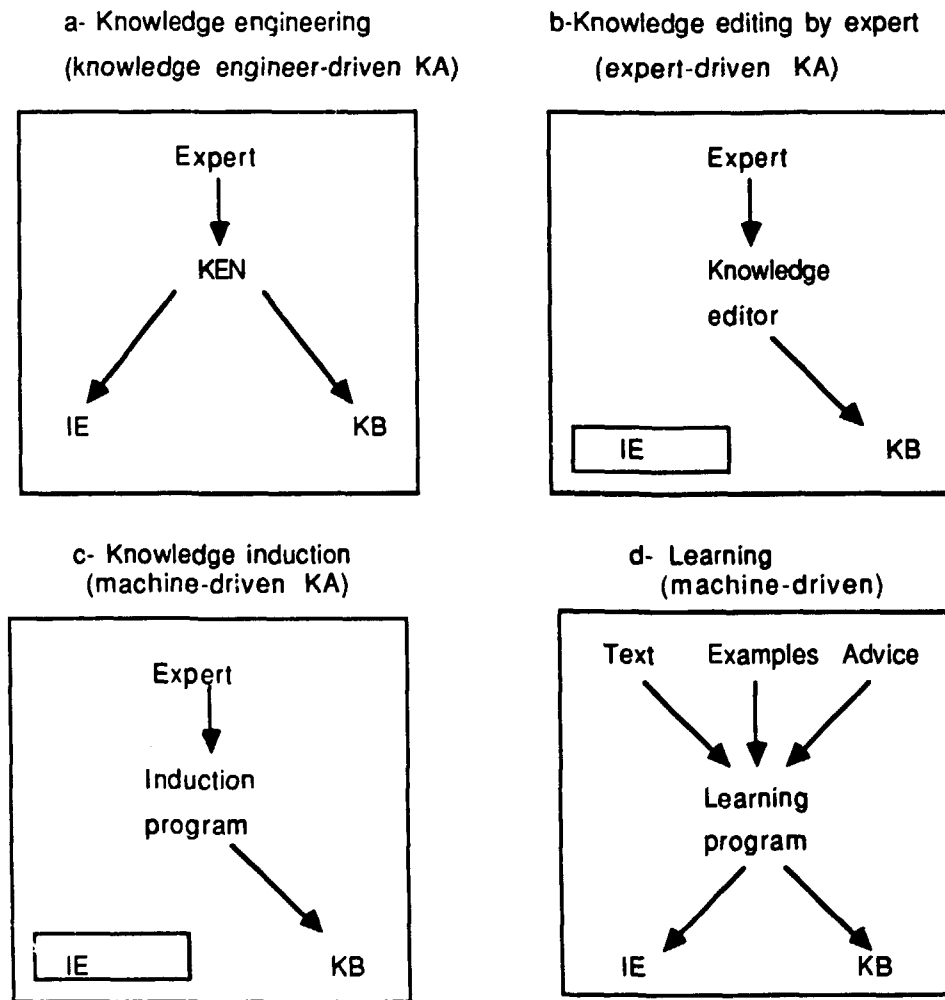
KA=Knowledge acquisition
IE=Inference engine
KB=Knowledge base
KEN=Knowledge engineer

Fig. 4.7: Modalities of KA, Adapted from [Wielinga et al., 1988], p.100

4.7.3 Methodologies for KA

There are various methodologies regarding the KA process in expert systems development [Boose 1986, De salvo 1988]. Examples are: the Precision Knowledge Acquisition[9] (PKA) methodology developed by Expert Knowledge Systems, Inc. ¡EKS 1988]. KADS methodology[10] [Schreiber et al. 1988]. Gruber and Cohen [Gruber & Cohen 1987] define three principles for the design of a knowledge system to facilitate KA. Arliszewski et al. [Arliszewski et al. 1987] present a methodology to design conceptual KA. Further, there are some tools for this purpose[11]. Cullen & Bryman [Cullen & Bryman 1988] argue that conventional approaches to knowledge acquisition is necessary. They claim not a single approach to knowledge acquisition, but almost a "family" of knowledge acquisition context. How this is done in practical terms, they say is the matter of later work! The most widely supported view of knowledge acquisition methodology is the descriptive model introduced by leading researchers [Buchanan et al. 1983]. They describe five stages of knowledge acquisition shown in Fig. 4.8.

The identification stage involves identifying the participants, characteristics of problems, resources and aims. The major products of the identification stage are task description (what knowledge systems will do), a description of a proposed method (how the system will use knowledge to perform the task) and identification of the sources of knowledge available for applying

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[9] For a brief description of the PKA methodology, please see [Naughton 1989].

[10] In this study (KADS Project), their view is that KBS building is a modelling activity. I.e. they assume KBS building as mapping from an understanding of behaviour in the real world to the description of the form of an artifact. They define three intermediate levels of description between the real world and the artifact.

[11] Concerning KA, there are some tools developed or under development. For example, Anjewierden [1987]. Further, some tools are advertised by various suppliers in most AI journals. Moreover, research continues a ways of automating some aspects of the KA process.

to the problem. In the conceptualization, the key concepts, relations and processes are determined. A formal language, such as conceptual structures can be of assistance for identifying key concepts, objects, processes and so on [Gruber 1989]. In the formalization stage, an appropriate knowledge representation is designed. This task also involves deciding that the concepts can be represented in statements of logic [Gruber 1989].

Stages	Tasks	Outcomes

**Identif-
ication**

Identify problem
characteristics

Description of tasks

Description of method

Source of knowledge

**Concept-
ualization**

Find concepts
to represent
knowledge

Determine the key
concepts, entities,
relation and processes

**Formali-
zation**

Design structure
to organize
knowledge

Knowledge represent-
ation is designed

**Implem-
entation**

Formulate rules
to embody
knowledge

Knowledge base is

constructed

Testing

Validate rules
that organize
knowledge

Test the prototype
system

Use feedback

Redesign

Reformulation

Refinements

Fig. 4.8: Stages of knowledge acquisition, Adapted from [Buchanan
et al. 1983], p.139.

In the implementation stage the knowledge base is constructed. The primary aim of this stage is to develop a prototype system for testing. In the final stage, testing the prototype system is evaluated, to see if it achieves the intended performance in test cases. The results of all previous stages of knowledge acquisition are considered for testing. As shown in Fig. 4.8, this methodology has various types of activities that occur during the KA process. This broad scope of the KA process helps one to realize why the KA problem has been difficult to handle. One may find that disparate approaches to KA address various parts of the problem [Gruber 1989].

4.8 Knowledge elicitation (KE)

4.8.1 KE: An attempt at definition

The terms KA and KE tend to be used interchangeably. But there is a clear distinction between them [Addis 1987]. Knowledge elicitation (KE) refers to extraction of knowledge from human experts. Knowledge elicitation is a critical step in developing expert systems. It has also often been acknowledged as the most significant problem in expert systems development [Garg-Janardan & Salvendy 1987]. There are disparate ways to elicit the knowledge of experts: Interviews[12], Induction from example, Documentation analysis, Simulation using prototype, Case study analysis, Observation analysis and so on [Evans 1988, Hart 1986, Garg & Salvendy 1987, Gammack & Young 1985 , Hoffman 1987, 1989, Breuker & Wielinga 1984, Shadbolt & Burton 1989, Welbank 1983, Wright & Ayton 1987]. Different knowledge elicitation techniques are applicable to different forms of knowledge [Gammack 1987]. KE is a critical first step in expert systems development. The performance of the expert systems depend on the reliability, validity and accuracy of the elicited knowledge [Garg & Salvendy 1987]. KE has its own problems such as communication between expert and knowledge engineer.

[12] For further reading regarding various types of interviews and its characteristic, see [Merton 1956, Breuker & Wielinga 1984, Lerner 1956, Zeisel 1981].

Hayes-Roth et al. [Hayes-Roth et al. 1983] have described the problem in this way:

"...The knowledge engineer's job is to act as a go-between to help build an expert system. Since the knowledge engineer has far less knowledge of the domain than the expert, however, communication problems imp..'a the process of transferring expertise into a programme..." .(p.129)

Duda and Shortliffe [Dura & Shortliffe 1983] also indicate that the process of build'.ng a knowledge base requires collaboration between a domain ...pert and an AI researcher.

Further, kno.. ..ge engineers often don't know where to start [Alexander .. al. 1987]. This can be due to inexperienced knowledge engineers [Sagheb-Tehrani 1991c]. The elicitation sub-process is not easy. It requires commitment, interest and enthusiasm from expert, knowledge engineer and user. Furthermore, it is futile to elicit, structure and represent knowledge in expert systems unless it is known what it is for [Hart 1988]. It is important that knowledge engineers realize that the purpose of expert systems is to model narrative thinking, not formal thinking. The distinction between formal and narrative modes of thinking helps one to better understand some of the difficulties of KA. Narrative thinking has to do with implicit assumptions and plausible methods of combination whereas in formal thinking one is allowed to be as confident in the outcome of a chain of reasoning as one is in the premises[13] [Kornell 1987]. Formal thinking has to do with conceivable chains of reasoning, using explicit premises and methods of combination. In the narrative thought, the goal is less clearly defined. The distinction between narrative and formal modes of thought is a distinction between various ways of thinking. From my point of view, formal thinking may be referred to as rational thinking or the rationalistic tradition.

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[13] The concerns of the formal and narrative modes of thought are different at most basic level. Formal thought is about how to know truth and it seeks closed, well-defined systems. Narrative thought is about how to construct meaning and it seeks open, dynamic systems [Kornell 1987].

As Winograd & Flores [1986] say, one may begin to reveal rational thinking by regarding this question "what do you do when faced with some problem whose solution you care about". According to rationalistic tradition, this can be depicted in a series of steps as follows:

1-Characterize the situation in terms of identifiable objects with well-defined properties.
2-Find general rules that apply to situations in terms of those objects and properties.
3-Apply the rules logically to the situation of concern, drawing conclusions about what should be done [Winograd & Flores 1986], p.15. This can be viewed as the epistemological assumption of rationalistic reasoning [Ehn 1988], p.53.

Narrative thinking can be referred to as irrational thinking. Dreyfus & Dreyfus [1986], say

"Although irrational behaviour-that is, behaviour contrary to logic or reason-should generally be avoided, it does not follow that behaving rationally should be regarded as the ultimate goal". p.36

As one may notice, the former thinking has been the basis for several critiques of AI[14]. Some more discussion of this matter is covered in Chapter 10. The implications of the distinction of KE can be reflected in the process of KA. The latter type of thinking believes that one cannot extract the heuristic knowledge from human experts. A human expert cannot verbalize his/her knowledge. On the other hand the former thinking believes that the rules are there functioning in the expert's mind. Otherwise, how can an expert perform the task? Here, one requires good method of knowledge extraction. From my point of view, this is where the problem exists, i,e. a lack of relevant KE methods. This deserves its own research which may fall within the cognitive sciences.

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[14] For example see, Deryfus [1979], Winograd & Flores [1986], Deryfus & Deryfus [1986] and Haugeland [1981].

4.8.2 What kinds of knowledge to elicit

In the context of knowledge elicitation, it is generally recognized that there are two kinds of knowledge, declarative (content) knowledge and procedural (process) knowledge[15] [McCarthy & Hayes 1981, Wright & Ayton 1987, Garg & Salvendy 1987, McGraw & Harbison 1989]. Declarative knowledge (equal to "knowing that") is information about facts, concepts and relationships of a particular domain. In other words, declarative knowledge refers to the nature of tasks. The main distinction between procedural knowledge and declarative knowledge is the ability to verbalize or express the knowledge [McGraw & Harbison 1989]. Procedural knowledge (can be linked to "knowing how" to do something) is information about how to reason with declarative knowledge. In other words, procedural knowledge is about the ways of doing a task efficiently [Wright & Ayton 1987, Garg & Salvendy 1987]. This knowledge is difficult for experts to verbalize. For instance imagine how difficult it would be for us to verbally describe how to ride a bicycle in an exact way! Knowledge engineers require special techniques for extracting this type of knowledge [McGraw & Harbison 1989].

4.8.3 Overview of some KE techniques

4.8.3.1 Interview technique

Interview is a technique that many knowledge engineers have used to elicit an expert's knowledge [Kim & Courthney 1988, Weiss & Kulikowski 1984]. The word "interview" has many varied connotations depending on the discipline that is defining the term [Stewart & Cash 1987]. There exists a general agreement that the main purpose of an interview is effective communication. The major benefit of the interview technique is its ability to assist in outcome clarification through repeated probing by the

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[15] knowledge can be further classified into surface (shallow) knowledge and deep knowledge. Shallow knowledge is similar to the heuristic rules found in the first generation of expert systems. Deep knowledge consist of domain theories and problem solving knowledge, the trend of the second generation expert systems [Steel 1985,1988].

interviewer [Agarwal & Tanniru 1990]. Interviews fall along a dimension. At one end is the structured, goal-oriented interview and at the other end is the unstructured interview. Structured interviews have a number of characteristics, such as pre-planning of the questions and their order, and specification of things the interviewer should and should not do. The idea that interviews can be structured beforehand is to make interviews more efficient [Hoffman 1989]. The structured interview has some benefits compared with unstructured interview. Its ability to extract particular information that is easy to review, interpret, and integrate, and the extent to which it forces the expert not to diverge from the aims of the knowledge acquisition session [McGraw et al. 1989]. Unstructured interview, characterized by asking "rather general questions about the field, tolerating digressions, tape recording everything and hoping to extract useful information from the transcript" [Welbank 1983]. What precise questions should one ask? Perhaps the best way to begin is to ask the human expert to talk about the domain of expertise so that one can establish an overview of the area. It is then possible to ask direct probing questions to access declarative and procedural knowledge [Wright & Ayton 1987]. Unstructured interview can be regarded as a useful technique for information gathering in the early stages of knowledge elicitation, when issue exploration and a broad familiarity with the domain is desired [Neale 1988]. In practice, interviews are rarely completely unstructured or completely structured [Agarwal & Tanniru 1990]. Both structured and unstructured interviews may be enhanced by the utilization of probes, i.e, follow-up questions to a particular part of an answer. While probing in a structured interview deals mainly with extraction of specific information relating to structure, in an unstructured interview probing deals primarily with issue clarification [Neale 1988]. This technique is generally controlled by KEN, i.e., knowledge engineer driven, as shown in Fig.4.7a.

4.8.3.2 Observation and protocol techniques

One can say, the best method of discovering people's procedural knowledge involves studying their behaviour whilst actually engaged in tasks which exercise their cognitive skills [Evans 1988]. Behaviour analysis is simply observing the user or expert while she/he is performing a particular task. For example, subjects may be studied in the laboratory performing tasks which only simulate those in the real world of application. Alternatively, experts may be observed in the field, i.e., whilst conducting their professional activity. This technique may involve watching a subject and making notes, or it could involve more complex techniques such as analysis of video taped episodes. This technique is generally controlled by the knowledge engineer (KEN), i.e., knowledge engineer driven, as shown in Fig.4.7a. In order to extract information about the subject's knowledge, one may consider informal observation and make some systematic attempt to trace the thought process used. In order to do this, one must record some continuous trace of behaviour, known as a protocol. Protocol analysis is the collection of information from subjects by having them "think aloud" whilst performing a task with the verbalizations being tape recorded for later analysis [Evans 1988]. This technique is driven by an expert, shown in Fig.4.7b. Ericsson and Simon [1984] provide a critical but comprehensive discussion on methods used to collect and analyse protocols and factors that users of protocol analysis should be aware of. They list timing of verbalizations, directness and content of verbalizations and amount of intermediate processing required as factors that affect the consistency and completeness of verbal reports. This technique is used mostly to understand a domain's process or task.

4.8.3.3 Documentation analysis and prototype techniques

Documentation analysis (text analysis) is utilized only for understanding the overall problem domain. It is particularly useful for systems where regulations and rules are the norm, such as in tax or law systems.

As there is no direct information interaction, documentation analysis reduces some of the communication problems between human expert and knowledge engineer. This technique is knowledge engineer driven, shown in Fig. 4.7a. Prototyping is commonly known as an evolutionary design method in software engineering. Prototyping is used when requirements are difficult to define in advance or when requirements may change significantly during development [Alavi 1984]. In other words, this technique is well-suited to domains that may not be fully understood through some form of verbalization. Prototyping is knowledge engineering driven in the context of ES development. The prototyping is useful for extracting expert reaction leading to further KE if necessary.

4.8.3.4 Induction technique

The classical approach to the extraction of knowledge is to program facts and rules into the machine. But, it requires a large amount of time to program the equivalent of human intelligence. An alternative approach allows the machine itself to learn how problems are solved. Among various types of learnings, learning from examples based on inductive inference is the most often used technique. The main idea behind induction is that instead of directly describing the decision-making processes, the human expert provides a set of examples cases consisting of decisions, along with the attributes which were considered in making those decisions. A computerized algorithm is then used to infer some rules from those examples [Hart 1985b,1986]. The reasoning is from the particular to the general. This is known as a bottom-up approach. The main advantage of this technique is that the human expert often finds it easier to provide examples of decision cases rather than to describe the decision making process itself. In other words, the use of examples helps reduce some of the communication problems between the expert and knowledge engineer. This technique is known as machine-driven, as shown in Fig.4,7c,d.

4. 8.4 Comparison of RA in SE and KE in KENG

Software engineering (SE) is an emerging area of practical and academic activity that provides the tools, techniques, and methods vital to the application of the knowledge of computer science and other fields in a systematic way to obtain desired development goals. Considerable study is being done in the area of requirements acquisition to reduce the misunderstanding between the user's requirements and the formal specifications. In SE contractors or end users decide what they want and communicate their requirements to software engineers. The software engineers design an overall system to meet the contractor's (client's) requirements. Put it differently, it is well understood that the development of effective information systems (IS) requires thorough analyses of the user requirements prior to IS design. This step in the process of systems development is known as information requirement analysis (RA) or requirement definition. The initial requirement which is usually imprecise and incomplete, focuses primarily on user requirements specified in terms of process, entity, and information flow structure. The final specification emphasizes the structure and behaviour of the desired software application.

RA is the process of understanding and recording in a clear form the needs to be met by the design and construction of a system. SE like any other engineered artifact goes through a life cycle model, notably, analysis, design, construction and evolution. Specifying a correct and complete information requirement is a necessary part of designing an IS. Many IS failures can be due to a lack of clear and particular information requirements. Clear identification of information requirements early in the design process produces more successful systems and allows for early correction of errors while the cost of correction is lower. In other words, the trend that is affecting what a software engineer does in development is the awareness that what a software engineer does in the early phase of the life cycle may have significant impacts on the cost and quality of later phases. In the design of expert systems, a similar sub-process of extracting knowledge from the expert has been studied under the banner of KA [Sagheb-Tehrani 1991a,b,1992a]. As mentioned earlier, KA is

the process of eliciting, structuring and representing (formalizing) knowledge from some knowledge source in order to construct an expert system. This means that the KA process is consist of the sub-processes of KE (knowledge elicitation), KU (knowledge utilization), and KR (knowledge representation). Thus, regarding this complex process, there is a clear distinction between KE and KA in the creation of expert systems development model. KENG is the art of designing and building expert systems (These terms have discussed before). SE is the art of designing and building IS. There are some important differences between SE and KENG. Broadly speaking, ES development in substantial ways is different from conventional computer systems. One may refer to some tasks of designing and building IS as SE. For example, the sub-process of RA in the life cycle model of IS development is referred to as SE. In the same way, the sub-process of KE in ES development can be referred to as KENG. There are some similarities in the activities of both RA and KE. But one cannot really claim that RA in SE is equivalent to KA in KENG. A knowledge engineer's task is ill-defined when compared with systems analyst's. This brief discussion is my reaction to a recent article by A.Byrd et al 1992. They claim that RA in SE and the KA process in KENG are two sides of the same coin. To put it differently, they claim that those processes are equivalent. Moreover, they have used the terms KA and KE interchangeably. For example, they refer to KE techniques as KA techniques [Byrd et al. 1992 pp.125-131]. From author's point of view, this is the main problem of their paper [Byrd et al. 1992] which has led to the misinterpretation of regarding RA as equivalent to KA. In my opinion, there are some similarities in both RA and KE activities. It is in this case researchers in both fields can learn from each other. When one examines closely, many entities and processes involved in RA and KE are almost identical. Furthermore, in my previous investigations [Sagheb-Tehrani 1990], the respondents of questionnaires reported that inexperienced knowledge engineers had some problems, because their expert systems were developed by DP experts. This indicates that they viewed KENG as equivalent to SE which led to the failure of their systems. This emphasizes that one should not treat RA and KA as two sides of the same coin. The following table shows a comparison of KE techniques.

KE techniques	Approach	Origin of application	Type of problem
-Interview	KEN driven	KENG/SE	High risk of communication problem between participating actors
-Documentation analysis	KEN driven	KENG	Misunderstanding , low risk of communication problem
-Case study	KEN driven	KENG/SE	Medium risk of communication problem
-Induction	Machine driven	KENG	Low risk of communication problem
-Prototype	KEN driven	KENG/SE	High risk of communication problem
-Protocol analysis	Expert driven	KENG	Low risk of communication problem
-Observation	Expert driven	KENG	Medium risk of communication problem

Table 4.3:Comparison of KE techniques

4.9 Knowledge representation (KR)

4.9.1 Introduction

Knowledge representation (KR) is a significant problem in knowledge acquisition (KA) process [Duda & Shortliffe 1983, Feigenbaum & MacCorduck 1984]. In other words, in what manners should the knowledge of a domain be represented in the computer so that it can be conveniently accessed for problem solving [Feigenbaum & McCorduck 1984]. In expert systems development, a good solution depends on a good representation. For expert systems applications, the initial choice of a representation technique is particularly important. This is because the possible representation techniques are diverse and the forcing criterion for the choice is normally not clear at the outset of the project. The consequence of inadequate selection can be a major problem in the later stages of an ES project, if it is discovered that critical information cannot be encoded within the chosen representation technique. A knowledge representation technique should support a number of different activities. Various techniques may be appropriate for representing different types of things and for supporting different kinds of activities. This can force us in some cases to either find a representation system that supports multiple uses of knowledge or else represent the same knowledge several times in various representational systems. It would be desirable to have a single representation technique in which knowledge that has multiple uses will support those uses. There are various knowledge representation techniques such as: frames, rules, semantic networks, scripts and hybrid [Ramsey & Schults 1989, Harmon & King 1985, Frost 1986, Waterman 1986],(See the following figure).

```
┌─────────────┐
│ Various types │
│             │
│ of knowledge │
│             │
│ represent-  │
│ ation       │
└─────────────┘────────────────┬──────Rules
                               │
                               │
                               ├──────Frames
                               │
                               │
          └────────────────────┼──────Semantic network
                               │
                               │
                               ├──────Scripts
                               │
                               └──────Hybrid
```
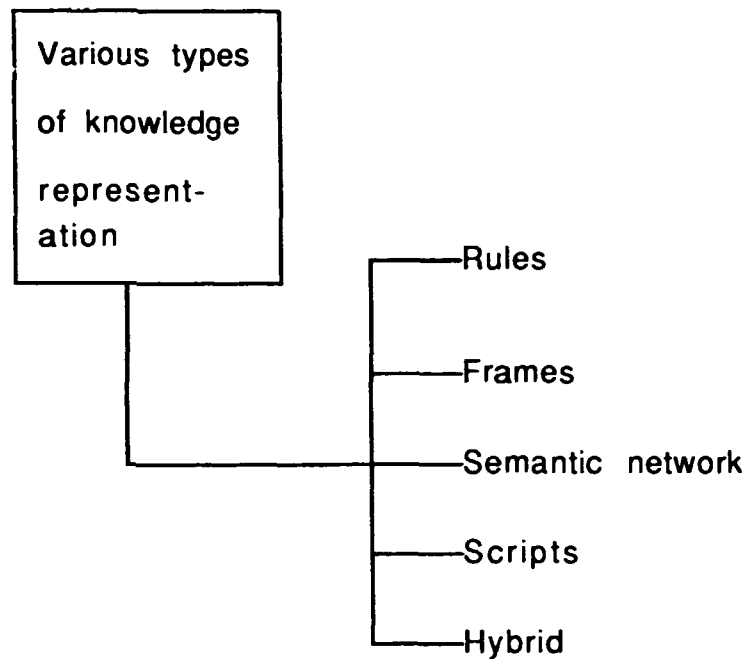
Fig. 4.9: Various types of knowledge representation

4.9.2 Semantic networks

Quillian [Quillian 1986] is generally acknowledged as the inventor of semantic networks. A semantic network consists of nodes which are connected together by arcs or links. Nodes represent objects, concepts, events or hypotheses and arcs (links) represent relationships between these nodes [Ramsey & Schultz 1989, Harmon & King 1985]. Semantic networks have been used for various purposes. They are usually used to describe hierarchical information (see Fig. 4.10).
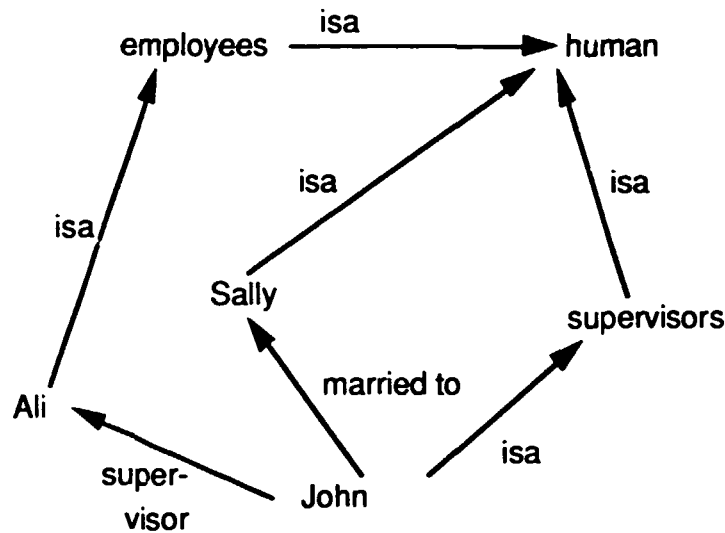
Fig. 4.10: A simple example of a semantic network

The main advantage of a semantic network is that related objects are located next to each other, so searching for information is usually straightforward. Also, semantic networks give a clear description of knowledge because they give a picture of the structure of the information. A shortcoming of this method is that there are no formal ways of dealing with them. In addition, the structure of a real-problem may get very complex. Thus, the search may be done in an inefficient way [Ramsey & Schultz 1989].

4.9.3 Rule-based representation

Rule-based systems (also called production systems[16]) are composed of production rules (rule-base), a data base (working memory) and a control system (rule interpreter). The domain knowledge in a rule-based system is represented as a set of rules of the type:

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[16] For further reading about production systems, please see [Newell & Simon 1972].

IF
Condition [A, B, C]
     THEN
Action   [Y].

A data base (working memory) is utilized to store facts or assertions created by rules. The control system determines which rule is applied next [Alty & Coombs 1984, Ramsey & Schultz 1989]. Fig. 4.11 illustrates a simple example.

Data base (working memory)
A=9, B=2, C=4, D=3
Rules :
1) IF A >= B   THEN   Y=A
2) IF B >= C   THEN   Y=B
3) IF A < B   THEN   X=D
4) IF B =< C   THEN   X=D, STOP.

Control structure
Try rules in sequence, until one fires. Terminate when stop is signalled.

Fig. 4.11: An example of a simple production system

4.9.4 Frames

Frames were originally developed by Minsky [Minsky 1975]. A frame is a method of representing descriptive information. A frame contains slots which contain values. Usually, a frame will describe a stereotyped class of objects, concepts, or events which have a set of expected slots. Slots may also contain default values, points to other frames, set of rules or procedures by which value can be achieved [Harmon & King 1985, Waterman 1986, Ramsey & Schultz 1989].

Concepts	
Slots:	Entries:
Slot 1	Value 1
Slot 2	Value 2
	Procedure 2
Slot 3	Value 3
....	.....
....	.....
Slot n	Value n

Fig. 4.12: A node in a frame system, Adapted from [Waterman 1986], p.75

Frames are good for representing descriptive information. Also, procedural and declarative knowledge can be represented by a frame. It can also represent hierarchies of information. One shortcoming is that there is no formal theory of frames, i.e., there are no formal ways of dealing with them yet [Frost 1986, Ramsey & Schultz 1989].

4.9.5 Scripts

Scripts [Sticklen et al. 1985] are frame-like structure which represents a common sequence of events such as "going into a shop, selecting some goods, and paying for them." [Frost 1986, Ramsey & Schultz 1989]. Prototype scripts consist of slots which can be filled in with details about a specific event when a script is instantiated. Further, scenes within scripts may lead into other scripts as well. There are preconditions which should be met before the sequence takes place. Roles are slots for the people who appear in an instance of the script, and props are slots for the objects which appear in an instance of the script. Results are the conditions which should be true after the completed script. Point of view is a slot for a person which indicates that the sequence of events in the script is from that person's point of view. Scenes are ordered and represent the chain

of events which take place [Ramsey & Schultz 1989]. See the following figure, regarding the above mentioned example.

Shop script:

props:

Money

Cash-register

Basket

Goods

Roles:

Customer

Shop attendant

Shop owner

Preconditions:

Customer perceives that he needs some goods

Customer has some money

Results:

Customer obtained intended goods

Customer has less money

Shop owner has more money

Point of view:

Customer

Scene 1: Enter into the shop

Search for intended goods

If the goods are not available, go to scene 2

If the goods are found, go to scene 3

Scene 2: Goods not available

Scene 3: Available goods

Fig. 4.13: A simple shop script example

The main advantages of a script is that it gives a natural way of representing and organizing descriptive information. The drawback of using scripts is that they can only be utilized when dealing with common sequences of events [Ramsey & Schultz 1989].

4.9.6 Hybrid

Sometimes more than one single form of knowledge representation (KR) is required for developing an expert system. Some expert systems have utilized the advantages of disparate KR techniques by combining them in one system. This is known as hybrid representation. The main objective of utilizing hybrid KR is to permit the representation of both shallow and deep knowledge[17]. One of the most common hybrid representations involves rule-based and frame or network representation (see Fig. 4.14). Hybrid representation is not recommended for a situation where the knowledge readily fits a single paradigm [Ramsey & Schultz 1989].

Concept 1	
Slot 1	Value 1
Slot 2	Rule-based
Slot 3	Value 3
- - - - - - - - - - -	- - - - - - - - - - - - - - - - -
Slot n	Value n

Fig. 4.14: Rule-based in slot frame, Adapted from [Ramsey & Schultz 1989], p.293.

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[17] Deep knowledge consists of domain theories and problem solving knowledge. Shallow knowledge is similar to the heuristics rules found in first generation expert systems. For more details, please see [Steel 1985, 1988].

Each of the above mentioned various representation methods has its own features. Selecting the appropriate knowledge representation method plays a significant role in the development of an expert system. The question of what is the best method of knowledge representation is still an open question in the AI community [Rauch-Hindin 1986]. This matter requires its own separate research. According to Ramsey & Schultz [1989], the following features should be considered when choosing a knowledge representation method:

-Ease of representation for particular domain

-Efficiency of space and time

-Relationship between knowledge base and inference engine

-Ease of human understanding and uncertainty.

4.10 Knowledge utilization

The other significant problem in expert systems development is knowledge utilization[18]. Knowledge utilization (how it is to be used) refers to how the inference engine should be designed [Feigenbaum & McCordouck 1984]. In other words, what form of reasoning (problem solving strategies) should be applied in order to achieve a good performance for a particular domain. What search strategies should be used in the relevant form of reasoning? What inference strategies should be utilized? These are the questions which a knowledge engineer is faced with, when designing an expert system (some forms of reasoning, search strategies and inference strategies are mentioned in Chapter 3).

4.11 Summary

In this chapter, the expert systems development process and associated problems were discussed. Various types of information systems and problems were explained. Also disparate approaches and methodologies of expert systems development were argued. The knowledge acquisition process, its approaches, methodologies and its problems were explained.

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[18] There are various models and paradigms describing and understanding knowledge utilization from many disparate disciplines. For a deep discussion, please see [Beal 1986].

5. SOME CONTRIBUTIONS TO THEORETICAL FRAMEWORK

5.1 Introduction

The objective of this section is not to present a complete account of system thinking history. The intention is to outline very briefly some aspects of my conception of system thinking essential for the understanding of its nature in the development of expert systems from my own point of view. Central to my understanding of system thinking essential for ESD is the "holistic view". As mentioned before, the study presented here is based on the "holistic view" school. Thus, this chapter may provide a better framework for the concept of a "holistic view".

5.2 System thinking

Nowadays, we live in a world which is quite complex. The complexity is defined by the number of elements in a system, their features, the connections between the elements, and the degree of organization inherent in the system [Schoderbeck et al. 1985]. For example, we may consider a transportation system which is consists of several types of transportation systems, such as railway systems, highway systems, seaway systems and airway systems. In order to conceive this, one is required to look at a system from a broader perspective, from a holistic viewpoint. The viewing of a problem as a whole is termed the system approach [Schoderbeck et al. 1985].

One can argue that the systems approach was born as the outcome of the recognition of the complex behaviour, which arises in both natural and contrived (man-made) systems, in order to achieve control over this behaviour.

There are various specialized frameworks for the systems approach, for example general the system theory (GST). One can say that the systems approach evolved out of a general system theory (GST). The main pioneer of GST was L.V. Bertalanffy [Bertalanffy1968]. Before GST emerged, one utilized the

analytical approach. GST is regarded as a methodology as well as a valid framework for viewing the real world. GST provides the framework for viewing complex phenomena as systems, as wholes, with all the relationships and parts [Schoderbeck et al. 1985].

5.3 GST: Its contribution to expert systems development

One of the main contributions of GST in expert systems development is, the holistic view. Comparing expert systems development with conventional computer based systems, one may recognize that expert systems development is much more complex than traditional computer based systems [Sagheb-Tehrani 1991c, 1993b]. This aspect is mentioned in the previous chapter. One cannot utilize the analytical approach for expert systems development, in which the whole is broken down into its constituent parts and then each of the decomposed elements is studied in isolation, i.e., without regarding their relationships with their environments.

For example, consider the KA process which consists of extracting knowledge, structuring and representing knowledge from some source to build an expert system [Sagheb-Tehrani 1991b, 1992a]. Applying the analytical approach for the above mentioned process in order to handle each sub-process in an isolated environment, one can never build an expert system. By not considering the relationships among various sub-processes and their environments, how can one for example, realize what knowledge to elicit; select an appropriate knowledge representation method or handle knowledge utilization. By considering the systems approach with which one attempts to provide the whole with all its interrelated and interdependent parts in interaction, one may handle a complex problem (in this case expert systems development) in an efficient way.

The other main contribution of GST is distinguishing between closed systems and open systems. In a closed system, no extra resources enter into the system from an external environment. All the resources of the system are presented in it [Schoderbech et al. 1985]. On the contrary, open systems import resources from

the external environment and then transform them into a useful
output for input into other systems in the environment
[Schoderbeck et al. 1985]. As mentioned before, the knowledge
base in an expert system is rather active and endeavours to
complete missing or uncompleted information via an interface
with a user. This implies that expert systems require a continues
interaction with their environment. Developing an expert system
with closed system thinking is not possible, because a knowledge
base is usually creative here while a data base is not. The
knowledge base plays a fundamental role in the expert system
function since all the actions performed by the system have their
origin in the interpretation of the knowledge base contents. As
the domain knowledge changes over time the knowledge base
should be changed as well. This process involves experts,
knowledge engineers and users. Experts have to evaluate how well
the knowledge base fits the overall structure of the problem
domain. Knowledge engineers act as designers of knowledge base.
From my point of view, expert systems development requires open
system thinking in order to be able to design an active knowledge
base (see the following figure).
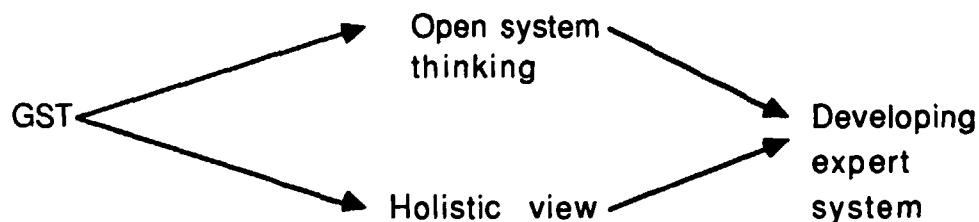
Fig. 5.1: Some contributions of GST in expert systems
development

5.4 The matter of design

Before explaining the GST contribution in the process of design
from my own point of view, it may be useful to first define a
definition of design, because designing can mean many different
things to the people who design. As Winograd and Flores [1986],
p.40, say, "In order to understand the phenomena surrounding a

new technology, we must open the question design. To them design is the interaction between understanding and creation. As Simon [Simon1982] says, we live in a world which is much more a man-made or artificial one today than it is a natural one. One may regard that all artificial things are designed. The processes of design is one or more participant's decision and consideration [Wise 1985]. Lawson [Lawson 1986] points out that the process of science and design are not analogous. The most important difference is that design is prescriptive while science is descriptive. In other words, design deals with questions of what should be and could be, while science deals with what is, how and why. According to Jones [Jones 1980], design is a blending of art, science and mathematics. There are various definitions of design. To find a definition for design, I examined much relevant literature. Some of the definitions and descriptions of designing which are given in [Jones 1980], p.3, are as follows:

-Decision making, in the face of uncertainty, with high penalties for error [Asimow 1962].
-Finding the right physical components of a physical structure [Alexander 1963].
-Engineering design is the use of scientific principles, technical information and imagination in the definition of a mechanical structure, machine or system to perform prespecified functions with the maximum economy and efficiency [Fielden 1963].
-Simulating what we want to make (or do) before we make (or do) it as many times as may be necessary to feel confident in the final result [Booker 1964].
-A goal-directed problem-solving activity [Archer 1965].
-A creative activity- it involves bringing into being something new and useful that has not existed previously [Reswick 1965].
-The imaginative jump from present facts to future possibilities [Page 1966].
-Relating product with situation to give satisfaction[Gregory 1966a,b].
-The performing of a very complicated act of faith [Jones 1966].
-The optimum solution to the sum of the true needs of a particular set of circumstances [Matchett 1968].

Hubel and Lussow [Hubel & Lussow 1984], p.3, say, "To design is also to plan, to lay out, to arrange, and to make selections". H.Simon [1982], p.133, The sciences of the artificial, should be read by anyone concerned with design and computing. In tneme, he points out, design is concerned with how things ought to be, with devising artifacts in order to obtain goals. Furthermore, the following definition was given in [TAHDEL 1976]: "The invention and disposition of the forms, parts or details of something according to a plan". Lawson [1986] and Freeman [1983] say that, the word of design has become one of those words whose meaning one cannot be really sure of. Therefore, one may say that specifying or finding a definition of design is not an easy job, because designing can mean many different things to the designer. One aspect of designing is important among designers, i.e, designing is challenging [Hubel & Lussow 1984]. All designers are challenged to solve real problems that will lead to improvements in people's environment. They are challenged to create things for human needs. Put differently, all designers realize that there is a reason for designing. Either they believe the solution will improve the quality of life or they believe the solution is a necessity. To design is to dedicate oneself to a problem. This requires gathering relevant information, observing basic functions and utility, regarding human factors and selecting suitable structures, forms, materials and methods [Hubel & Lussow 1984].

5.5 The Design Process: The process is common and endless

All designer's activities have something in common, i.e., all designers and activities have a basic process in common. Each process begins with a problem and works toward a solution, regarding its particular requirements, limits and situations. As one may realize from the various descriptions of designing mentioned above, the descriptions of designing are quite varied, but they do have a common theme of addressing the process of design, not the end results. One may understand the concept of design by looking at the process of design, i.e, from the first stage to the last stage. In this way, one can come up with the same problem as one did with defining a definition of design.

There exist many maps of design processes [Lawson 1986, Markus 1969, and Maver 1970] suggest that one requires to go through the decision sequence of analysis, synthesis, and evaluation in a map of design process. It is worth giving a rough definition of the above mentioned three terms, because, these terms often appears in the literature. Analysis refers to the ordering and structuring of the problem. Synthesis is the generating of solutions. Evaluation refers to the evaluation of suggested solutions against the goals defined in the analysis phase. It is significant that one's map of design process allows for feedback loops, (see the following figure), because todays design problems are very complex.
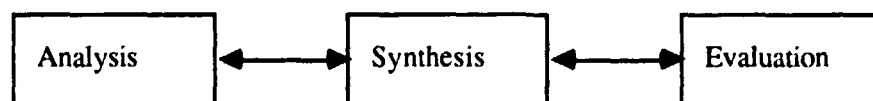
Fig. 5.2: A map of design process, Adapted from [Lawson 1986], p.28.

The feedback loops are very significant for the problems which require novel design situations, i.e., those design situations which are characterized as fluid situations [Bally et al. 1977]. Wise [Wise 1985] refers to them as open-ended and Rittel [Rittel 1969] refers to them as "wicked problems". In other words, those problems for which one cannot state a complete formulation consisting of all the information required for conceiving and solving them [Rittel & Weber 1981]. Regarding the ten distinguishing features [Rittel & Weber 1981], pp.89-98, one may come to the conclusion that most of todays design problems are characterized as wicked problems [Elam 1988]. One should realize that traditional design methods cannot handle such problems. Traditional design methods are too simple for solving such complex problems. A complex design problem offers an inexhaustible number of solutions. Therefore, the design process cannot have a limited and identifiable end. In other words, a designer can always endeavour to do a better job. It is the designer's job to identify the end of his/her process as a matter of judgement. Time, money, and information are often the main

factors for an early end to the design process [Lawson 1986]. Thus, one may view the design process as a continuous process.

5.6 Some factors involved in the design process

The use of a map of design process and its conception is based on one's general conceptions [Sagheb-Tehrani 1991a]. One's general conception is constructed by a number of factors such as, philosophy, problem-domain, morality, technology, politics, culture, religion, intelligence, and roles of designer and user. While the basic concepts of design are not well conceived, I have found the above mentioned concepts very useful in understanding the design process (See the following figure). Realize the role of various factors involved in the design process depends upon one's system approach.
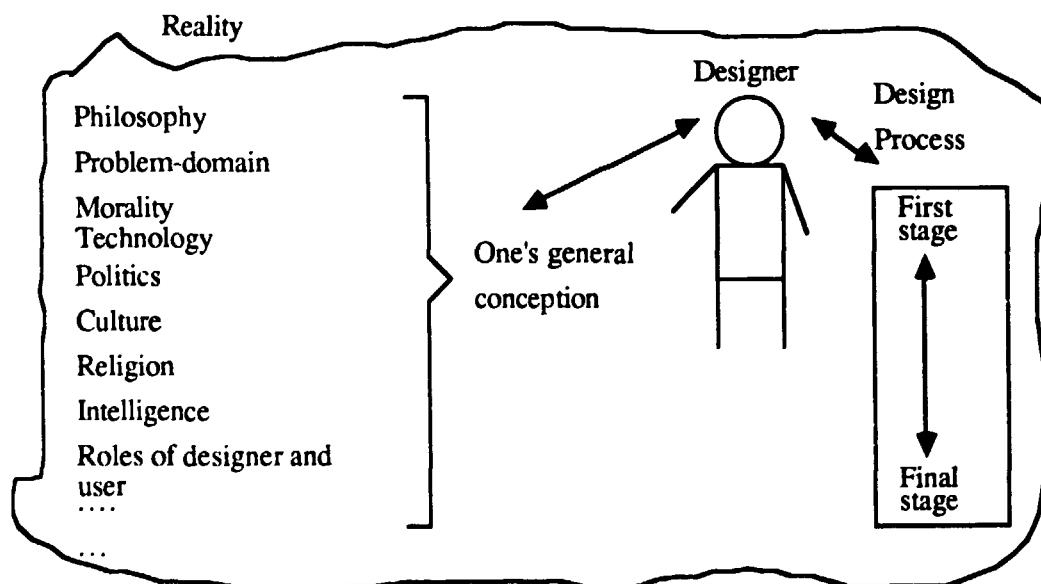
Fig. 5.3: One's map of design process, Adapted from [Sagheb-Tehrani 1991a], p.351

In studying design process, one may forget that the mind of the designer continues to function outside the design workshop. One should really view designing as one the many mental activities performed by designers [Lawson 1986]. Furthermore, Lawson [1986], p.119, says,

"In particular designers usually design not just because they enjoy doing it but also because they tend to be fascinated by the sort of things they create. This fascination cannot help but lead to a study which itself generates a collection of attitudes, which we will here call philosophies, which in turn must be seen to have their effect on the design process itself".

This matter (subject of philosophy in design) is supported both in Ehn's work[1] [Ehn 1988] and Winograd and Flores [1986]. They say, "...we must step back and examine the implicit understanding of design that guides technological development within our existing tradition of thought", [Winograd & Flores 1986], p.5.

A designer should realize that todays design problems are complex. A designer cannot keep everything in his/her mind. Therefore, the issue here is what kind of strategy should be employed. Lawson [1986] says, as the designers philosophies vary so do their strategies. For instance, many designers view the development of an information system as a linear process while other designers view it as another alternative process [Bally et al. 1977]. This is due to the designer's conception in general [Sagheb-Tehrani 1991a]. Churchman[2] [1979] says, the mind of a system planner may be influenced by politics, morality, religion and aesthetics. He refers to them as the enemies of the system approach. As indeed Ehn [1988] says,

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[1] In his work [Ehn 1988]pp.1-141, he discusses the philosophical issues for understanding design and use of computer artifacts. He emphasizes human practice which is a possible philosophical foundation serving as an alternative to the Cartesian design philosophies of rationalism and dualism. Put differently, he argues that human practice and understanding in everyday life should be taken as the ontological and epistemological point of departure in inquiries into design and use of computer artifacts p.123.

[2] Churchman has a humanistic approach to design process.

" A science of design and use of computer artifacts is advised to learn from the Social Sciences.....One message addressed to practical design was that it is a political process, in our society often a process of rationalization, and as such neither neutral nor rational as a mean for humanization. Hence, to participate in the design process, is to take a stand one way or another". pp.124-125.

Thus the political issues are important in design process. Gropius [1935] says, "The ethical necessity of the new architecture can no longer be called in doubt". Morality can have a useful impact upon a designer's process. This aspect is also supported in Ehn's work [1988]. For example, a designer should regard the following issues:

-Our long-range environmental concerns. In other words, pollution of our water, air and soil is threating our way of life.
-Realizing the limitation of our non-renewable resources. Such as, destroying our woods. A designer should regard, what can we do to contribute bring about renewal of these resources?
-Regarding the utilization of human resources. Replacing human labour with machines is continuing. A designer should address a number of question such as:
a-How many jobs will be created due to the new technology?
b-How many jobs will disappear along with new technology?
c-Will this new technology lead to more production? and so on.

In using a technology, one can create undesirable and threatening monsters. In the design process, one of the designer's responsibilities is to choose the most relevant technologies to be utilized [Hubel & Lussow 1984]. It is also the designer's responsibility to make use of different methods in the design process. Choosing a relevant technology can influence the utilization of various methods in the design process [Wise 1985]. In other words technology is one of the designer's most important resources. A designer must be informed about new developments in order to choose a relevant technology for making a product. A

designer should be aware of the negative applications of the technology. It can be either creative or destructive [Hubel & Lussow 1984]. Here, the political, cultural and religious issues are involved. Weinberg [1974] says, "Technology has provided a fix-greatly expanded production of goods-which enables our capitalist society to achieve many of the aims of the Marxist social engineer without going through the social revolution Marx viewed as inevitable". Weinberg [1974] argues further that technology has thus "fixed" the problems of poverty and, through the invention of the nuclear deterrent, has also "fixed" the problems of war. The matter of human intelligence is significant here. There is very little consent about what human intelligence is [Schank 1987]. It is not in the scope of this paper to define what is human intelligence in more detail. My intention is to emphasize that one's intelligence can influence one's design process. The nature of a user's needs and his/her roles in the design process is very important. This is relevant to roles of designers. Put differently, the roles of users and designers in the design process are correlated. Lawson [1986] says that, user's and designer's roles can rise to quite various views of the start or finish of the design process. Lawson [1986] says, one's view about the role of designers is related to the type of direction in which we wish society to go. It is not in the scope of this paper to define the above mentioned factors in more detail. Further, I have no competence in the field, i.e., various philosophical approaches to design. My intention was to emphasize that these factors (and possibly others) can influence one's design process.

5.7 The contribution of GST to the design process: From my point of view

One of the important things that a knowledge engineer should realize is the map of design process. The map of design process may vary from one field to another. The utilization of a map of design process and its conception depends upon one's general conception [Sagheb-Tehrani 1991a]. See Fig. 5.3 (as briefly discussed earlier). The holistic view plays its role here, i.e., one's general conception. If one does not have the holistic view, one cannot understand the role of various factors and their relationships, such as, intelligence, philosophy, politics and so on

in a design situation. In order to realize this, one must refrain from traditional thinking. Recognizing the holistic view approach, is very important for a designer, especially in views of today's problems which are complex and require a novel design process. A knowledge engineer can hardly handle the designing of an expert system using traditional thinking. Traditional design methods are too simple for developing expert systems where there are many users and there exist complex relationships among the elements of the system. One should really differentiate among designers by how disparate their design processes are and why, not by the end product of a designer (the latter known as viewing in traditional way) [Sagheb-Tehrani 1991a]. From my point of view, in order to realize this, one should have the holistic view. Put differently, the holistic approach is not to break down the whole into its constituent parts and then investigate each of the decomposed elements in isolation, but to attempt to view the whole with all its interrelated and interdependent parts in interaction. Thus, the design process is very important here which it is influenced by one's conception. Further, it is very vital that a designer be aware of disparate strategies, methods, techniques and tools in order to improve design processes with regard to their environment.

I may not have presented all there is to say about the design process. That is not my aim. I have neither the competence nor the intention to present a synthesis of the design process. The goal of this chapter was to outline my conception of system thinking essential for expert systems development with regard to the design process.

5.8 Summary

In this chapter, some contributions to the theoretical framework were discussed, regarding systems thinking. The concept of design was argued. Further, the matter of design process and its role were discussed. By reading this chapter, one should understand the design process, with regards to the "holistic view" tradition. As I have mentioned before, this matter is viewed from my point of view.

6. CONCEPTUAL MODEL AND SOME ISSUES

6.1 Background and summary

One way to understand expert systems is to examine the AI field which gave birth to expert systems. There are two main objectives of AI. The first goal is to create an intelligent machine. The second goal is to find out about the nature of intelligence. This study is related mostly to the first objective of AI. Expert systems development is a significant branch of AI and it is the most practical application of AI.

Expert systems are programs that handle real-world problems requiring expertise, i.e., expert systems utilize "humanlike" reasoning processes rather than computational techniques to solve a specific problem domain. Developing expert systems requires a kind of model. In this section an attempt is made to introduce a model of expert systems development based upon different issues.

6.2 Essential components of an expert system

Regarding disparate opinions about the components of an expert system, the author recognizes that an expert system essentially consists of the following key parts.

- A data base is the collection of data about objects and events on which the knowledge base will work in order to obtain intended results.
- A knowledge base consists of facts, assumptions, beliefs, heuristics ("expertise"), and methods of dealing with the data base to obtain intended outcomes.
- An inference engine allows inferences to be drawn from the interactions among the knowledge base and data bases.
- The concept of a knowledge acquisition process refers to the extracting, structuring and representing of knowledge.
- Interface is a part of an expert system which explains how solutions were reached and justifies the steps utilized to reach them.

- A human expert is a person who through years of experience has become expert at solving problems in a specific domain.

- A knowledge engineer is the person who designs and builds expert systems. This person is a computer specialist, knowledgeable in AI methods and who can apply various AI methods appropriately to real-world problems.

There are various approaches and methodologies for developing an expert system. Selecting an appropriate approach and methodology can influence the development process which in turn can influence the concept of components of an expert system. In Fig. 6.1, a relevant model with its structural linkages is presented.
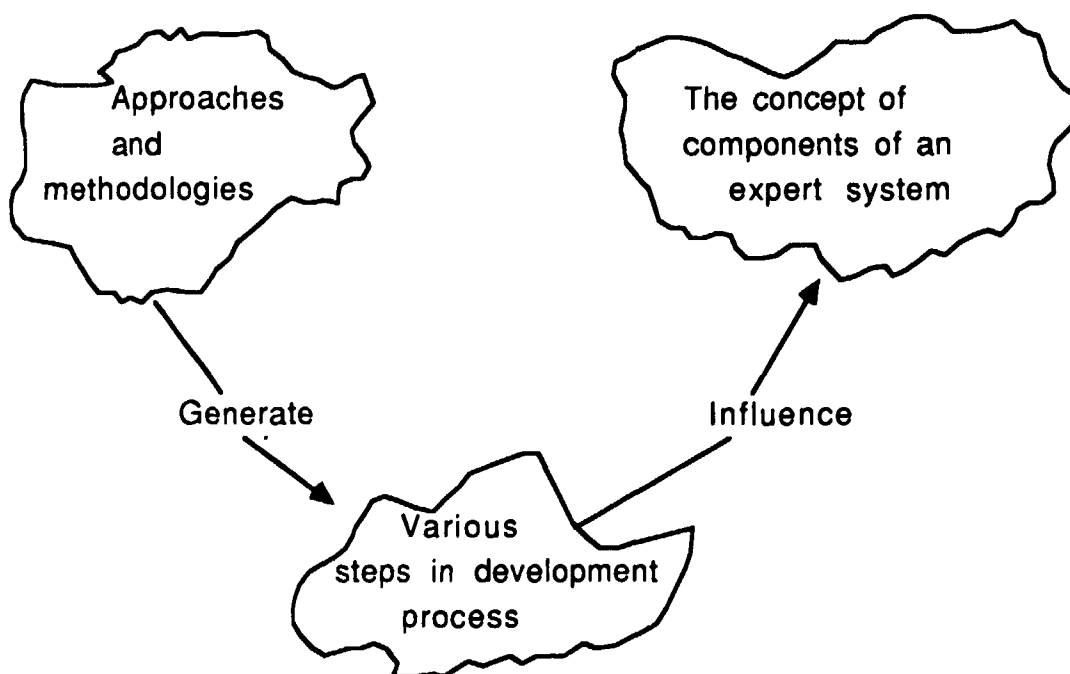
Fig. 6.1: A model of components of an expert system

There is a number of ways that one can classify expert systems. The most common classifications are by the area and tasks carried out by expert systems.

6.3 The essential features, perceived requirements and motivation for developing an expert system

The essential features of an expert system are as follows:

- Ability to solve real problems
- Represent knowledge symbolically
- Ability to update easily
- Ability to deal with uncertainty
- Ability to explain its reasoning and operation.

In order to build an expert system certain conditions regarding the involvement of human beings , management support, adequate resources and problem features must be met. Some requirements for building an expert system are summarized as follows:

- Applications are bounded
- Chosen problem should be solvable by human expert
- Adequate resources
- Have a qualified human expert
- Specify user requirements and goal/s of the system.

Motivation in developing an expert system plays a significant role. Put in other words, a successful implementation depends very strongly on motivation. The following motivations for developing an expert system are listed.

- Scarce human experts
- High cost of human experts
- Difficult access to human experts
- Consistency in human decision making
- Expert knowledge available anywhere, anytime
- Easy to reproduce expert knowledge
- Testing the new possibility of expert systems
- Dissatisfaction with human experts.

Regarding the relationships among these mentioned concepts, one may come to the issu. that the concept of perceived requirements for developing an expert system can direct the features of an expert system and influence the motivation of developing an expert system. Also, motivation can generate different concepts of characteristics of an expert system. In the following figure, a

model of those concepts with their structural linkages is presented.

The concept of motivation for developing an expert system

Influence

Generate

The concept of perceived requirements

Can direct

The concept of features of expert systems
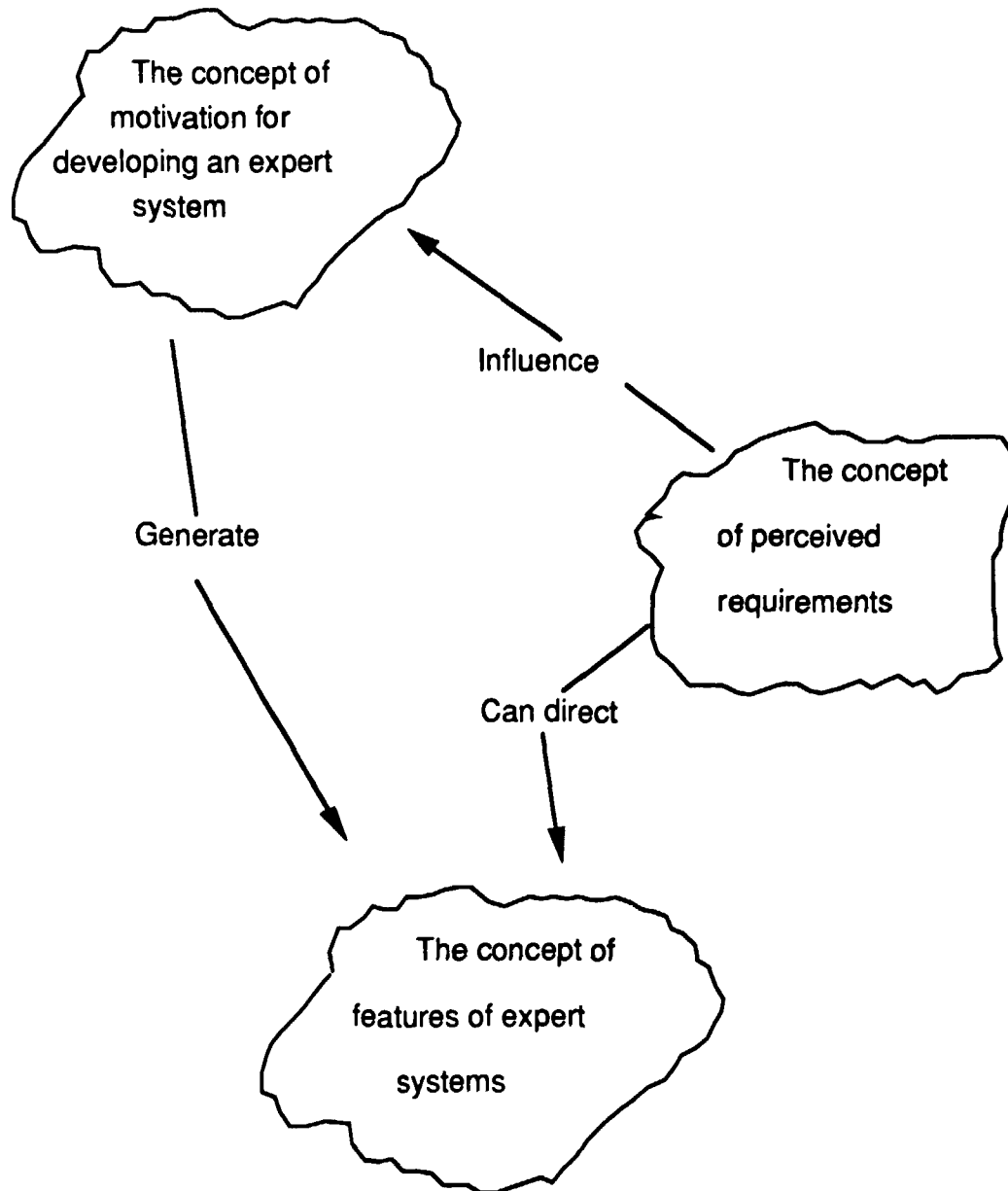
Fig. 6.2: A model regarding features, motivation and perceived requirements of developing an expert system

6.4 The role of an expert system and its responsibilities

An expert system can play many disparate roles, both for the user and for the organization. The following three roles were identified.

- Expert system as slave
- User as slave
- Expert system as a colleague of user.

It is important that a knowledge engineer differentiate between the various roles of an expert system at the outset of developing such systems. Furthermore, the responsibility of using an expert system requires more attention. In other words, who is responsible for the advice/decision given by the system? The responsibility of expert systems varies from one system to another, depending upon its role. The proposition is that a human must always stand between the decision taken by the system in order to test the plausibility of the result. Regarding the relationships among those concepts mentioned above, one may come to the issue that the concept of the role of expert systems can influence the trends of responsibilities of expert systems which can generate the concept of responsibility of expert systems that in turn can direct the concept of role of an expert system. In the following a model of those concepts with their structural linkages is presented.
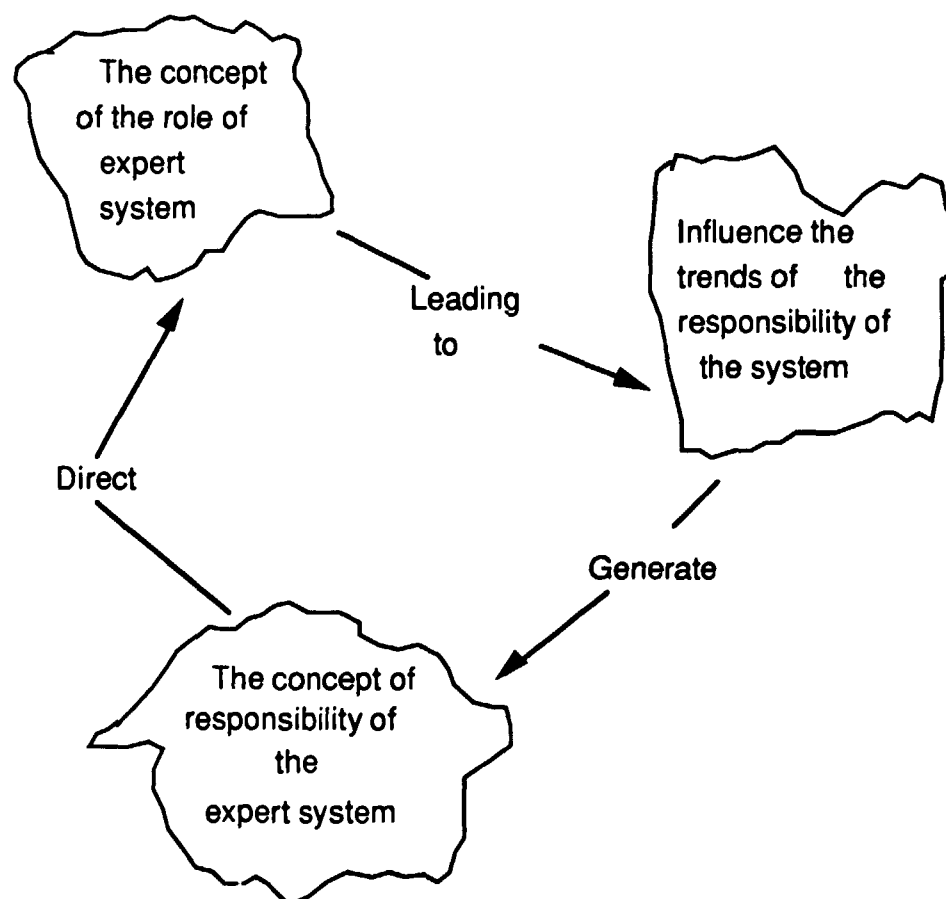
Fig. 6.3: A conceptual model of expert system's roles and its responsibilities, Adapted from [Sagheb-Tehrani 1993g]

6.5 Knowledge acquisition

The very first step in developing an expert system is to select a problem. Selection of a problem is a crucial step in the development process of an expert system. Successful expert systems development depends very strongly upon an appropriate selection of application. There are various criteria for selecting an appropriate application.

Expert systems are computer systems. There are different approaches for designing a computer system. Developing an expert system relies upon the techniques and tools developed in the AI field. Selection of a particular application may influence the selection of the relevant methodology for building an expert system.

Fundamental to the design of expert systems is the conception of knowledge. Among the expert systems development problems (see the following figure), knowledge acquisition (KA) is known as the bottleneck. Put another way, KA is an important obstacle and time consuming in the construction of expert systems [Sagheb-Tehrani 1991a, 1992b, 1993b]. KA is the process of eliciting, structuring and representing knowledge from some knowledge source to build an expert system.

Fig. 6.4: Some problems with developing an expert system, source [Sagheb-Tehrani 1990a], p.27
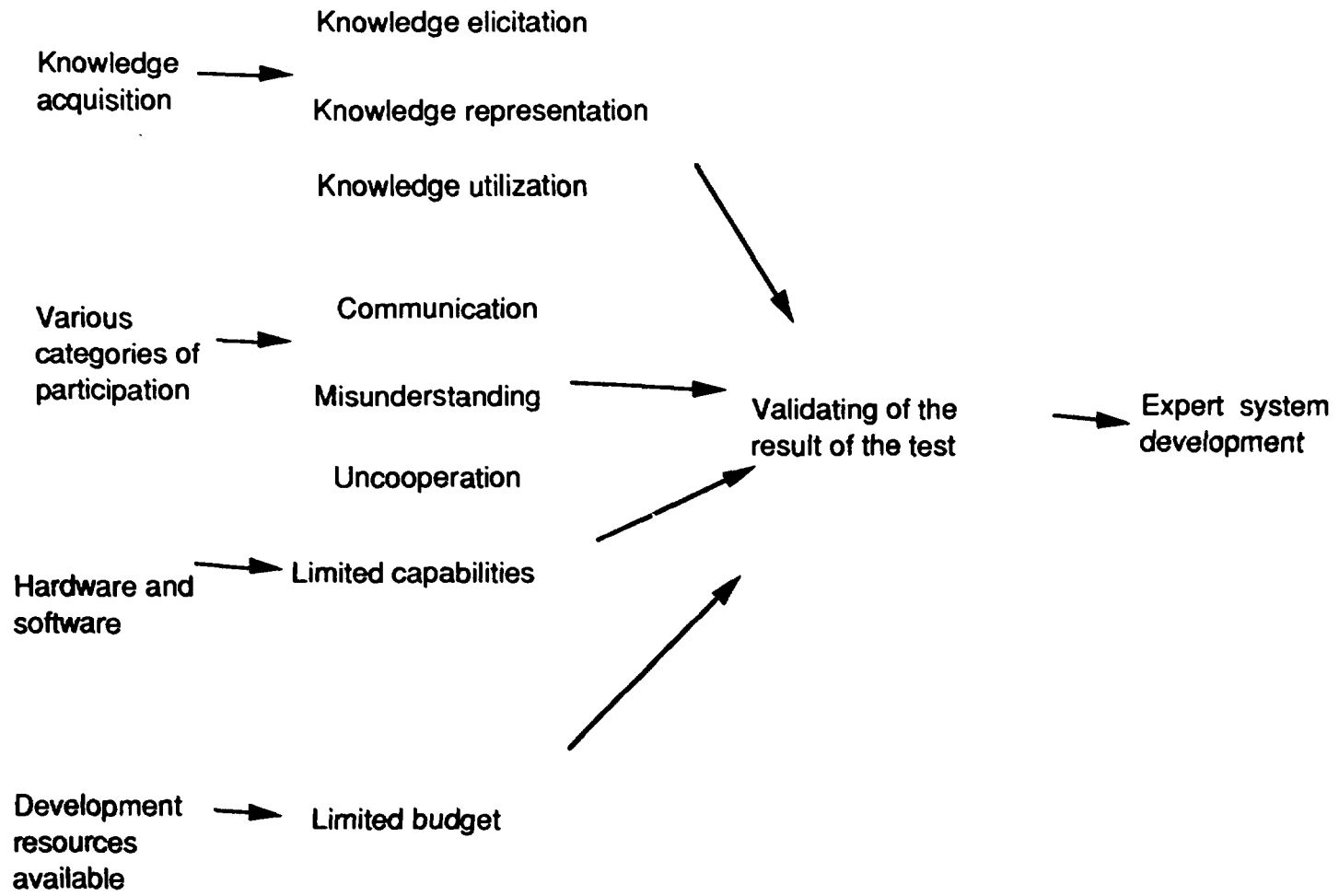
The knowledge acquisition process has its own problems such as, knowledge elicitation (KE), knowledge representation (KR) and knowledge utilization (KU). There are various kinds of KA approaches and methodologies. The following four KA approaches were identified.

- Knowledge engine-driven KA
- Expert-driven KA
- Knowledge induction (machine driven KA)
- Learning (machine driven KA).

KE refers to extraction of knowledge from human experts. This sub-process of the KA process is a critical step in developing expert systems. There are various ways to elicit the knowledge of experts for example, interviews, induction from example and so on. KR is a significant process in the processing of KA. There are disparate ways of representing knowledge in an expert system. These are, rules, frames, semantic network, scripts and hybrid. Each method has its own characteristic. Choosing the best method of KR is still an open question in the AI community. KU refers to how the inference engine should be designed, i.e., what forms of reasoning, what search strategies and what inference strategies should be utilized! The model may suggests a number of issues in general terms, such as: Various approaches of KA can direct the concept of KA process. Further, The concept of KA process leads to the concepts of KU, KR and KE [Sagheb-Tehrani 1991b,c, 1992a,b]. There exists a mutual relationship between the concepts of KU, KR and KE. The concept of KU is influenced by various relevant theories regarding disparate forms of reasoning, search strategies and inference strategies. Moreover, The concept of KR is influenced by selection of a relevant KR methodology. Finally, the concept of KE is influenced by selection of relevant KE method. The overall model for the KA process and its sub-processes with their structural linkages is presented in Fig. 6.5.
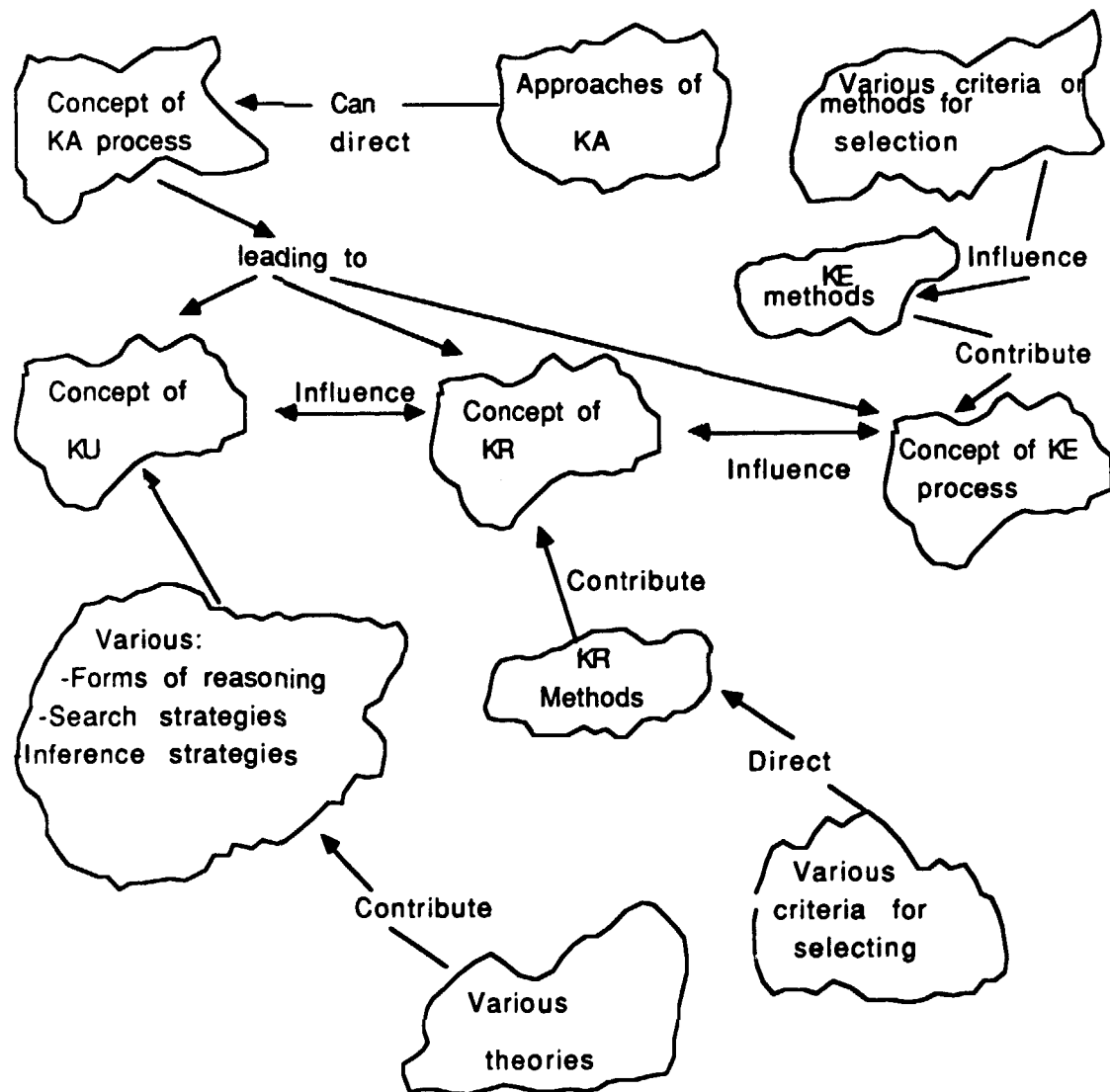
Fig. 6.5 A model of KA process with its relationships, Adapted
from [Sagheb-Tehrani 1991c,1992a]

6.6 Conceptual model of expert systems development

In this section an attempt is made to introduce a conceptual model of expert systems development based upon disparate issues and conceptual models which have been discussed so far. A conceptual model of expert systems development which is composed of various concepts and their structural linkages, is presented in Fig. 6.6. This may look very complex, as indeed expert systems development is complex[1]. Several direct and indirect benefits may accrue from the conceptual framework presented below. For example, this conceptual framework may facilitate comprehension the concept of KA process and its sub-processes in a better way. Furthermore, the various factors involved in expert systems development with their structural connections are presented. Thus, this can provide a systematic conception of expert systems development which can lead to a better development of expert systems development and use. Also, the matter of design process, different factors which can influence it and its role in expert systems development are illustrated. Indirect benefits accruing from this conceptual framework include, the scope for gaining insight into a broad apprehension of expert systems development. For example, generic components of an expert systems, types of knowledge, classification of problems and expert systems development methodologies. Furthermore, this work may provide a direction for more efforts to develop an exhaustive conceptual model that can effectively be used for successful implementation of expert systems projects. Put differently, the model will assist both academics and practitioners interested in the use of expert systems and support better implementation. In Chapter 9, the model is presented with more details of the hypotheses drawn on the findings of the study.

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[1] My recommendation for a better understanding of this conceptual model is to follow the entire theoretical framework.
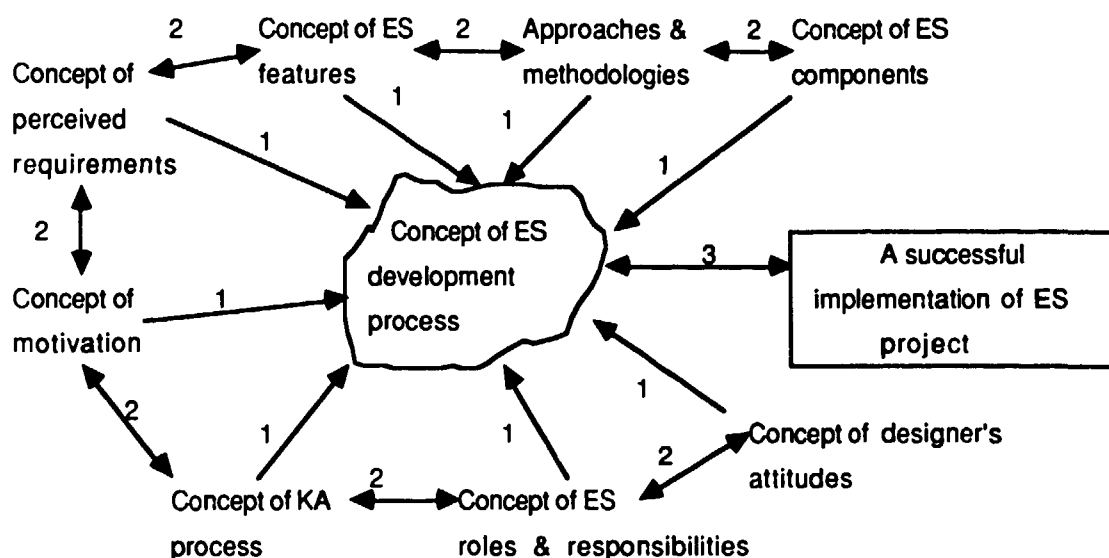
Fig. 6.6: A conceptual model of expert systems development,
Adapted from [Sagheb-Tehrani 1993d,e]

* The numbers refer to issues in the text.
ES=Expert systems KA=Knowledge acquisition

The model may suggest a number of issues regarding impacts of those concepts in expert systems development. The research issues are stated in general terms, the objective is to suggest significant outcomes that require to be studied further. The deeper discussion of the study issues may also emphasize that potential efforts are often complex with both positive and negative connotations.

Issue 1: The concept of the ES development process is constructed by the concepts of the expert system's components, various approaches and methodologies, expert system's features, perceived requirements for developing ES, expert system's motivation, KA process, expert system's roles and responsibilities and the designer's attitudes.

Issue 2: There exist mutual relationships among the concepts of the expert system's components, various approaches and methodologies, expert system's features, perceived requirements for developing ES, expert system's motivation, KA process, expert system's roles and responsibilities and the designer's attitudes.

Issue 3: A successful implementation of an expert system project is based on a good understanding of the concepts of the expert system's components, various approaches and methodologies, expert system's features, perceived requirements for developing ES, expert system's motivation, KA process, expert system's roles and responsibilities and the designer's attitudes.

One can say that expert systems development in substantial ways is different from conventional computer systems. Expert systems development is more complex than conventional computer systems [Sagheb-Tehrani 1993a,b,c].

6.7 Summary

In this chapter a model of expert systems development and some issues were presented, based upon theoretical studies. Moreover, various models regarding the essential components of an expert system, expert system's role and its responsibility, features, motivation and perceived requirements of developing expert systems, and KA process were presented.

PART III: PRESENTING THE EMPIRICAL PART OF MY PREVIOUS WORK

7. THE QUESTIONNAIRE SURVEY

7.1 Introduction

The questionnaire (Appendix II.II)[1] and a letter (Appendix II.I)[2] were mailed to twelve companies and their divisions. In almost all the cases, the questionnaire was answered by the person who was responsible for developing expert systems[3]. The letter (Appendix II.I)[4] explained very briefly the objective of this study for the person whom the questionnaire was mailed to. The construction and formulation of the questionnaire[5] aimed to provide clearness and visual attractiveness. As the intention was to elucidate both qualitative and quantitative aspects, some open-ended questions [Patton 1980] were included in the questionnaire and the remaining questions followed SCB's instructions[Wärneryed 1986]. The first page of the questionnaire concerned information about the respondent and some advice for filling in the questionnaire. The rest of the questionnaire contained 19 questions regarding the following points:

* What were the motives of organizations which developed expert systems?

* How did they reach their decision to do so ?

* What were the problems of such systems in practice ?

* What had happened to expert systems development and use in some of the companies included in S.Hägglund [1986] report?

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[1] The corresponding English translation is appendix I.II.

[2] The corresponding English translation is appendix I.I.

[3] In most cases, the persons who answered the questionnaire were the contact persons mentioned in Hägglund S & Johansson M [Kunskapsbaserade system, del II, Mekanresultat 87004Sveriges Mekanförbund, 1987]. In four cases, the determined respondents did not answer the questionnaire themselves. They sent the questionnaire to other knowledge engineers in their organizations.

[4] The corresponding English translation is appendix I.I.

[5] The approval of the questionnaire before sending it to various organizations took more time than I expected. My supervisor and I very carefully examined each question in the questionnaire. In some cases the formulation of some questions was changed totally and in other cases some terms were replaced with other terms which expressed the intended meaning better. One can say, this procrss was a kind of pre-testing of the questionnaire. One valuable experience I gained from this process is, it is rather easy to put a question in a questionnaire. But what are the consequences of each question to this study? Is it really necessary to have such question? and so on. It was not so easy after all to formulate a questionnaire.

I personally contacted the respondents of the questionnaire by telephone before sending it to them. Respondents of the questionnaire were positive to cooperating in this investigation by filling in the questionnaire. The questionnaire was mailed to the companies participating in this investigation during July 89-September 89, giving them almost three weeks to filling in the questionnaire counting from the date of mailing the questionnaire. In most cases, I received the answer before the expiry date of the questionnaire. Only one of them wrote a comment about understanding the questionnaire or any other difficulties regarding the questionnaire. In the respondent's opinion the formulation of the questionnaire was not clear and questions about the time and cost aspects of expert systems development in various phases were missing. In most cases, they wrote to me or mentioned in telephone conversations that they would like to have a copy of the final report. I regard this as an indication that the investigation was interesting for them and that the structure of the questionnaire was understandable. Only one company did not return the questionnaire. When I called them, the respondent said that the questionnaire did not suit their working environment. This was because, they worked with expert system shells. Among the answers which I received before the determined expiry date of the questionnaire, there were three cases in which the respondent did not fill in the questionnaire. I called them and asked them why they did not fill in the questionnaire. One of respondent said on the telephone that he could not fill in the questionnaire for the sake of the company's security. The two others said that they could not fill the questionnaire because they did not use expert systems.

7.2 Primary information

Twelve companies with their divisions initially agreed to participate in this investigation. Responses were received from 11 of them. The 12 companies which participated in the questionnaire investigation belonged to two different business fields. Eleven belonged to the industrial field and one was a consultant company.

I present the 12 companies with their divisions in various tables as C1, C2,C3,... for the sake of confidentiality, visual attractiveness and clear understanding of data for readers. Furthermore, Y means "Yes" and N means "No". D refers to a division from a company. For example (C3D1) where D1 is a division of company C3.

Field of business	Company	Number of ES developed	Response received	Questionnaire answered	Referred name of ES here
Industrial	C1		Y	N	
	C2	5	Y	Y	S1-S5
	C3D1		Y	N	
	C3D2		N		
	C4	3	Y	Y	S9-S11
	C5	2	Y	Y	S12-S13
	C6	1	Y	Y	S15
	C8D1		Y	N	
	C8D2	1	Y	Y	S14
	C9	1	Y	Y	S7
	C10	1	Y	Y	S6
Consulting	C7	1	Y	Y	S8
TOTAL	12	15	11	8	15

Table 7.1: Basic data of the number of participants and developed expert systems reported by the questionnaire investigation

All the respondents who answered the questionnaire were knowledge engineers and some of them were responsible for the development of expert systems. As one can see from the above table, 8 companies answered the questionnaire completely. Some of those companies developed more than one expert system.

For the purpose of this study, the chosen unit for working in the empirical part is an expert system, i.e., I will refer to those 15 expert systems as S1, S2, S3, ... respectively in the following sections as shown in the last column of Table 7.1.

Furthermore, as one can see from the above table, 8 respondents answered the questionnaire regarding those 15 expert systems. One alternative was to analyse the data according to respondents as the unit of investigation. The reason for regarding that alternative is that, as the investigation showed the respondents did not differe in some cases, for instance when answering some questions concerning their various expert systems. That is to say, they answered in general in some cases. The analysis of the 10 various pairs of S1-S5 (S1:S2, S1:S3, S1:S4........) showed that there were differences in almost every table. This was also true for 3 pairs of S9-S11 as well as for 1 pair of S12-S13. To be more specific, in the first case, there were differences in 14 tables out of 15, in the second case, there were differences in 5 tables out of 14 and the same in the last case. The analysis showed that in the first and second case (S1-S5, S9-S11) regarding Table 7.5, there were not any differences, i.e. the respondents in general did answer that particular question. Whereas in the third case (S12-S13) regarding Table 7.5, there were differences. Thus, as the analysis of the above mentioned alternative unit showed, there were differences in almost every table. The fact that respondents reporting more than one expert system most of the time differentiated between these systems in their answers supports the choice of expert system as the unit of investigation.

7.3 The presentation of findings of the questionnaire investigation

I use tables for presenting the findings of the questionnaire investigation. I find it practical to classify the obtained-data according to the following points:
1- The motives of organizations which developed expert systems
2- The decision to develop expert systems
3- Some problems of expert systems in practice
4- Testing the quality of expert systems
5- Satisfaction of expert systems and
6- The stage of the development of expert systems and its various views.
For the purpose of brevity, some abbreviated terms will be utilized in various tables. They are listed in Appendix V.

7.4 The motives of organizations which developed expert systems

The tables in this section correspond to the following questions in the questionnaire (Appendix II.II in Swedish, Appendix I.II in English) as shown below.

The questionnaire investigation showed that in 13 cases (87%)[6] out of 15, expert systems have been used to a limited level in various organizations. As shown in the following table.

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[6] The numbers in the brackets indicates the percentages which have been rounded up. For example the number 25.56 is written as 26 whereas the number 26.34 is written as 26.

No of expert systems	Used HE	Used CS	Used MS	Using ES	Not using ES	Applications
S1	X			X		Engineering
S2	X			X		Engineering
S3	X			X		Energy
S4	X			X		Consult
S5	X			X		Consult
S6	X				X	Engineering
S7	X			X		Consult
S8			X	X		Accountancy
S9	X			X		Electronic
S10	X			X		Electronic
S11		X		X		Electronic
S12	X			X		Pumps
S13	X			X		Credit system
S14	X	X			X	Telephone
S15	X			X		Air-craft

Table 7.2: Data of the companies using expert system with various applications (questions 2,4)

Human experts had been utilized earlier for the tasks of the expert system in all 13 cases as shown in the second column of Table 7.2. This does not imply that human experts were replaced by expert systems as will be discussed in section 6.7. Table 7.2 (fifth column) shows that those tasks which are partly handled by expert systems now, used to be handled in almost all cases (second column) by human experts. This will help one to better conceive the motives of developing expert systems in various organizations compared to their previous systems which will be shown in other tables.

Moreover, the last column in Table 7.2 is classified according to their domains. This kind of classification was mentioned in [Sagheb-Tehrani 1990a], Table 3, p.21. One may say that it would be better, if that classification was classified in the same way as Table 2 in [Sagheb-Tehrani 1990a], p.20, because, according to one's interest, one may wish to see for example, which one of those categories (Table 2) is easier to build and so on. On the other hand, the above mentioned classification (Fifth column, Table 7.2) may be interesting to others. Furthermore, the respondents reported in that way. Respondents of the questionnaire were asked to indicate about the motives of their expert systems development. In 10 systems (67%) out of 15 testing possibilities of such systems was pointed out as the main motive for developing expert systems.

The next two main motives were better access to and lower costs of expert systems compared with human experts, given in 7 cases (47%) as motives. Whereas the motive of consistency appeared in 6 cases (40%). Other motives such as education and support systems for personnel who used to work for their previous system were pointed out. As the following table shows.

Motives / Systems	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Better access	X	X		X	X			X	X						X
. Less cost		X			X			X		X	X			X	X
. Testing possibilities	X				X	X		X	X	X	X	X		X	X
. Consistency				X							X	X	X		X
. Do not know*			X												
. Other motives		X					X								

Table 7.3: Data regarding the motives for developing expert system (question 3)

In question 5 (Table 7.4) the respondents were asked about their satisfaction with their previous systems. In 6 cases (40%) they were dissatisfied with these, whereas in 5 cases (33%) they were satisfied with them. In 4 cases (27%) they did not know. The reason for dissatisfaction with human experts was almost the same in all cases. Most of them mentioned the difficult accessibility of human experts and the matter of consistency in their decision making.

Satisfaction / Systems	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Satisfied with CS											X				
. Satisfied with HE		X	X						X	X					
. Dissatisfied with CS															
. Dissatisfied with HE	X			X	X	X	X								
. Dissatisfied with MS								X							
. Unknown*												X	X	X	X

Table 7.4: Data regarding satisfaction of various companies with conventional system or human expert(question 5)

7.5 The decision to develop expert system

According to Table 7.5, in 7 cases (47%) the initiative of expert system development was taken by internal specialists and in 6 cases (40%) by management in various organizations.

Initiative / taken by Systems	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Personnel who took care of tasks								X							X
. Internal specialist								X	X	X	X		X	X	X
. External specialist							X								
. Management*	X	X	X	X	X							X			
. Respondent (KE)*						X									

Table 7.5: Data of the initiative taker in to developing expert system (question 7)

* This option was not included among alternative answers in the questionnaire.It was added by the respondents. This note may be borne in mind for the rest of tables when such " * " character encounter.

Besides, according to Table 7.6, in 12 cases (80%) the idea of expert systems development was supported by management, whereas in 9 cases (60%) it was supported by personnel who took care of the tasks before and in 5 cases (33%) personnel at the computer department.

ES develo. / Systems supported by	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Management	X	X	X	X	X	X	X		X	X		X		X	X
. Personnel who took care of tasks	X		X	X	X	X		X	X	X			X		
. Personnel at the Comp. Dep.								X		X	X	X			X

Table 7.6 : Data of the development of expert systems supported by various people in different organizations (question 8)

According to Table 7.7, the questionnaire investigation in 9 cases (60%) expert systems were developed by internal specialists, whereas in 6 cases (40%) expert systems developed by external consult. In 3 cases (20%) expert systems developed by personnel of the computer department. As the following table shows.

ES devel. / Systems by	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Internal specialist	X			X	X	X	X	X	X					X	X
. Personnel at the Comp. Dep.												X	X		X
. External consult	X	X	X	X	X	X									

Table 7.7: Data concerning the development of expert system by various person (question 9)

7.6 Some problems of expert systems in practice

Table 7.8 shows that in 11 cases (73%) there existed some problems with expert systems development, apart from knowledge acquisition, such as, limited time, budget and inexperienced knowledge engineers. Software problems were percieved in 4 cases (27%) whereas the limited budget occurred in 5 cases (33%). Unexperienced knowledge engineers and limited time occurred in 3 cases (20%) each. Inexperienced knowledge engineer problems occured in 3 cases in one company as well as limited time and budget belonged to another company. This indicate that inexperienced knowledge engineer and software problem were the most common problems in that company. Whereas the problem of limited time and budgets in other companies were the most common indirect problems. Other problems such as difficult domain, updating of system and the matter of priority in supporting expert systems in an organization were pointed out. The questionnaire investigation did not indicate any problems regarding the matter of lacking any specific development model. As shown in the Table 7.8.

some / Systems probl. with ES devel.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Software	X	X	X										X		
. Participant resistance§		X													
. Hardware problem														X	X
. Limited budget									X	X	X			X	X
. Limited time									X	X	X				
. Unexperienced KE	X	X	X												
. Lack of develo. models															
. Other problems						X	X	X							
. None				X	X							X	X		

Table 7.8: Data concerning some problems with developing expert system (question 11)

§ This is referred to in question 11 of the questionnaire as "With personnel who took care of tasks".

According to Table 7.9, knowledge acquisition problems were reported in 12 cases (80%). The questionnaire investigation showed five kinds of problems regarding knowledge acquisition.

knowledge / Systems acquisition problems	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Identify knowledge	X			X		X					X	X	X		
. Knowledge represen.	X				X						X	X	X		
. Limited access to qualified expert													X		
. Communication with expert	X												X		
. Unexperienced KE*			X												
. Software problem#						X		X	X	X					
. None				X	X										X

Table 7.9: Data concerning knowledge acquisition problems (question 13)

This is referred to in question 13 of the questionnaire as "Tools for extracting knowledge".

Moreover, identifying knowledge the most common problem, occurred in 6 cases

(40%). The next most common problem was knowledge representation which occurred in 5 cases (33%). Software problems were reported in 4 cases (27%). The problem of unexperienced knowledge engineer and access to qualified human expert (human expert who claimed to be an expert but was not) were pointed out. Almost all the respondents answered "No" to the question about using a specific tool for knowledge acquisition. Only in 1 case (7%) did the respondent answer "Yes", shown in the following table.

Using a / Systems specific tool for knowledge acquisition	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Yes$^\beta$														X	
. No	μ	X	X	μ	μ	X	μ	X	X	X	X	μ	μ		X

Table 7.10: Data regarding usi.ig tools for knowledge acquisition (question 14)

$^\beta$ The respondents reported the following tools: SAGE, OPS5, TIPC-Easy and Frame based system.
$^\mu$ The respondents did not make any comments on the relevant questions in the questionnaire.

Problems with experts arise from the requirement of eliciting knowledge from human experts. A number of problems with experts were identified shown in Table 7.11. In 10 cases (67%) there were problems with experts. The most common problem with experts was their limited time which was reported in 7 cases (47%). The problems of limited time and access occurred in 3 cases within the same company (they had had these problems before, shown in Table 7.11) , may indicate that these problems were quite significant for them.The next joint problem was limited access to the expert, reported in 4 cases (27%). Problems of misunderstanding reported in 3 cases (20%), whereas limited cooperation from the expert side was reported only in 1 case (7%). The problem of unqualified human experts (mentioned by respondents themselves) was reported in 2 cases (13%) from the same company.

Problems / Systems with expert	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Misunderstanding	X						X							X	
. Limited cooperation														X	
. Limited time				X					X	X	X	X	X	X	
. Limited access									X	X	X			X	
. Unqualified expert*	X	X													
. None			X			X									X
. Do not know*				X		μ									

Table 7.11: Data concerning some problems with expert (question 15)

The investigation showed that the most popular elicitation technique used for extracting knowledge from an expert was structured interviews which were reported in 11 cases (73%). This indicates that the problem with an expert is due to communication with the expert using this technique in order to extract knowledge from him. The next two popular techniques were unstructured interviews and documentation analysis which each was reported in 7 cases (47%). Simulation using a prototype occurred in 6 cases (40%) whereas case study analysis and observation of human experts, were reported in 5 cases each (33%) as shown in the following table.

Knowledge / Systems elicitation techniques used	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Induction from example												X			
.Unstructured interviews						X		X	X		X	X	X	X	
. Documentation analysis	X		X					X	X	X				X	X
. Simulation using prototype		X					X				X	X	X	X	
. Case study analysis			X		X	X	X						X		
. Structured interviews	X	X	X		X	X	X	X	X		X	X			X
. Observation analysis							X	X			X	X	X		
. Do not know*				X											

Table 7.12:Data concerning knowledge elicitation techniques used(ques.12)

As the following table shows in 8 cases(53%) they did not use any specific development model. i.e. they used a traditional approach. This is consistent with the study of literature. However the problem with lacking a specific development model which was pointed out in the study of literature was not reported in any case. This can be interpreted in two ways. First, they did not have any problems with lacking any specific development model as reported. Second, due to lacking a specific development model regarding knowledge acquisition as the key, caused problems in 12 cases (shown in Table 7.9) with knowledge acquisition.

Using a / Systems specific model for developing ES	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Yes	X	X		X				X				X	X		
. Tool*			X												
. No		X				X	X		X	X	X			X	X

Table 7.13: Data based on the use of a specific model for developing ES (ques. 19)
Those who answered "yes" to the above question concerning using a specific development model, in 2 cases (13%) used prototyping and in another 4 cases (27%) used their own development model.

7.7 Testing the quality of expert systems

To the question 18 on how they tested the quality of their expert systems all 15 cases (100%) answered that they approved it by confrontation with an expert. As the following table shows.

Testing / Systems	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Testing against historical data	X		X												
. Judging by expert	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
. Testing against specific data							X	X							
. Confrontation* with end-user								X						X	

Table 7.14: Data concerning the testing of the quality of ES (ques. 18)

This indicates that a human expert and a knowledge engineer are the permanent elements of the expert system development process. That is to say, the final decision is still made by a human expert. In other words, the present trends of expert systems development are towards aiding decision making or advising.

7.8 Satisfaction of expert systems

In 10 cases (67%) the respondents reported that they were satisfied with their expert systems as shown in Table 7.15. Various reasons were given for their satisfaction such as: solves the problem, consistency, better access, lower cost and good for their production. Three cases (20%) reported dissatisfaction with their expert systems. Different reasons were reported for this: limited implemented knowledge, wrong tool, non-competent knowledge implemented and limited available resources.

Satisfaction / Systems with ES	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Yes	X		X		X	X		X	X	X	X	X	X		
. No		X		X											X
. Unknown*							X							X	

Table 7.15: Data about satisfaction of various companies with their expert systems (question 17)

7.9 The stage of the development of expert systems and its various views

The questionnaire identified four various types of expert systems development stages. As shown in Table 7.16. In 4 cases (27%) the expert systems were in operation. In 6 cases (40%) the expert systems were in prototype and 3 cases (20%) were in final test. In 2 cases (13%) the respondents reported that the projects were stopped. According to my conception of the S.Hägglund [1986] report (According to the mentioned report, p. 2, the project started in 1985), those systems were not in operation four years ago either. This indicates that expert systems development takes a long time.i.e by comparing the year of expert systems development activity in Table 7.16 to now (1989), most of them are not in operation yet. As one may realize some of those systems have been developed after the investigation of the above mentioned report. Thus, the 15 systems here may not represent the same systems included in the above mentioned report.

State / Systems of ES in summer of 1989	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Operation	X							X				X	X		
. prototype				X		X			X	X				X	X
. Final test		X			X			X							
. Abandoned*		X	X												
. Year of development	86	85	89	86	89	85	88	87	88	89	89	87	86	83	88

According to my conception of the
S.Hägglund report

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
				C2		C10	C9	C7	C4			C5	C8D2	C6	
. Not operational	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
. Activity started⌀ in ES develop. in various companies	85	85	85	85	85	85	85	83	84	84	84	85	85	85	86

Table 7.16: Data concerning state of expert systems in various organizations (questions 6, 10)

⌀ The starting years of an activity for developing expert systems in these companies (C2,C9 and C8D2) were not mentioned in the S.Hägglund report. Thus, the year (85) mentioned in Table 7.16 for the above mentioned companies are my own assumption from the S.Hägglund report. The rest were mentioned in his report.

As Table 7.17 shows, to the question of results achieved by developing expert systems the respondents answered in 5 cases (33%) that consistency was the main result. The next most common was better access which occurred in 4 cases(27%). In 5 cases (33%) the results were not known due to uncompleted development of their expert systems. Other results such as more knowledge on expert systems for users and increasing competence about expert systems development in the organization were pointed out. No results were reported in 2 cases (13%) due to early termination of their projects.

Issues / Systems	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15
. Consistency	X				X	X						X	X		
. Better access		X			X	X						X			
. Less cost		X										X			
. Unknown *							X		X	X	X			X	
. Other issues								X							X
. None		X		X											

Table 7.17: Data about some issues after developing expert systems (question 16)

All the respondents mentioned different opinions on the question of what distinguished an expert system. Only in one case did they mention the difference between knowledge based systems and expert systems. One aspect common to several views about expert systems was the fact that knowledge becomes implemented explicitly in expe,t systems. The following table shows the various views about expert systems reported by the respondents.

Systems /	Views[7]
S1-S5	Solve real-problems. Use rules of thumb.
S6	Knowledge is implemented explicitly. Explain possibilities.
S7	An expert system is just as good as a human expert. In KBS the knowledge is implemented separately from the inference mechanism.
S8	KBS have more explicit knowledge about the problem domain than traditional computer based systems.
S9-S11	An easier way of implementing a limited domain knowledge.
S12-S13	Give a model of a human expert and use new programming techniques.
S14	A program which is used for problem-solving and uses AI techniques.
S15	Working heuristics. Explicit. A growing system. Often interactive with the users.

Table 7.18: Various reported views about expert systems (question 1)

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[7] The different views about expert systems were reported originally in Swedish by the respondents, so this may not be an exact translation.

This matter of various opinions upon the question 1 in the questionnaire may implies the same for the rest of questions. In fact, this matter is too general. The fact that the conception of one person differ from another's is dependent on many factors such as: the philosophical aspect, on's interest, background and so on. This matter lies outside of the scope of this study to discuss further. The point here is that one should be aware of this fact.

7.10 Summary

In this chapter, the empirical part of my previous work was presented. Various tables presenting the findings of the questionnaire investigation were also presented.

PART IV:EMPIRICAL FRAMEWORK

8.THE QUESTIONNAIRE INVESTIGATION

8.1 Introduction

The questionnaire (Appendix IV.I in English, Appendix IV.II in Swedish) and a letter (Appendix III.I in English, Appendix III.II in Swedish) were mailed to eleven organizations. In all of cases, the questionnaire was answered by the person who was responsible for developing expert systems. The letter (Appendix III.I) explained very briefly the goal of the study for the person whom the questionnaire was mailed to. The construction and formulation of the questionnaire was aimed at providing clearness and visual attractiveness. The approval of the questionnaire took more time than I expected before it was sent to the different organizations. My supervisor and a number of knowledge engineers and myself very carefully examined each question in the questionnaire. In some cases the formulation of some questions was changed. Furthermore, the intention was to elucidate both qualitative and quantitative aspects. The questionnaire comprised six pages. The first page contained information about the respondent and some advice for filling in the questionnaire. The rest of the pages contained 27 questions concerning the following points:

-What are the reasons for selecting an expert system solution to the problem?
-What are the most common problem domains and the characteristics addressed by them?
-How did the organizations decide to develop expert systems?
-What are the problems of designing expert systems in practice?
-What are the issues of expert systems after developing?
-What is the role of expert systems with respect to the user?

Before sending the questionnaire to the various organizations, I personally contacted the respondent of the questionnaire by telephone. The respondents were positive to cooperating in the investigation by filling in the questionnaire. The questionnaire was mailed to the organizations participating in this investigation during Oct. 1991- Jan. 1992, providing eight weeks for filling the questionnaire. counting

from the date of mailing the questionnaire. In the majority of cases, I received the answer before the expiry date of the questionnaire. Three organizations did not return the questionnaire in time. In some cases, I contacted the respondents of the questionnaire to obtain further information. Three organizations did not fill in the questionnaire completely. Different reasons were given such as, they had stopped their expert systems project or they were just planning to develop expert systems.

8.2 Background information

Eleven organizations participated in the investigation. Responses were received from eleven of them. The eleven organizations which participated in the questionnaire investigation belonged to the administrative (services) field. I present the names of those organizations in various tables as O1,O2, O3, ... for the sake of confidentiality, visual attractiveness and clear understanding of data for readers. Furthermore, Y means "Yes" and N means "No", see Table 8.1. Most of the respondents gave multiple answers to the questions.

Organization	No. of ES developed	Questionnaire answered	Referred names of ES here
O1	3	Y	S1,S2,S3
O2	1	Y	S4
O3	1	Y	S5
O4	1	Y	S6
O5	1	Y	S7
O6	1	Y	S8
O7		N	-
O8	3	Y	S9
O9		N	-
O10		N	-
O11	1	Y	S10
Total 11	12	8	10

Table 8.1 : Primary data regarding the number of participants and developed expert systems reported by the questionnaire investigation

As one can realize from the above table, eight organizations answered the questionnaire completely. Some of them developed more than one expert system. For the purpose of this study, the choosen unit for working in the empirical part is the expert system, i.e., I will refer to the ten expert systems as S1, S2, S3... respectively in the following sections, as shown in the last column of Table 8.1. The unit for organization 8 (O8), which developed more than one expert system is given as one system (see the last column of Table 8.1), because, there were no differences in the answers of the questionnaire. Put differently, the respondent did not differentiate in answering the questionnaire in this case. Thus, the fact that there were not differences in answering the questionnaire for three systems by the respondent O8 supports the choice of one system as the unit of investigation for O8. Regarding O1, the analysis of the 3 various pairs of S1:S2, S1:S3 and S2:S3 for each table showed that there were differences in 6 tables. Thus, the fact that the respondent of O1 reported 3 expert systems, differentiating between these systems in his answers, supports the choice of 3 expert systems as the unit of investigation for O1.

8.3 The presentation of findings of the questionnaire investigation

I utilized tables for presenting the findings of the questionnaire investigation. I found it useful and practical to classify the obtained data according to:

1-The reasons for developing expert systems and the most common problem domains
2-The decision to develop expert systems
3-Some problems of expert systems in practice
4-The outcomes of expert systems after developing
5-The role of expert systems

Some abbreviations terms will be utilized in various tables. They are listed in Appendix V.

8.4 The reasons for developing expert systems and the most common problem domains

The questionnaire investigation showed that in 4 cases (40%), expert systems have been used to a limited extent in the various organizations, as shown in Table 8.2. Human experts had been used earlier for the task of the expert system in 8 cases (80%), as shown in the second column of Table 8.2. This may help to better understand the motives of developing expert systems in different organizations compared to their previous systems which will be shown in other tables. The last column of Table 8.2 shows the domain/categories of the reported expert systems. This kind of classification was mentioned in Chapter 3, Tables 3.1 and 3.2.

No of ES	Used HE	Used CS	Used MS	Using ES	Applications area
S1	X			X	Consult/Debugging
S2	X			X	IS/Planning
S3	X			X	IS/Diagnosis
S4	X	X			IS/Diagnosis
S5	X	X			Credit/Control
S6	X				Credit/Control
S7					Analysis/Monitoring
S8	X				Production/Planning
S9	X				Consult/Control
S10		X		X	IS/Diagnosis
10	8	3		4	Total

Table 8.2: Data about the companies using expert systems with their domains (Questions 2,3,4)

In Question 5 (Table 8.3) the respondents were asked to indicate about their satisfaction with their previous systems. In 7 cases (70%) they were dissatisfied with human experts (HE). In 3 cases (30%) they were dissatisfied with conventional systems (CS). In 1 case (10%) satisfaction with human experts and one unknown were reported. In 3 cases (30%), reported dissatisfaction with their conventional computer systems. The reasons for dissatisfaction with human experts were

almost the same in all cases. Most of them mentioned the matter of inconsistency in decision making.

Satisfaction/System With		S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Satisfied	HE								X			1	10
.Dissatis.	CS				X	X					X	3	30
.Dissatis.	HE	X	X	X	X	X	X		X			7	70
.Unknown								X				1	10

Table 8.3:Data about satisfaction of various organizations with their systems (Question 5)

Respondents of the questionnaire were asked to indicate the motives for their expert systems development, shown in Table 8.4. In 6 cases (60%), the respondents reported that the problem was suitable for expert systems application. The next two main motives were less cost and consistency which were reported in 5 cases (50%). The next two motives were testing possibilities of expert systems, and availability of human experts which were reported in 3 cases (30%) each. Other motives such as, better quality, obtaining experience, gathering knowledge and availability of knowledge engineers were pointed out.

Motive/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Consistency	X	X		X		X			X		5	50
.Less costs	X	X		X			X		X		5	50
.Better access		X	X								2	20
.Testing possibility			X			X		X			3	30
.Problem was suitable for ES	X	X	X	X		X	X				6	60
.Availability of KE				X							1	10
.Availability of HE			X	X		X					3	30
.Others							X	X	X		3	30

Table 8.4: Data regarding the motives of developing ES (Ques. 6, 8)

Respondents of the questionnaire were asked to indicate the characteristics of the problem handled by expert systems, as shown in Table 8.5. In 4 cases (40%), the respondents reported that the problems were ill-structured. The next two main characteristics were semi-structured and structured which were reported in 3 cases (30%) each.

Characteristics/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Structured		X				X			X		3	30
.Semi-structured			X	X	X						3	30
.Ill-structured	X		X				X	X			4	40

Table 8.5: Data concerning the characteristics of the problem (Question 9)

8.5 The decision to develop expert system

According to Table 8.6, in 8 cases (80%) the initiative of expert systems development was taken by internal specialists and in 2 cases (20%) by external specialists.

Initiative/System taken by	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Internal specialists	X	X	X	X		X	X	X	X		8	80
.External specialists			X	X							2	20
.Others						X			X		2	20

Table 8.6 Data regarding person has taken the initiative to develop expert system in organizations (Question 10)

Besides, according to Table 8.7, in 9 cases (90%) the idea of expert systems development was supported by management, whereas in 2 cases (20%) it was supported by personnel who took care of tasks before. In 3 cases (30%), it was supported by personnel in the computer department. Others supporting the idea of expert systems development, were, users and people who were interested in testing possibilities of expert systems technology.

Supported/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Management	X	X	X	X	X	X	X	X	X		9	90
.Personnel who took care of tasks			X	X							2	20
.Personnel in the comp. dep.			X	X				X			3	30
.Other	X	X	X		X						4	40

Table 8.7: Data about the development of ES supported by different people in organizations (Question 11)

The questionnaire investigation showed that in 7 cases (70%) expert systems were developed by external specialists, while in 5 cases (50%) expert systems were developed by personnel in the computer department of organizations. In 2 cases (20%) expert systems were developed by internal specialists at the organizations, as shown in Table 8.8.

ES devel./System by	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Internal specialists				X			X				2	20
.External specialists	X	X	X	X	X			X	X		7	70
.Personnel in the comp. dep.				X	X	X	X			X	5	50

Table 8.8: Data regarding the development of ES by different people in organizations (Question 12)

8.6 Some problems of ES in practice

According to Table 8.9, in 8 cases (80%) there existed some problems with expert systems development. In 2 cases (20%), the respondents reported that they did not have any problems. The most common problem was knowledge acquisition which was reported in 8 cases (80%). The next most common problem reported in 6 cases (60%) was software problems. Other problems such as, limited budget, problems with using tools, hardware problems and knowledge engineers without experience were reported.

Some/System problems	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.None						X		X			2	20
.Hardware				X							1	10
.Software	X	X	X	X	X				X		6	60
.Limited budget				X							1	10
.Tools			X						X		2	20
.KE without experience			X						X		2	20
.KA problem	X	X	X	X	X		X	X	X		8	80
.Other								X			1	10

Table 8.9: Data concerning some problems with ES development in organizations (Question 14)

According to Table 8.10, knowledge acquisition problems were reported in 8 cases (80%). The questionnaire investigation identified that the most common problem with knowledge acquisition process was knowledge elicitation, reported in 8 cases (80%). Other problems such as, limiting their problems, communication with human experts and the problem in hand being too complex were pointed out.

KA/System problems	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.None						X		X			2	20
.Knowledge elicitation	X	X	X	X	X		X	X	X		8	80
.Other			X				X	X			3	30

Table 8.10 Data regarding KA problems (question 15)

The questionnaire investigation showed that the most popular elicitation technique used for extracting knowledge from human experts was the interview techniques reported in 9 cases (90%). Put differently, the unstructured interview was reported in 5 cases (50%) whereas the structured interview was reported in 4 cases (40%). The next two common elicitation techniques were the case study and prototype with simulation reported in 3 cases (30%). The next popular technique was observation analysis reported in 2 cases (20%). The other techniques such as documentation analysis and induction from examples were pointed out, as shown in Table 8.11.

Techniques/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	#	%
.Unstructured interview	X	X	X		X		X				5	50
.Structured interview			X	X			X		X		4	40
.Documentation analysis			X								1	10
.Observation methods and protocol analysis		X	X								2	20
.Prototype with simulation			X		X				X		3	30
.Case studies			X		X	X					3	30
.Induction from e.g.								X			1	10
.Other				X							1	10

Table 8.11 Data concerning KE techniques used (Question 16)

In question 17 (Table 8.12) the respondents were asked to indicate about their use of a specific tool for knowledge acquisition. Most of the respondents answered "Yes" to this question. In 9 cases (90%) the respondents answered "Yes", whereas only in 1 case (10%) the respondent answered "No".

Tool/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Yes	X	X	X	X	X	X		X	X	X	9	90
.No							X				1	10

Table 8.12 Data about using tools for KA in organizations(Ques. 17)

The questionnaire investigation (Table 8.13) showed that in 8 cases (80%), the respondents did not use any specific expert system development model, i.e., they used the traditional approach. In 2 cases (20%), the respondents used their own development model. This is supported in the literature study.

Model/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Yes					X		X				2	20
.No	X	X	X	X		X		X	X	X	8	80

Table 8.13: Data about using a specific model for developing ES (Question 22)

Problems with experts arise from the requirement of eliciting knowledge from human experts. The questionnaire investigation identified some problems with human experts, as shown in Table 8.14. In 7 cases (70%) there were problems with human experts. The most common problem with experts was misunderstanding which was reported in 4 cases (40%). The problem of limited time and access to experts, was reported in 2 cases (20%) each. Other problem such as limited cooperation of human experts was reported as well.

Problems/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.None		X		X			X				3	30
.Misunder-standing	X			X		X	X				4	40
.Limited cooperation			X								1	10
.Limited access		X							X		2	20
.Limited time			X	X							2	20
.Other			X								1	10

Table 8.14: Data about some problems with human expert(Question 18)

8.7 The outcomes of expert systems after developing

The questionnaire investigation showed that in 4 cases (40%) consistency was the main outcome of developing expert systems, shown in Table 8.5.

The next two main outcomes were less cost and better access to knowledge reported in 2 cases (20%) each. Other outcomes such as, gaining experience, and producing knowledge with a better quality were pointed out.

Issues/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.None								X			1	10
.Consistency	X	X				X	X				4	40
.Less cost		X			X						2	20
.Better access to knowledge		X	X								2	20
.Other			X			X		X			3	30
.Do not know									X		1	10

Table 8.15: Data about some issues after developing expert systems in organizations (Question 19)

In 8 cases (80%), the respondents reported that they were satisfied with developing expert systems, shown in Table 8.16. Different reasons were given for their satisfactions such as: consistency in decision making, better access to knowledge and less costs were pointed out. Only, in 2 cases (20%), did the respondents report dissatisfaction. Different reasons were reported such as, limiting the problem.

Satisfaction/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Yes	X	X	X		X	X	X		X	X	8	80
.No				X				X			2	20

Table 8.16: Data about satisfaction of various organizations with their expert systems (Question 20)

Question 21 (Table 8.17) was about testing the quality of their expert systems. In 7 cases (70%), they answered that they approved it by confrontation with human experts. In 3 cases (30%) the respondents reported, testing by specific data. Also, testing against historical data was reported in 2 cases (20%). Other ways were reported in 2 cases (20%), such as testing by their own methods of experiences.

Testing/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Testing against historical data					X			X			2	20
.Judging by human expert	X	X	X	X	X	X		X			7	70
.Testing against specific data					X		X	X			3	30
.Other					X				X		2	20

Table 8.17: Data concerning testing the quality of expert systems in organizations (Question 21)

The questionnaire investigation identified three types of expert systems development stages, as shown in Table 8.18. In 3 cases (30%), the respondents reported that their expert systems were in operation and in 4 cases (40%) in prototype stages. Also, in 2 cases (20%), the respondents reported that their expert systems were in the final testing stage. In one case (10%) the respondent reported that the project had been stopped. Four projects of expert systems were started in 1990, and two projects in 1989. The rest started in 1986, 1987 and 1991. This implies that expert systems development takes time and the expert systems technology market is growing.

State of ES in/System Janu. 1992	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Operation	X	X	X								3	30
.Final test							X	X			2	20
.Prototype				X	X	X				X	4	40
.Other									X		1	10
.Year of development	90	90	90	90	89	91	86	89	87	91		

Table 8.18: Data regarding state of expert systems in various organizations (Questions 7, 13)

8.8 The role of expert systems

In Question 23 (Table 8.19), the respondents were asked to indicate about who decides what gets done next. In 9 cases (90%), the respondents reported that the user decided what gets done next in the system. Only in one case (10%), was the management pointed out. This can be interpreted as the user, because the management can be the user of the system.

Initiative/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total
.User	X	X	X	X	X		X	X	X	X	9	90
.Other						X					i	10

Table 8.19: Data about who decide what gets done next (Question 23)

In Question 24 (Table 8.20), the respondents were asked to indicate who controls the dialogue between the system and user. In 7 cases (70%), the respondents reported that the user controls the dialogue. In 4 cases (40%), the respondents reported that the system controls the dialogue.

Control/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.User	X	X	X		X			X	X	X	7	70
.System				X	X	X	X				4	40

Table 8.20: Data about the control of dialog between system and user (Question 24)

According to Table 8.21, in 8 cases (80%), the respondents reported the function of their systems as providing advice for decision making. In 3 cases (30%), the respondents reported that the systems solve the problem, i.e, the system provides the relevant decision. Other functions such as the system providing data tables for better decision making was reported.

Function/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Advice			X	X	X	X	X	X	X	X	8	80
.Decide				X			X	X			3	30
.Other	X	X									2	20

Table 8.21: Data about the function of expert systems in various organizations (Question 25)

The questionnaire investigation showed that in 5 cases (50%), the respondents reported that the responsibility for expert systems was given to the users. In 3 cases (30%) the responsibility of the system was given to the human expert and designer for the system, shown in Table 8.22.

Responsibility/System	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Designer				X		X			X		3	30
.User	X	X	X		X	X					5	50
.Expert				X			X	X			3	30

Table 8.22: Data about the responsibility of expert systems in organizations (Question 26)

The questionnaire investigation showed that most of the expert systems were small in size, shown in Table 8.23. In 8 cases (80%), the respondents reported that the size of their expert systems was small. Only in 2 cases (20%) was a medium size reported.

Size[1] of/System system	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	Total #	%
.Small	X	X	X	X	X	X		X		X	8	80
.Medium							X		X		2	20

Table 8.23: Data about the size of the expert systems in various organizations (Question 27)

In Question 1 (Table 8.24), the respondents were asked to define an expert system. In all cases, they had a different view of expert systems. This is supported by the study.

System	Views[2]
S1-S3	Computerize a task which has been difficult to computerize with conventional computer systems.
S4	An interesting technique with its problems.
S5	One way of implementing knowledge and experience on computer in order to distribute to less experienced people.
S6	Rapid instructor, and friendly support system.
S7	Developing techniques of knowledge elicitation.
S8	Make use of rules.
S9	Logic.
S10	No answer given.

Table 8.24: Various views about expert system reported by the respondents (Question 1)

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[1] Small=50-500 rules, Medium=501-1500 rules, Large=1501-...[Harmon et al. 1988].

[2] The views were originally reported in Swedish. Thus, this may not represent an exact translation .

8.9   Interviews

8.9.1 Background

Eight months after collecting data by questionnaire investigation, two of the eleven organizations were further investigated. There are various approaches to collecting qualitative data through open-ended interviews. The two common approaches are known as structured (formal) and unstructured (informal) interviews. In the following cases, I used a combination of both approaches, i.e, both formal and informal open-ended interviews, consisting of a set of questions arranged with respect to the objective of the research questions. It was important to minimize variation in the questions posed to respondents by some formal open-ended questions. Regarding unstructured interview, some questions characterized rather general about the field were asked. The organizations chosen belonged to service business sectors. This stage of empirical investigation was initiated by contacting the respondents of the questionnaire from the relevant organizations chosen to make an appointment for an interview. Through interviews with managers and KENs an attempt was made to investigate the development of ES in the organizations as well as to evaluate the ES consequences for the organizations and the knowledge engineer personally. The interviews were both noted and tape-recorded. On two of the occasions the respondent did not feel comfortable with tape recording, so I did not use any tape-records in those occasions. This was important for later analysis. Actually, I enjoyed these interviews more than the others. I also felt less formal as well. The interviews lasted on the average about one and a half hours and were focused on the following matters:

-Background about the organization
-The reasons for developing ES
-The problems of ES development, motives, and issues
-The role of ES and management involvement.

8.9.2 The results of interviews in summary

Organization 6 (O6)

The company was created in 1906 and located in the industrial area of Malmö. The O6 Group comprises some 50 wholly or partly owned companies. Most of the companies are active in the production of energy, such as electricity, natural gas, solid fuels and chemicals. The O6 has about 4,000 employees. O6 shares have been listed on the Stockholm Exchange since 1966. In Feb. 1992, O6 had approximately 14,700 shareholders. The second largest owner is the German power company. The Group turnover was 9 billions SEK in 1991. Each year the Group invests up to 200 million SEK in research and development which 30 million SEK was allocated to O6 in 1991. About half of the investment was used for safety improvement measures, increased productivity and economic efficiency in existing operations.

According to the research and development manager, the firm chose ES application in order to save money by identifying errors at their tasks in an early stage. This was supported both by KEN and experts. Furthermore, they mentioned that by such systems, they can provide education for others in the organization who are less experienced. Their system is PC based, they use a tool named G2 and they bought from Gensym, an American company in Boston, for the price of 210,000 SEK. They are very satisfied with the tool. According to them, it is very easy to work with and provides a good work environment. It runs on a workstation, SPACK Station 2. The objective of the system is to find out about the condition of the heat in the reactor plant in good time for further planning. In Appendix VI you will find some copies of the system, comprising the plan of the reactor plant, some rules and diagnoses for one of the chiller. In the plan, one finds, a reactor (shown as BWR), turbine (shown as LHP), super heater (shown as MÖH) and chiller (shown as DK). When the temperature of the system is out of range, then the system gives a warning (shown in Fig. 2.2.2 Diagnose for chiller 3, in Appendix VI) in different colour and then further specifies the location (shown in Fig. 2.2.3 in Appendix VI). In order to understand the system deeply, one really should have a very good knowledge in the relevant field. My objective was to provide some primary information about the system.

The project started in 1989, and they had some help from external consultant. A guest Professor from Canada, and some body else at LTH. They are no longer with the project. Further, they are not present at LTH. The system is still at the prototype stage and they anticipate that the system will be used in the late Autumn/Winter 1993.

According to KEN, and the research and development manager, the system is going to be used as a tool to help the decision making process better. It is not intended to replace the human decision maker. They were all positive about this aspect. The quality of their system, i.e., the diagnosis of the system was judged in confrontation by human engineers at the company. And it is them who took the responsibility for the decision making. The system was not a big one, with respect to the number of rules in the system. It has less than 500 rules. One of their problems was misunderstanding engineers. It was not so difficult for engineers to formalize their knowledge, but the misunderstanding happened in the process of formalization by knowledge engineers. The other matter was that they encountered a too vast volume of information. Thus, it was difficult for them to define the limit. The initiative of development was taken by an internal specialist and was supported by the management. They are expecting to save a large amount of money by using the system. Furthermore, the quality of their decision making process will be increased. For example by identifying error in the system at an early stage, they will prevent a catastrophe in the system and save a lot of money.

Comments: In this case, by developing ES the company wanted to have a better quality decision making process, in order to identify errors of the system at an early stage which can lead to save a lot of money for the company. Regarding the motive of ES development in O6, one may come to the conclusion that their motive was to save money. The other important motive was to have a better quality decision making process. These motives are supported in the literature study. Their system was not a large one. One can place their system in the small size category with respect to the number of rules. The initiative of developing Es in O6 was taken by internal specialists and developed by some help from external consultants.   According to the interview results, this indicated that the internal specialists were DP specialists with no major background in KENG. The external consultant had some background in the field. This was supported by management. Otherwise, they could not go on with the project. However, their involvement in

the project was limited. From my point of view, one may conclude that their involvement was only motivated to have a better control of the process from their points of view. They were not directly involved in the development process of ES. They were informed about the progress of the project by reports provided by KEN.

Their system was in the prototype stage. This indicates that ES development usually takes a longer time than conventional computer based systems. This is partly due to the knowledge engineering process. This is explained in the theoretical part of the study. Their main problem was the limitation of knowledge elicitation for their system. This is supported both in the literature study and empirical study. The other problems such as misunderstanding of human experts or limited time of human experts were overcome somehow. The main issue of developing ES in the organization was to save money and obtain a better quality decision making process. However, the system was not in real use yet. But, that was their expectation. Regarding the role of ES in the organization, they viewed ES as an aiding medium in the decision making process. Put differently, the system was not going to be used instead of human expert. But as an aiding tool for a better decision making process. Thus, the final responsibility and decision making go to the decision maker in the organization.

Organization 5 (O5)

O5 is a wholly owned subsidiary of Teleinvest AB, which is a member of the Televerket Group. O5 is Televerket's research and development company. Their objective is to consolidate the Group's position and competitive ability as a telecommunications company, both internationally and domestically. Operations are organized into seven divisions such as service development, service research, communications systems, network development, systems research, telecommunications support systems and validation. The organization also has the group staff for standardization, licenses, patents and international activities. Televerket allocates 4% of its turnover to research and development of which O5 receives half (about 700 millions SEK). This indicates that future development by O5 is strongly dependent upon the performance of the Televerket Group. O5 is located in Malmö and has about 118 employees of which 19.5% are women. They have a joint project called "key exchange for open communications systems" which was carried out together with the National Institute of Standards Technology (NIST) in the US NIST's data security division developers the formal standards for data security followed by US federal agencies. The objective of the project was to develop a key exchange protocol for use in an open communication. They also have joint programmes with the European standardization organization ETSI. The O5 long-range objectives include the provision of services and systems that will obtain substantial competitive advantages for Televerket. They want the different business units to view O5 as a key partner in formulating their strategies and visions. The O5 staff consists of engineers, psychologists, behavioural scientists and social scientists. O5 developed an ES in 1986 in monitoring. They run the system on Macintosh and used Prolog, supplied by the LPA company. The respondent defined an expert system as a technique for developing KA. According to the respondent in the interview (KEN), the company wanted to prove the new possibility of ES. The management supported the initiative introduced by an internal specialist. They had not encountered many problems during the process of developing ES. The only problem was knowledge elicitation. They could not extract all the knowledge from human experts. In response to my question that why they could not extract knowledge from human expert, then KEN answered me, because human expert did not want to cooperate. Not because human expert could not. The respondent was almost sure that

human expert did not want to cooperate for the fear of losing his job. That was the respondent's perception in general. Furthermore, the respondent said that their domain application was not a "diffuse domains". According to KEN, diffuse domains are application areas which for different reasons, cannot be described in a simple way. One example is a domain that to a large extent requires human expert knowledge. Knowledge in the form of rules of thumb which are based on experiences rather than algorithms. According to KEN, their ES did not fall in this kind of "diffuse domain".

Regarding the use of specific model for developing ES, they used their own method of designing ES. This method is explained in a book [Peterson et al. 1990]. The other problem such as, difficulty access to human experts was managed anyhow. The objective of both management and KEN was that the system was not going to replace the human expert in the organization, but aid in a better decision making process, and educate other people with less experience in the organization. The *system is now in use and they are satisfied with it. They delivered the system to other organization in the Group. Unfortunately, I could not get into the organization which now uses the system. I had not been given any time with the user/responsible person of the system.* According to the KEN, the system can save the organization a lot of money by identifying an error in their tasks (for example in the communication system). As one may notice, at the time of receiving the data from questionnaire investigation, their system was under final testing.

Comments: In this case, the system is in use now. This was not considered in the analysis, because of the consistency with other relevant material based on the data gathered by the questionnaire investigation. The company wanted to prove the new possibility of ES technology. And they did not have many problems in developing their system which was not a large one. They had some problems in the process of KA, i.e., in the sub-process of extracting knowledge from human experts. And the reason was not that a human expert could not formulate his/her knowledge, but that the human expert did not want to do this. More, their domain of application was not " *a diffuse domain*" as explained. Generally, the KEN believed that the human expert is afraid to lose his/her job as a consequence of developing ES. Actually, this is an interesting matter. One can say that this can be true from some other people's view point and vice versa. In essence this matter falls within different perspectives of how one views the

experts knowledge. Also, in the theoretical part, I mentioned that it is possible that human expert will not cooperate in the process of extracting his/her knowledge because the fear of losing his/her monopoly. Thus, this may be taken to mean that a human expert can not verbalize his/her knowledge in some cases. One contribution for smoothing this problem is to explain to the human expert that the system is not going to replace him, but rather is going to aid him in his tasks. This matter should be explained at the outset of the project. This is known as the role of ES. Anyway the company was satisfied with their system and it was vital for them, because the system saves a lot of money and can provide competitive advantages.

8.10 Summary

In this section, the empirical part of this work was presented. Various tables presenting the findings of the questionnaire and interviews investigations were also presented.

PART V:CONCLUSIONS

9. RESULTS

9.1 Introduction

This chapter summarizes the results of the empirical studies in terms of the support for the issues drawn from the theoretical part. The empirical investigations attempted to identify the motives, some problems and issues of developing expert systems. Twenty three Swedish organizations which studied the potential of expert systems were included in the investigations. The investigation instrument used was questionnaires which were mailed to 23 organizations. All the organizations which participated in the investigations belonged to two business-unrelated fields. Twelve belonging to industrial fields, developed 15 expert systems, and eleven organizations belonging to administrative fields developed ten expert systems. The chosen unit for the study was expert systems. Totally, twenty five expert systems were developed by various organizations which participated in the study. Below the findings are summarized, some hypotheses are drawn, and their relations to the conceptual model of expert systems development as presented in Chapter 6 are shown in Fig. 9.1.

9.2 Motives for developing expert systems

Some motives for developing expert systems were identified by the questionnaire investigations, see the following table. According to Table 9.1, the most important motive for developing expert systems in industry branch was to test the new possibility of ES technology, whereas in the administrative (services) field the motive was dissatisfaction their previous systems. According to the literature study the most important motive was to save money. This implies that people in the industry branch have a different understanding of motivation for developing ES, compared with the understanding of people in the service branch. Along with the corporate aims of the organizations, motivation is the most important factor. Successful implementation of an expert system depends very strongly on motivation. Expert systems are successful in that they are fully implemented and satisfy performance requirements. Moreover, they should obtain psychological success as well. This concept of

successful implementation of ES is supported in the other similar international studies [Bachmann et al. 1993, Byrd 1992, Duchessi & O'keefe 1992, Motoda 1990].

Motives	Business fields				Total	
	Ind. N=15		Adm. N=10		N=25	
	#	%	#	%	#	%
.Testing possibilities	10	67	3	30	13	52
.Problem was suitable for ES	0	0	6	60	6	24
.Consistency	6	40	4	40	10	40
.Less cost	7	47	4	40	11	44
.Dissatisfied with previous system	6	40	8	80	14	56

Table 9.1: Data of motives for developing ES in various organizations (extracted from Tables 7.3, 7.4, 8.3, 8.4)

Put differently, once a good understanding of the motivation for developing an expert system has been attained, it can then guide other relevant concepts (explained before) involved in the expert systems development process, which can lead to a better implementation of expert systems projects, shown in Fig. 6.2, and 6.6. This is supported by the American study of ES [Byrd 1992] and British investigations, the Alvey program [Oakley & Owen 1989, Rees 1992, Duchessi & O'Keefe 1992], and Japanese studies of ES [Hirai 1988, Motoda 1990]. Regarding the above mentioned discussion, one can draw the following general hypothesis.

Hypothesis 1:Successful implementation of an expert system project depends very strongly on motivation.

As mentioned before, the concept of motivation with its structural linkages to other concepts involved in expert systems is presented in Chapter 6. Regarding the foregoing discussion and Hypothesis 1, then one can understand the relations of Hypothesis 1 to the model, shown in Fig. 9.1 (The figure is placed at the end of this chapter). This helps one to understand the model in a better way.

Furthermore, one may understand the importance of this hypothesis by further practical study. Moreover, to realize the importance of the concept of motivation, imagine yourself as a knowledge engineer in an organization and you want to introduce the expert system technology into the organization. Without having a clear understanding of the motivation for developing expert systems, how can you obtain the support of management, users and experts? Moreover, how could you define your requirements, resources and so on? When one has a good understanding of the motivation, one can better define the various concepts involved in the expert systems development process, (shown in Fig. 6.6) which can lead to better implementation of expert systems projects. Also, this aspect was mentioned in the evaluation of the Alvey programme [Oakley & Owen 1989], i.e., it is very important to have a broad understanding of expert systems development.

Regarding Hypothesis 1, one may draw the following particular hypothesis based upon the findings of the investigations shown in the last column of Table 9.1.

Hypothesis 2:The present (1992) common motive for developing expert systems is not to save money.

For example, according to Byrd [1992], the most important motive for developing ES in American organizations was the elimination of routine tasks. The next most important motive was related to the competitive advantage. This can be interpreted as testing the new possibility of expert systems technology. In this case, this matches the findings of this study as well. Furthermore, this aspect has been mentioned in the Japanese investigations [Hirai 1988, Motoda 1990]. According to UK studies [Ress 1992, Taylor 1992], time and cost savings were mentioned by 45% of the respondents.

Cultural environments differ from country to country. Consequently, it may be said that the above mentioned particular hypothesis is only tru in the context of Swedish organizations. While this may be true and for this reason I state it as a particular hypothesis, I have, nevertheless made the assumption that the Swedish environment is not different from other Scandinavian countries or for that matter, other countries in Europe.

However, this matter falls outside the scope of this study. My intention was to give the reason why I state the second hypothesis as a particular one. This may be borne in mind for the rest of "particular hypotheses" in the study.

9.3 Initiative, support and development of ES

The investigations identified the initiative[1]-taker of developing expert systems in various organizations, see the following table. In both industry and administrative (services) fields, the initiative of developing expert systems was taken by internal specialists. In 15 cases (60%) out of 25, the initiative of developing expert systems was taken by internal specialists in organizations. In 6 cases (24%), the management took the initiative of developing expert systems in organizations.

Initiative	Business fields				Total	
	Ind. N=15		Adm. N=10		N=25	
	#	%	#	%	#	%
.Internal specialists	7	47	8	80	15	60
.Management	6	40	0	0	6	24
.External specialists	1	7	2	20	3	12

Table 9.2: Data of the initiative taken by different people in various organizations (extracted from Tables 7.5, 8.6)

Once one has a broad understanding of the motivation, then one can obtain wider support from management. Introducing a new technology in an organization without the support of management can never be successful. The findings of the study showed that internal specialists had a good understanding of the motivation for expert systems development which led to a good support from management for developing expert systems, shown in Table 9.3.

[1] This aspect has not been investigated in any of the mentioned ES studies, i.e., in the American study [Byrd 1992], British investigations [Rada 1990, O'Neill & Morris 1989, Rees 1992, Taylor 1992], German study [Bachmann et al. 1993] and Japanese investigations [Hirai 1989, Motoda 1990].

Support	Business fields				Total	
	Ind. N=15		Adm. N=10		N=25	
	#	%	#	%	#	%
.Management	12	80	9	90	21	84
.Personnel who took care of tasks	9	60	2	20	11	44
.Personnel at computer dep.	5	33	3	30	8	32

Table 9.3: Data regarding the development of ES supported by different people in organizations (extracted from Tables 7.6, 8.7)

According to the findings of the study, in 21 cases (84%) the management supported the expert systems projects in various organizations. Tnis indicates that the involvement of management in expert systems projects is as vital as in any other project in any organization. This matter is supported in the American study of ES [Byrd 1992], and in the British Alvey programme [Oakley & Owen 1989], UK survey of ES [Rees 1992], in the Japanese study [Hirai 1988] and Duchessi & O'Keefe 1992. Furthermore, most ES are developed under the patronage of a "manager", the person who wants the system developed and operationalized. Thus, the manager provides the financial/resources directly or indirectly. Having top manager to support the ES project gives high visibility, stimulates organizational support and fosters operational use. One can draw the following general hypothesis based upon the findings of the study and theoretical framework.

Hypothesis 3:The management must supports the development of expert systems in their organizations.

Regarding the foregoing discussion, in order to understand the relation of Hypothesis 3 in the model, one should remember that to obtain the good support from management, one must have a clear understanding of the motivation. To put it differently, obtaining good support from management can be achieved by a clear understanding of the motivation which can influence the other concepts involved in the expert systems process , shown in Fig. 9.1.

This matter was also pointed out in the evaluation of the British Alvey programme [Oakley & Owen 1989], pp.293-294, and in the project of the Japan Information Processing Development Center (JIPDEC) [Terano et al. 1991], UK survey of ES [Rees 1992] and the American investigation of ES [Byrd 1992]. The investigation findings showed that in most cases expert systems were developed by internal specialists in the industry branch, whereas in the administrative (services) branch, in most cases expert systems were developed by external specialists. If one considers internal specialists to be the same traditional data processing (DP) specialists who only changed to a new title (e.g. opening a new department of AI in their organization) without enough relevant education and training, then the developing of expert systems by these persons is not recommended. This could be true for external specialists, who have chosen new names (e.g. knowledge systems company) for their companies in order to attract new customers.

ES developed by	Business fields				Total	
	Ind. N=15		Adm. N=10		N=25	
	#	%	#	%	#	%
.Internal specialists	7	47	2	20	9	36
.Personnel in the computer Dept.	2	13	5	50	7	28
.External consultant	4	27	7	70	11	44

Table 9.4: Data concerning the development of ES by different people in organizations (extracted from Tables 7.7, 8.8)

According to the findings of the investigations, in most cases the expert systems were developed by external specialists in both fields of business, see Table 9.4. In 11 cases (44%), the respondents reported that their expert systems were developed by external specialists. One may draw the following particular hypothesis with regard to the above discussion.

Hypothesis 4:The development of expert systems is usually performed by DP experts.

This can indicate that the internal specialists were not competent in the field of knowledge engineering to develop their own expert systems. This means that the universities and educational organizations should provide various courses in knowledge engineering. According to my knowledge, no major Swedish company has established AI groups having staff with Ph.D. competence in AI[2]. This is supported in the American study of ES [Byrd 1992] and UK study of ES [Rada 1990]. According to another UK survey of ES [Rees 1992] 75% of respondents answered "yes", when asked if their companies or an IT department with a formal IT strategy which included knowledge based systems (KBS). In other words 56% of them have particularly included KBS in that strategy.

9.4 Some problems of expert systems development and its use

The findings of the investigation showed that the most common problem was knowledge acquisition in both fields of business. Moreover, the findings showed that the most frequent problem within the KA process was knowledge elicitation. The problem of communication is likely to arise in this process. Also, the problems of the KA process (i.e., eliciting, structuring and representing) and limited available hardware and software resources were pointed out in the evaluation of the Alvey programme [Oakley & Owen 1989], p. 270, 282, and the Japanese investigations [Terano et al. 1991, Hirai 1988]. According to the American study [Byrd 1992], the KA factor was seen as the bottleneck in the successful implementation of ES. This is also supported in another British study [Cullen & Bryman 1988] and UK studies [Rees 1992, Taylor 1992] and a German study [Bachmann et al. 1993].

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2 This is supported in a report by Dan Strömberg, "Operational AI application in Sweden", FOA, Linköping, pp.1-8, 1990, Sweden.

Problems	Business fields				Total	
	Ind. N=15		Adm. N=10		N=25	
	#	%	#	%	#	%
.Software & hardware	9	60	7	70	16	64
.Limited available resources[3]	5	33	1	10	6	24
.KA problem	12	80	8	80	20	80
.Problem with HE	10	67	7	70	17	68

Table 9.5 Data regarding some problems with developing ES (extracted from Tables 7.8, 7.9, 7.11, 8.9, 8.14)

Human experts and knowledge engineers communicate with each other in the KE process. This is supported in the American and German studies [Byrd 1992, Bachmann et al. 1993] as well as the British investigations [Cullen & Bryman 1988, O'Neill & Morris 1989]. According to the UK survey [Rees 1992], technical problems with software were mentioned most frequently (about 20%) followed by difficulties of extracting expert knowledge (19%). The findings of this investigation showed that in 17 cases (68%) out of 25 this problem appeared, see Table 9.5. The findings showed that most of the expert systems developers did not use any tools in the knowledge acquisition process. This implies that most of the designers of expert systems use the knowledge engineer-driven KA, see Fig. 4.7a. This approach to the KA process has its own problem, which has been mentioned above. As the findings showed, various approaches to knowledge acquisition can have different problems. Regarding the above discussion, one can draw the following general hypothesis.

Hypothesis 5: The knowledge acquisition process is the main drawback in the process of developing expert systems, and various approaches to knowledge acquisition have their own problems.

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3 This is the combination of limited time and budget.

As the findings showed, various approaches to KA have their own problems, and this implies that various approaches can generate different steps in the development process of expert systems which can influence the concept of the components of an expert system. For example, the approach of knowledge engineer-driven to the KA process implies that human experts and knowledge engineers are the important elements of an expert system. Whereas in the machine-driven (Fig. 4.7d) approach to the KA process, the aspect of the elements of expert system can differ. Regarding the foregoing discussion and hypothesis, then one can realize the relation of the Hypothesis 5 in the model presented in Chapter 6, see also Fig 9.1. It has been mentioned that the most common problem in the knowledge acquisition process is knowledge elicitation. This is supported both by the literature study and the findings of the study. Thus, it is important that a knowledge engineer using the approach of the knowledge engineer-driven knowledge acquisition be well trained in interview techniques in order to reduce communication problems.

The findings of the investigation showed that 7 (28%) systems were in operation, see Tables 7.16, 8.18. This indicates that the development of an expert system generally takes a long time, a minimum of 2-3 years to complete most ES before the system is put into use. This is supported both in the American study of ES and UK study [Byred 1992, Rees[4] 1992]. Even after the ES is operational, the knowledge engineering process continues due to the validation process. The findings of the investigation showed that the knowledge engineers did not use any specific expert systems development model, see Table 9.6, which is supported in the British study [O'Neill & Morris 1989] and UK survey of ES [Rees 1992]. In a Japanese study [Motoda 1990], the percentage of ES in use was reported to be about 47% (i.e., about 189 systems out of 401 systems) in 1990. According to a British study [O'Neill & Morris 1989], about 274 systems were claimed to have been produced in total, of which a quarter (25%) were said to be operational[5]. In a German investigation [Brachmann et al. 1993], 27% (4 systems out of 15 systems) was mentioned as being successful.

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[4] According to Rees [1992], 22% of the respondent companies took over two years to develop and implement their system.

[5] This matter was not clearly mentioned in the American study [Byrd 1992].

Model	Business fields				Total	
	Ind. N=15		Adm. N=10		N=25	
	#	%	#	%	#	%
.Yes	6	40	2	20	8	32
.No	8	53	8	80	16	64

Table 9.6: Data referring to the use of a specific model for developing expert systems (extracted from Tables 7.13, 8.13)

Moreover, the findings of the investigation showed that 28% of the expert systems were developed for use in the fields of diagnosis and control (see Table 9.7), whereas in the Japanese investigation [Motoda 1990] 38% (i.e., 154 systems out of 401 systems) of the expert systems were developed for diagnosis and 25% (i.e., about 100 systems out of 401 systems) for planning. According to a German study [Bachmann et al. 1993], 33% (i.e., 5 systems out of 15 systems) of the expert systems were developed for diagnosis and 27% (i.e., 4 systems out of 15 systems) for configuration. A survey of British expert system literature in 1986 revealed an emphasis on medical expert systems. At one time a similar emphasis was evident in the US. Recent surveys of British expert systems activity suggest that the effort has moved towards financial and engineering applications [Rada 1990, Rees 1992, Taylor 1992].

Diagnosis		Control		Design		Planning		Other	
#	%	#	%	#	%	#	%	#	%
7	28	7	28	6	24	3	12	2	8

Table 9.7: Classification by application type (extracted from Tables 8.2, 7.2)

In addition, as mentioned above, the knowledge engineering-driven approach to the KA process were used in most cases according to the findings. The investigations showed that testing the quality of expert systems was by means of (judged by) confrontation with human experts, see Table 9.8. This kind of testing was supported in the British study of ES [O'Neill & Morris 1989] and the Japanese project [Terano et al. 1991]. They [O'Neill & Morris 1989] pointed out that the majority of those interviewed were using human expertise both for creating a knowledge base and validating the quality of the system in the later stage of a project.

Testing	Business fields				Total	
	Ind. N=15		Adm. N=10		N=25	
	#	%	#	%	#	%
.Judging by HE	15	100	7	70	22	88
.Testing against specific data	2	13	3	30	5	20

Table 9.8: Data concerning testing the quality of ES in various organizations (extracted from Tables 7.14, 8.17)

All these indicate that knowledge engineers and human experts are vital components of expert systems. This means that the expert system development process is an incremental process which requires additional participants such as, a qualified knowledge engineer (designer) and a qualified human expert. This aspect is also supported in the Japanese project [Terano et al. 1991], British studies [O'Neill & Morris 1989, Rees 1992] and American study [Byrd 1992]. One important requirement is for a qualified knowledge engineer (designer) to realize that expert systems development requires the design of an active knowledge base. That is to say, essential for successful implementation will always be the expansion capacity and cultivation of the knowledge base (this matter is discussed in the theoretical part). Put differently, a knowledge engineer should realize that validating the internal knowledge base architecture involves human experts and knowledge engineers. Human experts have to evaluate how well the knowledge base design fits the overall structure of the

problem domain. Knowledge engineers act as an interface between human experts and particular constructs of the knowledge base [Meseguer 1992]. Furthermore, the end users might develop a lack of trust in the recommendations and advice given by the system. This lack of trust may come through because of the lack of an explanation facility and not validating the knowledge base. So, a knowledge engineer should realize that a knowledge base is active compared to a database. In order to realize this a knowledge engineer should have the holistic view. This means that a knowledge engineer must depart from the traditional way of thinking. Regarding the above discussion, one can draw the following general hypothesis.

Hypothesis 6:A knowledge engineer should have a holistic view when developing expert system projects.

The above hypothesis indicates that a knowledge engineer (designer of ES) must refrain from the traditional way of thinking in order to understand the relationships of various concepts (shown in Fig. 9.1) involved in expert systems development. By realizing this, one can obtain a broader understanding of the expert systems development process which can lead to successful implementation of expert systems projects.

The findings showed that the user decides what gets done next, see Table 8.19. Moreover, Table 8.20 showed that the user controls the dialogue between the system and user in most cases. The responsibility of expert systems varies from one system to another, depending upon their roles. Regarding Fig. 6.3, the concept of the role of an expert system can influence the trends of responsibility of expert systems which can generate the concept of the responsibility of expert systems that in turn can direct the concept of the role of expert system. The findings showed that the responsibility of expert systems was given to the .ser in most cases, see Table 8.22. Moreover, the reported trends of using expert systems were towards providing advice in most cases, see Table 8.21. According to Frost [Frost 1986], most of the reported expert systems had the status of Fig. 3.11a, i.e., expert systems as slaves. Regarding the above discussion, one can draw the following general and particular hypotheses.

Hypothesis 7: It is important that a knowledge engineer differentiates between the various roles of an expert system at the outset of developing expert systems.

Realizing the role of an expert system can lead to higher motivation and successful implementation of an expert system project, see Fig. 9.1. This is pointed out in the Japanese project [Terano et al. 1991] and American study [Byrd 1992]. More, he [Byrd 1992] points out that 74% of the respondents indicate that expert systems are used as "advisors to human experts".

Hypothesis 8:The present trends of developing expert systems are towards aiding better decision making or advising.

This particular hypothesis is supported both by literature study and findings of the study. Put differently, a knowledge engineer must realize that the present trends of using an expert system is not to replace human experts with expert systems, but rather to use them for aiding the decision making process. In other words, for the time being, it is better to think of an expert system as an intelligent assistant than as a replacement for a human expert. By realizing this, the knowledge engineers can obtain better cooperation of the human expert. In other words, a knowledge engineer can reduce, the uncooperative trend on the side of human experts by explaining to them that they will not lose their jobs because of expert systems development. After all, their jobs provide them bread and butter. Human experts would not give up their monopoly easily [Newman 1988]. Once a human expert feels safe about his job, then this may lead to a better articulation of his knowledge for the knowledge engineer. Thus, a knowledge engineer may reduce the communication problems between human expert and knowledge engineer in the process of expert systems development. Furthermore, by realizing this, the knowledge engineer can have a clear motivation for expert systems development which can influence the other concepts involved in the expert systems development process, as explained before.

The investigations identified a number of outcomes after the developing of expert systems in various organizations, see Table 9.9.

Issues	Business fields				Total	
	Ind. N=15		Adm. N=10		N=25	
	#	%	#	%	#	%
.Consistency	5	33	4	40	9	36
.Less cost	2	13	2	20	4	16
.Better access	4	27	2	20	6	24
.Unknown	5	33	1	10	6	24
.Satisfied with ES	10	67	8	80	18	72

Table 9.9: Data referring to some issues after the developing of ES in various organizations (extracted from Tables 7.15, 7.17, 8.15, 8.16)

The investigations showed that the most common outcome was satisfaction with their expert systems, as reported in 18 cases (72%), see Table 9.9. Different reasons were given for their satisfaction, such as, better quality of decisions, better access to knowledge, better production and consistency. This matter is supported both in the American investigation of ES [Byrd 1992] and UK survey [Ress 1992]. Furthermore, they point out that one of the benefits of ES realized in various organizations is automated decision making. In other words, the quality of decision making rises because decisions can be prepared more quickly and more reliably. The expert systems can respond more readily to customers needs. The expert knowledge can be shared by others who are less experienced in the organizations. This knowledge may be used as a basis for decision making or for educating purposes. According to the UK survey [Rees 1992], the most tangible benefits were time saving (45%) and cost savings (36%). The findings of this study showed that expert systems increased the consistency and quality of decision making[6].

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[6] A good example of this is the equipment ordering process at Digital Equipment Corporation (DEC). DEC customers configure each computer order. A high percentage of all orders contained errors. These errors resulted in lost time, field engineering costs and lost revenue from missing components for which the customer refused to pay. DEC developed the R1 expert system to screen all orders before they were submitted to the company. In this case, the expert system increased the consistency

H1,H3 Concept of ES H1,H3 Approaches & H1,H3 Concept of ES
Concept of features methodologies components
perceived H1 H5
requirements H1 H5

H1, Concept of ES H6,H7 A successful
H3 development implementation of ES
Concept of H1 process H1,H3,H5 project
motivation

H1,H3 H6
H5 H7 Concept of designer's
attitudes
Concept of KA Concept of ES H1,H3
process H1,H3 roles & responsibilities
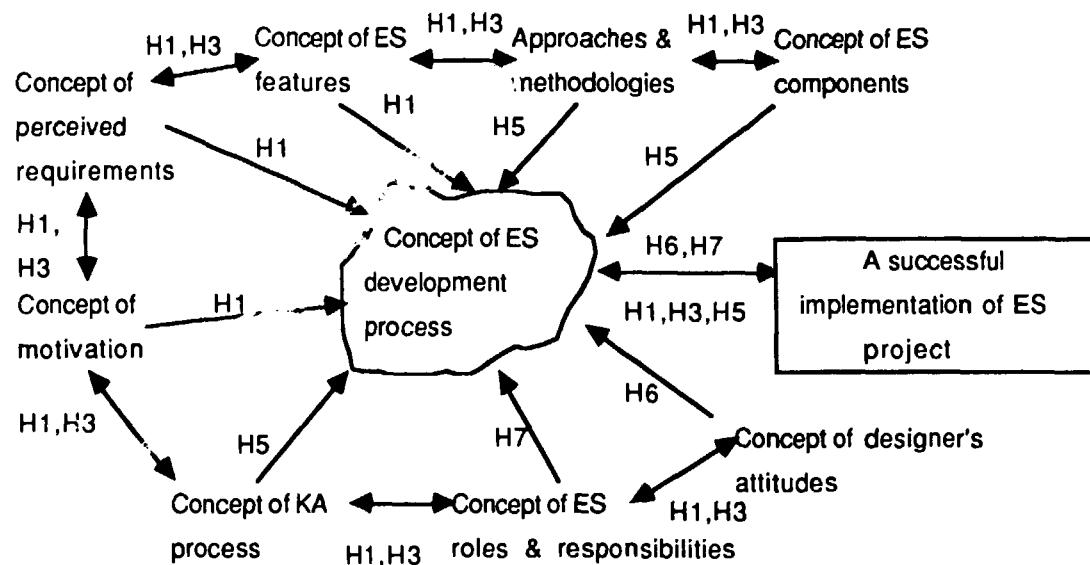
Fig. 9.1:A conceptual model of expert systems development, Source
[Sagheb-Tehrani 1993d,e]

H=Hypothesis
The numbers refer to the hypotheses in the text

9.5 By way of concluding remarks

There is a wide body of literature devoted to the development and application of expert systems. There is very little empirical evidence about expert systems application in an actual organizational context, except, in a few studies [Sviokla 1990]. Many questions, however would benefit from this investigation. For example, what are the important factors in successfully implementing expert systems in an organization? What are their problems and motives? What factors are involved in a company's move to invest in expert systems technology? What are the general issues realized from implemented expert systems?

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and quality of the decisions in the equipment ordering process. DEC once estimated that their system saved it $15m per annum in reduced errors and increased productivity [Rees 1992, Sviokla 1990]. This matter is emphasized in the interview cases of this study as well.

This work seeks to be a starting point in rectifying this situation and an attempt is made to create a broader theoretical framework for conceiving expert systems development. Thus, parts of this work is devoted to delineating relevant conceptual models which may contribute as the building blocks of a larger theoretical framework.

This chapter outlines the results of the study and draws some conclusions regarding their implications. Such conclusions are, however, generally formulated within the perspective of identifying the contribution of the study to knowledge in theoretical and empirical terms. I have endeavoured to show how the conceptual model for this study is useful for the identification of various concepts involved in expert systems development. Further research which examines the hypotheses presented here will greatly enhance our understanding of those significant factors that will contribute to expert systems technology improving organizational productivity and effectiveness. Within the framework of the study regarding the available resources, a perfect examination of how effectively each expert system was developed and used was not possible. It is difficult to predict how expert systems will fare in the future. All technologies have a limited life span and are replaced by other better innovations. Expert systems technology is not exceptional [Weitz 1990, O'Neill & Morris 1989]. From the findings of the study, it was evident that the expert systems market is still improving and making progress in an increasing variety of areas. This is true for the USA, Europe and Japan [Feigenbaum et al 1988, Harmon et al. 1988, O'Neill & Morris 1989, Rada 1990, Rees 1992, Taylor 1992, Hirai 1988, Motoda 1990, Ovum Ltd. 1989]. According to a UK survey [Rees 1992], ES technology is becoming a key technology in the manufacturing and finance sectors, both of great significant to the UK economy. Expert systems are spreading into almost every Swedish industry and Swedish large organizations and they are seeking the most efficient ways of introducing expert systems technology [Sagheb-Tehrani 1993b,f]. This survey would support the view that most of the large Swedish firms have expert systems development teams but their experience of building operational expert systems is limited. About 30% of the reported systems are in use (this could be more by now, i.e., the time of finishing this report), it is difficult to keep up with all of the progress in the field. Clearly, Swedish expert systems technology is growing [Sagheb-Tehrani 1993b,f].

The limits to this growth are not yet known, and one still does not really know what the domains are in which expert systems are likely to be successful. From the findings of the study, one can say that Swedish expert system technology has entered its first phase of practical use. The first phase deals with "how to build expert systems".

I will put forward a short-term prediction (say five years times). that Swedish expert systems technology will enter its second phase of practical use. The second phase deals with "what kind of expert system to build". Based on their experiences, industries will be able to evaluate what kind of expert systems are most effective.

Finally, as mentioned before, one can say expert systems development in substantial ways is different from conventional computer systems. Expert systems development are more complex than conventional computer systems [Sagheb-Tehrani 1993a,b,f].

10. POSTSCRIPT

This chapter contains a short discussion on the prediction of expert systems development in Sweden. This prediction presents my conception based both on literature studies and the findings of the investigation. Furthermore, a brief discussion regarding the criticism of expert systems is outlined from my point of view. It is significant that one realizes the role of tradition in ones critical basis. Here, my path falls within the rationalistic tradition. However, this (the criticism of ES) requires its own separate research. It is clear that the kinds of questions posed on this subject will only find answers as expert systems achieve widespread utilization. I hope this work (as an initial step) can contribute to this theme.

10.1 Prediction: A brief discussion

Scientists generally tend to overstate technological developments that are obtainable in the short-term and to underestimate what is obtainable in the long-term. Then, they are criticized for their lack of imagination or their exaggeration. The consequence of this axiom is that, specialists are normally reluctant to make either short-term or long-term predictions regarding future development in technology [McRobbie & Siekmann 1988]. The very important theological impact of expert systems is becoming apparent in two major fields of society, manufacturing and administration. In manufacturing, the productions of commodities will be characterized by increasing automation and the utilization of robots eventually leading in the fully automated factory. In administration, the norm is automated office.

To predict where we will be in the future (say, in about six years), it is always useful to know where we are now. In this case, we do not know exactly. That is to say, the extent to which expert systems technology has permeated the work place is not well known at the moment [Weitz 1990]. Market forecasts show a rising interest for expert systems, both in the USA and in Europe [Akselsen et al. 1989, Rees 1992].

According to Ovum research consultants [Ovum 1988], sales of products and development services in 1988 accounted for over $400 Million in the USA and Europe, and the expert systems market is growing at over 30% a year. The number of surveys on the nature of expert systems work in Britain is also growing at a similar rate [O'Neill & Morris 1989, Rees 1992, Taylor 1992]. This is also true for Japan [Hirai, 1988, Motoda 1990]. I will put forward a short-term prediction (say five years) which I believe can already be partially substantiated. The five years window implies that the likelihood of the diffusion of some technological breakthrough, will be low over the forecasting horizon [Weitz 1990]. The expert system development will become a part of knowledge engineering [Sagheb-Tehrani 1991c]. Many systems will be developed in planning and design. Highly efficient expert systems will be accepted as "colleague" (partners) in many professions. It may become possible to combine various expert systems, so that they can exchange information effectively. Efforts continue towards the utilization of deeper knowledge integration with other existing technologies and the introduction of new technologies. The area of knowledge acquisition and learning will be significant to researchers. In the long-term (say more than ten years) expert systems will be a standard part of man-kind life, both in manufacturing and administration. Future scientific research may become impossible without utilizing particular expert systems. The best expert system in various areas will be continuously refined. Those systems will become a vital part of organizations and economic wealth.

10.2 Criticism: A short discussion

The technology of the computer has been applied to the automation of office tasks and procedures. The technology of expert systems provide a new methodology for automating knowledge oriented processes. Generally, the critics of technology tend to fall into one of the following three camps [Zuboff 1982].

1) Some people accept any form of technology as progress towards some eventual conquest of nature.

2) Some people moan about new technology and consider them as a specific form of human debasement and depersonalization. 3) Finally, some people regard that technology is neutral and its meaning depends upon the uses to which mankind presses its application.

For example, there are views that as different kinds of expert systems come into widespread use, some aspects of a special dependence upon them may emerge, a dependence which could have serious consequences [Oravec ⁚988]. This kind of view which is too general and applicable to other kinds of IT, falls into the second camp, mentioned above by Zuboff [Zubof1982]. One may believe that the "expert systems dependence problem" is so serious and difficult to control, that eliminating such tools from our decision-making repertoire is the only solution. But, the increasing value of expert systems in organizations makes this option almost infeasible economically [Oravec 1988]. The basis for several critiques of AI[1] has been the dominant view of mind, declaring that cognition is not based on the systematic man'ation of representations. From my point of view, it is imp a t that one realizes the role of tradition in ones critical ba This is supported by Winograd & Flores [1986]. Here, I am nc ally concerned with the philosophical arguments, but with the rule of tradition in giving orientation to people who do not reg rd themselves philosophers, but whose ways of thinking ne ertheless embody a philosophical orientation. Regarding the f going point, most of the pioneer scientists in AI fall within t rationalistic tradition. According to Winograd and Flores [1986], from the rationalistic orientation view point, in the studies of thought, the emphasis is on the form of the rules and or the nature of the processes by which they are logically applied. Fields of mathematics, are taken as the basis for formalizing what goes on when a person perceives, thinks, and acts. For a scientist trained in science and technology it may seem self-evident that this is the right approach to thinking [Winograd & Flores 1986], p.16. Hubert Dreyfus and his brother Stuart[2] argue

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[1] For example see Dreyfus [1979], Haugeland [1981], Dreyfus & Dreyfus [1986], Winograd & Flores [1986], Ehn [1988].

[2] Their categorization is based on observations of everyday practice in professional learning and interpreted along the lines of existential phenomenology, in the tradition of philosophers like Martin Heidegger and Merleau-Ponty [Ehn

that expert systems will never perform as well as human experts due to the nature of expertise. They believe that true expertise arises through practical experience and cannot be obtained by simply following rules [Dreyfus and Dreyfus 1986]. In their critique of AI, they developed a five steps of skill acquisition model, in order to define what computers cannot do compared with human experts. They believe that learning a skill by a person normally passes through five stages[3]: novice, advanced beginner, competence, proficiency and expertise.

Novice: In the novice stage the person learning a skill is told to find particular context-free features and is told to act in a certain way when they are found. Features that relate to the particular situation are ignored and the novice may concentrate on searching for the context-free features. In other words, a novice applies context-free rules to objective facts and features in a relevant domain. The novice baker bakes bread as he/she has been told (a context-free rules), ignoring context like type of yeast and flour. From a novice point of view, improvement is a question of how well he/she manages to follow the learned rules.

Advanced beginner: By utilizing real-world examples the novice obtains experience and begins to recognize items immediately. This ability of the advanced beginner means that situational factors can be taken into account without always having to look for context-free features. One's performance improves when one gets considerable experience in coping with real situations. This is due to the fact that one not only gets better in using the learned rules but one also learns to use more complicated rules. The advanced beginner baker not only judges when to change the temperature of the oven according to the duration of the time specified by rules, but also from situational elements like touching the dough. The advanced beginner does not know when to violate rules, but from gained experienced from previous cases, he/she can also act according to situational elements.

1988]. In fact this path is valid for Winograd & Flores [1986] and Ehn [1988] as well.

[3] Thess five steps from novice to expert are explained in Chapter 2 of [Dreyfus & Dreyfus 1986], pp.16-36.

Competence: With more experience the advanced beginner will start to be overwhelmed by the number of context-free and situational features and will require to classify them into some form of hierarchy. In doing so the competent performer will have to take responsibility for the choice of hierarchy created. The competent performer can control the overwhelmingly increasing number of both context-free rules and situational elements. The competent performer improves and simplifies his/her performance by classifying them into some form of hierarchy or plan. The competent baker may choose and organize a plan to bake a particular type of bread as quickly as possible. In doing so, he/she will concentrate on the most vital context-free rules and situational elements, like the ideal conditions required for the dough to rise. Thus, he/she may violate the rules in order to fulfil the plan (i.e., to accomplish the above in as short a time as possible).

Proficiency: The proficient performer will normally be involved in the problem and will have a particular perspective on it. From this perspective particular features of the whole will tend to stand out, whilst others will tend to be less important. The proficient will not be examining individual features, instead the entire scene is examined. On the basis of prior experience, the proficient baker approaches a situation in which he realizes the temperature of the oven is not hot enough in order to make bread as quickly as possible. He/she then consciously decides to increase the temperature of the oven. Also, in this stage the proficient performer find himself/herself thinking analytically.

Expertise: The final stage is expertise. Through experience, the expert reaches a stage in which he simply acts. If the decision is important and time permits, the expert will examine the conclusions made. An expert usually knows what to do based upon practical understanding. An expert does not see a problem in some detached way, and he/she is not worried about planning or the future. An expert's skill has become so much a part of him that he bakes without effort, knowing how to minimize the time taken for the dough to rise. Besides, he/she does not have to evaluate and compare alternatives. However, this know-how may break down, if the conditions for the expertise change.

For example, baking bread with a traditional oven which has no temperature adjustment.

According to Dreyfus and Dreyfus [1986],
> "...it is highly unlikely that expert systems will ever be able to deliver expert performance. (Actually, we'd prefer to call them "competent systems" since we can find no evidence that they will ever surpass the third stage of our skill model.)"pp.102-103.

This is because, they regard the act of experts as arationall[4] [Dreyfus & Dreyfus 1986], p.36. Put differently, according to them, an expert acts unconsciously. If it is so, how can an expert surgeon act unconsciously during an operation and he/she wants to save the life of a patient (or to make money). As Plato says, the rules are there functioning in the expert's mind whether he is conscious of them or not. Otherwise, how can we account for the fact that he can perform the task?

Furthermore, from my point of view, there is inconsistency in their model, step 4, i.e., proficiency. On p.29, they claim that the proficient performer still finds himself thinking analytically about what to do. If this is so, how can they call ES "competent systems", because it is in that stage where the proficient also finds himself thinking analytically[5]. Thus, this implies that one can extract the knowledge of a proficient as rules.

Regarding their model of skill acquisition, the question is, whether there is any need to distinguish between expertise as the Dreyfus and Dreyfus model defined. Part of the answer to this

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[4] Dreyfus & Dreyfus [1986], define arational, as vast area exists between irrational and rational. The word rational is equivalent to calculative thought and so carries with it the connotation of "combining component parts to obtain a whole. Arational refers to action without conscious analytic decomposition and recombination. p.36. From my point of view, this definition does not make clear what is the difference among irrational, arational and transition.

[5] This matter has been interpreted by Ehn[1988], p.73, differently as well. He refers to proficient performance as arational. Put it differently, he considers both expert and proficient as arational, i.e., as one step in Dreyfus & Dreyfus acquisition model. This is my understanding.

question lies in there being no word in the English language which means "more skillful" or "more experienced" than "expertise" [Whitley 1991]. Dreyfus and Dreyfus [1986] predict terrible issues if something is not done to contain the dysfunctional effects that expert system usage may cause. They claim the following scenario: (p.121 of the first published by The free press, NY, 1986.)

> To the extent that junior employees using expert systems come to see expertise as a function of a large knowledge base and masses of inferential rules, they will fail to progress beyond the competent level of their machines. With the leap beyond competence to proficiency and expertise thus inhibited, investors in expert systems may ultimately discover that their wells of true human expertise and wisdom have gone dry.

The above prediction by Dreyfus and Dreyfus [Dreyfus & Dreyfus 1986] may appear to be a bit excessive. These hard-line approaches toward expert systems dependence issues are rooted in the "myth" of the intellectually "unaided" individual [Oravec 1988]. According to Zuboff's definition [Zuboff 1982], this falls into the second camp mentioned above. The author believes that what is significant about an individual is how he/she performs with the aid of an intellectual apparatus, i.e., the process which an individual uses [Sagheb-Tehrani 1992c, 1993a]. This has been widely recognized. As Winograd and Flores [1986], say, it is clear that one cannot understand a technology without having a functional understanding of how it is used. Furthermore, that understanding must incorporate a holistic view of the network of technologies and activities into which it fits, rather than treat the technology devices in isolation, p.6. We live in a world which is very complex. Regarding a hard-line approach of technology, an individual can hardly perform any complex task alone. As indeed Zuboff [Zuboff 1982], says, technology is neutral and its meaning based upon the uses to which humans press its application.

It falls outside the scope of this study to discuss the criticism of expert systems technology in more detail. As I have mentioned before, it deserves its own separate research. It is obvious that the kinds of questions posed on this matter will only find their answers as expert systems achieve widespread utilization. I hope this study (as an initial step) can contribute to this theme.

10.3 Summary

In this chapter, a short discussion of both the prediction of expert systems development in Sweden and criticisms of expert systems from my point of view were outlined.

APPENDICES

Guide to the appendix

Appendix I

Appendix I comprises the English translation of the questionnaire used in my earlier study and a letter which describes very briefly the objective of my previous study to various organizations.

Appendix II

Appendix II contains the original questionnaire and a letter (used in my previous study) which describes very briefly the objective of this study to various organizations in Swedish.

Appendix III

Appendix III contains the letter used in this study, both in Swedish and English.

Appendix IV

Appendix IV contains the questionnaire used in this study, both in Swedish and English.

Appendix V

Appendix V contains the list of some abbreviation used in both studies.

Appendix VI

Appendix VI contains some material relevant to the interview cases which shows some parts of ES at organization 6.

Appendix I.I

Title of research: Some problems with developing expert systems (knowledge based systems)

I, the under-signed am a researcher at the University of Lund, department of Inf & Comp Sciences, where, I am carrying out a project to gather information on the use of expert systems.

The objective of this study is to find out about the possibilities and problems of developing and using expert systems. The questionnaire is the starting point of this study. This work should also provide further basis for evaluating expert systems development and use.

With this background, I turn to your company with an appeal to fill in included questionnaire. All answers will be treated **strictly confidential**. Please, let the person/s who are familiar with developing/using/proving expert systems answer the questionnaire.

I am very grateful for receiving the answer before **890830** at the following address.

Yours faithfully

M.S.Tehrani

University of Lund
Dep of Inf & Comp Sciences
Sölvegatan 14 A,223 62 Lund.

Appendix I.II
University of Lund
Dept. of Information and Computer Science
Sölvegatan 14 A
S-223 62 Lund, Sweden
Project leader: Mehdi Sagheb-Tehrani/MST
89-06-20

Questionnaire about expert system (knowledge based system)

Please read the whole questionnaire before you start to fill it in.

Comment willingly on the questions and your views upon expert systems on a separate sheet.

If required, you can cross more than one alternative in some of the questions.

Company name..

Respondent's name...

Telephone..

Your position in the organization...

....

....

Your task in the
organization..

....

University of Lund
Dept. of Information and Computer Science
Sölvegatan 14 A
S-223 62 Lund, Sweden
Project leader: Mehdi   Sagheb-Tehrani/MST

Questionnaire about expert system (knowledge based system)

1- What do you consider distinguish an expert system (knowledge base system)?

....

2- Are you using expert systems now?

( ) No   ( )Yes

If yes, state which (System 1, S2,S3) and its application area...

....

If you have/had such a system, please fill in the rest of the questions

3-What did you expect of developing expert systems compared with your former working method?

(S1:) (S2:) (S3:) Consistency   (S1:) (S2:) (S3:)Less cost
(S1:) (S2:) (S3:) Better access
(S1:) (S2:) (S3:) Testing new possibilities
( ) Other state, what..

4- How did you handle your previous tasks for which you are now using expert systems?

(S1:) (S2:) (S3:) By human expert
(S1:) (S2:) (S3:) With conventional computer system
(S1:) (S2:) (S3:) Not at all
( ) Other way, what...

5- Were you satisfied with your previous work method?

( ) Yes ( ) No, why..

....

6- When did you procure expert systems? Please give year:

S1............... S2.................. S3................ ( ) Do not know

7- On whose initiative did you procure an expert system?

(S1:) (S2:) (S3:) Personnel who used to take care of tasks

(S1:) (S2:) (S3:) An internal specialist
(S1:) (S2:) (S3:) An external consult
( ) Other, state who..
8- Who supported the idea of proving expert systems?

(S1:) (S2:) (S3:) Management
(S1:) (S2:) (S3:) Personnel who used to take care of tasks
(S1:) (S2:) (S3:) Personnel at the department of computer
( ) Other state, who..

9-Who developed your expert systems?

(S1:) (S2:) (S3:) Internal specialist (not from comp dept)
(S1:) (S2:) (S3:) External consult
(S1:) (S2:) (S3:) Personnel at the computer department
( ) Other state, who..

10- At what development stage are your expert systems?

(S1:) (S2:) (S3:) Operation
(S1:) (S2:) (S3:)At final test for operation
(S1:) (S2:) (S3:) At prototype
( ) Other state, what..

11- What problems have you experienced in developing your expert systems?

( ) None ( ) Hardware problem( ) Software problem
( ) Limited time ( ) With Personnel who took care of tasks
( ) Limited budget
( ) System analyst (knowledge engineer) without experience
( ) Lack of a development model
( ) Other state, what................................

12- What techniques have you used in order to elicit knowledge for your expert systems?

(S1:) (S2:   ) (S3:   ) Unstructured interview
(S1:) (S2:   ) (S3:   ) Structured interview
(S1:) (S2:   ) (S3:   ) Documentation analysis
(S1:) (S2:   ) (S3:   ) Case studies
(S1:) (S2:   ) (S3:   ) Observation methods and protocol analysis
(S1:) (S2:   ) (S3:   ) prototype with simulation
(S1:) (S2:   ) (S3:   ) Induction from examples
( ) Other state, what..............................

13- What problems have you had concerning knowledge acquisition process for your expert systems?

( ) None ( ) Tools for extracting knowledge
( ) Communication with expert ( ) Identify knowledge
( ) Access to qualified expertise ( ) Knowledge representation
( ) Other state, what...

14- What tools have you used in order to elicit knowledge for your expert systems? For which system respectively?...........

....

15- What problems have you had with expert/s in order to elicit knowledge for your expert systems?

( ) None ( ) Misunderstanding
( ) Limited interest for cooperation ( ) Limited access
( ) Limited time
( ) Other state, What...

16-What results have you achieved in your organization by inserting expert systems?

(S1:) (S2:) (S3:) None (S1:) (S2:) (S3:)Consistency
(S1:) (S2:) (S3:) Less cost (S1:) (S2:) (S3:) Better access

( ) Other state, what...

17- Are you satisfied with your expert systems?

( ) Yes,why...
( ) No, why...

18- How did you prove quality of your expert system?

( ) Against historical data ( ) Judging by expert/s
( ) Testing against specific data
( ) Other state, What..............................

19- Have you used a specific developing model for your expert systems?

(S1:) (S2:) (S3:) No, why...

(S1:) (S2:) (S3:) Yes,
what...

Appendix II.I

Forskningprojekt:Expertsystems (Kunskapbaserade system); utveckling, problem och effekter

Undertecknad är forskare vid institutionen för Informationsbehandling-ADB i Lund. Där bedriver jag ett projekt för att samla kunskap om användning av expertsystem.

Syftet med denna undersökning är att ta reda på möjligheter och problem vid utveckling och användning av expertsystem. Denna enkät inleder undersökningen. Studien bör också ge de deltagande företagen ett ytterligare underlag för bedömning av expertsystems utveckling och användning.

Mot denna backgrund vänder jag mig till Ert företag med en vädjan om att fylla i bifogade enkät. Alla svar kommer att behandlas **strängt konfidentiellt**. Var vänlig och låt den/de person(er) som är särskilt förtrogna med att använda/prova/utveckla expertsystem,besvara enkäten.
Tacksam för att få svar före den **89-08-30** under adressen nedan.

Med vänliga hälsingar

M.S.Tehrani

Lunds Universitet
Inst.för Informationsbehandling-ADB
Sölvegatan 14A
223 62 Lund.
Mehdi Sagheb-Tehrani

Appendix II.II

Lunds Universitet
Inst. för Informationsbehandlig-ADB
Sölvegatan 14 A, 223 62 Lund
Projektledare: Mehdi Sagheb-Tehrani / MST
89-06-20

Enkät om expertsystem (kunskapsbaserade system)

Var vänlig läs hela enkäten innan Ni börja fylla i den.

Kommentera gärna frågor och Er syn på expertsystem på ett separat papper.

Ni kan kryssa för fler än ett alternativ i några frågor, om Ni tycker att det behövs.

Företagets namn ....

Uppgiftslämnarens namn...

Telefon...

Uppgiftslämnarens placering i organisation...

....

Uppgiftslämnarens arbetsuppgifter i organizationen (beskriv kortfattat)..
....

....

Lunds Universitet
Inst. för Informationsbehandlig-ADB 89-06-20
Sölvegatan 14 A, 223 62 Lund
Projektledare: Mehdi Sagheb-Tehrani / MST

Enkät om expertsystem (kunskapsbaserade system)

1. Vad anser Ni utmärker ett expertsystem (kunskapbaserat system)?

....

....

....

2. Använder Ni nu expertsystem?

( ) Nej ( )Ja

om ja, ange vilka(System1, S2, S3) och användningsområdet....

....

....

Om Ni har /hade ett sådant system var god fylla i resterande frågor .

3.Vad förväntade Ni av att skaffa expertsystem jämfört med tidigare arbetssätt?

(S1:)(S2:)(S3:)Konsekventare råd
(S1:)(S2:)(S3:) Mindre kostnader
(S1:)(S2:)(S3:) Bättre tillgänglighet
(S1:)(S2:)(S3:) Att prova en ny möjlighet
( ) Annat, ange vad...

4. Hur hanterades förut uppgifter för vilka Ni nu använder expertsystem?

(S1:   )(S2:   )(S3:   ) Av en expert
(S1:   )(S2:   )(S3:   ) med konventionellt datasystem
(S1:   )(S2:   )(S3:   ) Inte alls
( ) På annat sätt...

5. Var Ni tillfredställd med Ert tidigare arbetssätt?   (   ) Ja

( ) Nej, ange varför...

....

6. När skaffade Ni expertsystem? V g ange år:

S1: ....S2: ....S3: ....   (   ) Vet ej

7. På vems initiativ skaffade Ni expertsystem?

(S1:   )(S2:   )(S3:   )Personal som förut skött uppgifter
(S1:   )(S2:   )(S3:   )En intern specialist
(S1:   )(S2:   )(S3:   )En extern konsult
( ) Annat sätt, vilket ?..

8.Vilka personer understödde idén att prova expertsystem?

(S1:   )(S2:   )(S3:   ) Ledningen
(S1:   )(S2:   )(S3:   ) Personal som förut skött uppgifter
(S1:   )(S2:   )(S3:   )Personal på dataavd
( ) Någon annan? vem...

9. Vem valde/utvecklade Era expertsystem?

(S1:   )(S2:   )(S3:   )Intern specialist ej från dataavd
(S1:   )(S2:   )(S3:   )Extern konsult
(S1:   )(S2:   )(S3:   )Personal på dataavd
( ) Någon annan? vem...........................

....

10. Vilket utvecklingssteg befinner sig Ert/Era expertsystem?

(S1:   )(S2:   )(S3:   )I drift
(S1:   )(S2:   )(S3:   )Under sluttest för drift
(S1:   )(S2:   )(S3:   ) Under utveckling av prototyp
( ) Annan status, vilken?..

11. Vilket eller vilka problem har Ni haft under utveckling av Era *expertsystem?*

( ) Inget   ( ) Hårdvaruproblem
( ) Mjukvaruproblem ( ) Begränsad tid
(   )Med personal som skött uppgifter
( ) Begränsad budget
(   ) Systemerare(kunskapsingenjör) utan erfarenhet av expertsystem
(   ) Sakna en utvecklingsmodell
( ) Annat, ange vad...

12. Vilken eller vilka teknik(er) har Ni använt för att fånga kunskapen till Ert expertsystem?

(S1:   )(S2:   )(S3:   )Ostruktureade intervjuer
(S1:   )(S2:   )(S3:   )Strukturerade intervjuer
(S1:   )(S2:   )(S3:   )Studier av tidskrifter, böcker
(S1:   )(S2:   )(S3:   ) Observation av expert/ "tänka högta protokoll"
(S1:   )(S2:   )(S3:   ) Simulering med prototyp
(S1:   )(S2:   )(S3:   )Analys av fallstudier
(S1:   )(S2:   )(S3:   )Induktion från exempel
(   ) Annat sätt, vilket? ....

13.Vilket eller vilka problem har Ni haft för att fånga kunskapen till Ert expertsystem?

(   ) Inget (   ) Verktyg för kunskapsfångst
(   ) Kommunicera med expert
(   ) Tillgång till kvalificerad expertis (   ) Identifiera kunskapen
(   ) Representera kunskapen
( ) Annat, ange vad...

14.Har Ni för Ert arbete med att fånga kunskap använt några speciella verktyg? I så fall vilka för

respektive system?..

....

....

15. Vilket /vilka problem har Ni haft med expert/er för att fånga kunskapen till Ert expertsystem?

( ) Inget   ( ) Missuppfattningar
(   ) Begränsat intresse för samarbete
( ) Sällan tillgång till   ( ) Begränsad tid
( ) Annat, vad.................................

16.Vilken/vilka   resultat har Ni nått i Ert företag genom Ni införa expertsystem?

(S1:   )(S2:   )(S3:   ) Inget
(S1:   )(S2:   )(S3:   )Konsekventare råd
(S1:   )(S2:   )(S3:   ) Midre kostnader
(S1:   )(S2:   )(S3:   ) Bättre tillgänglighet
( ) Annat, vilket...................... ....

17. Är Ni tillfredställd med Era expertsystem?   ( )Ja, ange
varför...............................
( ) Nej, ange varför...

18. Hur prövade Ni kvaliteten på Era expertsystem?

( ) Mot historiska data   ( )Bedömning av expert(er)
( )Mot särskilda testdata
( ) Annat sätt, vilket..

19. Har Ni använt någon specifik modell för att utveckla Era expertsystem?
(S1:   )(S2:   )(S3:   ) Nej, ange varför...
(S1:   )(S2:   )(S3:   ) Ja, ange vilken................................

APPENDIX III.I

Title of research: Some problems with developing expert systems (knowledge based systems)

I, the under-signed am a researcher at the University of Lund, department of Inf & Comp Sciences, where, I am carrying out a project to gather information on the use of expert systems.

The objective of this study is to find out about the possibilities and problems of developing and using expert systems. The questionnaire is the starting point of this study. This work should also provide further basis for evaluating expert systems development and use.

With this background, I turn to your company with an appeal to fill in included questionnaire. All answers will be treated **strictly confidential**. Please, let the person/s who are familiar with developing/using/proving expert systems answer the questionnaire.

I am very grateful for receiving the answer before **920230** at the following address.

Yours faithfully

M.S.Tehrani

University of Lund
Dep of Inf & Comp Sciences
Sölvegatan 14 A,223 62 Lund.

Appendix III.II

Forskningprojekt: Expertsystems (Kunskapbaserade system); utveckling, problem och effekter

Undertecknad är forskare vid institutionen för Informationsbehandling-ADB i Lund. Där bedriver jag ett projekt för att samla kunskap om användning av expertsystem.

Syftet med denna undersökning är att ta reda på möjligheter och problem vid utveckling och användning av expertsystem. Denna enkät inleder undersökningen. Studien bör också ge de deltagande företagen ett ytterligare underlag för bedömning av expertsystems utveckling och användning.

Mot denna backgrund vänder jag mig till Ert företag med en vädjan om att fylla i bifogade enkät. Alla svar kommer att behandlas **strängt konfidentiellt**. Var vänlig och låt den/de person(er) som är särskilt förtrogna med att använda/prov a/utveckla expertsystem,besvara enkäten.
Tacksam för att få svar före den **92-02-30** under adressen nedan.

Med vänliga hälsingar

M.S.Tehrani

Mehdi Sagheb-Tehrani
Råbyv 15D:33 223 57 Lund
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Appendix IV.I

University of Lund
Dept. of Information and Computer Science
Sölvegatan 14 A
S-223 62 Lund, Sweden
Project leader: Mehdi Sagheb-Tehrani/MST
91-08-15

Questionnaire about expert system (knowledge based system)

Please read the whole questionnaire before you start to fill it in.

Comment willingly the questions and your views upon expert systems on a separate sheet.

If required, you can cross more than one alternative in some of the questions.

Company name...

Respondent's name..

Telephone...

Your position in the
organization...

....

....

Your task in the
organization..

1- What do you consider distinguishes an expert system (knowledge base system)?

....

2- Are you using expert systems(ES) now?

( ) No   ( )Yes

If yes, state how many (Expert System 1, ES2,ES3) and their application area.............

(ES1:)(ES2:)(ES3:)Credit   (ES1:)(ES2:)(ES3:)Computer system
(ES1:)(ES2:)(ES3:)Consult   (ES1:)(ES2:)(ES3:)Other, state what.................

3-Define which category your expert system/s falls into?

(ES1:)(ES2:)(ES3:)Design   (ES1:)(ES2:)(ES3:)Diagnosis
(ES1:)(ES2:)(ES3:)Control   (ES1:)(ES2:)(ES3:)Planning
(ES1:)(ES2:)(ES3:)Other, state what...

4- How did you handle your previous tasks for which you are now using expert systems?

(ES1:)(ES2:)(ES3:) By human expert
(ES1:)(ES2:)(ES3:) With conventional computer system
(ES1:)(ES2:)(ES3:) Not at all
(ES1:)(ES2:)(ES3:) Other way, what...

5- Were you satisfied with your previous work method?

( ) Yes   ( ) No, why..

6-What did you expect of developing expert systems compared with your former working method?

(ES1:)(ES2:)(ES3:) Consistency   (ES1:)(ES2:)(ES3:)Less cost
(ES1:)(ES2:)(ES3:) Better access
(ES1:)(ES2:)(ES3:) Testing new possibilities
(ES1:)(ES2:)(ES3:)Dissatisfied with previous way of handling tasks
(ES1:)(ES2:)(ES3:)Rare human expert
(ES1:)(ES2:)(ES3:) Other state, what...

7- When did you procure expert systems? Please give year:

ES1............ ES2.............. ES3............
(ES1:)(ES2:)(ES3:) Do not know

8- Why have you developed expert system/s?

(ES1:)(ES2:)(ES3:)Problem was suitable for expert system application
(ES1:)(ES2:)(ES3:)Availability of knowledge engineer
(ES1:)(ES2:)(ES3:)Availability of human expert
(ES1:)(ES2:)(ES3:)Other, state what...

9-Define the characteristics of the tasks for which you developed an expert system?

(ES1:)(ES2:)(ES3:)Structured
(ES1:)(ES2:)(ES3:)semi-structured
(ES1:)(ES2:)(ES3:)Ill-structured

10- On whose initiative did you procure an expert system?

(ES1:)(ES2:)(ES3:) Personnel who used to take care of tasks
(ES1:)(ES2:)(ES3:) An internal specialist
(ES1:)(ES2:)(ES3:) An external consult
(ES1:)(ES2:)(ES3:) Other, which one...

11- Who supported the idea of proving expert systems?

(ES1:)(ES2:)(ES3:) Management
(ES1:)(ES2:)(ES3:) Personnel who used to take care of tasks
(ES1:)(ES2:)(ES3:) Personnel at the department of computer
(ES1:)(ES2:)(ES3:) Somebody else? who...

12-Who developed your expert systems?

(ES1:)(ES2:)(ES3:) Internal specialist (not from comp dept)
(ES1:)(ES2:)(ES3:) External consult
(ES1:)(ES2:)(ES3:) Personnel at the computer department
(ES1:)(ES2:)(ES3:) Other state? who...

13- At what development stage are your expert systems?

(ES1:)(ES2:)(ES3:) Operation
(ES1:)(ES2:)(ES3:)At final test for operation
(ES1:)(ES2:)(ES3:) At prototype
(ES1:)(ES2:)(ES3:) Other state, what............ ....

14- What problems have you had under development of your expert systems?

(ES1:)(ES2:)'ES3:) None (ES1:)(ES2:)(ES3:) Hardware problem
(ES1:)(ES2:)(ES3:) Software problem
(ES1:)(ES2:)(ES3:) Limited time
(ES1:)(ES2:)(ES3:) With Personnel who took care of tasks
(ES1:)(ES2:)(ES3:) Limited budget
(ES1:)(ES2:)(ES3:)Tools
(ES1:)(ES2:)(ES3:)Validity of ES result
(ES1:)(ES2:)(ES3:) System analyst (knowledge engineer) without experience
(ES1:)(ES2:)(ES3:) Lack of a development model
(ES1:)(ES2:)(ES3:)KA problem
(ES1:)(ES2:)(ES3:) Other state, what..

15- What problems have you had concerning knowledge acquisition process for your expert systems?

(ES1:)(ES2:)(ES3:) None
(ES1:)(ES2:)(ES3:)Knowledge elicitation (extraction)
(ES1:)(ES2:)(ES3:) Implement knowledge
(ES1:)(ES2:)(ES3:) Other state, what..

16- What techniques have you used in order to elicit knowledge for your expert systems?
(ES1:)(ES2:)(ES3:) Unstructured interview
(ES1:)(ES2:)(ES3:) Structured interview
(ES1:)(ES2:)(ES3:) Documentation analysis
(ES1:)(ES2:)(ES3:) Case studies
(ES1:)(ES2:)(ES3:) Observation methods and protocol analysis
(ES1:)(ES2:)(ES3:) prototype with simulation
(ES1:)(ES2:)(ES3:) Induction from examples
(ES1:)(ES2:)(ES3:) Other state, what..

17- Have you used any tools for developing your expert system/s?

(ES1:)(ES2:)(ES3:)No   (ES1:)(ES2:)(ES3:)Yes, State
what.........................

....

18- What problems have you had with expert/s in order to elicit knowledge for your expert systems?

(ES1:)(ES2:)(ES3:) None   (ES1:)(ES2:)(ES3:)
Misunderstanding
(ES1:)(ES2:)(ES3:) Limited interest for cooperation

(ES1:)(ES2:)(ES3:) Limited access
(ES1:)(ES2:)(ES3:) Limited time
(ES1:)(ES2:)(ES3:) Other, What...

19-What results have you achieved in your organization by inserting expert system/s?

(ES1:)(ES2:)(ES3:) None   (ES1:)(ES2:)(ES3:)Consistency
(ES1:)(ES2:)(ES3:) Less cost
(ES1:)(ES2:)(ES3:) Better access
(ES1:)(ES2:)(ES3:) Other, what.................

20- Are you satisfied with your expert systems?

(ES1:)(ES2:)(ES3:)Yes,why... ....
(ES1:)(ES2:)(ES3:) No, why...

21- How did you prove quality of your expert system?

(ES1:)(ES2:)(ES3:) Against historical data
(ES1:)(ES2:)(ES3:) Judging by expert/s
(ES1:)(ES2:)(ES3:) Testing against specific data
(ES1:)(ES2:)(ES3:) Other way, What..

22- Have you used a specific developing model for your expert system/s?

(ES1:)(ES2:)(ES3:) No, why...
(ES1:)(ES2:)(ES3:)Yes, state what...

23 According to who's initiative decide your expert system/s that what to do next?

(ES1:)(ES2:)(ES3:)User   (ES1:)(ES2:)(ES3:)System
(ES1:)(ES2:)(ES3:)Other, state what...

24 Who controls the dialogue between system and user?

(ES1:)(ES2:)(ES3:)User   (ES1:)(ES2:)(ES3:)System
(ES1:)(ES2:)(ES3:)Other, state who...

25 What function does your expert system/s serve?

 (ES1:)(ES2:)(ES3:)Advice   (ES1:)(ES2:)(ES3:)Decide
(ES1:)(ES2:)(ES3:)Subordinate
(ES1:)(ES2:)(ES3:)Other, state what...

26 Who is responsible for your expert system/s?

(ES1:)(ES2:)(ES3:)User   (ES1:)(ES2:)(ES3:)Designer
(ES1:)(ES2:)(ES3:)Expert
(ES1:)(ES2:)(ES3:)Designer, expert, and user
(ES1:)(ES2:)(ES3:)Other, state who...

27 How many rules has your expert system/s?

(ES1:)(ES2:)(ES3:)Give total number...

Appendix IV.II

Lunds Universitet
Inst. för Informationsbehandlig-ADB
Sölvegatan 14 A, 223 62 Lund
Projektledare: Mehdi Sagheb-Tehrani / MST
91-08-15

Enkät om utveckling av expertsystem (kunskapsbaserade system)

Var vänlig läs hela enkäten innan Ni börja fylla i den.

Kommentera gärna frågor och Er syn på expertsystem på ett separat papper.

Ni kan kryssa för fler än ett alternativ i några frågor, om Ni tycker att det behövs.

Företagets namn ....

Uppgiftslämnarens namn..

Telefon..

Uppgiftslämnarens placering i organisation................................
....

....

Uppgiftslämnarens arbetsuppgifter i organizationen (beskriv kortfattat)...

....

....

1. Vad anser Ni utmärker ett expertsystem (kunskapbaserat system)?

....

....

....

2. Använder Ni nu expertsystem (ES)?

(　) Nej   (　)Ja

om ja, ange hur många ES (ES1, ES2, ES3) och applikationsområdet:

(ES1:)(ES2:)(ES3:)Bokföring
(ES1:)(ES2:)(ES3:)Undervisning
(ES1:)(ES2:)(ES3:)Konsult
(ES1:)(ES2:)(ES3:)Information system
(ES1:)(ES2:)(ES3:)Annat, ange vad...

3. Specificera till vilka kategori tillhör Ert/Era ES?

(ES1:)(ES2:)(ES3:)Tolkning
(ES1:)(ES2:)(ES3:)Diagnos
(ES1:)(ES2:)(ES3:)Planering
(ES1:)(ES2:)(ES3:)Felsökning
(ES1:)(ES2:)(ES3:)Handledning
(ES1:)(ES2:)(ES3:)Design
(ES1:)(ES2:)(ES3:)Övervakning
(ES1:)(ES2:)(ES3:)Reperera
(ES1:)(ES2:)(ES3:)Kontroll
(ES1:)(ES2:)(ES3:)Annat, ang vad.........

4. Hur hanterades förut de uppgifter för vilka Ni nu använder expertsystem?

(ES1:)(ES2:)(ES3:) Av en expert
(ES1:)(ES2:)(ES3:) med konventionellt datasystem
(ES1:)(ES2:)(ES3:) Inte alls
(ES1:)(ES2:)(ES3:) På annat sätt.....................

5. Var Ni tillfredställd med Ert tidigare arbetssätt?
( ) Ja: (ES1:)(ES2:)(ES3:)
( ) Nej: (ES1:)(ES2:)(ES3:), ange varför...

6.Vad förväntade Ni av att skaffa expertsystem jämfört med tidigare arbetssätt?

(ES1:)(ES2:)(ES3:)Konsekventare råd
(ES1:)(ES2:)(ES3:)Mindre kostnader
(ES1:)(ES2:)(ES3:)Bättre tillgänglighet
(ES1:)(ES2:)(ES3:)Att prova en ny möjlighet
(ES1:)(ES2:)(ES3:)Missnöje med tidigare arbetsätt
(ES1:)(ES2:)(ES3:)Rar expert
(ES1:)(ES2:)(ES3:)Annat, ange vad.............................

7. När skaffade Ni expertsystem? V g ange år:

ES1: ....ES2: ....ES3: ....( ) Vet ej

8. Varför valde/utvecklade Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:)Problemt var lämpligt for expertsystemsapplikation
(ES1:)(ES2:)(ES3:)Tillgänglighet av kunskapsingenjör
(ES1:)(ES2:)(ES3:)Tillgänglighet av expert
(ES1:)(ES2:)(ES3:)Annat, ange vad...............................

9. Beskriv de arbetsuppgifter för vilka Ni utvecklade Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:)Strukturerade
(ES1:)(ES2:)(ES3:)Halv-strukturerade
(ES1:)(ES2:)(ES3:)Dåligt-strukturerade

10. På vems initiativ skaffade Ni expertsystem?

(ES1:)(ES2:)(ES3:)Personal som förut skött uppgifter
(ES1:)(ES2:)(ES3:)En intern specialist
(ES1:)(ES2:)(ES3:)En extern konsult
(ES1:)(ES2:)(ES3:) Annat sätt, vilket ?..........................

11.Vilka personer understödde idén att prova expertsystem?

(ES1:)(ES2:)(ES3:) Ledningen
(ES1:)(ES2:)(ES3:) Personal som förut skött uppgifter
(ES1:)(ES2:)(ES3:)Personal på dataavd
(ES1:)(ES2:)(ES3:) Någon annan? vem.......

12. Vem valde/utvecklade Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:)Intern specialist ej från dataavd
(ES1:)(ES2:)(ES3:)Extern konsult
(ES1:)(ES2:)(ES3:)Personal på dataavd
(ES1:)(ES2:)(ES3:) Någon annan? vem.........

13. Vilket utvecklingssteg befinner sig Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:)I drift
(ES1:)(ES2:)(ES3:)Under sluttest för drift
(ES1:)(ES2:)(ES3:) Under utveckling av prototyp
(ES1:)(ES2:)(ES3:) Annan status, vilken? ....

14. Vilket eller vilka problem har Ni haft under utveckling av Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:)Inga (ES1:)(ES2:)(ES3:)Hårdvaruproblem
(ES1:)(ES2:)(ES3:)Mjukvaruproblem
(ES1:)(ES2:)(ES3:)Begränsad tid
(ES1:)(ES2:)(ES3:)Med personal som skött uppgifter
(ES1:)(ES2:)(ES3:)
Begränsad budget (ES1:)(ES2:)(ES3:)Verktyg
(ES1:)(ES2:)(ES3:)Giltighet av expertsystem resultat
(ES1:)(ES2:)(ES3:)Systemerare(kunskapsingenjör) utan erfarenhet av expertsystem
(ES1:)(ES2:)(ES3:)Saknat utvecklingsmodell
(ES1:)(ES2:)(ES3:)Fånga kunskapen (Knowledge acquisition problem)

(ES1:)(ES2:)(ES3:) Annat, ange vad...

15.Vilket eller vilka problem har Ni haft för att fånga kunskapen till Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:) Inget
(ES1:)(ES2:)(ES3:)Implementera kunskapen
(ES1:)(ES2:)(ES3:) Framlocka kunskapen (Knowledge elicitation)
(ES1:)(ES2:)(ES3:) Annat, ange vad...............................

16. Vilken eller vilka teknik(er) har Ni använt för att framlocka kunskapen till Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:)Ostruktureade intervjuer
(ES1:)(ES2:)(ES3:)Strukturerade intervjuer
(ES1:)(ES2:)(ES3:)Studier av tidskrifter, böcker
(ES1:)(ES2:)(ES3:) Observation av expert/ "tänka hög protokoll"
(ES1:)(ES2:)(ES3:) Simulering med prototyp
(ES1:)(ES2:)(ES3:)Analys av fallstudier
(ES1:)(ES2:)(ES3:)Induktion från exempel
(ES1:)(ES2:)(ES3:) Annat sätt, vilket? ....

17.Har Ni för Ert arbete med att utveckla Era/Ert expertsystem använt några speciella verktyg?

(ES1:)(ES2:)(ES3:)Nej
(ES1:)(ES2:)(ES3:)Ja, Ange vilket/Vilka.........

18. Vilket /vilka problem har Ni haft med expert/er för att framlocka kunskapen till Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:) Inget
(ES1:)(ES2:)(ES3:) Missuppfattningar
(ES1:)(ES2:)(ES3:) Begränsat intresse för samarbete
(ES1:)(ES2:)(ES3:) Sällan tillgång till
(ES1:)(ES2:)(ES3:) Begränsad tid
(ES1:)(ES2:)(ES3:) Annat, vad...

19.Vilket/vilka resultat har Ni nått i Ert företag genom Ni införa expertsystem?

(ES1:)(ES2:)(ES3:)Inget
(ES1:)(ES2:)(ES3:)Konsekventare råd
(ES1:)(ES2:)(ES3:) Midre kostnader
(ES1:)(ES2:)(ES3:)Bättre tillgänglighet
(ES1:)(ES2:)(ES3:) Annat, vilket................

20. Är Ni tillfredställd med Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:)Ja, ange varför.......
(ES1:)(ES2:)(ES3:)Nej, ange varför.....

21. Hur prövade Ni kvaliteten på Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:)Mot historiska data
(ES1:)(ES2:)(ES3:)Bedömning av expert(er)
(ES1:)(ES2:)(ES3:)Mot särskilda testdata
(ES1:)(ES2:)(ES3:) Annat sätt, vilket..................

22. Har Ni använt någon specifik modell eller metod för att utveckla Era expertsystem?

(ES1:)(ES2:)(ES3:)Nej, ange varför...........................
(ES1:)(ES2:)(ES3:) Ja, ange vilken............

23. På vems initiativ bestäms vad expertsystemet skall göra här näst?

(ES1:)(ES2:)(ES3:)Användare
(ES1:)(ES2:)(ES3:)Sytem
(ES1:)(ES2:)(ES3:)Annat, ange, vad..............

24. Vem styr dialogen mellan system och användare?

(ES1:)(ES2:)(ES3:)Användare
(ES1:)(ES2:)(ES3:)System
(ES1:)(ES2:)(ES3:)Annat, ange vem..............

25. Vilken typ av understöd ger Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:)Råd
(ES1:)(ES2:)(ES3:)Lösa problem(Avgöra beslut)
(ES1:)(ES2:)(ES3:)Underordnad
(ES1:)(ES2:)(ES3:)Annat, ange
vad..

26. Vem är ansvarig för Ert/Era expertsystem?

(ES1:)(ES2:)(ES3:)Utvecklare
(ES1:)(ES2:)(ES3:)Användare
(ES1:)(ES2:)(ES3:)Expert
(ES1:)(ES2:)(ES3:)Designer, Användare och expert
(ES1:)(ES2:)(ES3:)Annat, ange vem.........................

27. Hur många regler har Era/Ert ES?

(ES1:)(ES2:)(ES3:)Ange antal......................

Appendix V

List of some abbreviated terms utilized in various tables:

AI = Artificial intelligence
Adm=Administrative
Comp = Computer
CS = Conventional computer based system
Dep = Department
Devel = Developed
Develo = Development
ES = Expert system
HE = Human expert
IND=Industry
IS=Information system
KBS = Knowledge base systems
KE = Knowledge engineer
N = No
MS = Manual system
Probl = Problems
Represen = Representation
Satis=Satisfied
S1, S2,......= System 1, System 2, ...
Y = Yes
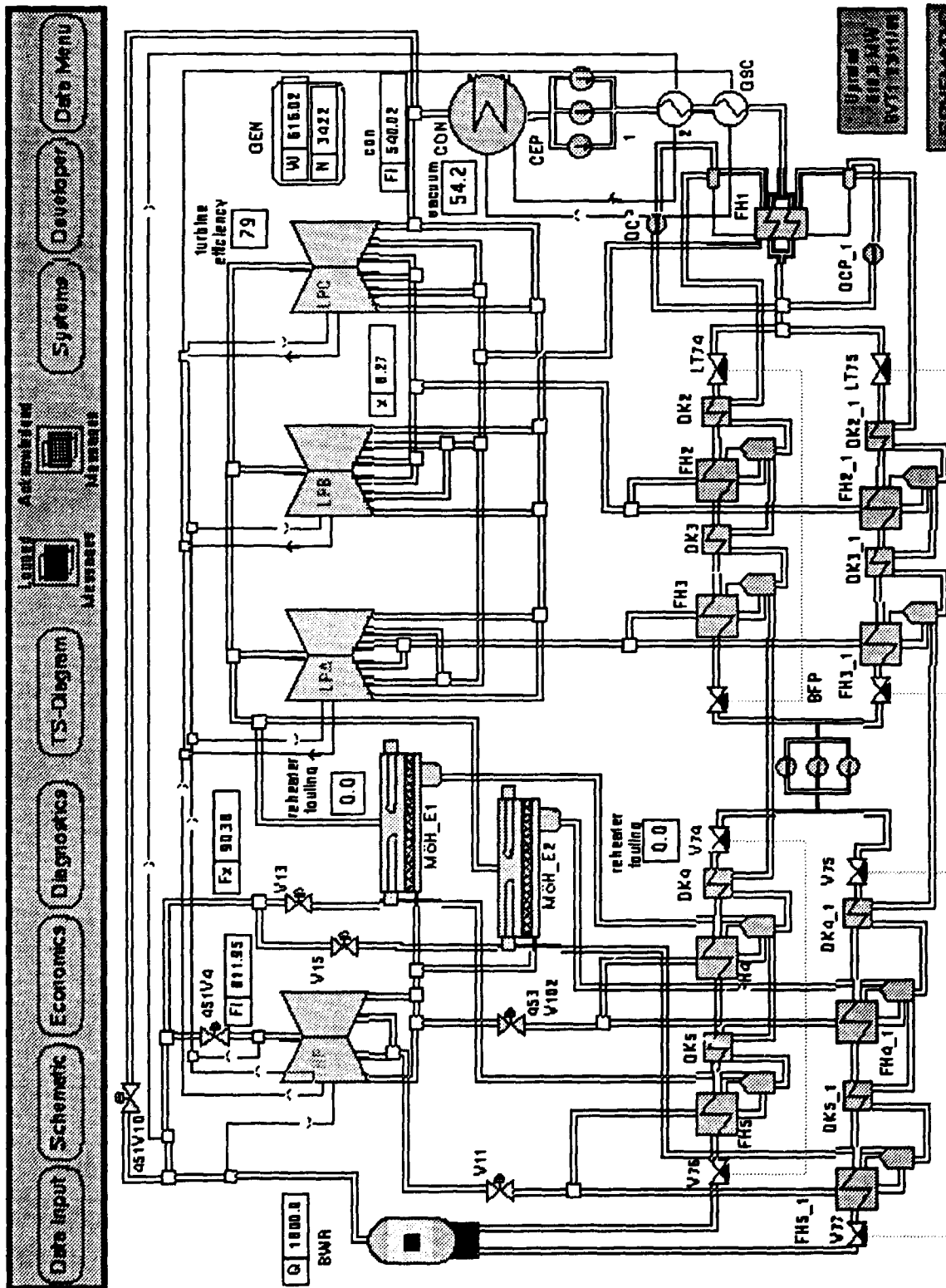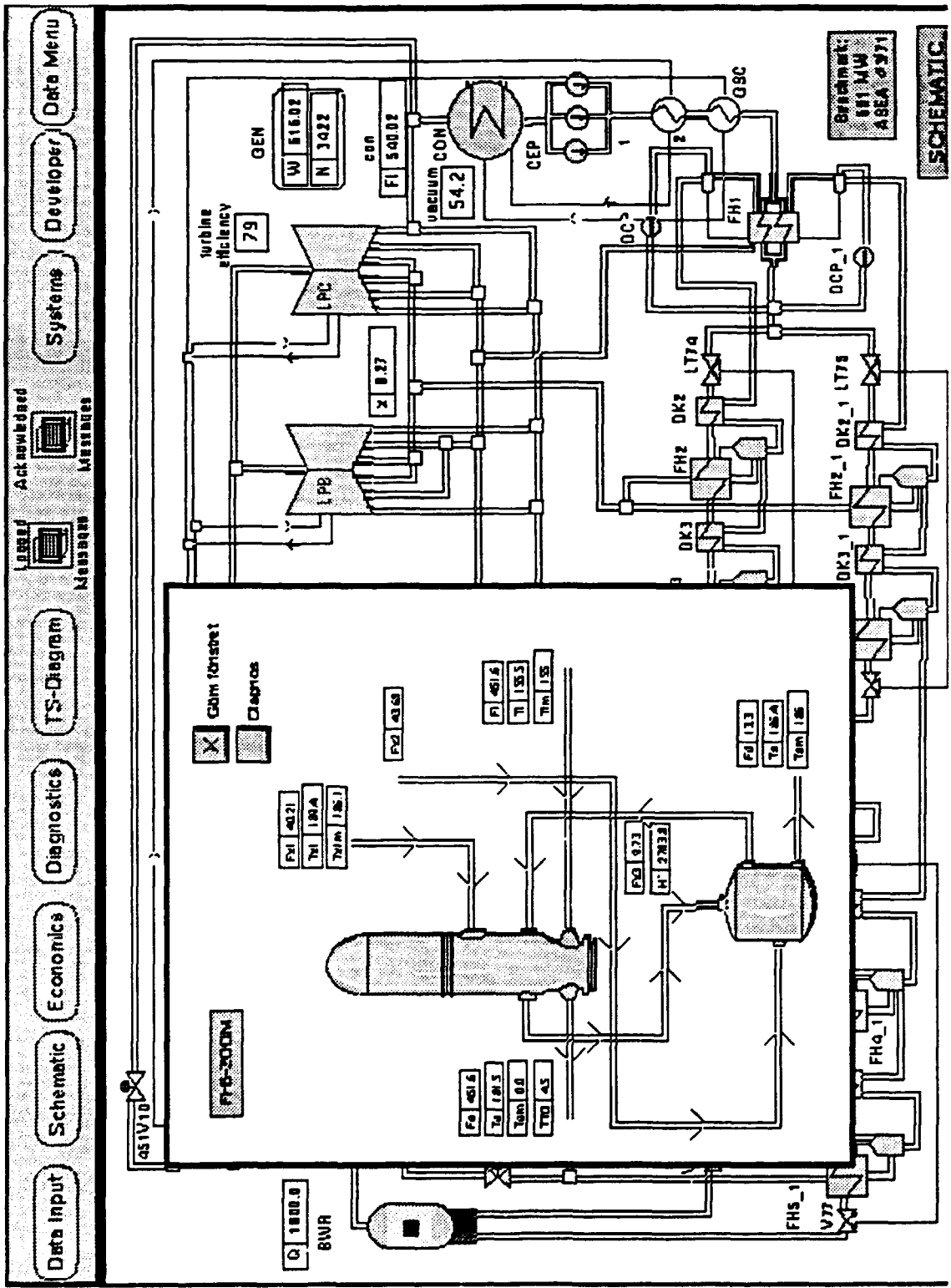
Diagnos för
Dränagekylare 3:

Diagnos för Dränagekylare 3, som den representeras i expertsystemet.
Bilden gäller för båda stråken. Se sidan 12 i dokumentet för dess regler
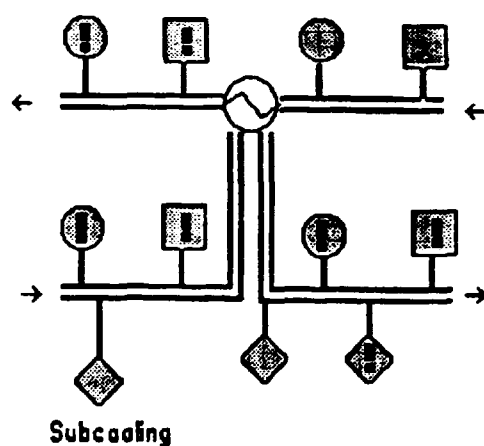och formler i expertsystemet.

Schema för dränagekylaren dk3 stråk 2

Göm fönstret

Felregler

Uppmätt värde som finns med
i processdaten

Beräknat värde

! Sannolikheten är större än 0.5 men
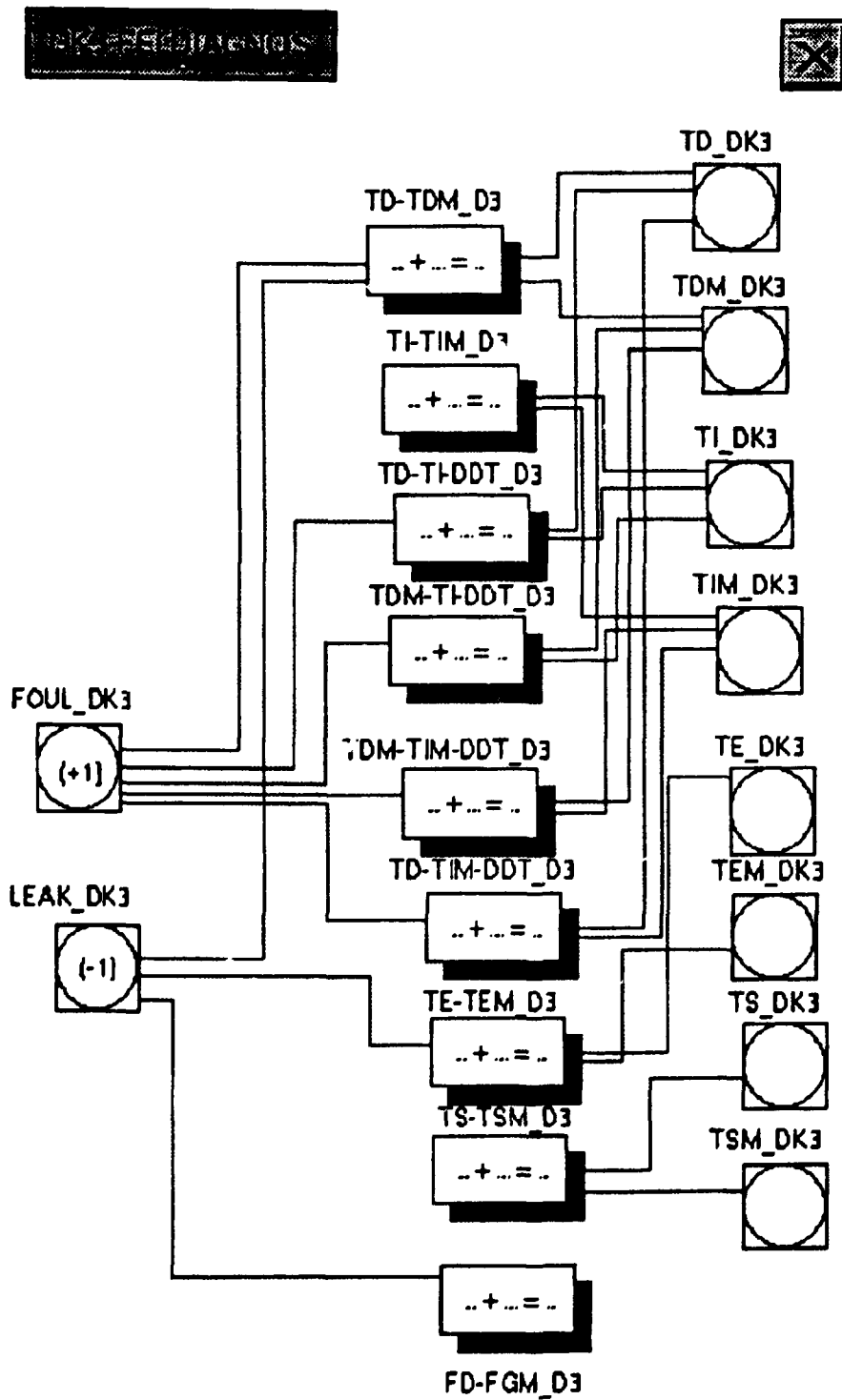**•** mindre än 0.8 att felet finns här

! Sannolikheten är större än 0.8 att
• felet finns här

Subcooling

Tim	112		Ti	93.1

| Tem | 115 | | Te | 98.3 |

| Tsm | 0.0 | | Ts | 115.2 |

| Tdm | 123 | | Td | 100.3 |

| Fd | 155.89 |

| Tdc | 8.6 |

Figur 2.2.2: Diagnos
för Dränagekylare 3

**Felregler för
Dränagekylare 3:**

Felregler för Dränagekylare3, som de ser ut i expertsystemet.

TD_DK3

TD-TDM_D3

.. + ... = ..

TDM_DK3

TI-TIM_D3

.. + ... = ..

TI_DK3

TD-TI-DDT_D3

.. + ... = ..

TDM-TI-DDT_D3

.. + ... = ..

TIM_DK3

FOUL_DK3

(+1)

TDM-TIM-DDT_D3

.. + ... = ..

TE_DK3

TD-TIM-DDT_D3

TEM_DK3

LEAK_DK3

(-1)

.. + ... = ..

TE-TEM_D3

.. + ... = ..

TS_DK3

TS-TSM_D3

.. + ... = ..

TSM_DK3

.. + ... = ..

FD-FGM_D3

*Figur 2.2.3: Felregler
för Dränagekylare 3*

the fx3 of any FV5-VÄXLARE fv = (the hx2
of fv - the h' of fv) / (the h" of fv - the h'
of fv) * the fx2 of fv

the fx2 of any FV5-VÄXLARE fv = the fd2 of
the mellanöverhettare connected at the
shell-side-2 of fv

the hx2 of any FV5-VÄXLARE fv = the hd2
of the mellanöverhettare connected at
the shell-side-2 of fv

the hx1 of any FV5-VÄXLARE fv = the he1
of thp

state variable : next value of the fd of any
FV5-VÄXLARE fv = the fx1 of fv + the
fx2 of fv, with initial value 62

state variable : next value of the ti of any
FV5-VÄXLARE fv = the te of the object
connected at the tube-side-1 of fv, with
initial value 155

the zx of any FV5-VÄXLARE fv = the z of
the object connected at the tube-side-2
of fv

the h' of any FV5-VÄXLARE fv = HLIQT(the
ts of fv)

the h" of any FV5-VÄXLARE fv =
HVAPT(the ts of fv)

the hs of any FV5-VÄXLARE fv = HLIQT(the
ts of fv)

the hsm of any FV5-VÄXLARE fv =
HLIQT(the tsm of fv)

the grd of any FV5-VÄXLARE fv = 4 * the
lastf of bwr /106

state variable : next value of the fx1 of any
FV5-VÄXLARE fv = abs((the fi of fv *
(the hi of fv - the he of fv) + the fx2 of
fv * the hx2 of fv - the fd of fv * the hs
of fv) / (- 1 * the hx1 of fv) * (the z of
v11) / 100 * (1 - the z of the object
connected at the tube-side-2 of fv)) ,
with initial value 17

GLOSSARY OF SOME SELECTED TERMS

Algorithm.

A formal procedure guaranteed to produce optimal solutions.

Artificial intelligence (AI).

The science that tries to make computer behave in ways that humans recognize as "intelligent" behaviour in each other.

AI workstation.

A combination of computer hardware and software oriented toward developing AI systems.

Backward chaining.

A problem solving approach in which the search starts from the goal and moves towards the initial state. It is also known as, goal directed or top down.

Breadth-first search.

A search strategy which is used in a problem solving approach. In contrast to the depth-first search strategy, the breadth-first search strategy develops those nodes that are closest to the start node. This makes the search process that tends to be more breadth than into depth.

Certainty factor.
Certainty factors are numerical measures which define a degree of certainty in a rule or fact.

Control strategies.
Techniques, an expert system uses to control which rules are fired.

Data base.
The set of facts, assertions and conclusions used by knowledge base in an expert system.

Declarative knowledge.
Forms of knowledge which can be verbalized or expressed. A form of knowledge which make assertion about entities and relationships between them, i.e. about the nature of task.

Depth-first search.
A kind of search strategy which is used in a problem solving approach. In depth-first strategy, the deepest node is choosen. The deepest node is the one which is farthest from the start node. This make the search process that tends to be more depth than into breadth.

Domain expert.
A human expert who has become highly proficient within a particular problem solving domain.

Domain knowledge.
Knowledge about the problem domain.

End-user.
The person who uses the finished expert system.

Expert.
See domain expert.

Expert system.
Expert systems are knowledge based systems that solve real problems which require a lot of expertise, if done by a human expert.

Expert system building tools (ESBT).
The support packages for developing expert systems.

Explanation facility.
An element of an expert system which explains how solutions are reached via a smooth interface with user.

Forward chaining.
A problem solving approach in which the search starts from the initial state and moves towards the goal state. It is also known as, bottom-up; data-driven or antecedent reasoning.

Frame.
A knowledge representation method which uses nodes representing concepts or objects. The nodes are connected by relations which form a network of hierarchy. The node's slot can be filled by values or procedures attached to the slots in order to add or delete value from the slots [Waterman 1986].

Fuzzy logic.
A kind of inference strategy used in some expert systems. An approach to approximate reasoning in which truth values and quantifiers are defined as possibility distribution which have tables, such as true, very true, not very true, many, not very many, few, and several. The rules of inference are not exact but approximate in order to manipulate information which is imprecise, incomplete or unreliable [Waterman 1986].

Heuristic.
Rules of good guessing, judgmental knowledge; the knowledge underlying "expertise"; rules of thumb that obtain desired solutions in domains that are difficult and poorly understood but do not guarantee them [Waterman 1986] and [Feigenbaum E A & McCordouck 1984].

Inference engine (IE).
A part of an expert system which processes the domain knowledge in the knowledge base in order to achieve new conclusions.

IKBS
Intelligent knowledge based system.

Knowledge acquisition (KA).
The process of eliciting, structuring and formalizing knowledge from some sources for developing an expert system.
Knowledge base (KB).
An element of an expert system that contains the domain knowledge.

Knowledge based systems (KBS).
KBS are systems which use knowledge about the domain for solving problems.

Knowledge elicitation (KE).
The process of extracting knowledge from a domain expert, i.e. a sub-process of KA.

Knowledge engineer (KEN).
The person who develops expert systems.

Knowledge engineering (KENG).
The process of developing expert systems.

Knowledge representation (KR).
The process of structuring and formalizing knowledge about a problem domain. i.e. a sub-process of KA.

Machine learning.
A field of research that is interested in developing programs that can acquire knowledge; presently the focus of this field is inducing the rules based on the input of an expert's example.

Natural language.
The standard method of exchanging information between people, such as English language.

Procedural knowledge.
Procedural knowledge is information about how to reason with declarative knowledge.

Production system.
A kind of rule-based system which contain rules of the type
 IF (condition) THEN (action)
It has three main elements, a data base, production rules and a control system.

Robotics.
A sub-field of AI whose aim is to build devices that can manipulate their physical surroundings in an intelligent way as a human does.

Search.
The process of looking among possible solutions for an specific problem in order to find a solution.

Semantic networks.
A method of knowledge representation consisting of a network of nodes, standing for concepts or objects, connected by arcs describing the relations between the nodes.

Tool.
See ESBT.

User.
A person who uses an expert system.

VLSI.
Very large scale integration electronic components on microelectronics chips. The current chips carry half a million transistors. The aim is to produce chips which carry ten million transistors [Feigenbaum & McCordouck 1984].

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Expert systems development: Some problems, motives and issues in an exploratory study

This is an inquiry into expert systems development (ESD). The background is author's conception based upon theoretical studies and empirical findings. The study attempts to provide evidence that either supports or refutes the anecdotes, gossips and speculations currently being spread through the academic journals dealing with the expert systems development in organizations. A conceptual model of ESD is introduced. The main goal of the model is to contribute to the knowledge of ESD.