ROUTLEDGE REVIVALS

Knowledge-Based Systems for Multiple Environments

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TABLE OF CONTENTS

PART I MULTIPLE ENVIRONMENTS AND MULTIPLE CONTEXTS IN KNOWLEDGE ENGINEERING

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PREFACE

This book identifies the problems facing the designer of multi-environmental knowledge-based systems, and explains the principles which must be followed to obtain successful results.

Systems based upon knowledge—whether they are computer systems or not—are increasingly called upon in the modern world to function in a variety of widely differing environments. Even the best present-day knowledge-based systems, however, display often fatal flaws when the environment in which they are used alters even slightly. The need for software deliberately constructed for multi-environmental use is being felt ever more widely, and will be increasingly demanded in fifth (and sixth) generation machines. Such systems must be able to perform satisfactorily over a wide band of varying environments, whether these arise because of the individual or cultural diversity of users or their changing circumstances, or because of the rapid progress of the technology upon which the knowledge of the system is based.

This volume is the first full-scale discussion of such systems, the requirements they must meet, and the methodology for designing and evaluating them. While primarily aimed at workers in Artificial Intelligence and Expert Systems, as well as the producers of other kinds of sophisticated software, the content of the book is of wider validity, just as the multi-environmental demands are of wider incidence. It will also be of great interest to:

Serious designers of software with a large and variable knowledge component.

Builders of systems for use in the Third World that would match carefully the local environmental, cultural and economic conditions of each particular developing country.

Planners, designers and prospective users of systems intended to withstand the effect of technology transfer.

Builders of computer design tools, and in general,

Designers of extended expert database systems or other ambitious knowledge-based systems.

The book can also be used as the second text in a number of courses in knowledge engineering, expert systems and applied AI. Not only departments of computer science and electrical engineering, but also other department such as psychology, business administration, and indeed those in any branch of science and engineering offering graduate courses and pursuing research in expert systems, need to have the know-how of what pitfalls to avoid when building an expert system using a commercially available shell. The methods of efficient knowledge elicitation, and techniques for the verification of elicited knowledge structures offered in our book are of crucial importance in this context.

The book divides into five parts:

1) Multiple Environments and Multiple Contexts in Knowledge Engineering,
2) Methods of Knowledge Elicitation,

3) Design of Knowledge-Based Systems and Robots for Multi-Environmental Situations,

4) Methods for Design Validation of Multi-Environmental Systems,

5) Epilogue on knowledge in present-day society.

The first part deals in some detail with the reasons why the multi-environmental approach is needed, and with some of the areas in which it is most called for. The second part goes more deeply than is usual into the crucial questions of determining the relevance of knowledge for a proposed system and methods for finding its essential structures. These are absolute prerequisites to the design of knowledge acquisition systems, which in our view cannot be general-purpose, but must be closely keyed to the appropriate domain and to the purpose of the ultimate system.

This leads naturally to the third part, which illustrates with successful examples the general principles for synthesis of actual systems able to distinguish contexts and therefore to perform specific functions in a variety of environments.

All such systems require careful validation, and the fourth part of the book discusses the special requirements which are needed for multi-environmental, multi-context systems. Emphasis is placed on the discovering of hidden differences in knowledge structures and on early checking of the dynamic match between the system architecture and the environments, prior to embarking on actual construction.

The fifth part, the epilogue, is a somewhat controversial consideration of economic aspects of knowledge in the contemporary world, especially of the cyclical effects of commercial confidentiality upon flexibility of knowledge and even upon its correctness.

Unlike most edited collections, this one began with a careful outline of the main subdivisions of its theme, after which the individual chapters were commissioned from a group of researchers of quite diversified background who had deeply explored their subjects. The participants in this group had a unique opportunity to work together on the development of the multi-environmental theme for several years. The present book is the result of their fruitful collaboration. In writing this book, each topic was covered in close connection with others, so as to form a coherent whole. Every section and chapter is preceeded by an editorial introduction clarifying its place in the scheme and summarising its contribution. Locating specific aspects and following cross-currents of the ideas is thus facilitated.

While primarily aimed at workers in Artificial Intelligence and Knowledge Engineering, as well as the producers of other kinds of sophisticated software, the content of the book is of wider validity, just as the multi-environmental demands are of wider incidence. We hope that our contribution will facilitate the efforts for a better match between technologies and natural as well as cultural environments, thus improving the overall quality of human life.

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March, 1991

PART I

MULTIPLE ENVIRONMENTS AND MULTIPLE CONTEXTS IN KNOWLEDGE ENGINEERING

Editorial Comments:

For the first time we raise in detail the topic of multi-environmental systems. We have organised the structure of exploration so that the first section of the book clarifies when and why this approach is needed. After investigating in detail actual problems in the first 4 chapters, a unified framework and methodology is proposed.

CHAPTER 1

INTRODUCING MULTI-ENVIRONMENTAL AND MULTI-CONTEXT KNOWLEDGE-BASED SYSTEMS: A NEW APPROACH

M. Ben-Ahmeida and L.J. Kohout

Editorial Comment:

Outlined here is the basic case for multi-environmental systems. This should be read first as it carries the basic motif for the book.

LIST OF CONTENTS

1.1. WHY MULTIPLE ENVIRONMENTS?

Within the artificial intelligence general framework, a new field called expert systems has appeared and attracted much interest over the last two decades. These computer programs have two fundamental characteristics that set them apart from conventional programming style. Firstly, an expert system is designed to perform a task usually requiring expertise of some domain, such as medical diagnosis, medical therapy, fault diagnosis. Secondly, the method applied to develop the system is to acquire and codify the knowledge used by human experts in a particular domain.

KNOWLEDGE-BASED SYSTEMS FOR MULTIPLE ENVIRONMENTS

Although expert systems have became to play a role in practical applications and are receiving currently large publicity, their use is restricted to very narrow knowledge domains, where these have been very successful. Their successful application remains problematic in the areas

a) where the knowledge of the domain is changing rapidly

b) where the knowledge domain is complex, with multiplicity of contexts

c) when the system is likely to be transferred from one to another environment.

This is demonstrated particularly vividly in medicine. In the medical field, expert systems have received much attention from both, computer and medical specialists in the last few years. As a result, a considerable variety of medical expert systems has been developed for diagnosing and recommending treatment of diseases. Although many of such systems have been developed for a restricted medical domain, very few are used in a real medical environment. Horn et al. (1985) points out that

> *... the last two decades have seen the development of a large number of medical expert systems such as CASNET (Weiss and Kulikowski, 1979), INTERNIST (Pople and Mayers 1982), MYCIN (Shortliffe 1976). Most of these systems have been shown to perform at the level of their domain experts. Despite the impressive performance very few systems have appeared in "real world" applications.*

This inadequacy of the current medical expert systems is caused by the fact that each of these systems has been developed for a restricted medical domain to match a specific medical environment and ignoring the multiplicity of contexts of the medical domain. Moreover, the same applies also to the expert systems dealing with other knowledge domains. The possibility of transferring medical systems to other medical environments is very limited. Medical environments, from one part of the country to another, and from one country to another, are different. These differences which prevent the transferability of such system to other medical environments in general and of medical environments in developing countries in particular, may be traced to several sources, some of which have to do with the nature of real life situations, others have to do with the accessibility and reliability of medical knowledge sources and with availability of computing facilities, as well as the incompatibility of the existing design methodologies to match the requirements of designing medical expert systems for a multi-environment situation. In order to deal adequately with these problems, we have to introduce multi-environments and multiple context into all the stages of construction of expert and knowledge-based systems.

1.2. WHAT IS A MULTI-ENVIRONMENTAL KNOWLEDGE-BASED SYSTEM?

What is understood by the term "multi-environmental situation" can be best demonstrated by an example from the medical domain. We shall see later, that the multi-environmental situation appears also in other domains, such as insurance underwriting, process control and robotics. But we shall discuss the medical example, which does not require specialist knowledge, first.

The term "medical environment" in our example covers the hospital users, such as consultants, physicians, nurses, technicians, patients and their activities. In the activity structure terminologies (see Chapter 5), this term includes participants, actions and properties of both.

In looking at the activity of the medical diagnosis and decision support using human experts, we can see that the expert specialist is helping a physician by means of his expertise to deal with a particular medical environment. When the medical expert is transferred to a new medical environment in another part of the country or another country, he has to capture the expertise of the other medical environment which is different from the expertise that the expert already has. Since expert performance can involve a combination of skill of rapidly recognising complex patterns in the environment, skill in interactive behaviour, skill in problem solving, and decision making skills, the characteristics of these skills may change with this transfer (Schvaneveldt et al., 1985).

This can be represented by the diagram of Figure 1.1. If the medical expert is transferred from medical environment (a) to (b), he has to capture the expertise of part (e) of the medical environment (b), where (d) is the overlap between both environments (the part of expertise which is similar in both (a) and (b). This overlap depends on the differences and similarities of the environments involved. For example, the overlap of expertise between two medical environments in England is much bigger than the overlap between a medical environment in England and in North Africa.

To make the so far rather vague notion of multi-environmental situation clear and more precise, we have to define what a multi-environment expert, and an multi-environment knowledge-based system are.

(i) **Definition:** A multi-environment expert is an expert with expertise of a particular knowledge domain who has the additional expertise of using his knowledge in more than one environment.

(ii) **Definition:** A multi-environmental knowledge-based system is a knowledge-based system which is modifiable in such a way that it can be used in more than one environment.

In spite of the widespread interest in medical expert systems, very little has been written about the modifiability and multi-environmental usability of these systems. It will be seen later that in many situations, medical expert systems need to be designed to match more than one environment.

Referring to our Figure 1.1, if the medical expert system is to be used in two medical environments (a) and (b), the expertise of both environments has to be captured.

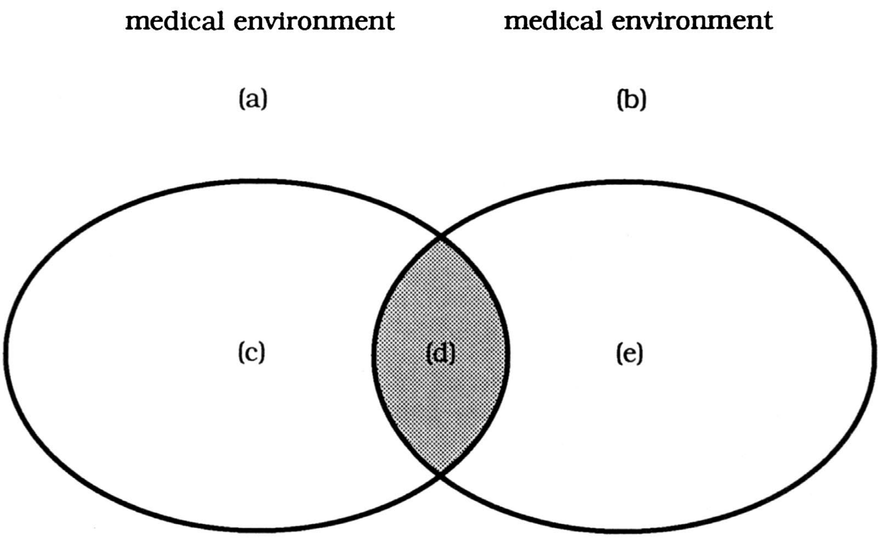

Figure 1.1. The overlap of two medical environments

1.3. MULTI-ENVIRONMENTS IN NON-MEDICAL KNOWLEDGE DOMAIN

The problem with transfer of a designed technological artefact from one to another environment also appears in Architecture. Below we provide a simple real live example from the architectural engineering field to point out the importance of capturing the knowledge about other environments in which the architect will design the buildings. The example follows:

Twenty five years ago or so, large buildings such as schools in some North African countries had been designed by western architect engineers who had never been in these countries, and knew very little about them. The buildings were inappropriate, and raised many problems with the necessity of expensive modification and readjustment. One example of many wrong features for instance, were the large glass windows which were completely unsuitable because of the high temperature increases during the day, and sunny days almost all year round.

It has been stated in this field that to design a building for more than one environment, architect engineers have to consider the following key points:

1) Acceptability of the building by different types of users.
2) Reliability of the building from the functional and the foundations point of view.
3) Protectability against misuse and undesirable activities.

We can see that the concepts of a structure and function (cf. Kohout, 1987) play important role here. The above is applicable also to the area of designing multi-environment medical expert systems, or indeed to the design of any multi-environment knowledge-based systems. An interesting comparison between the architect's approach to the design of building and the Activity Structures approach of Kohout, for designing knowledge-based systems was done by Mancini (1986). The following quotation points out the correspondence in his view, to the analogous terms in Kohout's approach:

> *There is a correspondence between system architecture and aspatial structure. The identification of the structure of the system's function the functional structure, can be arrived at, in similar fashion through the activity structure. Conversely, the embodiment of the functional structure into a particular substratum structure, say the various modules of a set of computer programs, corresponds to the designing of the spatial structures in the built environment.*

In a knowledge-based system for computer-aided manufacturing, each environment corresponds to a different industrial or manufacturing process to be controlled. In robotics, again, each modality of the robot's activity represents a separate environment and is also executed in a multiplicity of contexts.

1.4. WHAT IS MULTI-CONTEXT AND WHY SHOULD IT BE INTRODUCED?

Multiple context is generated by those features of the knowledge structures *which cause* that not all knowledge and data are equally relevant under all circumstances. This, what can be called "locality of relevance" can be effected by the interaction of several environments, or by the complexity of the situation in which the knowledge is used.

Again, we shall discuss this looking at the medical domain. In current AI and expert systems literature and at the scientific conferences concerned with these, the medical domain is usually trivialised. It is reduced to matching symptoms and physical signs to diseases to obtain diagnosis. The systems reached similar diagnoses to those of experts and it was therefore concluded, that we have nothing to learn from the medical domain in knowledge engineering. Yet, the medical domain in its full complexity presents many adequate solutions to some knowledge engineering problems, and a large variety of challenging problems of considerable complexity and difficulty, from which expert systems designers and knowledge engineers can learn. For this reason, we start again with the discussion of the medical domain.

The process of clinical decision making is of considerable complexity. For example, medical diagnosis is the process by which the disease is identified. It is similar to the art of detection. First clue are the symptoms; which are usually pain or fever, a physical problem or general ill-health. Interviewing the patient is the way to find out about the problem in detail. After the patient symptoms are discussed, a good idea of the general nature of the problem may be identified to a fair degree. This will direct the questions towards what physical signs are noticed and then to the configuration of the diseases that seem most likely.

As the next step, new elements in addition to symptoms and signs are introduced. These are laboratory data, radiology findings etc. The new components that have to be taken into account involve not only the diagnostic system, but a physician, the hospital system and medical records. Basically, even with this addition, the diagnostic process is the same. The physician looks at other similar cases, and suggests diagnosis, but more information is available. Part of this information comes from patient's records such as medical history e.g. previous diseases, treatment, etc. Other information includes details of patient's conditions during hospitalisation such as blood pressure, laboratory tests, etc.

Medical scientists sometimes know exactly how a disease presents itself, and occasionally why the treatment for it works. Medical opinion about diseases is constantly changing and each change is the result of extensive research. Every patient has a different level of resistance to a disease according to the age, diet, heredity factors, culture, beliefs and previous illnesses. Because of these variations, it is very difficult to make any categorical statement about medicine and diseases.

The words 'possibly', 'sometimes', 'usually', 'occasionally', 'extremely', 'rarely', 'excessive', 'mild' and 'common' are often used by the patient describing his symptoms or by medical knowledge sources describing signs (see Chapter 16). This reflects in practice the fuzziness and uncertainty of information in medicine. This in turn leads to locality of inference and local relevance of terms (cf. Bellman and Zadeh, 1975; Kohout et al. 1987).

With all of these complicating factors it is perhaps surprising that physicians are ever able to make a diagnosis. Their ability to unravel the complexities and uncertainties of diseases is a skill learned through experience and many years of education and intensive training they undergo before qualification. This points out the importance of a medical consultant or expert with many years of experience in providing the essential help in the diagnosing process to physicians with lesser experience.

Examining the goals of the majority of current medical expert systems, we discover that these inadequately treat such a complex situation. They are usually involved in a narrow specialty field and a single context.

For example, AI/RHEUM medical expert system assists physician, in diagnosing connective tissue diseases of clinical rheumatology by applying formal diagnostic criteria obtained from experts in their particular speciality. The system uses patient symptoms, signs, and laboratory findings to provide assistance with several diseases.

Another example is MYCIN, one of the well-known medical expert systems which was developed at Stanford University in 1976. This system assists physicians in selecting suitable antimicrobial therapy for patients with bacterial infections. The system identifies the agent or at least the type of the agent causing the infection, It uses knowledge relating infecting organisms to patient history, symptoms, signs, and laboratory test results. Based on this identification, the system recommends drug treatment, apparently according to the procedures followed by the physicians experienced in infectious diseases therapy. The scope of other such systems can be seen in Table 1.1.

The Table 1.1 shows clearly the restricted medical domains and medical environments in which these systems are used. For example, Thyroid MODEL was designed to diagnose disorders of thyroid which is one of several organs of the endocrine body system.

In contrast to this, dealing with the full complexity of medical clinical decision making leads to inducing multiple contexts in the knowledge structures. This has been demonstrated elsewhere and is further discussed in Chapter 10 of this book.

1.5. THE NEED FOR A MULTI-ENVIRONMENTAL DESIGN APPROACH

As Hayes-Roth (1984), and Parker (1983) pointed out, the process of building an expert system may span several months and sometimes several years. Acquiring knowledge, a major task of developing this system is not performed all at once. Bobrow et al., (1986) stated that in the course of the expert system development, it is typical to expand and reformulate the knowledge base many times. One reason is that choosing the terminologies and ways of factoring the knowledge base is subject to so much experimentation.

Table 1.1. Summary of a few selected medical expert systems

Med.E.S.	DOMAIN	Devel. Place	State Reached
ANGY	Diag. the narrowing of coronary vessels	University of Pennsylvania	Demonstration prototype
CENTAUR	Diag. interpretation of pulmonary function	Stanford University	Research prototyping
Diagnoser	To identify heart disease	University of Minnesota	Research prototyping
GUIDON	Diagnose congenital heart dis. in children	Stanford University	Research prototyping
HEME	Diagnose hematologic disease	Cornell University	Field prototyping
MIDX	Diag. of the liver syndrome (cholesis)	Ohio State University	Research prototyping
Thyroid MODEL	Diagnose disorder of Thyroid	Rutgers University	Demonstration prototyping

In all these previous design approaches, rather typical of the whole expert systems field, the elicitation of knowledge is inadequately separated from the expert system engineering process. That the dynamics of knowledge elicitation is different from the dynamics of the evolution of the system being implemented was argued by Behrooz (1986). In the multi-environmental situation, this is complicated by the fact that even slight environmental changes lead to vast differences in the structure of the knowledge structures (cf. Chapter 16) of this volume).

Furthermore the multi-environmental knowledge-based system design places emphasis on the need to explore the fundamentals of the engineering design process by looking at the suitability of the existing design methodologies for building such system in multi-environment situation.

1.6. THREE ESSENTIAL FEATURES OF MULTI-ENVIRONMENTAL KNOWLEDGE-BASED SYSTEMS: ACCEPTABILITY, RELIABILITY AND PROTECTABILITY

In this section we shall define, and further discuss in greater detail, the three key factors by which multi-environmental knowledge-based systems should be evaluated, namely acceptability, reliability and protectability.

A knowledge-based system will match more than one environment only if some definite conditions of its transferability from one to another environment in the predetermined set of environments are satisfied. For this reason, the importance of the whole, and of each of the environments of the set cannot be overemphasised. The main design constraints predetermine whether and how the conditions of transferability can be fulfilled.

ACCEPTABILITY ultimately determines the users' satisfaction with the system in each environment. The following definition determines what acceptability is and how it can be measured.

Definition 1.6-1: *Acceptability within an environment*

1. Acceptability is defined as the degree of users' satisfaction with the system in a particular environment.
2. User satisfaction is qualitatively determined by the set of functional requirements.
3. The degree of users' satisfaction is quantitatively measured by the ***degrees of containment*** between the set of ***intended*** functional requirements and the set of ***realised*** functional requirements. These may be differently determined in each particular environment.

In practice, with multi-environmental knowledge based systems, a greater emphasis must be given to determining the nature of the activities that the system will supply. The system should communicate with the users of each environment in a way familiar and acceptable to them. The mechanism for acquainting the users of each environment with the facilities needed in that particular environment may differ from one environment to another.

The second important factor that determines the quality of a multi-environmental knowledge-based system is RELIABILITY. An unreliable system produces unacceptable errors which are originated by a diversity of sources. The error sources divide into two distinct categories, namely

a) Mistakes in the design.
b) Failures caused by the outer environment in regard to the other environments in the shell.

For example, part of the outer environment are climatic factors. In some African countries (cf. Ben-Ahmeida, 1987), these are characterised by a high temperature increase during the day, high absolute humidity, high percentage of dust in the air, etc. These determine the choice of the acceptable hardware for this particular environment, as well as the nature of the maintenance procedures of the system. Fluctuations in the voltage of the mains electricity supply is another important factor.

PROTECTABILITY is the third and final factor that has to be considered in the knowledge-based systems usability for multi-environment situations. By going back to our medical example, protectability means preventing access to classified information by unauthorised user accidentally or otherwise.

Generally all medical information is sensitive in any medical environment, but it is not equally sensitive in the same environment or from one environment to the other. All the intended users of each medical environment have the right to access the information but the authority is not the same.

This emphasises the need to distinguish the two major forms of accessibility as:

1- Access of classified information by classified groups of users.
2- Access of classified information by individual users.

In building knowledge-based systems for a multi-environment situation, protection aspects, therefore, have to be considered for the following reasons:

1- For each environment there are various desired levels of protection which vary from one environment to the other.
2- For each environment there are dynamic changing requirements of protection levels.

Referring to the medical environmental case study presented in Chapter 2 illustrates this. It has been shown that the distinctions between the medical, social, language and educational aspects of various medical environments are significant. In addition to the variation of these factors from one medical environment to the other, the dynamism of each factor in the intended medical environments has to be considered.

The above highlights the need for a total design methodology that can deal adequately with the protection aspects in addition to the other aspects of a multi-environment situation. **Activity Structures** provide such a methodology (cf. Kohout 1987, and Chapter 5 of this volume).

1.7. MULTI-ENVIRONMENTAL RELIABILITY OF KNOWLEDGE

In a knowledge-based system, knowledge is the fundamental part. This knowledge also ought to be reliable. That means, it must not contain errors and must be consistent. If this is not so, it may be caused either by mistakes in the design or failures caused by the outer environment. The latter may be caused either by an improper use of the knowledge base, or by the cultural or semantic mismatch between the users and the system knowledge in a particular environment. The inconsistency may be caused either by the mismatch of the system with the environment or by design mistakes, i.e. those caused by the faulty procedures during the knowledge elicitation process. This has substantial practical consequences, namely:

a) Knowledge must be represented as the domain expert meant it to be.
b) Users must get only what is relevant in a particular context and in a particular environment. This determines what we call usability and accessibility, respectively.

Our multi-environmental approach, however, is to adopt the activity structures terminologies by dealing with this knowledge reliability from both functional and substratum point of view before it is transferred to implementation stage. Here by the **substratum** point of view is meant the structure and the *interrelationships* of individual hardware and software modules. The **functional** point of view takes into account the *structural description of the behaviour* of these modules (Kohout 1987, and Chapter 5, section 5.2.2 of this volume).

Therefore, according to this distinction between the functional and substratum structures, the knowledge structures from the sources of the intended environments need to be compared, analysed, and evaluated. This evaluation should be done by examining the functional reliability aspects, as well as the factors that influence the technology (i.e. hardware), the substratum in which the knowledge is stored.

1.8. TESTING KNOWLEDGE STRUCTURES: THEIR MULTI-CONTEXT ACCEPTABILITY AND MULTI-ENVIRONMENTAL RELIABILITY

Medical knowledge is the essential major part involved in building a medical expert system. Hence, the medical knowledge from the sources of several medical environments needs to be analysed, compared, and evaluated before it is transferred to the system, in order to provide reliable and compatible medical knowledge structures for the construction of a multi-environmental medical expert system.

In order to be able to do this comparison and evaluation in the process of development of multi-environmental knowledge-based systems, we need suitable tools and techniques to perform the following:

1) Complexity analysis and syntax comparison of the knowledge structures from the selected sources.
2) Structural analysis and evaluation of the knowledge structures.
3) Utilization of suitable design methodology that can deal with the multi-environmental design problems.

Medical data need to be analysed in ways which present and illustrate dependencies and implications among its variables in order to select reliable medical diagnostic knowledge. Fuzzy logic provides mathematical techniques for analysing medical data allowing the revelation of dependences, hierachies and partial order in the data. Bandler and Kohout (1979) discussed the reasons for using fuzzy logic as a tool for the analysis of these types of data.

Fuzzy relational products (Bandler and Kohout 1986, 1988) together with the fast algorithms (Bander and Kohout 1982, 1988) for testing of relational properties, a tool developed by Bandler and Kohout (1979) is used to analyse and evaluate medical knowledge structures from different medical knowledge sources to point out and compare dependencies and hierarchies in their knowledge structures (Bandler and Kohout 1980b, 1986 and Chapter 16 of this volume). This methodology, which is based on the theory of fuzzy relations, provides a natural way of dealing with problems in which the source of the imprecision is the absence of sharply defined criteria of class membership rather than the presence of random variables (Bandler and Kohout 1980b).

By proposing a total design methodology approach (based on activity structures) which is compatible with the three points above, for designing multi-environment medical expert systems and using fast fuzzy relational algorithms to analyse their knowledge structures, we provide some means to deal with the problem of multi-environment knowledge-based systems analysis and construction.

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CHAPTER 2

WHAT IS A MULTIPLE ENVIRONMENT AND HOW DOES IT AFFECT THE FUNCTION OF A KNOWLEDGE-BASED SYSTEM?

M. BEN-AHMEIDA AND L.J. KOHOUT

Editorial Comment:

This shows concretely how multiple environments are interleaved in medical practice in a particular culture.

LIST OF CONTENTS

2.1. INTRODUCTION

In this chapter, we shall present a concrete example from one of the developing countries in North Africa in which we examine the essential aspects of a complex medical environment of a developing country. It will become obvious from our detailed discussion of this situation, that some particular features or characteristics of such an environment may prevent transferability of the current medical expert systems, which are designed without due attention to complex multi-cultural and multi-environmental situation, that occurs in such a complex medical environment.

This case study highlights the fact that medical environments vary from one country to another, or may vary even within the same country. In addition to possible differences in medical knowledge about diseases appearing between medical environments, some other differences may be caused, for example, by patient's life-style and by what we shall call the local domestic atmosphere. This may influence the appearance of symptoms and signs and therefore have an impact on the character of diseases. It will, also, influence the quality of patient-physician interaction because of impact on the perception of language, culture, patient's education and beliefs.

Not much is said in the current literature about the suitability of medical expert systems to operate in a multi-environment situation, indeed its existence is usually ignored. While tools have been developed which are called skeletal or shell systems such as EMYCIN (Van Melle et al., 1981), and Expert (Weiss et al., 1979), these systems which are thought to eliminate the necessity of rebuilding a medical expert system from scratch do need to take multi-environments into account.

Section 2.2, reviews some of the skeleton medical systems that are available and examines their usability in the multi-environment situation. The important aspects of medical multi-environments are demonstrated in section 2.3 by discussing in some detail a real medical environment. In section 2.4, the dissimilar components of medical environments are investigated. Section 2.5 presents the main aspects of the medical multi-environment problem and final discussion on the question whether or not the current medical expert system can be transferred to other medical environments.

2.2. EXPERT SYSTEM SHELLS

Skeleton or shell medical expert systems can provide help in building a new medical knowledge base. These shells do offer various facilities for defining data types and writing rules according to some specified sets of conventions; these must be related to an environment. This use of the shell in a different knowledge domain than that for which it was originally designed can be done because of the separation between the knowledge base and the inference engine (see Figure 2.1). This provides the possibility to detach the knowledge base of one domain and replace it with one for a different domain (Jackson, 1986; Miller 1986).

A number of systems have been built using various expert system shells. In medicine for example, PUFF expert system diagnosing respiratory ailments was developed, using those parts of MYCIN that were knowledge domain independent, such as the facilities supporting the rule based inference and the explanatory facilities. The domain specific rules of MYCIN were replaced by the rules pertinent to the diagnosis of respiratory diseases.

Generally, the designs of expert systems in various domains using the same supporting shell are based on the assumption that the dynamics of expert inference is environment and context independent, the difference between the various distinct knowledge domains being captured by the contents of the domain dependent rule base only. Moreover, in a shell it

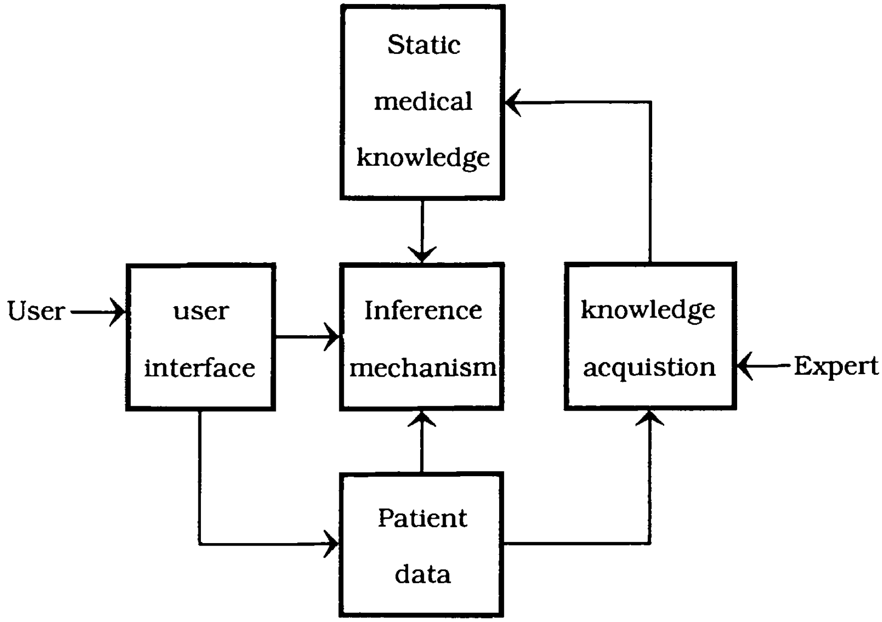

Figure 2.1. Architecture of the current medical expert system

is usually assumed that the process of substituting the rules by other rules for a different set of expert tasks is a relatively easy job in "real world" applications. Hayes-Roth (1984), however, highlights the difficulty of this process of substitution of the rules of one knowledge domain by the rules of another. He suggests that

> *Permitting the replacement of these rules by rules for a different task greatly simplifies the process of building an expert system for the second task, although in practice this process is rarely quite this simple.*

A few systems, however, have been built using these shells. The major advantage of using these shells is that the new system uses the available facilities of the original system. For instance, PUFF used the available facilities of MYCIN expert system, such as explanation features, etc. In a practical situation, however, it is doubtful whether these shells systems could be applied in any medical environment. Hayes-Roth (1984) points out the following problems which may arise in this context:

1. The old framework may be unsuitable to the new task. This is both the most likely and the most serious problem.
2. The control structure embodied in the inference engine may not sufficiently match the new expert's way of solving problems.
3. The old rule language may be not appropriate to the new task.
4. There may be task-specific knowledge hidden in the old system in unrecognised ways.

In addition to the above listed problems however, other problems appear. In medical multi-environment situations, the shell medical expert systems without specific domain knowledge, are very unlikely to be used for the following additional reasons:

1. The environment insensitive explanatory facilities are not adequate in a multi-environment situation, where the form and the contents of explanation crucially depends on the environment.
2. The shells are very expensive to buy in many medical environments, particularly in developing countries.
3. Most of these systems necessitate large computing facilities to run on. These facilities are not available in many medical environments of developing countries.

From what is said above it can be seen clearly that implementing medical expert systems using conventional shells that are currently available may not be the most appropriate way for building medical expert systems in a multi-environment situation at present. In the next section, we shall demonstrate the complexity of the multi-environment situation by examining the essential aspects of a real medical environment which have to be taken into account in building multi-environment medical expert systems. This will give the reader some appreciation of the difficulties that may occur.

2.3. MULTI-ENVIRONMENT MEDICAL ASPECTS

In this section we establish some important features of the multi-environmental problem of medical expert systems. This cannot be achieved in a concrete and easily understandable way without introducing a real example. We introduce an example that provides a good representation of the medical environments of developing countries that use the western medical system. If we want to introduce a completely different medical environment, the Chinese medical environment would be a good example, but the western medical framework does not fit the Chinese traditional medicine, and therefore we choose to present the concrete example from one of the North African countries. As an example of one of the developing countries, the Libyan medical environments are discussed here. It will be seen that this example demonstrates the features and characteristics of a multi-environment situation of considerable complexity.

Very few sources are available that adequately describe medical services in this country, therefore, most of our information has been collected by interviewing a number of local physicians with several years' experience, and from a direct experience with the health service. In this medical environment, all the hospitals and community Health Centres are supervised and supported completely by the Government. They are varying in size and in facilities according to population and geographical location. All patients, whatever their social class, their residencies, their nationalities, and whatever are the routes by which they have entered the hospital, are equivalent in receiving medical services in the same hospital.

Moreover, the facilities available, differ greatly from one hospital to another. Usually central hospitals in the cities are better equipped than other hospitals. Most of the equipment is imported from some industrial countries, such as West Germany, Italy, and the UK.

2.3.1. Hospital Staff Availability

The health service in Libya is staffed almost exclusively by foreign consultants, physicians and medical personnel. About 98% of the experts, 90% of the physicians, and 70% of the nurses are from foreign countries (Governmental Statistics, 1980). The majority of the foreign medical staff work as teams on the basis of one or two year contracts. Each team is from the same country and in many cases more than one team with members of different nationalities are working in the same hospital. Each team consists of consultants, physicians, nurses, and sometimes technicians. In addition to the foreign teams in the hospital, there are a number of local physicians, nurses and technicians as well as individual physicians from other Arab countries. The majority of local doctors were educated and trained in medical schools which were established recently in the local universities. The rest were educated in different foreign countries.

2.3.2. Patient Analysis

Although the majority of the patients are from a single homogeneous cultural group, the patients are different in their educational background, their health, beliefs and their customs. The largest group of patients are the rural and illiterate people. These persons share a value of traditional system, a set of experiences, behaviour patterns and a more conventional health and religious beliefs than other patients.

The other group is smaller than the previous group. It consists of the patients who may be described as having better level of education or professionals, whose patterns of thought and behaviour closely resemble each other. Beyond these groups, one can find a third group of patients who may be described as foreign experts, foreign labourers, visitors, and their dependents.

Although all sex and age groups are represented in the patient population, female patients tend to be more frequent than male patients in using the medical services, specifically those from rural and uneducated groups.

The first group seems to constitute a single class, about whom some generalisations could be made. They are fatalistic and poorly educated or illiterate. Their language is concrete and they seldom ask questions, preferring that other local staff provide them with the information. Usually, this type of patient tends to be older, very religious, and more patients of female sex are present in this group.

The other group of patients which may be classified as a distinct group, consists of urban and rural members, who are educated or partially educated. They ask more questions than the previous group and are more modern in their beliefs and their cultural traditions.

Both groups believe in the same religion and share certain characteristics. The majority have, and value, strong kinship ties. They value personal relationships and life co-operation. Female patients in both groups share also certain characteristics. The majority in both groups are poorly educated or illiterate, very conservative in dealing with male medical staff, and in many ways less able to communicate.

2.3.3. Styles of Physician-Patient Interaction

Roberts (1977) indicated a number of physician-patient and patient-physician interactive styles. The following describe physician-patient interactive styles where a *physician* is labelled as:

1. **Dominant** if, in his early contact with his patients, he tends to give orders, to take actions without first giving information, and to be unresponsive to patient's volunteered statements.
2. **Egalitarian** if, in his early contact with patients he tends to explain his actions and to ask for and respond to patient's statements.

The patient-physician *interactive* style can be classified into different types:

1. **Egalitarian**, if in his early contact with physician, he expected, and often demanded or negotiated for, as nearly equal share of information and decision making, as his situation allowed.

2. **Silent egalitarian** if, patient wants information but does not ask for it, and wants to share in decision making but does not make it known.

The majority of the patients belonging to the first group described in the previous section, behave in a subordinate manner in that they ask none or a very few questions. In the second group the majority of the male patients behave in egalitarian manner. The majority of female patients in this group behave in silent egalitarian manner.

Physician-patient communication is very extensively treated in the literature. Pendleton et al., (1983) reviewed extensive evidence which indicates that interaction between physician and patient needs to possess certain specific elements. Many of these elements may constitute necessary prerequisites for better diagnosis and effective treatment.

In view of the previous discussion, in the next section we will discuss the components of the medical environments which are not similar.

2.4. DISSIMILAR COMPONENTS OF MEDICAL ENVIRONMENTS

As we pointed out before, several components of a medical system are changeable from one medical environment to another. This needs to be taken into consideration when building a medical expert system for multi-environment situation. The following variable components were identified from the data collected about the selected medical environments.

2.4.1. Language

The majority of the patients are speaking the same language which is different from the language spoken by foreign medical staff. A short course in the local language is provided to new foreign medical staff including a few medical terms, which is hardly sufficient for basic communication with patients. As a result, only few words are acquired by the physician and nurses initially, to make it possible to communicate in a very poor way with most of the patients. Some patients of the second group try to communicate in the English language if the physician or nurse speaks this language. Few patients try to learn some words of the native language of the medical team and try to communicate with physician and nurses as adequately as they can. The size of the problem is bigger when a new medical team starts, and then the situation begins to improve with time and as experience in communication is acquired by both sides. The problem appears all over again when the old medical team finishes the contract and a new team takes its place. Many times the new medical team comes from a country different to that of the previous team. In this situation the language problem becomes more critical.

The following example is taken from one hospital in a city of about 250,000 population.

- Patients. Approximately 85% – speak Arabic.
- Local staff. Approximately 15% of the total staff speak Arabic, the rest other languages.