UNIVERSITY OF NAIROBI
SCHOOL OF COMPUTING AND INFORMATICS

Herbalist Diagnostic Support System: A Prototype

Presented By

Terah Stephen A. A.
(Reg. No. P/56/P/8268/2001)

A project report submitted in partial fulfillment of the requirements for the award of Master of Science in Information Systems

August 2009

DECLARATION

In presenting this project report in partial fulfillment of the requirements for a Master of Science degree in Information Systems at the School of Computing and Informatics, I agree that the library shall make it freely available for reference and study. It has not been submitted for any other degree or diploma of any other examining body. Except where acknowledged, this project is my original work.

Signed: ________________ Date: 17/8/2009

Terah Stephen A. A.
Reg. No. P/56/P/8268/2001

This project has been presented for examination with my approval as the university supervisor.

Signed: ________________ Date: 18/8/09.

Dr. Peter W. Wagacha
Lecturer
School of Computing & Informatics
University of Nairobi

ACKNOWLEDGEMENT

I would like to thank my supervisor, Dr. Peter W. Wagacha for his quality guidance and encouragement throughout the course of this project. His suggestions, comments and patience really assisted me in working on the project.

It will not be in order for me to fail to appreciate the ideas contributed by my lecturers Mr. Christopher A. Moturi and Mr. Opiyo towards my project work.

I also wish to acknowledge other academic lecturers in the School of Computing & Informatics (UoN) for building in me a strong foundation against which this work was realized.

May I also express my appreciation to Dr W. Imbiyoyi of Kakamega General Hospital and Mr. Paul Were of Catholic University for sparing time to assist me obtain symptoms of the various diseases. At this point, it is also worth thanking the herbalists who advised me about the herbs they use to manage the various disorders. Here, I should mention Agnes Mukai from Kangundo and Absalom Omolo from Homabay for their assistance.

It is also important for me to thank my classmates and friends, especially Bethwel Owuor for the many helpful discussions and inspiration even during hard times.

May I also thank my parents, brothers and sisters for their love, prayers and patience.

Last but not least, I would like to thank Almighty God for giving me the strength and persistence that were very necessary for me to achieve this goal.

ABSTRACT

The Herbalist Diagnostic Support System has been built using expert system techniques. Expert Systems are useful in capturing rare knowledge from a human expert into a computer system, thereby allowing a non-expert to be able to use the knowledge captured into the computer to solve problems from the associated problem domain. The knowledge acquisition bottleneck is a fundamental problem in building expert systems. This work gives a report on how a Herbalist Diagnostic Support System has been built in spite of the knowledge acquisition bottleneck. In this report a framework where the knowledge based system approach is applied to assist attend to patients in a herbalists setting has also been formulated. The resulting prototype that was designed was evaluated by doctors, herbalists and system analysts, and found to be acceptable. They also found the system interface acceptable.

ABBREVIATIONS

AI	- Artificial Intelligence
ES	- Expert System
KBS	- Knowledge Based System
KADS	- Knowledge Acquisition and Design Process
KB	- Knowledge Base
CMR	- Crystal Master Rule
CASE	- Computer Aided Software Engineering
RW	- Rosewaelar Test
VDRL	- Venereal Disease Research Laboratory
TPHA	- Treponema Pallidum Haemagglutination
CSF	- Cerebrospinal Fluid
UTI	- Urethral Tract Infection
PROLOG	- PROgramming LOGic.
WHO	- World Health Organization.
HMS	- Harvard Medical School.
US	- United States of America.
CBR	- Case Based Reasoning

GLOSSARY

Knowledge base - a declarative representation of the expertise, often in IF - THEN rules.

Working storage - data that is specific to the problem being solved.

Inference engine - the code at the core of the system which derives recommendations from the knowledge base and problem-specific data in working storage.

User interface - the code that controls the dialog between the user and the system.

Domain expert - the individual or individuals who currently are experts solving the problems the system is intended to solve.

Knowledge engineer - the individual who encodes the expert's knowledge in a declarative form that can be used by the expert system.

Expert system shell - An Expert System shell is a piece of software that contains the user interface, format to use to capture knowledge into the knowledge base, and an inference engine. The knowledge engineer uses the shell to build expert systems for a particular problem domain.

User - the individual who will be consulting with the system to get advice which would have been provided by the expert.

Prolog - Programming language used for developing artificial intelligence systems.

Herbalist - A person who grows, collects or specializes in the use of herbs especially, medicinal herbs or one who practices healing with herbs.

TABLE OF CONTENTS

LIST OF FIGURES

1

INTRODUCTION

1.1 The Background

Conventional doctors and nurses are not sufficient on the globe. Third world countries are most affected. Most of the few doctors and nurses in the third world countries like Kenya are also deserting their home countries in search for greener pastures in the European world. This problem is most critical in the rural areas of the third world. The situation is not different with regard to herbal or alternative medicine that has become widespread in the current world. Qualified herbalists are very few especially in the rural areas of third world countries like Kenya.

With the coming of computers and tools like artificial intelligence, it is now possible to capture human expertise into a computer system. In the proposed Herbalist Diagnostic Support System, the researcher explores the possibilities of using an expert system to support herbalists' diagnostic processes. Such a tool will be vital in the absence of the human expert herbalist either for disorder management or as a training tool.

1.2 Motivation

The purpose of this report is to present the systems analysis, design, implementation and recommendations resulting from a study carried out on diagnostic processes of herbalists. One goal of Artificial Intelligence is to develop system that display some form of intelligence. Expert systems form one such approach where knowledge from a human expert is captured into a computer system so as to be used as if it were the human expert.

The main motivation behind this project is to provide a solution in a real life situation using the idea of an expert system. The researcher has applied knowledge engineering to come up with a herbalist diagnosis support system. Diagnosis is an every day problem because human beings always fall sick and have to go through diagnosis for the disease to be identified before treatment.

The researcher also aims at demonstrating how expert systems can provide a way of preserving the knowledge of exceptionally good herbalists to be used long after these herbalists.

1.3 Statement of the Problem

Identifying the disorder afflicting a patient is one of the tasks a doctor or herbalist is faced with in his or her day to day work. This helps the doctor or herbalist know what medicine to administer. To practice as a herbalist, it requires some training. Sometimes the herbalist may not be available for consultation either for treatment or training as the case may be; the human expert may be on leave or even absent because of sickness. Under such circumstances, an intern or non expert can use the proposed expert system to identify and manage the disorder or as a training tool.

1.4 Objectives of the Project

The main objective of this project was to consolidate and integrate the understanding of computer systems design particularly in the use of AI techniques which were eventually to culminate to an expert system that would be able to identify the disorder that affects the patient. The system prompts the user with probable hypothesis regarding symptoms which are to be confirmed or denied. This would lead to a particular disease being identified. The system would then proceed to advice on the herbal medicine to use to manage or treat the disorder. More specifically, the researcher aims at coming up with a system

- That can identify a disorder when given the corresponding symptoms.
- That can advise on the herb or plant and preparation to use in managing the identified disorder depending on the region of residence.
- That provides a very user friendly interface that is simple and easy to learn and use.
- That makes traditional medicine knowledge more widely available.
- That helps preserve traditional medicinal knowledge.

1.5 Justification

Traditional medicine is an important aspect of people's culture. According to statistics from WHO, 80% of the world population uses traditional medicine.

Of late, herbal medicine has become very popular with the Kenyan public. This is evidenced in the many herbal medicine clinics that have been opened as well as the many advertisements on the media calling for people to visit the clinics for treatment in such clinics. The fact that the government of Kenya has set up a traditional medicine clinic at KEMRI to research on the medicinal value of plants is enough evidence that the government has a lot of interest in herbal medicine. Further still, the government of Kenya recognizes and provides a lot of support to local herbalists. To practice, the government requires herbalists to register with the ministry of culture. A draft bill on regulating traditional knowledge currently awaiting debate in parliament will help protect herbalists' inventions. In addition to this, there are many other organizations interested in traditional medicine. Some of the stakeholders are the National Council Association for Alternative and Complementary Medicine and Research., KEMRI, universities and the National Museum of Kenya.

Qualified herbalists are not many in our country, given that the public relied on conventional medicine until recently when herbal medicine clinics started becoming popular. Herbalists in our country have also not yet exploited ICT.

Fully developed, a tool based on the proposed prototype will be of great value in the current circumstances. It prompts the user to confirm symptoms and in this way the user leads it into identifying the disorder. It then suggests a herbal remedy for the disorder based on the region of residence of the patient or user. Such a system could support herbalists when making decisions during diagnosis and management of disorders. It will also be vital as a tool for training herbalists besides helping preserve traditional medicinal knowledge that could otherwise go with the human expert. It will also facilitate those researching about the medicinal value of plants such as the KEMRI traditional medicine clinic staff.

1.6 Scope

The project involves development of a prototypical expert system that helps identify the disorder or ailment afflicting a patient. The system then goes a head to suggest the plant or herb and preparation to use in managing the disorder, depending on the region of residence.

1.7 Limitations

The constraints of this project include the following:

- Development of the new system is to be completed within seven months
- Due to the researcher's inexperience in some of the software tools to be used during the implementation phase, there are bound to be potential software difficulties which may cause some delay. However, this problem can be overcome by allocating a lot of time for learning purposes.

1.8 Beneficiaries and/or Users of the System

This system can help the following:

- Herbalists curious to know what plants fellow herbalists in other regions use to treat a disease of interest.
- Trainee herbalists, who may use the system as a training tool.
- Pharmaceuticals keen to identify candidate plants and herbs from which compounds can be extracted and studied in an effort to develop new medicine.
- Botany students curious to know about the use of various plants.
- Doctors, who may want to know how herbalists handle a disease of interest.

1.9 Organization of the Report

Chapter 2 of this report provides a general note on alternative medicine. It goes on to examine how Case Based Reasoning can be applied in diagnosis. It also provides an overview of Expert Systems, besides examining development tools with the aim of selecting one suitable for this project. Chapter 3 gives the methodology that was used in developing the project besides identifying system requirements. Chapter 4 deals with knowledge elicitation and explains how domain knowledge was acquired. Chapter 5 deals with the design of the system and gives a tree structure of the disease identification process. Chapter 6 deals with system implementation and describes what the researcher did via rule generation, debugging and evaluation. Last but not least, chapter 7 gives achievements, recommendations, challenges and potential areas for further work.

Questionnaires that were used to collect data, sample data, sample code or rules, user manual, illustrative consultation session and evaluation data have been included in this project report as appendices.

2

LITERATURE REVIEW

2.1 Introduction

This chapter examines the place of alternative medicine in society, Kenya in particular. It thereafter, explores the various aspects of the area of Expert Systems in Computer Science. Issues like what exactly an expert system is, how it works and resources required to build one are discussed. It goes ahead to examine how Case Based reasoning can be used in diagnosis. In addition to this, a preliminary study of one AI programming language and three Expert System Shells is presented. The purpose of this study and discussion was to select an approach and tool for development of the expert system for the current project.

2.2 Alternative Medicine

Traditional or Alternative medicine is an important aspect of people's culture.

Statistics from the World Health Organization show that 3.5 billion people use traditional medicine. In Africa, 80 per cent of the population use traditional medicine. In an Australian medical journal published a few years ago, Edzard Ernst wrote that "about half the general population in developed countries use complementary and alternative medicine." A survey released in May 2004 by the National Centre for Complementary and Alternative Medicine, which is part of the National Institute of Health in the United States, found that in 2002, 36 per cent of Americans used some form of alternative therapy in the previous year and 50 per cent in a lifetime. This survey included yoga, meditation, herbal treatments and the Atkins diet. Twenty five per cent of the people researched said that they had used alternative medicine because a medical professional suggested it. Growing research indicates that the popularity of complementary and integrative medicine in the United States has increased dramatically in recent years.

Studies by David Eisenberg, director, Centre for Alternative Medicine Research and Education at Beth Israel Deaconess Medical Centre and associate professor of medicine at HMS has documented that 42 percent of adults in the US routinely use complementary medical therapies to treat their most common medical conditions.

There has been a drastic improvement on acceptance of alternative medicine in Kenya, where more people are now seeking medical help from herbalists. Most of the people fall back on the herbalists after conventional medicine fails to work. This observation was made by Professor Julius Mwangi, co-coordinator intellectual property at the University of Nairobi. He also observed that the use of nutrition to heal certain ailments is considered as alternative medicine. Nutritionists in the recent past have been in the forefront campaigning for proper dieting with much emphasis on nutrients such as carrot juice, which is believed to reduce the risk levels for osteoporosis, a disease that decreases bone density.

According to Prof Mwangi, the biggest challenge facing herbalists is how to standardize their prescriptions. Most herbalists prescribe to their patients a handful of a particular substance, or ask them to take so much of a certain concoction. Another question that has always begged an answer especially from the conventional medical fraternity is how sure the herbalists are of the quality and safety of the medicine they dispense. Many have also shied away from traditional medicine because of poor packaging. Just how does one take home a jerry can full of a hideous looking concoction.

Prof. Mwangi said that he had learnt a lot in an educational trip to China. He observed that the Chinese were quite advanced in the practice of traditional medicine and that they had even invented injections for traditional medicine.

A major milestone for herbalists in Kenya was achieved with the formation of a committee to draft a policy on traditional medicine and medicinal plants a few years ago. The justification of the draft policy is that close to 70 per cent of Kenyans use traditional medicine. The major recommendation made in the national policy on traditional medicine and medicinal plants was the integration of traditional medicine, medical plants products and practitioners into the commercial sector to enhance income at the individual, community and national level. The policy will enable protection of intellectual property rights of the traditional knowledge and plants as well as protect traditional medical practitioners from bio-piracy.

The country of Kenya is expected to develop a national strategy for promoting and regulating the use of traditional medicine, and providing alternative forms of treatment for the country's poor. The new arrangement will boost research into the use of both traditional knowledge and modern medicines to curb major diseases such as HIV/AIDS and Malaria. It will also encourage the conservation of biological resources from which traditional medicines are drawn.

A few years ago representatives of the ministries of health, agriculture, environment and national planning met in Nairobi with their counterparts from other countries in the Eastern Africa region to discuss ways of incorporating traditional medicine into national health programmes. This meeting was organized by the National Council of Population Development and the US National Institute of Health, and included participants from Uganda, Tanzania, Ethiopia, and Zambia.

Kenya's move to regulate traditional medicine coincides with a draft bill on regulating traditional knowledge currently awaiting debate in parliament. Also, the World Health Organization (WHO) has published guidelines on the proper use of traditional medicines, following increases in reports of adverse effects.

Earlier attempts to regulate the industry, including requiring the registration of traditional healers, have failed as a result of bitter rivalries between conventional doctors and traditional practitioners. Charity Ngilu, Kenya's health minister noted that a multi-sectoral approach could allow health systems to be built that guarantee access to both modern and traditional medicine for more than 80 per cent of the population.

Peter Eriki, the WHO representative in Kenya, observed that one of the priorities of the organization's Africa office is to advise on the development of policies, legal frameworks, and the local production of traditional medicine. He said that because the majority of the African population depends on traditional medicine in one way or another, there is a need to involve authorities responsible for conserving natural resources.

Eriki observed that the recent surge of public interest in the use of plants as medicine has been based on the assumption that the plants will be available on a continuing basis. However, today many medicinal plants face extinction, but detailed information is lacking. A former environment minister of Kenya, Newton Kulundu suggested that increased research into developing traditional medicines for the poor could be used to encourage communities to conserve biological diversity. He emphasized the need to preserve one of the most endangered tree species, *Prunus Africana,* whose bark contains medicinal compounds. Kenya has already banned the tree's export in order to protect it.

The foregoing literature shows that the whole world recognizes the importance of herbal medicine. It is also clear that the government of Kenya has a lot of interest in this area. It has even set up a traditional medicine clinic in KEMRI and requires one to register with the ministry of Culture to be allowed to practice in Kenya as a herbalist. Many local institutions such as the UoN also have interest in this area to the extent of having certification for herbalists in the Faculty of Pharmacy.

2.3 Expert Systems Overview

2.3.1 What is an Expert System?

It was believed that problems such as theorem proving, speech and pattern recognition, game playing and highly complex deterministic, and stochastic systems can only be tackled by human beings because their formulations and solutions require human abilities like thinking, observing, memorizing and learning. However, intensive research since the 1960's has shown that these problems can be formulated and solved by machines. The broad area of Computer Science that deals with these types of problems is referred to as

Artificial Intelligence (AI). The sub-areas of AI concerned are Pattern Recognition, Neural Networks, Automatic Theorem Proving, Automatic Game Playing and Natural Language Processing.

Expert Systems make another sub-area of AI. Several definitions of Expert Systems are found in literature. A few example definitions of expert systems follow.

- "A computer program that represents and reasons with knowledge of some specialist subject with a view to solving problems or giving advice." – Jackson M.
- "An intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solutions." – Edward Feigenbaum.
- "A system that uses human knowledge captured in a computer to solve problems that ordinarily require human expertise." – Efraim Turban and Jay Aronson.

Generally, these definitions consider *an expert system to be a computer system (hardware and software) that simulates human experts in a given area of specialization.* An expert system should be able to process and memorize information, learn and reason in both deterministic and uncertain situations, communicate with humans and/or other expert systems, make appropriate decisions and explain why these decisions have been made.

Expert Systems developed from a branch of computer science known as Artificial Intelligence (AI). AI is primarily concerned with knowledge representation, problem solving, learning, robotics, and the development of computers that can speak and understand humanlike languages. An expert system is a computer program that uses knowledge and reference procedures to solve problems that are difficult enough to require significant human expertise for their solution. Simply stated, expert systems are computer programs designed to mimic the thought and reasoning processes of a human expert.

Expert systems can be developed for many kinds of applications involving diagnosis, prediction, consultation, information retrieval, control, planning, interpretation and instruction. However, diagnosis still remains the primary application of expert systems, particularly for personal computers. They are used in applications where procedures or algorithms for the problem do not exist or are poorly defined, but good rules of thumb or heuristics are available. Although the use of expert systems is still limited and their primary function is as a tool for human experts, expert systems are rapidly being accepted for use by the non-expert to solve problems when human expertise is expensive, untimely or unavailable. Today, better development tools are available and closer interdisciplinary cooperation is resulting in researchers gaining more insight into the theory and concepts necessary to build effective systems.

Several notable expert systems have been developed. For example, CALEX is an expert system which was developed for the diagnosis of peach and nectarine disorders by the University of California in 1989. Like most expert systems, CALEX is rule-based and uses certainty factors, so that the knowledge-base consists of production rules in the form of IF - THEN statements. The inference engine pieces together chains of rules in an attempt to reach a conclusion. The knowledge base of the CALEX or Peaches diagnostic system contains approximately 600 rules for the diagnosis of 120 disorders of peaches and nectarines, representing most of the disorders in California. CITPATH, a computerized diagnostic key and information system, was developed to identify five major fungal diseases of citrus foliage and fruit in Florida in 1995. CITPATH also utilizes a rule-based approach which provides hypertext-linked descriptions and graphic displays of symptoms with reference to chemical control methods.

The Penn State Apple Orchard Consultant (PSAOC) is an example of another type of expert system which demonstrated the advantage of using specialists from different areas to develop large integrated modules. Horticultural applications that were developed include modules for weed control, foliar analysis interpretation, trickle irrigation scheduling and visual diagnosis of nutrient deficiencies. VITIS, a grape disease management expert system was also developed in a similar manner with specialists from

Pennsylvania, New York, Ohio, and Michigan working in cooperation. The VITIS model was also used as a model for AustVit, an Australian viticultural management expert system. AustVit uses the same logic in the approach to decisions and integrates viticultural, entomological, and plant pathological decision making to arrive at an integrated recommendation. Several other notable prototype expert systems with applications in agriculture were also developed but few were released commercially.

One other specific old example expert system is PROSPECTOR, which was designed by SRI International in association with the United States Geological Survey to assist geologists during mineral exploration work.

In the area of medicine, there has been limited research with regard to the application of expert systems. A specific example expert system in this area is DENDRAL, which was developed by Ed Feigenberg of Stanford University and acted as a chemist's assistant in interpreting data from mass spectrography.

Another specific example expert system in the area of medicine is MYCIN, which was also designed at Stanford University in the USA to deal with problems in the treatment and diagnosis of infectious diseases. This system contains a large knowledge base that contains facts and rules about the forms and causes of infectious diseases and can therefore, be used to aid the clinician in diagnosis.

2.3.2 How It Works

A closer look at the various components of an Expert System will help one understand how the system works. Figure 2.1 shows the various components of a typical expert system and the following paragraphs explain the functionality of each of the components.

The human experts provide the domain knowledge to the knowledge engineers. This may require the human experts to rethink, reorganize and restructure their own knowledge so as to provide it to the engineers in an ordered, well-defined and well-explained way. Often published literature can also act as a source of knowledge. In some cases, databases acquired from human experts, users and published herbal medicine materials can play the role of the human experts.

Whatever the source, knowledge engineers or a Learning Subsystem translate this knowledge into a language that the expert system understands. This knowledge representation language consists of structures such as logic, rules, semantic nets and frames or combinations of these structures. The computer memory space where knowledge is stored in this fashion is known as the knowledge base.

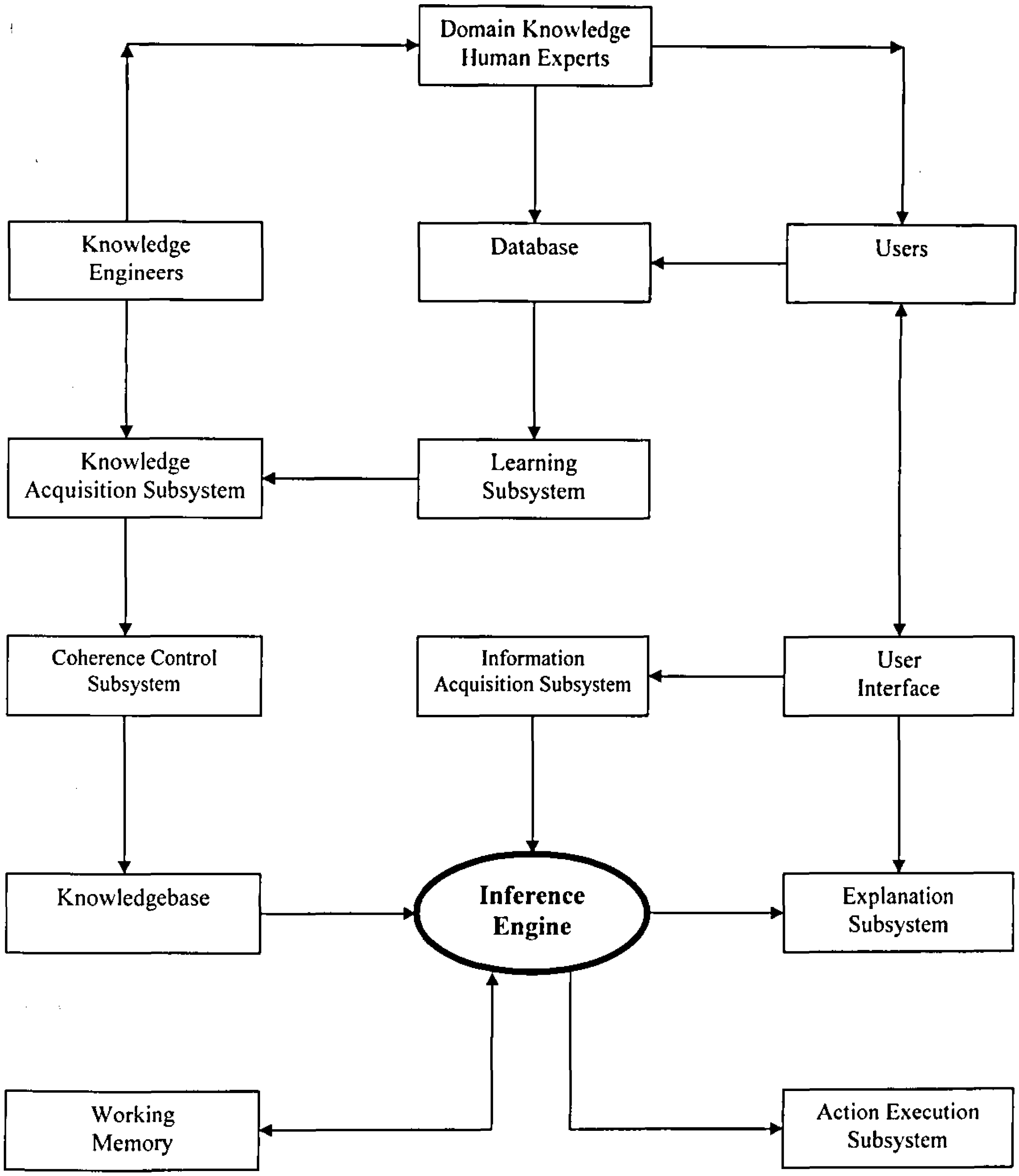


Figure 2. 1: Typical Components of an Expert System. (arrows show information flow)

The Knowledge Acquisition Subsystem and the coherence Control Subsystem help maintain Consistency and Coherence of the knowledge base.

The Inference Engine is the heart of the expert system. The main purpose of this component is to draw conclusions by applying the abstract knowledge. It contains strategies for controlling the selection and application of knowledge to draw conclusions.

Abstract knowledge consists of a set of objects and a set of rules that governs the relationships among the objects. Abstract knowledge is stored in a knowledge base and is static and permanent in nature. It does not change from one application to another. On the other hand, concrete knowledge is the evidence or the facts that are known or given in a particular situation. This type of knowledge is dynamic and changes from one application to another.

The Information Acquisition Subsystem provides the concrete knowledge to the Inference Engine. In addition, if the initial knowledge is limited and conclusions cannot be reached, the Inference Engine utilizes the Information Acquisition Subsystem in order to obtain the required knowledge and resume the inference process until conclusions can be reached. Often, the user interactively provides this information through the User Interface Subsystem. This also checks the validity of the user's entry.

The Action Execution Subsystem is the component that enables the Expert System to perform physical action and is available in situations where the Expert System is the controlling module of a system that does some physical activities.

When the user demands an explanation of the conclusions drawn, the Explanation Subsystem explains the process followed by the Inference Engine or the Action Execution Subsystem.

2.4 Approach to the Solution

The researcher considered two approaches to solving the current problem. The first approach is the rule-based approach where knowledge is encoded in classical IF – THEN rules (Appendix G). In the second approach known as Case-Based reasoning, knowledge is encoded in a library of past cases. Based on the data available, the researcher settled on using the purely rule-based approach, which is fairly simpler in the current project as opposed to the use of case-based reasoning or a combination of the two approaches.

2.5 The Case Based Reasoning Approach

2.5.1 Introduction

By Case-based reasoning (CBR), we refer to a cognitive and computational model of reasoning by analogy to past cases. The underlying idea in the use of past cases is the assumption that similar problems have similar solutions. Though this assumption is not always true, it holds for many practical domains. A basic premise in CBR is that many problems that decision makers encounter are not unique, but rather they are variations of other problems.

The CBR paradigm is different from other AI approaches. Traditional AI approaches rely on general knowledge of a problem domain, and tend to solve problems on a first principle. CBR systems solve new problems by utilizing specific knowledge encoded in a case base of past experience. This is similar to the way human beings solve problems in that they generally use what they know in solving a new problem.

For example, an auto mechanic who fixes an engine by recalling another car that exhibited similar symptoms uses case-based reasoning. Case-based reasoning is a prominent kind of analogy making. Similarly, doctors usually diagnose and prescribe on the basis of past cases personally experienced thus applying Case-based reasoning.

In case-based reasoning (CBR) systems expertise is embodied in a library of past cases, rather than being encoded in classical rules. Each case typically contains a description of the problem, plus a solution.

To solve a new problem, it is matched against the cases in the case base, and similar cases are retrieved. The retrieved cases are used to suggest a solution which is reused and tested for success. If necessary, the solution is then revised. Finally the current problem and the final solution are retained as part of a new case.

Case-based reasoning is liked by many people because they feel happier with examples rather than conclusions separated from their context. A case library can also be a powerful corporate resource, allowing everyone in an organization to tap into the corporate case library when handling a new problem.

2.5.2 The CBR Cycle

Aamodt and Plaza (1994) described CBR typically as a cyclical process comprising the four REs:

- REtrieve the most similar cases;
- REuse the cases to attempt to solve the problem;
- REvise the proposed solution if necessary; and
- REtain the new solution as a part of a new case.

A new problem is matched against cases in the case base and one or more similar cases are *retrieved.* A solution suggested by the matching cases is then *reused* and tested for success. Unless the retrieved case is a close match, the solution is *revised* to produce a new case that can be *retained.*

The CBR cycle starts with the description of the new problem to be solved. During the REtrieval process, the system first identifies the features of the problem by processing the input descriptors and trying to understand the problem. When a set of best matching cases is found, the system applies similarity metrics to assess the degree of similarity of the cases found and the new case submitted. Finally the best matching case is selected and retrieved with its relevant solution. Often, when a case is REused, an adaptation process is required to take account of the difference and readapt the solution of the retrieved case to the new case. The system, then REvises or evaluates the case solution generated by Reuse in the real environment (outside the CBR cycle) and then, if successful, it learns from the success (case REtainment).

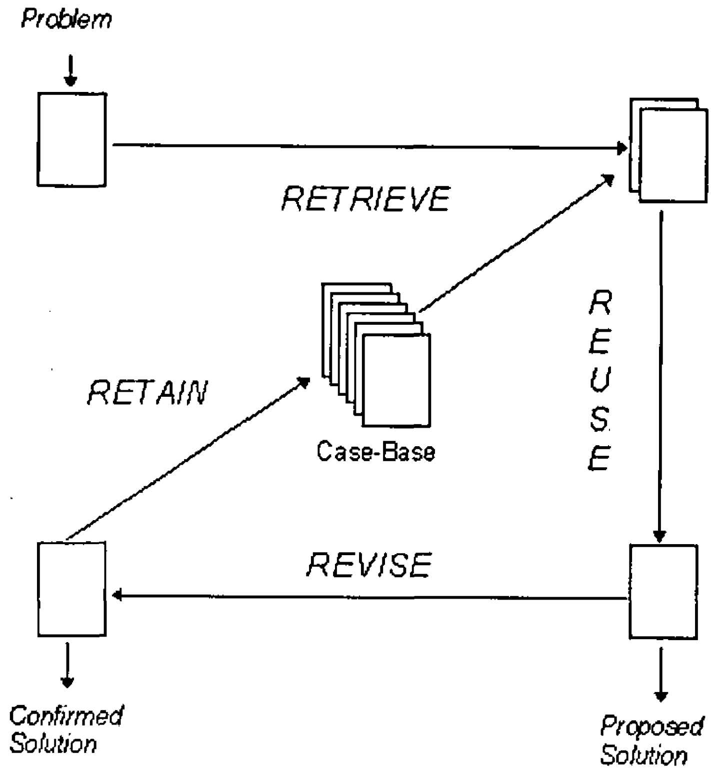


Figure 2. 2: The CBR Cycle

2.5.3 Suitability for the CBR Approach

Some of the characteristics of a domain that indicate that a CBR approach might be suitable include:

- records of previously solved problems exist;
- historical cases are viewed as an asset which ought to be preserved;
- remembering previous experiences is useful;
- specialists talk about their domain by giving examples;
- experience is at least as valuable as textbook knowledge.

Case-based reasoning is often used where experts find it hard to articulate their thought processes when solving problems. This is because knowledge acquisition for a classical KBS would be extremely difficult in such domains, and is likely to produce incomplete or inaccurate results. When using case-based reasoning, the need for knowledge acquisition can be limited to establishing how to characterize cases.

Case-based reasoning allows the case-base to be developed incrementally, while maintenance of the case library is relatively easy and can be carried out by domain experts.

In medicine, the knowledge of experts does not only consist of rules, but of a mixture of textbook knowledge and experience. The latter consists of cases, typical and exceptional ones, and the reasoning of physicians takes them into account. In medical knowledge based systems there are two sorts of knowledge, objective knowledge, which can be found in textbooks, and subjective knowledge, which is limited in space and time and changes frequently.

The problem of updating the changeable subjective knowledge can partly be solved by incrementally incorporating new up-to-date cases. Both sorts of knowledge can be clearly separated; objective textbook knowledge can be represented in form of rules or functions, while, subjective knowledge is contained in cases.

The arguments for case-oriented methods are as follows:

- Reasoning with cases corresponds with the decision making process of physicians.
- Incorporating new cases means automatically updating parts of the changeable knowledge.
- Objective and subjective knowledge can be clearly separated.
- As cases are routinely stored, integration into clinic communication systems is easy.

2.5.4 Example Medical Case-Based Reasoning Systems

In medicine, CBR has mainly been applied for diagnostic and partly for therapeutic tasks. One of the earliest medical expert systems that use CBR techniques is CASEY. It deals with heart failure diagnosis. The system uses three steps: A search for similar cases, a determination process concerning differences and their evidences between a current and a similar case, and a transfer of the diagnosis of the similar to the current case or if the differences between both cases are too important - an attempt to explain and modify the diagnosis. If no similar case can be found or if all modification attempts fail, CASEY uses a rule-based domain theory. The most interesting aspect of CASEY is the ambitious attempt to solve the adaptation task by general adaptation operators. However, as many features have to be considered in the heart failure domain and as consequently many differences between cases can occur, not all differences between former similar and current cases can be handled by the developed general adaptation operators.

The second expert system that uses CBR techniques is FLORENCE. It deals with health care planning. It handles the three basic planning tasks of diagnosis, prognosis and prescription.

Diagnosis is not used in the common medical sense as the identification of a disease, but it seeks to answer the question: "What is the current health status of this patient?" Rules concerning weighted health indicators are applied. The health status is determined as the score of the indicator weights.

Prognosis seeks to answer the question: "How may the health status of this patient change in the future?" Here, a Case-based approach is used. The current patient is compared to a similar previous patient for whom the progression of the health status is known. Similar patients are searched for first, concerning the overall status and subsequently concerning the individual health indicators. Since, further development of a patient not only depends on his situation (current health status, basic and present diseases), but additionally on further treatments, several individual projections for different treatments are generated. Prescription seeks to answer the question: "How can the health status of this patient be improved?" The answer is given by utilizing general knowledge about likely effects of treatments besides considering the outcome of using particular treatments in similar patients. That means it is a combination of a rule-based and a case-based approach.

2.6 Survey of Expert System Tools

Expert Systems can be developed using an AI language or an Expert System Shell. An AI language is a programming language that can be used to develop of artificial intelligence applications and expert systems. An Expert System Shell can be considered an expert system without a knowledge base. A survey of easily available Expert System tools was carried out. A large number of tools for development of expert systems are available on the market. However, the researcher was only able to examine the AI language Swi Prolog and three expert system shells.

2.6.1 AI Languages

Swi Prolog

Details about Swi Prolog are available at website http://www.swi-prolog.org. Generally, Prolog is a programming language used in development of expert systems. It is a declarative language that uses deductive reasoning to solve programming problems when given the necessary rules and facts.

Advantages of Swi Prolog are:

- It has built-in list handling capabilities that are very useful for representing sequences, trees, and so on.
- It is easy to build tables and databases while a program is running.

Disadvantages of Swi Prolog are:

- Predicates can become cumbersome because it lacks functional notation.
- There are some features which have not been standardized, and differ between implementations. For example, formatted input and output, file handling and sorting predicates.

2.6.2 Expert System Shells

Java Expert System Shell

The details of JESS (Java Expert System Shell) are available at the website http://herzberg.ca.sandia.gov/jess. It is a rule engine and scripting environment written entirely in Sun's Java language by Ernest Friedman-Hill at Sandia National Laboratories in Livamore, CA. jess was originally inspired by the CLIPS expert system shell, but has grown into a complete, distinct Java-influenced environment of its own. Using Jess, you can build Java applets and applications that have the capacity to "reason" using knowledge you supply in the form of declarative rules.

Advantages of Jess are:

- Source Code is available free of charge.
- It is platform-independent.
- It can be integrated with user codes.

Disadvantages of Jess are:

- Only limited documentation, help-file and user-forums are available.
- Graphical Interface will have to be created in Java by the user.

Expert Master

Details of XMaster are available at the website http://www.chrisnaylor.co.uk. It is an easy –to-use expert system shell for Windows developed and marketed by Chris Naylor Research Limited of UK. XMaster consists of two basic packages: XMaster Developer and XMaster User. Xmaster Developer is used to create an expert system. XMaster User is used to consult an expert system that has previously been created with XMaster Developer. It has an interactive graphical user interface for developing Expert Systems.

Advantages of XMaster are:

- It has very good documentation
- It has a very good Graphical Interface

Disadvantages of XMaster are:

- It is not freely downloadable from the web and hence it.
- The source code is hidden and hence, it may not require a lot of time for procurement.
- It is platform specific and runs only on Windows.

Crystal

CRYSTAL is a rule-based expert system shell marketed by Intelligent Environments. It is a PC based product in which knowledge is represented by rules. Commands can be integrated with rules to carry out a variety of functions including assigning variables and testing them, displaying forms, menus and explanatory text, and controlling the processing of rules. Command words within the language are provided from the menu or, in some cases, merely by moving the cursor position. This frees the programmer from having to type in the words every time.

Advantages of CRYSTAL are:

- It is very user-friendly and easy to learn.
- It is designed for users who have had minimal experience with expert systems.
- It has a simple and very good user interface.

Disadvantages of CRYSTAL are:

- It is not freely downloadable from the web and hence it.
- The source code is hidden and hence, it may not require a lot of time for procurement.
- Only limited documentation is available.

2.7 Proposed Herbalist Diagnostic Support System Architecture

The Herbalist Diagnosis Support System was implemented on a Personal Computer (PC). However, to make the system available to a bigger number of people or users, the expert system may need to be implemented on a network.

The theoretical design or architecture of the proposed system is shown in figure 2.3 that follows.

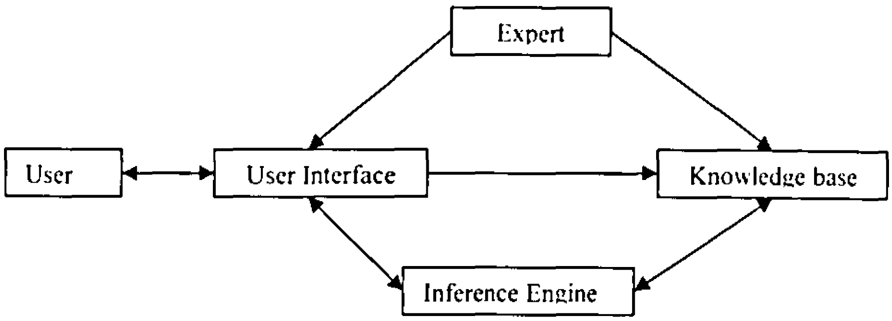


Figure 2. 3: Proposed System Architecture

The user interface is used to gather symptoms and region of residence from the user. It then sends this information to the inference engine. For its part, the inference engine matches the symptoms and region of residence provided with those in the knowledge base. If a match is found, the associated disorder and corresponding treatment advice is given to the user through the user interface. If a match is not found, it gives appropriate response again through the user interface.

2.8 Conclusion

From the foregoing discussion, the researcher settled on the CRYSTAL shell as the tool to use for the current project, because the researcher found it fairly simple to use, besides allowing the developer to present a lot of information to the user. The researcher also considers it a good idea to try to apply CBR to the current problem. A case-based diagnosis system could be used to retrieve past cases whose symptom lists are similar to that of the new case and thereafter, suggest diagnoses based on the best matching retrieved case. The idea of using herbal medicine for disorder management could be brought in at the final stage as the solution. Perhaps the outcome could then be compared to the outcome of the classical rule based approach the researcher used in the current project.

3

METHODOLOGY

3.1 Introduction

The scope of this project will be limited to disorder identification and suggestion of a herbal remedy. A Computer System that can assist users in deciding on the herbal drug to manage the disease or disorder is foreseen. The detailed system requirements have been presented in section 3.2 below. A project plan has been prepared in an attempt to build a computer system that satisfies these requirements. With sufficient data, it is possible to come up with a good system that can support herbalists in the management of disorders/diseases using herbal medicine. The system will also serve very well as a research tool in aiding people researching on the medicinal value of plants.

3.2 System Requirements

One of the objectives of this project is to define and/or specify a computer system that has been envisioned to store and utilize expertise to help select the best herbal medicine for a given disorder or disease depending on the region. With this objective in mind, a detailed System Requirement Document has been prepared. A requirement analysis and the resulting Requirement Document is very crucial for any software development project. The first and foremost reason for such a document is to document the problem at hand. It is also important for accomplishing the project within the limited time and resources. The problem at hand is to materialize an envisioned system. In this requirement document, only the functional requirements of the final system envisioned have been depicted. To build the system can be called the long-term ultimate goal of this project. However, the works of this project will be limited to accomplishing a small part of this bigger project.

The Computer System that is foreseen has many challenging requirements. The system must act as an expert who can answer relevant questions, explain the method of diagnosis used to identify the disease and determine or suggest the best herbal treatment. Broadly, these requirements can be stated as follows:

- To help users understand the disease afflicting them by referring to relevant literature and other materials from relevant professionals.
- To suggest measures to treat the disorder.
- To explain its own suggestions.

Detailed explanations of these requirements are presented in the next three sections.

Requirement 1

With the initiative of the user, the system will explain the process of identification of diseases by examining symptoms.

Requirement 2

The user will be prompted a few basic questions. The system will analyze the answers and attempt to assess the situation using its extensive knowledge base. Once it gets sufficient information, it will provide the identified disorder and suggest treatment if successful or give a failure message if not.

Requirement 3

On reaching a conclusion, the system should be able to explain how that conclusion is reached.

3.3 The Project Work

First, an initial literature survey of documents, books and other materials related to diseases was undertaken. Apart from theoretical aspects of the subject, the researcher interviewed herbalists, doctors and medical lab technicians in order to gather the necessary data. The questionnaires used are included in the report as appendices A and C. The information gathered was analyzed to pick out relevant details. In a separate effort, attempts were made to understand the details of an expert system and the resources required to build one. The details of this effort are presented in chapter 2. With the help of the above information, a feasibility study was carried out to investigate the hurdles of creating the proposed system and the ways to mitigate them. This study revealed that the available resources are not adequate to construct the knowledge base module of the expert system. Steps were taken to make up for this shortcoming by emphasizing on acquiring more structured knowledge. In an effort to construct the knowledge base, a survey of available tools was carried out. The result of this survey is presented in section 2.6. Within the time frame of this project, only a prototype of the expert system could be achieved. The approach taken in developing this project was the standard systems development methodology (KADS), which consists of four phases namely Knowledge Elicitation, Design, Implementation and Documentation.

3.5 General Procedure for Development of ES

Whether one uses an ES or an AI language, there are certain basic steps to go through when developing an Expert System. As we discuss these steps, it may be good to note this project will be implemented using the Crystal Shell.

Knowledge Acquisition

Knowledge acquisition is a time consuming process in which the knowledge engineer works alongside the participating expert and extracts, structures and organizes the information to be represented in the expert system. Knowledge acquisition requires no standard methodology for extracting knowledge. However, it usually involves a progressive number of personal interviews of the expert(s) to record information pertinent to the knowledge-base. Occasionally, the role of the knowledge engineer can be significantly reduced if the understanding of the development processes by the participating experts are substantial and they are willing, able to organize and express all the necessary information into facts or rules based on their personal heuristics.

Consistency in the naming conventions of facts or rules is vital, and the ability to develop a language which is familiar to the end users is also important. Acquired knowledge should be played back to experts, perhaps using a different medium than the one used to acquire it. During the knowledge acquisition phase, the knowledge engineer should identify the conclusions that the expert system should render and verify this knowledge as it is acquired. Knowledge acquisition should also be supplemented with a thorough review of current literature to provide the most available up-to-date information.

Knowledge Representation

After the domain has been identified and knowledge acquired from a participating expert, a model for representing the knowledge must be developed. Numerous techniques for handling information in the knowledge-base are available; however, most expert systems utilize rule-based approaches. The knowledge engineer, working with the expert, must try to define the best structure possible. Other commonly used approaches include decision trees, blackboard systems and object oriented programming.

Verification

Prior to testing an expert system with outside experts, every query response which should lead to a correct conclusion or diagnosis should be systematically verified with the knowledge-base. This procedure can be accomplished without the assistance of the participating expert and is essential to ensure that the expert system provides credible diagnosis in all cases. The knowledge-base should be adjusted to eliminate any identified conflicts or problems. Expert systems which utilize visual images to support text should also be verified to ensure each image correctly corresponds to the specific symptom described.

Validation

Validation should be done by the primary expert who was involved in the systems knowledge base development and knowledge representation. This phase provides the expert with the opportunity to explore the functioning expert system and make suggestions for changes in the interface design, image database or knowledge-base. Generally, the system should be challenged by the expert by presenting contrived problems or queries based on past field experience. Again, the system should be adjusted to eliminate any conflicts or design problems.

Validation provides the final opportunity to evaluate an expert system prior to testing by additional experts or other identified end users. The primary purpose of validation is to have the expert concede to the development of a credible prototype which provides a reasonably accurate diagnostic ability. Although validation is an essential phase to expert system development, problems of access to expert assistance, time and resource constraints can often make validation procedures impractical or limited.

Testing Expert Systems

When the knowledge engineer and the expert are satisfied that the expert system is complete, the system should be tested against an agreed upon performance criteria. At this time other experts can be invited to evaluate and use the system for testing purposes. Either real-world case scenarios or simulated cases can be used for testing purposes. Once the system has been adequately tested and found to meet a defined level of accuracy, efficiency and reliability, a final version can be prepared for distribution and use. However, in the event the system does not perform adequately, further verification or validation and field testing may be necessary before making a final version of the system available to the intended audience.

3.6 Prototyping in KBS Design/Development

Prototyping is an approach to software development that allows the developer to come up with a look alike or prototype version of the system to allow the user to get a feel of the software as early as possible in the process of development. The technique of prototyping is iterative, evolutionary and sometimes exploratory. This approach is illustrated in figure 3.1 that follows.

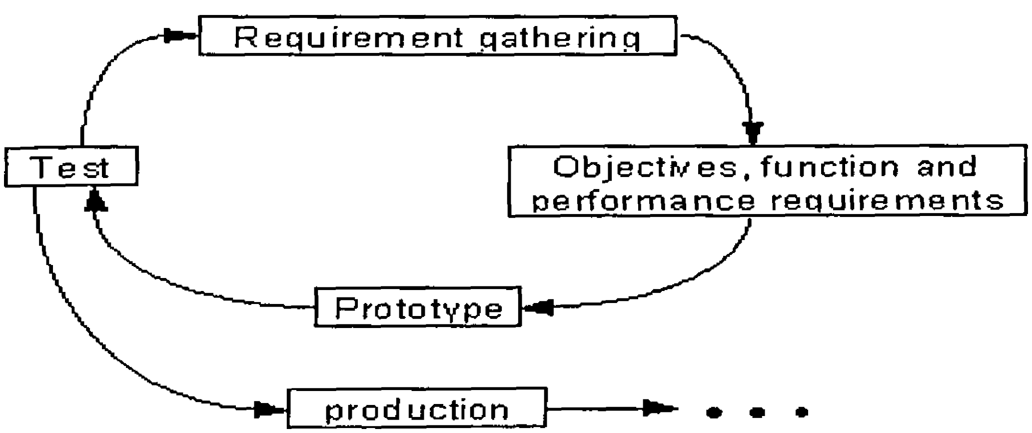


Figure 3. 1: Pictorial Representation of Prototyping

Prototyping has been criticized as being unstructured, lacking control and documentation and as being suitable only for small projects. However, it has become the most popular medium for developing KBS systems. This technique has been so successful in KBS development because knowledge engineering depends, perhaps more than any other form of software development, on the involvement of the users of the system. Another reason is the speed with which you can develop a system when using an expert system shell.

Prototyping also seems to be perfectly suited to the types of problems often encountered in KBS development, where the initial requirements are ill-defined, and the problem itself often ill-structured. In knowledge engineering, the prototype provides a sounding board for management, users and experts alike, and can be important in crystallizing system specifications, user requirements, human/computer interfaces, and the problem domain itself, i.e. exactly what knowledge must be obtained from the expert or experts to allow the system function correctly.

4

KNOWLEDGE ELICITATION

4.1 Introduction

During knowledge elicitation, information necessary for the development of the knowledge base is gathered, recorded and interpreted.

4.2 Information Gathering

In the development of an expert system, it is important to have accurate and detailed knowledge of the domain one wants to represent. It is with this in mind that the developer gathers information greedily. Knowledge bases are crucial components in expert systems, because they are the ones that give the required responses to queries. These knowledge bases should therefore, be researched thoroughly before implementation.

The information gathering phase of this project was divided into two parts. The first part of this phase comprised diagnosis. Here, the researcher gathered symptoms and names of lab tests for the various diseases from doctors and medical lab technicians. The second part of this phase comprised treatment. Here, the researcher gathered details of treatment for the various medicinal plants and or herbs and preparations to be used in managing the different diseases. In both parts of the Knowledge Elicitation phase, two approaches were used i.e., interviews and research.

4.2.1 Part One: Diagnosis

Interviews

Dr. Imbiyoyi of Kakamega General Hospital and Mr. Paul Were of Catholic University, and a few other medical laboratory technicians were interviewed to obtain a list of common diseases and the dominant symptoms that can help identify the diseases. The rich experience of these specialists also assisted the researcher identify diseases that have symptoms similar to those of the identified diseases in case of misdiagnosis, and the lab tests that can be conducted to confirm the ailments. The questionnaire that was administered to collect information from doctors and medical lab technicians is included in this report as Appendix C.

Research

The research involved comprehensive analysis of common diseases from recommended text books, journals and the Internet. A substantial amount of the knowledge base information regarding diseases and corresponding symptoms was obtained from this research.

4.2.2 Part Two: Treatment

Interviews

Three studies were conducted interviewing laypersons and specialist traditional practitioners. Knowledgeable members of the society were chosen with the aid of local community members and local administration. Local community members were requested to identify herbalists in their neighborhood. Twenty respondents were interviewed in the Kamba study and fifteen in South Nyanza. With the help of field research assistants, the researcher was involved in administering questionnaires during in-depth interviews. There were however pre-arranged appointments (like 2–3 days before) with the respondents' through/with the help of local administrators. Clearance to conduct research was obtained from local Government of Kenya administrative offices (chiefs) before the fieldwork started. The questionnaire that was administered to collect information from herbalists is included in this report as Appendix A.

Prior informed consent of informants was sought before questionnaires with both closed and open-ended questions were used to collect survey data. These interviews were conducted in Kiswahili, Kamba and Dholuo languages. Data collection entailed return visits and transect walks in which specimens of the medicinal plants were collected and identified using Agnew and Agnew (1994), Beentje (1994), Knox (1996), and Turill and Milne-Redhead (1952).

Research

The research involved comprehensive analysis of common diseases from text books and journals with orientation towards herbal medicine, and the Internet. A substantial amount of the knowledge base information with regard to diseases and plants or herbs for their management was obtained from this research.

A graphical representation of the information gathering process is shown in figure 3.1 that follows.

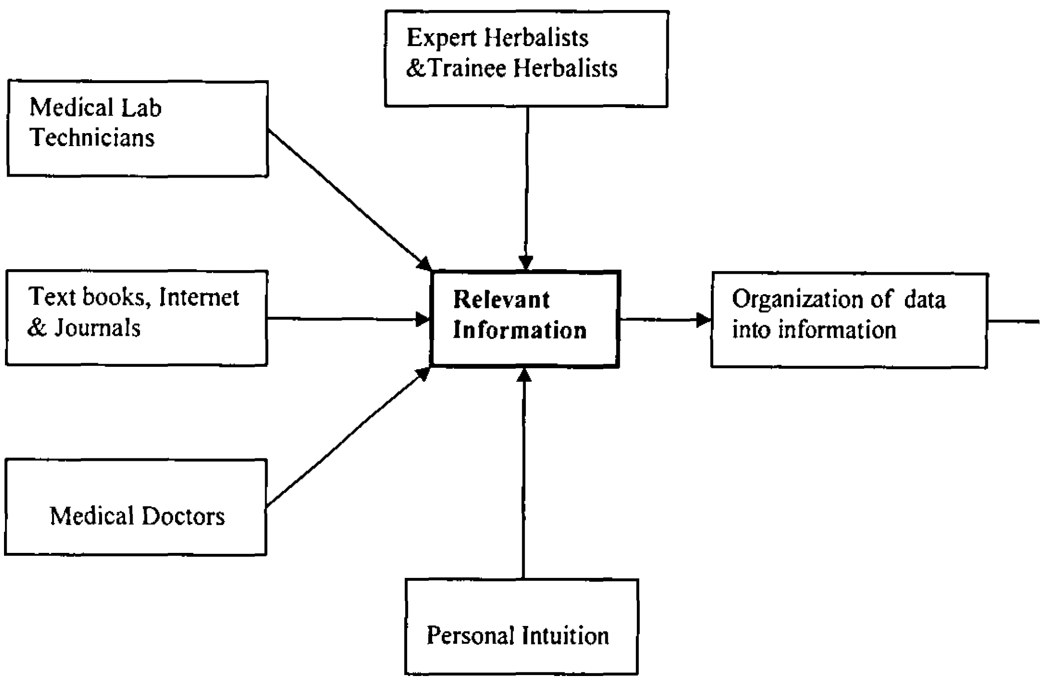


Figure 4. 1: Information Gathering Process

4.3 Organization of Data into Information

After thorough information gathering and compression, the information was carefully examined, judging mostly from heuristics, in order to pick out what would be important for the project. The expert system is aimed at identifying diseases through symptoms and thereafter, advising on the medicinal plant to be used in managing the disease. Characteristics without such value were discarded. After this was done for the different diseases, it was time to develop rules. This development is described in the design phase.

4.4 System Specification

In the software specification stage of any system the goals, objectives, services and constraints of that system are established. This is a crucial stage in the development life cycle because the solution to a problem greatly depends on how well that system has been specified. Responsible system designers must therefore, strive to have accurate requirement specifications before design.

From the information collected as mentioned in section 3.3, a set of function specifications that the system should meet are given to ensure that the functional goal of the system is clear. These functional specifications are mentioned in section 3.2 of chapter 3.

5

HERBALIST DIAGNOSTIC SUPPORT SYSTEM DESIGN

5.1 Introduction

The design phase of any software system development is a critical activity. It determines how well the specification requirements are going to be realized under minimum cost and effort. This system was implemented using the Crystal Shell. This is a specialized software tool used to develop expert systems. It contains the user interface, format to use to capture knowledge into the knowledge base, working memory and an inference engine. It employs backward chaining in its reasoning. Being an identification project, the Crystal Shell was chosen because it gave a more effective system.

Some of the basic features of this shell are indicated on its main menu that is shown below.

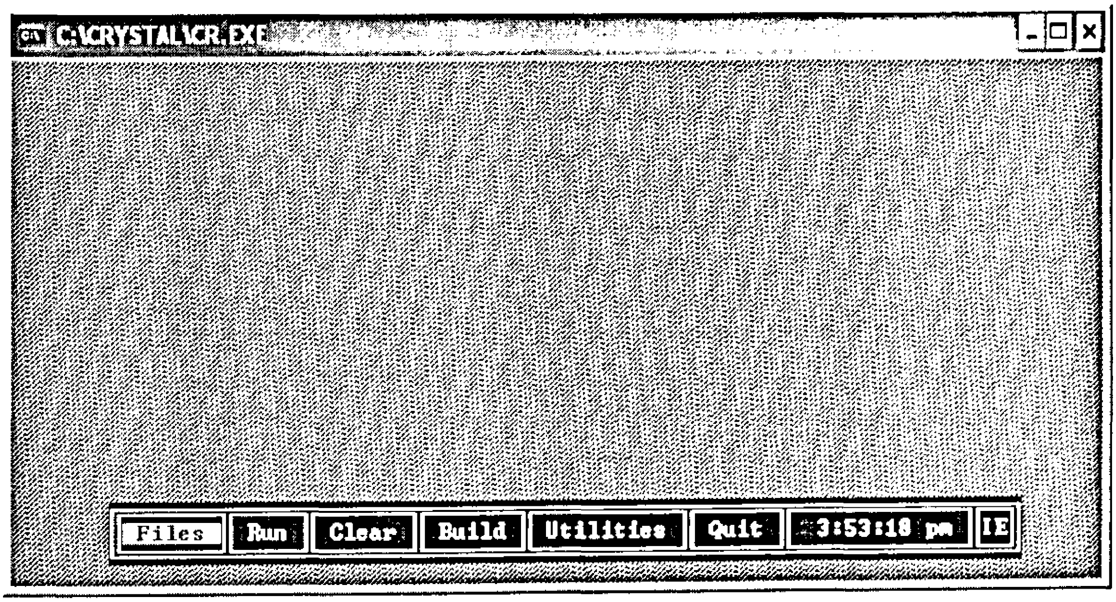


Figure 5. 1: Crystals Main Menu

This menu has several options as described below.

Files – This command is used to load, save and delete the knowledge base as the case may be.

Run – This command is used when the user wants to run or interact with the current or loaded knowledge base.

Clear – This command is used to delete conditions and/or rules when necessary.

Build – This command is used to add, modify or even delete rules from the loaded knowledge base.

Utilities – This command opens a menu with utilities for setting time and date as well as choosing the format to be used in displaying the time and date among other things.

Quit - This is used to quit from Crystal. It may also be invoked by typing 'Q' when at the main menu.

The various other design facilities that Crystal provides and that were employed in this project are discussed below.

5.2 Architectural Design

At this stage, we identify some of the key features of the proposed system and how they relate to each other. The major features include the following:

Inference Engine / Identification Feature

This component enables the user to lead the system into identifying the disorder by confirming symptoms by way of responding to the system prompted questions. It then searches through the knowledge base and settles on a disorder if it is able to identify one. If it fails to identify the disorder, it gives a failure message and advises the user or patient to consult a doctor. Thereafter, it gives the user the option of choosing to repeat the consultation session in order to change the responses given if the user feels that he or she was not accurate or not to if the user was accurate.

If the disorder is identified, the system proceeds to ask for the region of residence. If the residence region is covered, the system advises on the local herb or plant and preparation to use to manage the disorder. Otherwise, it informs the user about the disorder, and then proceeds to advise about the local herb to use and the region where to find it. You may also choose to consult a doctor nearest him or her.

Knowledge Base

This component makes available all the rules that are expected to lead the Identification module to intelligent conclusions.

The Explanation Facility

This feature explains to the user why and how the system would have reached a particular conclusion or why it would be asking a particular question at that particular stage.

The Main Menu

This menu allows the user to interact with the knowledge base. It is from here that we choose the knowledge base to load and run. It is also from here that we choose the 'Build' command if we wanted to modify or add new knowledge into the knowledge base. The main menu can be seen in figure 5.1.

5.3 Abstract Design

The Abstract Design explains the constraints under which the entire system will operate and what is expected of each module.

Identification Feature

This is the major component of the system. It works hand in hand with the knowledge base, where it picks out rules and prompts the user to respond to questions. These questions are derived from the conditions to be met for the rule to succeed. If a condition is not accepted (i.e. answer is no) and it is the first condition in that rule, the whole of that rule is discarded and the alternative rule is picked for verification. If the first condition is accepted (i.e. answer is yes), the querying function is called again with that rule having its first condition omitted. In effect the new rule will have its conditions reduced by one. Consequently, the accepted condition is stored as a fact in regard to that search. The process is repeated until the conditions are exhausted successively to culminate to a conclusion, which is returned as the identified disorder. If the last rule to be verified ends with a hypothesis that is rejected, the system concludes that the disorder could not be identified.

Since the Identification Feature is the main component of the system, other elements the user may require provided for are discussed below.

User Friendly Interaction Provision

As the system prompts a user to respond to questions, a variety of responses need to be expected. These responses include Y for yes, N for no or highlighting an option and pressing the Enter key to select the option as a response.

When the response is 'no', the corresponding rule is abandoned and the next one is picked up. At the same time the rejected condition is stored so that as the system verifies the new rule, the first thing it does is to compare the first condition of the new rule with the rejected conditions. If it is found among rejected conditions, the rule is also rejected and the succeeding one is picked. This process continues until a condition that is not among those rejected is found, in which case, the next question appears on the screen with the new rule. Notice that during successive tests, the mode of operation is not interactive.

If the response is 'yes', the condition is stored and the function is called again with the CMR rule. If at one point a condition is rejected, the next rule will be picked up. Now, the first thing the system does is to check whether any condition or symptom in that rule is among the rejected conditions or symptoms, in which case this will indicate that the new rule is not viable and it will be discarded. Otherwise, the condition will be accepted and subsequent questions based on the remaining conditions will be asked. If a 'no' response is given for the last condition in a rule, and no more conditions are available in that set of conditions, the search is deemed to be unsuccessful and the 'disorder cannot be identified' message will be echoed.

A curious user may be interested in knowing why a particular question has been asked. In such a case, he or she may need to ask 'why' such information is needed by pressing the

F1 key. Once a 'why' is asked, the system picks out the current rule, and responds that it is trying to verify the conclusion of that rule, where the current condition is a member of that rule. After the explanations, the same question is prompted again and the search continues as usual. A graphical representation of these responses is shown in figure 5.2 that follows.

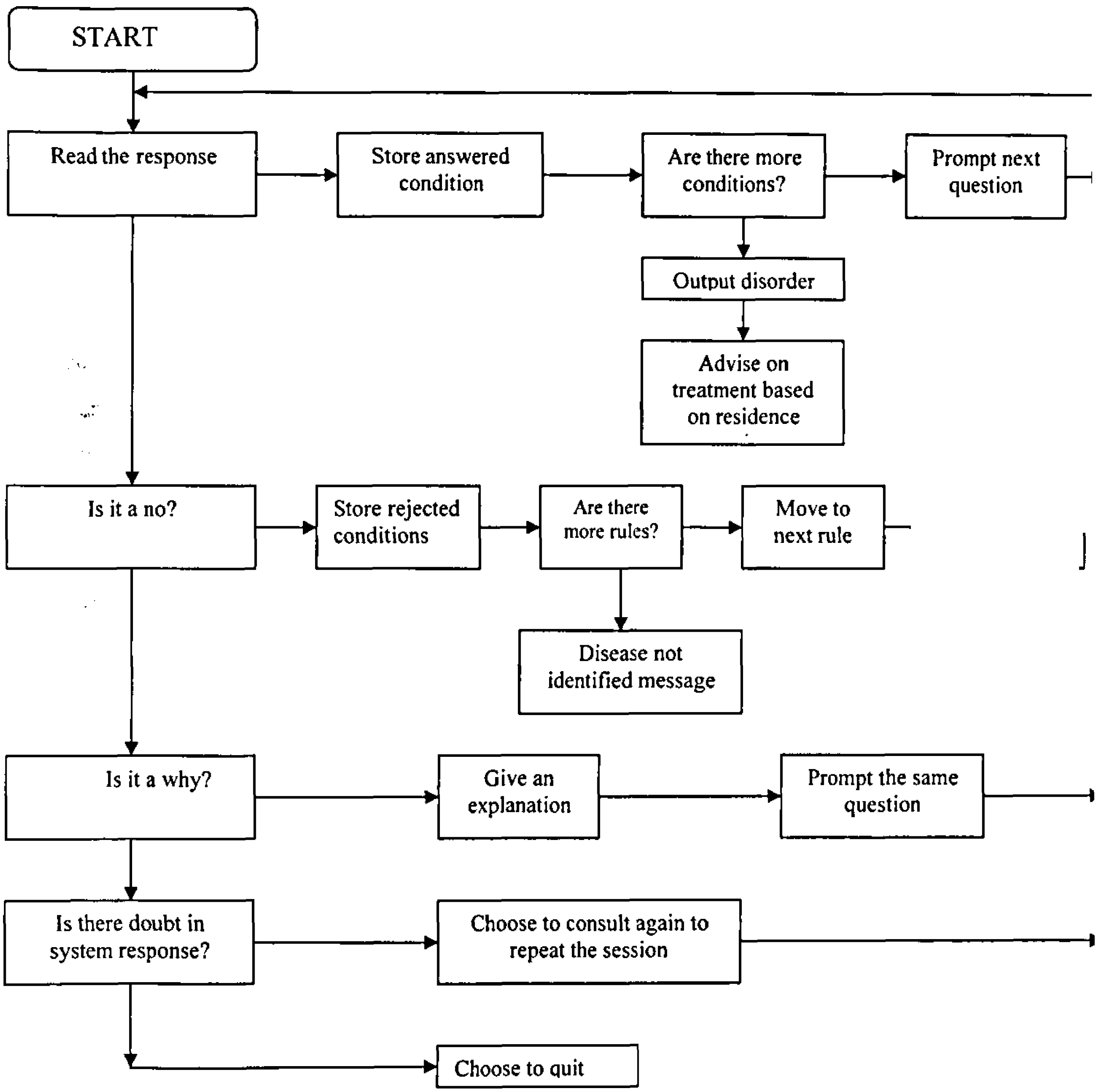


Figure 5. 2: Graphical representation of responses to the system queries

Knowledge Base

This is the body of knowledge that is manipulated to portray expertise in the system. The knowledge base is organized in terms of rules. Each rule has a set of conditions and a conclusion. To enhance the intelligence of the system, successful rules interrelate, in the sense that if a condition has been rejected in the current rule then the opposite of that will be implied in the succeeding rule, if the case applies. For example, if a condition like 'has headache" is rejected, it will be implied in the next rule that the user does not have headache and a condition like "does not have headache" should not be prompted for verification. Further still when a rule is rejected midway, those conditions or symptoms answered in the affirmative are stored so that the user is not prompted to respond to them again even if they appear in the new rule. This really enhances the system as it reduces redundancy in processing.

A tree representation of the disorder identification process is shown below. This represents what we could loosely call a binary search in the sense that at each node there will always be two alternatives, until a leaf is found. This is the underlying design principle for the whole knowledge base. A rule will therefore, consist of only the nodes which have a 'yes' leading to a particular leaf. This leaf becomes the conclusion of that rule. The tree structure for identification of the disorders is shown in figures that follow.

For simplicity, this tree diagram assumes four diseases, i.e., Malaria, Typhoid, Pneumonia and Meningitis. Similar tree diagrams can be obtained when a higher number of diseases are involved. It should therefore, be noted that the branches bearing "Unable to identify disorder" will lead to disorders and only a few will still have the same message when more diseases are captured into the knowledge base.

From the human expert, symptoms to identification the disorder were collected. For the disorder identification process, the collected symptoms were formed into rules, which were fed into the knowledge base. For example, to identify Malaria, the symptoms collected were headache, fever, dizziness, marked pallor and prolonged chills, and those for identifying Typhoid were watery stool at regular intervals, headache, fever, distended painful abdomen and coated tongue. A similar thing goes for other diseases involved. Assuming the two diseases of Malaria and Typhoid, the rules generated from the symptoms would be as follows.

(checking for Malaria)
if headache
  and fever
  and dizziness
  and marked pallor
  and prolonged chills

  then Malaria

else

  (check for Typhoid)
  if watery stool at regular intervals
    and headache
    and fever
    and distended painful abdomen
    and coated tongue

   then Typhoid

else
   (check for the next disorder)

else
   (check for the next disorder)

else
   (check for the next disorder)

else
   (give failure message)
   unable to identify disorder.

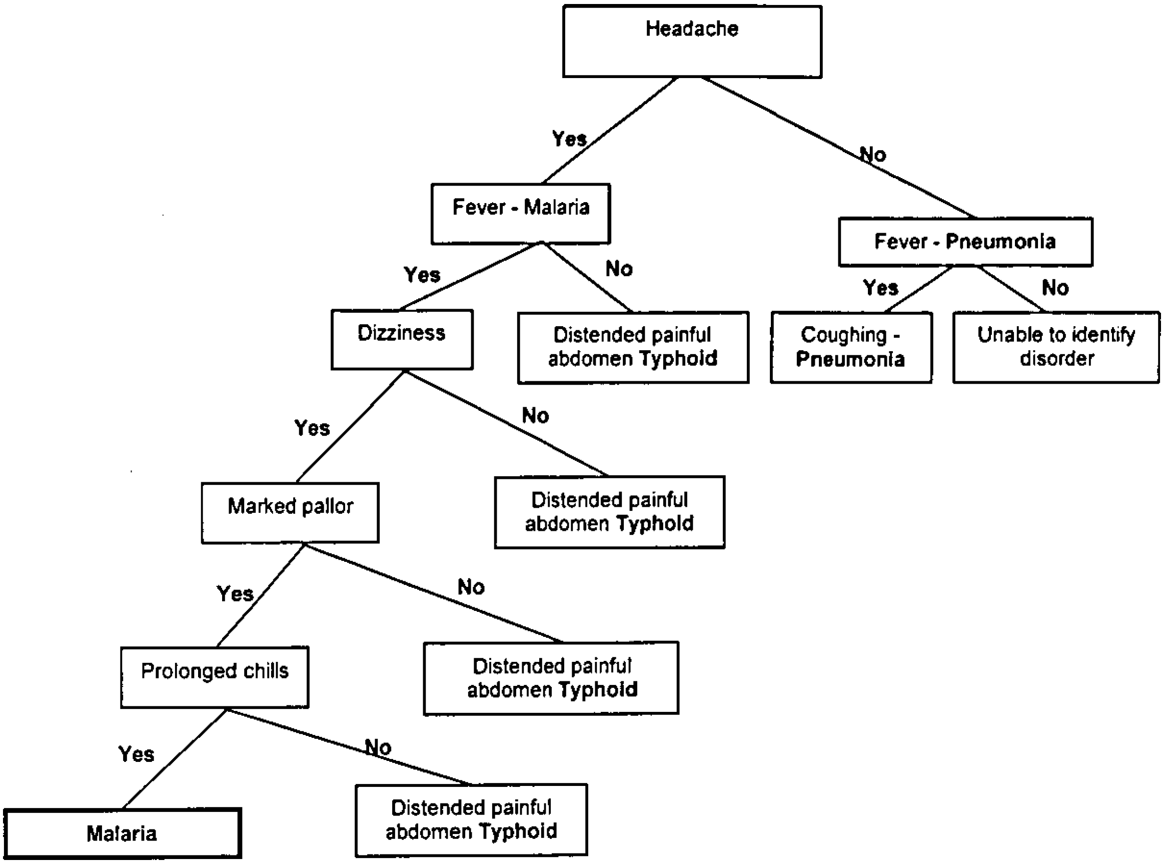


Figure 5. 3a: Tree diagram for identification of Malaria.

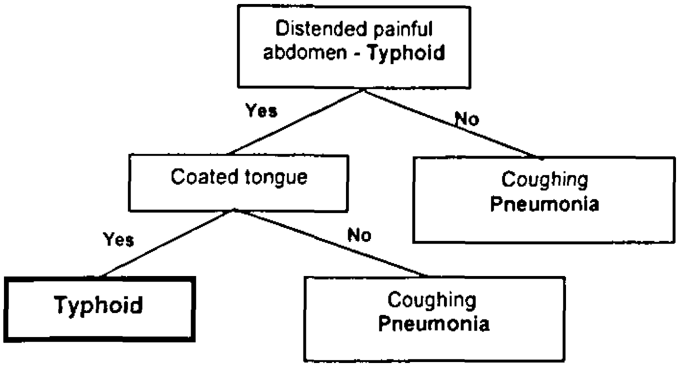


Figure 5.3b : Tree diagram for identification of Typhoid.

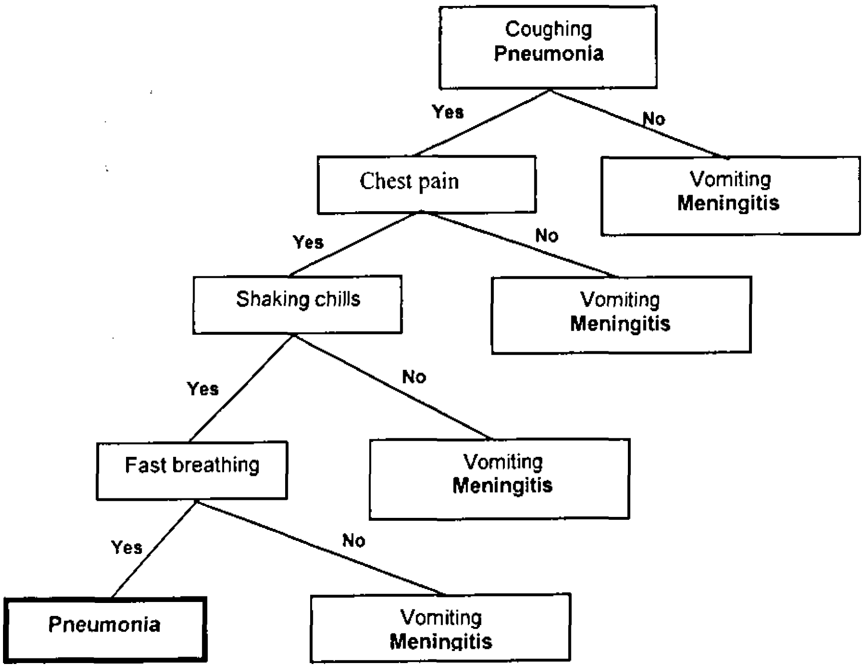


Figure 5.3c : Tree diagram for identification of Pneumonia.

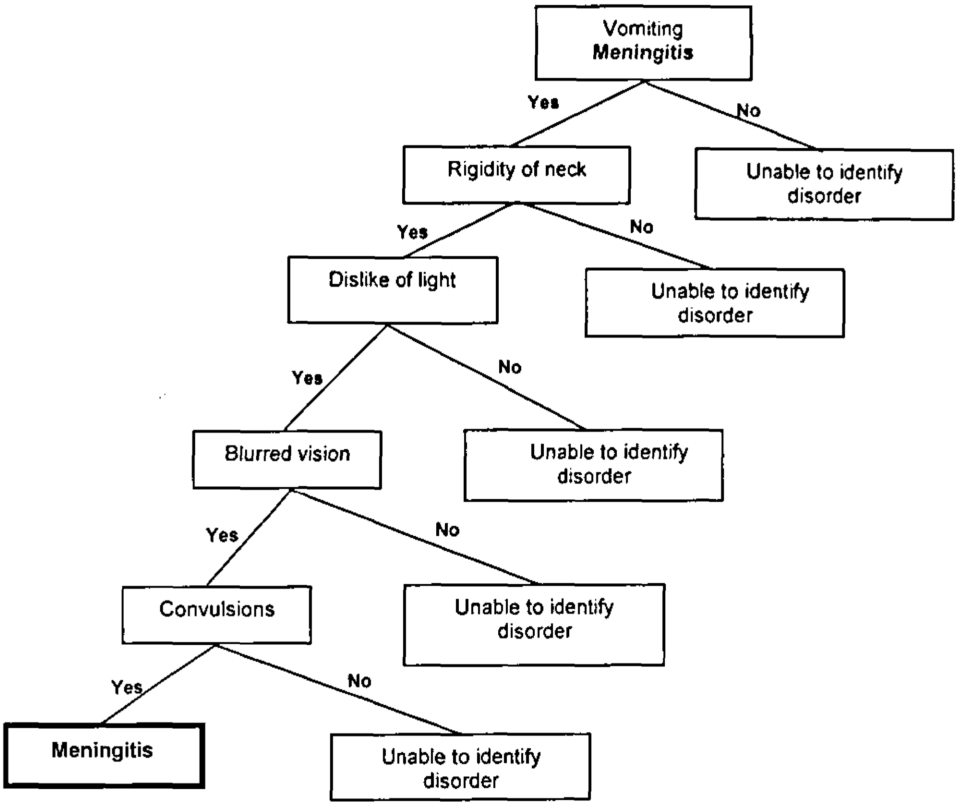


Figure 5.3d : Tree diagram for identification of Meningitis.

The disorder identification technique indicated was implemented using rules, see appendix G.

Interface Design

This deals with the design of interfaces between the various software components that constitute the entire system and also the interface between the system and the human user.

User Interface Design

This is an important component, since it is the one that allows the utility of the system to be tapped by users. Without a satisfactory human computer interface, the users may be discouraged from using the system. Therefore, there is need to have an effective interface. Here, we consider input from the users, output from the system and generally, the dialogue between them.

Input Design

Due to the nature of the program, being an expert system, and the shell being used to implement it, the inputs are very limited. The user is only allowed to respond to questions by typing either 'Y' for 'yes' and 'N' for 'no' or highlighting an option using navigation keys on the keyboard and thereafter, pressing the Enter key to give the selected response. For this reason, there is basically no need for data validation. The user will present input to the system via the keyboard.

Output Design

This considers all outputs to the screen including the question prompts and the eventual results. The questions are structured in a way that they are 'yes'/'no' questions, i.e. answers are not descriptive. This output design is preferred to the user driven approach where the user would be expected to input facts about the disorder in question. The danger of the user driven approach is that it would be difficult to validate the data and let it match identically with already stored facts. This would highly compromise the usability of the system.

The questions are prompted in a way that they follow each other logically. Questions which an implied answer can be borrowed from earlier questions are not asked as mentioned earlier. This greatly boosts the intelligence of the system.

After the questions are exhausted successfully, a conclusion of the last rule to be verified is output, having been identified as the disorder with the acknowledged symptoms. If the query is not successful, a message to 'disorder not identified' will be output. The user will be prompted to choose to either have another session or not. If the user chooses to have another session, control goes to the opening screen where the user will be allowed to start another consultation session. If the user chooses not to have another session, control goes to Crystal's main menu where the user will need to choose the 'Quit' command to be able to leave the knowledge based application.

A sample of the screens designed to help the user interact with the system are given below. The process of identifying and managing Malaria is assumed.

The Welcome or Opening screen would appear as follows

HERBALIST DIAGNOSTIC SUPPORT SYSTEM

WELCOME

This system will help you diagnose the following diseases:

1. Malaria 2. Typhoid Fever 3. Pneumonia 4. Meningits
5. Choloera 6. Diabetes 7. Asthma 8. Tuberculosis
9. Gonorrhoea 10. Amoebic Dysentry

(Press any key to continue)
Terah MSc project System 2009

The second screen, which has introduction instructions would appear as follows

INSTRUCTIONS

You will now select symptoms that relate to your case by answering the questions asked as accurately as possible

(Press any key to begin and ESC key to terminate)

An example screen to prompt the user for symptoms appears as follows. Similar screens would be used to capture other symptoms.

Headache

Yes
No

(Press Y for yes, N for no, F1 for explain)

Sample output screens would appear as follows. They give symptoms used in identifying the disorder obtained as well advise the user on management.

Disease Identified & Corresponding Symptoms

Malaria

Summary of leading Symptoms

1. Dizziness
2. Headache
3. Marked pallor
4. Fever
5. Joint and abdominal pains

(Press any key to proceed for advice on treatment & ESC key to terminate)

Diagnosis & Treatment Suggested

Diagnosis: **Malaria**

Recommendation: Blood Smear Test

Residence Region: Your region of residence is not covered

Treatment: You may take one glass of leave decoction of Ocimum Gratissimum (Mukandu) twice a day if you can get it.

Consult a doctor or herbalist nearest you in case you cannot get it or symptoms persist.

Notes: May be misdiagnosed as Pneumonia.

(Press any key to continue & ESC key to terminate)

Diagnosis & Treatment Suggested

Diagnosis: System unable to identify your disorder

Residence Region: -

Recommendation: You may proceed and press any key to take another session and change your responses in case they are inaccurate. Otherwise consult a doctor or herbalist nearest you

Treatment: -

Notes: May be misdiagnosed as Pneumonia.

(Press any key to continue & ESC key to terminate)

This is the last screen where the user chooses to have another session or quit.

The system has finished the current consultation session

Are you interested in another session?

Yes

No

(Press Y for yes, N for no, F1 for explain)

6

SYSTEM IMPLEMENTATION AND EVALUATION

6.1 Coding (Rule Generation)

This refers to the translation of the algorithm design into some programming language syntax. This translation is expected to retain the logic brought up in the design phase and the eventual functionality. Being an expert system in Crystal, this stage involved the generation of rules to be used in capturing knowledge into the knowledge base. Sample rules are included in the project report as appendix G.

Due to the excessive recursions that are dominant in expert systems, it would be very difficult to apply a language that is not artificial intelligence based. Crystal Shell has advanced features that handle recursions efficiently. It also has a window based interface that is quite simple and user friendly.

6.2 Debugging

A program fault that causes a program to fail during testing or after it has been commissioned is called a bug. Therefore debugging is a system implementation activity that involves going through the code searching for syntax as well as logical errors, with the aim of eliminating them.

Debugging is a taxing exercise because bugs are not easy to identify. It therefore takes a big chunk of the development time. The Crystal Shell software has a utility that assists the developer in locating syntax errors, thus making it easy to fix errors. Logical errors are however more intricate. With the help of the Trace function, invoked by pressing the F7 key, the developer is able to see what happens when a particular rule is being executed. The developer can therefore be able to find out where and why an erroneous output is being given and hence fix it. To the best of my knowledge, all serious bugs were eliminated.

6.3 Running the System

To start and run the system, one will be required to follow the steps in the user manual that appears as appendix I in the current project report.

6.4 Evaluating the usefulness of the Herbalist Diagnostic Support System

The developed system was experimented with in order to evaluate its usefulness. The evaluation process involved demonstrating that the system works according to specification and that functional and non-functional requirements are satisfied as much as possible. This evaluation was done with the help of doctors, herbalists and system administrators all numbering twenty. The system was given to them to try using it before completing the system usefulness evaluation questionnaire that appears in appendix E to ascertain that the requirements were met. The following goals were used in the evaluation process:

- Check whether the prototype system runs or not.
- Check the ability of the system to facilitate the work of the herbalist i.e. disorder identification and prescription.
- Check the system interface for user friendliness.

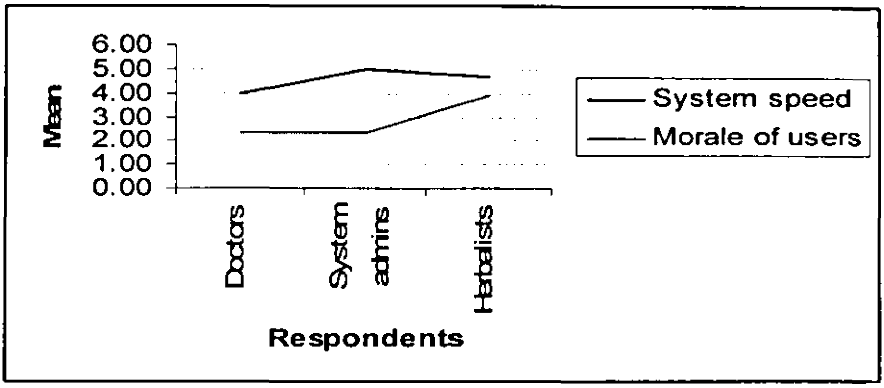
6.5 Evaluation Results of the Herbalist Diagnostic Support System Functionalities

The statistical analysis outcome of the survey carried out to evaluate the usefulness of the system appears in appendix F.

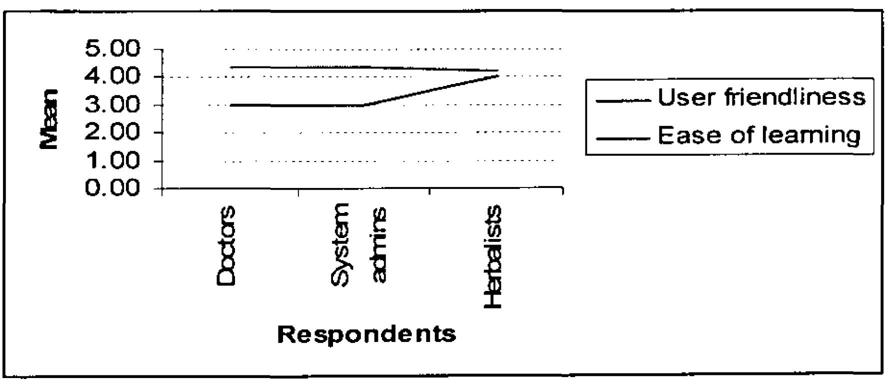
The system was found to be acceptable in its working. It successfully identifies disorders besides providing advice on how to manage the disorders using herbal medicine based on the region of residence on the region of residence. The system was also found to be robust and does not get into unrecoverable runtime errors when being executed.

The following brief contains a graphical representation of the outcome of the survey that was carried out on the sample of 20 users of the system.

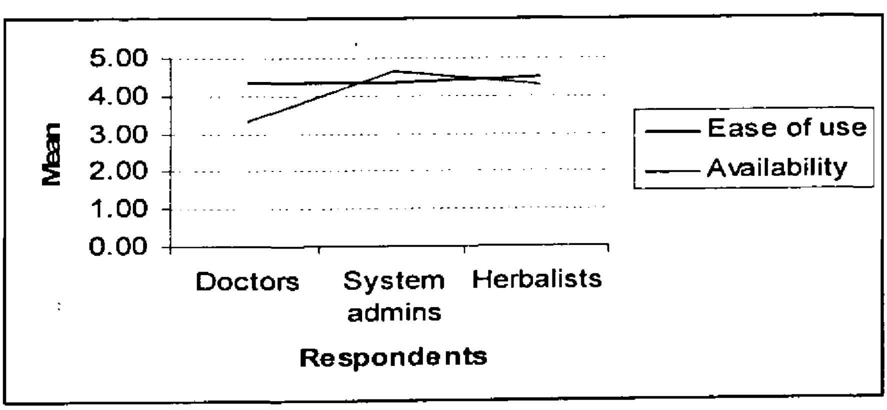
The system helped increase the morale of users significantly and was found to be fairly fast. This is illustrated in the graph that follows.



The system was also found to be user friendly and averagely easy to learn. The following graph indicates the need for improvement of the user interface to make the system much easier to learn.



The system was also found to be easy to use and readily available. The following graph demonstrates that.



7

CONCLUSIONS

7.1 Achievements

It can be said that the objectives of the project were achieved. The project was practical as well as academic. Both aspects were achieved to an acceptable degree. Due to the simple and short questions a user is expected to answer, the very interactive and informative screens, it is clear that the user will be able to tap the utility of the system easily. More appreciation of the power of the expert system based languages, expert system shells and expert systems in general was realized.

7.2 Recommendations

Expert systems development is an area of computing that tries to replace a human expert by having all the knowledge of a particular area captured in an electronic database. This exercise requires thorough research and high precision of data to ensure accuracy of the system. Therefore, ample time should be invested in the exercise. This was not possible within a period of six months. Therefore, some necessary information might have been omitted in the knowledge base of this project.

To come up with an efficient and user friendly system, it is necessary to have enhanced implementation languages or tools. Such tools should have capability of adding rules to the knowledge base online and ability to control memory allocation size among other necessary requirements.

For the sake of portability, the researcher recommends a PC based system. In fact the tool used is PC based.

It would also be very interesting if an implementation tool with identification of herbs by botanical name, local language or mother tongue name and capability to incorporate scanned pictures of the medicinal plants in the knowledge base was available. Outputting the name of the identified disorder together with the name and picture of the plant to be used in managing the disorder will make the user surer of the way forward. The local name could also help those without knowledge of botanical names know what plants to use without a lot of help.

7.3 Challenges

The researcher experienced a number of limitations in the course of this project work. Three such limitations worth notice are given below:

- Ethical and legal issues related to the use of computers in medicine cannot be ignored. If the Expert System gives the wrong diagnosis, who can be held responsible? Issues with whether human experts would find it acceptable to use the expert system arose as well.
- A lot of difficulty was also experienced in the extraction of the necessary knowledge for the inference engine to use from the human experts in the relevant field into the rule base i.e. knowledge engineering. Quite often explanations from the human experts were not clear.
- The researcher was not able to implement good security for the system, given that the shell used is an old one.
- The biggest challenge facing herbalists is how to standardize their prescriptions. Most herbalists prescribe to their patients a handful of a particular substance, or ask them to take so much of a certain concoction.

7.4 Further Work

As mentioned earlier in this report, an enhancement of the knowledge base is possible. The rules leading to the various disorders can be enriched by having more facts about the disorder. This way, even when heuristics are employed, it would be less possible to make a wrong conclusion when substantive questions are asked. A comprehensive online help system would enable users to use the system with ease, without the need for external assistance. Due to time limitations, online help was not implemented. It would be important to incorporate it in the system in future. However, a user guide or manual has been provided in Appendix I of this report.

With the installation of the recommended hardware and software, the module that would handle scanned pictures and mother tongue plant names will be an interesting enhancement to the system.

The researcher also recommends that Case Base Reasoning could be tried to see if it gives better results than the rule based approach that has been applied in the current project.

APPENDIX A - QUESTIONNAIRE FOR HERBALISTS.

PART 1:

1. We would appreciate it if you could complete the following information:
Name of interviewee:
Locality:
Age:
Sex:
Marital status:
Ethnic origin (check □ only one):
□ Luo □ Kamba □ Other: ______________________

2. What is your highest year of school completed:
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23+
(primary) (high school) (college/university) (graduate school)

3. Are you currently (check □ only one):
□ married □ widowed □ single □ divorced

SECTION A: PLANT UTILIZATION
How many diseases do you treat?
Please specify the name(s) of the plants you use:

Local name?
Why is plant named that?
Is the plant edible, Medicinal or both?
When is plant collected and who does it?
How are plants stored?
Plant used alone or with another plant?
Plant habitat?
Is this most preferred kind of plant for illness? Plant usage for animal illness?
Name the plant parts used
Plant part preparation?
Application method?
Amount? How often?

SECTION B: EVALUATION OF MEDICAL ETHNOBOTANICAL KNOWLEDGE

Does the respondent have some knowledge on traditional medicine? If yes,
What type of diseases does the informant know ------------------------------------

----

Which plants are used to treat these conditions ------------------------------------

----

What effects do these preparations have upon administration -----------------------

----

Local name	Ethnic name	Name meaning	Ailment treated	Part(s) used	Preparation	Application	Application regime

Thank you very much!

APPENDIX B - SAMPLE DATA COLLECTED FROM HERBALISTS.

Disorder	Region	Treatment
Malaria	Western Kenya	Leaf decoction of Momordica Foetida (**Ayuya Ohambla**) or Leaf infusion of Manihot Esculentum (**Cassava**) or Leaf infusion of Tithoia Diversifolia (**Maua Madongo**) or Dried leaf infusion of Gutenbergia Cordifolia (**Akech Rabuor Teng' Teng'**), etc.
	N. Eastern Kenya	Leaf decoction of Aloe Secundiflora (**Kiluma**) or Root decoction of Pupalia Lappacacea (**Klaamata Ikwata**) or Bark decoction of Melia Volkensii (**Mukau Kikau**) or Leaf decoction of Ocimum Gratissimum (**Mukandu**) etc.
	Vidunda	Leaf decoction of Cyperus-Exaltatus (Ikangaga)
Typhoid	Western Kenya	No local herb for managing Typhoid.
	N. Eastern Kenya	No local herb for managing Typhoid.
	Vidunda	Root decoction of *Psidium Guajava* (**Ipeta**).
Pneumonia	Western Kenya	Bark decoction of *Rauwolfia caffra* (**Matamaro, Oburko Kibuko**) or Leaf poultice of *Physalis-Minima* (**Nyatonglo Ojuo**) or Leaf decoction-vapour of *Artemisia-Afra* (**Nyumba Oyengwe**)
	N. Eastern Kenya	Bark decoction of *Croton Megalocarpus* (**Muthulu Kithulu**) or Stem decoction of *Euphorbia Candelabrum* (**Kyaa**) or Leaf infusion of *Strychnos Henningsii* or *Root decoctiion of Maytenus Putterlickoides* (**Muthunthi Kithunthi**), etc.
	Vidunda	No local herb for managing Pneumonia.
Meningitis	Western Kenya	No local herb for managing Meningitis.
	N. Eastern Kenya	No local herb for managing Meningitis.
	Vidunda	No local herb for managing Meningitis.
Cholera	Western Kenya	No local herb for managing Cholera.
	N. Eastern Kenya	No local herb for managing Cholera.
	Vidunda	No local herb for managing Cholera.
Diabetes	Western Kenya	No local herb for managing Diabetes.
	N. Eastern Kenya	Root infusion of *Plectranthus Cylindraceus* (**Klo Kininl**).
	Vidunda	No local herb for managing Diabetes.

Disorder	Region	Treatment
Tuberculosis	Western Kenya	Steam fumigation of Leaves of *Clausena-Anisata* (**Ang'we**) or bark decoction of *Microglossa-Pyrifolia* (**Nyabung Odidi, Nyabung Odit**)
	N. Eastern Kenya	Root decoction of *Fagaropsis Hildebrandtii* (**Muvindavinda**) or leave decoction of *Strychnos Henningsii* or root decoction of *Strychnos Madagascariensisi* (**Mumee Kimee**) or root decoction of *Uvaria Schefflen* (**Mukukuma**) etc.
	Vidunda	No local herb for managing Tuberculosis.
Gonorrhoea	Western Kenya	Root decoction of *Asparagus-Flagellaris* (**Obudo**) or stem decoction of Cassia-Siamea (**Ndege Owinu, Owinu, Oyieko**) or root decoction of *Pentas-Lanceolata*(**Bumba**)
	N. Eastern Kenya	Leaf decoction of *Asparagus Flagellaris* (**Kauusya, uusya**) or leaf decoction of *Asparagus Setaceus* (**Uusya**) or root infusion of *Carica Papaya* (**Muvaivai, Kivaivai**) or stem infusion of *Euphorbia Gossypina* (**Ndau ntheke, ndau ya kithekani**) etc.
	Vidunda	Root infusion of *Crinum-kirkii* (**Idaka**) or bark decoction of *Ficus-vallis-choudae* (**Ikuyumph'umba**).
Asthma	Western Kenya	No local herb for managing Asthma.
	N. Eastern Kenya	Fruit decoction of *Cucumis Dipsaceus* (**Kikungi**) or leaf decoction of *Euphorbia Tirucalli* (**Ndau**) or leaf decoction of *Strychnos Henningsii* or root difusion of *Securidaca Longipedunculata* (**Muuka**) or root decoction of *Strychnos Madagascariensis* (**Mumee Kimee**) or root decoction of *Uvaria Schefflen* (**Mukukuma**) etc.
	Vidunda	No local herb for managing Asthma.

APPENDIX C - QUESTIONNAIRE FOR DOCTORS /LAB TECHNOLOGISTS.

SECTION 1: PERSONAL DETAILS

1. Please fill in the blank spaces.

Name of interviewee: ______________________________

Title of interviewee: ______________________________

How old are you?: ______________________________

About how long have you been in your current profession?: _____ years.

What is your highest year of school completed? (check ☐ only one):
☐ primary ☐ high school ☐ college/university ☐ graduate school

What is your current marital status? (check ☐ only one):
☐ married ☐ widowed ☐ single ☐ divorced

SECTION 2: DISEASES AND SYMPTOMS

Please specify the name(s) of the disease(s) you treat and the symptoms you look for to identify the disease(s).

1. DISEASE NAME: ______________________________
   SYMPTOMS: - ______________________________
   - ______________________________
   - ______________________________
   - ______________________________

   MISDIAGNOSIS :

2. DISEASE NAME: ______________________________
   SYMPTOMS: - ______________________________
   - ______________________________
   - ______________________________
   - ______________________________

   MISDIAGNOSIS :

3. DISEASE NAME: ______________________________
   SYMPTOMS: - ______________________________
   - ______________________________
   - ______________________________
   - ______________________________

   MISDIAGNOSIS :

4. DISEASE NAME: ______________________________
   SYMPTOMS: - ______________________________
   - ______________________________
   - ______________________________
   - ______________________________
   MISDIAGNOSIS :

5. DISEASE NAME: ______________________________
   SYMPTOMS: - ______________________________
   - ______________________________
   - ______________________________
   - ______________________________
   MISDIAGNOSIS : ______________________________

6. DISEASE NAME: ______________________________
   SYMPTOMS: - ______________________________
   - ______________________________
   - ______________________________
   - ______________________________
   MISDIAGNOSIS : ______________________________

7. DISEASE NAME: ______________________________
   SYMPTOMS: - ______________________________
   - ______________________________
   - ______________________________
   - ______________________________
   MISDIAGNOSIS : ______________________________

8. DISEASE NAME: ______________________________
   SYMPTOMS: - ______________________________
   - ______________________________
   - ______________________________
   - ______________________________
   MISDIAGNOSIS : ______________________________

Please feel free to attach a sheet of your own with similar details for additional diseases that you have been handling.

SECTION 3: DISEASES AND CORRESPONDING LABORATORY TESTS

Please specify the name(s) of the disease(s) you treat and the laboratory tests that are usually conducted to identify the disease(s).

NAME OF DISEASE	NAME OF LABORATORY TEST

Thank you very much!

Appendix D - Sample Data Collected From Doctors/Lab Technologists.

Disorder	Symptoms	Name of Lab Test	Misdiagnosis
Malaria	Headache, Fever, Dizziness, Marked pallor and Prolonged chills	Blood Smear Microscopy	Typhoid Fever
Typhoid	Headache, Fever, Dizziness, Distended painful abdomen and Coated tongue	Widal Test	Malaria
Pneumonia	Fever, Coughing, Chest pain, Shaking chills and Fast breathing.	Chest X-ray Haemogram	Asthma or Malaria
Meningitis	Headache, Fever, vomiting, Rigidity of neck, Dislike of light, Blurred vision and Convulsions.	CSF Fluid Examination	Malaria
Cholera	Vomiting, Abdominal pains, Rice water stool 30 - 40 times a day, Severe dehydration, Muscle crumps.	Stool Culture	Amoebic Dysentry
Diabetes	Urination at close intervals, Intense hunger and thirst, Blurred vision and Dry skin.	Blood Sugar Test	Hypertension
Asthma	Difficult in breathing, Wheezing chest, Bronchial spasms and A lot of sweating.	Chest X-ray.	Pneumonia
Tuberculosis	Coughing, Chest pain, Blood in Sputum and Wasting.	Sputum Microscopy	AIDS
Gonorrhoea	Purulent greenish yellow urethral discharge and burning sensation during urination.	Gram	UTI
Amoebic Dysentry	Abdominal pain, Blood/Mucus stool at close intervals.	Feacal Microscopy for Ova and Cysts.	Typhoid Fever

APPENDIX E - QUESTIONNAIRE FOR SYSTEM USEFULNESS EVALUATION

Questionnaire to be filled by herbalists, system administrators and other users

Introduction

The Herbalist Diagnosis Support System helps the user identify the disorder or ailment afflicting a patient. The system then goes a head to suggest the plant or herb and preparation to use in managing the disorder, depending on the region of residence.

Kindly mark the best option on the scale provided.

(1) Disagree Very Strongly (2) Disagree Strongly (3) Disagree (4) Agree

(5) Agree Strongly (6) Agree Very Strongly.

Questions (Kindly tick only one option)

1. The system is always available.
   1 □ 2 □ 3 □ 4 □ 5 □ 6 □

2. The speed of the system is adequate.
   1 □ 2 □ 3 □ 4 □ 5 □ 6 □

3. The system does not ask about the same symptom more than once in the same consultation session (i.e. is not redundant).
   1 □ 2 □ 3 □ 4 □ 5 □ 6 □

4. The system meets user needs.
   1 □ 2 □ 3 □ 4 □ 5 □ 6 □

5. The system is user friendly.
   1 □ 2 □ 3 □ 4 □ 5 □ 6 □

6. The system has an attractive interface.
   1 □ 2 □ 3 □ 4 □ 5 □ 6 □

7. The system is easy to use.
   1 □ 2 □ 3 □ 4 □ 5 □ 6 □

8. The system easy to learn.
   1 □ 2 □ 3 □ 4 □ 5 □ 6 □

ıe system has a good explanation facility through which it tells the user why it quires about a particular symptom.

□ 2□ 3□ 4□ 5□ 6□

he system provides a summary of the symptoms leading it into identifying the .sorder identified.

□ 2□ 3□ 4□ 5□ 6□

he system increases the morale of the users.

□ 2□ 3□ 4□ 5□ 6□

The symptoms the system asked for were adequate in identifying the disorder.

□ 2□ 3□ 4□ 5□ 6□

he solution or prescription suggested by the system satisfies the user.

□ 2□ 3□ 4□ 5□ 6□

e be free to add any information that you could help us improve the Herbalist ıosis Support System.

ional Comments

____

____

____

____

ks a lot for your time, contribution and participation.

:m Developer: Stephen A. A. Terah.
e of the respondent: ________________
in the system: ____________________ (User, System Administrator, Herbalist)

Appendix D - Sample Data Collected From Doctors/Lab Technologists.

Descriptive		No	Min	Max	Total	Mean	Std dev
System availability	Doctors	3	3	4	10	3.33	0.58
	System admins	3	4	5	14	4.67	0.58
	Herbalists	14	3	5	60	4.29	0.73
	Total	20	3	5	84	4.20	0.77
System speed	Doctors	3	3	5	12	4.00	1.00
	System admins	3	4	6	15	5.00	1.00
	Herbalists	14	3	6	65	4.64	0.84
	Total	20	3	6	92	4.60	0.88
Redundance	Doctors	3	4	4	12	4.00	0.00
	System admins	3	4	4	12	4.00	0.00
	Herbalists	14	4	6	65	4.64	0.63
	Total	20	4	6	89	4.45	0.60
Meeting user needs	Doctors	3	3	4	10	3.33	0.58
	System admins	3	3	4	11	3.67	0.58
	Herbalists	14	3	5	56	4.00	0.39
	Total	20	3	5	77	3.85	0.39
User friendliness	Doctors	3	4	4	12	4.00	0.00
	System admins	3	4	4	12	4.00	0.00
	Herbalists	14	3	5	57	4.07	0.62
	Total	20	3	5	81	4.05	0.59
Interface attractiveness	Doctors	3	3	3	9	3.00	0.00
	System admins	3	3	3	9	3.00	0.00
	Herbalists	14	3	6	56	4.00	0.96
	Total	20	3	6	74	3.70	1.03
Ease of use	Doctors	3	3	6	13	4.33	1.54
	System admins	3	3	6	13	4.33	1.53
	Herbalists	14	3	6	63	4.50	0.94
	Total	20	3	6	89	4.45	1.00
Easy to learn	Doctors	3	3	6	13	4.33	1.54
	System admins	3	3	6	13	4.33	1.54
	Herbalists	14	3	6	59	4.21	0.97
	Total	20	3	6	85	4.25	1.04
Explanation facility goodness	Doctors	3	3	4	10	3.67	0.58
	System admins	3	3	4	10	3.67	0.58
	Herbalists	14	3	5	58	4.14	0.77
	Total	20	3	5	78	3.90	0.79
Summary of symptoms	Doctors	3	3	4	10	3.67	0.58
	System admins	3	3	4	11	3.67	0.58
	Herbalists	14	3	6	63	4.50	0.76
	Total	20	3	6	84	4.20	0.83
Morale of users	Doctors	3	2	3	7	2.33	0.58
	System admins	3	2	3	7	2.33	0.58
	Herbalists	14	2	5	55	3.93	1.00
	Total	20	2	5	69	3.45	1.14
Symptoms adequacy	Doctors	3	3	3	9	3.00	0.00
	System admins	3	3	4	10	3.33	0.58
	Herbalists	14	3	5	56	4.00	0.78
	Total	20	3	5	75	3.75	0.75
Prescription satisfaction	Doctors	3	3	4	11	3.67	0.58
	System admins	3	3	3	9	3.00	0.00
	Herbalists	14	3	5	58	4.14	0.53
	Total	20	3	5	78	3.90	0.51

APPENDIX G - SAMPLE RULES

The following are sample rules that were used to capture knowledge into the knowledge base. The researcher assumed five diseases in the knowledge base.

Diagnosis is finished
IF Introduction menu is displayed
AND Instructions are displayed
AND Symptoms assessed & Diagnosis displayed
AND Advise on whether to loop or quit is given

OR : Restart Rule

Introduction menu is displayed
IF : Test mode(14)
AND : Display form

Instructions are displayed
IF : Display form

Symptoms assessed & Diagnosis displayed
IF Disorder identified and residence region checked

Disorder identified and residence region checked
IF Malaria
AND The region of residence is covered

OR Typhoid
AND The region of residence is covered

OR Pneumonia
AND The region of residence is covered

OR Meningitis
AND The region of residence is covered

OR Cholera
AND The region of residence is covered

OR : Display form

Malaria

IF Headache
AND Fever
AND Dizziness
AND Marked pallor
AND Prolonged chills
AND : Display form

OR : Fail

Typhoid

IF Watery stool at regular intervals
AND Headache
AND Fever
AND Distended painful abdomen
AND Coated tongue
AND : Display form

OR : Fail

The region of residence is covered

IF Is your region of residence Western Kenya?
AND : Display form

OR Is your region of residence North Eestern Kenya?
AND : Display form

OR Is your region of residence Vidunda?
AND : Display form

OR : Display form

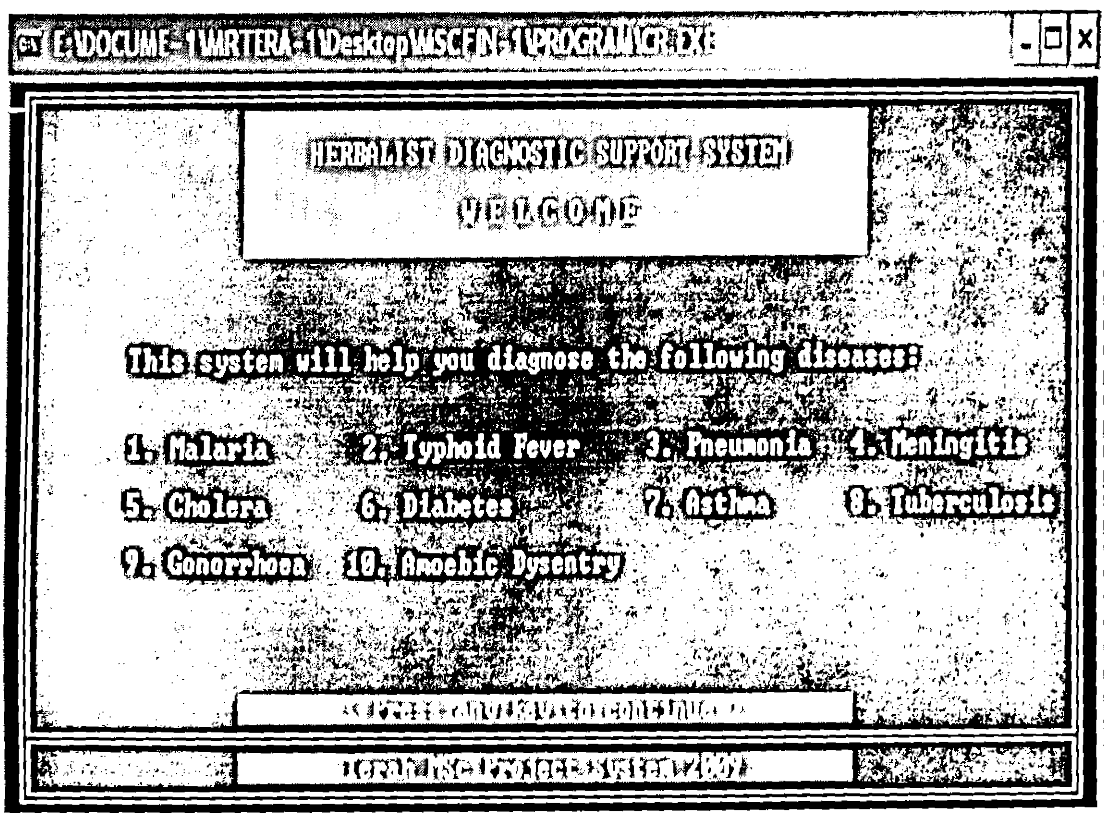
Advise on whether to loop or quit is given

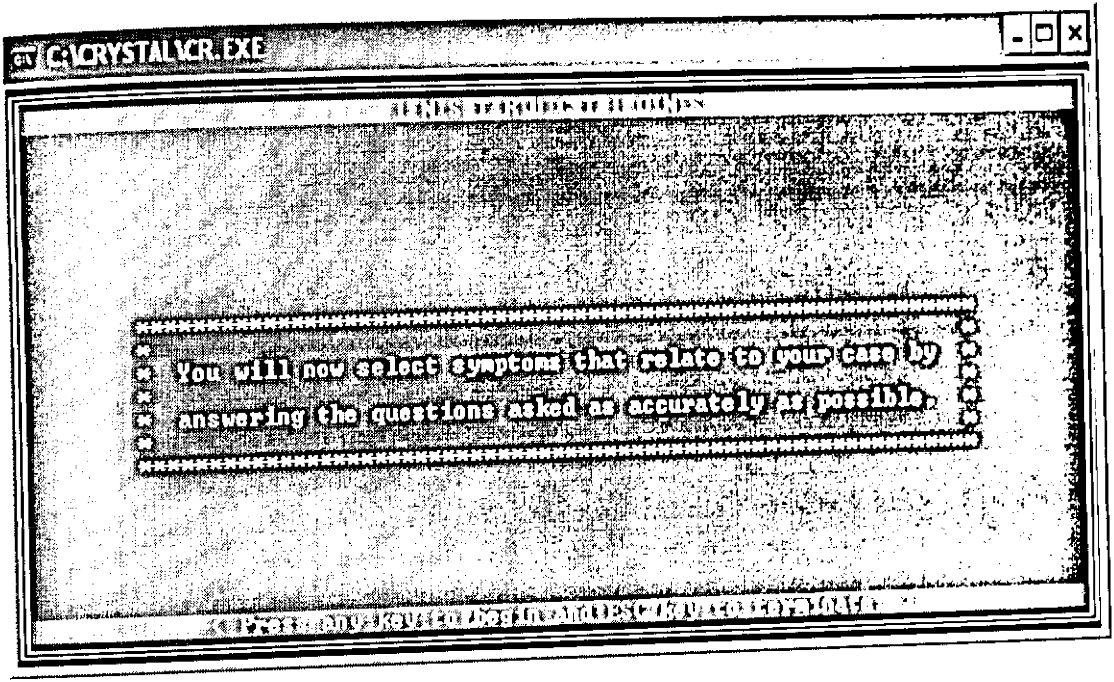
IF menu ExitLoopmnu
AND : Test ExitLoopmnu = 1
AND : KB Re-run

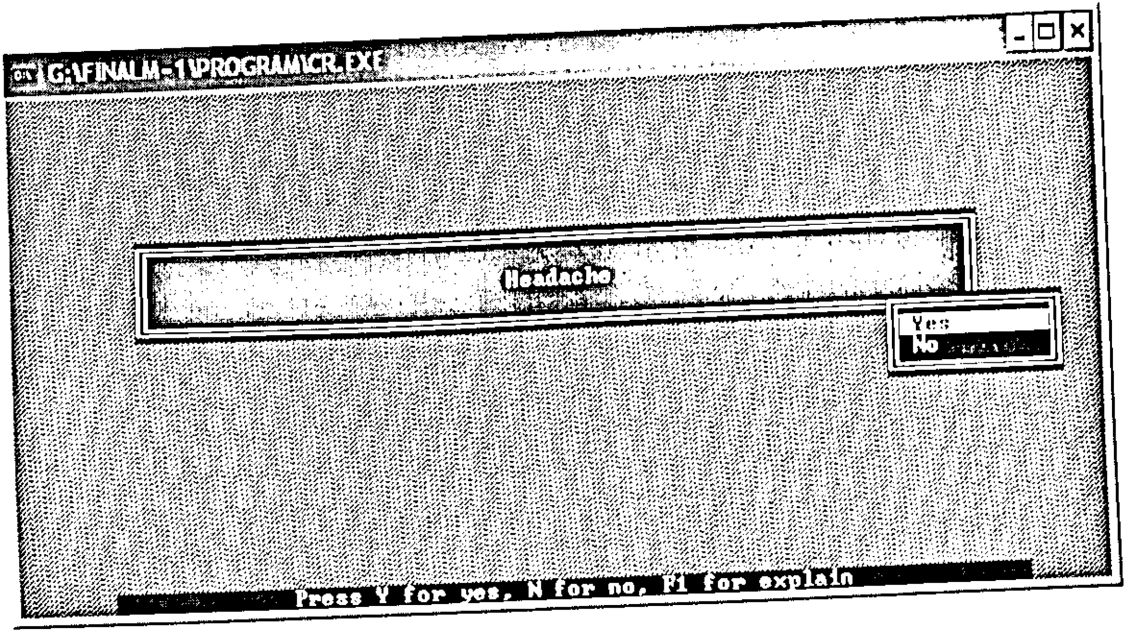
OR : Test ExitLoopmnu = 2
: Quit

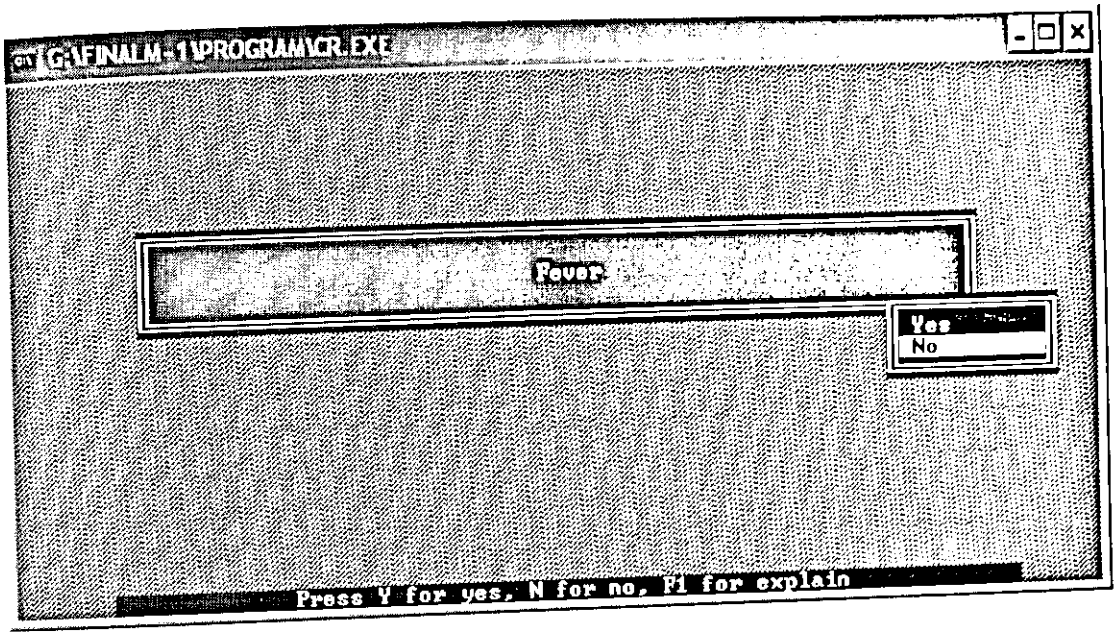
APPENDIX H - EXAMPLE CONSULTATION SESSION

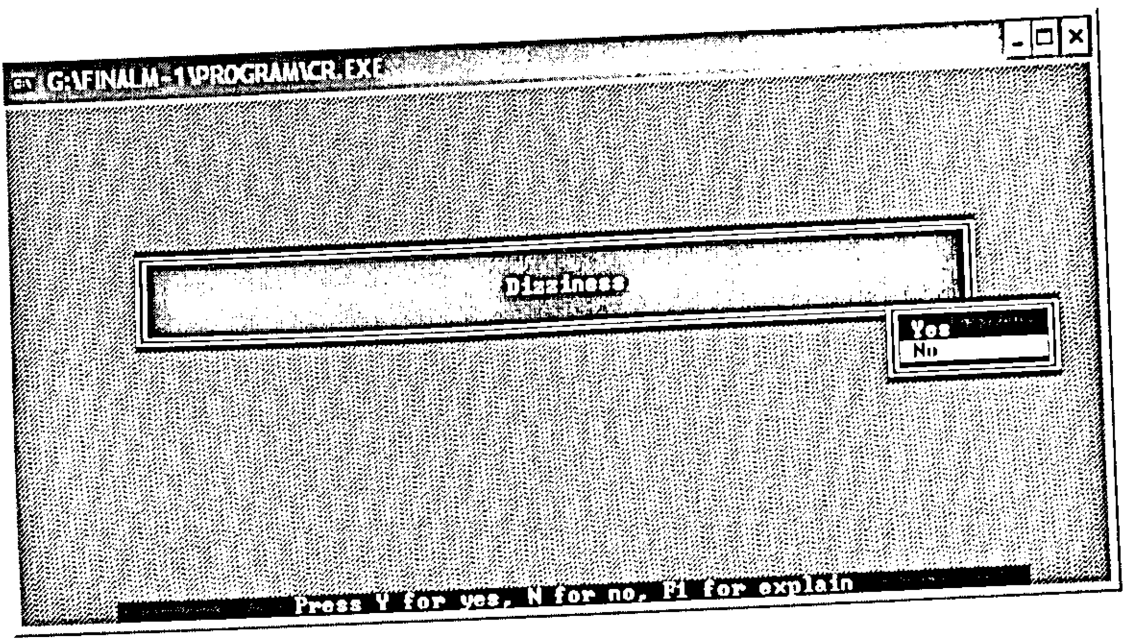
In this illustration session, we assume that the user has symptoms of Malaria. The Welcome Screen appears first and is followed by the Instructions Screen. After these two screens, there will be several screens prompting the user to give symptoms. This will be followed by a screen that gives the disorder identified if any and a failure message if that is the case. After these screens, there will be another screen asking for the region of residence. If the region is covered, there will be a screen giving treatment suggestions. Otherwise, other necessary advice will be given. The session ends with a screen that asks if the user needs to have a repeat session upon which, it goes to the first screen. Otherwise, the user quits the application altogether.

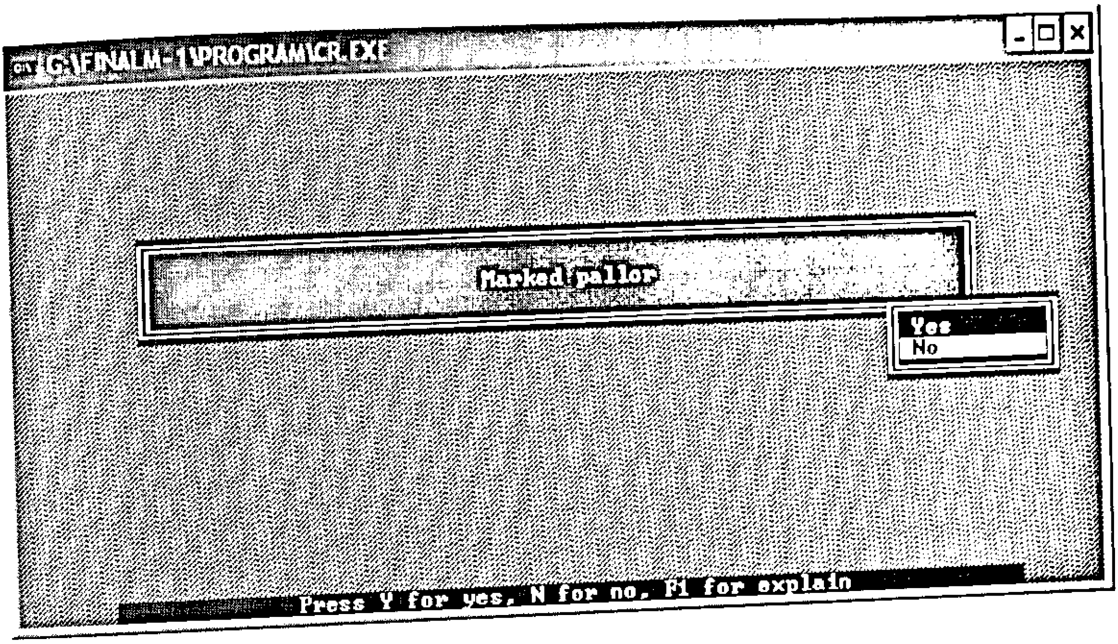


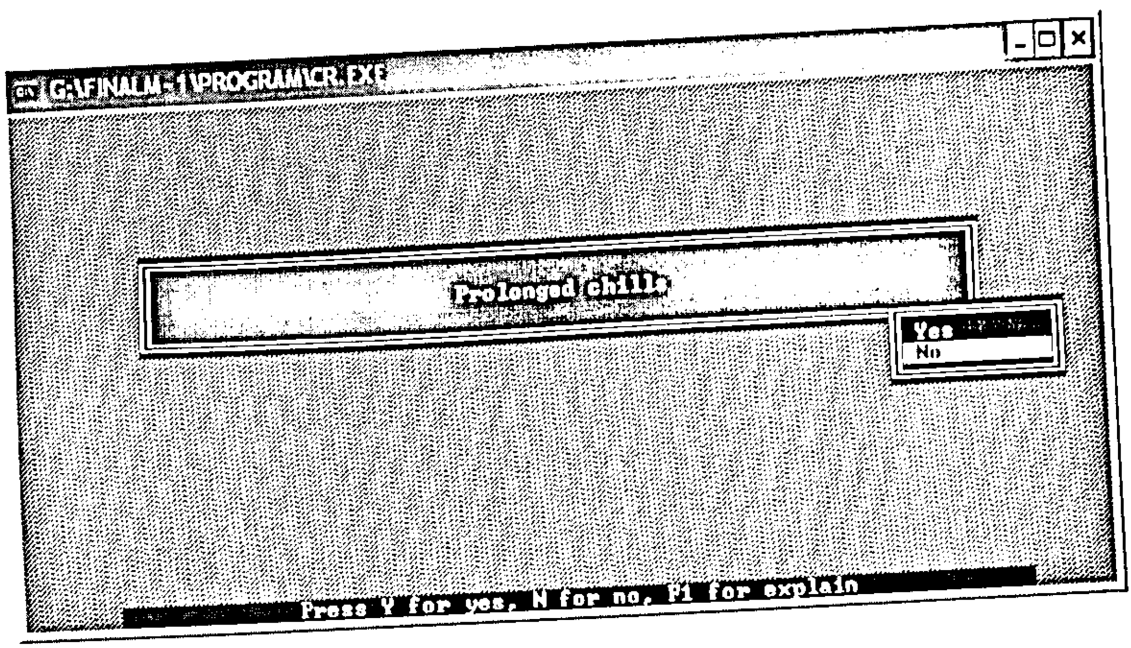

C:\CRYSTAL\CR.EXE
You will now select symptoms that relate to your case by answering the questions asked as accurately as possible.

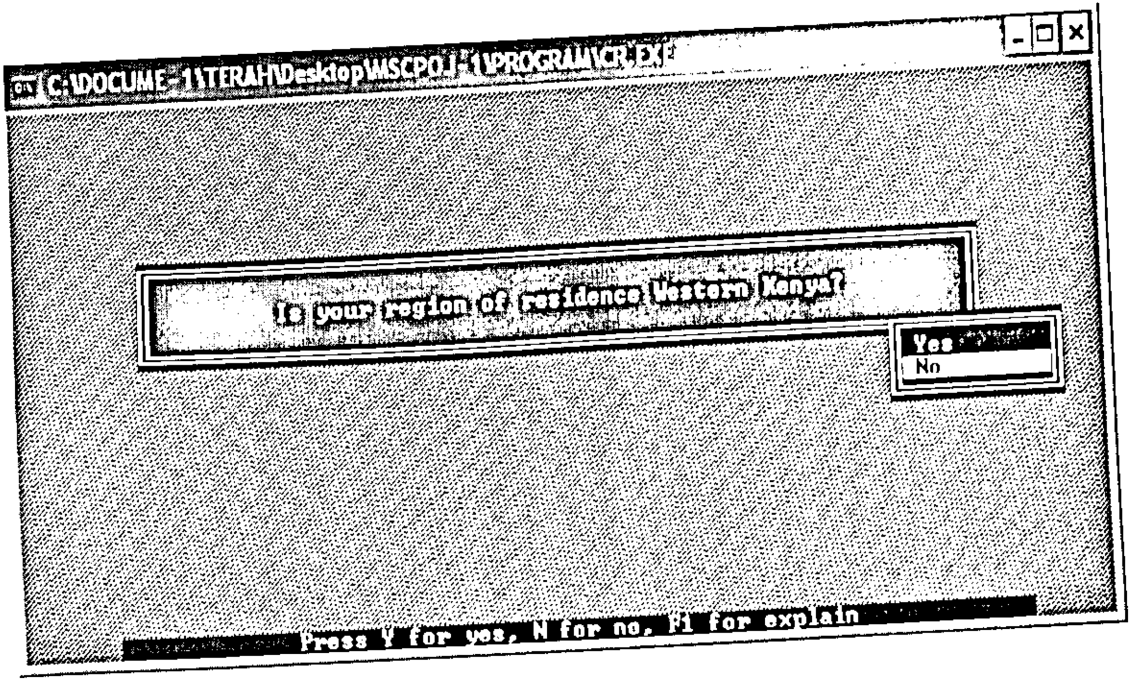

G:\FINALM~1\PROGRAM\CR.EXE
Headache
Yes
No
Press Y for yes, N for no, F1 for explain

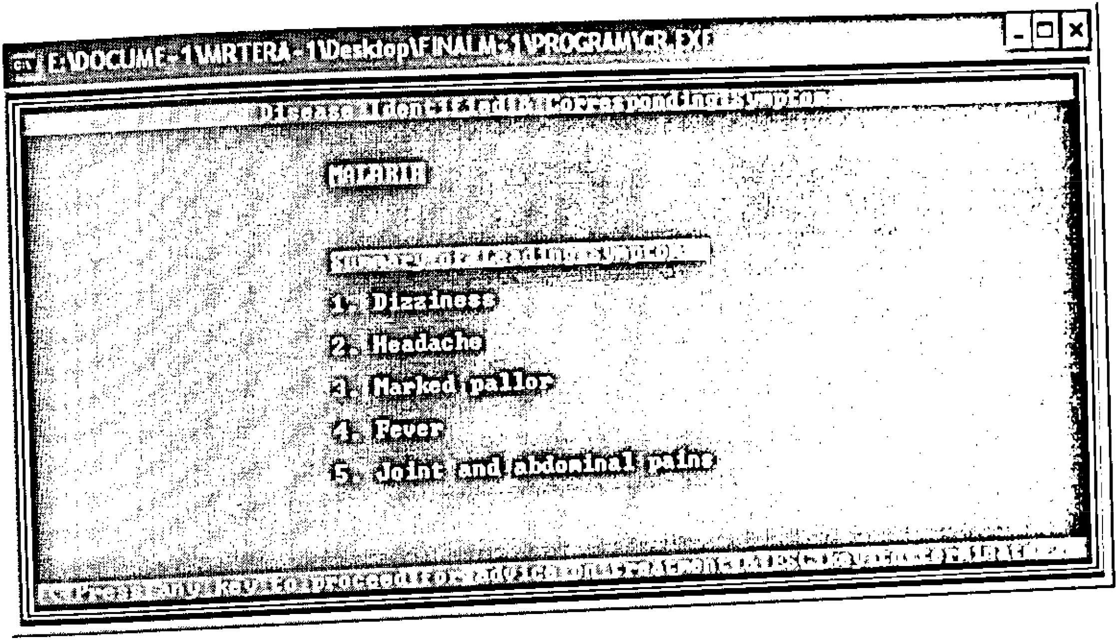

G:\FINALM~1\PROGRAM\CR.EXE
Fever
Yes
No
Press Y for yes, N for no, F1 for explain

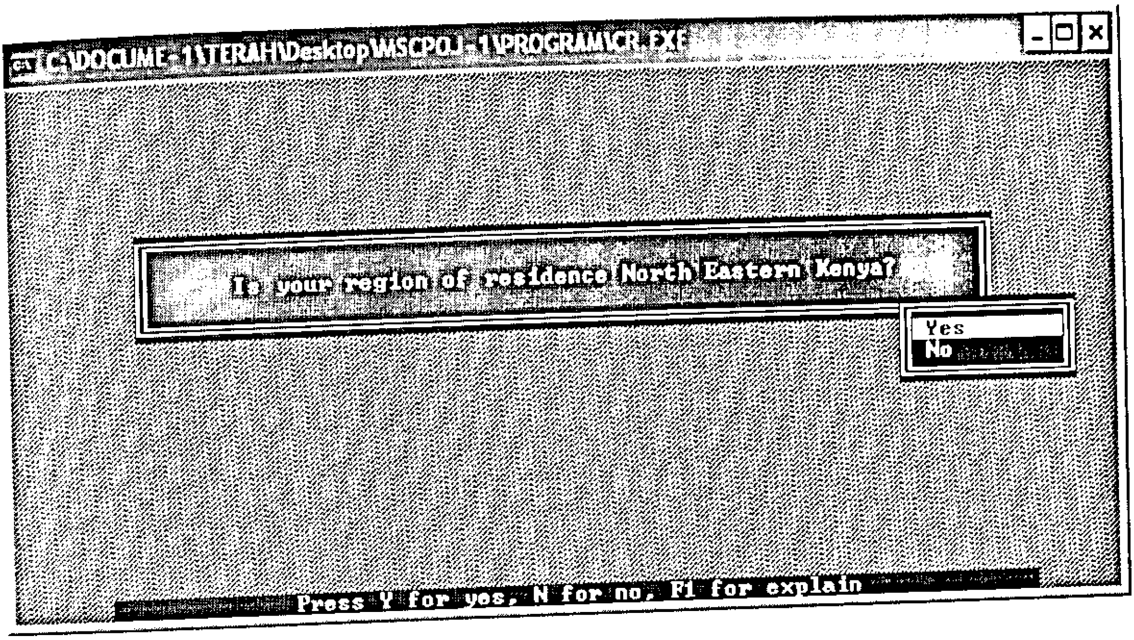

G:\FINALM~1\PROGRAM\CR.EXE
Dizziness
Yes
No
Press Y for yes, N for no, F1 for explain

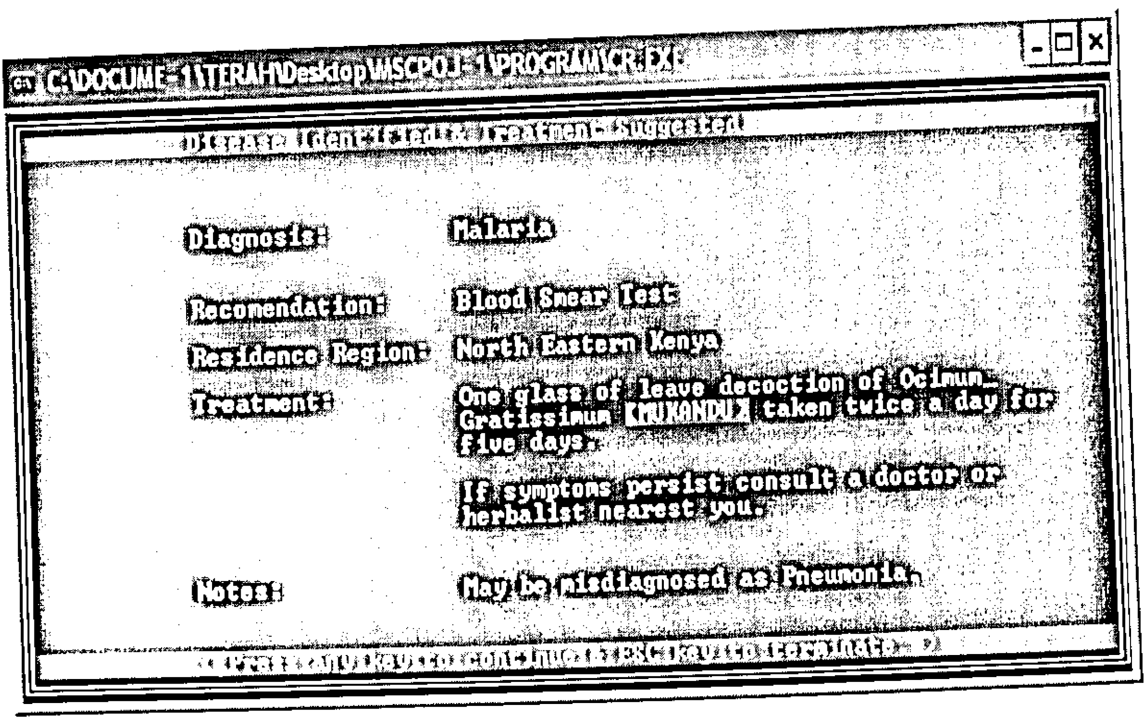

G:\FINALM~1\PROGRAM\CR.EXE
Marked pallor
Yes
No
Press Y for yes, N for no, F1 for explain

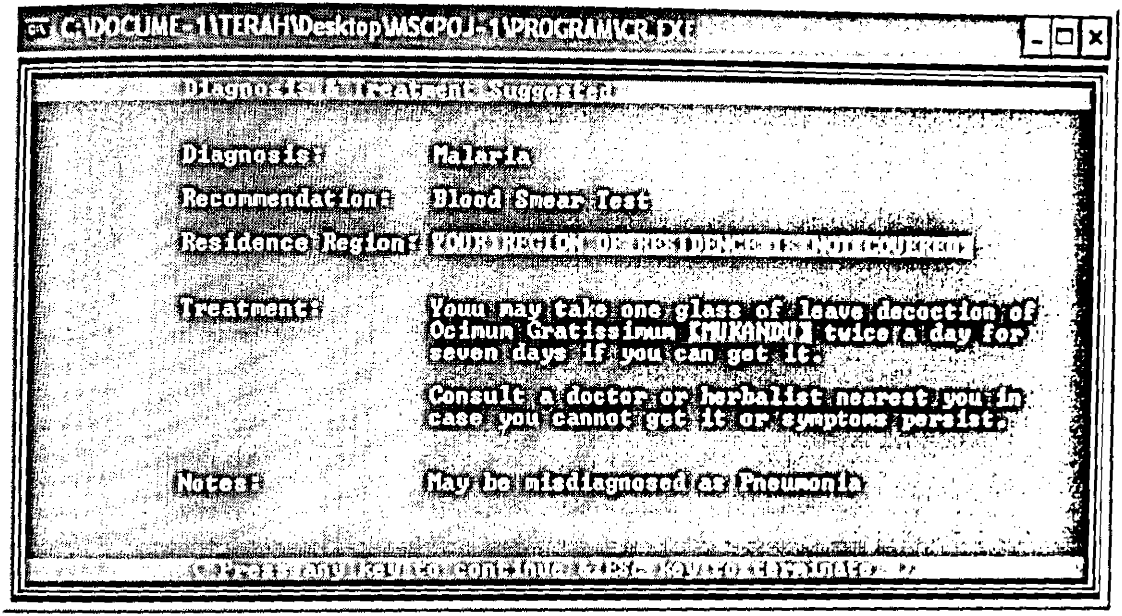

G:\FINALM~1\PROGRAM\CR.EXE
Prolonged chills
Yes
No
Press Y for yes, N for no, F1 for explain

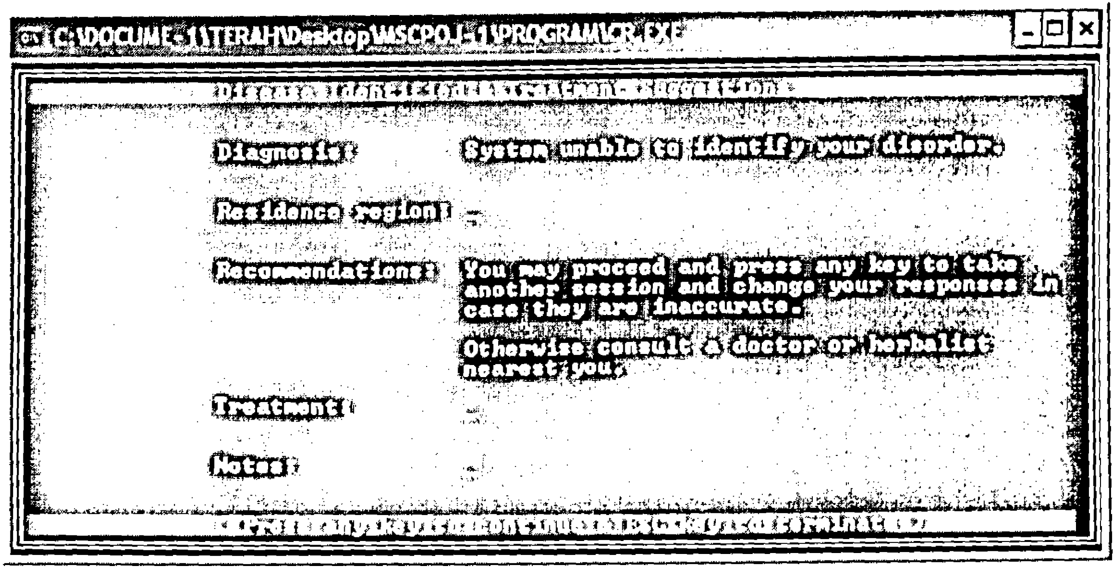

C:\DOCUME~1\TERAH\Desktop\MSCPOJ~1\PROGRAM\CR.EXE
Is your region of residence Western Kenya?
Yes
No
Press Y for yes, N for no, F1 for explain


E:\DOCUME~1\MRTERA~1\Desktop\FINALM~1\PROGRAM\CR.EXE
MALARIA
1. Dizziness
2. Headache
3. Marked pallor
4. Fever
5. Joint and abdominal pains

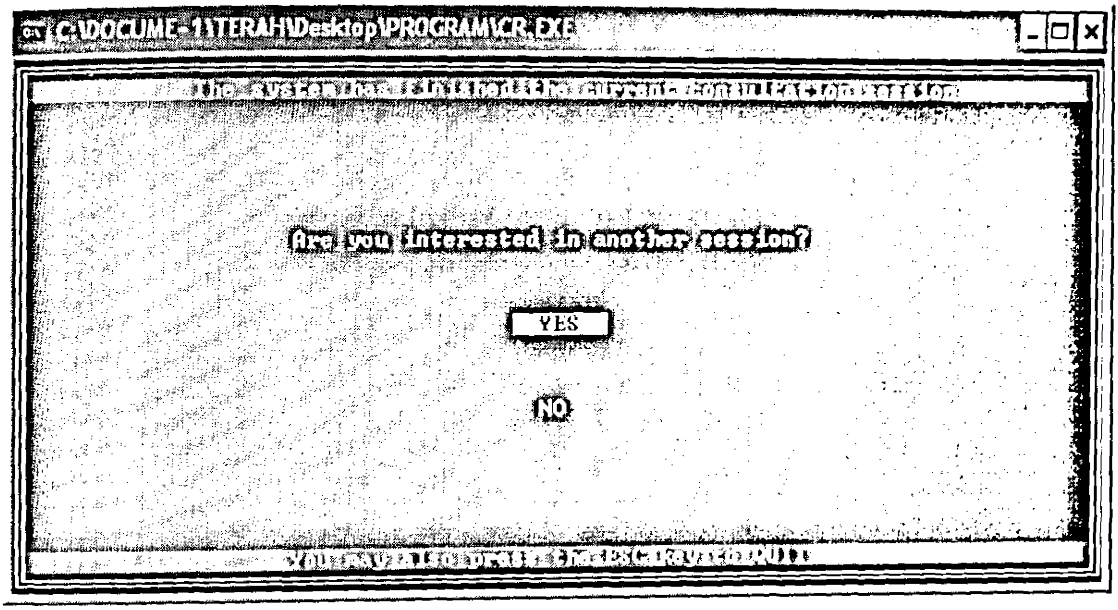

C:\DOCUME~1\TERAH\Desktop\MSCPOJ~1\PROGRAM\CR.EXE
Is your region of residence North Eastern Kenya?
Yes
No
Press Y for yes, N for no, F1 for explain


C:\DOCUME~1\TERAH\Desktop\MSCPOJ~1\PROGRAM\CR.EXE
Disease Identified & Treatment Suggested
Diagnosis: Malaria
Recomendation: Blood Smear Test
Residence Region: North Eastern Kenya
Treatment: One glass of leave decoction of Ocimum Gratissimum [MUKANDU] taken twice a day for five days.
If symptoms persist consult a doctor or herbalist nearest you.
Notes: May be misdiagnosed as Pneumonia.


C:\DOCUME~1\TERAH\Desktop\MSCPOJ~1\PROGRAM\CR.EXE
Diagnosis & Treatment Suggested
Diagnosis: Malaria
Recommendation: Blood Smear Test
Residence Region: YOUR REGION OF RESIDENCE IS NOT COVERED
Treatment: Youu may take one glass of leave decoction of Ocimum Gratissimum [MUKANDU] twice a day for seven days if you can get it.
Consult a doctor or herbalist nearest you in case you cannot get it or symptoms persist.
Notes: May be misdiagnosed as Pneumonia



C:\DOCUME~1\TERAH\Desktop\MSCPOJ~1\PROGRAM\CR.EXE
Diagnosis:
System unable to identify your disorder.
Residence region:
Recommendations:
You may proceed and press any key to take another session and change your responses in case they are inaccurate.
Otherwise consult a doctor or herbalist nearest you.
Treatment:
Notes:


C:\DOCUME~1\TERAH\Desktop\PROGRAM\CR.EXE
The system has finished the current consultation session
Are you interested in another session?
YES
NO

APPENDIX I - USER MANUAL

The developer of this user manual assumes that Crystal is already installed on your machine and is located in the default directory, C:\Crystal and that the knowledge base file is copied into this directory. The researcher also assumes that you are starting from the windows Desktop.

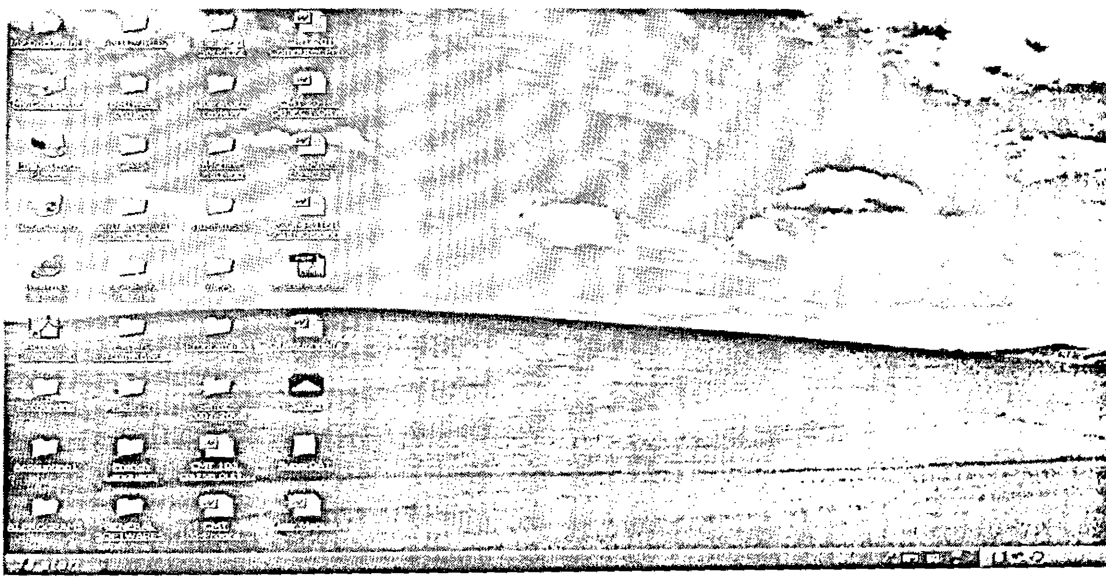


Figure 2: Windows Desktop.

Step 1: Click on Start.

You will see the following screen.

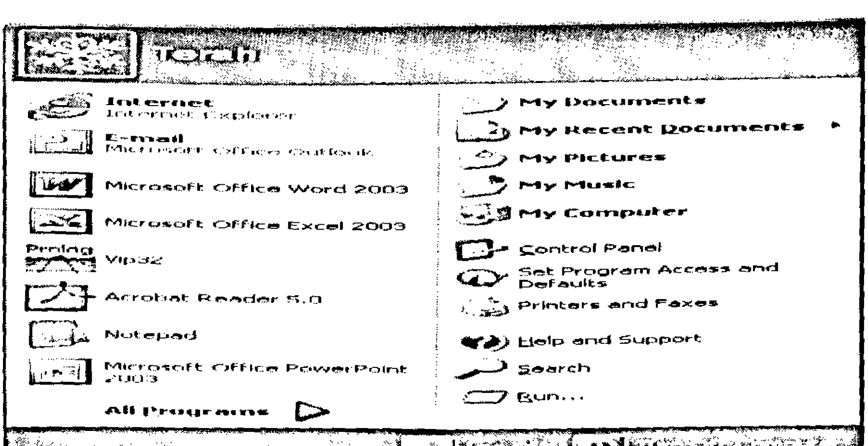


Figure 2: Start Menu

Step 2: Click on the Run... command.

You will see the following screen

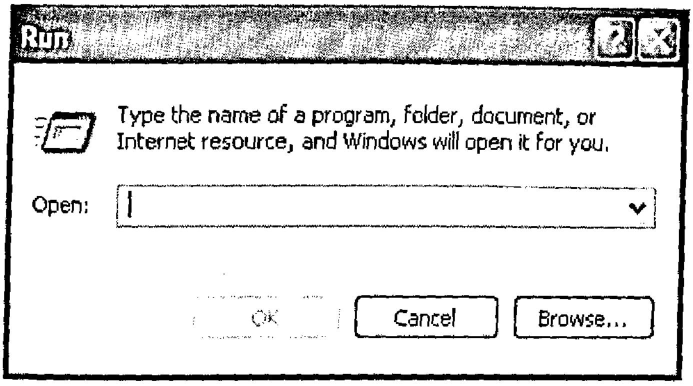


Figure 3: The Run... Command Dialog box

Step 3: Click on the Browse... button and then on the downward pointing arrow to the right of the "Look in" box. This opens a menu in which you need to click to select "Local Disk C".

You will see the screen that follows.

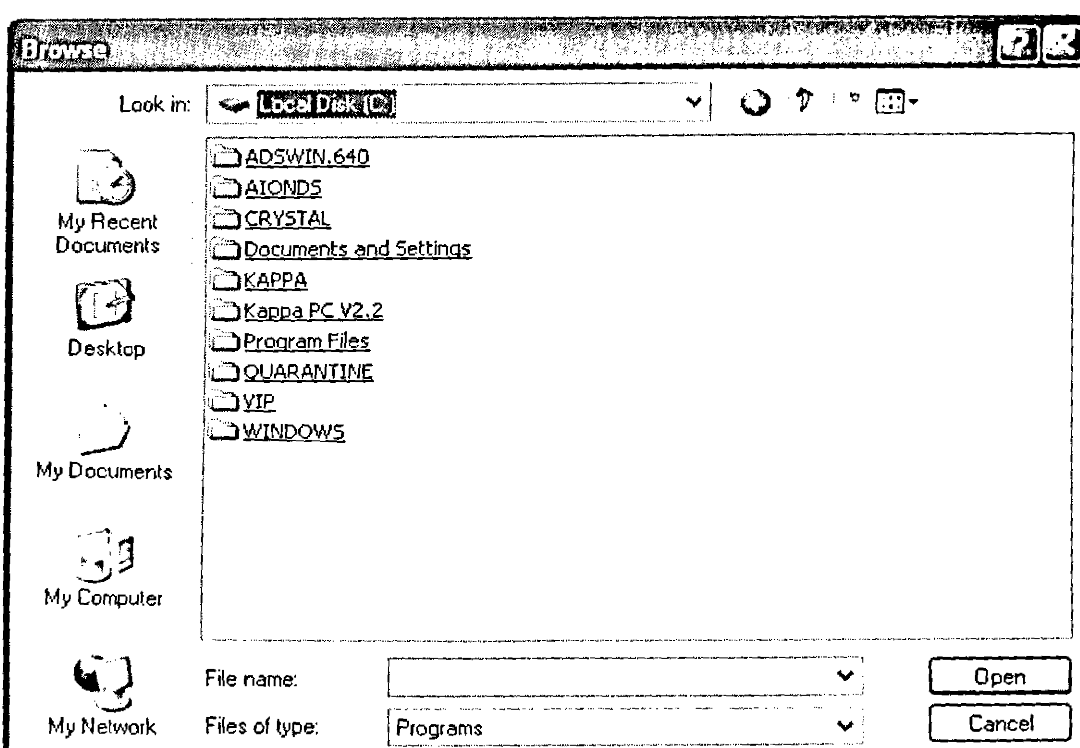


Figure 4: The Browse... Command dialog box

Step 4: Click and select the CRYSTAL folder. This opens a menu in which you need to click to select the CR icon.

You will see the screen below.

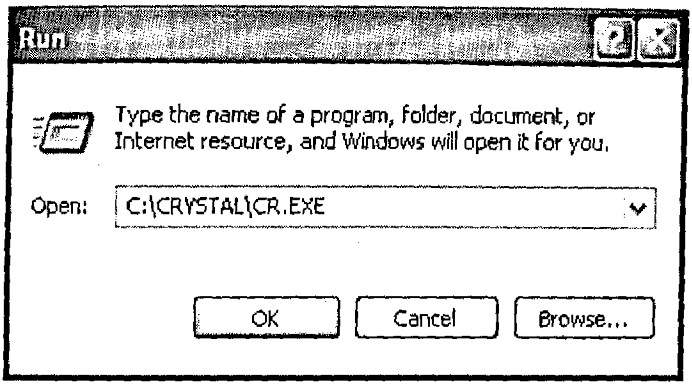


Figure 5: The Run… command dialog with the Crystal executable file command.

Step 6: Now click on the OK button.

If you successfully followed the instructions the Crystal Opening screen that bears the logo and the Copyright message appears.

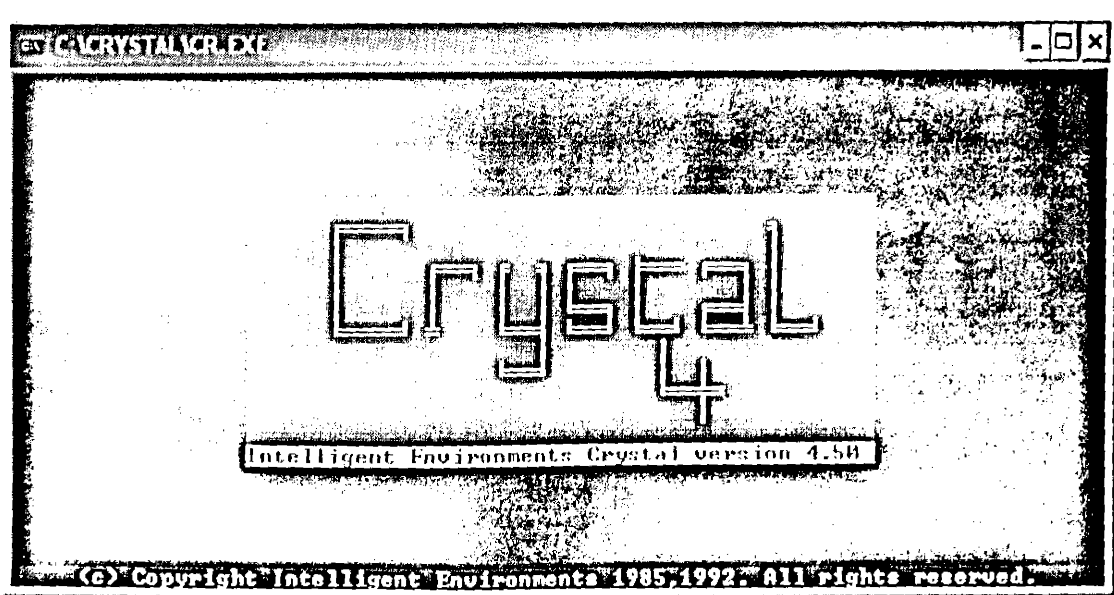


Figure 6: Crystal Opening Screen.

After a moment the opening screen automatically gives way and Crystal's Main Menu screen that follows displays.

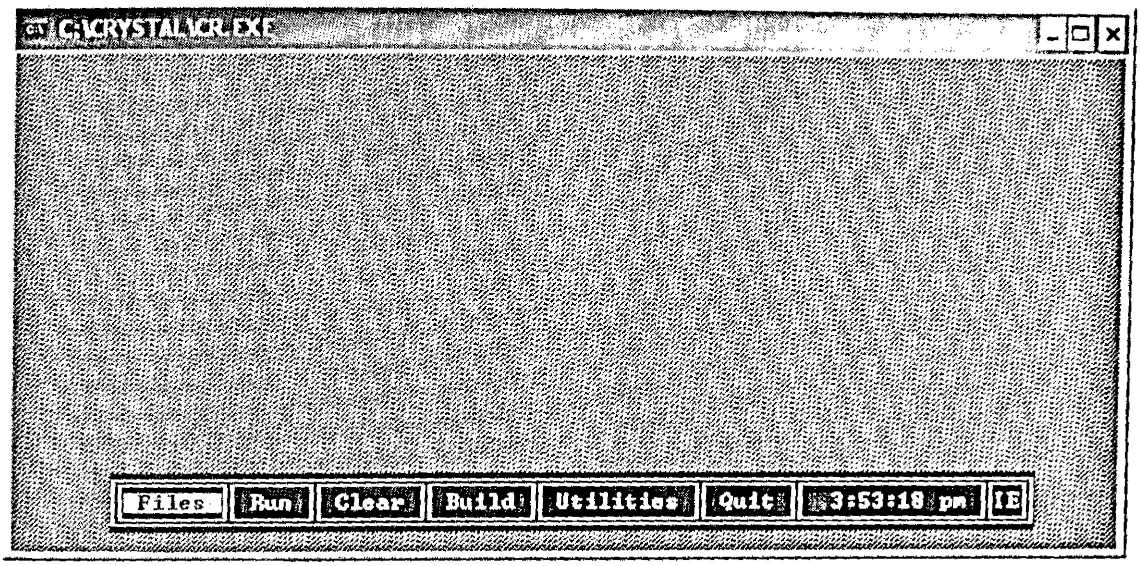


Figure 7: Crystal's Main Menu

Step 7: Move the cursor to the **Files** menu using the LEFT arrow Key on the keyboard and press the **ENTER** Key.

The screen that follows will appear.

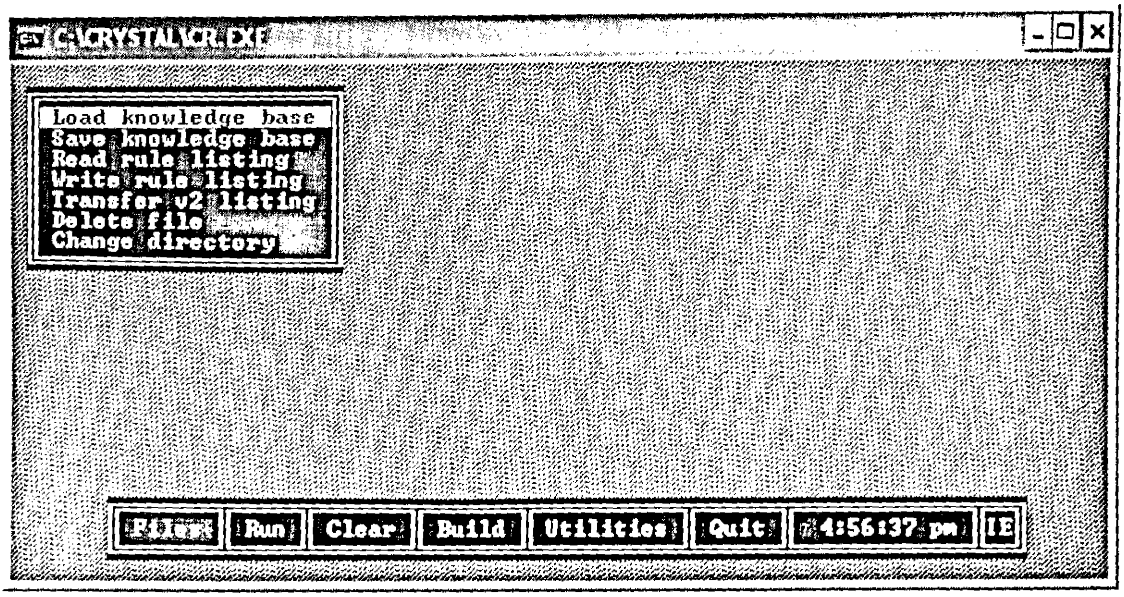


Figure 8: Screen bearing the "Load Knowledge Base" command.

Step 8: Use the appropriate navigation arrow keys on the keyboard to move the cursor to the "Load knowledge base" option on the expanded "Files" menu and press the ENTER key.

The screen that follows is displayed.

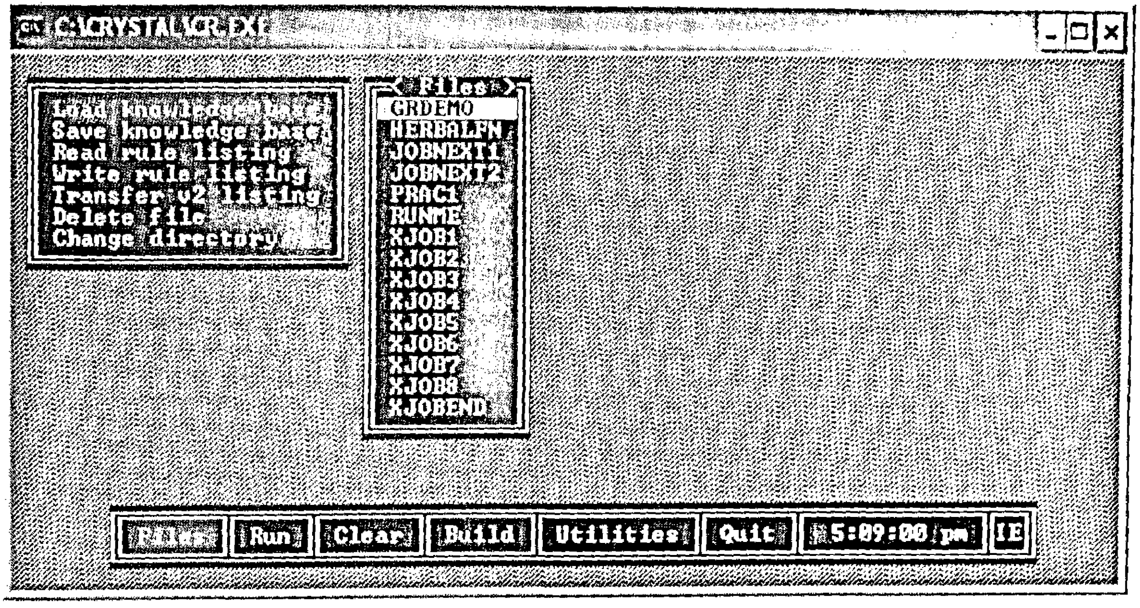


Figure 9: Screen bearing knowledge bases that can be loaded.

Step 9: Use the appropriate navigation arrow keys on the keyboard to move the cursor to the knowledge base you want to load and press the ENTER key.

Crystal's Main menu screen appears again.

Step 10: Now use the appropriate navigation arrow keys on the keyboard to move the cursor to the **Run** menu and press the ENTER key.

The expert system you selected will start running.

You will now respond to whatever it asks you to do appropriately as you wait for its response.

REFERENCES

1. Ian H. Witten and Eibe Frank. *Data Mining: Practical Machine Learning Tools and Techniques*, Morgan Kaufmann: San Francisco. 2005.
2. David J. Hand, Heikki manila, and Padhraic Smyth. *Principles of Data Mining*. The Massachusetts Institute of Technology (MIT) Press. 2001.
3. Efraim Turban and Jay E. Aronson. *Decision Support Systems and Intelligent Systems*. Pearson Education, 2000.
4. Smith, P. *An Introduction to Knowledge Engineering*. International Thomson Computer Press: UK, 1995.
5. Jackson, M. *Understanding Expert Systems Using Crystal*. John Willey & Sons: England, 1992.
6. Dr. D. R. Gala, Dr. Dhiren Gala and Dr. Sanjay Gala. *Diabetes, High Blood Pressure Without any Fear*. Navreet Publications (India) Ltd, 1986.
7. Ian Sommerville. *Software Engineering*. Addison Wesley: London, 1998.
8. Mkong'ola E. E. *A Study of the Social Acceptance and the use of Medicinal Plants in Mikumi Division, Tanzania*. BSc. Degree Project. CUEA. 2005.
9. Oketch Odhiambo. *A Case-Based Approach to Restaurant Selectiion*. MSc. Information Systems Project. UON, 2001.
10. Turrill, W.B. and E. Milne-Redhead, eds. 1952. *The Flora of Tropical East Africa*. Crown Agents, London.
11. Knox, E. 1996. *List of East African Plants*. National Museums of Kenya, Nairobi.
12. Beentje, H. 1994. *Kenya Trees, Shrubs and Lianas*. National Museums of Kenya, Nairobi.
13. Agnew, A.D.Q. and S. Agnew. 1994. *Upland Kenya Wild Flowers*, 2nd ed. East African Natural History Society, Nairobi.
14. Aamodt & Plaza1994: Aamodt, A., and Plaza, E. 1994. *Case-Based Reasoning: Foundational Issues, Methodological Variations, and System Approaches*. AICom - IOS Press.
15. Avron Barr, Edward A. Feigenbaum, Paul R. Cohen. 1982. *The Handbook of*

Artificial Intelligence. HeurisTech Press.

16. Jay *Liebowitz* & Daniel *Desalvo. 1989. Structuring Expert Systems: Domain, Design, and Development*. Prentice Hall Professional Technical Reference.
17. Journal of Ethno biology and Ethno medicine 2007 3:36.
18. http://www.scidev.net/en/news/kenya-to-develop-traditional-medicine-action-plan.html, 14/4/2009.
19. http://allafrica.com/stories/200801141606.html, 14/4/2009.