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ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF COMPUTING

A THESIS ON

**DEVELOPING KNOWLEDGE BASED SYSTEM FOR ACUTE
DIARRHEAL DISEASES DIAGNOSIS AND TREATMENT**

By

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January, 2017

Adama, Ethiopia.



ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

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DEPARTMENT OF COMPUTING

A Thesis Submitted to the Department of Computing of Adama Science and Technology University in Partial Fulfillment of the Requirements for Degree of Master of Science in Information Systems

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DECLARATION

This thesis is my original work and has not been submitted for a degree in any university.

Rahwaezgi Gebrekrstos

January, 2017

Adama, Ethiopia.

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LIST OF ACRONYMS

1. AI Artificial Intelligence
2. KB knowledge Base
3. ES Expert System
4. KR Knowledge Representation
5. KBS Knowledge-based system
6. KBSDDD knowledge based system Diarrhoeal disease diagnosis
7. KA Knowledge acquisition
8. WHO World Health Organization
9. RBR Rule Based Reasoning
10. CBR Case Based Reasoning

ABSTRACT

*Acute Diarrhoeal disease is widely recognized as a major cause of child morbidity and mortality in many developing countries, particularly in sub-Saharan Africa. In Ethiopia, Acute Diarrhoeal disease is one of the most frequent causes of childhood and a major contributor to child mortality. The frequency and severity of diarrhea is aggravated by lack of access to sufficient clean water and sanitary disposal of human waste, inadequate feeding and washing practice; poor housing conditions and lack of access to adequate and affordable health care. The burden is disproportionately high among children in low and middle-income countries. Young children are especially vulnerable to diarrheal disease and a high proportion of the deaths occur in the first 2 years of life. To this end, knowledge is acquired using both structured and unstructured interviews from domain expert and relevant document analysis method was used to capture domain knowledge. Then, the acquired knowledge is modeled using decision tree that represents concepts and procedures involved in diagnosis and treatment of Diarrhoeal disease. Production rules are used to represent the domain knowledge and knowledge-based system is developed using SWI Prolog editor tool. It uses backward chaining which begins with possible solutions or goals and tries to gather information that verifies the solution. The system prototype was evaluated using visual interactive and close ended questionnaires method; it was shown that the domain experts are satisfied with the system prototype performance. And the proposed knowledge based system gain about **75%** of user acceptance.*

Keywords: *Knowledge-Based System, Knowledge representation, knowledge acquisition, Diarrhoeal disease.*

CHAPTER ONE

1. INTRODUCTION

1.1. Background of the Study

Acute diarrheal diseases are one of the main problems affecting children in the world, reducing their well-being and creating considerable demand for health services. Diarrheal diseases are leading cause of death, especially among children under five in developing countries. Childhood mortality rate in general and infant mortality in particular, are often used as broad indicators of social development or as specific indicators of health status (Anegesom 2015).

According to the World Health Organization (WHO) and UNICEF, there are about two billion cases of Diarrheal worldwide every year, and 1.9 million people die from Diarrheal each year, mostly in developing countries. More recent review also indicated that most of those who die from Diarrheal children under the age of five and means that more than 5000 children are dying every day as a result of Diarrhoea. All child deaths from diarrhea, 78% occur in the African and South-East Asian regions. Globally in this age group, acute Diarrheal is the second leading cause of death (after pneumonia), and both the incidence and the risk of mortality from Diarrheal are greatest among children in this age group. Other direct consequences of Diarrheal in children include growth faltering, malnutrition, and impaired cognitive development in resource-limited countries (Prof. M. Farthing 2012).

Diarrhoeal diseases remain one of the most important causes of morbidity and mortality in developing countries, especially in African countries. It is a major health problem, which can be caused by a variety of causative agents. These causative agents include bacterial, viruses and parasites (Wanzahun Godana 2013).

Child mortality reduction by two-third is one target of Millennium Development Goal. Diarrhea is defined as a child with loose or watery stool for three or more times during a 24–hours period. The frequency and severity of diarrhea is aggravated by lack of access to sufficient clean water and sanitary disposal of human waste, improper feeding practices and hand washing, poor housing conditions and lack of access to adequate and affordable health care (Anegesom 2015).

Diarrheal spreads through contaminated food or drinking-water, or from person-to-person as a result of poor hygiene. The vast majority of these deaths from Diarrheal are among children

under-five years of age living in low- and middle- income countries. Diarrheal due to (personal or domestic hygiene) around the house socio economic factors may affect, directly and indirectly, environmental, behavioral, nutritional, and demographic risk factors (Farthing 2008).

In urban Ethiopia, the median incidence for the under two years of age is 6.5 episodes per child per year. The proportion of mortality associated with diarrheal in Ethiopia is about 22.6% in the different regions with a median of 45 %. It has been found that attempts to reduce diarrheal deaths with vertical programs do not have a major impact unless integrated interventions are directed to persistent diarrheal -malnutrition complex (TESFAHUN 2003).

Published studies conducted between 1994 and 2000 in Ethiopia on the prevalence of under-five Diarrheal showed the variability of the diseases across the country, 11.4% to 37%, Cause of child morbidity and mortality in developing countries is multi-factorial. Exposure of poor environmental, socio-demographic and behavioral factors is causes of morbidity and mortality in under-five children. The child's morbidity depends on the interaction of socio-economic, physical, behavioral and environmental factors. Hence to understand children's morbidity one has to examine the linkage and interactions among the aforementioned factors (Muluken Dessalegn 2011).

1.2. Knowledge Based System

The Knowledge-Based Expert System (KBES) is the first realization of research in the field of Artificial Intelligence (Rajendra Akerkar 2010). In AI, knowledge based system is an intelligent computer program that aims to use task-specific knowledge and inference techniques to solve problems at the level of a human expert. It imitates the decision making ability of a human expert in a particular domain and can also give advices and explanations. Human experts use the knowledge they have about the domain and techniques that lead how to use the knowledge to solve problems. Knowledge based systems handle problems in the same way (Chuks 2012).

The basic idea behind knowledge based system is simply that expertise, which is the vast body of task-specific knowledge, is transferred from a human to a computer. Knowledge based system is a problem solving and decision making system based on knowledge of its task and logical rules or procedures for using knowledge. Both the knowledge and the logic are obtained from the experience of a specialist in the area (Priyanka Sahni April 2015).

1.3. Statement of the Problem

Worldwide diarrheal disease is the second leading cause of death in under-five year children only to pneumonia which accounts for one in nine child deaths. It is responsible for 1.7 billion morbidity and 760, 000 mortality of children every year and kills 2,195 children every day more than malaria, measles, and AIDS combined (Anegesom 2015).

In developing countries, diarrhea is responsible for 25-30% of deaths among children younger than five years of age. Sub-Saharan Africa remains the most affected region by diarrheal mortality and morbidity of children. Approximately 40% of childhood deaths from diarrhea worldwide were occurred in Sub-Saharan Africa by the year 2000, although only 19% of the world's under five population lives in this region (Getahun 2014).

In Ethiopia, as in other developing countries, diarrhea disease is one of child health problems. The recent Ethiopian Demographic Health Survey of 2011 reported that the prevalence of diarrhea in under five children was 13 percent. Other studies done in different parts of Ethiopia have also showed that incidence and prevalence of diarrhea is very high among under five children (AYELE 2014).

Ethiopian Demographic and Health survey 2011 reported that 13% of the children had diarrhea in the two weeks preceding the survey at the national level and in Tigray region. According to the 2010 report of the Ministry of Finance and Economic Development, 20% of the childhood death in the country was due to diarrhea. In Ethiopia diarrhea is the second cause of death among under-five children secondary to pneumonia. Poor sanitation, lack of access to clean water supply and inadequate personal hygiene are responsible for 90% of diarrheal disease occurrence (Anegesom 2015).

Diarrhea disease makes every demand on health facilities and national health budget in developing countries. Almost 30% of persons seeking treatment are estimated, suffering from diarrhea illness. In Ethiopia some of the factors associated with diarrhea in children such as , obtaining water from storage container by dipping, availability of latrine facilities, living in a house with fewer number of rooms, have been identified, diarrhea is still a major public health problem among children under 5 years old (AYELE 2014).

In most developing countries insufficient of medical specialist has increase the mortality of patients suffered from various diseases. The insufficient of medical specialists will never be overcome within a short period of time. Current practice for medical treatment required patients to consult specialist for further diagnosis and treatment. Other medical practitioner may not have enough expertise or experience to deal with certain high-risk diseases. However, the waiting time for treatments normally takes a few days, weeks or even months. By the time the patients see the specialist, the diseases may have already spread out. As most of the high-risk disease could only be cured at the early stage, the patients may have to suffer for the rest of their life (Wan Hussain Wan Ishak 2011).

Computer technology could be used to reduce the number of mortality and reduce the waiting time to see the specialist. The system deals with medical data and knowledge domain in diagnosing patient's conditions as well as recommending suitable treatments for the particular patients. The patients can use the information and monitor their risk level from their home or office without having to consult the physician (Wan Hussain Wan Ishak 2011).

The goal of the design of the knowledge based system is to capture the knowledge of a human expert relative to some specific domain and code this in a computer in such a way that the knowledge of the expert is available to a less experienced user (Vinayak V Kulkarni 2014).

In this study an attempt was made to answer the following research questions:

- ⇒ How to design Knowledge based system for Acute Diarrheal disease diagnosis and treatment?
- ⇒ How to acquire model, represent, and implement knowledge based system prototype for Acute Diarrheal disease diagnosis and treatment?

1.4. Objective of the study

1.4.1. General Objective

The general objective of this research is to design and develop a prototype of knowledge based system that diagnosis and recommend treatments in Tigrigna language for Acute Diarrheal diseases.

1.4.2. Specific Objective

The specific objectives of the study are the following:

- ⇒ To review literature in order to have an understanding on concepts, principles and technologies of knowledge base systems.
- ⇒ To acquire explicit knowledge from domain experts and relevant documents respectively for extracting the domain knowledge used in the real life.
- ⇒ To model and represent the domain knowledge using suitable knowledge representation techniques.
- ⇒ To develop prototype knowledge based system in Tigrigna language that demonstrates the capacity of knowledge based system for diagnosing and treating Acute Diarrheal diseases.
- ⇒ To test and evaluate the performance and user acceptance of the developed prototype.
- ⇒ To forward recommendation and suggestion for future work.

1.5. Scope and Limitations of the Study

The scope of this study is developing prototype knowledge based system using Tigrigna language and evaluating its application. There are a number of Diarrheal diseases in Ethiopia. However, this research study focused only on the common Diarrheal diseases that frequently occurred in Ethiopia that is called Acute Diarrheal disease (አተገ). The domain knowledge selected and prioritized by domain experts. Detailed explanation about the diseases, symptoms, treatments and preventions mechanisms are provided by the system.

1.6. Methodology of the Study

Methodology provides an understanding of how a research is conducted and organized in order to obtain information that is helpful for developing the design of a research. The methods used in this research are described below.

1.6.1. Literature Review

In order to have deep understanding on the problem of this study, it is vital to review several literatures that have been conducted in the field so far. For this reason, related literature such as books, articles, proceeding papers and some other sources that are retrieving from the internet is consulted so that to understand the domain knowledge, concepts, principles and methods that are important for developing knowledge-based systems.

1.6.2. Interviewing Domain Experts

Both organized and non-formal interviews were employed to elicit tacit knowledge from domain experts. Since one of the specific objectives of this research is extracting tacit knowledge which is embedded and personalized in experts mind. For this research, four experts were selected from Adigrate hospital for interview about acute diarrheal disease.

1.6.3. Knowledge Representation and Modeling

After the knowledge is acquired it is represented using rule based knowledge representation method. For this research the knowledge representation method, rule based is chosen because it clearly demonstrates the domain knowledge. In a rule based system much of the knowledge is represented as a rule that is as conditional sentences relating statements of facts with one another. Most human disease diagnosis is predefined sets of rules. There are already defined sets of symptoms that enable to identify the infection. As a result rule based representation method is more appropriate to represent and demonstrate the real domain knowledge in diagnosing Diarrheal infections. Additionally, rule based systems are the most commonly used knowledge representation language in clinical medicine (Sasikumar 2007).

1.6.4. System Development and Implementation Tool

Prolog programming language was used to develop the prototype knowledge based system. Prolog (programming in logic) is one of the most widely used programming language, especially

in the artificial intelligence research, natural language processing, system development, and so on. It is very useful especially on those mentioned areas to specify the situation (rules and facts) and the goal (query). The reason of the selection of this programming language is the features and abilities of the language that incorporate it. Prolog is a declarative language (we specify what problem we want to solve rather than how to solve it) and has the capacity to describe the real world.

SWI Prolog is the most inclusive and widely used Prolog development environment. It has flexible and fast interface. In addition, it is portable to many platforms, including almost all UNIX/Linux platforms and Windows Vista. Additionally, it is non-commercial version of Prolog. So, it can be easily accessed. Therefore, the prototype knowledge based system is developed in SWI Prolog.

1.6.5. Testing and Evaluation

The developed prototype rule based system was tested and evaluated to ensure the performance of the system in meeting towards established objectives. The evaluation process was concerned with system user acceptance validations of the prototype. System user acceptance testing is concerned with issues impacting how well the system addresses the need of the user. To assess human factors visual interaction together with questionnaires methods was used. They evaluated the system by using closed and open ended questionnaires.

1.7. Significance of the Study

The immediate beneficiary of this study is primary healthcare workers (extensions) and practitioner health professionals. Particularly, the prototype has great significance to teach primary health care workers and nurses in order to have well understanding about clinical types of diarrhea. As a result, those health workers can use the system in diagnosing Diarrheal disease on primary care sectors where highly qualified professionals are unavailable. With the proper utilization of knowledge, the knowledge-based systems increase productivity, and enhance problem solving capacity in a flexible manner.

Such systems can also document knowledge for future use and training. This leads to have increased quality in problem solving process. It is also advantageous for remote and rural areas that have scarcity of highly qualified professionals and medication facilities. Hence, the result of

this study will be used as an input for the development of a full-fledged knowledge based system that can be used for diagnosis and treatment of diarrhea.

1.8. Organization of the Study

The remaining part of the thesis is organized as follows: Literature Review (Chapter Two) – In this chapter, conceptualizing the basic ideas of knowledge based system is essential to understand sufficiently the notion of knowledge based systems. So this chapter attempts to give some overview, of knowledge based systems, state the merits of knowledge based systems, explore the applicability of knowledge based systems, assess the architecture of knowledge based systems and discusses the knowledge based system development phases and as well as the frequently dissemination of Diarrheal diseases in Ethiopia.

Chapter three discusses about knowledge acquisition with its technique and knowledge representation model. Methodology of the study used to carry out the research is discussed. The knowledge engineering methodologies, how knowledge for the research is acquired, modeled and verified is provided in detail. The development life cycle used in the research are explained.

Knowledge Base System Development, the knowledge acquisition procedures followed are explained. The represented and implemented knowledge in the computer system is shown. Decision tree was employed to show the generic representation of the system and detailed knowledge representation was presented using IF_THEN representation technique; and Chapter Four explains about system implementation which contains system prototype and user interface.

Chapter Five deals with about system testing and evaluation and finally, Chapter six is discussed about conclusion and recommendation which contain overview research study and feature works.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. INTRODUCTION

Conceptualizing the basic ideas of knowledge based systems is crucial to understand fully the concept of knowledge based systems. So, this chapter tries to discuss some overview of Artificial Intelligence and knowledge based systems, state the worth of knowledge based systems, explore the applicability of knowledge based systems, assess the architecture of knowledge based systems and discusses knowledge based systems development phases are involved.

2.2. An Overview of Artificial Intelligence and Knowledge Base System

Integrating computer technology and artificial intelligence is a promising approach in the provision of quality health delivery services in medicine. Artificial intelligence (AI) is a branch of computer science concerned with the design and implementation of programs which are capable of emulating human thinking skills, such as problem solving, visual perception and language understanding. It is concerned with the creation of computer programs to perform activities which, if performed by a person, would require intelligence (Aderonke A. Kayode 2013).

Artificial Intelligence in Medicine (AIM) as a field emerged in the early 1970's in response to several simultaneous needs, opportunities, and interests. An increased demand for high-quality medical services coupled with the explosive growth of medical knowledge has led to the suggestion that computer programs could be used to assist physicians and other health care providers in discharging their clinical roles in diagnosis, therapy and prognosis (Aderonke A. Kayode 2013).

An important goal of artificial intelligence research is to devise machines to perform various tasks normally requires human intelligence (R. SOLOMONOFF 1966). Artificial intelligence has the advantages over the natural intelligence as it is more permanent, consistent, less expensive, has the ease of duplication and dissemination, can be documented and can perform certain tasks much faster and better than the human (Avneet Pannu 2015).

According to (Raza 2009) there are different types of AI technology such as Expert systems, natural language processing, robotics, speech understanding, speech (voice) recognition, computer vision and scene recognition, intelligent computer-aided instruction, neural computing, intelligent agents, automatic programming, translation of languages, and summarizing news can all be considered AI technologies. The major technologies are expert systems, neural networks, intelligent agents, fuzzy logic, and genetic algorithms.

The early efforts in building Artificial Intelligence programs were intended to create general-purpose problem solvers. However, those attempts were failed. It was difficult to create successful general purpose problem solvers expert systems. This led to the development of expert systems that uses domain specific knowledge to solve problems (Sasikumar 2007).

2.3. Knowledge Based System

Knowledge-based systems (KBS) are an important class of intelligent systems originating from the field of Artificial Intelligence. They can be especially useful for solving complex problems in cases where purely algorithmic or mathematical solutions are either unknown or demonstrably inefficient. Building real-life KBS is a complex task. Since their architecture is fundamental different from classic software, classical software engineering approaches cannot be applied efficiently. Some specific development methodologies, commonly referred to as knowledge engineering, are required. In AI rules are probably the most popular choice for building knowledge based systems that is the so-called rule-based expert systems. Rule based systems (RBS) are used extensively in practical applications, especially in domains such as automatic control, decision support, and system diagnosis. They constitute today one of the most important classes of KBS (Nalepa 2006).

In Artificial Intelligence, knowledge based system is an intelligent computer program that aims to use task-specific knowledge and inference techniques to solve problems at the level of a human expert. It imitates the decision making ability of a human expert in a particular domain and can also give advices and explanations. Human experts use the knowledge they have about the domain and techniques that lead how to use the knowledge to solve problems. Knowledge based systems handle problems in the same way (Chuks 2012).

The area of KBS development has matured over the past two decades. It started with first-generation expert systems with a single flat knowledge base and a general reasoning engine,

typically built in a rapid-prototyping fashion. This has now been replaced by methodological approaches that have many similarities with general software engineering practice. KBS development is best seen as software engineering for a particular class of application problems. These applications problems typically require some form of reasoning to produce the required results (P-H. Speel 2001).

With the proper utilization of knowledge, the knowledge-based systems increase productivity, document rare knowledge by capturing scarce expertise, and enhance problem solving capabilities in most flexible way. Such systems also document knowledge for future use and training. This leads to increased quality in problem solving process. However, the scarcity and nature of knowledge make the KBS development process difficult and complex. The transparent and abstract nature of knowledge is mainly responsible for this. In addition, this field needs more guidelines to accelerate the development process (Akerkar,Sajja 2010).

2.3.1. Advantages of knowledge based system

A chief advantage of knowledge based systems is their low cost compared with the expense of paying an expert or team of specialists. A user-friendly interface to the system allows the user to specify symptoms and to clarify the problem in response to questions asked by the system. The goal is to lead the user to discover a solution to the problem (Peter 1996).

Knowledge based systems are important sets of applications of Artificial Intelligence for both commercial related problems and scientific importance (Abdullah 2006).

And the main inspiration of developing knowledge based system includes:

- ⇒ **Replication of Expertise:** Knowledge based systems are vital to provide many (electronic) copies of an expert's knowledge and it can be consulted even when the expert is not personally available. Expertise may not be available within the needed place and time due to many critical problems such as geographic distance and retirement.
- ⇒ **Union of Expertise:** knowledge based systems integrate knowledge of different expertise in a particular domain and providing in one place the union of what several different experts know about a particular domain.

- ⇒ **Documentation:** In addition, knowledge based systems provide a clear record of the best knowledge available for handling a specific problem. Hence, knowledge based systems are the best technology to preserve expertise knowledge for future use.
- ⇒ **Increase Efficiency and effectiveness:** They help to distribute widely rare human knowledge and minimize human expertise needed at a number of locations at the same time, and with less amount of time. When expertise is unavailable, a knowledge based system can act as an expert on demand to save time. Knowledge based systems can save money by leveraging expert, and allowing users to function at higher level and promoting Consistency. Additionally, knowledge based systems can increase cost-effectiveness in the transfer and dissemination of existing knowledge.
- ⇒ **Used as Learning Tool:** Similarly, knowledge based systems can be used to distribute experts' knowledge in a structured manner. Particularly, they provide beginner with expert advice on a specific subject and aids in training new employees. As a result, knowledge based systems bring greater innovation by allowing creative professionals to explore, understand; discard and rework many alternative paths to a needed solution.

2.3.2. Knowledge Based System Architecture

Architecture is a blue print that helps to represent the structure of the system. System architecture is a conceptual model that defines the structure and guidelines of the system. It also helps to describe set of rules, tools and standards that should be incorporated in the corresponding systems (EJIGU 2012). According to pool (Poole 1999), knowledge based system has its own architecture that depicts its basic components as shown in Figure 2.1 below.

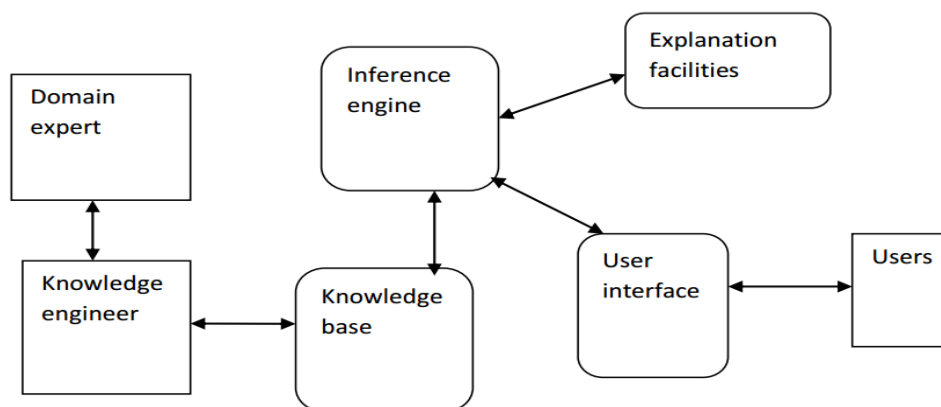


Figure 2.1: Knowledge Based System Architecture

Domain Expert: Domain Expert is a knowledgeable and skilled person capable of solving problems in a specific area or domain. This person has the greatest expertise in a given domain. In the knowledge based system development, the expertise has been captured in the knowledge based system. Therefore, the expert must be able to communicate his or her knowledge, be willing to participate in the knowledge based system development and commit a substantial amount of time to the program development. The domain expert is the most important player in the knowledge based system development team.

Knowledge Engineer: Knowledge engineering can be viewed from two perspectives: narrow and broad. According to the narrow perspective, knowledge engineering deals with knowledge acquisition, representation, validation, inferencing, explanation, and maintenance. Alternatively; according to the broad perspective, the term describes the entire process of developing and maintaining intelligent systems.

The knowledge possessed by human experts is often unstructured and not explicitly expressed. A major goal of knowledge engineering is to help experts articulate what they know and document the knowledge in a reusable form (A. Ranjan 1988). In addition, the knowledge engineer needs to consider what tools to use for building an expert system (Pro.Dr.-ING.HUNGER 2005).

The basic model for knowledge engineering has been that the knowledge engineer mediates between the expert and knowledge base, eliciting knowledge from the expert, encoding it for the knowledge base, and refining it in collaboration with the expert to achieve acceptable performance (Pro.Dr.-ING.HUNGER 2005).

The ability and personality of the knowledge engineer directly influence the expert. Part of successful knowledge acquisition involves developing a positive relationship with the expert. The knowledge engineer is responsible for creating the right impression, positively communicating information about the project, understanding the expert's style, preparing the sessions, and so on. The skills required by knowledge engineers are shown in Technology Insights. The basic model of knowledge engineering portrays teamwork in which a knowledge engineer mediates between the expert and the knowledge base. The following tasks performed by knowledge engineers at different stages of knowledge acquisition (A. Ranjan 1988):

- ⇒ Advise the expert on the process of interactive knowledge elicitation.
- ⇒ Set up and appropriately manage the interactive knowledge acquisition tools.

- ⇒ Edit the un-encoded and coded knowledge base in collaboration with the expert.
- ⇒ Set up and appropriately manage the knowledge-encoding tools.
- ⇒ Validate application of the knowledge base in collaboration with the expert.
- ⇒ Train clients in effective use of the knowledge base in collaboration with the expert by developing operational and training procedures.

Figure 2.2 shows the process of knowledge engineering and the relationships among the knowledge engineering activities. Knowledge engineers interact with human experts or collect documented knowledge from other sources in the knowledge acquisition stage. The acquired knowledge is then coded into a representation scheme to create a knowledge base. The knowledge engineer can collaborate with human experts or use test cases to verify and validate the knowledge base. The validated knowledge can be used in a knowledge-based system to solve new problems via machine inference and to explain the generated recommendation (Ranjan 2002).

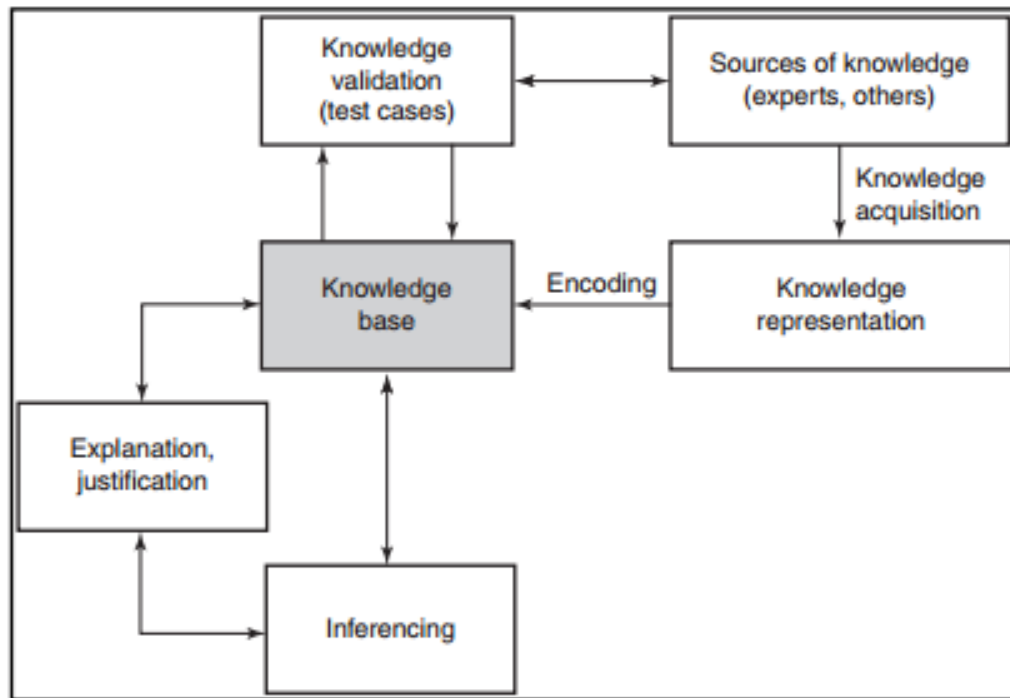


Figure 2.2: Process of Knowledge Engineering

The results show that the system has had the following advantages:

- ❖ It reduced the time required to reach diagnostic decisions.

- ❖ It now formulates more consistent diagnostic decisions.
- ❖ It better utilizes the hospital's information systems.

Knowledge Base: The permanent knowledge of an expert system is stored in a knowledge base. It contains the information that the expert system uses to make decisions. This information presents expertise gained from top experts in the field. This knowledge comes in the form of facts and rules. Facts are minimal elements of the knowledge which must be identified before anything else. Rules consist of *_if...then* 'statements, where a given set of conditions will lead to a specified set of results (Aderonke A. Kayode 2013). It is the duty of the experts in a particular domain to research and compile data to fill into a knowledge base for use by an expert system to meet demand of expert ideas. As the system matures, new rules maybe added and existing ones maybe amended or deleted from the knowledge base with the use of the knowledge acquisition module.

All these are normally done to take into account inventions, innovations and discoveries as technology improves. In addition, expert knowledge is formally represented in a knowledge base which means that the system cannot forget unlike what humans do with the increase in time (Chuks2 2012).

Inference Engine: The inference engine is a computer program that controls the execution, and uses rules to respond to a query and determine whether a suitable match can be found in the fact list, through backward or forward chaining. It determines which rules will be applied to a given question and in what order by using information in the knowledge base (Aderonke A. Kayode 2013). This acts rather like a search engine, examining the knowledge base for information that matches the user's query (Negnevitsky 2005). The purpose of the inference engine is to seek information and relationships from the knowledge base and to provide answers, predictions, and suggestions in the way a human expert would (Ayman Al Ahmar 2010).

Explanations Facility: The explanation facilities enable the user to ask the expert system how a particular conclusion is reached and why a specific fact is needed. An expert system must be able to explain its reasoning and justify its advice, analysis or conclusion (Negnevitsky 2005). Many system can retrace the reasoning sequence employed and explain what was done at each step and why. This explanatory capability enables the user to accept or reject the system's conclusions if he disagrees with its reasoning and aids the expert in debugging the system. The usefulness of

the explanatory system derives from the fact that the reasoning performed reflects the user's own reasoning processes (Firschei 1985).

Human experts are often asked to explain their views, recommendations, or decisions. If ES are to mimic humans in performing highly specialized tasks, they too need to justify and explain their actions. An explanation is an attempt by an ES to clarify its reasoning, recommendations, or other actions (e.g., asking a question). The part of an ES that provides explanations is called an explanation facility (or justifier). The explanation facility has several purposes (Ranjan 2002).

- ⇒ Make the system more intelligible to the user.
- ⇒ Uncover the shortcomings of the rules and knowledge base (i.e., debugging of the systems by the knowledge engineer).
- ⇒ Explain situations that were unanticipated by the user.
- ⇒ Satisfy psychological and social needs by helping the user feel more assured about the actions of the ES.
- ⇒ Clarify the assumptions underlying the system's operations to both the user and the builder.
- ⇒ Conduct sensitivity analyses. (Using the explanation facility as a guide, the user can predict and test the effects of changes on the system.)

Explanation in rule-based ES is usually associated with a way of tracing the rules that are fired during the course of a problem-solving session. This is about the closest to a real explanation that today's systems come, given that their knowledge is usually represented almost exclusively as rules that do not include basic principles necessary for a human-type explanation (Ranjan 2002).

Explanation is an extremely important function because understanding depends on explanation, thus making implementation of proposed solutions easier. For example, an experiment that Ye and Johnson (1995) conducted with auditors indicated that ES explanation facilities can make a system's advice more acceptable to users. Ye and Johnson also found that justification is the most effective type of ES explanation for bringing about a change in users' attitudes toward a system (Ranjan 2002).

User Interface: The User Interface is one of the major components of an expert system which allows bi-directional communication between system and user is considered to be a critical part of the success of an expert system. The user interface consists of all screens of interaction

between the user and the ES (Ayman Al Ahmar 2010). The user interface is generally not a part of the ES technology, and was not given much attention in the past. However, it is now widely accepted that the user interface can make a critical difference in the perceived utility of a system regardless of the system's performance (Edward Feigenbaum Chair May 1993). The purpose of the user interface is to ease use of the expert system for developers, users, and administrators (Abraham 2005).

2.4. Phases of Knowledge Based System Development

2.4.1. Knowledge acquisition

Knowledge acquisition is a general term used to represent the process of acquiring expert expertise. It is used for the process of developing a computational problem-solving model, specifically a program to be used in some consultative or advisory role. Programs built based on knowledge acquisition from experts is called "Expert Systems". No doubt that Knowledge acquisition plays a significant function in building knowledge based system (Dr. Adel Hamdan Mohammad 2010).

In designing expert systems, the process of eliciting information has been termed knowledge acquisition. According to Hoffman (1987), knowledge acquisition (elicitation) involves extracting problem-solving expertise from knowledge sources, which are usually domain experts. Waterman (1985) defines knowledge acquisition as the process of extracting, structuring and organizing knowledge from several sources, usually human domain experts, so it can be used in a program. This knowledge acquisition process involves one or more knowledge engineers interacting with one or more domain experts, each of which brings a certain set of attributes to this interaction with the goal of developing a shared representation or model, of the expert's problem solving processes.

The acquisition of knowledge is a major and critical phase in the development of an expert system. Knowledge acquisition is considered by many to be the most difficult and precarious stage in the knowledge engineering process. Rook & Croghan (1989) and Hwang (1994), amongst others, stated that knowledge acquisition has often been described as the bottleneck in knowledge based systems development.

The objective of knowledge acquisition is to gather the required knowledge, interpreting the acquired knowledge, analyzing and validating the knowledge content. Based on the acquired knowledge, the KBS was designed using decision tree model. Therefore, knowledge acquisition process of this thesis was based on domain expert interviewing, observing and reviewing of related documents (Ergado 2016). Similarly, the success of any expert system depends on its knowledge acquired in initial phases of building the expert system.

So the emphasis in building an expert system should be on the knowledge acquisition phase (Dr. Adel Hamdan Mohammad 2010).

O'Neil (1989) attempted through surveys to demonstrate why the vast majority of expert systems fail. Some of the reasons noted by him and others include:

1. The lack of user participation in design (Rees, 1993);
2. The lack of structure and organization of knowledge acquisition (McGraw & Harbison-Briggs, 1989);
3. Communication problems between the knowledge engineer and the domain expert (O'Neil, 1989; Jeng, Lieng & Hong, 1996);
4. Failure in identifying the right candidates for knowledge acquisition (Stein, 1993);
5. Failure of verification and validation.

2.4.2. Knowledge Acquisition Techniques

Key to the success of the design and development of the expert system is the choice of the correct or most appropriate technique for knowledge acquisition. As noted by Niederman (1996), much research is available discussing the various techniques. Several knowledge acquisition techniques include structured and unstructured interviews, “constrained-processing tasks” including both simulation of familiar tasks and the use of scenarios, and the use of “tough cases”. Byrd, Cossick and Zmud’s (1992) list includes observation of the expert in action, unstructured elicitation which corresponds to unstructured interviews, mapping domain knowledge as a combined effort between the knowledge engineer and expert to develop a cognitive map, formal analysis of the domain, and structured elicitation corresponding to structured interviewing. Byrd, Cossnick & Zmud (1992) agree that it be best to use the above techniques in some combination, depending on what works in a particular environment (Niederman, 1996). Choices include

interviewing, observations and protocol analysis (Wolfgram, Dear & Galbraith, 1987), among other techniques.

Transferring expert expertise is not an easy task. To understand the problem of knowledge transferring, it is important to understand how expert deals with his expertise. Also the domain expert has an amount of knowledge (facts and rules) which usually not aware and so he does not know exactly what is needed for the expert system. Also some experts lack computational and representational power. Knowledge engineer has a very important role in building an expert system. The interaction between a knowledge engineer and the domain expert affects the performance of the resulted expert system. So knowledge engineer must be aware of the methods used for knowledge elicitation and have an excellent idea about the best method used for knowledge acquisition based on the type of knowledge and type of organization (Dr. Adel Hamdan Mohammad 2010). However, extracting knowledge from a human expert is a difficult process – it is often called the ‘knowledge acquisition bottleneck’. Quite often experts are unaware of what knowledge they have and the problem-solving strategy they use, or are unable to verbalize it. Experts may also provide us with irrelevant, incomplete or inconsistent information (Negnevitsky 2005).

Usually we start with reviewing documents and reading books, papers and manuals related to the problem domain. Once we become familiar with the problem, we can collect further knowledge through interviewing the domain expert. Then we study and analyze the acquired knowledge, and repeat the entire process again. Knowledge acquisition is an inherently iterative process.

Interview and observation are very important techniques in knowledge acquisition since using them in a proper way allows knowledge engineers to acquire tacit knowledge (highly personal knowledge which is hard to formalize and difficult to communicate or share with others) and explicit knowledge (can be expressed in words and numbers and shared in the form of scientific data). Interviewing a domain human expert with an excellent preparation for the interview can result in a huge amount of useful explicit knowledge acquisition. Here are some good ways to prepare for an interview with experts: identify your domain area in a very specific way; determine exactly what type of knowledge (or particular problem-solving knowledge) you need to acquire; put an open and closed questions to clearly satisfy your request.

Observation is considered as an excellent method for acquiring tacit knowledge. This type of knowledge is hard to elicit using regular methods such as interviewing or other methods. It is useful to use monitoring programs in large organizations especially in industrial organizations. Monitoring experts during performing sensitive tasks can be very useful for acquiring tacit knowledge embedded in expert minds and then if the organization makes a discussion session with all interested employees with the experts to explain their behavior and to clarify every action done during performing their sensitive tasks will be very helpful in the process of knowledge acquisition (Dr. Adel Hamdan Mohammad 2010).

2.4.3. Knowledge Modelling

Models are used to capture the essential features of real systems by breaking them down into more manageable parts that are easy to understand and to manipulate. Models are very much associated with the domain they represent. That domain will define their practicing communities, modelling languages and the associated tools used. “A model is a simplification of reality”. Real systems are large entities consisting of interrelated components working together in a complex manner. Models help people to appreciate and understand such complexity by enabling them to look at each particular area of the system in turn. Models are used in systems development activities to draw the blueprints of the system and to facilitate communication between different people in the team at different levels of abstraction. People have different views of the system and models can help them understand these views in a unified manner (M.S. ABDULLAH 2002). Knowledge should be modeled on a higher level than that of exploited knowledge representation formalisms, to avoid premature design decisions and to facilitate communication with domain experts (Rafea 1994).

The modelling process constructs conceptual models of knowledge-intensive activities. During the knowledge acquisition stage, most of the knowledge is unstructured and often in tacit form. The knowledge engineer will try to understand both the tacit and the explicit part of the knowledge and then use simple visual diagrams to stimulate discussion amongst users and knowledge experts. This discussion process generates ideas and insights as to how the knowledge is used, how decisions are made, and the factors that motivate and so on. The knowledge engineer then has to construct the conceptual model from what has been discussed during the knowledge acquisition stage. This communicates the knowledge to the information

specialist who will transform the model into workable computer programs or codes. This approach is similar to that of software engineering where models are used to represent user requirements. The main difference here is that in knowledge engineering it is the modelling of knowledge and its related flows whereas software engineering models the information and process flow (M.S. ABDULLAH 2002).

More recently, there has been a paradigm shift in knowledge engineering. Knowledge engineering is no longer simply a means of mining the knowledge from the expert's head. It now encompasses "methods and techniques for knowledge acquisition, modelling, representation and use of knowledge". The shift towards the modelling approach has enabled knowledge to be re-used in different areas of the same domain. In the past, most knowledge systems had to be developed from scratch every time a new system was needed, and it could not interact with other systems in the organization. The paradigm shift towards a modelling strategy has resulted in reducing development costs (M.S. ABDULLAH 2002).

Experience has shown that eliciting and explicating knowledge is best seen as a modelling activity, also called conceptual modelling. This activity takes the form of a specialized type of requirements engineering. KBS construction methods typically provide tools for knowledge analysis in the form of so-called conceptual models of knowledge or simply knowledge models. A knowledge model provides an implementation-independent specification of knowledge in an application domain. Typically, a knowledge model provides formats for writing down both static domain knowledge (rules, classes, relations) as well as reasoning strategies in which this domain knowledge is used to solve a particular problem. An important feature of knowledge engineering research is that it provides us with predefined, reusable models for certain knowledge-intensive tasks, also called problem-solving methods (P-H. Speel 2001).

Models are important for understanding the working mechanisms within a knowledge-based system, such as: the tasks, methods, how knowledge is inferred, the domain knowledge and its schemas. Conceptual modelling is central to knowledge engineering. Modelling contributes to the understanding of the source of knowledge, the inputs and outputs (M.S. ABDULLAH 2002).

2.4.4. Knowledge representation

Knowledge representation is a process of transferring the knowledge from a human expert to a knowledge base of an expert system. The knowledge base of an ES contains both factual and

heuristic knowledge. Knowledge representation is the method used to organize the knowledge in the knowledge base. Knowledge bases must represent notions as actions to be taken under circumstances, causality, time, dependencies, goals, and other higher-level concepts (Makhubele 2012).

Furthermore, the acquired knowledge should be immediately documented in a knowledge representation scheme. At this initial stage, the selected knowledge representation strategy might not be permanent. However documented knowledge will lead the knowledge engineer/ developer to better understanding of the system and provides guidelines to proceed further. Rules, frames, scripts and semantic network are the typical examples of knowledge representation scheme. It is responsibility of the knowledge engineer to select appropriate knowledge presentation scheme that is natural, efficient, transparent, and developer friendly. One may think for hybrid knowledge representation strategies like rules within the frames in slots like “on need” and “on request”; semantic network of default frames (Akerkar,Sajja 2010).

Rule Based Systems: Knowledge is represented in production rules or simply rules. Rules are expressed as IF-THEN statements which are relatively simple, very powerful as well as very natural to represent expert knowledge. An example of a simple rule is shown below:

IF the sky is cloudy,

THEN bring an umbrella.

For an expert system using rule-based methods, the domain knowledge is represented as sets of rules. When the IF part of a rule is satisfied by the facts, the action specified by the THEN part is performed under a control system i.e. a rule interpreter/sequencer. The rule’s action may modify the set of facts in the knowledge base such as by adding new fact. This would therefore produce inference chains which can be either forward chaining or backward chaining and can be displayed to the user to help explain how the system reached its conclusions. A major feature of a rule-based system is its modularity and modifiability which allow for incremental improvement and fine tuning of the system with virtually no degradation of performance.

Amongst the above techniques, rule-based methods are most popular and are commonly used as the knowledge-base in expert systems since their advantages generally outweigh their disadvantages (Peter 1996).

Forward Chaining: Forward chaining is the data-driven reasoning. The reasoning starts from the known data and proceeds forward with that data. Each time only the topmost rule is executed. When fired, the rule adds a new fact in the database. Any rule can be executed only once. The match-fire cycle stops when no further rules can be fired. Forward chaining is essentially data driven. That is, the system starts with the initial set of elements in the working memory and keeps on firing rules until there are no rules which can be applied or the goal has been reached. In effect, the system is moving forward from the current state to a goal state. This strategy is suitable for applications in which the number of goal states is large. That is, there is no single, unique goal state. The goal state is required to satisfy some constraints. The tasks of planning, design and synthesis are in general best suited for forward chaining (Sasikumar 2007).

Backward Chaining: Backward chaining is a goal driven strategy. Backward chaining involves decomposing a problem into sub-problems and solving each one of them. That is, the goal is reduced to sub-goals and each sub-goal is reduced further, and so on, until they are solvable directly (Sasikumar 2007).

On a computer, the program starts with a goal to be verified as either true or false. Then it looks for a rule that has that goal in its conclusion. It then checks the premise of the rule in an attempt to satisfy the rule. It examines the assertion base first. If the search fails there, the program looks for another rule that has the same conclusion as the first rule. An attempt is then made to satisfy the second rule. The process continues until all the possibilities that apply are checked or until the rule initially checked (with the goal) is satisfied. If the goal is proven false, then the next goal is tried. In some inferencing, the rest of the goals can be tried in succession, even if the goal is proven true (Ranjan 2002).

In the context of rule based systems, backward chaining is achieved by the following algorithm (Sasikumar 2007):

1. Assume the goal is to infer a fact, say G. Set current goal to G.
2. Find the rules which can infer G. If there are no rules for G use step 4.
3. In each of the rules look at the sub-goals to be solved. Treat each sub-goal as a new goal and repeat steps 2 and 3 with the new goal as current goal. If all sub-goals in a rule succeed, the conclusion of the rule can be added to the working memory.
4. If G matches a working memory element, it succeeds or else it fails 4.

Backward chaining is used when the number of possible initial states are large, compared to the number of goal states. The tasks of classification and diagnosis are best suited for backward chaining.

Case-Based Representation: Case-Based Representation is a methodology for problem solving that focuses on the reutilization of past experience. It is based on solutions, information and knowledge available in similar problems previously solved. The implementation of this method requires the existence of a knowledge base that contains the cases that contain previous experience. CBR's basic principle is that similar problems will have similar solutions. In CBR, new solutions are generated not by chaining, but by retrieving the most relevant cases from memory and adapting them to new situations. That is, CBR solves new problems by adapting previously successful solutions to similar problems. Thus in CBR, reasoning is based on remembering (Cabrera 2010). CBR works in much the same manner as our memories. We learn new things, we learn more about old things, and we retain and reuse new information. It will differ from logic or rules based engine in aspects of recording and retrieving cases (Aderonke A. Kayode 2013).

In CBR the structures handled are known as **cases** (Cabrera 2010). A case is a contextualized piece of knowledge representing an experience. It contains a past lesson, that is, the content of the case and the context in which the lesson can be used. Typically a case comprises: the problem, the solution to the problem, and the outcome after the solution has been applied to the problem (Aderonke A. Kayode 2013). So that cases in the knowledge base represent collection of specific experienced, captured and learned situations of the application domain. Each case is constituted with three main parts (Ranjan 2002).

- **Situation/Problem description:** describes specific circumstances, states of a situation, and state of the environment when this particular case is recorded.
- **Solution:** provides how the problem described in the problem description was solved or treated in a particular instance.
- **Outcome:** describes the final result or consequence and feedback gained from following the proposed solution.

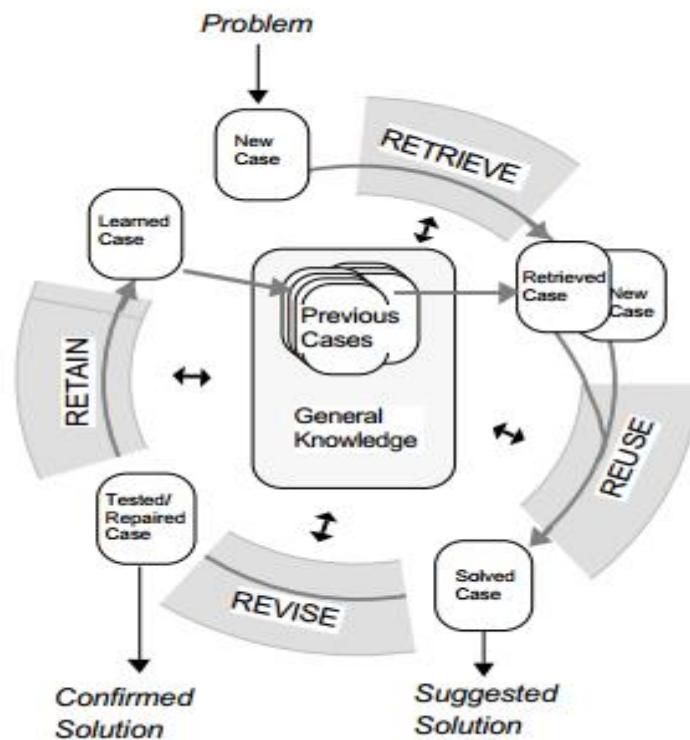


Figure 2.3: The Case-based Reasoning (Agnar Aamodt 1994).

Whenever, a new input case has to be dealt with, the case-based system performs inference in four phases known as the CBR cycle: (i) retrieve, (ii) reuse, (iii) revise and (iv) retain. The retrieval phase retrieves from the case base the most relevant stored case(s) to the new case. Indexing schemes and similarity metrics are used for this purpose. Indexing enables the efficient retrieval of relevant cases from the case base, thus limiting the search time. Similarity metrics assess the relevance of the retrieved cases to the new case. A simple approach to similarity assessment is the nearest neighbor matching. One or more retrieved cases, deemed most relevant to the new case, are used for dealing with it. In the reuse phase, a solution for the new case is created based on the retrieved most relevant case(s). The revise phase validates the correctness of the proposed solution, perhaps with the intervention of the user. Finally, the retain phase decides whether the knowledge learned from the solution of the new case is important enough to be incorporated into the system. Quite often the solution contained in the retrieved case(s) is adapted to meet the requirements of the new case. Usual adaptation methods are substitution, transformation and derivational replay. For the adaptation task, domain knowledge, usually in

the form of rules, is employed. Incorporation of knowledge during the operation of a case-based system enhances its reasoning capabilities.

This is a major advantage, since the knowledge base of intelligent systems employing other representations remains rather static during operation (Prentzas 2007).

To use Case-based Reasoning a few problems have to be solved: A representation form for cases has to be determined, an appropriate retrieval algorithm has to be selected and an infinite growth of the case base has to be avoided e.g. by clustering cases into prototypes and removing redundant cases or by restricting the case base to a fixed number of cases and updating the case base during an expert consultation session, but the main problem of Case-based Reasoning is the adaptation task. Little research has been undertaken on this topic and only formal adaptation models, but no general methods have been developed so far. The adaptation still depends on domain and application characteristics. Case-based Reasoning seems to be a suitable technique for medical knowledge based systems. However, the adaptation task is the bottleneck that has to be solved. Though adaptation is sometimes a rather easy task in medical application it may become an insurmountable difficulty (Rainer Schmidt 2001).

Frame: If we need to focus on the properties of certain objects, then using frames and objects is a good choice. A frame is a data structure that includes all the knowledge about a particular object. This knowledge is organized in a special hierarchical structure that permits a diagnosis of knowledge independence. Frames are basically an application of object-oriented programming for artificial intelligence and ES. Frames, as in frames of reference, provide a concise structural representation of knowledge in a natural manner. In contrast to other representation methods, with frames, the values that describe one object are grouped together into a single unit called a frame. Thus, a frame encompasses complex objects, entire situations, or a managerial problem as a single entity. The knowledge in a frame is partitioned into slots. A slot can describe declarative knowledge (e.g., the color of a car) or procedural knowledge (e.g., “activate a certain rule if a value exceeds a given level”) (Fensel et al., 1998 and Jackson, 1999).

The advantage of using frame based approach is its expressive power, easy to set up slots for new properties and relations, easy to include default information and easy to detect missing values. Its drawback includes: difficult to program, difficult for inference, lack of inexpensive software (Gobena 2014).

Semantic Network: A semantic network is widely used as knowledge representation technique. It represents the connection between objects or class of objects (Gobena 2014). They are graphical depictions of knowledge composed of nodes and links that show hierarchical relationships between objects (Russell and Norvig, 2002). It is made up of a number of circles, or nodes, that represent objects and descriptive information about the objects.

An object can be any physical item, such as a book, a car, a desk, or even a person. Nodes can also be concepts, events, or actions. A concept might be the relationship between supply and demand in economics, an event such as a picnic or an election, or an action such as building a house or writing a book. Attributes of an object can also be used as nodes. These might represent size, color, class, age, origin, or other characteristics. In this way, detailed information about objects can be presented (A. Ranjan 1988).

One of the most interesting and useful facts about a semantic network is that it can show inheritance. Because a semantic network is basically a hierarchy, the various characteristics of some nodes actually inherit the characteristics of others. Semantic networks are used basically to provide visual representation of relationships and can be combined with other representation methods (A. Ranjan 1988). However, semantic networks have problems in knowledge representation which include: no internal structure of nodes, relationships between multiple nodes is not possible and no easy way to represent heuristic information, meaning attached to nodes might be ambiguous and exception handling is difficult (Gobena 2014).

2.5. Knowledge Based Systems Development Tools

For many years Lisp has been a language of choice for symbolic computation. Features of Lisp are: programs are represented by list structures, and primitive operations are operations on lists. Lisp is the foundation of many expert systems and shells, such as CLIPS. In last decades it was extended in many ways, including object-oriented framework CLOS. There are, however, problems with Lisp. The main problem is that lists have limited knowledge representation capabilities. Another is that no strong programming methodology has emerged from Lisp-based tools. There is a number of different dialects of Lisp language too.

Prolog is both flexible and powerful, with strong logical foundations. It has facilities for both knowledge representation and processing. Opposed to Lisp which is a symbolic language, Prolog

is a declarative one. However, it does have dual semantics, both declarative and procedural. It is well-suited to symbolic rather than numerical problems.

Since there is only a small semantic gap between expert-systems and Prolog, the language is an ideal tool for practical development of these systems.

The Prolog language is based on predicate logic. Prolog clauses are Horn clauses from the logical point of view. In order to find solutions (satisfy goals) Prolog uses the resolution rule and unification. Prolog is studied in detail in. It has some important features to support logic-based reasoning. The Prolog inference engine uses backward-chaining with backtracking and recursion.

Meta programs treat other programs as data. They are used to help in both understanding and building knowledge-based systems. Prolog is almost unique in the extent to which it can serve as its own meta-language. A Prolog program can create new goals, examine itself, and modify the inference engine, blurring the distinction between program and data. Prolog-based meta-interpreters are ideal to build forward-chaining inference engines (Nalepa 2006).

2.6. Knowledge Based System for Integrated Development

The Knowledge-based systems can be used for interpretation, prediction, diagnosis, design, planning, monitoring, debugging, repair, instruction, control, etc. Such advanced technology should be made available in urban and rural areas to utilize expert knowledge for holistic development. Such systems export knowledge in underdeveloped and remote area where expertise is rare and costly. Hence, knowledge-based systems should be at the primary consideration while designing the development plan for a nation. The share of AI/KBS systems in IT is improved significantly (Rajendra Akerkar 2010).

In addition, today's KBS are easier to use, less expensive and integrate well with traditional technologies, so it can provide a fundamental technology to the majority of the applications for today's scenario. The four major dimensions of the rural development process namely; Economical, Social, Physical and Health development are considered for the holistic development. Major resources for development are considered as Natural Resources, Human Resources, Livestock and Agricultural Resources.

According to Sajja and Akerkar (2010), the knowledge based system applications classified according to the above dimensions & resources can be represented in the Figure 2.4 below.

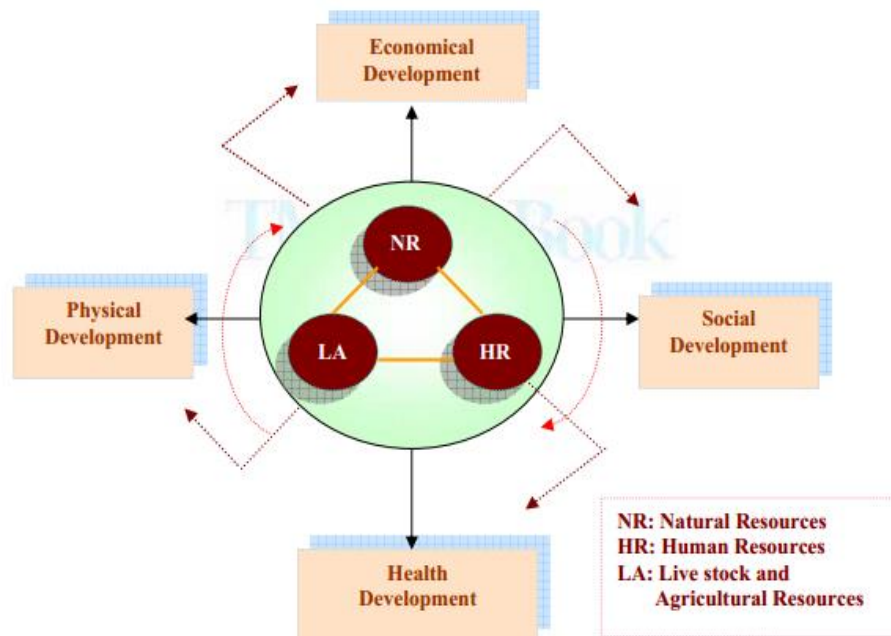


Figure 2.6.1: Dimensions of Development through Knowledge-Based Systems.

According to Sajja and Akerkar (2010) described the Application of knowledge based systems in different dimensions as mentioned in the Table 1 below.

In Physical Development	Economic Development
<ul style="list-style-type: none"> ⇒ KBS for infrastructural planning Network monitoring systems ⇒ KBS for resource sand material management ⇒ Knowledge-based planning for land use and land reform ⇒ KBS for river and land use management ⇒ KBS for soil health card for villagers ⇒ KBS for intelligent manufacturing and new product development 	<ul style="list-style-type: none"> ⇒ Employment exchange services ⇒ Market reforms/information systems ⇒ New product development advisory ⇒ Business selection advisory ⇒ Tax planning system ⇒ Knowledge-based planning of agricultural products ⇒ Knowledge-based planning for agricultural inputs ⇒ Knowledge-based diagnosis for plants and animal diseases

Social Development	Health Improvement
<ul style="list-style-type: none"> ⇒ Cultural information ⇒ Tourism portal ⇒ Identity/ration card ⇒ Voters identification and election related systems ⇒ Intelligent system to identify suitable beneficiaries for Government/NGO schemes ⇒ Child and women health/nutrition systems ⇒ Community health ⇒ e-learning 	<ul style="list-style-type: none"> ⇒ Government schemes information system ⇒ Diet planning system ⇒ Disease diagnostic system ⇒ Disease diagnostic system for cattle and livestock ⇒ Patient monitoring system ⇒ Medical insurance ⇒ KBS monitoring in surgical process ⇒ KBS for guided neuro-surgery

Table 1: Application of Knowledge Based System for Development

2.7. Knowledge Based System Application in Medical

Artificial Intelligence in Medicine (AIM) as a field emerged in the early 1970's in response to several simultaneous needs, opportunities, and interests. An increased demand for high-quality medical services coupled with the explosive growth of medical knowledge has led to the suggestion that computer programs could be used to assist physicians and other health care providers in discharging their clinical roles in diagnosis, therapy and prognosis.

One of the first uses of AI on a practical level was the coupling of expert medical knowledge with computer-based technology. As early as the 1960s, computer scientists and physicians recognized the possibility that computers could assist doctors in the diagnosis and treatment of diseases (Aderonke A. Kayode 2013).

Working as a team, Feigenbaum, Buchanan and Lederberg developed DENDRAL, the first successful knowledge-based system. The key to their success was mapping all the relevant

theoretical knowledge from its general form to highly specific rules ('cookbook recipes') (Feigenbaum et al., 1971).

DENDRAL marked a major 'paradigm shift' in Artificial Intelligence: a shift from general purpose, knowledge-sparse, weak methods to domain specific, knowledge intensive techniques. The aim of the project was to develop a computer program to attain the level of performance of an experienced human chemist. Using heuristics in the form of high-quality specific rules – rules-of-thumb – elicited from human experts, the DENDRAL team proved that computers could equal an expert in narrow, defined, problem areas.

The DENDRAL project originated the fundamental idea of the new methodology of expert systems – knowledge engineering, which encompassed techniques of capturing, analyzing and expressing in rules an expert's 'know-how'. DENDRAL proved to be a useful analytical tool for chemists and was marketed commercially in the United States.

The next major project undertaken by Feigenbaum and others at Stanford University was in the area of medical diagnosis. The project, called MYCIN, started in 1972. MYCIN was a rule-based expert system for the diagnosis of infectious blood diseases. It also provided a doctor with therapeutic advice in a convenient, user-friendly manner (Shortliffe, 1976).

The researchers working with medical diagnosis by computer made major contributions to the development of Expert Systems. A particularly noteworthy contribution was that of Buchanan and Shortliffe (Buchanan and Shortliffe, 1984).

Shortliffe came up with a simple calculus of certainty factors which enabled one to use information such as this and to combine evidence from many individual bits of information. MYCIN (Buchanan and Shortliffe, 1984) was a pioneering ES which demonstrated the value of this technique of reasoning under uncertainty. MYCIN deals with the identification and treatment of blood infections. It handled diagnosis and suggested appropriate medication and dosage. It used a variety of information, including patient's complaints and pathological laboratory reports. Even healthy people harbour bacteria, and therefore pathological tests could be occasionally misleading. MYCIN took such possibly misleading evidence and managed to use it intelligently. It also had information reflecting the fact that a bacterium normally susceptible to a given antibiotic may turn out, in some individuals, to be resistant to that antibiotic.

The very high quality performance of MYCIN, in the face of such uncertainty, went a long way to convince the world of the power of the ES paradigm.

Another probabilistic system that generated enormous publicity was PROSPECTOR, an expert system for mineral exploration developed by the Stanford Research Institute (Duda et al., 1979). The project ran from 1974 to 1983. Nine experts contributed their knowledge and expertise. To represent their knowledge, PROSPECTOR used a combined structure that incorporated rules and a semantic network. PROSPECTOR had over a thousand rules to represent extensive domain knowledge. It also had a sophisticated support package including a knowledge acquisition system.

PROSPECTOR operates as follows. The user, an exploration geologist, is asked to input the characteristics of a suspected deposit: the geological setting, structures, kinds of rocks and minerals. Then the program compares these characteristics with models of ore deposits and, if necessary, queries the user to obtain additional information. Finally, PROSPECTOR makes an assessment of the suspected mineral deposit and presents its conclusion. It can also explain the steps it used to reach the conclusion. PROSPECTOR performed at the level of an expert geologist and proved itself in practice.

The expert systems mentioned above have now become classics. A growing number of successful applications of expert systems in the late 1970s showed that AI technology could move successfully from the research laboratory to the commercial environment. During this period, however, most expert systems were developed with special AI languages, such as LISP, PROLOG and OPS, based on powerful workstations. The need to have rather expensive hardware and complicated programming languages meant that the challenge of expert system development was left in the hands of a few research groups at Stanford University, MIT, Stanford Research Institute and Carnegie-Mellon University. Only in the 1980s, with the arrival of personal computers (PCs) and easy-to-use expert system development tools – shells – could ordinary researchers and engineers in all disciplines take up the opportunity to develop expert systems. A 1986 survey reported a remarkable number of successful knowledge based system applications in different areas: chemistry, electronics, engineering, geology, management, medicine, process control and military science (Waterman, 1986). Although Waterman found

nearly 200 expert systems, most of the applications were in the field of medical diagnosis. Seven years later a similar survey reported over 2500 developed expert systems (Durkin, 1994).

2.7.1. Review of Related Works

There are several of researches done locally on Knowledge Based Expert System domain area. Among those research studies are reviewed with their objective, design method, knowledge representation, modeling and implementation and finally the research results are discussed as follows.

Developed the potential for applying KBS for diagnosis of acute respiratory tract infections. The research was conducted using rule-based representation technique to find solution for the problem of preserving domain expert's knowledge on the diagnosis of acute respiratory tract infections. Therefore, to solve such problem knowledge about the diagnosis of acute respiratory tract infections was acquired from domain experts and secondary sources. Then, the acquired knowledge was modeled using decision trees and represented in the form of production rules. Prolog programming language has been used to implement the prototype system. In this study, he recommended for further study to develop an expert system for diagnosis of respiratory infections (SOLOMON 2010).

The research study aimed to diagnosed patient with anxiety mental disorder by developing prototype for Knowledge Based System that simulates the Services of Psychiatrists and psychologists. In this study decision tree used to represent the knowledge that acquired. The research study followed Rule Based Reasoning approach using, if then rules and used backward chaining reasoning mechanism to inference the rules. The research study to fill the gap that existed in medical domain for mental disorder patient problem and lack Knowledge, to address problems the research study provide alternative solution to diagnosed mental disorder. The prototype system was developed using SWI-prolog editor tool. The research study Result shows 86% of the performance of the prototype was validated and 85% of the prototype system accuracy was evaluated (SEBLEWONGEL 2011).

The research to investigate the applicability of rule based reasoning approach in the development of Knowledge Based System for Hospital triage service to improve the quality Decision made by general practitioners and to provide effective service to the patient. The research study used decision tree knowledge representation technique to represent acquired Knowledge and the rule

structured using if then rules. The research study starts fill the gap of triage treatment in Hospital not properly categories of the disease type, patient forced to pay addition cost and spending a lot of time to get service in Hospital. To address those problem the research study develop KBS prototype to reduce the repetition of task and waiting time in Hospital. It is also helpful to human expert by providing the required knowledge. The prototype system was developed using SWI-prolog editor tool. The research study Result show 85% of the performance of the prototype was validated and 80% of the prototype system accuracy was evaluated (TAGEL 2013).

The research was focused on the area of Agriculture for coffee diseases diagnosis and treatments. Its goal was to design Knowledge Based System to diagnosis common coffee disease and provide treatments. It is also helpful that provide information for non-experts about coffee production. It uses decision tree model to represent the acquired knowledge using if then rules Knowledge structured. Then, the knowledge is represented using production rule and the prototype system was developed using SWI-Prolog editor tool. The prototype system registered 83.6% performance after extensively tested and evaluated (Berhanu 2012).

The research was to develop knowledge Based System for Cereal Crop disease diagnosis and treatment that assist Agriculture experts. In the research study decision tree was used to represent the knowledge that acquired from the experts. It uses Rule Based Reasoning approach using if then rules and backward reasoning mechanism to inference the rules. Then, the knowledge is represented using production rule and the prototype system was developed using SWI-Prolog editor tool. The prototype system registered 80.9% performance after extensively tested and evaluated (EJIGU 2012).

The study was developed a prototype of KBS for blood transfusion. This study was conducted using rule-based representation technique to solve the problem of existence of knowledge gap among the domain experts on which blood type to transfuse for patients in need of urgent or non-urgent transfusion. Accordingly, tacit knowledge was acquired using both interview and observation techniques and secondary sources using document analysis technique. The acquired knowledge was modeled using hierarchal knowledge representation method. Then, the knowledge is represented using production rule and the prototype system was developed using SWI-Prolog editor tool. The prototype system registered 82.5% performance after extensively tested and evaluated (GUESH 2012)

CHAPTER THREE

3. KNOWLEDGE ACQUISITION AND MODELING

3.1. Introduction

The main objective of this chapter is to acquire knowledge from domain experts and secondary sources on Acute Diarrheal diseases and diagnosis techniques as well as modeling the acquired knowledge for representation.

Knowledge acquisition is the process of obtaining facts and rules from the domain expert so that the system can draw expert level conclusions. The process of knowledge acquisition is difficult especially if the knowledge engineer is unfamiliar with the domain. There are two major sources for knowledge acquisition: experts and documents such that it extracts from an extensive literature review through related books, reports, projects and published papers.

Knowledge acquisition includes identifying the knowledge, representing the knowledge in a proper format, structuring the knowledge, and transferring the knowledge to a machine. The process of knowledge acquisition can be greatly influenced by the roles of the three major participants: the knowledge engineer, the expert, and the end user (Gobena 2014).

The process of collecting, organizing and compiling the knowledge and implementing it in the form of a knowledge base is a laborious task. It does not end with the development of the system. The knowledge base has to be continuously updated and/or appended depending on the growth of knowledge in the domain. A knowledge acquisition facility, which will act as an interface between the expert/knowledge engineer and the knowledge base, can form an integral component of an expert system (Krishnamoorthy, C.S and Rajeev, S. 1996).

Moreover, in this chapter the following activities are carried out which include:

- ⇒ Knowledge analysis, the process of making sense of the information collected during the knowledge elicitation.
- ⇒ Knowledge structuring, the process of expressing the analyzed knowledge in an understandable and usable form.

- ⇒ Knowledge modeling, the process of connecting the decision flow of the acquired knowledge and relationship between concepts. Expressing knowledge in a format that facilitates its representation and its handling by a computer.

3.2. The Knowledge Acquisition Process

The process of knowledge acquisition in this research work includes the basic activities such as extracting or gathering the required information how to diagnose and treat Acute Diarrheal diseases, analyzing the collected information to capture the relevant knowledge, structuring the analyzed knowledge in an understandable and usable form and modelling the knowledge in a format that facilitates its representation by a computer. The researcher used concepts discovered during the knowledge elicitation phase to build a model of the domain. The knowledge used for building of the knowledge-based system in this study focused on knowledge regarding the diagnosis and treatment of Acute Diarrheal diseases.

The most important factor in knowledge acquisition is the extraction of knowledge from sources of expertise and its transfer to the knowledge base and then to the inference engine. Acquisition is actually done throughout the entire development process (Ranjan 2002).

3.2.1. Reviewing Related Documents and Manuals

Document analysis involves extracting the required knowledge from existing documentations. Hence, document analysis has been done to acquire the necessary explicit knowledge found in different secondary sources of knowledge. Accordingly, different books, articles, international conference papers, Diarrheal diseases protection guide lines and Internet resources were reviewed and analyzed. Therefore, relevant and desired knowledge was extracted and hence structured in a manner that is suitable for knowledge modelling and knowledge representation.

3.2.2. Interviewing Domain Experts

Both structured and unstructured interviews were employed to elicit explicit knowledge from domain experts. Since one of the specific objectives of this research is extracting explicit knowledge from domain experts. For this reason, four domain experts from Adigrate Hospital were selected for interview.

These experts were interviewed about major Acute Diarrheal diseases that affect individuals and community in Ethiopia and the symptoms of these diseases as well as treatments undertaken to control such diseases.

During face to face communication, the information obtained from experts has been recorded manually by using pen and paper sheet. Even though it was monotonous, an iterative consultation was carried out with these highly experienced and qualified experts so that to acquire the relevant explicit knowledge which is important to generate the proposed rules. Finally these experts were consulted to verify the correctness of the acquired knowledge.

Profiles of domain experts participated in the interview process are presented in the Table 2 below.

No	Educational level of experts	Position	Work Experience	Occupational role
1	Specialist In Internal Medicine	Internist	12	Ward coordinator and medical treatment
2	Degree In Medicine	General Practitioner	3	Medical treatment
3	B.Sc. Degree In Health Science	Health officer	4	Medical treatment
4	B.Sc. Degree In Nursing	Nurse	7	Medical treatment

Table 2: Domain expert’s profiles

3.3. General Categories of Acute Diarrheal Diseases

Diarrheal diseases are among the three most important causes of morbidity and mortality in low income countries including Ethiopia. Lack of sanitation facilities is a serious health risk and obliges people to practice open defecation, thereby increasing the risk of disease transmission (Demeke Getu 2013). Diarrheal diseases can be classified by several methods with duration of the symptom being foremost. Diarrhea lasting less than 2 weeks is considered acute (Hall, 2010). This phenomenon is most likely caused by an infectious agent, such as bacterial, parasitic or viral invasion, or by a non-infectious agent such as dietary indiscretion or a new medication

(Amerine & Keirse, 2006). Acute diarrheal is typically self-limiting and resolves quickly with no lasting sequelae (Amerine & Keirse).

Infectious agents are one of the factors associated with acute diarrhea. Some of these pathogens can cause an inflammatory response in the gut where the epithelial lining is damaged either by a toxin produced by the organism or by an organism invading the mucosa (Bliss, Doughty, Heitkemper, 2006). Some organisms that cause an inflammatory response are “Cytomegalovirus, Herpes simplex virus, Shigella, Salmonella, Chlamydia, Neisseria gonorrhoeae, Campylobacter jejuni, Clostridium difficile, Escherichia coli O157:H5, Entamoeba histolytica” (Bliss et al., p. 427).

There are organisms that cause acute diarrhea that do not produce an inflammatory response although the person may have a low grade fever, malaise, nausea and vomiting as well as diarrhea. These causative organisms include “Norwalk virus, Rotovirus, Staphylococcus aureus, Clostridium perfringens, Vibrio cholerae and enterotoxigenic Escherichia coli ...” (Bliss, Doughty, Heitkemper, 2006, p. 427). Less commonly, protozoa such Giardia or Cryptosporidium may be the causative factor (Armerine & Keirse, 2006).

Diarrhea lasting longer than two weeks but resolving within a month is known as persistent diarrhea (Bushen, & Guerrani, 2003). This is typically a slower to resolve infection or continuing use of an offending agent (Amerine. & Keirse, 2006). Chronic diarrhea, on the other hand, lasts longer than four weeks (Bliss, Doughty, Heitkemper, 2006).

Chronic diarrheal can be the result of disease processes, medication, genetic abnormalities, or a variety of other causes (Doughty, 2006; Marchiondo, 2009).

Infectious secretagogues include Vibrio cholerae, E.coli, Camylobacter jejuni, Salmonella, Shigella, and Clostridium difficile (Farthing, 2006). These pathogens secrete toxins that bind with the structures within the gut, altering, sometimes irreversibly, the amount of fluid secreted into the bowel (Bliss, Doughty, Heitkemper, 2006). As an example, the toxin excreted by the pathogen cholera causes massive secretory diarrhea which, during its acute phase, can be as much as 24 liters in 24 hours (Farthing). According to the domain expert those selected disease are the most significant disease that can easily dissemination among individuals and community in Ethiopia. The selected diseases can be summaries as the following diagram.

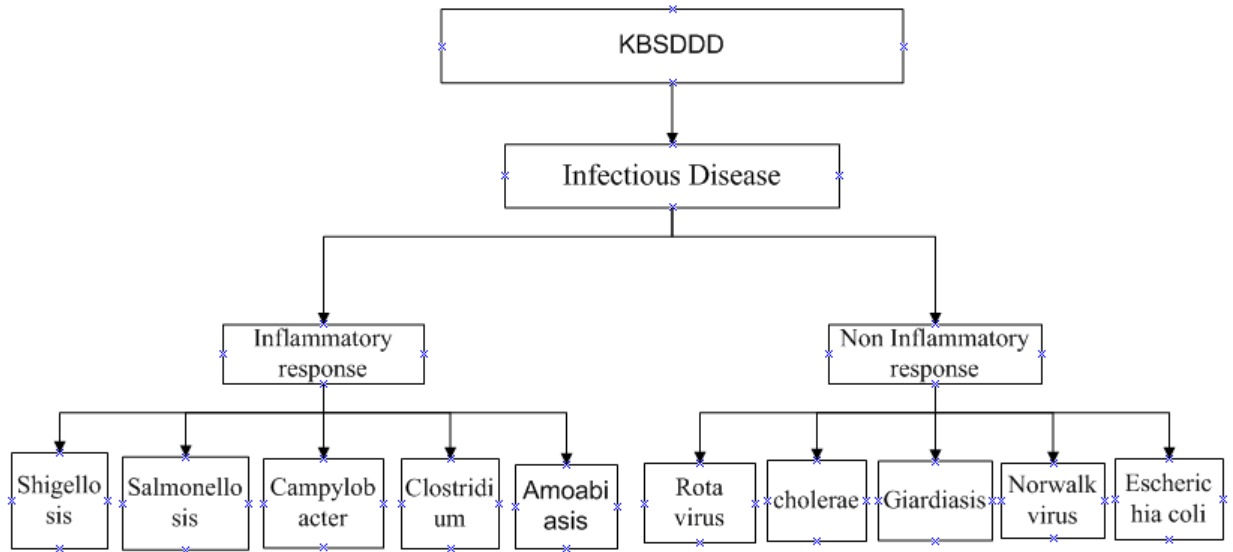


Figure 3.1: Block Diagram for Acute Diarrheal Disease Category

Cholera

Cholera is an acute diarrheal disease that can in a matter of hours result in profound, rapidly progressive dehydration and death. Accordingly, cholera gravis (the severe form) is a much-feared disease, particularly in its epidemic presentation. Fortunately, prompt aggressive fluid repletion and supportive care can obviate the high mortality that is historically associated with cholera. Although the term cholera has occasionally been applied to any severely dehydrating secretory diarrheal illness whether infectious in etiology or not it now refers to disease caused by *V. cholera* serogroup 01 or 0139—i.e. The serogroups with epidemic potential (kasper fauci 2015).

Humans become infected incidentally but, once infected, can act as vehicles for spread. Ingestion of water contaminated by human feces is the most common means of acquisition of *V. cholera*. Consumption of contaminated food also can contribute to spread. There is no known animal reservoir. Although the infectious dose is relatively high, it is markedly reduced in hypochlorhydric persons in those using antacids and when gastric acidity is buffered by a meal. Cholera is predominantly a pediatric disease in endemic areas, but it affects adults and children equally when newly introduced into a population. In endemic areas, the burden of disease is often greatest during "cholera seasons" associated with high temperatures, heavy rainfall, and

flooding, but cholera can occur year-round. For unexplained reasons, susceptibility to cholera is significantly influenced by ABO blood group status; persons with type O blood are at greatest risk of severe disease if infected, whereas those with type AB are at least risk.

Shigella

The human intestinal tract represents the major reservoir of *Shigella*, which is also found (albeit rarely) in the higher primates. Because excretion of shigellae is greatest in the acute phase of disease, the bacteria are transmitted most efficiently by the fecal-oral route via hand carriage; however, some outbreaks reflect foodborne or waterborne transmission. In impoverished areas, *Shigella* can be transmitted by flies. The high-level infectivity of *Shigella* is reflected by the very small inoculum required for experimental infection of volunteers (100 colony-forming units [CFU]), by the very high attack rates during outbreaks in day-care centers (33-73%), and by the high rates of secondary cases among family members of sick children (26-33%). Shigellosis can also be transmitted sexually.

Shigella epidemics have often occurred in settings of human crowding under conditions of poor hygiene-e.g. Among soldiers in campaigning armies, inhabitants of besieged cities, groups on pilgrimages, and refugees in camps. Epidemics follow a cyclical pattern in areas such as the sub-Saharan Africa. These devastating epidemics, which are most often caused by *S. dysenteriae* type 1, are characterized by high attack and mortality rates (Kasper Fauci 2015).

Amebiasis

Amebiasis is an infection with the intestinal protozoan *Entamoeba histolytica*. About 90% of infections are asymptomatic, and the remaining 10% produce a spectrum of clinical syndromes ranging from dysentery to abscesses of the liver or other organs.

About 10% of the world's population is infected with *Entamoeba*, the majority with noninvasive *Entamoeba dispar*. Amebiasis results from infection with *E. histolytica* and is the third most common cause of death from parasitic disease (after schistosomiasis and malaria). Invasive colitis and liver abscesses are sevenfold more common among men than among women; this difference has been attributed to a disparity in complement-mediated killing. The wide spectrum of clinical disease caused by *Entamoeba* is due in part to the differences between these two infecting species. *E. histolytica* has unique isoenzymes, surface antigens, DNA markers, and

virulence properties that distinguish it from other genetically related and morphologically identical species, such as *E. dispar* and *E. moshkovskii*.

The potential of *E. moshkovskii* to cause diarrhea, weight loss, and colitis was recently demonstrated in a mouse model of cecal infection. However, the pathogenic potential of this species is not clear. Areas of highest incidence of *Entamoeba* infection (due to inadequate sanitation and crowding) include most developing countries.

Rotavirus

Worldwide, nearly all children are infected with rotavirus by 3-5 years of age. Neonatal infections are common but are often asymptomatic or mild, presumably because of protection by maternal antibody or breast milk. Compared with rotavirus disease in industrialized countries, disease in developing countries occurs at a younger age, is less seasonal, and is more frequently caused by uncommon rotavirus strains.

Moreover, because of sub optimal access to hydration therapy rotavirus is a leading of diarrheal death among children in the developing world, with the highest mortality rates among children in sub-Saharan Africa (Kasper Fauci 2015).

Giardiasis

Giardia intestinalis (also known as *G. lamblia* or *G. duodenalis*) is a cosmopolitan protozoal parasite that inhabits the small intestines of humans and other mammals. Giardiasis is one of the most common parasitic diseases in both developed and developing countries worldwide, causing both endemic and epidemic intestinal disease and diarrhea (Kasper Fauci 2015).

Campylobacter jejuni

Campylobacter infection (campylobacteriosis) is a bacterial infection which most commonly causes gastroenteritis (also known as 'gastro') but may also cause illness affecting the entire body. Campylobacter germs (bacteria) are commonly found in raw meat, particularly raw poultry such as chicken. Cooking meat thoroughly usually kills the bacteria. Campylobacter may also be found in unpasteurized milk or untreated water (including ice cubes made from untreated water). Occasionally, mushrooms and shellfish can contain campylobacter. Pets (including cats and dogs) and other animals infected with campylobacter can also pass on the bacteria to the people.

Campylobacter are a group of germs (bacteria) that are a poisoning. Bacterium that typically infects the bowels. Now the leading cause of bacterial food poisoning, Campylobacter jejuni is most often spread by contact with raw or undercooked poultry. A single drop of juice from a contaminated chicken is enough to make someone sick. People most often get infected by eating or drinking food or water, often raw poultry, fresh produce, or unpasteurized milk. A person can also be infected by close contact with infected people or animals.

Food poisoning occurs when food or water contaminated with germs (microbes), poisons (toxins) or chemicals is eaten or drunk. Microbes include bacteria, viruses and parasites. A parasite is a living thing that lives in, or on, another living organism. Typically, food poisoning causes gastroenteritis, an infection of the gut (intestines). This leads to Diarrhoea and sometimes also to being sick (vomiting) (kasper fauci 2015).

Escherichia coli

E. coli (Escherichia) coli is the name of a germ, or bacterium, which lives in the digestive tracts of humans and animals. There are many types of E. coli, and most of them are harmless. But some can cause bloody diarrhea. Some strains of E. coli bacteria (such as a strain called O157:H7) may also cause severe anemia or kidney failure, which can lead to death. Other strains of E. coli can cause urinary tract infections or other infections. People get an E. coli infection by coming into contact with the feces, or stool, of humans or animals. This can happen when you drink water or eat food that has been contaminated by feces. E. coli can get into meat during processing. If the infected meat is not cooked to 160°F (71°C), the bacteria can survive and infect you when you eat the meat.

Human or animal feces infected with E. coli sometimes get into lakes, pools, and water supplies. People can become infected when a contaminated city or town water supply has not been properly treated with chlorine or when people accidentally swallow contaminated water while swimming in a lake, pool, or irrigation canal. The bacteria can also spread from one person to another, usually when an infected person does not wash his or her hands well after a bowel movement. E. coli can spread from an infected person's hands to other people or to objects.

Other foods that can be infected with E. coli include:

- Raw milk or dairy products. Bacteria can spread from a cow's udders to its milk. Check the labels on dairy products to make sure they contain the word "pasteurized." This means the food has been heated to destroy bacteria.
- Raw fruits and vegetables, such as lettuce, alfalfa sprouts, or unpasteurized apple cider or other unpasteurized juices that have come in contact with infected animal feces (Kasper Fauci 2015).

Salmonellosis

Salmonellosis is a type of food poisoning caused by the *Salmonella enterica* bacterium. There are many different kinds of these bacteria. *Salmonella* serotype Typhimurium and *Salmonella* serotype Enteritidis are the most common types in sub-Saharan Africa. Salmonellosis is more common in the summer than in the winter. Children are the most likely to get salmonellosis. Young children, older adults, and people who have impaired immune systems are the most likely to have severe infections.

People can get salmonellosis by eating food contaminated with salmonella. This can happen in the following ways:

- Food may be contaminated during food processing or food handling.
- Food may become contaminated by the unwashed hands of an infected food handler. A frequent cause is a food handler who does not wash his or her hands with soap after using the bathroom.
- *Salmonella* may also be found in the feces of some pets, especially those with diarrhea. You can become infected if you do not wash your hands after contact with these feces.

Reptiles, baby chicks and ducklings, and small rodents such as hamsters are particularly likely to carry *Salmonella*. You should always wash your hands immediately after handling one of these animals, even if the animal is healthy. Adults should also be careful.

Clostridium difficile

Clostridium difficile infection (CDI) is a unique colonic disease that is acquired most often in association with antimicrobial use and the consequent disruption of the normal colonic microbiota. The most commonly diagnosed diarrheal illness acquired in the hospital, CDI results

from the ingestion of spores of *C. difficile* that vegetate, multiply, and secrete toxins, causing diarrhea and pseudomembranous colitis (PMC) in the most severe cases.

Norwalk virus

The Norwalk virus is the prototype strain of a group of small (27-40 nm), nonenveloped, round, icosahedral viruses with relatively amorphous surface features on visualization by electron microscopy. These viruses have been difficult to classify because they have not been adapted to growth in cell culture and no animal models are available. Molecular cloning and characterization have demonstrated that the viruses have a single, positive-strand RNA genome - 7.5 kb in length and possess a single virion-associated protein-similar to that of typical caliciviruses-with a molecular mass of 60 kDa. On the basis of these molecular characteristics, these viruses are presently classified in two genera belonging to the family Caliciviridae: the noroviruses and the sapoviruses (previously called Norwalk-like viruses and Sapporo-like viruses respectively).

No	Infectious disease	Common symptoms
1.	Cholera	only mild diarrhea, sudden onset of explosive and life-threatening diarrhea, sudden onset of painless watery diarrhea which is a nonbilious, gray, slightly cloudy fluid with flecks of mucus, no blood, and a somewhat fishy, inoffensive odor, vomiting, And muscle cramps,
2.	Shigella	fever, limited watery diarrhea which is characterized by uninterrupted excretion of small volumes of bloody mucopurulent stools, malaise and anorexia, And mild abdominal discomfort to severe cramps And vomiting, And tenesmus,
3.	Amebiasis	If severe abdominal pain high fever and profuse diarrhea, And gradual onset of lower abdominal pain and mild diarrhea,

		And malaise, weight loss and diffuse lower abdominal or back pain.
4.	Rotavirus	If abrupt onset diarrhea, vomiting frequently preceding the onset of diarrhea, fever, weight loss,
5.	Giardiasis	diarrhea and abdominal pain, bloating and belching, flatus, nausea and vomiting and weight loss,
6.	Campylobacter jejuni	diarrhea which is bloody and fever, abdominal pain and cramping, nausea and vomiting,
7.	Escherichia coli	Diarrhea, which may range from mild and watery to severe and bloody, Abdominal pain and cramping or tenderness, And Nausea and vomiting.
8.	Salmonellosis	Diarrhea and fever, abdominal pain and cramps, nausea and vomiting, anorexia and weight loss.
9.	Clostridium difficile	diarrhea which ranges from soft and unformed to watery or mucoid in consistency, Patients may have as many as 20 bowel movements per day, And abdominal pain and cramps,
10	Norwalk virus	headache, fever chills and myalgias And stools are characteristically loose and watery, without blood mucus or leukocytes,

Table 3: Summarized Infectious Diarrheal Disease

3.4. Conceptual Knowledge Modeling

Experience has shown that eliciting and explicating knowledge is best seen as a modelling activity, also called conceptual modelling. This activity takes the form of a specialized type of requirements engineering. KBS construction methods typically provide tools for knowledge analysis in the form of conceptual models of knowledge or simply knowledge models. A knowledge model provides an implementation-independent specification of knowledge in an application domain. Typically, a knowledge model provides formats for writing down both static domain knowledge (rules, classes, relations) as well as reasoning strategies in which this domain knowledge is used to solve a particular problem. An important feature of knowledge engineering research is that it provides us with predefined, reusable models for certain knowledge-intensive tasks, also called problem-solving methods (Nalepa 2006).

During the knowledge modelling phase, the specialist's knowledge (elicited by various techniques) is represented in a knowledge model. A knowledge model is a structured representation of knowledge using symbols to represent pieces of knowledge and the relationships between them. Knowledge models include symbolic character-based languages such as logic, diagrammatic representations such as networks and ladders, tabular representation such as matrices and structured text such as hypertext. The generation and modification cycle of a knowledge model is an essential part of the knowledge modelling phase.

The model helps to ensure that all stakeholders in a project understand the language and terminology being used and quickly conveys information for validation and modification where necessary. The knowledge models are also of great value during cross-validation with other specialists (C.L. Emberey 2007).

3.4.1. Decision Tree Structure

A decision tree takes as input an object or situation described by a set of properties, and outputs a yes/no "decision." Decision trees therefore represent Boolean functions. Functions with a larger range of outputs can also be represented, but for simplicity we will usually stick to the Boolean case. Each internal node in the tree corresponds to a test of the value of one of the properties, and the branches from the node are labelled with the possible values of the test. Each leaf node

in the tree specifies the Boolean value to be returned if that leaf is reached (Russell and Norvig, 2002).

For knowledge-based systems, decision trees have the advantage of being comprehensible by human experts and of being directly convertible into production rules. Moreover, when used to handle a given case, a decision tree not only provides the solution for that case, but also states the reasons behind its choice. These features are very important in typical application domains in which human experts seek tools to aid in conducting their job while remaining “in the driver’s seat.” Another advantage of using decision trees is the ease and efficiency of their construction compared to that of other classifiers such as neural networks (ALMUALLIM 2002).

Decision tree was used to Model the knowledge. These decision tree structures are the base for the prototype knowledge based system development. The prototype knowledge base system is developed based on the model presented in this decision tree structure.

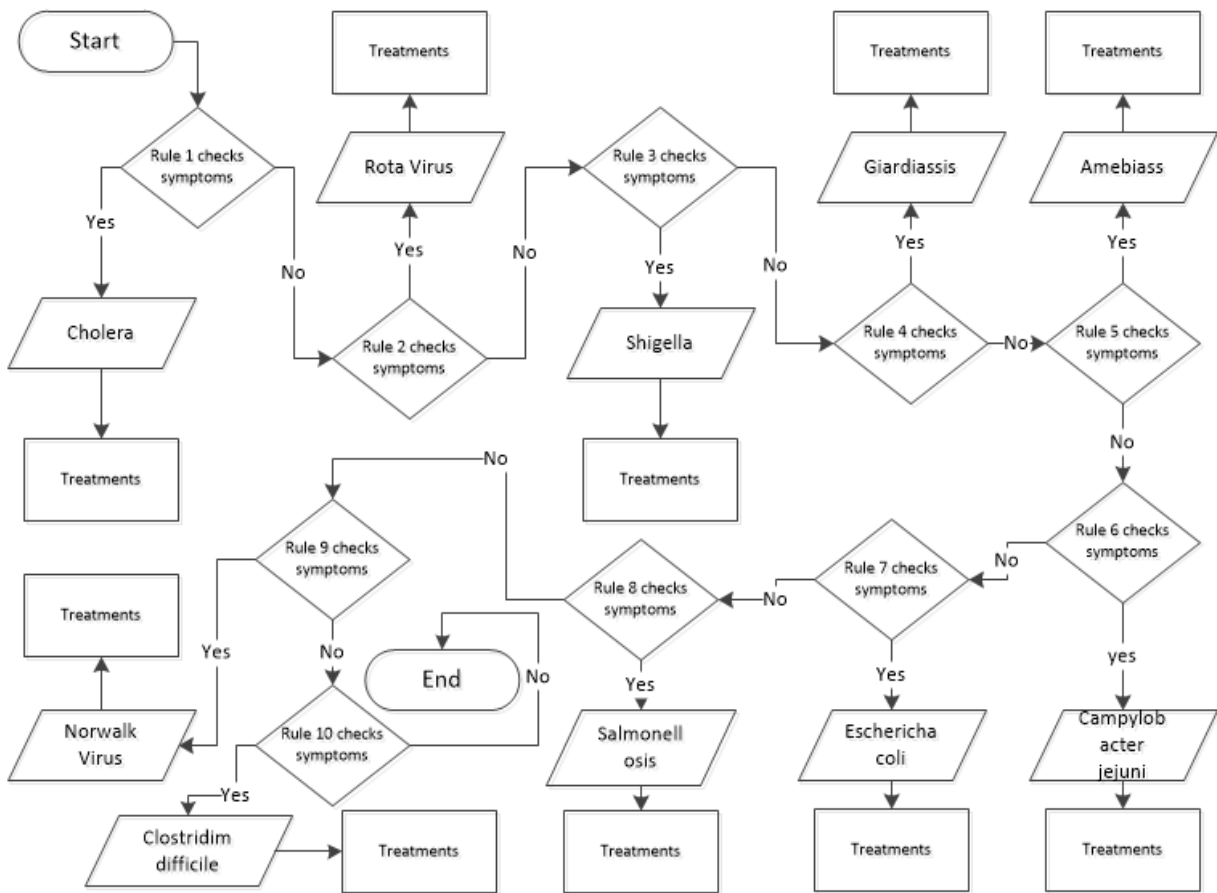


Figure 3.2: Decision Tree for Acute Diarrheal Disease Diagnosis

CHAPTER FOUR

4. KNOWLEDGE BASED SYSTEM DEVELOPMENT

Knowledge-based system development has a series of steps and phases like other software development. It also has the system evaluation phase, which measures the performance of the knowledge-based system through verification and validation. The knowledge-based system can be implemented after the knowledge acquisition, knowledge modeling and representation phases. These phases must be given emphasis to make the implementation easy and fast.

4.1. Architecture of the Prototype Knowledge-Based System

The Acute Diarrheal Disease Diagnosis knowledge-based system prototype is implemented based on the decision tree model and the knowledge represented in a form of rule-based representation. The SWI Prolog implementation tool is used to develop the prototype, which has different components. It involves user interface, knowledge base, and inference engine and explanation facility. Figure 2.6 shows the architecture of the proposed prototype constructed.

As shown in figure 2.6 the knowledge engineer elicits the appropriate knowledge using knowledge acquisition methods. The knowledge collected need to be modeled and encoded in such a way that it should be represented in machine understandable form. Subsequently, the knowledge base is built using the declarative programming tools which involves the fact base and rule base. The system interacts with users through user interface in a form of questions and answer. First, the user starts to answer the questions in a form of yes or no. Next, the inference engine searches for the appropriate goal that matches with the facts based on the answer of the user.

Finally, it replies the appropriate result to the user through the user interface. On the other hand, the system prototype has the facility to explain if the user needs more explanation on the disease. The detail of how each component interacts in the prototype development is described as the follows.

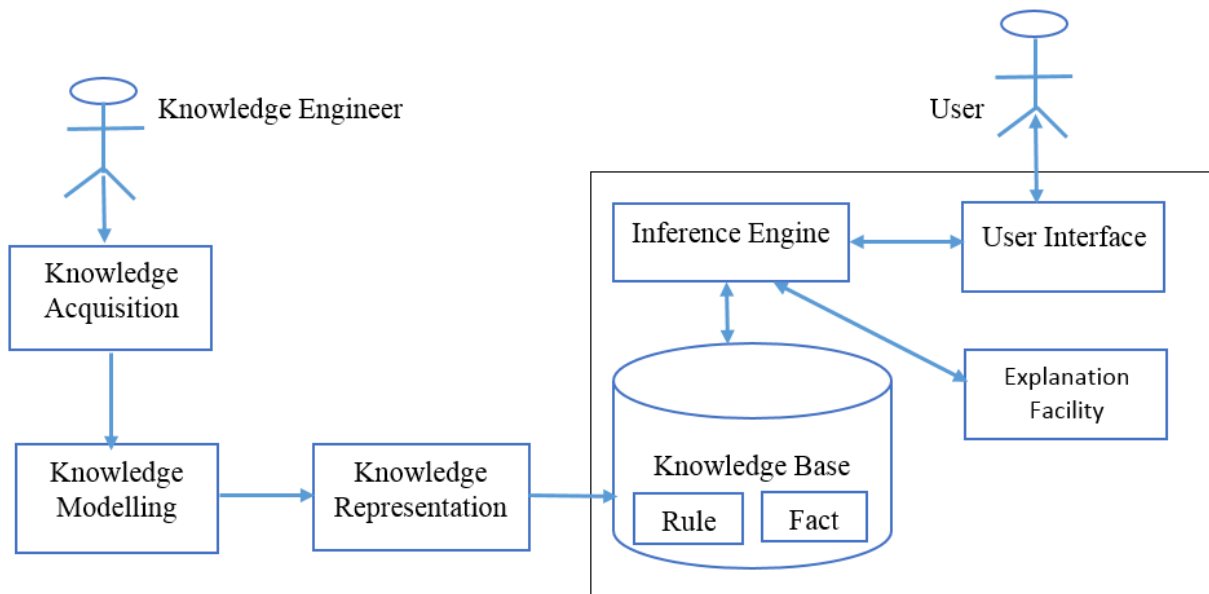


Figure 4.1: Prototype Knowledge Based System Architecture

4.2. The Knowledge Base

Knowledge base is encoded in a form of rule-based representation. The rule-based representation is the method, which the diarrheal disease diagnosis system is represented in a form of if...then clauses. When if part holds true the then part, the goal, of the rule is fired. However, if the condition or if part does not fit the goal the inference continues to search for another condition until the goal satisfied.

To implement the DDDKBS prototype development, the acquired knowledge is represented using production rules as “if-then” rules since rule based approach is applicable for which the experience and knowledge of human experts is captured in the form of IF-THEN rules and facts.

Similarly, in this study, the rules that contain the diarrheal diseases and their major symptoms are formulated in sequences and expression of the form of:

If first premise,

Second premise,

Then conclusion.

If the premises are true, then the actions are executed. When premises are examined by the inference engine, conclusion is executed if the information supplied by the user satisfies the conditions part of the rules. Conditions are expressions involving attributes of major symptoms of diarrheal diseases and logical connective rules. These rules are the bases of knowledge base construction.

Furthermore, rules used in this study are developed based on the knowledge modeled using decision trees which are discussed in chapter three of knowledge modeling. The above rules are the same as prolog rules that work in backward chaining as indicated below:

Conclusion:-

First premise,

Second premise ...

As the result, the knowledge base of this prototype knowledge based system consists of all facts and domain expert knowledge about the descriptions of diarrheal diseases and treatments. It also includes the knowledge represented in the if-then rules in which facts in the conditional parts have the same parameter with the facts bases that are asked for the user to prove whether the disease occur or not.

Even though the above backward chaining reasoning mechanism is implemented in this study, for the convenience of communication the following sample rules are represented using the IF-THEN forms as presented below.

Sample rules for diarrheal diseases diagnosis:

Rule 1: IF ሒደት ውፅኦት ምህላው

AND ብሃንደበት ዝጅምር፣ንሂወት ኣብ ሓደጋ ዘውድቕ ውፅኦት

AND ብሃንደበት ዝጅምር ቃንዛ ዘይብሉ ግራጫ ሕብሪ ዘለዎ፣ደም ዘይተሓወሶ

፣ጨና ዘይብሉ ቀጢን ተቕማጥ

AND ተምላስን ቃንዛ ጭዋዳን ምህላው

AND ቃንዛ ጭዋዳ

THEN ብምርመራ መሰረት ዝተረኸበ ሕማም ኮሌራ እዩ

Rule 2: IF ረስኒ፣ውሱን ዝኾነ፣ቀፃልነት ዘለዎ፣ሒደት ትሕዝቶ ዘለዎ ደምን ንፋጥን ዝተሓወሶ ውፅኣት
AND ድኻምን ድሌት ምግቢ ምቕናስን
AND ካብ ዝተወሰነ ሕማም ከብዲ ክሳብ ቁርፅት ከብዲ
AND ተምላስ ምህላው
AND ኣብ እዋን ሰገራ ሓይሊ ዝተመልኦ ምፍታን
THEN ብምርመራ መሰረት ዝተረኸበ ሕማም ሺገሎሲስ እዩ

Rule 3: IF ሓያል ዝኾነ ሕማም ከብዲ፣ትኩሳትን በዝሒ ዘለዎ ውፅኣት
AND ቀስ ኢሉ ዝጅምር ታሕተዋይ ክፋል ከብዲን ሒደት ውፅኣትን
AND ድኻም፣ቃንዛ ሑቕ
THEN ብምርመራ መሰረት ዝተረኸበ ሕማም ኣሜቢያሲስ እዩ

Rule 4: IF ብሃንደበት ዝጅምር ማያዊ ውፅኣትን
AND ቅድሚ ውፅኣትን ዝጅምር ተምላስ
AND ልዑል ረስኒ፣ ተምላስ፣ ማያዊ ውጽኣትን
AND ልዑል ረስኒ ሰውነት ጽምእት ሰብነትን ዘጠቓልል
THEN ብምርመራ መሰረት ዝተረኸበ ሕማም ሮታ ቫይረስ እዩ

Rule 5: IF ውፅኣትን ቁርፅት ከብዲን
AND ብተደጋጋሚ ምጉሳዕ
AND ፎሲ፣ምዕውልዋልን ተምላስን
AND ከብደት ምቕናስ
THEN ብምርመራ መሰረት ዝተረኸበ ሕማም ጃርዲኦሲስ እዩ

Rule 6: IF ደም ዝተሓወሶ ውፅኣትን ረስኒን
AND ሕማም ቁርፅት ከብዲን
AND ምዕውልዋልን ተምላስን

THEN ብምርመራ መሰረት ዝተረኸበ ሕግም ካምፒሎባክተር እዩ

Rule 7: IF ካብ ቀጢን ሒደት ክሳብ ሓያልን ደም ዝተሓወሶን ውፅኣት

AND ሕግምን ቁርፅት ከብዲን

AND ምዕውልዋልን ተምላስን

THEN ብምርመራ መሰረት ዝተረኸበ ሕግም ኢሸሪሺያ ኮላይ እዩ

Rule 8: IF ውፅኣትን ረስኒን

AND ምዕውልዋልን ተምላስን

AND ድሌት ምግብን ክብደትን ምቕናስ

THEN ብምርመራ መሰረት ዝተረኸበ ሕግም ሳልሞነሎሲስእዩ

Rule 9: IF ልስሉስ ዝኾነ ወይ ከዓ ቀጢን ንፋጥ ዝመስል ውፅኣት

AND ሕሙማት ኣብ መዓልቲ ልዕሊ 20 ጊዜ ከውፅኦም ይኸእል

AND ሕግምን ቁርፅት ከብዲን

THEN ብምርመራ መሰረት ዝተረኸበ ሕግም ክሎስትሪዲየም ዲፊሳይል እዩ

Rule 10: IF ምዕውልዋልን ተምላስን

AND ሕግም ርእሲ፣ረሲኒ፣ምንቕጥቃት ሰውነትን ቅርጥማትን

AND ልስሉስ፣ቀጢን፣ደም ዘይብሉ ውፅኣት

THEN ብምርመራ መሰረት ዝተረኸበ ሕግም ኖርዎልክ ቫረስ እዩ

4.3. The Inference Engine

The inference engine consists of inference mechanism and control strategy that enables deriving conclusion for a given query. It comprises formal reasoning involving matching and unification, similar to the one performed by human experts to solve problems in a specific area of knowledge. The backward chaining mechanism is used in this study during the system prototype development. It starts from the desired goals and backtracks through all sub goals and supporting facts. Then, the inference engine continues searching for the appropriate rule until the goal is satisfied and executed. The backward reasoning purposively implemented in this study because it is appropriate that the goals are defined and the rules, which fit these goals are also available. On the other hand, the Prolog programming language in which the prototype is constructed also uses backward chaining mechanism.

During the reasoning processes, the inference engine starts from the consequents (diarrheal disease) and checks the symptoms of the occurrence of this disease to prove the hypothesis (disease). If antecedents (symptoms) are evaluated as true, then it logically follows the consequents are proved and hence appropriate treatment, description and prevention mechanism of the disease is provided.

4.4. The User Interface

In this knowledge based system, the users interact with the system by which the system asks the user a series of questions and the user responds by saying “yes (አዎ)” or “no (አይኮን)” based on the users answers, the system provides conclusions for the user request by communicating through the user interface. The system first displays the welcome message to the user and prompts to type “መርምር.” and to press Enter button. Figure 2.7 depicts the user interface of diarrheal disease diagnosis and treatment system.

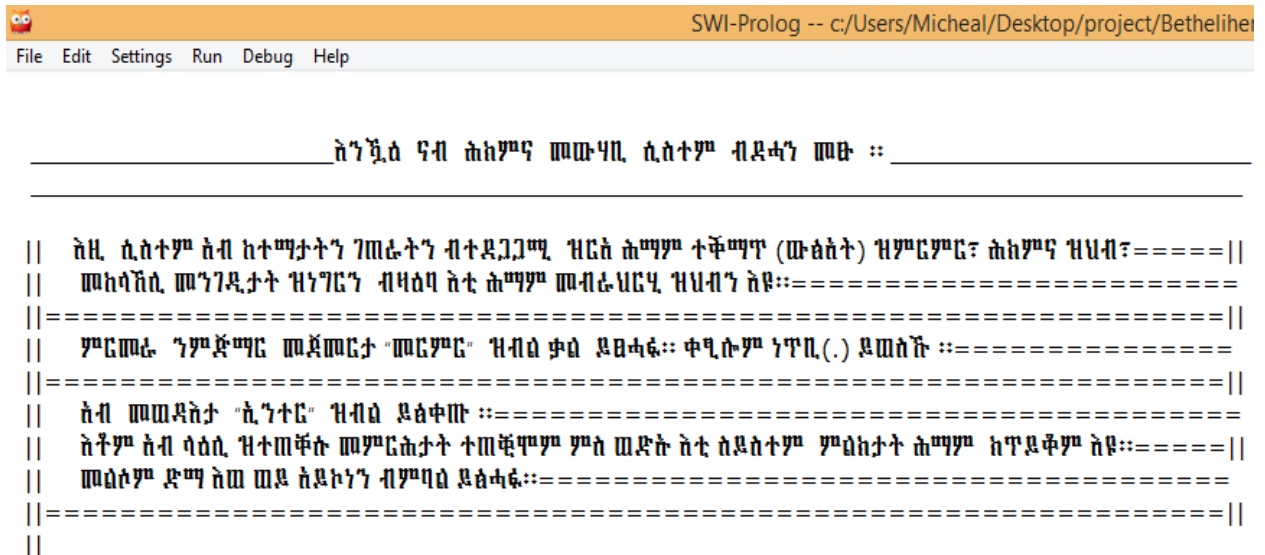


Figure 4.2: A Welcome Dialog Window of DDDKBS User Interface.

After the welcome window of DDDKBS user interface is displayed, the user interface allows the users to interact with the system by starting the system as indicated in Figure 2.8 below. The user can start the system by typing “መርምር.” and putting full stop at the end. The following figure shows the sample dialogue windows between the user and the system to identify Giardiasis disease (ሕማም ጃርዲያ).

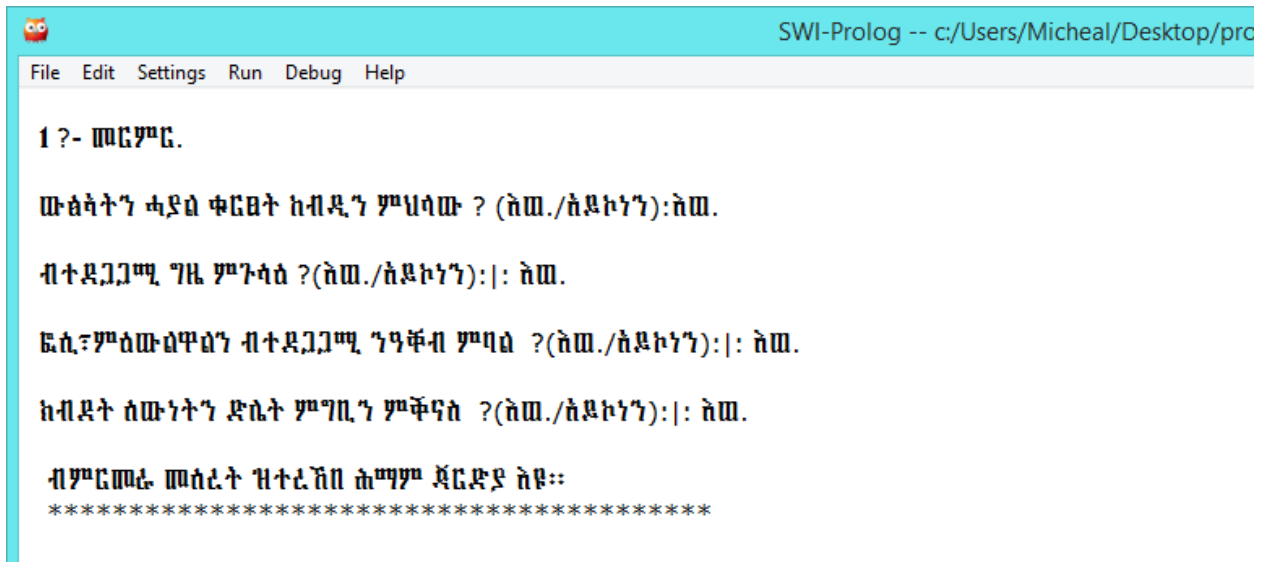


Figure 4.3: Dialogue window between the user and the system to identify Giardiasis disease

After the system identifies the type of diarrheal disease, then it provides the recommended treatment for the identified disease. As indicated in the following window the identified disease is based on the user input from the dialogue and the system provides the recommended treatment for the identified disease.



Figure 4.4: Sample dialogue window of the system’s treatment for the identified disease.

After the disease is identified and provided its treatments, then the system provides the prevention mechanism about the disease to the user as indicated in the following window.

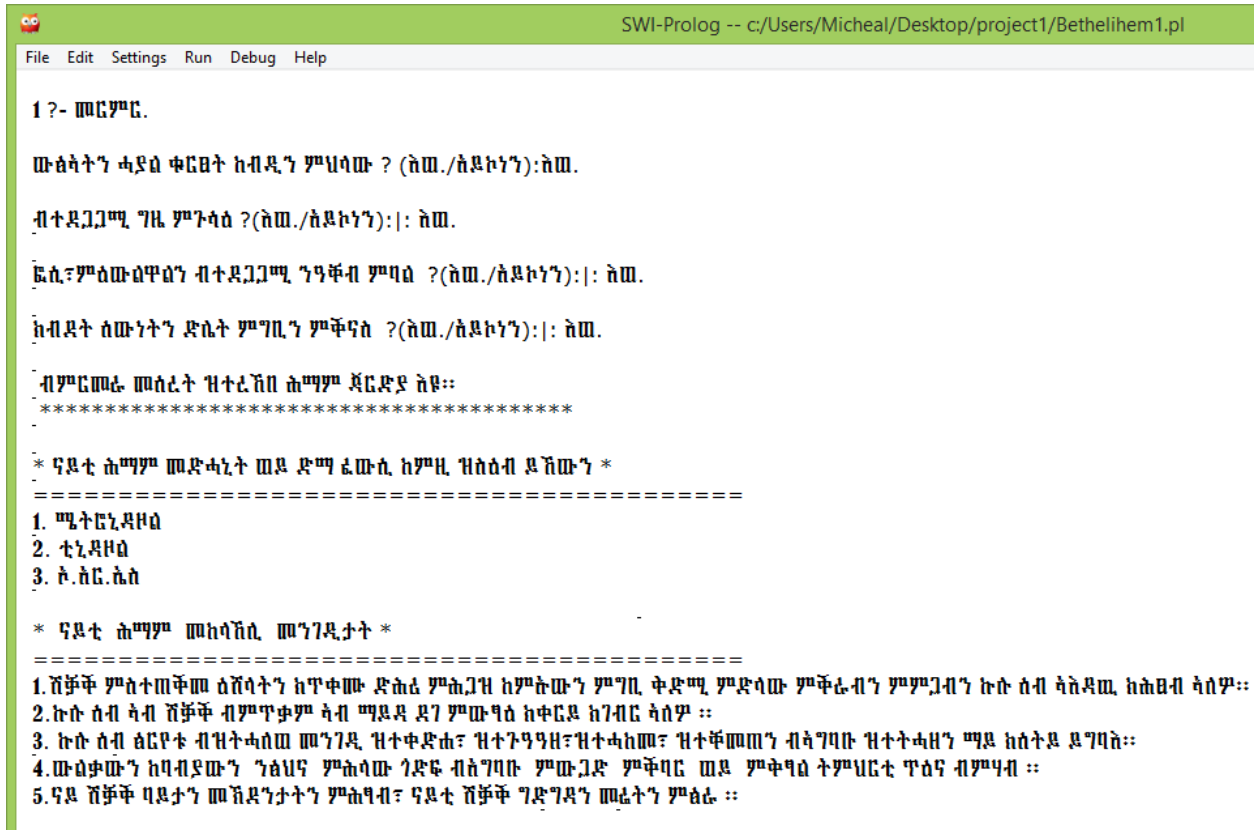


Figure 4.5: Sample dialogue window provides prevention mechanisms for the identified disease.

4.5. Explanation Facility

Human experts are often asked to explain their views, recommendations, or decisions. If ES are to mimic humans in performing highly specialized tasks, they too need to justify and explain their actions. An **explanation** is an attempt by an ES to clarify its reasoning, recommendations, or other actions (e.g., asking a question). The part of an ES that provides explanations is called an **explanation facility** (or **justifier**). The explanation facility is included in the DDDKBS to give detail explanation about the disease diagnosed. After the system has diagnosed the type of disease and the necessary treatment and prevention mechanisms are recommended, the system asks the user “Do you want more explanation ? “ (ስለ እቲ ሕማም ተወሳኺ መብራህርሂ ይደልዩ ዶ?) If the user say “YES” (አወ), it provides detail explanation. Otherwise if the user say “NO” (አይኮነን), the blank space with lines displayed on the screen, after that the system asks the user “Do you want to proceed? “ (ካለእ ተቕማጥ ዘምፅእ ሕማም ንምፍላጥ ይደልዩ ዶ?). Similarly if the user “YES” (አወ), it starts asking the symptoms of the disease. If the user say “NO”

(አይኮነን), it displays the message “Thank You So Much for Using The System In A Good Manner” (እዚ ሲሰተም ብአግባቡ ስለ ዝተጠቐሙ ብጣዕሚ ነመስግን።) to indicate that it is the end.

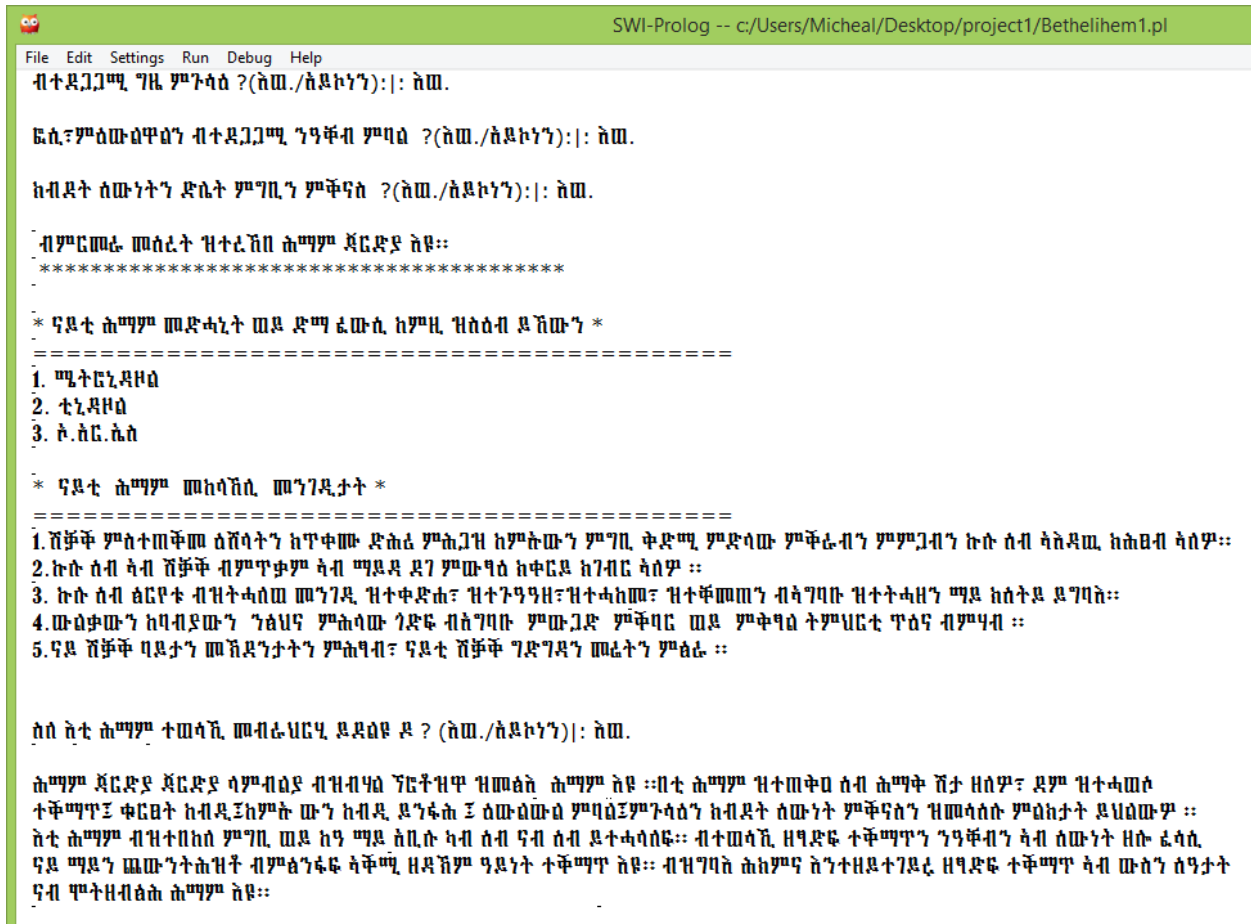


Figure 4.6: Sample dialog window when more explanations provided about Giardiasis disease.

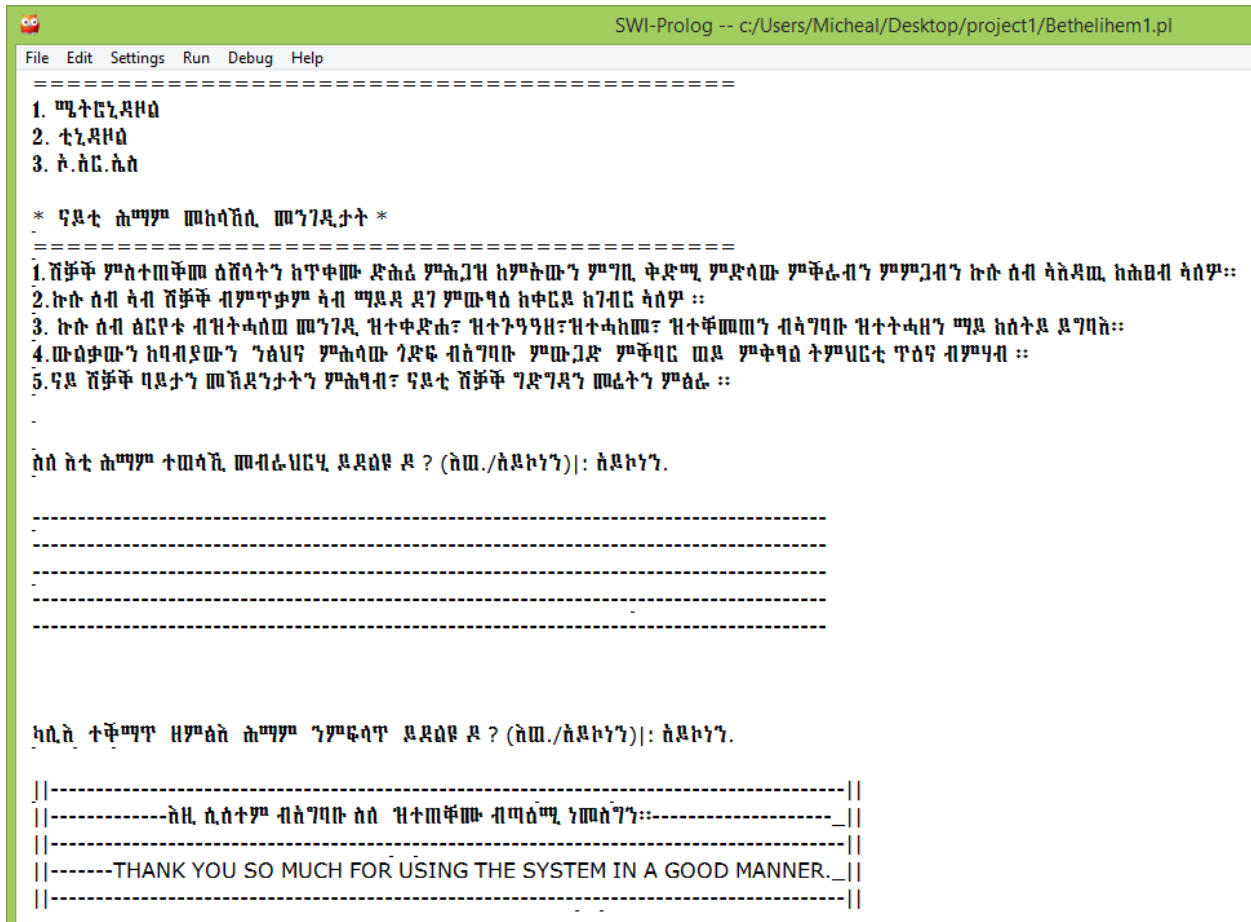


Figure 4.7: Dialog window when no more explanations needed and not proceed to diagnosis.

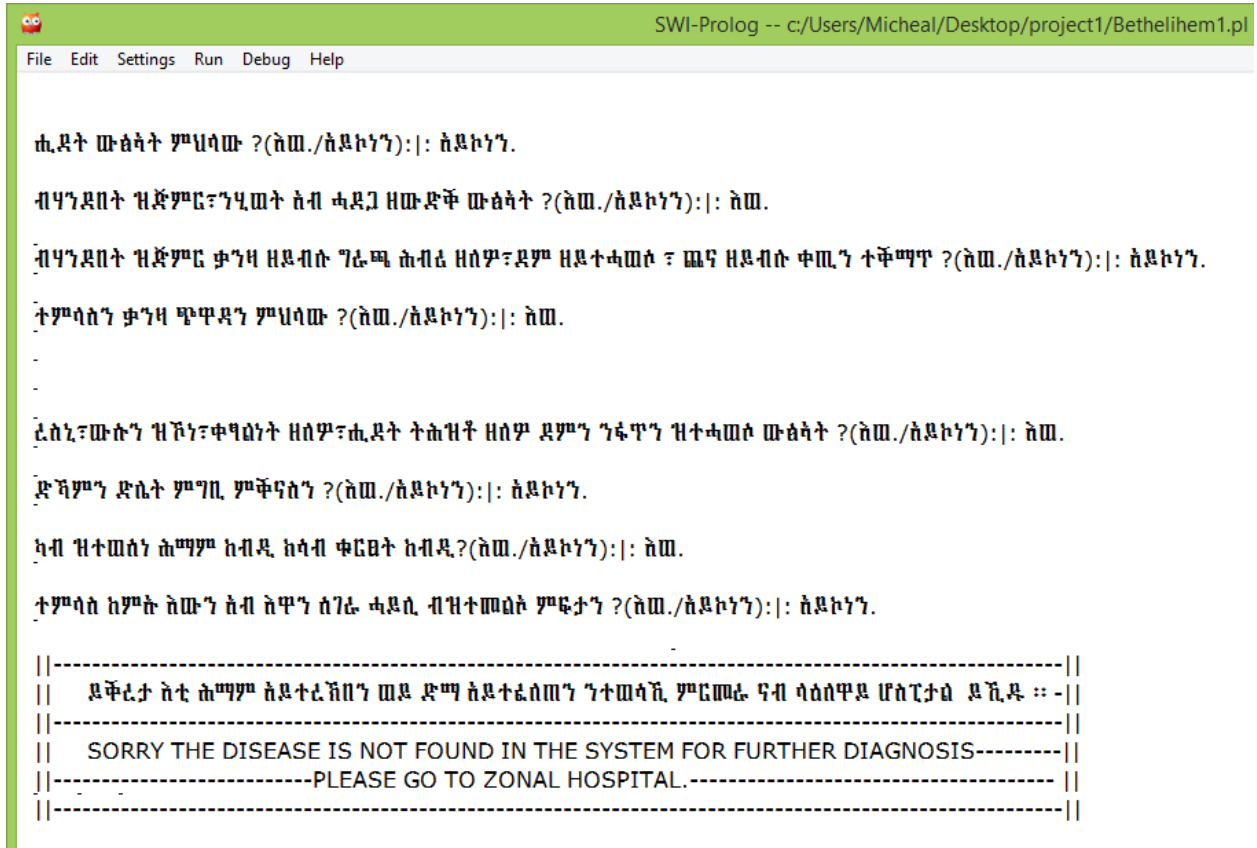


Figure 4.8: Sample dialog window when the system is not identified the disease.

CHAPTER FIVE

5. SYSTEM TESTING AND EVALUATION

After implementing knowledge based system the final step is measuring the performance of the system whether the objective achieve or not. Testing and evaluation of the prototype knowledge based system is the final step that helps the knowledge engineer to measure whether the system achieve the proposed objective or not. For the purpose of this research study, knowledge based system for Diarrhoeal disease diagnosis system is tested and evaluated based on the objective of the system. This is to measure the accuracy of the system during the diagnosing processes. Measurement is from the point of view whether the system achieved its objective or not. In this study the performance of the system is measured against human expert decision using predictive validation method. The user acceptance of the system is carried out during the user interacts with the system prototype.

The knowledge based system user acceptance is measured by using close ended questions. The system evaluators directly interact with the system to measure its performance from the points of its correctness in assigning the patient case in the correct category. In addition, the validation test was done by comparing solved cases against the system conclusions on the similar issues. By comparing the result obtained from the system conclusion, the evaluators determine the performance of the system. Therefore, knowledge based system performance is measured using close ended question, and second by using the test case validation method. The details of each evaluation method are discussed in the following section.

5.1. DDDKBS User Acceptance Evaluation

Evaluation of the prototype knowledge based system is an important phase that helps to measure the performance of the developed system. In this study, DDDKBS is evaluated to recognize accuracy and efficiency of description and treatments provided by the system in diagnosing Diarrhoeal disease. It also helps to check whether the objective of this research work is achieved.

Knowledge based System evaluation using visual interaction is used to ascertain how domain experts interact with developed system. Direct interaction intend system user to evaluate the performance of the knowledge based system from the users ‘‘ point of view. In addition, this method helps to ensure the performance of the prototype by assessing the feedback acquired

from the domain expert towards the developed system. Semi-Structure questions are developed to assess and evaluate the appropriateness and applicability of KBSDDD in the domain area. This evaluation method allows expert to make comments while interacting the system (Anumba and Scott, 2001).

It also helps to ensure the performance of the prototype by assessing the feedback of the experts towards the developed system and altering the parameter as desired. To evaluate Diarrheal Disease diagnosing knowledge based system in this study, four domain experts were selected as system evaluators. Before starting the evaluation, the researcher explained the objective of the developed system and how the users interacts with the system. This explanation helps the evaluator get full understanding how they consult the system in getting advice.

Then, the domain experts were allowed to interact with the system by running number of cases having similar parameter with the facts incorporated in the knowledge base. After the consultation of the system, to assess the user acceptance of the prototype knowledge based system, questionnaires were distributed. Using these questionnaires, domain expert's feedback towards this developed system was gathered for analysis.

The type of questionnaire distributed for feedback collection from the evaluators were closed ended questionnaire focusing on easiness, attractiveness, time efficiency, accuracy of Diarrheal Disease Diagnosis Knowledge Based System. The questionnaire also focused on the applicability of the system in diagnosing Diarrheal Disease, problem solving ability and the significance of the system in the domain area.

The format of the questionnaire was adapted from Tagel Aboneh (2013), which used to evaluate to pre-medical triage diagnosis prototype knowledge based system and performance evaluation of knowledge based System.

The adapted questionnaires were modified in the context of Diarrheal Disease diagnosing knowledge based system.

To achieve the goal of evaluation four domain experts were selected purposively from Adigrat hospital. These domain experts were actively involved during knowledge based system development process such us in knowledge acquisition, knowledge modeling, knowledge representation, verification and validation of the content of knowledge base.

	incorporate sufficient knowledge to diagnosis a given diseases?	0	0	1	2	1	4	80%
6	Does the system provide appropriate treatment for the patient?	0	0	0	2	2	4.5	90%
7	Does the system has significance in the domain area?	0	0	2	1	1	3.75	75%
Total average performance (%)							3.78	75%

As shown in table 4 above, 10% of the respondents rated ‘easiness of the prototype’ as fair, and 15% as good and the remaining 40% responded as very good. In the same way, for question ‘attractiveness of the prototype’ 10% of the respondents rated fair and 15% as good and the remaining 40% responded very good. Similarly, for question ‘efficient in time’ 15% of the respondents rated the criterion good and 65% as very good.

At the same time for criteria ‘the accuracy of the prototype to make correct decision’ 15% respondent rated as good, 40% of the respondent respond very good and the remaining 25% responded excellent. Likewise, for the criteria of ‘does the prototype incorporate adequate knowledge’ 15% of the respondents rated good and 40% of the respondent respond very good and the remaining 25% responded excellent. Again 40% of the respondent rate as very good for the criteria of ‘the ability of the system in making right conclusions and right recommendation of treatments’ and the rest 50% respond as excellent. Finally, for the question related to ‘significance of the knowledge base system in the domain area’ 30% of the respondent rated as good and 20% rated as very good and remaining the 25% of respond as excellent.

To summarize table 4 above based on the responses of four system evaluator, the average performance obtained is **3.78** on a scale of **5**. This value is the result obtained from the values assigned for each close ended question. The result indicates that about **75%** of users are satisfied

by the performance of the knowledge based system. It means that the proposed knowledge based system gain about **75%** of user acceptance.

5.2. Discussion

The evaluation and testing procedures help to address the question of user acceptance and accuracy of the prototype. Visual interaction and questionnaire methods are used to assess user's acceptance issues and applicability of the prototype. Based on the evaluation results obtained from visual interaction with closed ended questions none of the evaluators respond as poor, fair and good. On the other hand evaluators reply very good seventeen times (49%) and excellent eleven times (38.8%) the following table summarizes the results obtained on close ended questions.

Table 5: Users evaluation result summary on closed ended questions

Respondents who respond as	Poor(1)	Fair(2)	Good(3)	Very good(4)	Excellent(5)	average
Total number	0	2	7	14	5	3.78
avge out of 100%	0	28%	60%	40%	14%	75%

As shown in the above Table 5 the overall average user acceptance evaluation of the prototype Knowledge based system is about 75%, this means the prototype is accepted by 75% of respondents. Therefore, above 75% of users are satisfied with the easiness, attractiveness, speed, accuracy, adequacy problem solving ability and the significance of the prototype knowledge based system in the domain area. This implies that the prototype modeled relevance and satisfactory domain knowledge in useful way and it performs well in making right decisions on the diagnosis of Diarrheal Disease.

CHAPTER SIX

6. Conclusion and Recommendations

6.1. Conclusion

Acute Diarrhoeal disease is widely recognized as a major cause of child morbidity and mortality in many developing countries, particularly in sub-Saharan Africa. In Ethiopia, Diarrhoeal disease is one of the most frequent causes of childhood and a major contributor to child mortality. It can last several days, and can leave the body without the water and salts that are necessary for survival. Most people who die from diarrhea actually die from severe dehydration and fluid loss.

Hence, in this study an effort has been made to design and develop a prototype of knowledge based system that can provide advice for experts and health workers (extensions) to facilitate the diagnosis and treatment of patients affected by Diarrhoeal disease.

In developing the system prototype, knowledge is acquired using both structured and unstructured interviews with domain experts and from relevant documents by using documents analysis method to find the solution of the problem. The acquired knowledge is modeled using decision tree that represents concepts and procedures involved in diagnosis and treatment of Diarrhoeal disease. Then, the validated knowledge is represented using rule-based representation technique and codified using SWI-Prolog editor tool for building the knowledge-based system to provide domain experts and healthcare workers (extensions) to diagnosis Diarrhoeal disease and provide treatments.

Furthermore, this Prototype knowledge based system developed and tested in this research work is an important tool in timely protection outbreak and dissemination of Diarrhoeal disease as well as providing advising domain experts and healthcare workers (extensions). Such system can be really useful in rural areas where experts are unavailable.

The significance of the system is also highly appreciated by domain experts in assisting and supporting healthcare workers (extensions) “ and development agents in areas where skilled experts are not accessible. By being a sharing and training tool for development agent (DA) workers, the proposed system can improve the skill of development agent (DA) workers in diagnosis Diarrhoeal disease and provide treatments.

The idea behind developing knowledge based system is that, it can enable many people to benefit from the knowledge of one expert in domain specific problems. So, Diarrhoeal diagnosing Knowledge Based System developed in this research is applicable and promising to apply the judgment and experiences of domain experts in diagnosing the Diarrhoeal and providing the descriptions and treatments of the diseases.

1.1. Recommendations

The following recommendations are given based on the observed opportunities and uncover areas by this research.

- ❖ The study included only acute Diarrhoeal disease that frequently outbreak in Ethiopia. However the scope of the knowledge based system should be expanded to include chronic Diarrhoeal disease.
- ❖ We were intended to build huge and massive knowledge based system that incorporate rules and facts, but the time was not enough and convenient to make that it concrete.
- ❖ In its present version, this system is a standalone one. For the future, it will be more attractive and effective if a Web-based version of it is developed that would make the diagnostic system accessible to anyone with a computer and an Internet connection.
- ❖ The command line user interface is prone to error. As a result graphical user interface should be considered in the future.
- ❖ This rule based system unable to learn from experience and do not operate with cases which have not matching facts in the rule base of the system. As a result the development of self-learning system should be considered.

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Appendix I

Interview Questions with domain experts

After introducing the objective of the study, respondents were requested to participate by responding the interview questions. The answers of the respondents were recorded by using paper and pen for the following interview questions. The following interview questions are the main area to cover how general practitioners diagnose a patient.

1. What is Diarrhoeal disease?
2. What are the common Diarrhoeal disease that affect Ethiopian community?
3. What are the risk factors of Diarrhoeal disease?
4. Why Ethiopian community is frequently affect by Diarrhoeal disease?
5. What are the common signs and symptoms of Diarrhoeal disease?
6. What are the concepts and procedures to diagnosis Diarrhoeal disease?
7. In the time of diagnosing the patient using only signs and symptoms, can we say the patient is affect with Diarrhoeal disease?
8. What laboratories testing method used while diagnosing a patient?
9. How to manage and stop the dissemination of Diarrhoeal disease in Ethiopian community?
10. What are the treatments and prevention mechanisms recommended for the types of Diarrhoeal diseases?

Appendix II

Questionnaire to evaluate the performance of the Diarrhoeal diseases rule based knowledge based system:

1. Is the rules in the prototype easy to understand?
1. Poor 2. Fair 3. Good 4. Very good 5. Excellent
2. Is the user interface of KBSDDD attractive?
1. Poor 2. Fair 3. Good 4. Very good 5. Excellent
3. Is the KBSDDD system efficient in time?
1. Poor 2. Fair 3. Good 4. Very good 5. Excellent
4. How much accurate the system is in categorizing the patient into the correct category?
1. Poor 2. Fair 3. Good 4. Very good 5. Excellent
5. Does the system incorporate sufficient knowledge to diagnosis a given diseases?
1. Poor 2. Fair 3. Good 4. Very good 5. Excellent
6. Does the system provide appropriate treatment for the patient?
1. Poor 2. Fair 3. Good 4. Very good 5. Excellent
7. Does the system significant in the domain area?
1. Poor 2. Fair 3. Good 4. Very good 5. Excellent