ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF INFORMATION SCIENCE

A SELF-LEARNING KNOWLEDGE BASED SYSTEM FOR DIAGNOSIS AND TREATMENT OF DIABETES

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BY

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Chair person, Examining Board	Signature
_____	_____
Advisor	Signature
_____	_____
Examiner	Signature

DEDICATION

I would like to dedicate my thesis work to my beloved brother Engineer Nebyi Gebremariam. Thank you for all you have done. God bless you, Neba!

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First and foremost, I would like to thank God without his assistance neither completing my thesis work nor my effort would have been successful.

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LIST OF ACRONYMS AND ABBREVIATIONS

AC: Accuracy

A1C: Glycated Hemoglobin

AI: Artificial Intelligence

CBR: Case-Based Reasoning

CLISP: C Language Integrated Production System

dL: deciliter

F: F-measure

FOL: First-Order-Logic

FP: False Positive

FPG: Fasting Plasma Glucose

KBS: Knowledge-Based System

LISP: List Processing

mg: milligram

NLP: Natural Language Processing

OGTT: Oral Glucose Tolerance Test

P: Precision

PROLOG: Programming in Logic

R: Recall

TP: True Positive

ABSTRACT

Diabetes is a permanent disease in which the human body's cells either do not respond properly to insulin or insulin production is insufficient. If the disease is not treated well and on time, it can lead to severe health problems like heart disease, blindness, failure of kidney, and amputations of the lower extremity. Therefore, this chronic disease needs dietary control, physical exercise and insulin management.

However, among people in the developing countries like Ethiopia, permanent diseases are growing to be causes of death. These problems are becoming worse due to the scarcity of specialists, practitioners and health facilities. In Ethiopia, there has been observed a threat of increased diabetes prevalence and the number of death rates imputed to diabetes reached above 21,000 in 2007.

In an effort to address such problem, this study attempts to design and develop a prototype self-learning knowledge-based system that can provide advice for physicians and patients to facilitate the diagnosis and treatment of diabetic patients. To this end, knowledge is acquired using both structured and unstructured interviews from domain experts which are selected using purposive sampling technique from Black Lion Hospital Diabetes Center. Relevant documents analysis method is also followed to capture explicit knowledge. Then, the acquired knowledge is modeled using decision tree that represents concepts and procedures involved in diagnosis and treatment of diabetes and 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.

Moreover, in testing and evaluating the prototype system eighteen patients' history are selected in order to test the accuracy of the prototype system and also for ensuring whether the prototype system satisfies the requirements of its end-users or not. Thus, the overall total performance of the prototype system is 84.2%. The prototype system achieves a good performance and meets the objectives of the study. However, in order to make the system applicable in the domain area for diagnosis and treatment of diabetes additional study is needed like updating the rules in the knowledge base of the system automatically, incorporating a well designed user interface and a mechanism of NLP facilities.

Keywords: Knowledge-Based System, Self-learning, Diabetes.

CHAPTER ONE
INTRODUCTION

1.1 Background of the Study

Diabetes is a long-lasting disease associated with irregularly high levels of glucose (sugar) in the blood. If the disease is not treated well and on time, it can lead to severe health problems like heart disease, blindness, failure of kidney, and lower extremity complications **[1]**. Diabetes is a chronic disease in which the human body's cells either do not respond properly to insulin or insulin production becomes insufficient. In order to understand the concept of diabetes, it is important to know how our body cells use glucose to produce energy. As a matter of biological process, the food that someone eats is transformed into glucose and energy is generated from glucose. This energy makes the body cells to accomplish their tasks. During the process of energy production, pancreas (a gland organ in the digestive system) produces a hormone called insulin. Insulin enables the body cells to absorb glucose. Nevertheless, diabetic individuals either cannot produce this hormone properly or their body cannot appropriately use it for usual body functions. Consequently, this creates the accumulation of glucose in the blood and when the accumulated glucose is not used by the body cells, then signs of diabetes start to come out **[1]**.

There are several symptoms of diabetes. The most common symptoms include polydipsia or increased excessive thirst, polyuria or increased frequent urination, polyphagia or too much hunger, unexplained weight loss, weakness or tiredness, vision problem, slow-healing wounds, dizziness, and irritability **[2]**.

There are two main types of diabetes **[3]**. These are Type 1 and Type 2 diabetes. Sometimes, Type 1 diabetes is called insulin-dependent diabetes. In this type of diabetes, a person's pancreas either produces little insulin or it cannot produce any insulin. Diabetic patients with Type 1 diabetes are around 10% of the population. Most people think that Type 1 diabetes occurs among young people. However, a person can get Type 1 diabetes at any age. This type of diabetes can be controlled by daily injections, meal planning, exercise, self-blood glucose monitoring, and education **[1]**. Type 2 diabetes is the most common type of diabetes that is also known as non-insulin-dependent diabetes. In this type of diabetes, the pancreas produces insulin, but it does not yield sufficient amount or the body may have difficulty in using it properly. Most of the time, it

is associated with age (senility), obesity (being overweight), history of diabetes in the family, and lack of physical exercise. Again, this type of diabetes can be controlled by meal planning, reaching and maintaining a healthy weight, exercise, possible use of diabetes pills or insulin injections, self-blood glucose monitoring, and education **[1]**.

Therefore, this chronic disease needs dietary control, physical exercise and insulin management. However, the existing practices for medical treatment need patients to see specialist for diagnosis and treatment. Other medical physicians may not have sufficient knowledge or skill to deal with certain diseases like diabetes. Nevertheless, the waiting time for treatments usually takes a few days or weeks. By the time the patients get the chance to see the specialist, the disease may create other serious health problems. The patients may suffer throughout their life since most of the diseases like diabetes could only be treated at the early stage **[4]**.

Knowledge-based intelligent systems can be employed to reduce the number of deaths and the waiting time to see the specialist. The systems developed by imitating human intelligence could be employed to help the medical doctors in making decision without consulting the specialists. The system is not meant to replace the specialist or medical doctor, but it is developed to help general physicians and specialists in diagnosing, predicting condition of patient, and providing treatments from certain grounds or experiences. Thus, using knowledge-based systems can be an encouraging solution to reduce cost, time, human expertise and medical error **[4]**.

Balakrishnan and Honavar **[5]** noted that "knowledge-based systems can be used in a variety of domains. The major once include medical diagnosis, plant disease diagnosis, crop management problem diagnosis, credit evaluation and authorization, financial evaluation, identification of software and hardware problems and integrated circuit failures, troubleshooting of electrical, mechanical and electronic equipment, fault detection in nuclear power systems, oil exploration, prospecting and seismic studies".

Knowledge-based systems are one of the specialized branches of artificial intelligence functioning in a specific domain to offer wise decisions with reasoning. Tacit and explicit knowledge can be acquired, modeled, and represented using several knowledge representation techniques such as logic, production rules, semantic nets, frames and cases. The main benefits provided by such system are wise decisions, learning from experience, explanation and/or reasoning, and solving problems **[6]**.

In this study, the researcher needs to develop a low-cost automated knowledge-based system incorporating the skills of medical experts to help the patients in self-diagnosis and management of diabetes.

1.2 Statement of the Problem and its Justification

A study conducted by Wild et al. **[7]** shows that the occurrence of diabetes in people at any age throughout the world was predicted 2.8% in 2000 and 4.4% in 2030. The numbers of people living with diabetes were one hundred seventy-one million in 2000 and will be expected to increase to three hundred sixty-six million in 2030. Moreover, an increase in the number of people between 2000 and 2030 will reside in the cities of less-developed countries and there will be a rise in the numbers of adults living with diabetes by 69% in less-developed countries. Similarly, the number of adults living with diabetes is expected to increase by 20% in more developed countries.

Among the people of less-developed countries like Ethiopia, long-lasting diseases are the growing causes of death. Moreover, these problems become worse due to the scarcity of specialists, practitioners and health facilities. In Ethiopia, there were 103 hospitals and 338 medical centers in 2000. Nevertheless, there were only two medical schools which train medical specialists (physicians) in the nation. The medical doctors/patient ratio was less than 3:100,000 **[8]**. Hence, Ethiopia is under threat of increased diabetes prevalence and the number of deaths imputed to diabetes reached above 21,000 in 2007 **[9]**.

According to Wild et al. **[7]**, the number of people living with diabetes is increasing due to population growth, aging, urbanization, overweight and lack of physical exercise. Besides, several studies indicate that access to health care is other problem which contributes to the poor diagnosis of people living with diabetes in Ethiopia **[10]**. Patients are expected to travel long distances to their nearest medical center in order to get medical service. Around 60% of the rural people living with diabetes had to travel more than 40 km to reach their nearest hospital, 23% travelling more than 100 km and 13% above 180 km **[10]**.

The nature of diabetes is a lifelong disease and cannot be treated for once and last. Because of this, patients need consistent treatment. However, in our country, there are no sufficient numbers of specialists and medical doctors **[8]**. This condition leads to disproportional numbers of

physicians and patients. Because of this problem, patients are not getting enough diagnoses and treatment. Thus, the significance of conducting this study is to support physicians in the diagnosis and treatment of diabetic patients, particularly in our county where more than 85% of the Ethiopian population lives in rural areas **[11]**. If diabetic patients get proper treatments, they can control their sugar level, which will further enable them to minimize the number of deaths which could result due to diabetes.

In the last decade, as shown in table 1.1, several studies were conducted locally on knowledge-based systems in order to support reasoning and finding solutions for certain problems like in the area of health and medicine. These are Prototype knowledge-based system in antiretroviral therapy **[12]**, Design and development of a prototype knowledge-based system for HIV pre-test counseling **[13]**, The potential for applying knowledge-based system for diagnosis of acute respiratory tract infections **[14]**, Prototype knowledge-based system for anxiety mental disorder diagnosis **[15]**, and Designing a knowledge-based system for blood transfusion **[16]**. However, as shown in table 1.1, the knowledge-based systems using rule-based representation technique did not hold all the necessary rules, and they are not self-learning. In addition, the review shows that there is limited work to apply KBS in medicine domain. Thus, there is a need to design a self-learning knowledge-based system that can update its knowledge through experience.

Author's Name	Year	Title	Technique used	Self-learning
Anteneh **[12]**	2004	Prototype Knowledge-Based System in Antiretroviral Therapy	Rule-based reasoning	No
Redeit **[13]**	2006	Design and Development of a prototype Knowledge-Based System for HIV Pre-Test Counseling	Rule-based reasoning	No
Solomon **[14]**	2010	The Potential for Applying Knowledge-Based System for Diagnosis of Acute Respiratory Tract Infections	Rule-based reasoning	No
Seblewongel **[15]**	2011	Prototype Knowledge-Based System for Anxiety Mental Disorder Diagnosis	Rule-based reasoning	No
Guesh **[16]**	2012	Designing a Knowledge-Based System for Blood Transfusion	Rule-based reasoning	No

Table 1. 1 Summary of local related works on KBS

Hence, the aim of this study is to design a self-learning knowledge-based system for diagnosis and treatment of diabetes that assists to control the sugar level of patients, and in order to minimize the number of deaths because of diabetes, especially in remote and rural areas of the country.

To this end, the study attempts to explore and find solutions for the following research questions:

- What suitable domain knowledge exists in an explicit and tacit form for diagnosis and treatment of diabetes?
- How to model and represent the acquired knowledge for developing the knowledge-based systems?
- How to design a self-learning knowledge-based system that automatically updates its knowledge?

1.3 Objectives of the Study

The general and specific objectives of the study are the following.

1.3.1 General Objective

The main objective of this study is to design and develop a prototype self-learning knowledge-based system that can provide advice for physicians and patients in order to facilitate the diagnosis and treatment of diabetic patients.

1.3.2 Specific Objectives

With the aim of achieving the above general objective, the study also has the following specific objectives:

- To review and compile some literatures so as to help readers understand the concepts, and principles of knowledge-based systems.
- To acquire tacit and 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 a prototype self-learning knowledge-based system for diagnosis and treatment of diabetes.
- To test and evaluate the performance of the prototype system with the help of professional experts in the field.

1.4 Scope and Limitations of the Study

The scope of this research is to design a self-learning knowledge-based system for diagnosis and treatment of diabetes. Diagnosis and treatment of diabetes using knowledge-based system helps to reduce death rate because of diabetes. Nevertheless, it does not provide diagnosis and treatment facilities for gestational and other type of diabetes.

According to Longo et al. **[17]**, diabetes is classified into four groups. These are Type 1, Type 2, gestational and other types of diabetes. However, the authors designated Type 1 and Type 2 diabetes as the two most common groups of diabetes. As a result, the researcher focused only on these two broad groups of diabetes.

Although tacit knowledge about diabetes is acquired from Internists and medical doctors from Black Lion Hospital using interviews in order to have detail understanding of the domain

knowledge, it was difficult to interview them at any time because they have a shortage of time. Due to this reason, the knowledge acquisition process is challenging task and took too much time. Besides, adequate knowledge may not be extracted from domain experts due to the personal nature of tacit knowledge.

The knowledge-based system gives possible treatments for diabetic patients. These include suggesting medications one should take, foods should be eaten, physical exercises, foods to be avoided or limited, and monitoring glucose level in the blood. As a knowledge-based system, it also enables to remember the patient history from experience and update its knowledge accordingly.

1.5 Methodology of the Study

With the aim of achieving the objective through answering the research questions of this study, the following methods and techniques are used.

1.5.1 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 retrieved from the internet are consulted so as to understand the domain knowledge, concepts, principles and methods that are important for developing knowledge-based systems.

1.5.2 Methods of Knowledge Collection

In this study explicit and tacit knowledge is acquired from both codified (documented) sources and non-codified (non-documented) sources respectively. Non-codified sources of knowledge are acquired from Internists and medical doctors who work in the Black Lion Hospital by using interview and critique knowledge elicitation methods to filter the acquired knowledge. Similarly, codified sources of knowledge such as medical books, training manuals and journal medical articles are acquired by using document analysis technique.

1.5.3 Knowledge Modeling and Representation Methods

In this study, after the knowledge is extracted from codified and non-codified sources, it is modeled using decision tree and represented using production rule which is one of the

knowledge representation techniques. Decision trees models by constructing a tree based on training instances with leaves having class labels is used. These are easy to interpret (can be represented as if–then-else rules). Production rules are easy for a human expert to read, understand and maintain. Production rules contain simple syntax that is flexible and easy to understand and are reasonably efficient in diagnosing problems of the form: IF (condition), THEN (conclusion). The reasons for using productions rules for this study are because of its ease of encapsulation of knowledge and ease of extensions to the knowledge base in the future **[1]**. The prototype system uses backward chaining also called goal-driven chaining which begins with possible solutions or goals and tries to gather information that verifies the solution.

1.5.4 System Development and Implementation Tool

A prototyping approach is followed to develop the knowledge-based system. Prototyping is preferred as it enables for better management of the system during implementation, i.e. testing and demonstration **[18]**.

In this study, a knowledge engineer is involved throughout the development process of the knowledge-based system. Four major procedures or steps are followed in developing the KBS. These are:

(1) **Knowledge acquisition**: The knowledge engineer interviewed four domain experts to extract the tacit knowledge. The knowledge engineer also acquires the explicit knowledge from relevant documents such as medical books, manuals and other sources.
(2) **Knowledge modeling**: The acquired knowledge is modeled using decision tree by constructing a tree based on training instances with leaves having class labels.
(3) **Knowledge representation**: After modeling the acquired knowledge using decision tree, it is represented using production rule which is easy to understand and reasonably efficient in diagnosing problems of the form: IF (condition), THEN (conclusion).
(4) **Testing and evaluation**: Finally the prototype is built and extensively tested and evaluated to make sure whether the system is accepted by the end-users and the performance of the system is accurate.

Akerkar and Sajja **[19]** noted that the knowledge engineer should play a crucial role in knowledge elicitation, knowledge modeling, knowledge representation, implementation, testing and evaluation of the KBS.

To develop the knowledge-based system, Prolog programming language is used. Specifically, SWI-Prolog editor has been chosen for this study. SWI-Prolog editor has debugging tool and flexible help system. Moreover, the code is readable and easier to update and maintain. It offers backward reasoning capability, which is found to be suitable for medical diagnostic and management problems.

1.5.5 Testing and Evaluation

To meet the established objectives of this study, the prototype system is extensively tested and evaluated including both performance of the prototype system and issues of user's acceptance. Eighteen patients cases are selected by applying purposive sampling technique from Black Lion Hospital Diabetes Center for testing performance of the prototype system. These patients cases are grouped into three based on the similarities of the patients cases. These are Type 1 diabetes patients cases, Type 2 diabetes patients cases, and other diabetes type patients cases. The correct and incorrect results are classified by comparing decisions made by the domain experts on the cases of patients and with the prototype system conclusions. The performance comparison parameters such as precision, recall and F-measure are used to measure the accuracy of the prototype system. Issues of user's acceptance testing are also done to see the quality of advice and to access to what extent the KBS satisfies the domain experts.

1.6 Significance of the Study

Knowledge-based systems are artificial intelligent tools functioning in a specific domain to provide advice and consultation in decision making. 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 medical 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 diabetes.

1.7 Organization of the Thesis

The main body of this thesis is organized in five chapters. The first chapter introduces the background of the study and statement of the problem and its justification. It also presents objectives of the study, scope and limitations of the study, methodology of the study, and significance of the study.

The second chapter presents review of related literature. It provides an overview of knowledge-based system, architecture of KBS, types of knowledge, knowledge acquisition, knowledge modeling, knowledge representation, knowledge verification, validation, usability and usefulness, tools used in KBS development, applications of knowledge-based system, and review of related works.

The third chapter discusses the acquisition of knowledge from different sources, and conceptual modeling of the acquired knowledge using decision tree. It also discusses the representation of the validated acquired knowledge using production rules for developing the prototype system.

The fourth chapter presents implementation of the knowledge-based system. It also presents the testing process and discusses the evaluation result on the performance of the prototype system. Besides, it shows analysis and interpretation as a basis for discussing the findings of the study.

Finally, chapter five puts the major findings, based on which it provides concluding remarks and recommendations for further research in the domain area.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview of Knowledge-Based System

Knowledge-based system (KBS) is a computer program that is derived from a computer science field of study known as Artificial Intelligence (AI). The systematic aim of AI is understanding intelligence by developing computer programs that show intelligent behavior. It deals with methods of inferring mechanisms using the computer and in what way knowledge can be represented using different techniques for inferring **[20]**.

According to Engelmore and Feigenbaum **[20]**, "intelligence deals with many cognitive skills, comprising the capability to find solution of problems, learn, and understand language. However, developments up to the present time in AI have been made in the area of problem solving - concepts and methods for constructing program that reason about problems instead of finding the solution".

The area of human intellectual endeavor to be captured in a knowledge-based system is called the task domain **[21]**. Task denotes to certain goal-directed, problem-solving endeavors. Domain denotes to the area within which the task is being performed. Typical tasks are diagnosis, planning, scheduling, configuration and designing **[21]**.

Moreover, as depicted in table 2.1, there are better essences of knowledge-based systems than any computer-based information systems **[22]**. Actually, KBS was evolved from expert systems. It is a computer-based information system that creates knowledge after the process of data or information and can be used for decision making. Hence, the processed data or information is easily understandable by the KBS but not possible by traditional computer-based information systems.

Traditional Computer-Based Information System (CBIS)	**Knowledge-Based System (KBS)**
Provides a certain solution and focuses on efficiency	Enhances power to the solution and focuses on effectiveness without any assurance of solution
Follows data and/or information processing approach	Follows knowledge and/or decision processing approach
Supports in actions associated with decision making and routine transactions; aids need for information	Transfer of knowledge; if necessary, it makes a decision based on knowledge, justifies it, and improves it
Manipulation technique is numeric and algorithmic	Manipulation technique is mainly symbolic/connectionist and non-algorithmic
These systems make less errors	These systems learn from past faults
Require comprehensive information and/or data	Can handle incomplete and ambiguous information, data, or knowledge
Functions for complex, integrated, and wide areas in a reactive manner	Functions for narrow domains in a reactive and proactive manner

Table 2. 1 Differences between KBS and CBIS adopted from [22]

2.1.1 Objectives of Knowledge-Based System

As Turban **[23]** noted, one example of the specialized branches of AI is KBS. The objectives of KBS are listed as follows:

- Offers a great level of intelligence
- Supports individuals in finding out and constructing new fields
- provides a huge amount of knowledge in several areas
- Assists in knowledge management that is deposited in the knowledge base
- Finds solution for social problems in a well manner than the traditional computer-based information systems.
- Gains new observations by imitating new circumstances
- Provides important software development productiveness
- Importantly decreases time and money to construct automated systems

2.1.2 Advantages of Knowledge-Based System

The main advantages of using a knowledge-based system are descried as follows **[19]**:

Permanent documentation of knowledge: A knowledge engineer extracts knowledge from domain experts and relevant documents for a certain problem domain and represents it using one of the knowledge representation techniques and transfers it into the knowledge base. This helps end-users to use the knowledge stored for a long-term from the documented knowledge in the knowledge base at any time.

Cheaper solution and easy availability of knowledge: It is assumed very huge, complicated and expensive to develop a KBS. Nevertheless, it costs once for building the knowledge base. After duplicating it into many copies, it is simple to use the knowledge in many places. This interrupts the dominations of domain experts and makes simple to acquire and utilize knowledge. On the contrary, educating new domain experts is inefficient and costly. Therefore, the aim of developing KBSs is to reduce cost, time, human expertise and medical error.

Dual advantages of effectiveness and efficiency: Since knowledge-based systems are computer-based systems, they have efficiency-directed factors such as speed, accuracy, control, and permanent content storage. It is possible to make the knowledge-based system effective by integrating the knowledge element. They are more efficient than domain experts and attempts to become equally effective like domain experts.

Consistency and reliability: Since the knowledge element is integrated into the KBS and the capability to perform effectively, the trustworthiness of the system rises. Besides, dupery and errors can be stopped. Information can be accessible rapidly for making decision with appropriate justification. As the level and amount of knowledge rises, making right decision will rise and thereby reduce the threat of wrong decision.

Justification for better understanding: The reliability of the domain experts relies on the capability to explain their decisions. This can be offered by using the reasoning and justification component of the KBS to the end-users. If there is a well understanding of the decisions made by end-users of the system, then it increases the quality and trustworthiness of the system.

Self-learning and ease of updates: With the assistance of the inference engine of the system, the knowledge base always updates its knowledge from experience. The knowledge-based system can update its knowledge either using automatic machine learning or manually by the knowledge engineer. Such self-learning advances the adaptability and tractability of the system.

2.1.3 Limitations of Knowledge-Based System

The following are some of the major drawbacks of using the KBS **[19]**:

Partial self-learning: The knowledge-based systems can explain when they made a decision and learn from experience by updating its knowledge. However, the represented knowledge may not be completely known so that the knowledge-based system can learn partially from experience. Besides, domain experts can conform automatically to new conditions though KBSs should explicitly update their knowledge.

Creativity and innovation: It is not possible computer-machines to show a certain behavior as creative as humans do. Domain experts can answer back in a creative manner to new conditions though knowledge-based systems as a maximum can deal with the five basic senses. KBSs do not have any methodology to deal with invention, the ability to create and common sense. If we use AI methods in KBS, humanlike five basic senses can be partly applied. The vision, listening, smell, taste, and touch tasks are implemented so that they cannot totally assist activities associated to perception, emotion, and enjoyment. This is because knowledge-based systems are now reliant on symbolic input though human beings have a varied of sensory experience.

Weak support of methods and heuristics: Knowledge-based systems cannot operate with their full capacity if there is no response given or the problem is out of the system's knowledge. When the heuristics is applied to look for a solution from the search space, the success of the systems relies on the quality of the heuristics. Thus, the responsibility depends on the knowledge engineer to develop the heuristics.

Development methodology: System development is not only an art but also a science. For example, in the development of information systems there is no one common accepted methodology. There are common guidelines and lifecycle models that help to develop all types of computer-based information systems. However, there is no common development model that helps knowledge engineers to develop a KBS.

Knowledge acquisition: It is the transfer of knowledge from its source into an appropriate format that can be used by the knowledge-based system. Knowledge is basically personal in nature and is therefore very challenging to extract the embedded knowledge from human mind.

Development of testing and certifying strategies and standards for knowledge-based systems: A knowledge-based system operates in a specific problem domain. The absence of standardization is the main limitation of the existing state of acceptance of knowledge-based system. The acquired knowledge from its source should be tested before representing it into the knowledge base using one of the knowledge representation techniques. Likewise, the knowledge base should be tested even after the representation of the validated knowledge. Standards such as verification, validation and quality metrics are required for ensuring the quality of the KBS.

2.2 Architecture of Knowledge-Based System

The societies and industries are getting knowledge-based and dependent on various decision-making capabilities of experts. KBS can act like an expert available when needed without wasting any time. KBS can be seen as an effective tool since it comprises knowledge from several domain experts in a specific area for a long time. According to Sajja and Akerkar **[24]**, every KBS have at least five main components. These components are depicted schematically in figure 2.1 and are explained below.

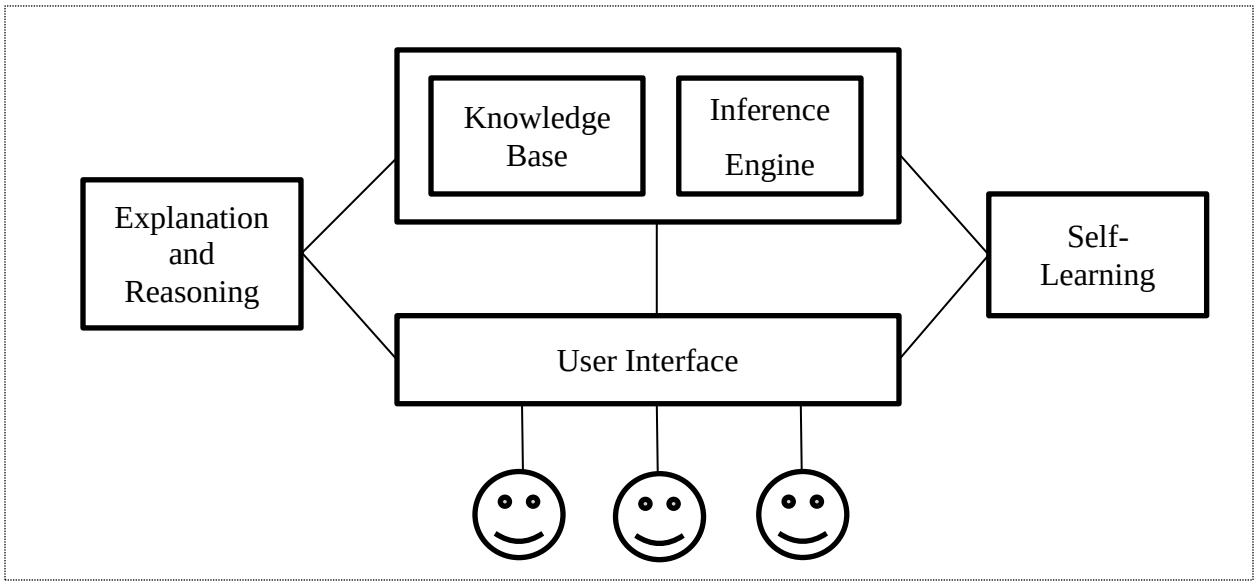

Figure 2. 1 Architecture of KBS adopted from [19]

2.2.1 Knowledge Base

The knowledge base comprises specific knowledge on a certain domain that makes human an accurate expert on the specific domain. This knowledge is extracted from human expert and encoded in the knowledge base using different knowledge representation techniques. In a knowledge-based system, one of the main techniques used for representing the knowledge is rule. A rule has an IF/THEN type structure which links a certain identified information in the IF part with the concluded information in the THEN part.

An example can be given as follows:

Rule: **IF** symptoms of diabetes = "related symptoms of diabetes"
AND lab test result using FPG = "≤99 mg/dL",
THEN diabetes type = "Diabetes Free"

Given fact: The patient has signs of related symptoms of diabetes and the laboratory result using FPG test method shows 99 mg/dL.
Conclusion: The diagnosed patient is free from diabetes.

This rule contains knowledge which represents for diabetes diagnosis. It links the condition of the patient with the type of diabetes the patient has. Using the rule, one can construct a comprehensive knowledge base for diagnosing different domain problems **[24]**.

2.2.2 Inference Engine

According to the end-user input and the set of facts from the knowledge base and/or other sources, the inference engine infers facts or makes conclusions from the knowledge base. Three main techniques are known when deducing facts or drawing conclusions from the knowledge base **[6]**, these are: forward chaining, backward chaining and hybrid chaining.

Forward chaining technique is also called data-directed inference. It begins with some facts and rules in the knowledge base and attempts to find all possible conclusions from the data. This technique is appropriate when a goal state is indeterminable.

On the other hand, backward chaining which is also called goal-directed inference technique begins with possible conclusions or goals and functions towards the back to find supporting facts

that verifies the goal. This technique often offers better explanation and reasoning for how we reached at a specific goal.

When there exists a very complex problem domain, the above two techniques can be merged to produce an efficient program called hybrid chaining. Hence, in order to design the strategies used by the expert in the domain area, KBS must implement a complex inference engine that may involve both backward and forward chaining techniques.

2.2.3 Explanation/Reasoning Facility

In addition to delivering the end outcomes, domain experts together with KBSs can clarify 'how' they reached at outcomes. This ability is usually essential since this kind of problems to which KBSs are carried out need an explanation of the outcome delivered to the end-users. KBSs also have the ability of justifying 'why' a certain problem is being questioned **[25]**.

For example, if an automated banking machine (ABM) comes to a decision to take-up the card of end-user, then the ABM can show an explanation message like:

> *"Sorry, password still incorrect after three trials. We withheld your card, for your protection. Please contact your bank during regular office hours for help".*

According to Castillo et al. **[26]**, in several domains of problems explanations of the actions are essential because of the hazards related with the conclusions to be fired. For instance, in the medical diagnostic field, medical physicians are liable at the end of the day for the diagnoses made, irrespective of the help tools applied to make the actions. In these circumstances, in the absence of an explanation facility, medical physicians may not be capable to justify the reasons for diagnosis to their patients.

2.2.4 Self-Learning

Self-learning is one of the elements of KBS which tries to imitate the learning capability of human beings. It is possible to update the knowledge base of the KBS either manually or automatically using machine learning algorithms **[24]**.

According to Akerkar and Sajja **[19]**, "Self-learning is a scientific task that enables the knowledge-based system to learn automatically from the inference process, cases executed, and

environment. To carry out such tasks, one needs to have a control mechanism that discovers general conjectures and knowledge from specific data and experience, based on sound statistical and computational principles".

One of the key characteristics of KBS is the capability to learn. According to Castillo et al. **[26]**, there are three methods of learning. These are structural learning, parametric learning and learning by memorization.

Structural learning denotes to certain features associated to the structure of knowledge such as rules and probability distributions. For example, finding a new related symptom for a certain disease or incorporating a new rule in the knowledge base.

Parametric learning denotes to conjecturing the parameters required to build the knowledge base. For example, conjecture of probabilities associated with symptoms or diseases.

Learning by memorization denotes the capability of KBS to learn from experience based on the existing data. Using this method, KBS can carry out different activities such as storing or memorizing knowledge, and learning from the facts base.

Let us see the following example program that shows self-learning using learning by memorization method **[27]**. This is shown in figure 2.2 as follows:

```
? - start.
Type names all in lower case, followed by period.
Type “stop.” to quit.

Please enter the name of state? england.
The capital city of england is london.

Please enter the name of state? china.
I do not know the capital city of that state.
Please tell me.
Please enter the name of capital city? beijing.
Thank you.

Please enter the name of state? egypt.
The capital city of egypt is cairo.

Please enter the name of state? china.
The capital city of china is beijing.

Please enter the name of state? stop.
Saving the facts base...
Done.
```

Figure 2. 2 A program that shows self-learning

In the above figure 2.2, the program has learned what the capital city of china is. The learning process is continuous, i.e. when we run the program at the next session and question for the capital city of china, the program replies the right answer.

2.2.5 User Interface

As Castillo et al. **[26]** noted, user interface is a channel for communication between the KBS and the end-user. Therefore, in order for the KBS to be an interactive *tool*, it should include a means to show and retrieve information in a simple manner. Examples of information to be shown are the consequences made by the inference engine, the justifications for such consequences, and an explanation for the actions made by the KBS. Conversely, when no consequence can be arrived

by the inference engine like because of the absence of information, the user interface offers a mechanism for attaining the desired information from the end-user. Therefore, an insufficient implementation of the user interface that does not assist this process would hinder the importance of the KBS by the end-users. Moreover, the reason for the significance of the user interface component is that end-users usually evaluate KBSs based on the quality of the user interface instead of the KBS itself.

2.3 Types of Knowledge

Knowledge is a set of facts designed for a special activity, procedures, and decision commonly articulated as rules **[19]**. As shown in table 2.2, types of knowledge can be used in AI. These types of knowledge may come from various sources like human mind, books, documents, sensors, computer files and so on.

Knowledge Type	**Meaning**	**Example**
Permanent	Not changeable knowledge	Human beings are mortal; water falls down, etc.
Static	Unchangeable knowledge for a certain period of time	Rules and principles
Dynamic	Endlessly changing knowledge	Prices of coffee

Table 2. 2 Types of knowledge adopted from [19]

2.3.1 Levels of Knowledge

It is possible to symbolize knowledge at various levels. The two common are shallow and deep knowledge **[28]**.

Shallow Knowledge is the representation of outermost level information that is used to address with very particular conditions. The shallow knowledge form represents the input and output relationship of a certain system. Intrinsically, it can be preferably represented in terms of IF-THEN rules. Shallow representation is narrow. A collection of rules by itself may have limited meaning for the end-user. This may restrict the ability of the system to offer suitable justifications to the end-user. Shallow knowledge may also be inadequate in describing complex circumstances.

Deep Knowledge is the interior and causal structure of a certain system and comprises the relations between the system's elements. It can be applied to various tasks and various circumstances. It is also hard to automate this kind of knowledge. The system developer should have a complete intellectual ability of the main components and their relations.

2.3.2 Categories of Knowledge

Knowledge can be classified as declarative, procedural, or meta-knowledge **[28]**.

Declarative knowledge is a descriptive representation of knowledge. It expresses facts like what things are. It is expressed in an actual statement, for instance, there is a positive relationship between cigarette smoking and cancer. Experts of the domain tell us about facts and relationships. This kind of knowledge is regarded as shallow information that domain experts can articulate. It is mainly essential in the early phase of knowledge acquisition.

Procedural knowledge conceives the way in which things function under various collections of conditions. Hence, it comprises successions in a gradual manner and how-to kinds of instructions; it may also comprise justifications. It includes automatic replies to inputs. It associates to the procedures used in the problem-solving process. For example: information about defining the problem, gathering of data, process of the solution, and criteria of evaluation.

Meta-knowledge is knowledge about knowledge. In knowledge-based systems, meta-knowledge is knowledge about the operation of knowledge-based systems (i.e., about their reasoning capabilities).

2.4 Knowledge Acquisition

Knowledge can be gathered from different sources such as books, databases, images, maps, flow of diagrams, stories, sensors, and so on. According to Anand and Singh **[29]**, there are usually two types of knowledge sources. These are documented (tacit) knowledge and undocumented (explicit) knowledge. Tacit knowledge is commonly deeply ingrained in human mind and organizations through experience. Explicit knowledge is relatively simple to express and capture in the form of books, tables, diagrams, and so on. Knowledge can be discovered and collected by using either the human senses or machines (e.g., scanners, cameras, pattern matchers, intelligent agents) **[28]**.

The extraction of appropriate knowledge from experts and other sources are the essential aspects in the knowledge-based system development process. In fact, knowledge acquisition is performed during the whole knowledge-based system development process **[28]**.

2.4.1 Methods of Acquiring Knowledge from Experts

Acquiring knowledge from experts is not a simple task. It involves knowledge identification, knowledge representation in an appropriate format, organizing the knowledge, and transferring the knowledge to a computer machine. Some of the reasons that increase to the difficulty of knowledge acquisition from experts and its transfer to a computer machine are stated below **[28]**:

- Experts possibly will not recognize to express or state clearly their knowledge.
- Experts possibly have shortage of time to be able to work together with knowledge engineers.
- Examining and filtering knowledge is very difficult.
- Ways for knowledge elicitation possibly are ill-defined.
- It is hard to identify a particular knowledge when it is mingled with unrelated data and information.
- Knowledge engineers possibly will vary their behavior when they are conducting an interview, and bad communication factors that occur among people may affect the knowledge collection task.

The process of acquiring knowledge from experts could be significantly acted upon by the roles of the three main actors: the knowledge engineer, the expert, and the end-user. The best approach to the interrelationships of these actors is provided by Sandahl **[30]**. He suggested that experts must play a very significant role in the construction of a knowledge base. The knowledge engineer must act as a trainer of knowledge structuring, a tool designer, and a catalyst at the interface between the expert and the end-users.

The knowledge engineer should have the factual social skills. Some roles of the knowledge engineer are discussed below **[31]**:

Good communication skills: The process of knowledge elicitation demands a lot of time for discussion and debate. When results have been accorded with experts, it should be recorded. This needs an excellent use of the spoken and written word, diagrammatic representation, and

clarification of body communication. Most of all there should be a good association between the knowledge engineer and expert. A person having a bad communication skill cannot be an effective knowledge engineer.

Intelligence: The knowledge engineer often updates his/her knowledge through learning. He/she wants to be capable to update a new knowledge domain, and know sufficient of the terminology and principles to be capable to argue it completely with a recognized expert. He/she should keep informed with developments in hardware and software. Moreover, he/she wants to have knowledge of disciplines such as formal logic, probability theory and psychology.

Tact and diplomacy: The attainment of the task possibly relies on the collaboration of little number of significant experts. An expert who has been estranged by self-seeking or undiplomatic handling will incline to drop off interest. Any idea that is suggested that a program can substitute or outdo the expert can be catastrophic. Thus, it is an indication that the expert is unable to offer the factual information in a suitable manner.

Empathy and patience: The knowledge engineer and expert should work in partnership with valuing one another as a team. This implies that the knowledge engineer should appreciate the problems faced by the expert.

Persistence: Outcomes may come gradually. So, to find the solution of the problems, the knowledge engineer should be persistent; he/she should keep his/her passion and trust in the task. Even though there are obstacles, he/she should be able to believe that achievement will come at the end.

Logicality: The knowledge engineer wants to be capable to contend rationally, knowing effective statements and offering substantial refutation by examples for potential mistakes. The comprehensiveness and consistency of the evolving model should also be evaluated. This necessitates a level of strong thought and logicality.

Self-confidence: The intermingling of these abilities should be synchronized by self- confidence. Even though the knowledge engineer is technically capable person, scared person would not be capable to regulate a task. Developing a knowledge-based system is a difficult task and the knowledge engineer should have sufficient self-confidence to keep up passion for the task.

Domain knowledge: It is better to discuss the knowledge engineer with the domain expert in the domain expert's terminology. Thus, it will be more useful for the knowledge engineer to have certain background knowledge of the domain.

Programming knowledge: The components of the knowledge-based system such as the knowledge base and inference mechanisms are implemented in a program. It is recommended but insignificant that the knowledge engineer may be able to understand programming and different knowledge representation techniques. However, an intellectual and versatile approach is the most significant thing during knowledge acquisition process.

2.4.2 Knowledge Acquisition Methods

Knowledge acquisition methods can be classified into manual and computer-based. Computer can support to acquire knowledge using semi-automatic or fully-automatic means **[32]**.

2.4.2.1 Manual Knowledge Acquisition Methods

The manual knowledge acquisition methods comprise **[32]**: Interview (structured and unstructured), tracking methods, and observation.

Interviews: The most frequently used form of knowledge acquisition is interviewing. This is an unambiguous technique that comes out in numerous inconsistencies. It encompasses a direct exchange of ideas between the human expert and the knowledge engineer. Information is gathered with the help of instruments such as tape recorders, questionnaires, and so on and is consequently transliterated, analyzed, and coded. During the interview, the expert is presented with an imitated case or, preferably, with a real problem that the KBS will be anticipated to find the solution. The expert is inquired to talk the knowledge engineer via the solution of the problem.

One variant of the interview approach starts with no information at all being given to the expert. Whatever facts the expert needs should be inquired for openly. This variant makes the expert's path via the domain more manifest, mainly in terms of defining the input a KBS would expect. The interview process can be boring. It lays great demands on the domain expert. The expert should be able to exhibit expertise and express it. On the contrary, it needs little equipment and

can generate a huge amount of information. There are two main types of interviews **[32]**: unstructured and structured interviews.

At the beginning of any study, numerous knowledge acquisition interview sessions are frequently conducted informally. Beginning informally avoids wastage of time and aids to proceed rapidly to the main structure of the domain. Normally, it is followed by a formal technique. Contrary to what numerous people think, unstructured interviews are not easy. Actually, they may present the knowledge engineer with a number of very problematic consequences.

Unstructured interviewing rarely offers comprehensive or well-ordered descriptions of cognitive processes. There are several reasons for this: the domains are complex; the experts frequently find it very hard to express some of the most significant elements of their knowledge; domain experts may interpret the lack of structure as implying that they need not prepare for the interview; data acquired from an unstructured interview are often unrelated, exist at varying levels of complexity, and are hard for the knowledge engineer to review, interpret, and integrate; and few knowledge engineers have the training and experience to efficiently conduct an unstructured interview. Hence, it should be supplemented by structured interviews.

Structured interview is a systematic and goal-driven process. It coerces organized communication between the knowledge engineer and the expert. The structure decreases the interpretation problems inbuilt in unstructured interviews and permits the knowledge engineer to avert the bias caused by the subjectivity of the domain expert. Structuring an interview needs care to many procedural issues, which are listed as follows **[28]**:

- The knowledge engineer studies obtainable material on the domain to identify main demarcations of the relevant knowledge.
- The knowledge engineer reviews the planned KBS capabilities. He/she identifies targets for the questions to be inquired during the knowledge acquisition session.
- Using a form, the knowledge engineer properly schedules and plans the structured interviews.
- The knowledge engineer may write sample questions, concentrating on question type, level, and questioning methods.

- The knowledge engineer makes sure that the domain expert understands the purpose and goals of the session and motivates the expert to prepare before the interview.
- During the interview, the knowledge engineer follows guidelines for conducting interviews.
- During the interview, the knowledge engineer uses directional control to keep the interview's structure.

Tracking methods: It is a collection of techniques that try to track the reasoning process of an expert. It is a widely held approach among cognitive psychologists who are interested in discovering the expert's train of thought in reaching a conclusion. The knowledge engineer can use the tracking process to find what information is being used and how it is being used. Tracking methods can be formal or informal **[28]**. The common formal method is protocol analysis.

Protocol analysis (also called verbal protocol analysis) is a method by which the knowledge engineer gets in depth knowledge from the expert. A protocol is a record or documentation of the expert's stepwise information-processing and decision-making behavior. In this method, the expert is inquired to accomplish an actual task and to articulate his/her thought processes. The expert is inquired to think loudly while carrying out the task or solving the problem under observation. Usually, a recording is made as the expert thinks loudly; it describes every aspect of the information processing and decision-making behavior. The recording becomes a record, or protocol, of the expert's currently happening behavior. Later on, the recording is transliterated for additional analysis and coded by the knowledge engineer. The process of protocol analysis is listed as follows **[33]**:

- Offer the expert with a full range of information usually related with a task.
- Inquire the expert to articulate the task in the same manner as would be done normally while articulating his/her decision process and record the articulation on tape.
- Make statements by transliterating the verbal protocols.
- Collect the statements that look to have high information content.
- Simplify and rewrite the gathered statements and create a table of production rules from the gathered statements.
- Generate a sequence of models by using the production rules.

Observations: Occasionally, it is possible to observe an expert at work. In many ways, this is the most obvious and direct approach to knowledge acquisition. However, the difficulties involved should not be underestimated. For example, most experts advise several people and may work in several domains at the same time. In this case, the knowledge engineer's observations will also cover all the other activities. Therefore, large quantities of knowledge are being gathered, of which only a little is useful. In particular, if recordings or videotapes are made, the cost of transliterating large amounts of knowledge must be carefully considered.

As Mohammed et al. **[32]** noted, observations which can be seen as a special case of protocols are of two types: motor movements and eye movements. With observations of motor movements, the expert's physical performance of the task (e.g., walking, reaching, talking) is documented. With observations of eye movements, a record is made of where the expert fixes his/her stare. Observations are used mainly as a way of assisting verbal protocols. They are largely expensive and time-consuming.

2.4.2.2 Computer-Based Knowledge Acquisition Methods

Acquiring knowledge from experts can be supported using computer-based tools. These tools offer surroundings for knowledge engineers to identify knowledge via an interactive process **[32]**.

Besides, semiautomatic methods that use computer-based tools for helping the knowledge acquisition process are also possible to extract knowledge automatically from the set of data. The process of finding useful information and patterns from the set of data using computers is known as knowledge discovery. In early 1990s, the process was also known as machine learning. But, currently knowledge discovery and data mining are becoming widely used terms **[28]**.

2.5 Knowledge Modeling

Models are applied to express the important characteristics of real-time systems to understand in a simple way by dividing them into small parts. Models are more related with problem domain they represent **[34]**. Real-time systems are huge objects comprising of interconnected elements doing in complications as teamwork. Models assist individuals to weigh-up and know such complications by supporting them to explore every specific area of the system. Models are applied in the construction process of systems to draw the architecture of the system and to

simplify the exchange of information between several individuals in the group at various levels of abstraction. Individuals have several understandings of the system and models can assist them to know these understandings in a coordinated way.

According to Schreiber et al. **[35],** the modeling process builds conceptual models of knowledge-intensive activities. During the knowledge acquisition process, the knowledge engineer will attempt to understand both the tacit and explicit form of knowledge and then use visual tools to make an exchange of views between domain experts and end-users. This exchange of views produces concepts and understandings with regard to how the acquired knowledge is applied, how judgments are made, and so on. And the knowledge engineer should build the knowledge model from the acquired exchange of views with domain experts and end-users. This helps the knowledge engineer to transfer the knowledge model into functional computer-machine programs.

A paper by Wielinga et al. **[36]** argues knowledge models are very significant for knowing the operational means in the development process of a knowledge-based system. According to Schreiber et al. **[35],** knowledge modeling is a vital stage of the knowledge engineering process. It can provide a means to easily understand the source of knowledge, the inputs and outputs of knowledge, and the designation other parameters.

Different techniques can be used in modeling the domain knowledge, for example, decision trees can help steps (decisions) to find a solution for a certain problem domain. Decision trees play a crucial role in the knowledge modeling process. A decision tree is a graphical representation of the search space of a certain problem domain. It carries out classification by building a tree based on training instances with leaves having class labels. A node in the tree represents a decision rule on one or more attributes when solving the problem and the leaf nodes growing out from the node represents the predicted class labels of the decision **[37]**.

2.6 Knowledge Representation

A representation is a collection of agreements for describing the real world. It is the dedication to a vocabulary, data structures, and programs that let domain knowledge to be acquired and used. According to Buchanan and Duda **[38]**, there are three main requisites on a representation scheme of KBS. These are extendibility, simplicity and explicitness.

Extendibility: The data structures and access programs should be able to adjust readily to different conditions by permitting extensions to the knowledge base in the absence of coercing significant changes. A good method of constructing a knowledge base is through incremental improvement. Even though it is difficult for experts to define the whole knowledge for concerning problem areas at a time, they can define a subgroup and then improve it over a certain period of time by analyzing its effects.

Simplicity: The data structures were incomprehensible and unchangeable. When the syntax of the knowledge base is defined, at a large extent the access routines can be defined. But, novel reasons will come out for accessing the knowledge base just like clarifying of the contents of the knowledge base, analysis of the associations among items, display, or training. For these reasons, easy data structures give more advantages. From the developer's perspective, there are two ways of sustaining simplicity: continuing the form of knowledge as uniform as possible or writing unique access functions for inhomogeneous representations. Another way of sustaining simplicity is using the same terminology as the experts use.

Explicitness: Representing an abundant expert's knowledge is to offer a robust knowledge base of the system for solving problems with superior performance. But as a knowledge base should be constructed incrementally, it is essential to offer ways for examining and correcting it without difficulty. When items of knowledge are represented explicitly and using simple terms, the experts who are constructing knowledge bases can control which items are present and which are absent.

Knowledge representation is a means of encoding the domain expert's knowledge in a suitable medium. According to Kock **[6]**, the common techniques of knowledge representation are: logic, rules, semantic nets, frames, and cases. The researcher discusses three general schemes for representing knowledge, namely logic, rules, and cases as follows.

2.6.1 Logical Representation

Logic is not a means for computer-machines to store knowledge though it verifies to be a decisive tool to think about how computer-machines store knowledge. It is part of mathematics and can be used in different forms to reason about the rightness of computational representation and inference **[6]**.

If all people express and represent facts and thoughts with the same natural language like English, there will be less misunderstanding in the world **[39]**. However, natural languages exhibit ambiguity. The problem is the meaning of a sentence relies on the sentence itself and on the context on which the sentence was spoken. One method to lessen this problem is to agree upon rules for the language to express and represent the knowledge. Therefore, to define the language we should specify the syntax and the semantics of the language. To specify the syntax of a language, we should say what expressions or structures are allowed in the language and what sentences are using those expressions or structures. And to specify the semantics of a language, we should express what sentences mean in terms of mapping to a real world. Thus, using a logical representation means selecting a specific well defined language and following it.

There are more logics which are widely used for knowledge representation due to their expressiveness. These expressive logics help us to convert the sentences expressed in natural language into the logical representation.

One of the commonly used expressive logics is First-Order-Logic (FOL). FOL is expressive enough to concisely represent any kind of situation that is expressed in natural language. FOL represents objects and relations between constants, variables, predicates, functions and quantifiers in addition to propositions. For example, "Everyone at AAU is smart" can be written in FOL as:

$$\forall_X \text{ at}(X, \text{aau}) \rightarrow \text{smart}(X)$$

The symbol *aau* is constant: an object in the world about which we want to talk. The symbols *at* and *smart* are predicates which represent relationships between the arguments which appear inside the brackets. For example in *at*, the relationship specifies that a person (first argument) at aau (second argument). The symbol X is a variable, which can take on a range of values. This enables us to be more expressive and we can quantify X with the "for all" symbol ∀, so that our sentence of predicate logic talks about all possible X's.

FOL is more expressive and helps us to express and represent facts about the real world **[39]**. Moreover, it allows us to reason about the real world by using rules of induction. We can consider FOL as any natural language like English or Amharic. First we should convert sentences from English to FOL so as to express facts about the real-world. We should also convert from FOL to English in order to understand what the system has deduced from the facts

we provided it. To perform this, we should deal with the expressions or structures we are allowed in FOL (the syntax of the language). Besides we should express in FOL what sentences mean in terms of mapping to the real world (the semantics of the language) and how we convert either from English to FOL or from FOL to English. Therefore, let us see with examples how to convert from a certain language to Logic and vice-versa.

FOL	**English**
likes(kibrom, injera)	Kibrom likes injera
likes(genet,Food) → ethiopian(Food)	Genet likes food if that food is Ethiopian
likes(abel, X) → likes(X, ronaldo)	Abel likes anybody who likes Ronaldo
likes(hiwot, X) → footballer(X) ∧ english(X)	Hiwot likes somebody if they are a footballer and they are English

Table 2. 3 Translation of sentences from English to FOL and vice-versa

2.6.2 Rule-Based Representation

Rules are one of the common knowledge representation and reasoning techniques **[40]**. Their prominence roots primarily from their naturalness, which simplifies understanding of the represented knowledge. The format of a rule is:

IF (conditions), THEN (conclusion).

The IF part of a rule represents the conditions of a rule, which checks the truth value of collection of facts. When the condition is true, the THEN part of a rule is concluded as a new collection of facts. The conditions of a rule are associated between one another with logical connectives such as AND, OR, NOT, etc. When enough conditions of a rule are fulfilled, the conclusion is drawn and the rule is assumed to execute.

As Prentzas and Hatzilygeroudis **[41]** noted, the major advantages of rules are:

Compact representation of general knowledge: Using rules general knowledge about a certain problem domain can be represented in a well manner.

Naturalness of representation: Rules are very popular and natural knowledge representation technique because they are similar with natural language expressions. They can imitate the domain expert's means of thinking in several problem domains.

Modularity: Every rule is a distinct knowledge component that can be added or deleted into/from the knowledge base without affecting the other rules in the knowledge base.

Provision of explanations: The capability to offer justifications for the drawn conclusions in a direct manner is a key characteristic, given that justifications in specific problem domains are considered necessary.

2.6.3 Case-Based Representation

It is a process that uses related problems to find the solution of the existing problem. It comprises of two steps **[6]**:

- Discover those cases in memory that solved problems analogous to the existing problem, and
- Adapt former solutions to match the existing problem

The case library forms an additional significant element in case-based representation. The inference cycle using case-based representation consists of:

- Retrieving solutions
- Adapting solutions, and
- Testing solutions

The vital step is to discover and retrieve a relevant case from the case library. Cases are stored using indexes. The stored case comprises a solution to be adapted by changing the parameters of the previous problem to fit the novel condition ensuing in a recommended solution. If the examined solution is effective, then it will be added to the case library. Knowledge acquisition in case-based representation requires little effort for the reason that of the graininess of the knowledge. Knowledge is presented in precedent or resultant cases. In addition to the knowledge representation language, the knowledge engineer desires additional encouragements such as tools to edit the knowledge base; inference tracers to help in error detection; and analytical tools to discover, update and regularly examine the represented knowledge or attributes **[6]**.

2.7 Knowledge Verification, Validation, Usability and Usefulness

According to Juristo and Morant **[42]**, there are four types of evaluations to be conducted on KBS. These are verification, validation, usability and usefulness.

Verification is the rightness of the developed KBS to be evaluated. It can be conducted entirely on the formal model or on the computable model whose syntax is clearly stated for their rightness to be evaluated. It assures whether the knowledge on the formal model or on the computable model does not comprise syntactical faults. This means it assures the coordination between several elements of the KBS. A verified KBS denotes the acquired knowledge from domain experts and secondary sources rightly.

Validation is checking the knowledge base of the KBS for semantic faults that may occur during the KBS development. A validated KBS comprises the correct knowledge to perform like the domain expert in the domain area. Thus, validation searches for faults in the KBS behavior when it attempts to find a solution for a certain domain problem.

Usability is an association between the KBS and the end-user. This means whether the end-user is satisfied when he/she interacts with the KBS. Therefore, it must be evaluated before installing the KBS to the end-user.

Usefulness refers the association among the new KBS, the end-users, and the company that owns the product. The usefulness view can be noticed when the new KBS accomplishes its job. It is not possible to evaluate the new KBS if it is not functional.

Performance measures: Precision, Recall, and Accuracy are the common parameters used for measuring the performance of a certain classifier **[43]**. These parameters are defined in terms of the instances that are relevant and the instances that are correctly classified (or retrieved). The following table 2.1 shows the confusion matrix which can be used to calculate P, R and Accuracy of the classifier.

	PREDICTED CLASS		
ACTUAL CLASS		Class = YES	Class = NO
	Class = YES	TP	FP
	Class = NO	FN	TN

Table 2. 4 Metrics for performance evaluation

- The **precision** (P) is the proportion of the classified information which is relevant, as calculated using the equation:

  P = TP/(TP +FP)

- The **recall** (R) is the proportion of the classified relevant information versus all relevant information, as calculated using the equation:

  R = TP/(TP +FN)

- The **F-measure** is the harmonic mean of precision and recall, as calculated using the equation:

  F = 2 * P * R/(P + R)

- The **accuracy** (AC) is the fraction of the total number of predictions that were correct, as calculated using the equation:

  AC = (TP +TN)/(TP + FP + TN +FN)

2.8 Tools Used in Knowledge-Based System Development

A KBS tool is a collection of software instructions and utilities taken to be a software package designed to support the development of knowledge-based systems. KBS can be built using programming languages namely LISP and Prolog. John McCarthy **[44]** published an outstanding paper showing a handful of simple operators and a notation for functions, one can develop a full programming language. He named this language LISP (List Processing) because one of his main personal views was to use a simple data structure called a list for both code and data. There are several versions of LISP, such as KLISP and C Language Integrated Production System (CLIPS).

Prolog is a logic programming general purpose fifth generation (AI) language **[45]**. It has a purely logical subset, called "pure Prolog", in addition to a number of extra logical features.

Prolog has its roots in formal logic, and in contrast to numerous other programming languages, Prolog is declarative. The program logic is expressed in terms of relations, and execution is activated by running queries over these relations. The language was first believed by a group around Alain Colmerauer in Marseille in the early 1970s. According to Kowalski **[46]**, the first Prolog system was developed in 1972 by Alain Colmerauer and Phillipe Roussel.

According to Robertson and Kingston **[47],** there are around 200 KBS tools and the products are grouped into three main categories based mainly on functionality which also occur to vary markedly in the platforms on which they are available. These groups are: Shells, Languages, and Toolkits.

Inference ART and KEE are among the first commercially effective toolkits to build KBS **[24]**. In addition to support towards knowledge acquisition and representational features, there are extra features like price, flexibility, ease of use, user friendliness and vendor availability and support, and documentation support from the tool need to be weighed before final selection.

2.9 Applications of Knowledge-Based System

According to Masizana-Katongo et al. **[48]**, the application of AI research and development is a substantial evolving research area to help health and medicine. The main initiatives to increase the quality, accuracy and timeliness of healthcare data and information supply are evolving throughout the world. Since the 1970's, systems such as knowledge-based systems have been used to accomplish efficient and effective data processing on complex problems to support several problem domains. The authors define a knowledge-based system as **[48]** "…a computing system capable of representing and reasoning about some knowledge - rich domain, such as internal medicine or geology, with a view of solving problems and giving advice". Several domains have taken the merit of the advent of AI technology since 1970's. The most widely held application has been in the area of health and medicine.

Knowledge-based systems can be used in a number of applications. The common applications are discussed as follows **[19]**:

Advisory systems: Knowledge-based systems are preferable than any computer-based information systems for advising purposes. This is because knowledge-based systems are goal-

directed, have the ability to adapt to different situations, and have the capacity to justify their decisions.

Health care and medical diagnosis systems: The process of finding out the errors in a certain system or identifying the state of sickness in a living system according to the analysis of noisy or incomplete data is called diagnosis. The interpretation of different medical reports such as dermatology reports and physicians' decisions can be verified in a simple manner with the assistance of knowledge-based systems.

Tutoring systems: The tutoring system wants to communicate with the end-user in a friendly style, recognize their status and offer a means to get the teaching modules in a cost-efficient manner. End-users can communicate with the system in their mother tongue language to get the teaching modules based on their desire and request.

Control and monitoring: Monitoring is a continuous interpretation of signals and making important decisions if interference is necessary. For example, such kind of monitoring can be applied to an artificial life support system attached to a person who requires medical care after the surgical process.

Prediction: It is forecasting what will happen in the future according to the models developed on the previous and current status. For example, a knowledge-based system can forecast about the volatile market.

Planning: A plan is a program of activities that can be done to realize objectives. Such kind of a plan assists in using limited resources effectively by preparing a series of activities to be done. Activities associated with the development of software needs preparing a plan and monitoring stages. However, the knowledge-based system permits a slight change from the plan. The extent of such change without troubling the total goal is identified by the knowledge-based system.

Searching larger databases and data warehouses: It is not a simple task to look for and retrieve relevant information from huge databases. For example, specifically in the Internet the sources of information in the databases are dispersing widely. Therefore, using the knowledge-based systems the end-user can retrieve the needed information in an efficient manner.

2.10 Review of Related Works

There are limited researches done locally towards designing KBS in the area of health and medicine.

Anteneh [12] developed a prototype KBS for antiretroviral therapy. The study was conducted using rule-based representation technique to solve the problem of providing treatment for HIV/AIDS patients. Thus, to address such problem knowledge about treatment for HIV/AIDS was acquired from codified sources such as textbooks related to the domain problem and modeled using hierarchical structure that represents concepts and procedures needed in drug selection. Then, the validated knowledge is represented using production rules. These rules were implemented in the Knowledge Pro Gold expert system shell tool. In this study, he recommended for further research to develop a comprehensive HIV treatment expert system that comprise follow up and drug resistance monitoring.

Redeit [13] designed and developed a prototype KBS for HIV pre-test counseling. The research was conducted using rule-based representation technique to find solution for HIV voluntarily testing problem as open discussion about sex and sexually transmittable diseases are considered as humiliation by the culture of the Ethiopian people. Therefore, to solve such problem knowledge about pre-HIV test counseling was acquired using unstructured interviews method from domain experts and from codified sources like standard VCT guidelines. Then, the acquired knowledge was represented using production rules and implemented using Knowledge ProGold Version 3.0. The outcome of the evaluation was 86.6% that is the accuracy of the prototype system. In this study, he recommended for further research to make the prototype system full-fledged that comprises post-HIV test counseling.

Solomon [14] 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.

Seblewongel [15] developed a prototype of rule-based KBS for anxiety mental disorder diagnosis. This study was conducted using rule-based representation technique to find solution for mental health problem which is not gaining enough cares. Thus, knowledge about anxiety mental disorder was acquired using both structured and unstructured interviews from domain experts and from secondary sources by using document analysis method to find solution of the problem. Then, the acquired knowledge was modeled using decision tree structure that represents concepts and procedures involved in anxiety disorders diagnoses. The outcome of the validation was 85% that is shown as the performance of the prototype. In this study, she recommended for further research to make the rule-based KBSs to learn from experience and update their knowledge.

Zewditu [49] developed a prototype of case-based KBS for Type 2 diabetes management. This research was conducted using case-based representation technique to solve the problem of poor diagnosis with Type 2 diabetes. Therefore, she questioned the domain experts using unstructured interview technique to find solution of the problem. Moreover, knowledge is acquired from relevant secondary sources by using document analysis method. Subsequently, the acquired knowledge was modeled using tree like structure known as ladders. The case-based comprised 42 Type 2 diabetes management cases and was kept in plain text file. An average value of 69% recall and 46% precision was scored as the performance of the prototype system. In this research, she recommended for further study to consist of all the necessary rules for Type 1 diabetes and make the rule-based KBSs self-learning by updating their knowledge through experience.

Guesh [16] developed a prototype 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. In this study, he recommended for further research to make full-fledged system that includes both blood screening and transfusion of blood practices.

As to the researcher knowledge no attempt has been done to design a self-learning KBS for diagnosis and treatment of diabetes. However, International experiences show that **Singh [1]** developed a prototype of rule-based expert system for diagnosis and treatment of diabetes. This research was conducted using rule-based representation technique to find solution of the problem of 16 million Americans who were affected by diabetes disease. Diabetes is the seventh leading cause of death in the United States and is extensively circulated in South Texas. The prototype system was developed to act as a diagnostic-assistance tool for nurses to speed up and guide in diagnosis and treatment of Type 2 diabetes only. In this research, he recommended for further study to comprise all the required rules for Type 1 diabetes.

To conclude, several studies have been developed using rule-based representation technique to reason out the solution of a particular problem. But, the KBSs did not learn from experience and update their knowledge, i.e. they are not self-learning. Thus, in this study an attempt is made to design a self-learning KBS that can update its knowledge through experience.

CHAPTER THREE

KNOWLEDGE ACQUISITION, MODELING AND REPRESENTATION

3.1 Knowledge Acquisition in KBS Development

Knowledge acquisition is the process of eliciting, structuring and organizing knowledge from human experts, books, documents, and sensors. On the other hand, it refers computer files and transfering to the knowledge base using knowledge representation techniques used in knowledge-based system; namely, logic, production rules, semantic nets, frames and cases **[50]**. The acquired knowledge may be specific to the problem domain and the problem solving procedures, or it may be general knowledge (e.g., knowledge about business), meta-knowledge (knowledge about knowledge). In this field, many professionals have disclosed a common understanding that knowledge acquisition is a very difficult task to carry out **[31]**.

The acquisition of knowledge is the most important and decisive phase in building knowledge-based systems. However, it is an extremely hard and capable of making an error task that knowledge engineer does while developing a knowledge-based system. As a result of the challenges and difficulties confronted in the transfer of expertise knowledge, knowledge acquisition has been depicted as the obstruction of knowledge based systems development **[28]**.

In this chapter, the knowledge engineer collects diabetes cases and model it by using decision tree structure. The major features concerning to diabetes diagnosis and the essential concepts are identified about the diagnosis procedures. These aids to develop the prototype using rule-based reasoning. The study explores the applicability of rule-based reasoning in health and medicine particularly for diagnosis and treatment of diabetes. The knowledge for this study is acquired from domain experts by using interviewing and critiquing knowledge elicitation methods, and from relevant documents by using documents analysis technique which have been employed to purify the acquired knowledge.

3.2 Steps in Knowledge Acquisition

According to Jones **[51]**, there are two main steps in knowledge acquisition process that are accomplished by the knowledge engineer so as to develop knowledge-based system. These are knowledge elicitation and knowledge structuring.

3.2.1 Knowledge Elicitation

It involves extracting knowledge from human experts, and/or written documents to build a knowledge-based system. In this study, the knowledge required to build a knowledge-based system was elicited from both tacit and explicit sources of knowledge. Tacit knowledge is collected from four experts in the domain area from Black Lion Hospital (that are working as - Internist and Diabetologist, Internist and Endocrinologist, Internist and Endocrinologist, and Nurse) by using structured and unstructured interviews (the sample interview questions used are found in Appendix I). Domain experts are chosen purposefully for wide-ranging discussion using structured and unstructured interviews to understand the domain knowledge. These experts are essentially taking part during the study and asked to verify the rightness of the acquired knowledge. Moreover, explicit source of knowledge has been collected from the internet, manuals, research papers and journal articles, etc.

3.2.2 Knowledge Structuring

It involves using concepts discovered during the knowledge elicitation session to build a model or representation of the domain experts. It is a process where knowledge engineer uses 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 diabetes cases.

3.3 Knowledge of Diabetes

Diabetes is a long-lasting disease that happens when the human body has problem in an accurate manner governing the amount of glucose in the blood. To know diabetes, it is important to know the role of glucose acts in connection with the body, and what can occur when governing of glucose goes wrong and the amount of blood glucose level comes to be hazardously low or high **[1]**.

The tissues and cells that form the human body are living entities, and need nutrition to remain in a life state. The cells that take-in nutrition is a kind of sugar known as glucose. The cells of human body are totally in need of the blood to take along glucose to them. In the absence of access to enough glucose, the cells of human body have nothing that can be consumed to produce energy and shortly pass away. Individuals take-in nutrition, not glucose and during the

digestion process the nutrition will be converted into glucose. After the nutrition is changed into glucose, it goes into the blood and the amount of glucose in the blood will increase. Lastly, the blood will transport the converted glucose to different tissues and cells of the human body **[52]**.

Even though glucose may exist in the blood, adjacent cells are not capable to obtain that glucose in the absence of support of a chemical hormone known as insulin. Insulin plays a key role to open the cells, letting them accept and use the existing glucose **[53]**. Cells take glucose from the blood with the help of insulin. The amount of glucose level decreases as glucose moves out from the blood and moves into the cells. It can be assumed that insulin serves as a channel for transporting glucose between the blood and cells. It is essential to know when the amount of insulin level increases, the amount of glucose level in the blood decreases. Since the amount of glucose moves into the cells are going to be used for energy by the cells of the human body, the body is considered to control and buffer the amount of sugar in the blood stream to keep up a stable amount to satisfy the desires of cells. One of the human body's organ, pancreas generates, stores and discharges into the blood to get the amount of glucose back. However, individuals living with diabetes either cannot produce this hormone in the right manner or their body cannot properly use it for normal body functions. Therefore, this creates the accumulation of glucose in the blood and when the accumulated glucose is not used by the body cells, then signs and symptoms of diabetes start to emerge **[1]**.

As noted in **[54]**, the following are the common signs and symptoms of diabetes.

- Polydipsia or excessive thirst
- Polyuria or frequent urination
- Polyphagia or excessive hunger
- Unusual weight loss
- Tiredness
- Blurred Vision
- Dizziness

If the amount of glucose in the blood becomes very high and left untreated, then it brings unconsciousness and probably passing away. The signs and symptoms of diabetic patient depends on when their diabetes is discovered and what type of diabetes they have. The signs and symptoms of diabetes could differ depending on the types of diabetes.

3.3.1 Types of Diabetes

The most common types of diabetes can be divided into two groups (table 3.1), Type 1 diabetes (Insulin-dependent diabetes) and Type 2 diabetes (non-insulin-dependent diabetes). This division is based upon whether the blood sugar problem is caused by insulin deficiency (Type 1 diabetes) or insulin resistance (Type 2 diabetes) **[55]**. A comparison of the two diabetes types is presented in table 3.1.

	Type 1 Diabetes	**Type 2 Diabetes**
Age of onset	Usually during childhood or puberty; symptoms develop rapidly	Frequently after age 35; symptoms develop gradually
Nutritional status at time of disease onset	Frequently undernourished	Obesity usually present
Genetic predisposition	Moderate	Very strong
Defect or deficiency	β cells are destroyed, eliminating production of insulin	Insulin resistance combined with inability of β cells to produce appropriate quantities of insulin
Frequency of ketosis	Common	Rare
Plasma insulin	Low to absent	High early in disease; low in disease of long duration
Acute complications	Ketoacidosis	Hyperosmolar state
Treatment	Insulin is always necessary	Diet, exercise, oral hypoglycemic drugs; insulin may or may not be necessary

Table 3. 1 Comparison of Type 1 and Type 2 diabetes adopted from [55]

Type 1 Diabetes is induced by an inappropriate immune response of the body, where the body's immune system begin to destroy β cells by eliminating production of insulin in the pancreas. Hence, the body can not bring about the required insulin. The disease can have an effect upon individuals of any age, but most of the time it begins in individuals having the age less than 35. Individuals having this type of diabetes require injections of insulin daily so as to control the

amounts of glucose in their blood. In the absence of insulin, individuals with type 1 diabetes will pass away.

Type 1 diabetes rapidly develops and can comprise symptoms like **[56]**:

- Polydipsia or excessive thirst
- Polyuria or frequent urination
- Polyphagia or excessive hunger
- Unusual weight loss
- Tiredness
- Blurred vision
- Slow-healing wounds
- Recurring infections

This type of diabetes can be controlled by daily insulin injections, a healthy diet, self-blood glucose monitoring, and consistent physical activity. This enables individuals with type 1 diabetes to lead a normal lives.

In every year many individuals affected with type 1 diabetes is at an increasing rate. The reasons are not yet understood but it is assumed because of alterations in environmental risk factors, premature happenings in the womb, or caused by a virus infections.

Type 2 Diabetes is the most common type of diabetes. It ordinarily happens in adult individuals, but is progressively realized in youngsters. In type 2 diabetes, the body is capable to yield insulin. However, it is either insufficient or it has difficulty in using it properly leading to an accumulation of glucose in the blood.

Individuals with type 2 diabetes may stay unconscious of their disease for a prolonged period of time since symptoms may require years to come out or be realized, during which time the body is being discredited by surplus blood glucose. Many individuals are diagnosed only when complications of diabetes come to be apparent.

According to International Diabetes Federation **[56]**, the reasons for developing type 2 diabetes are still not understood though there are some essential risk factors that are mentioned below.

- Obesity or more than average fatness
- Poor nutrition
- Physical inactivity or sedentary lifestyle
- Increasing age
- Genetic background of diabetes
- Ethnicity
- Poor diet during gestation affecting the developing child

When we compare individuals with type 1 diabetes and type 2 diabetes, most individuals with type 2 diabetes do not ordinarily need injections of insulin in a day-to-day life. However, they may be dictated to take insulin plus a healthy nutrition and increase physical exercise to control their condition.

The number of individuals with type 2 diabetes is increasing very quickly throughout the world. This increase is related with economic development, ageing populations, increasing urbanisation, nutritional changes, physical inactivity and alterations in other lifestyle patterns.

3.3.2 Criteria for Diagnosis of Diabetes

According to National Diabetes Information Clearinghouse **[57]**, blood tests are applied for diagnosis of diabetes and prediabetes since at first patients having type 2 diabetes may not show symptoms. Blood tests for all types of diabetes include taking blood at offices of medical institution and sending the blood sample to a laboratory for examination. Laboratory testing of blood is required to make sure laboratory test results are correct. Glucose measuring equipments (for instance, finger-stick equipments) used in offices of medical institution are not sufficiently precise for diagnosis though it may be applied as a sign of high glucose in the blood. Blood testing helps medical institutions to discover and provide treatment for diabetes before complications took place and to discover and provide treatment for prediabetes, which can slow down or discontinue type 2 diabetes from evolving. Any one of the following screening test for diabetes can be used for diagnosis **[57]**:

Fasting Plasma Glucose (FPG) test

It is applied to diagnose and identify diabetes and prediabetes. It is the best screening test applied for diagnosing diabetes since it is easier and faster to perform, more convenient and acceptable to

patients, and less expensive. It measures the amount of glucose in the blood of individuals who hasn't eat for at least eight hours before testing and is the most trustworthy when given in the morning.

An FPG >= 100 mg/dL but <= 125 mg/dL is a sign for individuals having prediabetes. And an FPG >= 126 mg/dL is a sign for individuals living with diabetes.

Oral Glucose Tolerance Test (OGTT)

It can be applied to diagnose and identify diabetes and prediabetes. Many studies pointed out that the OGTT is more complex than the FPG test though it is less convenient to manage. When applied to screening test for diabetes or prediabetes, it measures the amount of glucose in the blood after an individual takes-in at least eight-hours and two-hours after the individual drinks a liquid containing 75 grams of glucose dissolved in water.

If the two-hour blood glucose level is greater than or equal to 140 and less than or equal to 199 mg/dL, the individual has an indication of prediabetes. If reasserted by testing again, a two-hour glucose level of greater than or equal to 200 mg/dL means an individual has diabetes.

A1C test

It is applied to identify type 2 diabetes and prediabetes though it is not suggested for diagnosis of type 1 diabetes. It is a screeing test that tells the average of an individual's blood glucose levels over the past 90 days and does not indicate each day changeabilities. It is more appropriate for patients than the outdated blood glucose tests since it does not need fasting and can be done at any time of the day.

The laboratory test result using the A1C test is descibed by percentage. The greater the percentage, the greater an individual's blood glucose levels have been. A normal A1C test result level is less than 5.7%.

An A1C of greater than or equal to 5.7% and less than or equal to 6.4% shows prediabetes. Individuals diagnosed with prediabetes may be tested again within one year. Individuals with an A1C less than 5.7% are free from diabetes. Individuals with an A1C greater than 6.0% must be

thought at very great risk of evolving diabetes. An A1C test result level of greater than or equal to 6.5% indicates an individual has diabetes.

Table 3.2 below summarizes the blood test levels for diagnosis of diabetes and prediabetes **[57]**.

		A1C (percent)	**Fasting Plasma Glucose (mg/dL)**	**Oral Glucose Tolerance Test (mg/dL)**
	Diabetes	6.5 or above	126 or above	200 or above
	Prediabetes	5.7 to 6.4	100 to 125	140 to 199
	Normal	Less than 5.7	99 or below	139 or below
Definitions: mg = milligram, dL = deciliter				

Table 3. 2 Blood test levels for diagnosis of diabetes and prediabetes

As presented in table 3.2, for all the three tests, within the prediabetes range, the higher the test result, the greater the risk of diabete **[57]**.

3.3.3 Management of Diabetes

Nowadays, there are operational treatments for diabetes although not possible to make diabetic patient healthy again. If you are able to get the proper medication, quality of care and well medical advice, then you can have a healthy life and lessen the possibility of growing complications.

To control diabetes in a good manner, the amount of glucose in your blood should be as close to normal as possible. This can be done by performing the following **[58]**:

Physical exercise: The diabetic patient should perform physical exercise on most of days of the week for at least thirty minutes for a day like brisk walking, swimming, cycling, and dancing.

Control body weight: The diabetic patient should lose body weight to increase insulin resistance, and decrease blood pressure. Hence, it is essential to attain and keep a healthy body weight.

Healthy eating: The diabetic patient should be far away from foods having more content of sugar and saturated fats, and restricting alcoholic drink.

Avoid tobacco: Using tobacco is faced in diabetic patients with serious diabetes complications.

Monitor complications: An important part of good diabetes care is monitoring and timely discovery of complications. This comprises consistent foot and eye checks, controlling blood pressure and blood glucose, and assessing threats for cardiovascular and kidney disease.

Blood sugar monitoring: There are two common techniques used by doctors to control the sugar level in the blood of individuals living with diabetes. These are frequent measurements of blood glucose and measurement of hemoglobin A1C **[59]**.

- **Frequent measurements of blood glucose:** The amount of sugar in the blood can be measured before fasting. The patient should not eat food for at least 8 hours before taking sample blood for testing. The aim is to make the fasting sugar level in the blood between 70 and 120 mg/dL.
- **Measurements of hemoglobin A1C:** It is used to measure the average sugars level that was accumulated in our blood for the last 2-3 months by looking at the level of sugar in our hemoglobin. Hemoglobin is a protein that is found in red blood cells and its function is to transport oxygen within the body. In the normal case, the level of glucose in the blood is low, but, if it is abundant it will stick with the hemoglobin. Hemoglobin A1C test tells the amount of glucose that had stacked with the hemoglobin within the last 2-3 months.

According to Ethipian Diabetes Association **[60]**, the following table 3.3 is used as a guidline for blood sugar monitoring.

A1C (%)	Advice	FPG (mg/dL)
> 13.0	You have to consult your physician (doctor), if the result is above 325 mg/dL.	>325
≥8.0 and ≤13.0	If the glucose level is ≥183 and ≤325 mg/dL, then it indicates that your glucose level control was not effective. If the glucose level is always in this range, then you are highly likely to be affected with the complications of diabetes disease.	≥183 and ≤325
≥7.0 and <8.0	If the glucose level is ≥155 and <183 mg/dL, your control of the glucose level is not as much. Re-examination of the glucose level is required to correct the necessary things.	≥155 and <183
≥6.0 and <7.0	If the glucose level is ≥126 and <155 mg/dL, it indicates that you were previously exercising well, had a healthy diet and taken your insulin properly. So, you should continue on doing these.	≥126 and <155
≥4.0 and <6.0	If a person is non-diabetic, then FPG test result is ≥68 and <126 mg/dL. But if the person is diabetic and the number is in this range, this indicates repeated low glucose level. This requires consultation with your doctor to the problems.	≥68 and <126

Table 3. 3 Guideline for blood sugar level monitoring

During the knowledge acquisition process, the knowledge engineer attempts to understand both the explicit and tacit part of the knowledge. It uses simple visual diagrams to motivate discussion with domain experts. This discussion process creates thoughts and understandings with regard to how the knowledge is applied, how decisions are reached, and the factors that stimulate. The knowledge engineer then has to build the conceptual model from what has been discussed throughout the knowledge acquisition phase so as to ease knowledge representation in the knowledge base **[61]**.

3.4 Conceptual Modeling

Conceptual modelling is extensively acknowledged as the critical stage of knowledge acquisition. Before a knowledge-based system can be constructed, knowledge should be identified and collected, and a model of domain knowledge should be built. Models are applied to acquire the important characteristics of problem domains by decomposing them into more controllable parts that are simple to know and to use. Models are very related with the domain they denote **[34]**. "A model is a simplification of reality" **[62]**. Models support individuals to increase in value and know such complexity by allowing them to investigate each specific area of the system successively. Models are applied in systems development tasks to depict the designs of the system and to simplify communication between disparate individuals in the group at disparate levels of abstraction. Individuals have disparate opinions of the system and models can aid them know these opinions in a combined way.

According to Richard et al. **[37]**, one of the most extensively applied methods of conceptual modeling is called decision tree. Decision tree commonly acts a key role in a knowledge modeling process. Decision tree is used for the search space of a certain problem and presented by a graph. A node in the tree denotes a decision to be attained when finding a solution of a certain problem, and the branches extended from the node show the potential values of the decision. To find the solution of a certain problem, anyone then traces by way of its tree using data of a certain problem to select a branch at every node.

In this study the knowledge used for diagnosis and treatment of diabetes is acquired from domain experts and relevant documents analysis. In the following sections the model of concepts in the diagnosis and treatment of diabetes are discussed.

3.4.1 Concepts of Symptoms

In the diagnosis of diabetes, the domain experts have a concept of symptoms that is used to differentiate the related symptoms of diabetes and the non-related symptoms of diabetes. For the related symptoms of diabetes, the domain experts have a general knowledge about the common symptoms of the two types of diabetes.

In the process of knowledge gathering through interview, the domain experts (physicians) explained that there are symptoms that are used for diagnosing the new patient who came for

treatment. The possible symptoms used for the domain experts to identify whether the new patient has a chance to be diabetic or not are the following:

- Polydipsia or excessive thirst
- Polyuria or frequent urination
- Polyphagia or excessive hunger
- Unusual weight loss
- Tiredness
- Blurry vision
- Dizziness

Domain experts usually recognize diabetes by the appearance of at least the above first three basic symptoms, i.e. polyuria (frequent urination), polydipsia (excessive thirst) and polyphagia (excessive hunger). This concept is shown in table 3.4 as follows.

Attribute Name	**Values**	**Basic symptoms**
Symptoms of diabetes	related symptoms of diabetes	excessive thirst, frequent urination, and excessive hunger.
	non-related symptoms of diabetes	Symptoms excluding excessive thirst, frequent urination and excessive hunger.

Table 3. 4 Concepts of symptoms

After checking symptoms in the patient, the next concept that the domain experts used is the concept of laboratory test result. This concept is the most important and useful concept in order to conclude whether the patient is diabetic or not.

3.4.2 Concepts of Laboratory Test Result

Since considering only the symptoms of diabetes are not enough to conclude that whether the patient have diabetes or not, laboratory test result is the key part and the most important concept for the decision. Because of this the domain expert sends the patient for a laboratory test.

The laboratory test result is done by taking the patient's blood. As the domain experts said 75% of diagnosis is done during face-to-face conversation between the domain expert and the patient, but the rest 25% of diagnosis is a phase of decision.

The blood test result tells to the domain experts the amount of glucose in the blood. The domain experts have a concept of how much amount of glucose in the blood should exist in the diabetes, prediabetes, and normal condition.

The following is one of the most common type of laboratory testes that the domain experts should know that will help them in order to make decisions:

Fasting Plasma Glucose (FPG) test: This is the most common type of testing the amount of sugar in the blood before the patient takes breakfast. In this test the domain experts know the amount of glucose in the blood. This concept is shown in table 3.5 as follows.

Attribute Name	**Values in mg/dL**	**State**
Lab result using FPG test	126 or above	Diabetes
	100 to 125	Prediabetes
	99 or below	Normal

Table 3. 5 Concepts of lab test result

Since there are two types of diabetes, the domain expert also has another concept of diagnosis to know in which type the patient may fall. Age is the main concept of the domain experts to classify the patients diabetes type. The age concept of the domain expert is discussed below.

3.4.3 Concepts of Age

The third concept of domain experts in diagnosing patients is age of patient. Domain experts first listen the general symptoms from patient and sends for making a laboratory test. If the lab test result indicate diabetes, the next question that they have to raise is asking age of patient. Knowing age of patient helps domain expert in trying to classify in which diabetes type the patient be under. Even if it is difficult to differentiate whether the patient has either Type 1 or Type 2 diabetes, age of patient leads domain experts' concept of thinking that the patient has either Type 1 or Type 2 diabetes.

Most domain experts said that types of diabetes can be classified by age of patients. But in rare cases this does not work. The domain experts concept and decision passed is summarized in table 3.6.

Attribute Name	**Values**	**Type of diabetes**
Age	≤15	Type 1
	>15 to 35	Type 1 or Type 2
	>35	Type 2

Table 3. 6 Concepts of age

After the concept of age is analyzed, the domain experts have another concept that will help them for diagnosing the new patient. This concept is family history of diabetes and/or obesity will help to decide for.

3.4.4 Concepts of Family History of Diabetes and/or Obesity

The domain experts have a concept of family history of diabetes and/or obesity. The family history of diabetes and/or obesity may cause the patient to be diabetic. By considering this the domain expert asks the patient for his/her family history of diabetes and/or obesity, then the domain expert can decide the patient has Type 2 diabetes, especially for patients with age between 15 and 35 years. This concept is shown in the table 3.7 as follows.

Attribute Name	**Values**	**Age**	**Decision**
Family history of diabetes	exists	>15 to 35	Type 2 diabetes
	doesn’t exist	>15 to 35	?
Obesity	exists	>15 to 35	Type 2 diabetes
	doesn’t exist	>15 to 35	?

Table 3. 7 Concepts of family history of diabetes and/or obesity

After this concept the next concept that domain experts used is the concept of ketone and/or autoantibodies existence in the blood during laboratory testing.

3.4.5 Concepts of Ketone and/or Autoantibodies

This concept is the most useful concept in order to conclude whether the patient is diabetic Type 1 or other diabetes type. If age of the diabetic patient is between 15 and 35 years old and did not exist family history of diabetes and has not shown obesity. Summary of result of this concept is shown in table 3.8 as follows.

Attribute Name	**Values**	**Age**	Family history of diabetes and/or obesity	**Decision**
Ketone and/or autoantibodies	exists	>15 to 35	doesn't exist	Type 1 diabetes
	doesn't exist	>15 to 35	doesn't exist	Other diabetes type

Table 3. 8 Concepts of ketone and/or autoantibodies

To summarize, the decision tree based on conceptual model depicted in figure 3.1 shows the levels of decisions that domain experts use during diagnosis and treatment of diabetes.

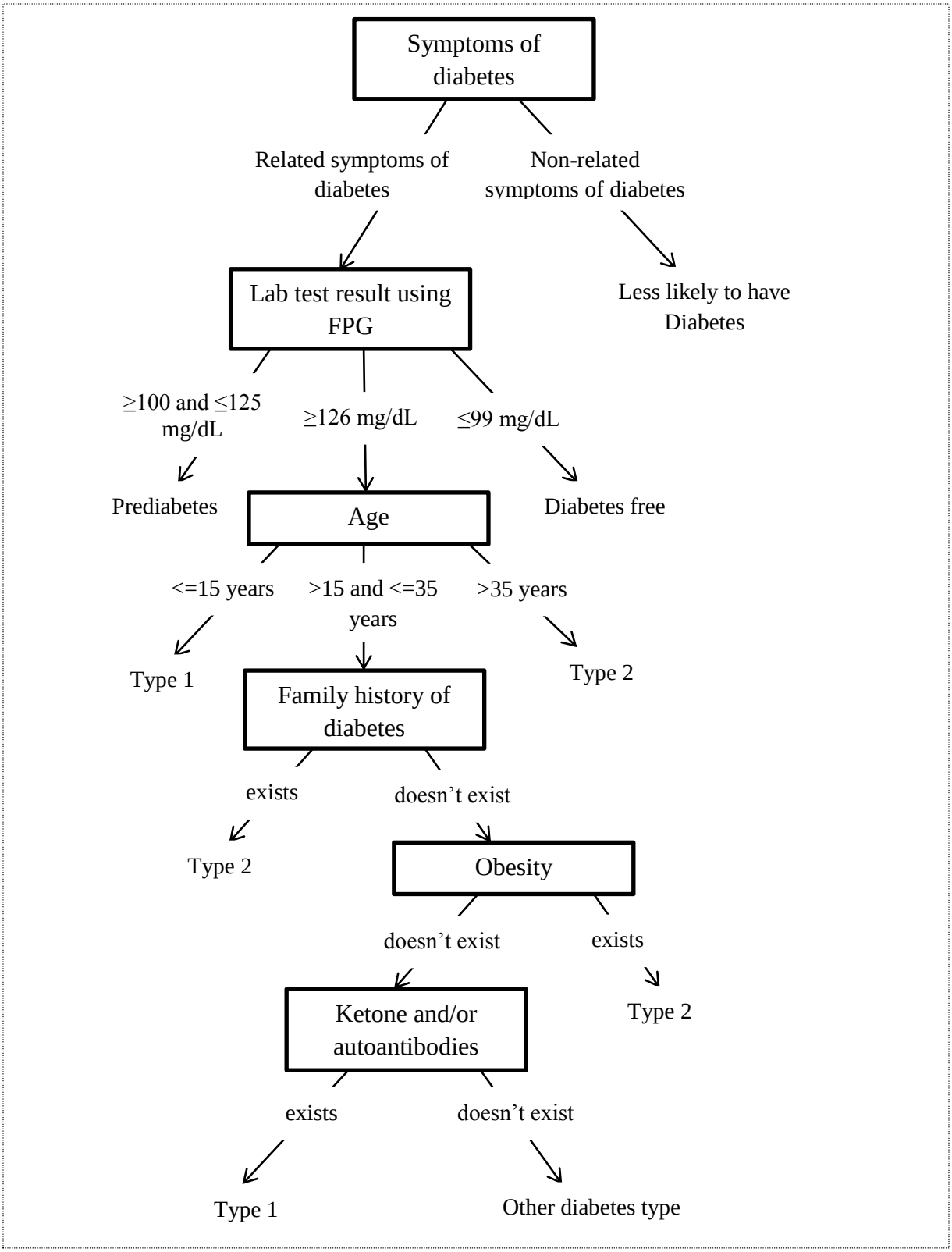

Figure 3. 1 Decision trees for diagnosis and treatment of diabetes

As shown in the above figure 3.1, the decision tree structure shows the flow of knowledge in the diagnosis and treatment of diabetes. First it checks the appearance of the basic symptoms of diabetes in the patient and sends for a laboratory blood test to decide whether the patient is diabetic, prediabetic or normal. If the patient has diabetes, then it further diagnoses the patient to identify which diabetes type the patient has. It considers the concepts of age, family history of diabetes and/or obesity, and ketone and/or autoantibodies to decide whether the patient has Type 1, Type 2 or other type of diabetes.

In general, the necessary knowledge was extracted from domain experts and relevant documents analysis was made for building the decision tree model of concepts in the diagnosis and treatment of diabetes. This is used for building the knowledge-based system that can provide advise for patients and experts.

3.5 Knowledge Representation

Once the knowledge has been acquired and modeled, the next step is knowledge representation using appropriate format that is both understandable by end-users, experts and inference engine.

knowledge representation is a means of encoding the human expert's knowledge in an appropriate medium. It is the dedication to a vocabulary, data structures, and programs that let domain knowledge usable. There are several commonly used techniques for knowledge representation in the development of knowledge-based systems. These are logic, production rules, semantic nets, frames and cases.

In this study a rule-based knowledge representation and reasoning is followed. They are one of the most commonly used technique for the development of knowledge-based systems. Knowledge is represented in the form of condition-action pairs: IF this condition (or antecedent-condition or premise) occurs, THEN some action (or conclusion or consequence) will occur.

The following rules in the knowledge base of the prototype are expressed with natural language rules IF … THEN …

Rule 1:

IF symptoms of diabetes = "non-related symptoms of diabetes",

THEN diabetes type = "Less likely to have Diabetes"

Rule 2:

IF symptoms of diabetes = “related symptoms of diabetes”

AND lab test result using FPG = “≤99 mg/dL”,

THEN diabetes type = “Diabetes free”

Rule 3:

IF symptoms of diabetes = “related symptoms of diabetes”

AND lab test result using FPG = “≥100 AND ≤125 mg/dL”,

THEN diabetes type = “Prediabetes”

Rule 4:

IF symptoms of diabetes = “related symptoms of diabetes”

AND lab test result using FPG = “≥126 mg/dL”

AND age = “≤15 years”,

THEN diabetes type = “Type 1 diabetes”

Rule 5:

IF symptoms of diabetes = “related symptoms of diabetes”

AND lab test result using FPG = “≥126 mg/dL”

AND age = “>35 years”,

THEN diabetes type = “Type 2 diabetes”

Rule 6:

IF symptoms of diabetes = “related symptoms of diabetes”

AND lab test result using FPG = “≥126 mg/dL”

AND age = “>15 and ≤35 years”

AND family history of diabetes = “exists”,

THEN diabetes type = “Type 2 diabetes”

Rule 7:

IF symptoms of diabetes = “related symptoms of diabetes”

AND lab test result using FPG = “≥126 mg/dL”

AND age = “>15 AND ≤35 years”

AND family history of diabetes = “doesn’t exist”

AND obesity = “exists”,

THEN diabetes type = “Type 2 diabetes”

Rule 8:

IF symptoms of diabetes = “related symptoms of diabetes”

AND lab test result using FPG = “≥126 mg/dL”

AND age = “>15 AND ≤35 years”

AND family history of diabetes = “doesn’t exist”

AND obesity = “doesn’t exist”

AND ketone and/or autoantibodies = “exists”,

THEN diabetes type = “Type 1 diabetes”

Rule 9:

IF symptoms of diabetes = “related symptoms of diabetes”

AND lab test result using FPG = “≥126 mg/dL”

AND age = “>15 AND ≤35 years”

AND family history of diabetes = “doesn’t exist”

AND obesity = “doesn’t exist”

AND ketone and/or autoantibodies = “doesn’t exist”,

THEN diabetes type = “Other diabetes type”

The all prolog rules used in the knowledge base of the prototype self-learning knowledge-based system are found in Appendex II.

CHAPTER FOUR

IMPLEMENTATION OF THE PROTOTYPE SYSTEM

4.1 Introduction

In the following sections, the implementation includes the real construction of the prototype system for diagnosis and treatment of diabetes. After the necessary knowledge is represented using a rule-based knowledge representation technique, the next step is coding the represented knowledge using Prolog programming language into a suitable format that is understandable by the inference engine. For this study, SWI-Prolog editor tool is used to construct the prototype system.

4.2 Architecture of the Prototype System

An architecture is a blueprint showing how the components of the prototype self-learning knowledge-based system interacts and interrelates. Figure 4.1 illustrates the architecture of the prototype system.

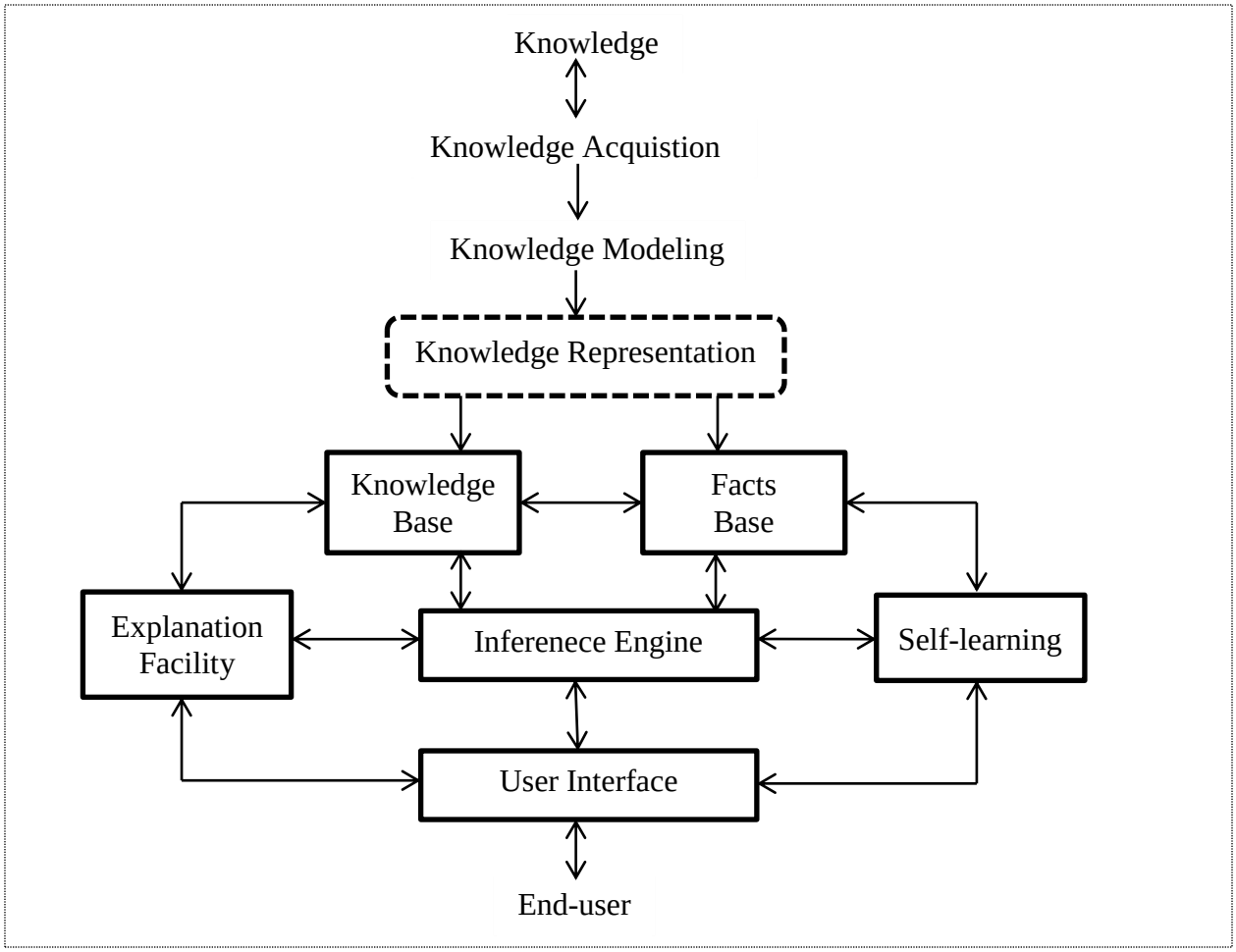

Figure 4. 1 Architecture of the prototype self-learning knowledge-based system

As shown in figure 4.1, the developed prototype system functions by asking questions to the new patient who came for diagnosis and treatment of diabetes. First it checks the appearance of the basic symptoms of diabetes in the patient and sends the patient for a laboratory blood test to decide whether the patient is diabetic, prediabetic or normal. If the patient has diabetes, then it further diagnoses the patient to identify which type of diabetes the patient has. To decide whether the patient has Type 1, Type 2 or other type of diabetes, it considers the risk factors of diabetes such as the concept of age, family history of diabetes and/or obesity, and ketone and/or autoantibodies. Besides, if the previous diagnosed test result of a certain patient shows the patient is prediabetic and when the patient wants to diagnose again, the test result shows the patient has diabetes. The system automatically remembers the patient's history from the facts base and decides the patient has Type 2 diabetes, i.e. the prototype system learns from experience and updates its knowledge accordingly. Lastly, it recommends treatments for patients

based on the type of diabetes the patient has and the patient can enter the amount of glucose level before fasting in order to get an advice from the prototype system to help the patients to control their sugar level.

4.2.1 Knowledge Base

Knowledge base is a set of rules or the encoded knowledge about diagnosis and treatment of diabetes of the prototype system. The validated knowledge is represented in the form of rules by rule-based representation technique and the rules are codified to the knowledge base of the prototype system using Prolog programming language. Sample rules in the knowledge base of the prototype system are discussed as follows.

Rule 1:
```
fasting (Fasting), integer (Fasting), Fasting >= 126,
    write ('"YOU HAVE DIABETES"').
```

In the above rule 1, the system requests the patient to insert the amount of glucose level in his/her blood with fasting. That means, the patient should not eat food for at least eight hours before laboratory testing. After the patient inserts the amount of glucose level, then, if the amount of glucose level is greater than 126 mg/dL, automatically the system draws conclusion that is displayed to the patient is “YOU HAVE DIABETES”.

Rule 2:
```
write ('Please answer the following questions to identify your diabetes type: '), nl, nl,
    age (Age), integer (Age), Age > 35), nl,
    write ('"YOU ARE DIABETIC TYPE II PATIENT"'),
    assertz (diabetes(Name,diabetic_type_2)), tell('D:/diabetes.pl'),
    write (':- dynamic(diabetes/2).'), nl, listing(diabetes), told.
```

After the system in rule 1 made a decision that says the patient has diabetes, then in rule 2 it further asks the patient to identify the patient’s diabetes type. It asks the age of the patient because age of the patient helps to identify whether the patient has Type 1 or Type 2 diabetes. If the age of the patient is greater than 35 years, the system draws conclusion that says “YOU ARE DIABETIC TYPE 2 PATIENT”. Besides, the system stores/keeps patient’s name and Type 2 diabetes to the facts base of the prototype system. This helps to remember the patient’s history at next time in order to give appropriate treatment to the patient.

An additional component of the prototype system is facts base which is a database used to accumulate the set of facts which is used by the rules of the prototype system. It comprises facts about the specific case of the problem being diagnosed.

The facts represented in the facts base relies on the type of application. Initially, the facts base can comprise known facts by the prototype system which are used by the inference engine to acquire facts and match them with the rules of the prototype system. The facts about the problem solved are added to the facts base by using rules of the prototype system.

The contents of the facts base changes with each problem circumstances. Therefore, it is the dynamic component of a knowledge-based system.

In this study, the researcher used elements of the facts base of the prototype system in the following sample format:

diabetes(yakob, diabetic_free). **%** to represent the fact that yakob is free from diabetes
diabetes(abel, prediabetes). **%** to represent the fact that abel has prediabetes
diabetes(selam, other_diabetes_type). **%** to represent the fact that selam has other diabetes type
diabetes(mohammed, diabetic_type_1). **%** to represent the fact that mohammed has diabetes Type 1
diabetes(yonas, diabetic_type_2). **%** to represent the fact that yonas has diabetes Type 2

According to the above sample format, the researcher represented the facts about the problem in the facts base of the prototype self-learning knowledge-based system.

If the diagnosed result of a patient is either Type 1 or Type 2 diabetes, it is not possible to update the history of the patient. This is because diabetes is a long-lasting disease and cannot be treated for once and last, i.e. a permanent disease. The main challenge faced during implementation of the facts base is, the failure of the facts base to keep the previous diagnosed result that shows patient's history of free from diabetes in the facts base of the prototype system. Let us consider as an example from the above represented facts in the facts base.

diabetes(yakob, diabetic_free). **%** to represent the fact that yakob is free from diabetes

When yakob wants to make diagnosis at another time and the diagnosis result is other than "diabetic_free", the system automatically deletes the previous yakob's history from the facts base and updates the facts base with new yakob's patient history as follows.

diabetes(yakob, diabetic_type_1). **%** to represent the fact that yakob has diabetes Type 1 diabetes

Thus, after updating the patient's history of those free from diabetes, keeping the previous diagnosed result that shows patient's history free from diabetes in the facts base of the prototype system is not implemented and assumed by the researcher as least important. This is because the objective of the research work is to treat patients living with diabetes.

4.2.2 Explanation Facility

In addition to offering the end results, the prototype system can explain 'what' a request to repeat for clarification before it reached on its conclusions. This ability is usually important since the type of problems to which knowledge-based systems are carried out need an explanation of the result delivered to the end-users. It has also the ability of justifying 'why' a certain problem is being questioned. For example, the following figure 4.2 illustrates the 'what' and 'why' explanation facility that is used to make the results easily understandable by the end-users and build a good communication between the end-users and the system.

```
1 ?- start.

Welcome to a Self-learning Knowledge-Based System for Diagnosis and Treatment of Diabetes

         <Written by Solomon Gebremariam, December 2012 G.C>


% D:/diabetes.pl compiled 0.00 sec, 1,360 bytes

Please enter your name: mohammed.

Hello! mohammed, do you need general information about diabetes?(yes/no): yes.

Diabetes is a disease where the body cannot properly produce or use insulin. Insulin is a hormone
that turns the foods you eat into energy. If your body cannot turn food into energy, not only will
your cells be starved for energy, you will also build up glucose (sugar) in your blood. This will
lead you to have high blood glucose levels. Over years, the high blood glucose level can damage
major organs like your heart, eyes, and kidneys.

Do you want to make diagnosis?(yes/no): yes.

Please give (yes.) or (no.) answer to the following questions and
If the questions are unclear you can ask by entering (what.) and (why.)

Do you feel excessive thirst?(yes/no/what): what.

This is to mean you need to drink water frequently?(yes/no/why): why.

Because high level thirsty is the most important symptom of diabetes. So, do you feel excessive thirst?(yes/no):
|: yes.

Do you urinate frequently?(yes/no/what): what.

This is to mean you get a pee frequently?(yes/no/why): why.

Because frequent urination is the most important symptom of diabetes. So, do you urinate frequently?(yes/no):
|: yes.

Do you feel excessive hunger?(yes/no/what): ▮
```

Figure 4. 2 Sample 'what' and 'why' explanation facility

As shown in the above figure 4.2, it is a sample dialogue between the end-user and the prototype system. The prototype system asks a question like "Do you feel excessive thirst?(yes/no/what): " through the user interface to the end-user. If the end-user clearly understands the question, the end-user might insert 'yes' or 'no' to the user interface of the prototype system. But if the end-user does not clearly understand the question, the end-user can ask for further clarification by inserting 'what' question to the user interface of the prototype system. Then the prototype system provides answers by saying "This is to mean that do you drink water frequently?(yes/no/why): ". Again, if the end-user wants an answer for the reason 'why', the prototype system provides the answer to clarify the reason why by saying "Because high level thirsty is the most important symptom of diabetes". After clarifying 'what' and 'why' questions, the prototype system requests the end-user to insert 'yes' or 'no' answers by saying "So, do you feel excessive thirst?(yes/no): ". Finally, the end-user inserts to the user interface either 'yes' or 'no'. The prototype system continues for another question by saying "Do you urinate frequently?(yes/no/what): ".

End-users need explanation facilities in the system during and after the problem solving. The developer of the system included 'what' and 'why' explanation facilities during problem solving

and ‘how’ explanation facility after problem solving. However, the end-users required more explanation facilities during problem solving like ‘what if’ and after problem solving like ‘why not’ questions which were not included during testing the system. According to end-users’ suggestion, additional explanation facilities like ‘what if’ and ‘why not’ are included after testing the system.

Moreover, the developer considers the explanation facilities included in the system are easily understandable by the end-users. However, the end-users particularly the nurses were unable to understand some of the explanations provided by the system. The main challenge faced during testing the system is end-users need explanation facilities with diagrams to be offered by the system. Therefore, designing a graphical user interface must be incorporated in the system for the future work in order to help end-users to easily understand the explanation facilities provided by the system.

4.2.3 Self-Learning

As discussed in section 2.2.4, individuals can learn new things and on certain occasions be unable to remember knowledge that is not in regular uses. Imitation of such learning is an essential component of a knowledge-based system structure. Learning is nothing but adding new facts into its knowledge base as it runs and remembers that fact at the next time **[27]**. Thus, knowledge-based system can be developed, and modify its knowledge by integrating the learning component into their structure.

The learning prototype system attempts to store the details of a specific patient diagnosed. The facts base is stored on a separate file called **“diabetes.pl”** and becomes updated whenever the end-user ends the program. The following figure 4.3 shows a sample dialogue with the prototype system:

```
1 ?- start.

Welcome to a Self-learning Knowledge-Based System for Diagnosis and Treatment of Diabetes

         <Written by Solomon Gebremariam, December 2012 G.C>


% D:/diabetes.pl compiled 0.00 sec, 1,324 bytes

Please enter your name: yemane.

Hello! yemane, do you need general information about diabetes?(yes/no): no.

Do you want to make diagnosis?(yes/no): yes.

Please give (yes.) or (no.) answer to the following questions and
If the questions are unclear you can ask by entering (what.) and (why.)

Do you feel excessive thirst?(yes/no/what): yes.


Do you urinate frequently?(yes/no/what): yes.


Do you feel excessive hunger?(yes/no/what): yes.


Do you get unusual weight loss?(yes/no/what): yes.


Do you get fatigue problem?(yes/no/what): no.


Do you get dizzy?(yes/no/what): no.


Do you get vision problem?(yes/no/what): yes.


HIGHLY DIABETES POSITIVE GUESS!

PLEASE MEASURE THE GLUCOSE LEVEL IN YOUR BLOOD USING FASTING PLASMA GLUCOSE TEST TO ASSURE!

LABORATORY TESTING PROCESS IS STARTED HERE ...

N.B: THE PATIENT SHOULD NOT EAT FOOD FOR AT LEAST EIGHT HOURS BEFORE TESTING.


Please enter the amount of glucose level in your blood (mg/dL): 122.


"YOU HAVE PRE-DIABETES"

Do you need to see treatment?(yes/no): yes.

===================RECOMMENADTION======================

Pre-diabetes means a person is at increased risk for developing Type 2 diabetes, as well as for
heart disease and stroke. People with pre-diabetes develop Type 2 diabetes within 10 years.
So, treatment consists of losing a modest amount of weight (7% of total body weight) through healthy eating and
moderate exercise, such as walking, 30 minutes a day, five days a week. Do not worry IF you can not get to your
ideal body weight. Losing just 10 to 15 pounds can make a big difference.

You are loging out from the system. ARE YOU SURE?(yes/no): yes.

PLEASE COME AND CHECK AGAIN, GOOD BYE!!
% Break level 1
[1] 2 ?-
```

Figure 4. 3 A sample dialogue with the prototype system

From the above figure 4.3, the system requests the end-user to enter the name of the patient before continuing to the diagnosis process and the system diagnoses the patient by asking the basic signs and symptoms of diabetes and recommends the patient to measure the amount of glucose level in his/her blood using FPG test. If the amount of glucose level in the blood of the patient is between 100 and 125 mg/dL, the system concludes the patient has pre-diabetes. Finally, the system advices the pre-diabetic patient to lose his/her weight, make physical exercise, and eat healthy foods. Otherwise, the patient is expected to live with Type 2 diabetes within 10 years **[63]**.

```
1 ?- start.

Welcome to a Self-learning Knowledge-Based System for Diagnosis and Treatment of Diabetes

         <Written by Solomon Gebremariam, December 2012 G.C>


% D:/diabetes.pl compiled 0.00 sec, 1,424 bytes

Please enter your name: yemane.

yemane, "LAST TIME YOUR DIAGNOSIS RESULT WAS PRE-DIABETES"

Do you want to make diagnosis?(yes/no): yes.

Please give (yes.) or (no.) answer to the following questions and
If the questions are unclear you can ask by entering (what.) and (why.)

Do you feel excessive thirst?(yes/no/what): yes.


Do you urinate frequently?(yes/no/what): yes.


Do you feel excessive hunger?(yes/no/what): yes.


Do you get unusual weight loss?(yes/no/what): yes.


Do you get fatigue problem?(yes/no/what): no.


Do you get dizzy?(yes/no/what): no.


Do you get vision problem?(yes/no/what): no.

HIGHLY DIABETES POSITIVE GUESS!

PLEASE MEASURE THE GLUCOSE LEVEL IN YOUR BLOOD USING FASTING PLASMA GLUCOSE TEST TO ASSURE!

LABORATORY TESTING PROCESS IS STARTED HERE ...

N.B: THE PATIENT SHOULD NOT EAT FOOD FOR AT LEAST EIGHT HOURS BEFORE TESTING.


Please enter the amount of glucose level in your blood (mg/dL): 135.

yemane, "YOU ARE DIABETIC TYPE 2 PATIENT"

Do you need to see treatment?(yes/no): no.

If you do not know how to use the system you can press(how/no): no.

You are loging out from the system. ARE YOU SURE?(yes/no): yes.

PLEASE COME AND CHECK AGAIN, GOOD BYE!!
% Break level 1
[1] 2 ?- start.

Welcome to a Self-learning Knowledge-Based System for Diagnosis and Treatment of Diabetes

         <Written by Solomon Gebremariam, December 2012 G.C>


% D:/diabetes.pl compiled 0.00 sec, 1,424 bytes

Please enter your name: yemane.

yemane, "YOU ARE DIABETIC TYPE 2 PATIENT"

Do you need to see treatment?(yes/no): ▮
```

Figure 4. 4 A sample dialogue that learns from experience

As shown in the above figure 4.4, the prototype system has learned by remembering the details of the patient: Yemane being diagnosed. When the patient wants to diagnose next time using the

system, the system requests the patient to enter the amount of glucose level in his blood with fasting. If the amount of glucose level is greater than 126 mg/dL, the system automatically draws conclusion by saying to the patient “yemane, YOU ARE DIABETIC TYPE 2 PATIENT”. This is because the system learns from experience that the patient was pre-diabetic and after a certain time the patient is expected to develop Type 2 diabetes disease. If the amount of glucose level in the blood of the patient is greater than 126 mg/dL, the patient becomes diabetic and the system does not attempt asking further questions to identify the type of diabetes. Instead the system learns from experience and draws conclusion “YOU ARE DIABETIC TYPE 2 PATIENT”. Besides, it updates the history of the patient in the facts base of the prototype system.

The learning process is permanent. That means, if we run the system at another time and question for the details of the patient, we will hereafter get the right response.

4.2.4 User Interface

User interface is a means of communication with the end-user that enables to interact easily with the prototype self-learning knowledge-based system. Its duty is to translate the prolog rules of the prototype from its representation in the knowledge base which may not be clear by the end-users to the end-users understandable form.

The end-user of the system can start the diagnosis by inserting the word “start” then full stop “.” and press “enter” using the SWI-Prolog Editor window. The welcome window will be displayed in order to help the end-users to interact easily with the system. This is shown in figure 4.5 as follows:

```
1 ?- start.

Welcome to a Self-learning Knowledge-Based System for Diagnosis and Treatment of Diabetes

         <Written by Solomon Gebremariam, December 2012 G.C>

% D:/diabetes.pl compiled 0.00 sec, 1,424 bytes

Please enter your name: aster.

Hello! aster, do you need general information about diabetes?(yes/no): no.

Do you want to make diagnosis?(yes/no): yes.

Please give (yes.) or (no.) answer to the following questions and
If the questions are unclear you can ask by entering (what.) and (why.)

Do you feel excessive thirst?(yes/no/what): yes.

Do you urinate frequently?(yes/no/what): yes.

Do you feel excessive hunger?(yes/no/what): yes.

Do you get unusual weight loss?(yes/no/what): no.

Do you get fatigue problem?(yes/no/what): no.

Do you get dizzy?(yes/no/what): no.

Do you get vision problem?(yes/no/what): no.

HIGHLY DIABETES POSITIVE GUESS!

PLEASE MEASURE THE GLUCOSE LEVEL IN YOUR BLOOD USING FASTING PLASMA GLUCOSE TEST TO ASSURE!

LABORATORY TESTING PROCESS IS STARTED HERE ...

N.B: THE PATIENT SHOULD NOT EAT FOOD FOR AT LEAST EIGHT HOURS BEFORE TESTING.

Please enter the amount of glucose level in your blood (mg/dL): ▮
```

Figure 4. 5 Sample dialogue that uses three basic symptoms to guess high diabetes positive

After the welcome window is displayed, the system requests the end-user to insert the name of the patient before proceeding to the diagnosis process. Then it gives general information about diabetes if the end-user needs to know about diabetes. Next the system can diagnose the patient by asking the most common signs and symptoms of diabetes so as to enable the system to predict whether the patient has diabetes or not. When the system guesses as high diabetes positive using symptoms, it depends on the appearance of at least the above first three main symptoms, that is feeling of excessive thirst, feeling of frequent urination and feeling of excessive hunger must be answered as ‘yes’ by the end-user. After this the system suggests the patient to measure the amount of glucose level in his/her blood using Fasting Plasma Glucose (FPG) test to assure. This

is the most important and useful suggestion by the system in order to conclude whether the patient has diabetes or not.

```
1 ?- start.

Welcome to a Self-learning Knowledge-Based System for Diagnosis and Treatment of Diabetes

         <Written by Solomon Gebremariam, December 2012 G.C>

% D:/diabetes.pl compiled 0.00 sec, 1,424 bytes

Please enter your name: yemisrach.

Hello! yemisrach, do you need general information about diabetes?(yes/no): no.

Do you want to make diagnosis?(yes/no): yes.

Please give (yes.) or (no.) answer to the following questions and
If the questions are unclear you can ask by entering (what.) and (why.)

Do you feel excessive thirst?(yes/no/what): yes.

Do you urinate frequently?(yes/no/what): yes.

Do you feel excessive hunger?(yes/no/what): yes.

Do you get unusual weight loss?(yes/no/what): no.

Do you get fatigue problem?(yes/no/what): no.

Do you get dizzy?(yes/no/what): no.

Do you get vision problem?(yes/no/what): yes.


HIGHLY DIABETES POSITIVE GUESS!

PLEASE MEASURE THE GLUCOSE LEVEL IN YOUR BLOOD USING FASTING PLASMA GLUCOSE TEST TO ASSURE!

LABORATORY TESTING PROCESS IS STARTED HERE ...

N.B: THE PATIENT SHOULD NOT EAT FOOD FOR AT LEAST EIGHT HOURS BEFORE TESTING.

Please enter the amount of glucose level in your blood (mg/dL): 150.

"YOU HAVE DIABETES"

Please answer the following questions to identify your diabetes type:

yemisrach, enter your age: 36.

"YOU ARE DIABETIC TYPE 2 PATIENT"

Do you need to see treatment?(yes/no): yes.


------------------------Foods you should eat------------------------

Less calorie content food, carbohydrate foods digested slowly, low-fat food, low-salt foods, protein foods

------------------------Medications you should take------------------------

Sulfonylurea, meglitinides, biguanides, alpha-glucosidase inhibitors: are used for treatment of diabete type 2

------------------------Exercises------------------------

AEROBIC EXERCISE: walking, hiking, jogging, biking, swimming ...,NOTE:-always remember and exercise for health weight
```

```
    ------------------------Foods to avoid or limit------------------------

WHOLE GRAINS: White breads, croissants, sweet rolls, high-fat white crackers, waffles
VEGETABLES and FRUIT: Parsnip, pumpkin, white potatoes (high GI)
MILK: Milk products higher than 1% fat Cheese higher than 21% MF and creams
MEAT and ALTERNATIVES: Hydrogenated oils, coconut and palm oils Shortening, butter,
Lard, hard margarines No more than 1/4 cup nuts per day (high calories) Chocolate and carob
SWEETS: Sugar and regular jams, jellies, syrups, candies, gelatins, gum, honey.

Do you want to monitor glucose level in your blood using FPG test?(yes/no):
|: yes.


LABORATORY TESTING PROCESS IS STARTED HERE ...

N.B: THE PATIENT SHOULD NOT EAT FOOD FOR AT LEAST EIGHT HOURS BEFORE TESTING.


Please enter the amount of glucose level in your blood (mg/dL): 130.

===================RECOMMENADTION======================

If your glucose level is between 126 and 155 mg/dL, it indicates that you were previously
exercising well, had a healthy diet and taken your insulin properly. So, you should continue on doing these.

Do you want to monitor glucose level in your blood using hemoglobin A1C test after 2-3 months?(yes/no):
|: yes.


LABORATORY TESTING PROCESS IS STARTED HERE ...

Please enter the amount of glucose level in your blood (%): 9.

===================RECOMMENADTION======================

If the glucose level is between 8 and 13 %, then it indicates that your glucose level control was not effective.
If the glucose level is always in this range, then you are highly likely to be affected with the complications of diabetes disease.

You are loging out from the system. ARE YOU SURE?(yes/no): yes.

PLEASE COME AND CHECK AGAIN, GOOD BYE!!
% Break level 1
[1] 2 ?-
```

Figure 4. 6 Sample dialogue to identify the patients diabetes type

After the prototype system guesses either high diabetes positive or less chance of diabetes using symptoms, the system further suggests the patient to measure the amount of glucose level in his/her blood using FPG test. As shown in the above figure 4.6, the laboratory test result shows the patient has diabetes and the system further asks the user to identify whether the patient is diabetic Type 1 or Type 2. After identifying the diabetes type, the system recommends the treatment facilities such as the diet information, medication, exercise and foods to avoid or limit. Moreover, the system advices the patient to monitor his/her glucose level either using FPG or hemoglobin A1C test methods. FPG test enables the patient to control his/her glucose level daily and hemoglobin A1C is used to measure the average sugars level that is accumulated in the patient's blood for the last 2-3 months by looking at the level of sugar in the patient's hemoglobin. This is because if diabetic patients get proper treatments, they can control their sugar level, which will further enable them to minimize death rates due to diabetes.

```
1 ?- start.
Welcome to a Self-learning Knowledge-Based System for Diagnosis and Treatment of Diabetes
         <Written by Solomon Gebremariam, December 2012 G.C>

% D:/diabetes.pl compiled 0.00 sec, 1,528 bytes
Please enter your name: kebede.
kebede, "YOU ARE DIABETIC TYPE 1 PATIENT"
Do you need to see treatment?(yes/no): yes.

------------------------Foods you should eat----------------------------------
CARBOHYDRATE FOODS: Bread, Grain, Rice, Pasta ...
FAT FOODS: Butter, Oils, Avocado ...
NOTE:- Carbohydrate content should be balanced with insulin produced in your body
------------------------Medications you should take------------------------
APIDRA(insulin glulisine), HUMALOG(insulin pro), HUMULIN(insulin regular):- are the most important insulin injection types
------------------------Exercises----------------------------------
AEROBIC EXERCISE: walking, hiking, jogging, biking, swimming ...
------------------------foods to avoid or limit------------------------
WHOLE GRAINS: White breads, croissants, sweet rolls, high-fat white crackers, waffles
VEGETABLES and FRUIT: Parsnip, pumpkin, white potatoes (high GI)
MILK: Milk products higher than 1% fat Cheese higher than 21% MF and creams
MEAT and ALTERNATIVES: Hydrogenated oils, coconut and palm oils Shortening, butter,
Lard, hard margarines No more than 1/4 cup nuts per day (high calories) Chocolate and carob
SWEETS: Sugar and regular jams, jellies, syrups, candies, gelatins, gum, honey.
Do you want to monitor glucose level in your blood using FPG test?(yes/no):
|: yes.

LABORATORY TESTING PROCESS IS STARTED HERE ...
N.B: THE PATIENT SHOULD NOT EAT FOOD FOR AT LEAST EIGHT HOURS BEFORE TESTING.

Please enter the amount of glucose level in your blood (mg/dL): ■
```

Figure 4. 7 Sample dialogue that remembers the patient history from experience

In the above figure 4.7, the system requests the end-user to insert the name of the patient. After the end-user inserts name: 'kebede', the system automatically remembers the history of the patient being diagnosed and it proceeds directly to the treatment option rather than diagnosing the diabetic patient again and again since diabetes is a permanent disease. Thus, it recommends the treatment facilities such as the diet information, medication, exercise and foods to avoid or limit. Besides, the system advices the patient to monitor the patient's glucose level either using FPG or hemoglobin A1C test methods.

After the prototype is built, it should be extensively tested and evaluated to make sure that the system is accepted by the end-users and the performance of the system is accurate. Testing and evaluation of the prototype system is discussed in the following section:

4.3 Testing and Evaluation

After the prototype self-learning knowledge-based system for diagnosis and treatment of diabetes is implemented in ProLog (**Pro**gramming in **Log**ic) using SWI-Prolog editor tool, ultimately every knowledge-based system must be tested and evaluated to ensure that whether the performance of the system is accurate and the system is usable by the end-users.

The scope of testing and evaluation that is accomplished and the significance involved to it relies on the size, complexity, and other features of the knowledge-based system. As the aim of testing and evaluation of the knowledge-based system is to assure that the prototype system does what it is required to do, we can test and evaluate a knowledge-based system as long as we already understand what to expect. Therefore, in this study testing and evaluation of the prototype system has two aspects. These are system performance testing, and user acceptance testing.

In system performance testing section, a number of patients history are selected by the researcher in order to test the accuracy of the prototype system. The correct and incorrect outcomes are identified by comparing decisions made by domain experts on the patients history and with the conclusions of the prototype system.

Under user acceptance testing section, the process of ensuring that whether the prototype system satisfies the requirements of its end-users is performed. This permits end-users to test the prototype system by actually using it and evaluating the benefits received from its use.

4.3.1 System Performance Testing

System performance testing is the process of determining whether the prototype system is correct, that is whether it meets the level of accuracy as required. It confirms whether the right prototype system has been built.

This testing method is applied to evaluate the performance of the prototype system using the parameters precision, recall and F-measure. These three parameters are used in order to measure the accuracy of the prototype system.

In this study, four Internist doctors and two nurses are selected from Black Lion Hospital Diabetes Center for the purpose of testing the prototype system. The criteria for selecting the evaluators is because of the fact that the medical doctors are Internists and the nurses work in the

diabetes center. Eighteen patients test cases are circulated equally to the evaluators, that is three patients test cases for each evaluator.

In the process of testing the performance of the prototype system, the domain experts classify correctly and incorrectly diagnosed patients cases by comparing the judgments reached by the prototype system with that of the domain experts' judgments reached on the same patients test cases.

Performance of this prototype system is usually evaluated using the data in the matrix. The following table 4.1 shows the confusion matrix for a three class classifier.

KBS Suggestion				
Type 1 diabetes	**Type 2 diabetes**	**Other diabetes type**	**Class names**	**Experts Suggestion**
5	2	0	**Type 1 diabetes**	
1	4	0	**Type 2 diabetes**	
0	0	6	**Other diabetes type**	

Table 4. 1 Confusion matrix of the prototype system

The entries in the confusion matrix as shown in table 4.1 have the following meaning in the context of this study. Accordingly, of the total 18 diagnosed patients cases in the first column shows 6 diagnosed patients cases are classified as 'Type 1 diabetes' out of which 5 diagnosed patients cases are correctly classified and 1 diagnosed patient case is incorrectly classified. The second column shows, of the total 6 diagnosed patients cases 4 diagnosed patients cases are classified as 'Type 2 diabetes' and 2 diagnosed patients cases are incorrectly classified. Besides the third column shows, of the total 6 diagnosed patients cases 6 diagnosed patients cases are classified as 'Other diabetes type'. In general, from 18 diagnosed patients cases 15 diagnosed patients cases are classified correctly and 3 diagnosed patients cases are classified incorrectly. Thus, the following information result shows judgments reached by the prototype system:

Correctly diagnosed patients cases …… 15 …… 83.33%
Incorrectly diagnosed patients cases ……. 3……... 16.67%

The performance of the prototype system is calculated thoroughly by using confusion matrix presented in table 4.1.

The prototype system register 83.33% in diagnosing patients with diabetes which is an encouraging accuracy result after it has been evaluated by domain experts. As the accuracy result shows the prototype system has almost similar judgment skill like the domain experts in diagnosing patients with diabetes.

The summarized generated result for this performance measure is shown in table 4.2. This table contains the detailed accuracy by class that include the true positive rate(TP rate), the false positive rate (FP rate), the precision (P), recall(R) and F-measure.

	TP Rate	**FP Rate**	**Precision**	**Recall**	**F-Measure**	**Class names**
	0.71	0.1	0.83	0.71	0.76	**Type 1 diabetes**
	0.8	0.15	0.67	0.8	0.73	**Type 2 diabetes**
	1	0	1	1	1	**Other diabetes type**
Weighted average	**0.8333**	**0.0833**	**0.8333**	**0.8333**	**0.8333**	

Table 4. 2 Detailed accuracy of the prototype system

According to the TP Rate in table 4.2, the type of diabetes that are correctly classified out of all diabetes type shows that '**Other diabetes type**' class scores the highest TP Rate (100%), followed by the '**Type 2 diabetes'** class (80%) and '**Type 1 diabetes'** class (71%).

However, taking only the TP Rate for measuring the performance of the KBS suggestion can be confusing. Instead, we should take the commonly used measuring parameters for measuring the performance of any classifier such as weighted average of precision and recall in order to measure the performance of the KBS suggestion. Thus, the weighted average precision shows 83.33% of the predicted positive cases that were correct is the permormance registered by the KBS suggestion. Similarily, the weighted average recall also shows 83.33% of the positive cases among all cases that actually belong to the relevant subset.

The problem of mistyping of diabetes is common even when the domain experts made a decision to identify the patient's diabetes type. This is due to the lack of modern laboratory facilities used

for identifying the patient's diabetes type. Developed coutries have adequate laboratory facilities to identify the type of diabetes the patient has. They can easily identify the type of diabetes by measuring the amount of C-peptide in the blood of diabetic patients, i.e. the amount of C-peptide in the blood of patients with Type 1 diabetes have less than 1.5 nmol per L and patients with Type 2 diabetes have greater than 1.5 nmol per L **[64]**. However, in our country, such kind of diagnosis method is not used by the domain experts due to the scarcity of resources. The domain experts attempt to identify the patient's diabetes type by using the concepts of age, family history of diabetes and/or obesity, and ketone and/or autoantibodies. This is the reason why the prototype system didn't register high performance. This shows that the domain knowledge of any problem should be very strong and constant overtime to apply rule-based representation technique in developing the knowledge-based system.

4.3.2 User Acceptance Testing

User acceptance testing is usually a crucial factor in the success of a knowledge-based system. Irrespective of how accurate the performance measures are, how complete the system may be, or how trustworthy the knowledge-based system is, all development may be useless if the knowledge-based system is not acceptable by end-users.

Every domain expert evaluator offers various patients history test to the prototype system and search decisions made by the prototype system. The evaluators assess the accuracy of the prototype system by using the following standards, these are: simplicity of use and interact with the prototype system, attractiveness of the prototype system, efficiency in time, the accuracy of the prototype system in reaching a decision to identify the types of diabetes, including adequate knowledge in the prototype system, the ability of the prototype system in making the right conclusions and recommendations, the ability of the prototype system to remember the patients' history, and the importance of the prototype system in the domain area. These evaluation standards are customized from Redeit **[13]**, Pu et al. **[65]** and Seblewongel **[15]**. The questionnaires used to test the performance of the prototype system by domain experts is found in appendix III.

The researcher fixed values for each attributes of the questionnaire for the purpose of evaluating the performance of the prototype system on the side of the end-users. The values for all attributes are fixed as: Excellent = 5, Very good = 4, Good = 3, Fair = 2 and Poor = 1. This allows the

domain experts to put their values for each criteria of evaluation. The following table 4.3 illustrates the outcomes achieved after evaluation by domain experts.

No.	Criteria of evaluation	Poor	Fair	Good	Very good	Excellent	Average
1.	Simplicity to use and interact with the prototype system	1	1	1	1	2	**3.33**
2.	Attractiveness of the prototype system	0	0	1	1	4	**4.50**
3.	Efficiency in time	0	0	1	1	4	**4.50**
4.	The accuracy of the prototype system in reaching a decision to identify the types of diabetes	0	1	1	0	4	**4.17**
5.	Including adequate knowledge about diabetes in the prototype system	0	0	2	4	0	**3.67**
6.	The ability of the prototype system in making right conclusions and recommendations	0	0	2	1	3	**4.17**
7.	The ability of the prototype system to remember the patients history	0	0	0	1	5	**4.83**
8.	Importance of the prototype system in the domain area	0	0	0	1	5	**4.83**
		Total average					**4.25**

Table 4. 3 Performance evaluation by domain experts

As shown in the above table 4. 3, 33.33% of the evaluators scored the simplicity to use and interact with the prototype system criteria of evaluation as excellent, 16.67% as very good, 16.67% as good, 16.67% as fair and 16.67% as poor. The second evaluation criteria attractiveness of the prototype system showed a greater rate of attractiveness by the evaluators the majority is scored 66.67% as excellent, 16.67% as very good, and 16.67% as good. In the efficiency of the prototype system with respect to time criteria of evaluation, 66.67% of the evaluators scored as excellent, 16.67% as very good, and the rest 16.67% as good.

Moreover, 66.67% of the evaluators gave the prototype system an excellent score with regard to the accuracy of the prototype system in reaching a decision to identify the type of diabetes the patient has, 16.67% as good, and 16.67% as fair. And when asked if the prototype system included adequate knowledge about diabetes, 66.67% of the evaluators rated the prototype system as very good and 33.33% as good. The ability of the prototype system in making right conclusions and recommendations criteria was scored by half of the evaluators as excellent while 33.33% and 16.67% of the evaluators scored it with good and very good respectively.

To this end, equal scores were given for both the ability of the prototype system to remember the patients history and the importance of the prototype system in the domain area criteria, 83.33% of the evaluators gave the prototype system excellent while 16.67% rated the prototype system as very good. Finally, the average performance of the prototype system according to the evaluation results filled by the domain experts is 4.25 out of 5 or 85% which is above very good.

4.3.3 Discussion

As discussed in the above under sections 4.3.1 and 4.3.2, the accuracy of the prototype system is calculated as 83.33% and the average evaluation result filled by the domain experts in the domain area is 85%, respectively. The overall performance of the prototype system is 84.2%.

There are some challenges encountered during the study which limits the prototype system to register a better performance for diagnosis and treatment of diabetes. These are discussed as follows:

- Training was given to the domain experts on how the system functions and on how to use and interact with the system. However, from six evaluators, two of them are nurses and they are not satisfied by the user interface of the prototype system. The two evaluators responded that, they want to insert their queries to the user interface in their local language and also want the decisions provided by the system in their local language so as to understand the decisions made by the system. Due to this reason, two evaluators replied as poor and fair rating value for the simplicity to use and interact with the prototype system criteria of evaluation. Besides, the medication treatments one should take recommended by the system especially for Type 1 diabetes is responded as difficult to understand. This is because Type 1 diabetic patients should inject insulin two times per

a day and the place of injection should be at different part of the patient's body. So, the system must show where the patient should inject the insulin in the form of diagrams to clearly understand the medication treatments provided by the system.

- Eventhough the two common types of diabetes are Type 1 and Type 2 diabetes, the evaluators suggested to include knowledge about gestational diabetes in the system. Due to this reason, two evaluators replied as good rating value for evaluation criteria including adequate knowledge about diabetes in the prototype system.
- Even though tacit knowledge about the diagnosis and treatments of diabetes is extracted from the domain experts using interviewing method in order to have detail understanding of the domain knowledge, it is challenging to extract the necessary knowledge due to the personal nature of tacit knowledge.
- During coding the represented knowledge about diabetes using the SWI-Prolog editor tool, the facts base of the prototype system is able to update its knowledge automatically. However, the researcher encountered a challenge to update the rules of the knowledge base of the prototype system automatically.

In general, the testing and evaluation outcomes of the prototype system has achieved the objectives of the study. However, additional study is needed to bring complete implementation and use of self-learning knowledge-based system for diagnosis and treatment of diabetes.

CHAPTER FIVE
CONCLUSION AND RECOMMENDATIONS

The earlier chapters have brought to light some significance issues in the design of the prototype self-learning knowledge-based system for diagnosis and treatment of diabetes. In this part, the researcher concludes the study work and gives recommendation for future investigation in the health and medicine area.

5.1 Conclusion

Diabetes is a permanent disease that happens either when the pancreas does not produce sufficient insulin or when the body cannot effectively use the insulin it generates. It is also a chronic disease and will not be treated for once and last. Due to this reason, patients need self-diagnosis and consistent treatment. But, in our country, there are no sufficient numbers of physicians. This condition leads to disproportional numbers of physicians and patients. Because of this problem, diabetic patients are not getting enough diagnosis and treatment.

Hence, in this study an effort has been made to design and develop a prototype of a self-learning knowledge-based system that can provide advice for physicians and patients to facilitate the diagnosis and treatment of patients living with diabetes.

In developing the prototype system, 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 diabetes. 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 advise for patients and experts.

Also in testing and evaluation of the prototype system, eighteen cases of patients are selected using purposive sampling method in order to test the accuracy of the prototype system. The correct and incorrect results are identified by comparing decisions made by the domain experts on the cases of patients and with the conclusions of the prototype system. And also the process of ensuring that the prototype system satisfies the requirements of its end-users is performed. This

permits end-users to test the prototype system by actually using it and evaluating the benefits received from its use. As the testing result show, the overall performance of the prototype system registers 84.2%.

The strong side of the prototype system shows that the facts base of the system is able to update its knowledge from experience automatically. However, there is a need to resolve recommendation conflict between experts vs. KBS due to lack of modern laboratory facilities used for identifying the type of diabetes.

Generally, the prototype system achieves a good performance and meets the objectives of the study. However, in order to make the system applicable in the domain area for diagnosis and treatment of diabetes, some adjustments like automatically updating the rules in the knowledge base of the system, incorporating a well designed user interface and a mechanism of NLP facilities are needed.

5.2 Recommendations

From the presentations of the findings of the study, the following recommendations for future study are forwarded:

- Domain experts are questioned to fill the results regarding the usability of the user interface of the system, i.e. whether it is easy to use and interact with it or not. Most of the evaluators gave lowest rating value. A wide-ranging graphical user interface must be designed like using VB.net and there should be a mechanism of NLP in order to assist end-users to put their need to the user interface in their local language and easily understand the advices offered by the system. Therefore, further research must be done to make the system easily usable by the end-users.
- Tacit knowledge about the diagnosis and treatment of diabetes is extracted from the domain experts using interviewing method in order to have detail understanding of the domain knowledge. However, it was a difficult task to extract the necessary knowledge due to the personal nature of tacit knowledge. Therefore, it is important to apply data mining techniques to extract the hidden knowledge about diabetes and more research work must be done to integrate the application of data mining techniques with knowledge-based systems.
- The rules in the knowledge base of the prototype system should be updated with the aim of learning from experience so as to update its knowledge. Therefore, additional research should be accomplished to update the rules of the system automatically.
- A method must be investigated on how to integrate the prototype system with the existing health information systems. This would lead to the development of standards applicable to all, enabling suitable information exchange and planning for additional improvement of functionality.

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APPENDICES

Appendix I

Interview Questions

The importance of this interview questions is to extract tacit knowledge from specialists in internal medicine that will support for the development of a self-learning knowledge based system for diagnosis and treatment of diabetes**.** The interviewer stores the answerers' reply using pen, paper, and voice recorder of mobile phone as well. I would like to thank for your cooperation and valuable information.

1. What is diabetes?
2. What are the risk factors of diabetes?
3. What are the complications of diabetes?
4. What are the common signs and symptoms of diabetes?
5. What are the most fundamental symptoms that you consider when making diagnosis of diabetes?
6. In diagnosis using only signs and symptoms of diabetes, can we say the new patient is diabetic or not?
7. What are the most common types of diabetes?
8. What are the laboratory testing methods used for diagnosis of diabetes? Which one is the most common laboratory testing method used for diagnosis of diabetes?
9. What is prediabetes?
10. How can we differentiate Type 1 with Type 2 diabetes during diagnosis?
11. How can we manage Type 1 diabetes?
12. How can we manage Type 2 diabetes?
13. What are the treatments recommended for Type 1 diabetic patients?
14. What are the treatments recommended for Type 2 diabetic patients?
15. What are the main challenges encountered during diagnosis of diabetes?

Appendix II

A Self-learning Knowledge Based System for Diagnosis and Treatment of Diabetes Prolog Code:

```
%This is a Self-learning Knowledge Based System for Diagnosis and Treatment of Diabetes.
%to start the diagnosis write "start" then "." and press "enter".
bloodTest(Fasting,R):-
   ((fasting(Fasting),integer(Fasting),Fasting=<99,R is 1));
   ((fasting(Fasting),integer(Fasting),Fasting>=100,Fasting=<125,R is 2));
   ((fasting(Fasting),integer(Fasting),Fasting>=126,R is 3)).
isDiabetes(Thirsty,UrinateFrequently,Hungry,WeightLoss,Fatigue,DryMouth,VisionProblem,Re
s):-
   ((thirsty(Thirsty),Thirsty=='yes', T is 20); (thirsty(Thirsty),Thirsty=='no', T is 0)),
   ((urinateFrequently(UrinateFrequently),UrinateFrequently=='yes', U is 20);
(urinateFrequently(UrinateFrequently),UrinateFrequently=='no', U is 0)),
       ((hungry(Hungry),Hungry=='yes', H is 20); (hungry(Hungry),Hungry=='no', H is 0)),
   ((weightLoss(WeightLoss),WeightLoss=='yes', W is 1);
(weightLoss(WeightLoss),WeightLoss=='no', W is 0)),
   ((fatigue(Fatigue),Fatigue=='yes', F is 1); (fatigue(Fatigue),Fatigue=='no', F is 0)),
   ((dryMouth(DryMouth),DryMouth=='yes', D is 1); (dryMouth(DryMouth),DryMouth=='no',
D is 0)),
   ((visionProblem(VisionProblem),VisionProblem=='yes', V is 1);
(visionProblem(VisionProblem),VisionProblem=='no', V is 0)),
   Res is T+U+H+W+F+D+V.
treatmentFunc(Name,Type,Answer3):-
  ((Type=='diabetic_type_1',answer(Answer3),Answer3=='yes',nl,
   write('------------------------Foods you should eat----------------------------------'),nl,nl,
   write('CARBOHYDRATE FOODS: '),write('Bread, Grain, Rice, Pasta ...'),nl,nl,write('FAT
FOODS: '),
   write('Butter, Oils, Avocado ...'),nl,nl,write('NOTE:- Carbohydrate content should be balanced
with insulin produced in your body'),nl,nl,
   write('------------------------Medications you should take------------------------'),nl,nl,
```

```
    write('APIDRA(insulin glulisine), HUMALOG(insulin pro), HUMULIN(insulin regular):- are
the most important insulin injection types'),nl,nl,
    write('------------------------Exercises----------------------------------'),nl,nl,
    write('AEROBIC EXERCISE: walking, hiking, jogging, biking, swimming ...'),nl,nl,
    write('------------------------foods to avoid or limit------------------------'),nl,
    foodsToAvoid(Name,Answer3));
   (Type=='diabetic_type_2',answer(Answer3),Answer3=='yes',nl,nl,
    write('------------------------Foods you should eat------------------------'),nl,nl,
    write('Less calorie content food, carbohydrate foods digested slowly, low-fat food, low-salt
foods, protein foods'),nl,nl,
    write('------------------------Medications you should take------------------------'),nl,nl,
    write('Sulfonylurea, meglitinides, biguanides, alpha-glucosidase inhibitors: are used for
treatment of diabetes Type 2'),nl,nl,
    write('------------------------Exercises------------------------'),nl,nl,
    write('AEROBIC EXERCISE: walking, hiking, jogging, biking, swimming ...,NOTE:-always
remember and exercise for healthy weight'),nl,nl,
    write('------------------------Foods to avoid or limit------------------------'),nl,
foodsToAvoid(Name,Answer3));(Type=='prediabetes',answer(Answer3),Answer3=='yes',nl,nl,
        write('==============RECOMMENDATION=================='),nl,nl,
        write('Prediabetes means a person is at increased risk for developing Type 2 diabetes, as
well as for'),nl,
        write('heart disease and stroke. People with prediabetes develop Type 2 diabetes within
10 years.'),nl,
        write('So, treatment consists of losing a modest amount of weight (7% of total body
weight) through healthy eating and'),nl,
        write('moderate exercise, such as walking, 30 minutes a day, five days a week. Do not
worry IF you cannot get to your'),nl,
        write('ideal body weight. Losing just 10 to 15 pounds can make a big
difference.'),nl,nl,choice(Name,5))).
yesss2(Name,Type,Answer2):-
((answer(Answer2),Answer2=='yes',nl,choice(Name,Type,2));(answer(Answer2),Answer2=='no'
,display3(Name,Type))).
```

```
yesss4(Name,Answer4):-

((answer(Answer4),Answer4=='how',nl,choice(Name,4));(answer(Answer4),Answer4=='no',choi
ce(Name,5))).
yesss5(Name,Option):-
            ((option(Option),Option=='yes',nl,write('PLEASE COME AND CHECK AGAIN,
GOOD BYE!!'),break);(option(Option),Option=='no',answer1(Name))).
%.....Diagnosis starts.....%
start:- display_welcome, introduction.
display_welcome:-
   nl,
   write('Welcome to a Self-learning Knowledge-Based System for Diagnosis and Treatment of
Diabetes'),nl,nl,
   write('        <Written by Solomon Gebremariam, December 2012 G.C>'),nl,nl,nl.
introduction:-
   ensure_loaded('D:/diabetes.pl'),nl,write('Please enter your name:
'),read(Name),answer1(Name).
answer1(Name) :-
    diabetes(Name,Type),nl,
    write(Name),((Type=='diabetic_free',write(', "LAST TIME YOUR DIAGNOSIS RESULT
WAS DIABATES FREE"'),retract(diabetes(Name,Type)),nl,display2(Name,Type));
        (Type=='prediabetes',write(', "LAST TIME YOUR DIAGNOSIS RESULT WAS PRE-
DIABETES"'),retract(diabetes(Name,Type)),nl,display2(Name,Type));
        (Type=='unknown_diabetes_type',write(', "LAST TIME YOUR DIAGNOSIS RESULT
WAS UNKNOWN DIABETES TYPE"'),nl,nl,write('Please go for further diagnosis using X-ray
or City Scan to identify your diabetes type.'),nl,nl,write('GOOD BYE!!'),nl,break);
        (Type=='diabetic_type_1',write(', "YOU ARE DIABETIC TYPE 1
PATIENT"'),nl,display3(Name,'diabetic_type_1'));
        (Type=='diabetic_type_2',write(', "YOU ARE DIABETIC TYPE 2
PATIENT"'),nl,display3(Name,'diabetic_type_2'))).
answer1(Name):-
   nl,
```

```
    write('Hello,'),write(Name),write('! The following general information is about diabetes.
'),nl,nl,
            write('Diabetes is a disease where the body cannot properly produce or use insulin.
Insulin is a hormone'),nl,
    write('that turns the foods you eat into energy. If your body cannot turn food into energy, not
only will'),nl,
    write('your cells be starved for energy, you will also build up glucose (sugar) in your blood.
This will'),nl,
    write('lead you to have high blood glucose levels. Over years, the high blood glucose level can
damage'),nl,
    write('major organs like your heart, eyes, and kidneys.'),nl,display2(Name,'aa').
display2(Name,Type):-
    nl,
    write('Do you want to make diagnosis?(yes/no): '),
    read(Answer2), assert(answer(Answer2)),
    yesss2(Name,Type,Answer2).
display3(Name,Type):-
    nl,
    write('Do you need to see treatment?(yes/no): '),
    read(Answer3), assert(answer(Answer3)),
            ((Answer3=='yes',
treatmentFunc(Name,Type,Answer3));(Answer3=='no',display4(Name))).
display4(Name):-
    nl,
    write('If you do not know how to use the system you can press(how/no): '),
    read(Answer4), assert(answer(Answer4)),
    yesss4(Name,Answer4).
foodsToAvoid(Name,Answer3):-
    (answer(Answer3),Answer3=='yes',
    nl,
    write('WHOLE GRAINS: White breads, croissants, sweet rolls, high-fat white crackers,
waffles'),nl,
```

```
   write('VEGETABLES and FRUIT: Parsnip, pumpkin, white potatoes (high GI)'),nl,
   write('MILK: Milk products higher than 1% fat Cheese higher than 21% MF and creams'),nl,
   write('MEAT and ALTERNATIVES: Hydrogenated oils, coconut and palm oils Shortening,
butter,'),nl,
   write('Lard, hard margarines No more than 1/4 cup nuts per day (high calories) Chocolate and
carob'),nl,
   write('SWEETS: Sugar and regular jams, jellies, syrups, candies, gelatins, gum,
honey.')),nl,monitorGlucoseLevel_1(Name).
monitorGlucoseLevel_1(Name):-
         nl,nl,write('Do you want to monitor glucose level in your blood using FPG
test?(yes/no):'),nl,
         read(YesNo), assert(yesNo(YesNo)),
         ((YesNo=='yes',nl,nl,
   write('LABORATORY TESTING PROCESS IS STARTED HERE ...'),nl,nl,
   write('N.B: THE PATIENT SHOULD NOT EAT FOOD FOR AT LEAST EIGHT HOURS
BEFORE TESTING.'),nl,nl,nl,
   write('Please enter the amount of glucose level in your blood (mg/dL): '),
   read(Fasting), assert(fasting(Fasting)),nl,
         ((Fasting>325,write('===================RECOMMENADTION============
==========='),nl,nl,
                  write('You have to consult your physician (doctor), if the result is greater than
325 mg/dL.'),monitorGlucoseLevel_2(Name));
          (Fasting>=183, Fasting=<325,
write('===================RECOMMENADTION======================='),nl,nl,
                  write('If the glucose level is greater than or equal to 183 and less than or equal to
325 mg/dL, then it indicates that your glucose level control was not effective.'),nl,
               write('If the glucose level is always in this range, then you are highly likely to be
affected with the complications of diabetes disease.'),monitorGlucoseLevel_2(Name));
          (Fasting>=155,
Fasting<183,write('===================RECOMMENADTION===================
====='),nl,nl,
```

```
                    write('If the glucose level is greater than or equal to 155 and less than 183
mg/dL, your control of the glucose'),nl,
              write('level is not as much. Re-examination of the glucose level is required to correct
the necessary things.'),monitorGlucoseLevel_2(Name));
          (Fasting>=126,
Fasting<155,write('==================RECOMMENADTION==================
====='),nl,nl,
                    write('If the glucose level is greater than or equal to 126 and less than 155
mg/dL, it indicates that you were previously'),nl,
              write('exercising well, had a healthy diet and taken your insulin properly. So, you
should continue on doing these.'),monitorGlucoseLevel_2(Name));
          (Fasting>=68,
Fasting<126,write('==================RECOMMENADTION==================
====='),nl,nl,
                    write('If a person is non-diabetic, then FPG test result is greater than or equal to
68 and less than 126 mg/dL. But if the person is diabetic'),nl,
              write('and the number is in this range, this indicates repeated low glucose level. This
requires consultation with your doctor to the problems.'),monitorGlucoseLevel_2(Name))));
         (YesNo=='no', monitorGlucoseLevel_2(Name))).
monitorGlucoseLevel_2(Name):-
         nl,nl,write('Do you want to monitor glucose level in your blood using hemoglobin A1C
test after 2-3 months?(yes/no):'),nl,
         read(YesNo2), assert(yesNo2(YesNo2)),nl,nl,
         ((YesNo2=='yes',
   write('LABORATORY TESTING PROCESS IS STARTED HERE ...'),nl,nl,
   write('Please enter the amount of glucose level in your blood (%): '),
   read(A1c), assert(a1c(A1c)),nl,
         ((A1c>13,write('==================RECOMMENADTION==============
========'),nl,nl,
                  write('You have to consult your physician (doctor), if the result is greater than
13%.'),nl,nl,choice(Name,5));
```

```
(A1c>=8,A1c=<13,write('==================RECOMMENADTION==============
=========='),nl,nl,
                write('If the glucose level is greater than or equal to 8 and less than or equal to
13%, then it indicates that your glucose level control was not effective.'),nl,
                write('If the glucose level is always in this range, then you are highly likely to be
affected with the complications of diabetes disease.'),nl,nl,choice(Name,5));
(A1c>=7,A1c<8,write('==================RECOMMENADTION===============
=======''),nl,nl,
                write('If the glucose level is greater than or equal to 7 and less than 8%, your
control of the glucose'),nl,
            write('level is not as much. Re-examination of the glucose level is required to correct
the necessary things.'),nl,nl,choice(Name,5));
(A1c>=6,A1c<7,write('==================RECOMMENADTION===============
=======''),nl,nl,
                write('If the glucose level is greater than or equal to 6 and less than 7%, it
indicates that you were previously'),nl,
            write('exercising well, had a healthy diet and taken your insulin properly. So, you
should continue on doing these.'),nl,nl,choice(Name,5));
(A1c>=4,A1c<6,write('==================RECOMMENADTION===============
=======''),nl,nl,
                write('If a person is non-diabetic, then hemoglobin A1C test result is greater
than or equal to 4 and less than 6%. But if the person is diabetic'),nl,
            write('and the number is in this range, this indicates repeated low glucose level. This
requires consultation with your doctor to the problems.'),nl,nl,choice(Name,5))));
        (YesNo2=='no', choice(Name,5))).
choice(Name,Type,2):-
   write('Please give (yes.) or (no.) answer to the following questions and'),nl,
   write('If the questions are unclear you can ask by entering (what.) and (why.)'),nl,nl,
   write('Do you feel excessive thirst?(yes/no/what): '),
   read(Thir),nl,
   ((Thir=='what',write('This is to mean you need to drink water frequently?(yes/no/why):
'),read(New),(New=='why',nl,
```

```
    write('Because high level thirsty is the most important symptom of diabetes. So! do you feel
excessive thirst?(yes/no): '),nl,
read(Neww),Thirsty=Neww,assert(thirsty(Thirsty));New=='yes',Thirsty=New,assert(thirsty(Thir
sty));New=='no',Thirsty=New,assert(thirsty(Thirsty))));
    (Thir=='yes', Thirsty = Thir, assert(thirsty(Thirsty)));(Thir=='no',Thirsty =
Thir,assert(thirsty(Thirsty)))),nl,
    write('Do you urinate frequently?(yes/no/what): '),
    read(Urn),nl,
    ((Urn=='what',write('This is to mean you get a pee frequently?(yes/no/why):
'),read(New),(New=='why',nl,
    write('Because frequent urination is the most important symptom of diabetes. So, do you
urinate frequently?(yes/no): '),nl,
read(Neww),UrinateFrequently=Neww,assert(urinateFrequently(UrinateFrequently));New=='yes
',UrinateFrequently=New,assert(urinateFrequently(UrinateFrequently));New=='no',UrinateFrequ
ently=New,assert(urinateFrequently(UrinateFrequently))));
    (Urn=='yes', UrinateFrequently = Urn,
assert(urinateFrequently(UrinateFrequently)));(Urn=='no',UrinateFrequently =
Urn,assert(urinateFrequently(UrinateFrequently)))),nl,
    write('Do you feel excessive hunger?(yes/no/what): '),
    read(Hung),nl,
    ((Hung=='what',write('This is to mean you need food frequently?(yes/no/why):
'),read(New),(New=='why',nl,
    write('Because high level hunger is the most important symptom of diabetes. So, do you feel
excessive hunger?(yes/no): '),nl,
read(Neww),Hungry=Neww,assert(hungry(Hungry));New=='yes',Hungry=New,assert(hungry(H
ungry));New=='no',Hungry=New,assert(hungry(Hungry))));
    (Hung=='yes', Hungry = Hung, assert(hungry(Hungry)));(Hung=='no',Hungry =
Hung,assert(hungry(Hungry)))),nl,
    write('Do you get unusual weight loss?(yes/no/what): '),
    read(Weigh),nl,
    ((Weigh=='what',write('This is to mean you are under weight?(yes/no/why):
'),read(New),(New=='why',nl,
```

```
    write('Because unusual weight loss is one of the symptom of diabetes. So, do you get unusual
weight loss?(yes/no): '),nl,
read(Neww),WeightLoss=Neww,assert(weightLoss(WeightLoss));New=='yes',WeightLoss=Ne
w,assert(weightLoss(WeightLoss));New=='no',WeightLoss=New,assert(weightLoss(WeightLoss
))));
    (Weigh=='yes', WeightLoss = Weigh,
assert(weightLoss(WeightLoss)));(Weigh=='no',WeightLoss =
Weigh,assert(weightLoss(WeightLoss)))),nl,
    write('Do you get fatigue problem?(yes/no/what): '),
    read(Fat),nl,
    ((Fat=='what',write('This is to mean you get fat or overweight?(yes/no/why):
'),read(New),(New=='why',nl,
    write('Because fatigue problem is one of the symptom of diabetes. So, do you get fatigue
problem?(yes/no): '),nl,
read(Neww),Fatigue=Neww,assert(fatigue(Fatigue));New=='yes',Fatigue=New,assert(fatigue(Fat
igue));New=='no',Fatigue=New,assert(fatigue(Fatigue))));
    (Fat=='yes', Fatigue = Fat, assert(fatigue(Fatigue)));(Fat=='no',Fatigue =
Fat,assert(fatigue(Fatigue)))),nl,
    write('Do you get dry mouth?(yes/no/what): '),
    read(Moth),nl,
    ((Moth=='what',write('This is to mean is your moth dry?(yes/no/why):
'),read(New),(New=='why',nl,
    write('Because dry mouth is one of the symptom of diabetes. So, do you get dry
mouth?(yes/no): '),nl,
read(Neww),DryMouth=Neww,assert(dryMouth(DryMouth));New=='yes',DryMouth=New,asser
t(dryMouth(DryMouth));New=='no',DryMouth=New,assert(dryMouth(DryMouth))));
    (Moth=='yes', DryMouth = Moth, assert(dryMouth(Fatigue)));(Moth=='no',DryMouth =
Moth,assert(dryMouth(DryMouth)))),nl,
    write('Do you get vision problem?(yes/no/what): '),
    read(Vis),nl,
    ((Vis=='what',write('This is to mean do you have vision problem?(yes/no/why):
'),read(New),(New=='why',nl,
```

```
    write('Because vision problem is one of the symptom of diabetes. So, do you get vision
problem?(yes/no): '),
read(Neww),VisionProblem=Neww,assert(visionProblem(VisionProblem));New=='yes',VisionP
roblem=New,assert(visionProblem(VisionProblem));New=='no',visionProblem=New,assert(visi
onProblem(VisionProblem))));
    (Vis=='yes', VisionProblem = Vis,
assert(visionProblem(VisionProblem)));(Vis=='no',VisionProblem =
Vis,assert(visionProblem(VisionProblem)))),nl,
isDiabetes(Thirsty,UrinateFrequently,Hungry,WeightLoss,Fatigue,DryMouth,VisionProblem,Re
s),
    ((Res<60, nl,write('LESS LIKELY TO HAVE DIABETES!'),nl,nl,nl);(Res>=60,
nl,write('HIGHLY LIKELY TO HAVE DIABETES!'),nl,nl)),nl,
    write('PLEASE MEASURE THE GLUCOSE LEVEL IN YOUR BLOOD USING FASTING
PLASMA GLUCOSE TEST!'),nl,nl,
    write('LABORATORY TESTING PROCESS IS STARTED HERE ...'),nl,nl,nl,
    write('N.B: THE PATIENT SHOULD NOT EAT FOOD FOR AT LEAST EIGHT HOURS
BEFORE TESTING.'),nl,nl,nl,
    write('Please enter the amount of glucose level in your blood (mg/dL): '),
    read(Fasting), assert(fasting(Fasting)),nl,
    bloodTest(Fasting,R),nl,
    ((R is 1, write('"YOU ARE DIABATES FREE"'),assertz(diabetes(Name,diabetic_free)),
        tell('D:/diabetes.pl'),write(':-
dynamic(diabetes/2).'),nl,listing(diabetes),told,nl,nl,choice(Name,5));
    (R is 2, write('"YOU HAVE PRE-DIABETES"'),assertz(diabetes(Name,prediabetes)),
        tell('D:/diabetes.pl'),write(':-
dynamic(diabetes/2).'),nl,listing(diabetes),told,nl,nl,display3(Name,'prediabetes'));
    (R is 3, ((Type=='prediabetes',nl,write('"YOU ARE DIABETIC TYPE 2
PATIENT"'),assertz(diabetes(Name,diabetic_type_2)),tell('D:/diabetes.pl'),write(':-
dynamic(diabetes/2).'),nl,listing(diabetes),told,nl,nl,display3(Name,'diabetic_type_2'));(write('"Y
OU HAVE DIABETES"'))),nl,nl,nl,
    write('Please answer the following questions to identify your diabetes type: '),nl,nl,
    write(Name),write(', enter your age: '), read(Age), assert(age(Age)),nl,
```

```
(((age(Age),integer(Age),Age=<15),nl,write('"YOU ARE DIABETIC TYPE 1
PATIENT"'),assertz(diabetes(Name,diabetic_type_1)),tell('D:/diabetes.pl'),
write(':-
dynamic(diabetes/2).'),nl,listing(diabetes),told,nl,nl,display3(Name,'diabetic_type_1'));
((age(Age),integer(Age),Age>35),nl,write('"YOU ARE DIABETIC TYPE 2
PATIENT"'),assertz(diabetes(Name,diabetic_type_2)),tell('D:/diabetes.pl'),
write(':-
dynamic(diabetes/2).'),nl,listing(diabetes),told,nl,nl,display3(Name,'diabetic_type_2'));
((age(Age),integer(Age),Age>15,Age=<35),write('Does diabetes history exist in your
family?(yes/no): '), read(Genetic), assert(genetic(Genetic)),nl,
(genetic(Genetic),Genetic=='yes'),nl,write('"YOU ARE DIABETIC TYPE 2
PATIENT"'),assertz(diabetes(Name,diabetic_type_2)),tell('D:/diabetes.pl'),
write(':-
dynamic(diabetes/2).'),nl,listing(diabetes),told,nl,nl,display3(Name,'diabetic_type_2'));
((age(Age),integer(Age),Age>15,Age=<35),write('Are you obese?(yes/no): '),
read(Obesity), assert(obesity(Obesity)),nl,
(genetic(Genetic),Genetic=='no'),(obesity(Obesity),Obesity=='yes'),nl,write('"YOU ARE
DIABETIC TYPE 2 PATIENT"'),assertz(diabetes(Name,diabetic_type_2)),tell('D:/diabetes.pl'),
write(':-
dynamic(diabetes/2).'),nl,listing(diabetes),told,nl,nl,display3(Name,'diabetic_type_2'));
((age(Age),integer(Age),Age>15,Age=<35),write('Is there any ketone and/or autoantibodies
found in your blood during testing?(yes/no): '),nl,
read(KetoneAutoantiBodies),assert(ketoneAutoantiBodies(KetoneAutoantiBodies)),nl,(genetic(
Genetic),Genetic=='no'),(obesity(Obesity),Obesity=='no'),
(ketoneAutoantiBodies(KetoneAutoantiBodies),KetoneAutoantiBodies=='yes'),nl,write('"YOU
ARE DIABETIC TYPE 1 PATIENT"'),
assertz(diabetes(Name,diabetic_type_1)),tell('D:/diabetes.pl'),write(':-
dynamic(diabetes/2).'),nl,listing(diabetes),told,nl,nl,display3(Name,'diabetic_type_1'));
((age(Age),integer(Age),Age>15,Age=<35),(genetic(Genetic),Genetic=='no'),(obesity(Obesity),
Obesity=='no'),
(ketoneAutoantiBodies(KetoneAutoantiBodies),KetoneAutoantiBodies=='no'),nl,write('"YOUR
DIABETES TYPE IS UNKNOWN"'),
```

```
        assertz(diabetes(Name,unknown_diabetes_type)),tell('D:/diabetes.pl'),write(':-
dynamic(diabetes/2).'),nl,listing(diabetes),told,nl,nl,choice(Name,5))))).
choice(Name,3):-
   write('To go to treatment information enter yes otherwise no: '),
   read(TreatmentOption), assert(treatmentOption(TreatmentOption)),nl,
   write(Name),write(', are you Type 1 or Type 2 diabetic patient?(1/2): '),
   read(Type), assert(type(Type)),
   treatmentFunc(Name,Type,TreatmentOption).
choice(Name,4):-
   nl,
   write('Type names all in lower case, followed by period.'),nl,nl,choice(Name,5).
choice(Name,5):-
   nl,write('You are loging out from the system. ARE YOU SURE?(yes/no): '),
   read(Option), assert(option(Option)),
   yesss5(Name,Option).
```

Appendix III

The importance of this evaluation form is to evaluate to what extent the prototype system is usable by the end-users in the domain area. I would like to thank for your cooperation and valuable information.

The values for all attributes in the following table are fixed as: Excellent = 5, Very good = 4, Good = 3, Fair = 2 and Poor = 1.

No.	Criteria of evaluation	Poor	Fair	Good	Very good	Excellent	Average
1.	Simplicity to use and interact with the prototype						
2.	Attractiveness of the prototype system						
3.	Efficiency in time						
4.	The accuracy of the prototype system in reaching a decision to identify the diabetes types						
5.	Including adequate knowledge about diabetes in the prototype system						
6.	The ability of the prototype system in making right conclusions and recommendations						
7.	The ability of the prototype system to remember the history of patients						
8.	Importance of the prototype system in the domain area						
		Total average					

N.B: Put ‘X’ symbol on the available place for the corresponding attribute values for each criteria of evaluation.

Declaration

I declare that the thesis is my original work and has not been presented for a degree in any other university.

Solomon Gebremariam

January 2013

This thesis has been submitted for examination with my approval as university advisor.

Million Meshesha (PhD)