2019-10

A Cloud-Based Expert System for Diabetes Treatment Using Mobile Intelligence

Worku, Yitbarek

BAHIR DAR UNIVERSITY

BAHIR DAR INSTITUTE OF TECHNOLOGY

SCHOOL OF POSTGRADUATE STUDIES

FACULTY OF COMPUTING

A CLOUD-BASED EXPERT SYSTEM FOR DIABETES TREATMENT USING MOBILE INTELLIGENCE

BY YITBAREK WORKU

BAHIR DAR, ETHIOPIA

October, 2019

A CLOUD-BASED EXPERT SYSTEM FOR DIABETES TREATMENT USING MOBILE INTELLIGENCE

Yitbarek Worku Tamir

A Thesis Submitted to the School of Graduate Studies of Bahir Dar University in Partial Fulfillment of the Requirements for Degree of Master of Science in Information Technology.

Advisor Name: Gebeyehu Belay (PhD. of Eng.) Asct Professor

BAHIR DAR, ETHIOPIA

October, 2019

DECLARATION

I, the undersigned, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the University and can also evoke penal action from the sources which have not been properly cited or acknowledged.

Name of the student Yitbarek Worku ______Signature __________

Date of submission: 10/1/2019

Place: Bahir Dar, Ethiopia

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

Advisor Name: Gebeyehu Belay (PhD. of Eng.) Asct Professor___

Advisor's Signature: ______________________________

APPROVAL

Bahir Dar Institute of Technology-Bahir Dar University

School of Research and Graduate Studies

Faculty Computing

Student: Yitbarek Wokru ________ 02/10/2019

Names and Signature of Members of the Examining Board

Approved By:

Advisor:

Gebeyehu Belay (PhD) ________ ________ 02/10/2019

Name Signature Date

External Examiner:

Adane Leta Mamuye (PhD) ________ ________ 02/10/2019

Name Signature Date

Internal Examiner:

Mekuanint Agegnehu (PhD) ________ ________ 02/10/2019

Name Signature Date

Chair Holder:

Tesfa Tegegne (PhD) ________ ________ 02/10/2019

Name Signature Date

Faculty Dean: Belete Biazn (MSc) ________ ________ 02/10/2019

Name Signature Date

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DEDICATION

I would like to dedicate my thesis work to my beloved friend Mr. Shibru Debele and my beloved families. Thank you for all you have done. God bless you!

ACKNOWLEDGMENT

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

Next my sincere gratitude to my advisor Dr. Gebeyehu for his commitment, encouragement, valuable comments, stimulating advice, and constructive suggestions who made me to pass the difficulties what I faced and finish my thesis work. What I have achieved would not have been possible without his genuine and professional guidance.

I am also grateful to give special thanks to all staff members of Aksum university referral hospital and Dangila hospital for their cooperation during the knowledge acquisition process, testing and evaluation of the prototype system.

It is my pleasure also to express my thanks to all my beloved family members for their encouragement. Lastly, my heartfelt thanks to all dear friend who help and encouragement which helped me in all the time of my stay during my study.

ABSTRACT

The study was focused on an integration of expert system, mobile intelligence, and cloud for the diagnosis of diabetes type-1, type-2, and type-3. Diabetes occurred when a range of blood sugar is above normal (Fast Plasma Glucose >=100 mg/dL). Because the pancreas does not produce enough insulin or do not use insulin properly or both.
Expert System is a program that uses knowledge base and inference engine to solve the problem in much more efficiently that are to require significant human expertise.
Cloud has offered different services for developers to develop, manage, and deploy without fee and with fee to reduce the limitation of mobile- application.
The number of people living with diabetes is increasing due to population growth, aging, addiction, urbanization, overweight, lack of physical exercise, and other complicated diseases. Moreover, these problems become worse due to the scarcity of specialists, miss diagnosis, and health facilities. Therefore, the diabetics need consistent treatment like dietary control, physical exercise and insulin management.
To develop the prototype, the knowledge was extracted with semi-structure interview, and literature review, which are selected using purposive sampling technique from Aksum University and Dangla referral hospital because of accessibility of them. Then, the acquired knowledge is modeled using decision tree, and then represents using rule-based knowledge representation techniques and reasoning through hybrid chaining inference mechanism, which concludes a type of diabetes by checking the symptoms of diabetes through android studio and firebase platforms.

In testing and evaluating the prototype system, thirties diabetics’ cases are selected to test the accuracy of the prototype system and also ensure whether system satisfies the requirements of the end-users or not. Thus, the overall total performance of the prototype system is 81.65%. The reason why the prototype doesn’t record higher performance was an integrated system encountered some challenges during user acceptance testing like portability, usability, reliability, and functionality of the system. However, to make the system applicable in the domain area additional study is needed like diagnosis a disease with the user input instead of only the knowledge base, designed for other complicated diseases, large databases in cloud and data mining techniques.

Keywords: Artificial Intelligence, Expert System, Diabetes, Rule Based Method, Cloud Computing, Google platform, Firebase.

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LIST OF ABBREVIATIONS

A1C:	-	Glycated Hemoglobin
AI	-	Artificial Intelligence
API	-	Application Programming Interface
CBR	-	Case Based Reasoning
CC	-	Cloud Computing
dL:	-	Decilite
EC2	-	Amazon Elastic Compute Cloud
ES	-	Expert System
F:	-	F-measure
FP:	-	False Positive
FPG:	-	Fasting Plasma Glucose
IaaS	-	Infrastructure-as-a-Service
IDF	-	International Diabetes Federation,
JSON	-	JavaScript Object Notation
KBS	-	Knowledge Based System
LISP:	-	List Processing
mg:	-	Milligram
MI	-	Mobile Intelligence
P:	-	Precision
PaaS	-	Platform-as-a-Service
PROLOG:	-	Programming in Logic
R:	-	Recall
SaaS	-	Software –as –a –Service
SDK	-	Software Development Kit
TP:	-	True Positive
WM	-	Working Memory
XaaS	-	Everything as-a- Services

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CHAPTER-ONE

INTRODUCTION

1.1. Background

Diabetes is a disease with disordered metabolism and inappropriate hyperglycemia due to the body does not have sufficient quantities of insulin or the cells do not use insulin properly, or both (Ibrahim M.Ahmed, 2015). A person who live with diabetes encountered a problem to generate energy from glucose, because glucose has a great role for human body by providing fuel needed for daily life. In addition to as it cannot be cured especially in the case of type-1, it also can create many complications diseases like, heart, kidney, blindness, nerve damage, leg and foot amputations, death, etc. So diabetes needs consistent follow-up, because the amount of blood glucose in our body can increase or decrease unexpectedly in a day, (Dr. Abdullah Al-Malaise Al-Ghamdi, Majda A.Wazzan, Fatimah M. Mujallid, Najwa K.Bakhsh et al., 2011) from fasting plasma glucose (FPG) normal up to 100 mg/dL. For a diabetic person, the blood glucose diagnosed when FPG levels are 126 mg/dL (Ketan D. Bodhe, 2017).

According to the International Diabetes Federation (IDF), in 2014, 387-million people worldwide suffered from diabetes, while it is estimated that by 2035 this number will growth to 592 million. The undiagnosed cases of diabetes reach up to 179 million. In 2014, 4.9-million deaths were attributed to diabetes, while the associated annual cost in health expenditure was estimated at USD 612 billion dollars, which corresponded to 11% of total spending in adults (Zarkogianni , 2018).

AI has many branches concerned with speech, vision, artificial neural system, expert system, robotics, natural language, understanding and learning, and so on. One of the goal of research in this area is focused on the development of systems which show some of the features of human intelligence (Alma, 2014). Expert System is a computer program that uses knowledge base and inference engine to solve the problem in much more efficiently that are difficult enough to solve and to require significant human expertise for their solution (Pannu, 2015). Knowledge base is a set of rules and facts which represent the domain of an application while Inference engine is a program part of the system that imposes a general control approach on how the system is working by using the rule in the knowledge base to solve a problem. It doesn't mean expert system have only the above mentioned components, it has user interface, working memory, and explanation facility are the reaming components. But the effectiveness of expert system is majorly depend upon the collection of highly accurate and precise knowledge and the way how to draws the conclusion (Anjaneyulu, 1998).

The expert`s knowledge is available when the human expert might not be and so that the knowledge can be available at all times and in many places, as necessary. Unfortunately, physician's assistance is not always available when the diabetics need it, not only this bust also experts are perishable, unpredictable, expensive, incomplete explanation and response, misunderstanding and unreliable consecutive results, and has slow processing and reproduction. To provide a service which is affordable, permanent, consistent, fast processing and quick replication, high performance, unemotional, explicitly explain the reasoning, stable and reliable diagnosis and treatment for diabetes expert system has its own solution. However, the only expert system doesn't offered comprehensive solutions for patients. So it needs other merged technologies like, mobile intelligence and cloud services to reduce the challenges (accessibility of networked computers, skill to access information from internet through computer, etc.) of the expert system.

A mobile application or "mobile app" is defined as an application that can be executed on a mobile platform. In our smart-phone, there are so many applications have been installed. Those applications have to require large memory space, high battery power, and processor in order to install, run, communicate and update. So cloud has solutions for such like challenges of mobile-based expert system.

Cloud computing technology has a great role in governmental and non-governmental organizations by providing different cloud service through different cloud models for customers with fee and without fee based on their needs and consumptions. Different basic delivery services for cloud computing are Software –as –a –Service (SaaS), Platform-as-a-Service (PaaS), Infrastructure-as-a-Service (IaaS), and Everything-as-a-Service (XaaS). As we described in figure 1.1, those cloud stacks provide different types of services, which can be managed by either service provider or user (Tata, 2012).

Software –as –a –Service (SaaS) is a capability in which the customers ready to use the provider's applications running on the cloud, this means customers purchase the ability to access and use service that is hosted in the cloud platform. Facebook, Twitter, and web-based email systems are offered by Google (Grance, 2011).

Platform-as-a-Service (PaaS) is platform that allows the creation of applications on cloud platforms, the developers ready to use platforms to host client created, deploy and manage applications by using programming languages or tools provided by service provider on the cloud infrastructure quickly and easily and without the complexity of buying and maintaining the software and infrastructure under it. Google App Engine, Firebase, are common major examples of PaaS, which provided by Google (Samir Tata , 2012).

Infrastructure-as-a-Service (IaaS) is the lowest level of the cloud services. The end users can organize and handle the systems in terms of ready to use storage, computing and/or network resources, operating systems and other fundamental computing resources where the end users can deploy and run the software. Amazon's EC2 is an example of an IaaS (K E Narayana, Sailesh Kumar, Dr.K.Jayashree et al., 2017).

Everything-as-a-Service (XaaS) is a suitable platform by providing reliability, conditional security, high availability, low maintenance level and scalability (Perakovic, 2011), because as we depicted in figure 1.1, it refers to one or a combination of cloud services,. It allows intelligence applications to be developed, deployed, scaled and repurposed as users' business grows (Accenture, 2017). XaaS proved different cloud service like SaaS, PaaS and IaaS Consequently.

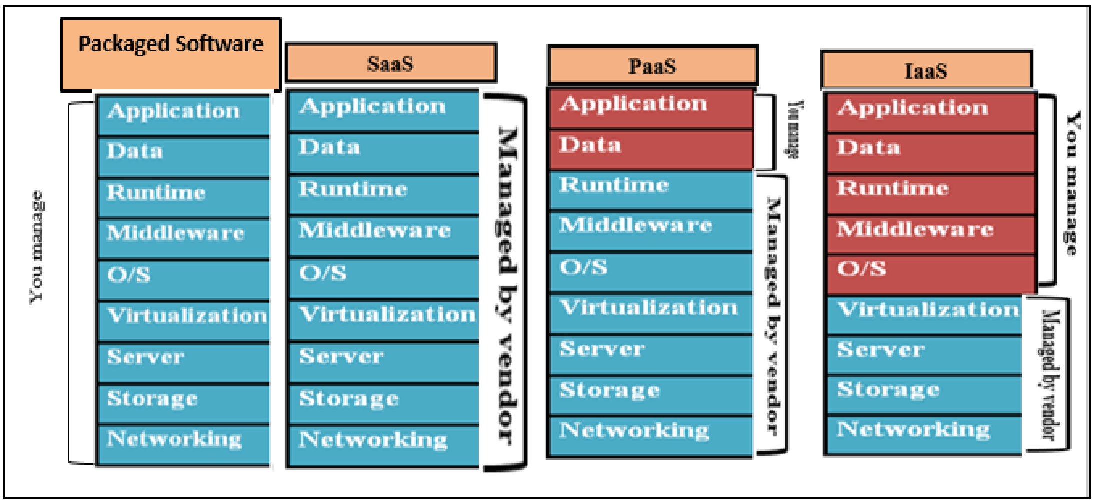


Figure 1. 1: XaaS model (M, 2011)

As we have seen and understood from the title of the research, the study is an integrated of mobile-based expert system with cloud through different tools and techniques. This means, instead of used a powerful processor and large memory space on our mobile devices, the end-users can use memory with a strong security mechanisms, and powerful processors in the clouds to run their programs, and other related services which, are offered by cloud. So, any diabetic connects to a cloud, using his/her mobile device, after username and password authentication to store his/her profile for future case as an information. Because the data stored on the cloud can easily retrieved, place in safe, and secure with best security technique adopted. Physicians will maintain the diabetic's history related data set and test results through his or her smart mobile phone and though the diabetic is at a remote location, he or she can prescribe the physician through e-mail, mobile SMS and other notification mechanisms based on the most recent felling tested through a mobile phone.

Gratefulness to the development of smart-phone and cloud technology; diabetics and physicians access and test the feelings and fast plasma glucose of patients for prober diabetes diagnosis and treatment, which depends on mobile cloud platform and tool called firebase.

In order to develop an expert system, the knowledge engineer performs the task of extracting the knowledge from two domain expert through semi-structured interview, and document analysis. The extracted knowledge has being modeled using decision tree and placed in the knowledge base in the form of rules-based knowledge representation techniques and then converted into a computer program. The hybrid inference mechanism used this information in conjunction with the rules in the knowledge base to derive additional information about the problem being addressed. The end-users supplies facts or other vital information to the expert system through the user interface. Finally, the system could determine diabetes type, make decisions and recommendations based on the diabetes type, and answers questions the user has and provides an explanation of its reasoning based on user input.

1.2. Statement of the Problem

Diabetes in nature, is a lifelong disease and cannot be treated for once and last, in other word it can't cured. So it needs day to today managements. But, in Ethiopia, there is the scarcity of specialists, inconsistent decisions and lack of health facilities. Because of this problem, diabetics are not getting enough diagnoses and treatment and other consecutive mistakes. The root cause of this problems are the number of people living with diabetes is increasing due to population growth, aging, addiction (smoking and alcohol drinking), overweight, lack or irregular of physical exercise, and other complicated diseases like blood pressure and kidney disease. Whatever without a systematic diagnosis, no correct treatment can be accomplished in diabetes. So, the prototype system has offered proper determine of diabetes type, and then proper diagnosis and treatments, constant control sugar level, which will further enable them to minimize the number of deaths which could result due to diabetes.

A study conducted by (Wild, 2004), 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.

Mostly the rural areas are lack to use networked computers and lack of skill to access information on the internet through computer. Thus, the study has being addressing those problem by providing mobile application in local language to diagnosis and treatment for all diabetes type for diabetics and physicians. Even, they could simply access information/knowledge about the way how to control the diabetes to live long life with it.

The main concerns of mobile users are storage space and processing time due to do complex calculations. This leads to reduce mobile battery life-time, this does not allow the user to run scalable application on mobile. Security also one of the biggest worries of mobile applications, which has become a very important and critical issue for different information of diabetics. In order to alleviate this problem, an integrated of expert system, mobile application, and cloud were identified as a powerful with extensive potential in domain area.

Thus, the significance of conducting this study is to support physicians by decision making to reduce misidentify and misdiagnoses rate of diabetes, and processing time, and the system also support for diabetics particularly who lives in rural area to control their blood glucose by access day to day feels. In this study, I could contributed for feature researcher in domain area is the way how to connect mobile application to cloud through firebase which, provide different features and strong security mechanisms like email, phone, twitter, etc. to prevent diabetics' profiles as an profession. The study attempts to answered and find solutions for the following research questions.

1.3. Research Questions

1. How to knowledge acquisition is done form explicit or and tacit knowledge for all diabetes type in Ethiopia?
2. How to model and represent the acquired knowledge to develop the systems?
3. How to connect the developed mobile application with cloud?
4. To what extent the cloud support authentication, uploading, downloading, and available as per the diabetics need?

1.4. Objective of the Study

1.4.1. General Objective

The genera objective of this study is design an integrated mobile-based expert system with cloud for diabetes diagnosis and treatment for physicians and diabetics.

1.4.2. Specific Objectives

The specific objectives of the study are the following:

- To review and compile literature so as to help us understand the domain knowledge.
- To extract the required knowledge from domain experts.
- To modeling and representing the acquired knowledge.
- To develop a prototype system to diagnosis and treatment for all diabetes types.
- To connect mobile-based expert system with cloud.
- To test and evaluate the performance of the prototype system by experts and diabetics.

1.5. Methodology

For the best of this thesis work and the findings, we defined the required materials, procedures, tasks, and tools that, we used throughout the research. The required data and or knowledge for this thesis would be gathered via semi-structure interview, and literature review or document analysis.

1.5.1. Literature Review

In order to understand the current state of the art in the area of mobile-based expert system on cloud for all type of diabetes treatment, different literatures that have been conducted in the field so far. For this reason, related literature such as books, articles, reports, and some other sources that are retrieved to understand the domain knowledge for developing a prototype system.

1.5.2. Data Collection Instrument

In this thesis, the knowledge was extracted from Dangla and Aksum hospitals' composed of 30 diabetic's record for performance evaluation purpose. And also semi-structure interview and document analysis were conducted to identify the existing challenges to determining diabetes, diagnosis and treatment procedures. Domain experts from Dangla and Aksum hospitals were chosen for the interview. The public hospitals were chosen because they characterized by producing the accessibility of them. Selected participants answered the interview question. Data and or knowledge gathered from experts for this research design were then confirmed with the challenges listed in the research problem. The knowledge were also different symptoms, control mechanisms and the way how to determine each type of diabetes to live a long life with diabetes.

1.5.3. Sampling and Techniques

The population of this study were defined as found in Dangla and Aksum referral hospital diabetes' experts. We have been preferred Aksum and Dangla purposively which is participants decide to preselected criteria (accessibility of hospitals and the current availability of experts) relevant to a particular research question (Owen, 2006).

The selection criteria of domain experts for the study was based on the profession, availability, and their immediate position in the diabetes diagnosis and treatment.

1.5.4. Data Sources of the Study

In research, primary and secondary data source are used.

1.5.4.1. Primary Data Sources

Semi-structured interview was used to collect primary data. The reason why we preferred semi-structure was to gain knowledge from experts in-depth on their opinions, thoughts, experiences, challenges, feelings and more reliable information about the problem being solved (Nicholson, Shawn W, 2008)

1.5.4.2. Secondary Data Sources

Document analysis is the systematic examination of instructional documents such as literature, books, lecture notes, and other written documents. So we preferred document analysis data gathering techniques from secondary data sources.

1.5.5. Prototype System Development producers

In this research, a knowledge engineer is involved throughout the knowledge acquisition. (Sajja, 2010), noted that the knowledge engineer should play a crucial role in knowledge elicitation, knowledge modeling, knowledge representation, implementation, testing and evaluation of the expert system. The major procedures in the developed prototype system were:

- Knowledge acquisition: It is the process of extracting data or and knowledge form experts. In order to develop an expert system the knowledge has to be extracted from two domain experts, who are selected based on the profession, availability, and their immediate position in the diabetes diagnosis and treatment through knowledge engineer. The knowledge engineer also acquires the explicit knowledge from relevant documents. This knowledge is then converted into a computer program.
- Knowledge modeling: It is a structured representation of knowledge using symbols to represent pieces of knowledge and the relationships between them. The acquired knowledge is modeled by using decision tree to capture the

essential features of real systems by breaking them down into more manageable parts that is easy to understand and translate to rule-based knowledge representation technique.

- Knowledge representation: In knowledge representation, the elicited knowledge was changed to a form for efficient computer manipulation. In expert system, so many knowledge representation technique are there. Rule-based, frames, and semantic network are the typical examples of knowledge representation scheme. However, we preferred rule-based, which is easy to understand and reasonably efficient in diagnosing problems of the form: IF-THEN and its ease of encapsulation of knowledge and ease of extensions to the knowledge base in the future.
- Developing the prototype system: After modeled and represent the acquired knowledge, we develop the system and connected to cloud through firebase.
- Testing and evaluation: Finally the prototype system has being tested by evaluate the performance of the prototype system and user-acceptance by experts and diabetics respectively to make sure whether the system performance is accurate or not.

1.5.6. Prototype System Development Tools

To develop the prototype system of this study, the first tool what we have been used firebase Google platform and tool was used. The reason why we preferred this platform instead of others was for the following reasons (Mehta , Bhavin M Madhani , Nishay Patwardhan, Radhika et al., 2017).

i. Forget about infrastructure, the developer doesn't have to worry about the backend of the application; it just has to provide an interactive user interface for the users of the application.

ii. Make smart, data-driven decisions, during the development of the application, the developer is supported by many of the services provided by Firebase. So the developer doesn't have to think about storage of data and use the data as requires.

iii. Free to start, scale with ease, Firebase is absolutely free to start; all its services are provided to the developer without any charges. But as the application grows there are charges involved in it.

iv. Work across platforms, Firebase is providing support for many platforms such as Web and Android.

The second tool what we has been preferred for this study was Android studio 3.2 instead of others editors and versions of android studios. Because this android studio has being supported cloud platform for developers with other consecutive features like, security, storage, cloud message, crash repots... etc. Moreover, the rule-based knowledge representation technique also easier and seemly for android to update and maintain the code.

1.5.7. Testing and Evaluation of the Prototype system

The prototype system has been testing and evaluating by system performance testing and user's acceptance testing. Thirty diabetics' cases are selected from Dangla hospital for system performance testing through domain experts. These diabetics cases are grouped into three based on the similarities of the patients cases. These are type-1, type-2, and type-3 diabetes cases. Domain experts classified those diabetic cases into the correct and incorrect results by comparing decisions made by experts with the prototype system conclusions. User's acceptance testing are also done by nine diabetics to see the quality of advice and to access to what extent the expert system satisfies the diabetics. The performance comparison parameters such as precision, recall and F-measure are used to measure the accuracy of the prototype system.

1.6. Scope and Limitation of the Study

The scope of this study is design an integrated of mobile-based expert system with a cloud system for diagnosis and treatment of all types of diabetes with convenient or local language. However, the prototype system did not provide complete translation of languages to each other for more understanding for end-users. And also the developed prototype system does not learn from experience.

1.7. The Significance of the Study

Expert systems are artificial intelligence tools functioning in a specific domain to provide advice and consultation in decision making. With the accurate utilization of knowledge, the expert systems decrease the costs of using resources (battery, processing time, additional data processing, memory, etc.), danger (miss diagnosis and hazard environments), and increase problem solving capacity in a flexible manner, the speed of data processing, permanence and multiple expertise, easily scalability and maintainability, availability, and Increased reliability. The prototype systems have an advantageous for remote and rural areas that have scarcity of medical professionals and medication facilities. In general the significance and beneficiaries of the study are:

- Health care researchers/ experts/health offices
- Non Experts in the sector
- Country's Government by reduce number of death and annuity of experts,
- Expert system professionals/ IT Researchers
- The Researcher (We)

1.8. Thesis Organization

This thesis is organized as follows. Chapter 2 presents literature review and different related works on cloud-based expert system for diabetes treatment using mobile intelligence. Chapter 3 focuses on the methodology of the proposed. Chapter 4 presents the design of cloud-based expert system for diabetes treatment using mobile intelligence. Test result where shown and discussed in Chapter 5. Finally, in Chapter 6, conclusion and future works are presented.

1.9. Definition of Terms

Backward Chaining-it also called goal-directed technique begins with possible goals and functions towards the back to find supporting facts. As described clearly in fig, an expert system finds out the answer to the question, "Why this happened?"

Forward Chaining - is a strategy of an expert system to answer the question, "What can happen next?" It is reasoning from facts to the conclusion resulting from those facts.

Inference Engine - Applies the facts to the rules and determines the questions to be asked of the user in the user interface and in which order to ask them. This is the invisible part of the expert system, which is active during a consultation of the system (when the user chooses to run the program).

Knowledge Base - Where information is stored in the expert system in the form of facts and rules (basically a series of IF statements).

User Interface - Where the user interacts with the expert system. I.e. where questions are asked and advice is produced.

Working Memory - Contains the facts received from the user via questions asked during a consolation session with the expert system.

Domain - Area of knowledge of an expert system

Knowledge Acquisition - The process of getting the knowledge from expert sources that will entered into the expert system, e.g. interviewing an expert, researching a topic.

Cloud computing –is not a service itself. It is a paradigm that has the potential to provide different cloud service models in many deployment models for all users.

Google platform- is a cloud-based environment with everything required to support the complete lifecycle of building and delivering web and mobile based (cloud) applications without the cost and complexity of buying and managing the underlying hardware, software, provisioning, and hosting.

Knowledge engineering- it refers to all technical, scientific and social aspects involved in building, maintaining and using the expert system.

Firebase - Firebase is a platform and a tool that provide set of services for building high-quality mobile applications.

CHAPTER-TWO

LITERATURE REVIEW

The literature review is a means demonstrating an authors' knowledge about a particular problem that has been identified, or needs to be answered. The review focused on the selected and published scientific articles, books, and others. In this thesis the literature, we followed different approaches to review for the purpose. The synonyms works that have been done before are discussed in details and presented as the subsequent sub-topics (Randolph, 2009).

2.1. Artificial Intelligence Disciplines

The significant success applications of AI has been reported in different disciplines including field of medicals, militaries, chemistry, engineering, manufacturing, management, and others (Tan, 2016). The term Artificial Intelligence (AI) refers to the activity of building intelligence systems. It is a technology of making computers to simulate human beings intelligence (Owaied, H. H., Malek Abu-A'ra, M. and Farhan, H. A. et al., 2010). Today, AI is used in business, science, engineering, manufacturing, and many other fields, because it has many branches concerned with speech, vision, artificial neural system, expert system, robotics, natural language, understanding and learning, and so on together to make the machines as intelligence as humans. In general, the primary goal of Artificial Intelligence (AI) is to develop systems that are capable of exhibiting some of the features of human intelligence. However, in healthcare environment the main concern of AI is the building of artificially intelligence systems that can help a physician in carrying out disease diagnosis (Pannu, 2015).

2.2. Overview of Expert System

Expert systems are sophisticated interactive computer programs which use high quality, specialized knowledge in some narrow problem domain to solve complex problems in that domain. It is a software system that contains a significant amount of knowledge in an explicit and declarative form. Expert systems have been referred to with a variety of names such as expert systems, intelligence assistants, epistemological systems and design and analysis systems. The two terms most popular in common usage, often used synonymously, are expert system and Knowledge based system. Expert system programming can be categorized based of the particular subject area and it purpose of applications, as such type of diagnosis , repair, instruction, interpretation, prediction , design and planning, simulation, reengineering, control, classification or identification and others many. Each type of expert system programming development would apply different rules, code, sequence of algorithm, interactive method between user and program etc. (Tan, 2016). Expert system emulates the behavior of human expert within a well-defined and narrow domain of knowledge (Tan C.-f. , 2008). It is a system that draws upon the knowledge of human experts captured in a knowledge base to solve problems that normally require human expertise.

2.3. Architecture of Expert system

The system architecture is a blueprint that helps to represent the structure of the system. It is a conceptual model that defines the structure and guidelines of the system. It also helps to describe the set of convections, rules, tools, and standards that should be incorporated in the corresponding systems. According to (Pannu, 2015) , the expert system has its own architecture that depicts its basic components

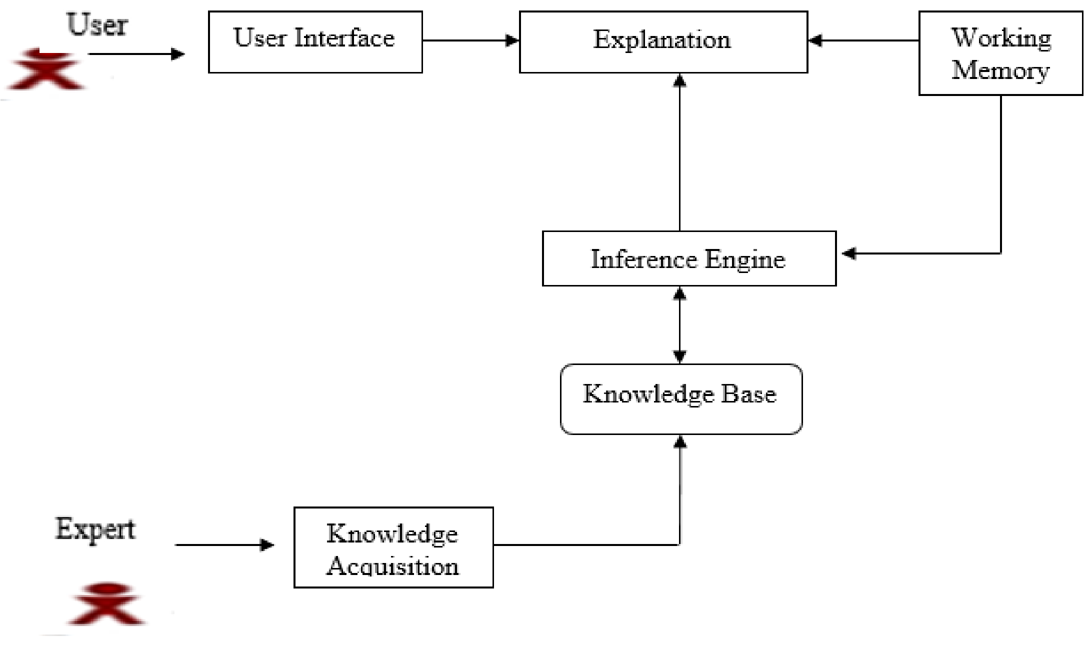


Figure 2. 1: Architecture of ES Adopted from (Pannu & Student, 2015)

Expert: is a knowledgeable and skilled person capable of solving problems in a specific area or domain. The domain expert is the most important player in the expert system development team (Abdallah, K., Mohamed T., and Louis, F et al., 2005).

Knowledge Engineer: According to Gaines and Shaw (Poole, D., Mackworth A. and Goebel, R et al., 1999), Knowledge engineers someone who is capable of designing, building and testing expert system including:

- The knowledge engineer interviews the expert to elicit his or her knowledge;
- The knowledge engineer encodes the elicited knowledge for the KB.
- Interrogates the domain expert to find out how a particular problem is solved.
- Establishes what reasoning methods the expert uses to handle facts and rules and decides how to represent them in the expert system.
- Chooses some development tools for encoding the knowledge.

2.4. Facts or and Knowledge of Diabetes

Diabetes occurs when the blood sugar levels is increase higher than normal. In other word, it is a fault in the body's ability to convert sugar or glucose to energy. Sugar provides fuel for our body. Diabetes develops when the pancreas fails to produce enough insulin or cells do not use insulin or both to control keeping blood sugar level within normal ranges. Today, the most challenging disorder across the globe is diabetes (Kumar, P S Jagadeesh et al., 2015). Most diabetics are unaware that they are in risk of diabetes, even have type-2 diabetes (Ahmed, Ibrahim M et al., 2015). So the disease is rapidly expanding. Not only that, it is an important that we monitor and control all the different types of diabetes that can cause genetic and other diseases, such heart disease, kidney disease, blindness, nerve damage, leg and foot amputations, death, and so on. As a result, it requires regular monitoring to successfully decrease the risk of complications and improve the quality of life of the patient. Because it cannot be cured, however, we can be controlled by drugs, planned diet, regular exercise and other technical methods (Ahmed, Ibrahim M et al., 2015).

2.5. Symptoms of Diabetes

Based on the discussion with domain experts during the interview, and analyzing various secondary sources like literature review and manuals. The following various general symptoms of diabetes has been elicited for the prototype development of this research work. The basic major symptoms for all types of diabetes are mentioned in in appendix II in which the symptoms which apply to a particular type of diabetes are stored with 1 and which is not applicable are stored with 0. The symptoms of diabetes which are mentioned in the table some not applicable in the case of females like Impotency (Sexual erectile dysfunction) and vice versa the symptoms which are not applicable in case of males are only considered in case of females like previous pregnancy, baby over 9 pounds during previous pregnancy, Nausea, vaginal mycosis infection, loss of menstruation, polycystic ovary syndrome, low blood sugar in the baby immediately after delivery (Anouncia, Margret et al., 2013).

2.6. Classification of Diabetes

Most cases of diabetes fall into the three broad categories of type 1, type 2, and type 3 or gestational diabetes (Patra, P Santosh Kumar et al, 2012).

2.6.1. Diabetes Type-1

In this type of type of diabetes, diabetic's body is does not capable to produce enough insulin that is needed by the body. Type-1 diabetes was previously called insulin-dependent diabetes mellitus (IDDM). Because the diabetic with type-1 diabetes are dependent on insulin to survive (Akter, 2015), Insulin controls how much glucose occur in our blood. The pancreas makes the hormone insulin. People who have type-1 diabetes can no longer make this hormone, because the cells in the pancreas that are responsible for producing insulin are destroyed. When the insulin is not enough, sugar builds up in the bloodstream instead of going into the cells where it is used for energy. Type-1 diabetes usually occurs in the children or adults but was traditionally termed "juvenile diabetes" because it represents a majority of the diabetes cases in children , although it can occur at any age, and typically in people who are lean (Akter, 2015). Based on (CDRH, 2016), type-1 diabetes may account for 5% to 10% of all diagnosed cases of diabetes. Risk factors are less well defined for type-1 diabetes than for type-2 diabetes. If, unfortunately, family member with diabetes, it affected himself not just physically but also psychologically. Genetic and environmental factors are involved in the development of this type of diabetes (Chen, Jian-xun et al., 2010).

2.6.1.1. Symptoms of Diabetes Type-1

A person who lives with this type of diabetes has been show different symptoms. Type-1 diabetes rapidly develops and can comprise symptoms like (Federation, 2018).

Table 2. 1: Major Symptom of Type-1 Diabetes

No'	Symptoms	No'	Symptoms
1	Excess thirst / Polydipsia	6	Increased fatigue
2	Frequent urination / Polyuria	7	Fruity breath odor
3	Excess hunger / Polyphagia	8	Bed wetting
4	Unusual weight loss	9	Frequent infection
5	Blurred vision	10	Slow-healing wounds

2.6.1.2. Treatment of Diabetes Type-1

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 life. The care team needs to include different experts in different domain areas like, sport advisors, psychologists, medical doctors, nutritionists, nurses, social workers and so on (Chen, 2010). This type of diabetes can be controlled by effective healthcare management and regular checking of self-blood glucose monitoring, the blood pressure, regular physical exercises, meal planning, glycemic level monitoring, strong adherence to drug regimens and daily injections (Bhandari, 2015). Failure to effectively take note and monitor the above parameters can lead to complications such as cataract, hypertension, kidney related problems, death and many more (Adeyemo, 2016).

2.6.2. Diabetes Type-2

Type-2 diabetes also called Non-Insulin-Dependent Diabetes Mellitus (NIDDM) or adult-onset diabetes. Because it occurs when the body produce a sufficient insulin, but not effectively utilized lean (Akter, 2015). Type-2 diabetes may account for about 90% to 95% of all diagnosed cases of diabetes. Risk factors for type-2 diabetes include older age, obesity, family history of diabetes, prior history of gestational diabetes, impaired glucose tolerance, physical inactivity, and race/ethnicity (Food, 2016).

According to (Federation, 2018), 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

2.6.2.1. Symptoms of Diabetes Type-2

In many cases, in type-2 diabetes symptoms usually develop much more slowly and the disease may remain undiagnosed for many years. Type-2 diabetes is often associated with a strong genetic predisposition (Akter, 2015).

Table 2. 2: Symptoms of Type-2 Diabetes

No'	Symptoms	No'	Symptoms
1	Excess thirst	7	Blurred vision
2	Frequent urination	8	Increased fatigue
3	Excess hunger	9	Frequent infection
4	Over weight	10	Slow-healing wounds
5	Family history	11	Irritability
6	Obesity	12	Weight fluctuation

2.6.2.2. Treatment of Diabetes Type-2

Mostly, it occurs in older people, specially a person who live with obesity, lack of exercise, family history of diabetes, heart diseases, and had sedentary lifestyles (Ahmed, Ibrahim M et al., 2015), so it must be treated by proper care of diet, exercise, home blood glucose testing, and oral medication (Al-ghamdi, Abdullah Al-malaise et al., 2011).

2.6.3. Diabetes Type-3

Diabetes type-3 known as gestational diabetes mellitus (GDM) is a condition in which women exhibit high blood glucose levels after the process of becoming pregnant involving fertilization or implantation or both called conception. During pregnancy usually around the 24th week many women develops gestational diabetes (Ibrahim M.Ahmed, Abeer M.Mahmoud, Mostafa Aref, Abdel-Badeeh M.Salem et al., 2017). It is developed when a pregnant woman, who have never had diabetes before, have a high blood glucose level during pregnancy (Al-ghamdi et al., 2011). Once the GDM woman becomes normal, she has increased the risk of developing GDM in later pregnancies as well as in later life. It develops in 2% to 5% of all pregnancies but usually disappears when a pregnancy is over (Akter, 2015).

2.6.3.1. Symptoms of Diabetes Type-3

This type of diabetes mostly occur a person, who is older women, those with the previous history of glucose intolerance, those with a history of large for gestational age babies, women from certain high–risk ethnic groups, and any pregnant woman who has elevated fasting, or casual, blood glucose levels.

Table 2. 3: Symptoms of Type-3

No’	Symptom	No’	Symptom
1	Over weight	3	Baby over 9 pounds during previous pregnancy
2	Previous pregnancy	4	Family history of diabetes during pregnancy

2.6.3.2. Treatment of Diabetes Type-3

To determine if gestational diabetes is present in pregnant women, a standard OGTT should be performed after overnight fasting (8–14 hours) by giving 75g anhydrous glucose in 250–300 ml water (Annex 1). Plasma glucose is measured fasting and after 2 hours (WHO, NCD/NCS/ et al., 1999). Gestational diabetes is fully treatable but requires careful medical supervision throughout the pregnancy (Patra, 2012). Treatment requires a diet plan that provides the growing baby with sufficient calories and nutrients also reasonable exercise (Al-ghamdi et al., 2011). A significant portion of this type of diabetes becomes normal after delivery. Once the GDM woman becomes normal, she has increased the risk of developing GDM in subsequent pregnancies as well as in later life (Akter, 2015).

The symptoms of diabetes are not enough to conclude that whether the patients 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.

Each type of diabetes treatment using may take different inputs from the diabetic and physician like, name, pregnancy, age, sex, marital status, BMI, fast blood glucose, systolic blood pressure, diabolic blood pressure, cholesterol, triglyceride, etc. The quality of the inputs has an impact not only on the consequences but also on the diagnostic precision.

2.6.4. Pre-Diabetes

Pre-diabetes shows a situation that happens when a person's blood glucose levels are higher than normal but not high enough for a diagnosis of type-2 diabetes. Many people destined to develop type-2 diabetes spend many years in a state of pre-diabetes (Patra, 2012).

2.7. Major Effective Factors of Diabetes

Each type of diabetes can occur in different factors are mentioned in table 2.4.

Table 2. 4: Effective factors of diabetes

High FPG test result	Low physical activity less than 3 times per week
Age	Itchy skin
Family history	Depression & stress
Obesity	Tingling sensation
Pregnancy	Hidden diabetes
Over weight	Ovarian cyst
History of vascular disease	Hyperlipidemia
Abortion	Irritability
High blood pressure	Etc.

2.7.1. High FPG in the Blood

After checking symptoms in the diabetic, the next criteria that the experts used is the laboratory test result. This criteria conclude whether the patient is diabetic or not. The experts have a thought of how much amount of glucose in the blood should exist in the diabetes, pre-diabetes, and normal person.

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 experts know the amount of glucose in the blood. This idea is shown in table 2.5 as follows

Table 2. 5: FPG Test Result

Attribute Name	Values in mg/dL	State
	99 or below	Normal
	100 to 125	Pre-diabetes
	126 or above	Diabetes

Since there are three types of diabetes, the domain expert also has other criteria to know in which type the patient may fall.

2.7.2. Factors of Age for Diabetes

Another criteria experts in diagnosing patients is age of diabetic. Domain experts first listens the general symptoms from diabetic and sends for making a laboratory test. If the lab test result indicates diabetes, the next question that they have to raise is asking age of patient. The domain expert’s concept and decision passed is summarized in table 2.6.

Table 2. 6: Diabetics’ Age Range

Attribute Name	Values	Diabetes type
	>15+ Pregnant	Gestational
	>35	Type 2
	≤15	Type 1
	>15 to 35	Type 1 or Type 2

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

2.7.3. Obesity of Patient's

The experts have a criteria of diabetic obesity level. By considering this the expert asks the patient for his/her obesity, then the expert can decide the patient has type 2 diabetes, especially for patients with age between 15 and 35 years. This criteria is shown in the table 2.7 as follows.

Table 2. 7: Criteria of obesity of diabetic

Attribute Name	Values	Age	Decision
Obesity	Exists	15 to 35	Type-2 diabetes
Obesity	doesn't exist	15 to 35	Check other symptoms

2.7.4. Family History of Diabetic's

The family history of diabetes can cause the patient to be diabetic. By considering this the expert asks the patient for his/her family history of diabetes, then the expert can decide the patient has Type-2 diabetes, especially for patients with age between 15 and 35 years. This criteria is shown in the table 2.8 as follows.

Table 2. 8: Family history of diabetic's

Attribute Name	Values	Age	Decision
Family history of diabetes	Exists	15 to 35	Type-2 diabetes
Family history of diabetes	doesn't exist	15 to 35	Check other factors of diabetes

2.7.5. Pregnancy Status of the Diabetic

This criteria is the most useful concept in order to conclude whether the patient has gestational or other diabetes type. The diabetes gender and pregnancy can be a cause the patient to be diabetic. By considering this the expert asks the status of pregnancy, and his/her family history of diabetes during pregnancy, then the expert can decide the patient has gestational. Summary of result of this concept is shown in table 2.9 as follows.

Table 2. 9: Criteria of pregnancy

Attribute Name	Values	Age	Family history of diabetes during pregnancy	Decision
Pregnancy	Exists	15 to 35	Exist	Gestational
Pregnancy	doesn't exist	15 to 35	doesn't exist	Other diabetes type

2.8. Expert System Development Tools

Most expert systems are developed using specialized software tools called shells. These shells are collection of software packages and tools to design, develop, implement, and maintain expert system. It does not contain knowledge base. For every domain knowledge, a knowledge engineer prepares knowledge base with the help of domain experts. One of the most popular shells widely used are CLIPS, E2glite, EXSYS CORVID, Prolog etc. although, expert system can be developed using like java and framework like .NET programing languages (U. Nilsson and J. Maluszynski et al., 2000).

2.9. Expert System Applications

Expert system have been applied to virtually every areas knowledge, such as agriculture, engineering, education, environment, mechanics, courts, medicines, etc... All application of expert system use the same or all components of expert system. The main difference among them is the way how to conclude or reasoning. Expert systems can be used in a number of applications. The common applications are discussed as follows (R.A. Akerkar and P.S. Sajja et al., 2010):

Configuration systems: those expert systems offer the way how to assemble exist components of the system in the right way in the right time. Specifically in domain knowledge of electronics, during the device encountered the problem in their regular functions, experts have being used this system to run with normal function it.

Advisory systems: most experts can confuse to decide something before the action is done. During the time of this situation, expert system is preferable for advising purposes. Because expert systems have the capacity explain their decisions based on the inference engine and knowledge base.

Diagnosis system: in health environment, different researchers have proposed in variety domain knowledge to determine the disease, diagnosis and to give treatment for patients in variety form by conclude subordinate problems based on observed facts.

Tutoring systems: such like expert systems provide an intelligence teaching mechanism in different format or friendly style, so that the students can access an information which, is related to a teaching modules and they can ask what, why, how, when, where, and what if type questions just as if a human was teaching in less cost.

Controlling and Monitoring: controlling is the directive of process, may need explanation, diagnosis, monitoring, planning, checking, and medications while monitoring is a consistent explanation of indicators to making a vital decisions for different purposes.

Planning: based on the knowledge domain, expert system has being planned different program of activities can be done to achieve the objectives. For example our prototype system has like diet planning, exercising planning, planning of checking blood glucose and planning of appointment to get services, and plan of medications.

Prediction: expert system has estimating what will happen in the future based on the models developed on the previous and current status. Some large organizations have being used expert system in e-commerce system for predict market space.

2.10. Cloud Computing Services

Cloud computing technology has a great role in governmental and non-governmental organizations by providing different services, like applications, platforms and infrastructures /services on demand through web browsers, scalable and elastic runtime environments, virtualization (in the form of storage, hardware, and networking), and the combination of two or more those services. Those above- mentioned cloud services are grouped into different kinds of services respectively, Software-as-a-Service(SaaS), Platform-as-a-Services(PaaS), infrastructure –as –a –Services (IaaS), and Everything-as-a-Services (XaaS). We have been selected cloud platform (Firebase) to implement this study. In cloud computing environment both user and services provider can manage some or all services layers, for instance, as we shown in figure 2.4, in SaaS layers, application, data, runtime, middleware, o/s, virtualization, storage, server, and networking from top to bottom all managed by service providers. Google and Salesforce are the common cloud services provider in this way (Tata, 2012).

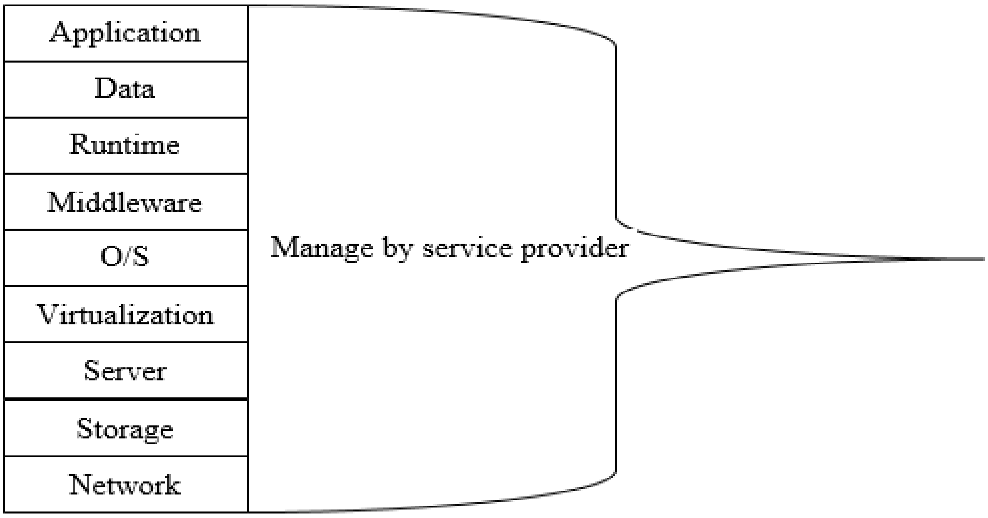


Figure 2.2: SaaS layers

As we shown in figure 2.5, the first two consecutive top layers (Application and Data) are managed by the user rather than services provider. As we mentioned earlier Google, Microsoft, Amazon Web Services (AWS), OrangeScape and Salesforce.com etc, could manage the reaming bottom layers to serve their customer without the cost and complexity of buying different resources and managing the underlying hardware and software layers with fee, if the services they used is not more than allowed quota.In another speech, the above mentioned different services providers could provide PaaS in different manner and purpose (Tata, 2012).

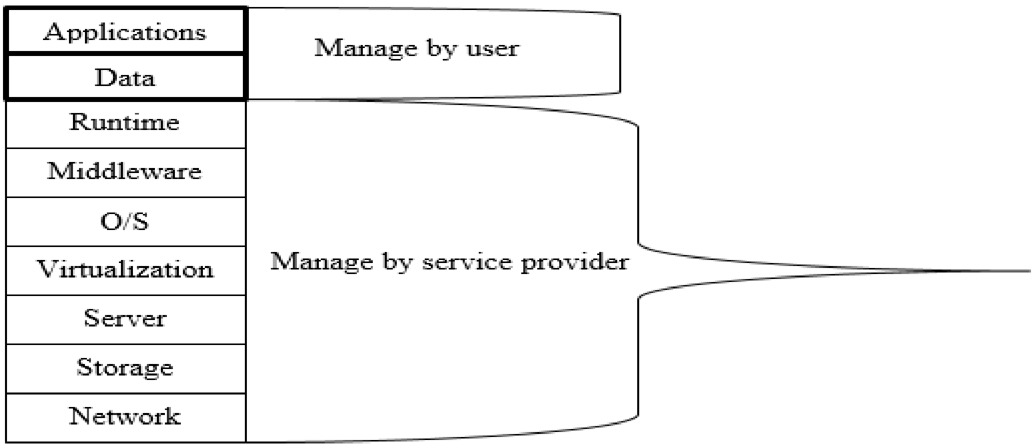


Figure 2.3: PaaS layers

One of the distribution models of the cloud computing is Infrastructure as a Service. This is the base layer of the cloud stack that serves as a foundation for the other two layers, for their execution. As we described in figure 2.6, this stack delivers infrastructure on demand in the form of virtual hardware, storage, and networking through a service provider. The reaming services are managed by the user.

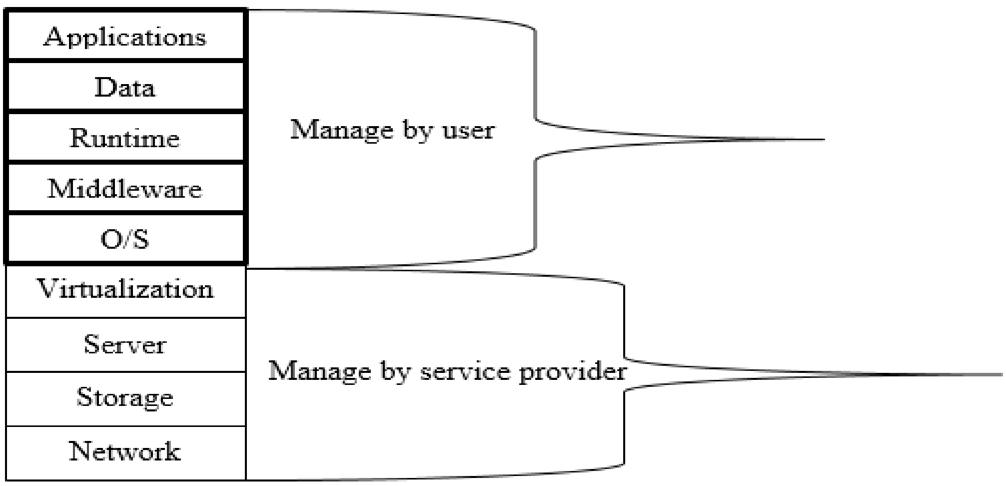


Figure 2.4: IaaS layers

2.11. Cloud Computing Model

Cloud services can be categorized into different deployment models depending on the dedicated audience, service limits, or clouding approach. There are four types of cloud models are introduced: the public, private, hybrid, and community cloud (Kavitha, 2014).

In the public cloud model, The cloud infrastructure is provisioned for open use by the general public or a large industry group over the internet on a commercial basis by a cloud service provider and are owned by a third party organization that offers the cloud service. The services can be free or charged per use. Consumers use the service without having to set up, host, manage, back up or update the software, hardware and data center. Public cloud providers manage the infrastructure and pool resources into the capacity required by its users. Google, Amazon, and Microsoft are examples of public cloud vendors who offer their services to the general public. Data created and submitted by consumers are usually stored on the servers of the third-party vendor. Another issue with public cloud is that you may not know where your data is stored or how it is backed up and whether unauthorized users can get access to it. Reliability is another concern for public cloud networks (Al-roomi, May et al, 2013).

In the private model, the cloud infrastructure is made available for a specific organization, anyone within the organization can access the data, services and web applications but users outside the organizations cannot access the cloud (Al-roomi, May et al, 2013). The cloud infrastructure is operated solely for an organization and accessed only by the members of the organization and/or by granted third parties. The purpose is not to offer cloud services to the general public, but to use it within the organization. It has the potential to give the organization greater control over the infrastructure. The only big advantage that private cloud has over the public cloud is that of data security and privacy. The major drawback of a private cloud is its higher cost (Goyal, 2014).

In the hybrid cloud, The infrastructure consists of a number of clouds of any type or a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability cloud (Kavitha, 2014). A hybrid cloud is a composition of at least one private cloud and at least one public cloud. It is typically offered in one of two ways: a vendor has a private cloud and forms a partnership with a public cloud provider, or a public cloud provider forms a partnership with a vendor that provides private cloud platforms. It allows for scalability and cost-effectiveness of public clouds, while also offering the security and control of private clouds (Goyal, 2014).

In a community cloud, the cloud infrastructure is shared by multiple organizations from a certain community with similar objectives and requirements (e.g., mission, security requirements, policy, and agreement considerations) (Al-roomi, May et al, 2013). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises. It is somewhat similar to a private cloud, but the infrastructure and computational resources are exclusive to two or more organizations that have common privacy, security, and regulatory considerations, rather than a single organization (Goyal, 2014).

2.12. Firebase Features

Firebase is a platform and a tool that is encompasses the set of services for building mobile applications that are real-time with a highly simpler platform easily which permits developers to build high-quality applications (Srivastava, Neha et al., 2017). Firebase by itself it not service, it is a cloud service supplier and backend as a service .A special platform is provided by firebase for building mobile and web application. It can build the application and update it in real time. Firebase is very easy and it stores data in JSON format. We do not need to configure our server when we use firebase. Everything will be handled by firebase automatically. So server side coding is not required. It will save time and will make us more productive. Obviously, both server-side code and client-side code is required for building a web application. It requires a backend that handles a database to store the records, authentication to authenticate the identity of the user accessing it (Srivastava, Neha et al., 2017).

Storage: - Database in firebase is a cloud-based database and does not need SQL-based queries to store and fetch data. Database system is cloud-stored and encoded as JSON objects. The database can be seen as a tree where each information is stored as a node coded in JSON with an associated key. Data should be stored in Key/Value structure so, define your application state into Key/Value. In a Firebase database, A node is added to the existing structure when a new data is added into the database. Files can be uploaded and downloaded in a secure manner without being affected by network quality (Srivastava, Neha et al., 2017).

Hosting: -Firebase is also used for hosting purposes and delivers web content very fast and the content is always delivered securely .A firebase database cannot be hosted locally and has to be hosted on Firebase servers. But it is possible to test it locally via the Firebase Database Manager called Firebase Command Line Interface. This interface allows to managing, test and deploy a database (Srivastava, Neha et al., 2017).

Authentication: Firebase provides login through Gmail, GitHub, Twitter, Facebook and also let the developer create custom authentication (Mehta , Bhavin M Madhani , Nishay Patwardhan, Radhika et al., 2017). In order to securely store a user data and personalized the user page, we need to know the identity of the user to meet this need, Firebase has its own backend services for the allow authentication. The authentication can be based on a password, phone numbers or federated identity (Google, Facebook, Twitter) (Nicolas, 2018).

Notifications: - This feature lets you create attractive push notifications. You can send to particular users or to all the users. Fast and Easy to create and send a notification (Mehta , Bhavin M Madhani , Nishay Patwardhan, Radhika et al., 2017).

Cloud messaging: Firebase cloud messaging allows let you to deliver messages to a different platform at no cost. Messaging is also used for notifications purposes (Nicolas, 2018).

Crash reporting: This feature is used to prepare a report of all the app crashes and errors in the application (Srivastava, Neha et al., 2017).

Remote config: This feature is very helpful for your application to test your application before applying any updates to it. You can test a user’s behavior by inspecting its use with your application (Mehta , Bhavin M Madhani , Nishay Patwardhan, Radhika et al., 2017). This feature allows updating the user application without the need of deploying the current updated app (Srivastava, Neha et al., 2017).

2.13. Application of Firebase

Forget about infrastructure: the developer doesn’t have to worry about the backend of the application; it just has to provide an interactive user interface for the users of the application.

Make smart, data-driven decisions: The developer is supported by many of the services provided by Firebase. So the developer doesn't have to think about storage of data and use the data as requires.

Free to start, scale with ease: Firebase is absolutely free to start; all its services are provided to the developer without any charges.

Work across platforms: Firebase is providing support for many platforms such as Web, Android and IOS (Mehta , Bhavin M Madhani , Nishay Patwardhan, Radhika et al., 2017).

2.14. Application of Cloud Computing

Cloud computing technology has to provide different services through different services providers like Google, Microsoft, Amazon, etc. on subscription-basis (George, 2014). In a large collection of servers in distributed data centers, cloud Computing services include Google Docs, Office 365, DropBox, Skydive, Google drive, E-mail, Facebook, and other communication applications. Inputs of cloud computing have decreased the limitation of different intelligence systems in the different domain. The combination of the cloud computing and mobile intelligence technology has simplified the way how to implement a specific task.

2.15. Related Works

(Al-ghamdi, Abdullah Al-malaise et al., 2011), They introduced a cloud-based expert system for diabetes treatment using Google app engine. The system is an open source software, also researchers and developers can add to it. It is web-based flexible, easy to use, and guarantees the security with email notification. However, our system requires a different security mechanism like,email, phone, Facebook, twitter, and crash reporting notification and other futures from physicians and cloud.

The inputs was personal information about the diabetics like diabetes type, age, weight, and sex, three blood glucose tests breakfast, lunch, and dinner. There is also another input which is A1C test. A1C test measured for people with diabetes to provide an index of average blood glucose for the previous three to four months. It tells what percentage of the hemoglobin has glucose sticking to it. The normal level of A1C in the people without diabetes is approximately 4% to 6%. There were a few limitations existing. Results out of a 100 total evaluation data differ from Doctor's diagnosed results, resulting in about 96% accuracy. It is found that the proposed algorithm predicts the diagnosis strength that outperforms the efficiency of expert system with the knowledge base. The few limitations of concern included that the symptoms accommodated for the disease were based only on the diabetics' and physicians' inputs. Their system has been tested through entering blood glucose by 15 diabetics with different type of diabetes and by the help of two physicians.

(Akter, 2015), the study was designed and developed an android-based diabetes management system android application for diagnosis and treatment of all diabetes types based on patient data where patient data can be demographic or clinical. Demographic data is related to the information such as patient's age, sex, location, income, etc. Clinical data is may be physical signs and laboratory results. Physical signs are those detected by a physical examination of patient, like BMI (body-mass index), pulse rate and blood pressure. Laboratory results are those detected via laboratory tests, like blood test, urine test, etc. The diagnosis of the system is based on the patient data. The system is done through Eclipse programming language by rule-based approach, which acquired from medical doctors on the basis of patient data. The system have been tested system using 10 brands of mobile devices by 50 users and found satisfactory results. A questionnaire was provided to the users about the systems comfortability, usefulness, effectiveness compared to the systems describe in the references. The performance of the system was shown in 84, 10, 6, and 0 % and excellent, good, average, and poor respectively. However, the proposed system has encounter some challenges like, diabetic's record history availability, security, life of mobile battery, working memory capacity and processing capacity of the diagnosis. Therefore our system will be reducing the limitation of such like challenges.

(Gebremariam, 2013), the study was attempts to design and developed a prototype self-learning knowledge-based system that could provide advice for physicians and diabetics to simplify the diagnosis and treatment of type-1, and type-2 diabetes. To implement the study, the knowledge was acquired using both structured and unstructured interviews from experts, and then, the acquired knowledge is modeled using decision tree and production rules were used to represent the domain knowledge and expert system was developed using SWI Prolog editor tool. It was used backward chaining which begins with possible solutions or goals and tries to gather information that verifies the solution. Furthermore, in testing and evaluating the prototype system

18 diabetics' history were selected to test the accuracy of the prototype system .Thus, the overall total performance of the prototype system was 84.2%. However, he mentioned some limitations like, the end-users need to the user interface in their local language and easily understand the advices offered by the system and also the study has been made to design and develop a prototype that can provide advice for physicians and patients to facilitate the diagnosis and treatment of patients living with type 1and type 2 diabetes. Therefore, further research must be done to make the system easily usable by the end-users and facilitate the diagnosis and treatment for all type of diabetes

(Ystems, 2013), they proposed to provide a model for integrating cloud computing with mobile intelligence technology to provide mobile intelligence tutoring systems on cloud. The architecture they used was based on multi-layer architecture of mobile Cloud Computing. In systems implemented with the proposed model, the relationship between quality of service (QoS) and quality of experience (QoE) as a benchmark for measuring the performance of cloud-based systems was required. It has valuable advantages as follows. The proposed system allows the users to enjoy an intelligence learning every-time and every-where, increased the life of mobile device battery, It raised working memory capacity and processing capacity of the educational system moreover to the greater benefit of the educational system, reduces training costs and hardware dependency, and increases consistency, efficiency, and data reliability.

In (Kumar, P S Jagadeesh et al., 2015), a detailed survey been conducted on analysis and diagnosis of cloud computing based healthcare for diabetes. It is so interesting that cloud computing though an emerging technology; found the core of healthcare monitoring and management of all diseases and diabetes as such. Diabetes lays the foundation for various malfunctioning of the important organs including kidney, heart, brain, liver, etc. and periodical analysis of them is very essential. The annual health report of various organs and periodical blood glucose level report of the diabetic patient should make available with the doctor through cloud. Though the earlier medication of diabetes was based on paper and pen, pictorial evaluation of the patient healthcare was not possible and with cloud computing the doctors can make the pictorial analysis. By storing the diabetes patient's medication history in cloud, analysis and diagnosis of his timely health care can be made available to the doctor 24x7 hours either through his mobile, IPad, Laptop or Desktop in remote areas. In-accordance with security issue, more rigorous research is supposed to be conducted in-order to make in an efficient cloud computing based healthcare for analysis and diagnosis of diabetes.

In (Zarkogianni, Konstantia et al., 2018), they proposed an integration of data originating from sensor-based systems and e-health records combined with smart data analytics methods and powerful user centered approaches enable the shift toward preventive, predictive, personalized, and participatory diabetes care. They used a critical literature review analysis is conducted focusing on advances in: 1) sensors for physiological and lifestyle monitoring, 2) models and molecular biomarkers for predicting the onset and assessing the progress of diabetes, and 3) modeling and control methods for regulating glucose levels. Glucose and lifestyle sensing technologies are continuously evolving with current research focusing on the development of noninvasive sensors for accurate glucose monitoring. A wide range of modeling, classification, clustering, and control approaches have been deployed for the development of the clinical decision support systems (CDSS) for diabetes management. Sophisticated multiscale, multilevel modeling frameworks taking into account information from behavioral down to molecular level are necessary to reveal correlations and patterns indicating the onset and evolution of diabetes.

(George, 2014), the study was about cloud-based diabetes management to utilize the cloud power in diabetes treatment and research. He then introduced a new concept of Blue Circled Cloud, which is meant for centralized management of diabetes via cloud. It is web based, flexible and easy to use the centralized diabetes management facilities as different hospitals and clinics have their own Hospital Information Systems (HIS) for the treatment and interaction or sharing of critical patient information among these isolated HISs are limited or even null. A centralized data center is the key to BCC, which needs to be highly secure and state of the art, to serve all kinds of users in an optimum manner as per the roles and privileges.

CHAPTER-THREE

KNOWLEDGE ACQUISITION, MODELING AND REPRESENTATION

3.1. Architecture of the Prototype System

As we shown in figure 3.1, the system architecture of a cloud-based expert system for diabetes treatment using mobile intelligence, which is a conceptual model that defines the structure and guidelines of the system.

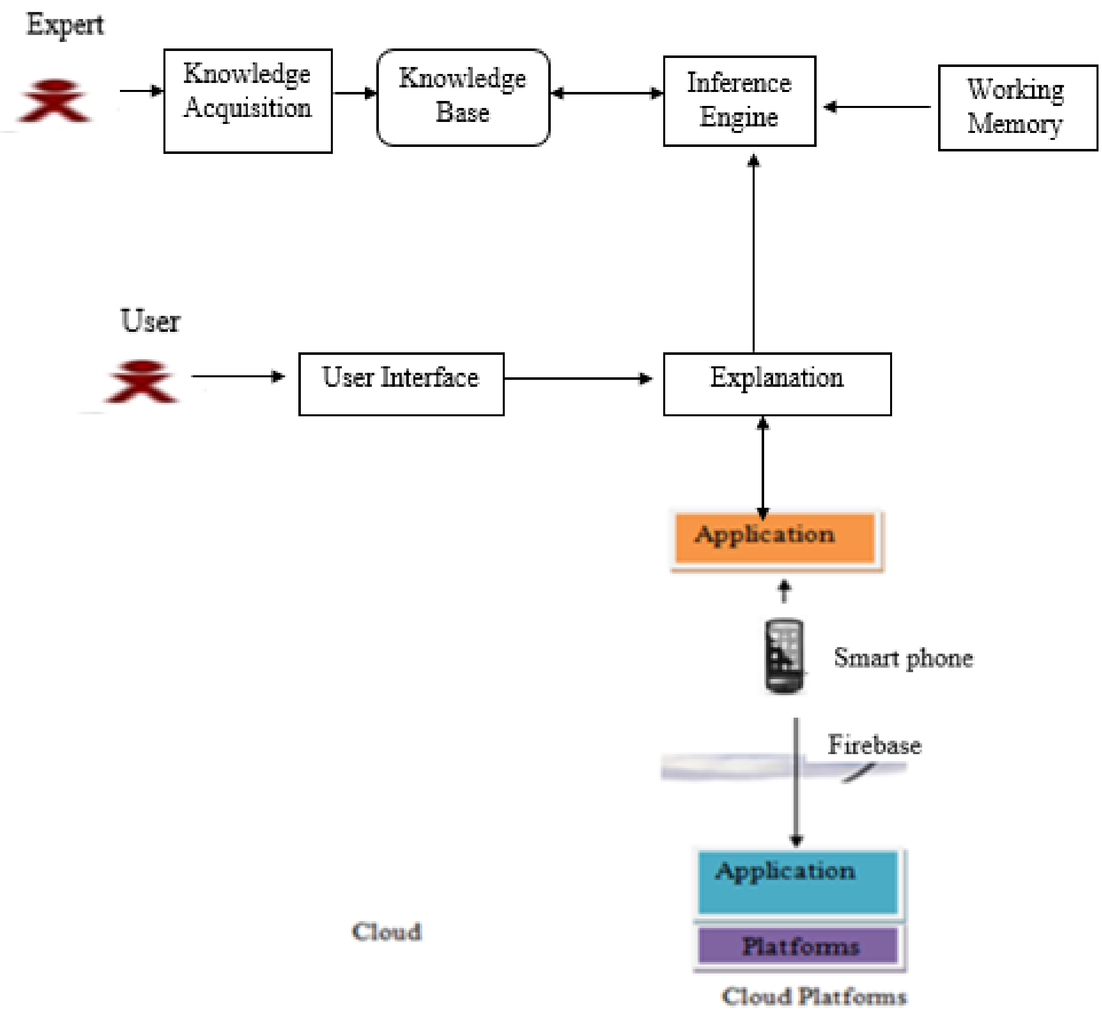


Figure 3. 1: Architecture of the prototype system

3.2. Knowledge Acquisition in Expert System Development

The first task in the development of the expert system is knowledge acquisition. It is the extraction of an appropriate domain knowledge from two Aksum and Dangla referral hospital experts, medical books, and Medias and so on. According to (Gebremariam, 2013), there are two types of knowledge sources. These are undocumented (tacit) knowledge and documented (explicit) knowledge. Tacit knowledge is commonly gain in human mind and organizations through experience while explicit knowledge is relatively extract in the form of books, tables, diagrams, and other sources are the essential aspects in the expert system development process (A. Anand and M.D. Singh et al., 2011). In fact, the knowledge engineer performed different activities during the whole expert system development process.

3.2.1. The Process of Knowledge Acquisition

To acquire tacit and explicit knowledge from experts and documented files respectively, we have used semi-structured interviews, and document analysis or literature reviews as they orders. Mostly, the process of knowledge acquisition can be classified into manual and computer-based. Computer can support to acquire knowledge using semi-automatic or fully-automatic means (Saiyd, 2010).

3.2.1.1. Manual Knowledge Acquisition Methods

The manual knowledge acquisition methods contain, semi-structured and document analysis.

Semi-structured interviews used a topic guide that serves as a checklist to ensure that all interviewees provide information on the same topics interview. The list of predetermined nine interview questions which were used as guide during interview represent in detail appendix I. The reason why we preferred this type of interviews was to gain knowledge from individuals in-depth on people's opinions, thoughts, experiences, challenges, feelings and more reliable, accurate, real-time information about the problem being solved.

Document analysis: is a systematic examination of documents such as literatures, lecture notes, and manuals in order to identify and describe an instructional needs, activities and challenges. In this technique, the knowledge engineer majorly focused on the previous research on the same domain knowledge.

3.2.1.2. Computer-Based Knowledge Acquisition Methods

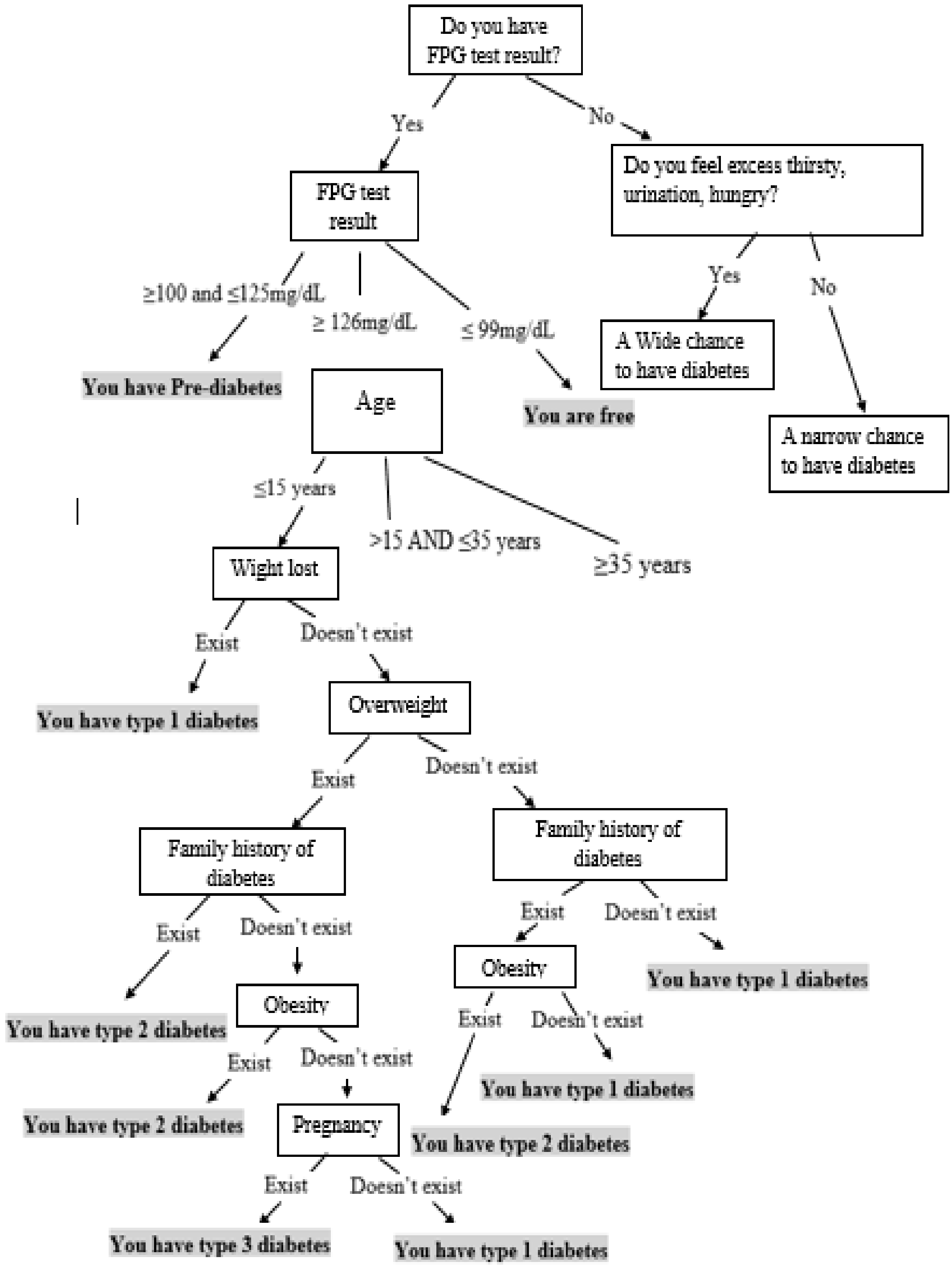
To get tacit knowledge from domain experts, the knowledge engineer can use computer-based tools to simplify the knowledge acquisition process and to identify the domain knowledge of the problem being solved.

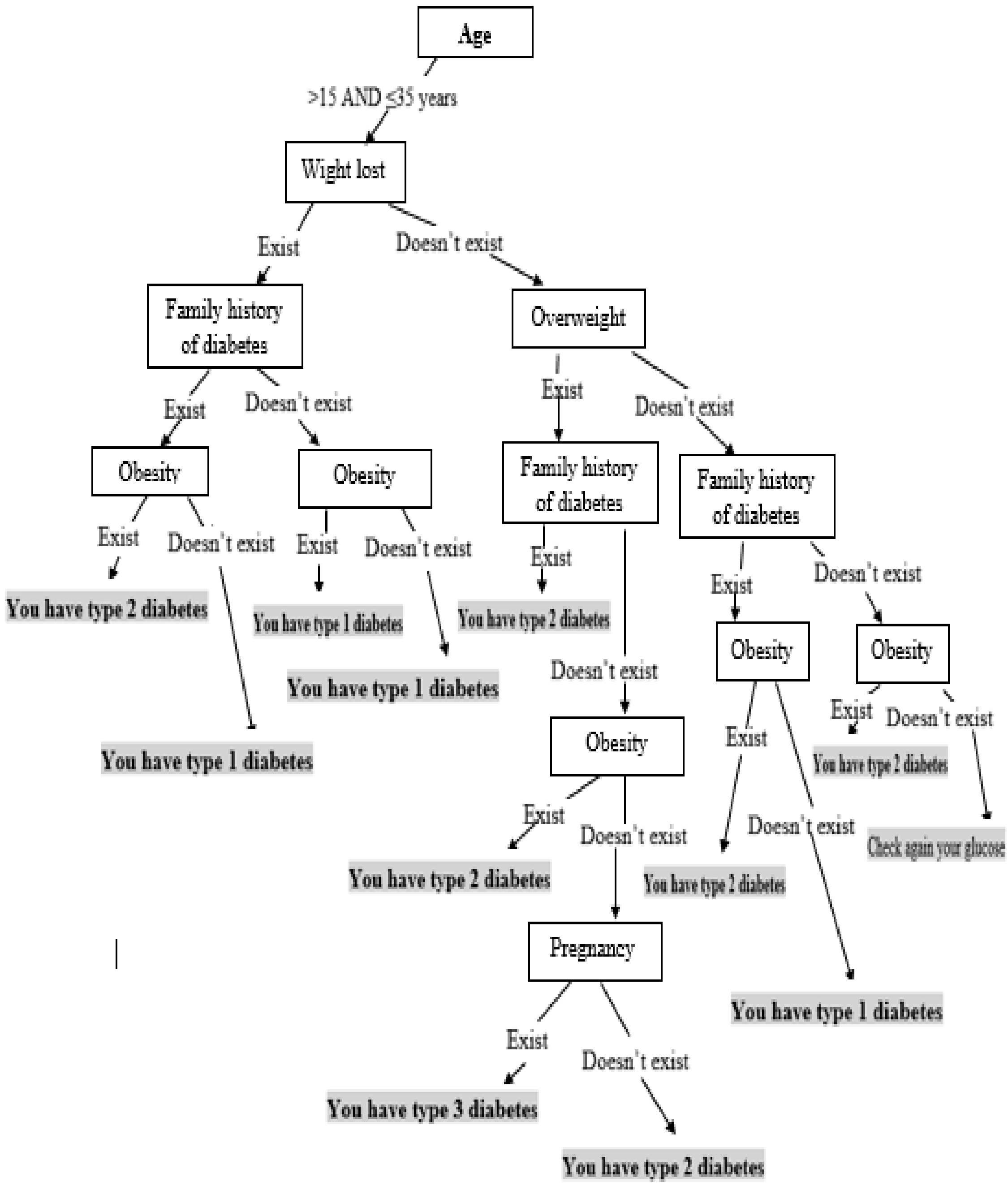
3.3. Knowledge Modeling in Expert System

Knowledge modeling is a structured representation of knowledge using symbols to represent pieces of knowledge and the relationships between them. According to (Gebremariam, 2013), the modeling process encompass conceptual models that helps to clarify the structure of a knowledge intensive business tasks. The knowledge model of an application provides a specification of the data or and knowledge structures required for the application. This helps us to implement inference from the knowledge model through. We preferred a decision trees to model the domain knowledge to find a solution for a certain problem domain decision that is easy to understand and translate to rule-based knowledge representation technique.

3.4. Decision Tree of the Prototype System

The required knowledge was extracted from domain experts and relevant documents analysis was made for building the decision tree model of criteria in the diagnosis and treatment of all diabetes type. So, the symptoms of diseases associated with the types of diabetes causing for the symptoms/ disorders are modeled using decision tree. This is used for building the expert system that can provide advice for diabetics. As we shown in figure 3.2, the decision tree structure shows the flow of knowledge in the diagnosis and treatment of diabetes. First it checks the existence of the FPG test result of the diabetes to decide whether the patent is normal or pre-diabetes. However, the system has being considered age, weight, family history of diabetes, obesity, and pregnancy in addition to FPG testing done to decide whether the patient has type-1, type-2 or type-3.


Do you have FPG test result?
Yes
No
FPG test result
≥100 and ≤125mg/dL
≥ 126mg/dL
≤ 99mg/dL
You have Pre-diabetes
You are free
Do you feel excess thirsty, urination, hungry?
Yes
No
A Wide chance to have diabetes
A narrow chance to have diabetes
Age
≤15 years
>15 AND ≤35 years
≥35 years
Wight lost
Exist
Doesn't exist
You have type 1 diabetes
Overweight
Exist
Doesn't exist
Family history of diabetes
Exist
Doesn't exist
You have type 2 diabetes
Obesity
Exist
Doesn't exist
You have type 2 diabetes
Pregnancy
Exist
Doesn't exist
You have type 3 diabetes
You have type 1 diabetes
Family history of diabetes
Exist
Doesn't exist
You have type 1 diabetes
Obesity
Exist
Doesn't exist
You have type 1 diabetes
You have type 2 diabetes


Age
>15 AND ≤35 years
Wight lost
Exist
Doesn't exist
Family history of diabetes
Overweight
Exist
Doesn't exist
Exist
Doesn't exist
Obesity
Obesity
Family history of diabetes
Family history of diabetes
Exist
Doesn't exist
Exist
Doesn't exist
Exist
Exist
Doesn't exist
You have type 2 diabetes
You have type 1 diabetes
You have type 2 diabetes
You have type 1 diabetes
Doesn't exist
Obesity
Obesity
You have type 1 diabetes
Obesity
Exist
Doesn't exist
Exist
Doesn't exist
You have type 2 diabetes
Exist
Doesn't exist
Doesn't exist
You have type 2 diabetes
Check again your glucose
You have type 2 diabetes
Pregnancy
You have type 1 diabetes
Exist
Doesn't exist
You have type 3 diabetes
You have type 2 diabetes

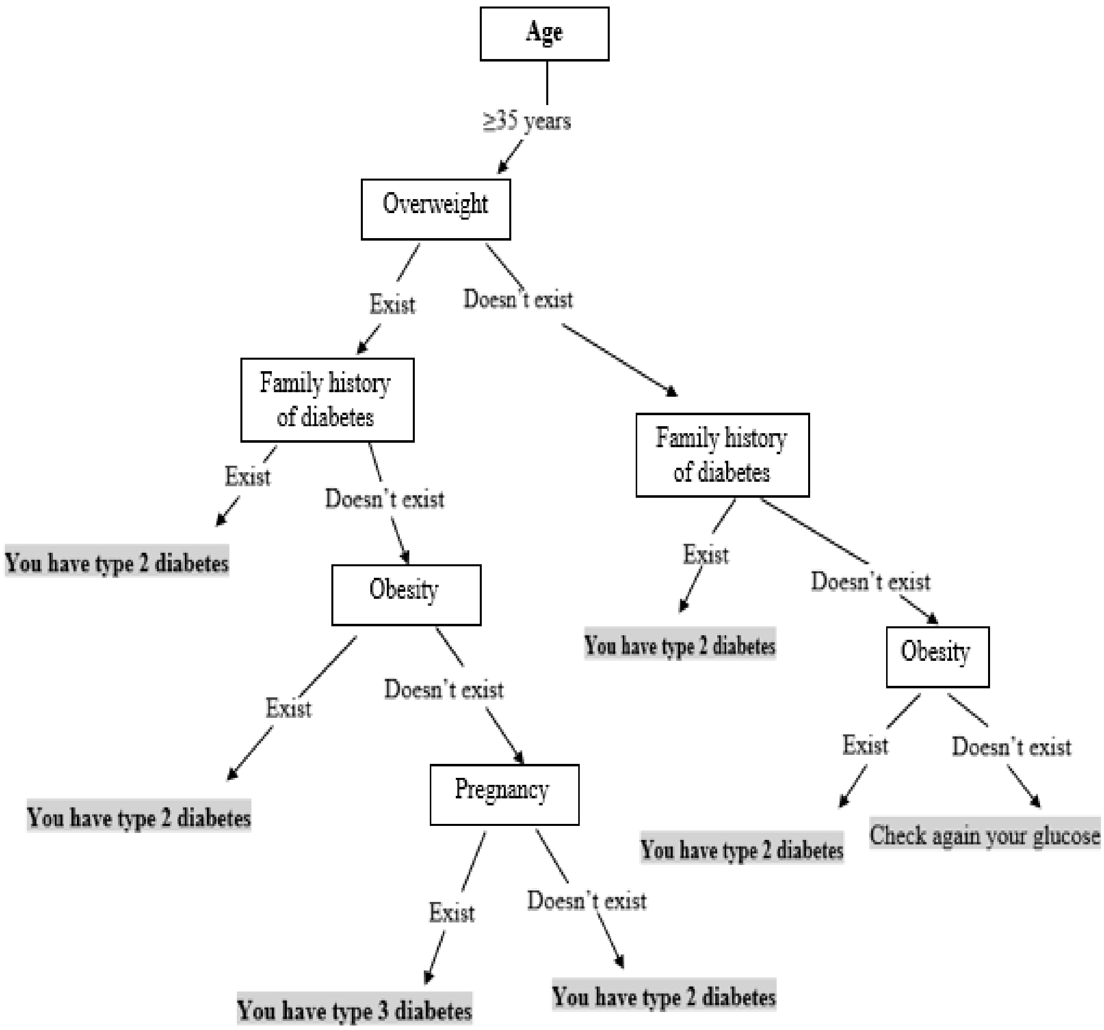


Figure 3. 2: Decision trees for diagnosis and treatment of diabetes

3.5. Knowledge Representation

Knowledge representation is an output of knowledge model produced as an output of knowledge acquisition. The acquired knowledge should be instantly documented in a knowledge representation scheme using appropriate form for efficient computer manipulation. Rule-base, cased-based, logic, semantic networks, frames, and ontologies are majorly used for knowledge representation techniques in the development of expert systems. However, the preferred knowledge representation technique in this study was rule-based i.e. the extracted knowledge was could represent in IF-THEN formats where satisfying the conditions of the IF clause allows the inference of conclusions in the THEN clause. The reasons for we preferred rule-based for this study is contain simple syntax that is flexible and easy for expert and knowledge engineer to understand, evaluate, implement, and maintain and is efficiently reasonable in diagnosing problems of the form IF-THEN.

3.5.1. Rule-Based Representation

IF (conditions), THEN (conclusion).

When the condition is true, the THEN part of a rule is concluded as a new collection of facts. The following rules in the knowledge base of the prototype are illustrated with rule-based knowledge representation technique. The remaining set of rules are explained and represent in detail appendix IV.

Rule 1:

IF FPG = "haven't test result",

AND excess thirsty, urination, hungry = "exist",

THEN patient has = "a wide chance to be a diabetes"

Rule 2:

IF FPG = "haven't test result",

AND excess thirsty, urination, hungry = "doesn't exist",

THEN patient has = "a bit chance to be a diabetes"

Rule 3:

IF FPG = "have test result",

AND FPG= "≤99 mg/dL",

THEN patient is = "You Are Free from Diabetes"

Rule 4:

IF FPG = "have test result",

AND FPG = "≥100 AND ≤125 mg/dL",

THEN diabetes type = "You Are ongoing to Pre-diabetes"

Rule 5:

IF FPG = “have test result”,

AND lab FPG = “≥126 mg/dL”,

AND age = “≤15 years”,

AND weight lost=”exist”,

THEN diabetes type = “You Have Type-1 Diabetes”

Rule 6:

IF FPG = “have test result”,

AND lab FPG = “≥126 mg/dL”,

AND age = “≤15 years”,

AND weight lost=”doesn’t exist”,

AND overweight =”exist”,

Family history=”exist”,

THEN diabetes type = “You Have Type-2 Diabetes”

Rule 7:

IF FPG = “have test result”,

AND lab FPG = “≥126 mg/dL”,

AND age = “≤15 years”,

AND weight lost=”doesn’t exist”,

AND overweight =”exist”,

AND Family history=”doesn’t exist”,

AND obesity =”exist”,

THEN diabetes type = “You Have Type-2 Diabetes”

3.5.2. Case-Based Representation

Case-based reasoning (CBR) is used to solve problems by remembering a previous similar situation and by reusing information and knowledge of that situation. It consists of two steps find those cases in memory that solved problems similar to the current problem, and adapt previous solutions to fit the current problem. The critical step is to find and retrieve a relevant case from the case library. Cases are stored using indexes. The stored case contains a solution, which is then adapted by modifying the parameters of the old problem to suit the new situation resulting in a proposed solution (Anjaneyulu, 1998).

3.5.3. Semantic Networks Representation

Semantic networks- focus on the relationships between different concepts. They are graphical depictions of knowledge composed of nodes and links that show hierarchical relationships between objects (Alty, 1989). It is made up of a number of circles, or nodes, that represent objects and descriptive information about the objects. In this way, detailed information about objects can be presented. Nodes are interconnected by links, or arcs, that show the relationships between the various objects and descriptive factors. Some of the most common arcs are of the IS-A or HAS-A type. IS-A is used to show a class relationship.

3.5.4. Frame-Based Representation

Frames-If we need to focus on the properties of certain objects, then using frames and objects is a good choice. A frame is a data structure that includes all the knowledge about a particular object. In contrast to other representation methods, with frames, the values that describe one object are grouped together into a single unit called a frame. Thus, a frame encompasses complex objects, entire situations, or a managerial problem as a single entity. The knowledge in a frame is partitioned into slots (Russell S, 2002).

Decision tables-Knowledge of relations can be represented in decision tables. In a decision table, knowledge is organized in a spreadsheet format, using columns and rows. The table is divided into two parts. First, a list of attributes is developed, and for each attribute, all possible values are listed. Then a list of conclusions is developed. Finally, the different configurations of attributes are matched against the conclusion.

Knowledge for the table is collected in knowledge acquisition sessions. Once the table is constructed, the knowledge in the table can be used as input to other knowledge representation methods (Fensel, D., Angele, J, and Struder, R. et al., 1998) .

3.6. Inference Engine

Inference engine is a program part of an expert system. It provides a control mechanism that applies the obvious knowledge in the knowledge base to the task-specific data to arrive at some solution or conclusion (Gaines, 1992). It represents a problem-solving model, which works with the data contained in the working memory and in the knowledge base to derive new information about the problem to be solved. According to (Pannu, 2015), two inference mechanisms are commonly used as the problem-solving strategies of an expert system are backward or/and forward chaining

3.6.1. Forward Chaining

Forward chaining is a strategy of an expert system to answer the question, “What can happen next?”

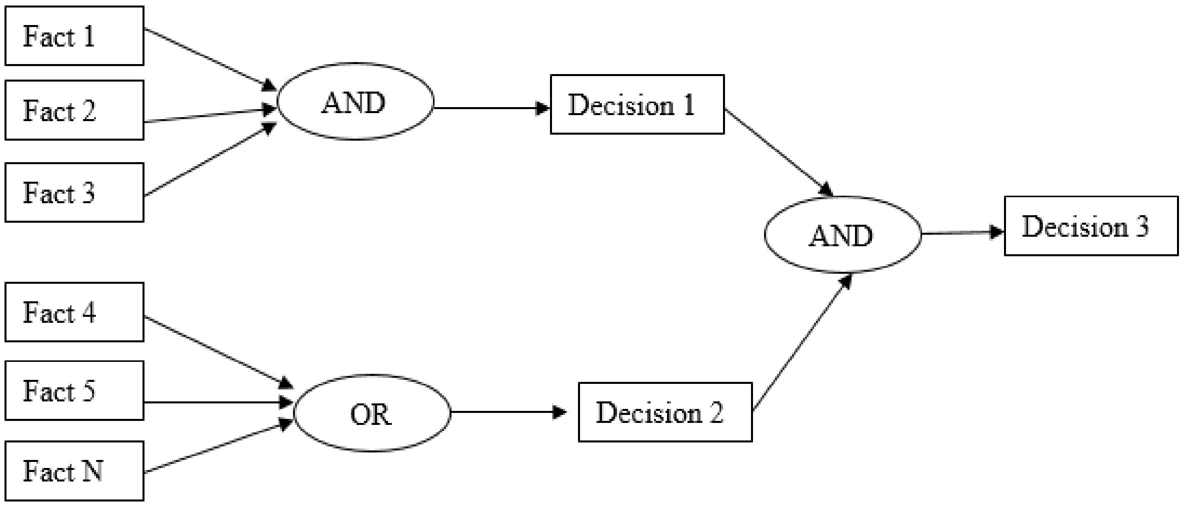


Figure 3. 3: Forward chaining adopted from (Pannu & Student, 2015)

As we shown in figure 3.3, it begins with some facts and rules in the knowledge base and attempts to find all possible conclusions from the facts. It is known as rule-driven engines. For example, if you see some symptoms of diabetes type-1, then you have diabetes type-1 (conclusion) (Gebremariam, 2013).

3.6.2. Backward Chaining

Backward chaining inferencing mechanism is called goal-directed inference technique begins with possible conclusions or goals and functions towards the back to find supporting facts.

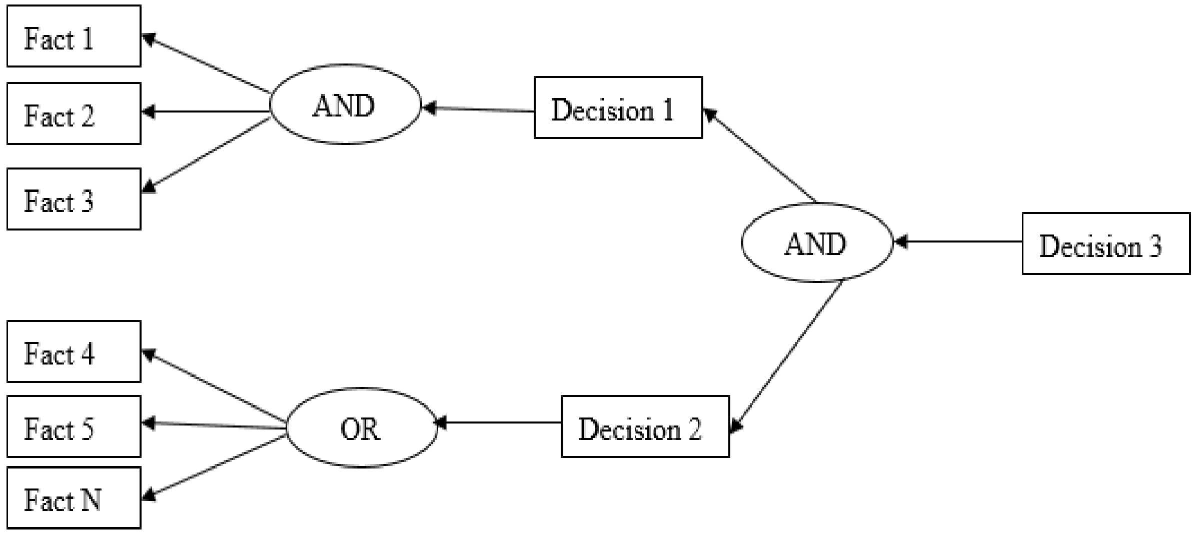


Figure 3. 4: Backward chaining adopted from (Joseph Giarratano, 1998)

As we described clearly in figure 3.4, an expert system finds out the answer to the question, "Why this happened?" On the basis of what has already happened, the interface engine tries to find out which conditions could have happened in the past for this result (Gebremariam, 2013).

An inference engine of expert system may use either or both mechanisms depending on the design or flow of information. 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, expert system must implement a complex inference engine that may involve both backward and forward chaining techniques (Joseph Giarratano, 1998).

CHAPTER-FOUR

IMPLEMENTATION OF THE PROTOTYPE SYSTEM

The implementation of the prototype system includes the actual structure of the 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 Android studio editor tool is used to construct the prototype system into a suitable format that is understandable by the inference engine.

4.1. User Interface of the Prototype System

User interface: It is the major component of the system that provides a channel for communication between users that enables to interact easily with the system. It allows the user to query with the system through any standard I/O unit and receive the results of those queries.

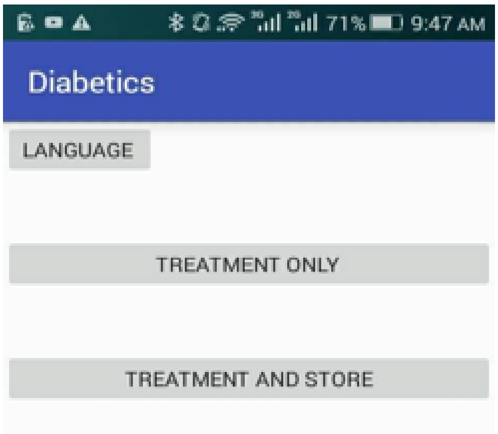


Figure 4. 1: Home page of the prototype system

As we illustrated in figure 4.1, the end-user can start the diagnosis by choosing the convenient or local language to provide best understanding and accuracy about diagnosis and treatment.

The system allows the users to interact with the system by selecting a language English, Amharic, Affan Oromo, or Tigrigna.

Figure 4. 2: Language selection page of the prototype system user interface

As we illustrated figure 4.2, the prototype system has being offered the list of language options request to choose the convenient language for clarification before it reached on its conclusion to make the results easily understandable by the end-users and build a good communication between the end-users and the prototype system. If the end-user selects English, then the system and the end-user could communicate through English language until they finish. Finally the following page have display.

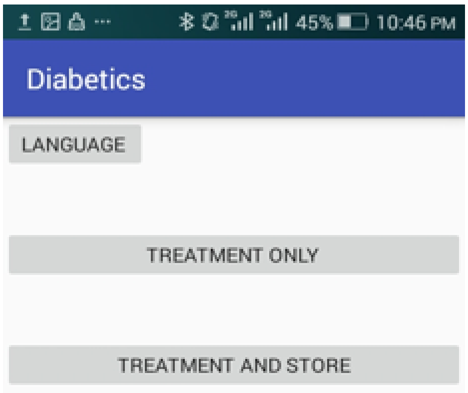


Figure 4. 3: English language selection page

As we shown in figure in 4.3, the system has being provided two diagnosis and treatment options. The first option is “TREATMENT ONLY”, in this option the end-user could simply access and test the level of blood glucose without storing his/her profile for further treatment. The second option is “TREATMENT AND STORE”, in this option, the end-user could store his/her profile after diagnosis and treatment for further diagnosis and treatments.

Figure 4. 4: Amharic language selection page

As we shown in figure 4.4, the end-user preferred "አማርኛ ቋንቋ" for diagnosis and treatment until the task finished.

Figure 4. 5: Affan Oromoo language selection page

As we shown in figure 4.5, the end user has preferred "Affan Oromoo " for last diagnosis and treatment of his/her diabetes. It does not mean the end-user can't change the language.

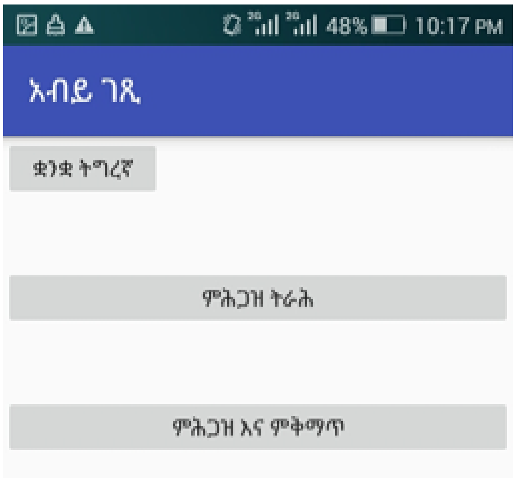


Figure 4. 6: Tigrigna language selection page

As we described in figure 4.6, the end-user also has selected "Tigrigna" language before he/she preferred either the" treatment only" or "treatment and store". If the end-user selects "treatment only" link in English, Amharic, Affan Oromoo, and Tigrigna language respectively the following page will be display.

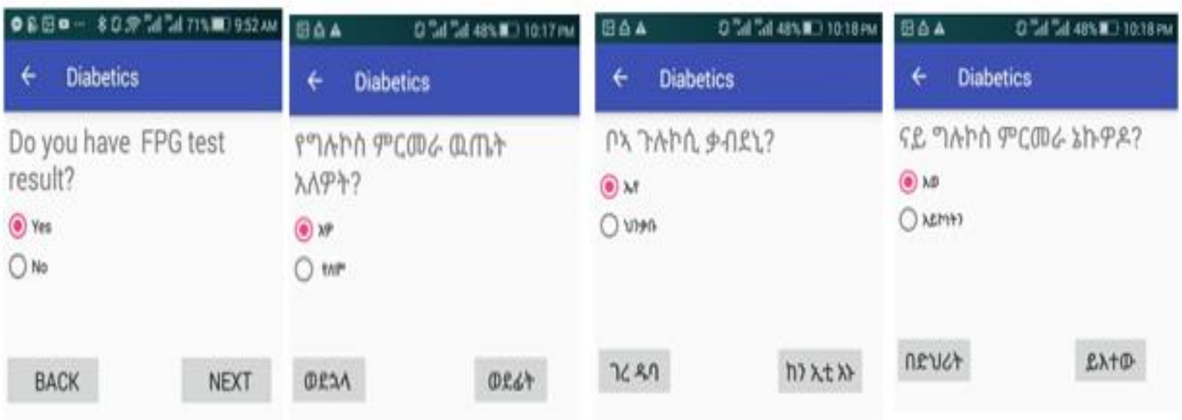


Figure 4. 7: Treatment selection page of the prototype system in English language

4.2. Explanation Facility of the Prototype System

Explanations facility provides an explanation regarding to the conclusion it makes. In addition to providing the end results, the prototype system has being offered the way of diagnosis and treatment methods through either FPG test or only symptoms by press yes or no option in different local language.

Figure 4. 8: Treatment selection page of the prototype system in English language

As we shown in figure 4.8, the developed prototype system request the end-user to answer the questions in English language " Do You Have FPG test result?", If the end-user select option "Yes", then the system will display the following page .

Figure 4. 9: FPG Request page of the system

Unfortunately, the patient may not have the fast plasma glucose test result at everywhere, So, the patient should select the option "No" and attempts to diagnosis through his/her pain feel.

Figure 4. 10: Symptoms request page of the system

As we shown in figure 4.10, if the end-user select option “No”, then the system has displayed the following consecutive system questions which, answered by the patient based on feelings of the patent.

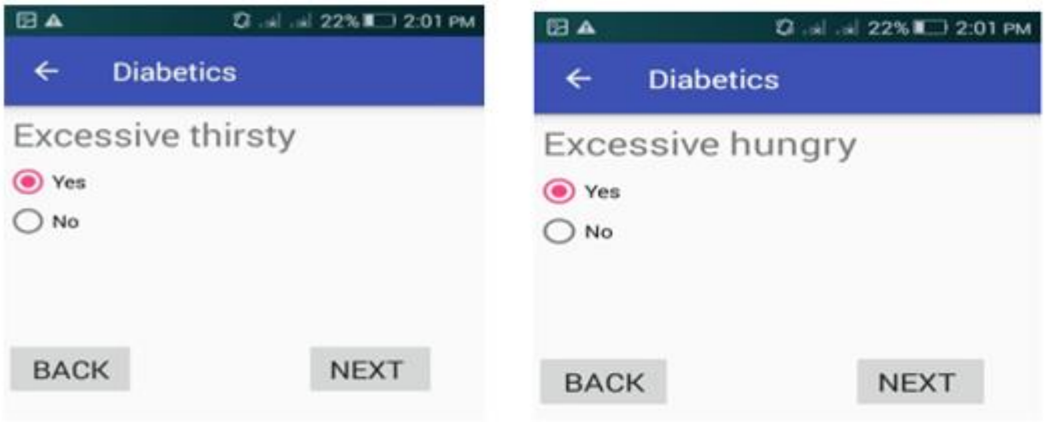


Figure 4. 11: Sample symptom identification request page

The system request to the end-user to enter the glucose level in his/her blood using FPG lab test result.

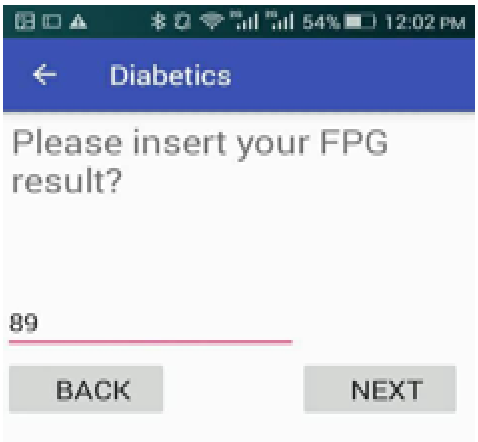


Figure 4. 12 Symptoms request page of the system

As the prototype system shown in figure 4.12, the end-user has entered the FPG test result is 89 mg/dL. If FPG lab result is less than 100 mg/dL, then the system being conclude the patent is “free from diabetes” without any further diagnosis. Finally the system has offered explanation facility and recommendation about the task that will be done by the patient in the following way.

Figure 4. 13 Sample explanation page of the prototype system

As the system has been explained in figure 4.13, the system advices the end-user based on physicians' recommendation to make average weight, make physical exercise, and eat healthy foods. However, you don't forget checking your glucose level regularly. Because the following attributes are the major factors of diabetes.

- Age
- Family history
- Obesity level
- Other diseases, like blood pressure, kidney disease and others, if not, the patient could expected to live a long life with diabetes within keeping doing the appropriate control mechanism and others.

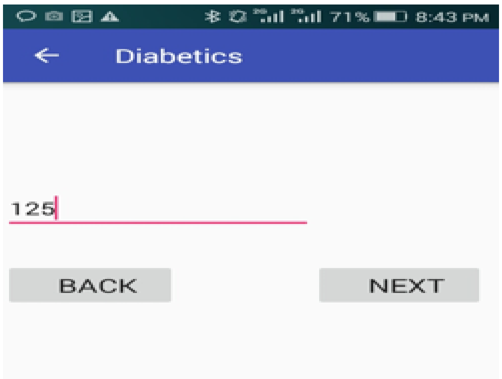


Figure 4. 14: Sample page response page of end-user

As we shown in figure 14, if the end-user has entered the FPG test result is between 100 and 125 mg/dL, then the system being conclude the patent is "has pre-diabetes" without any further diagnosis. Finally, the system has provide the explanation about the way how the patient to live along life with it.

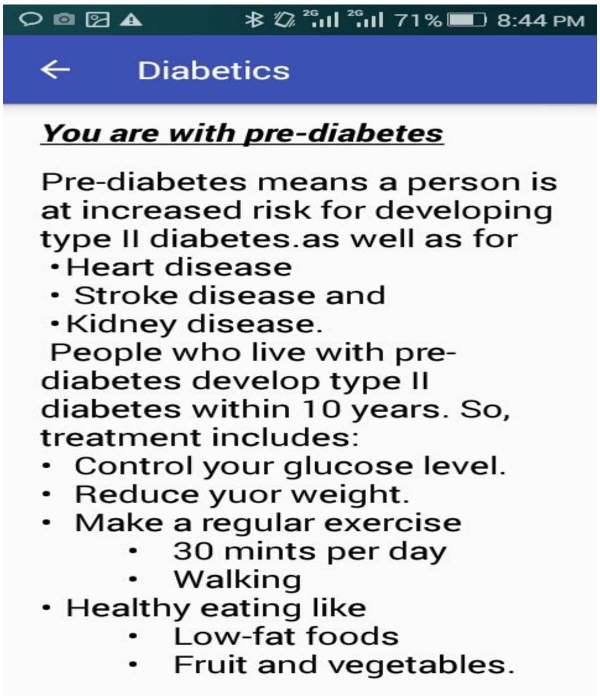


Figure 4. 15: Sample page of system explanation

If the laboratory test result shows greater than 126 mg/dL, then system conclude the patient has diabetes, however the system does not determine diabetes type in this level. The system should again more questions to identify whether the patient has diabetic type-1, type-2, or type-3.

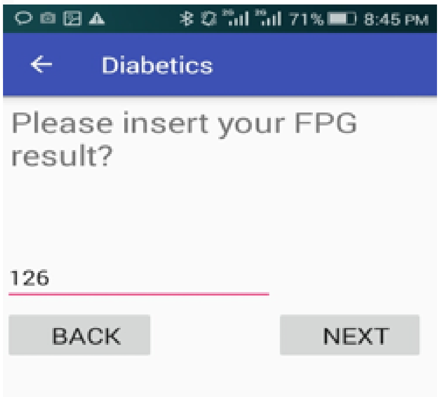


Figure 4. 16: Sample page to determine the diabetic's diabetes type

As we shown in figure 4.16, to decide whether the patient has type-1, type-2 and type-3 diabetes, the decision considers the risk factors of diabetes such as family history of diabetes, age, obesity, gender or pregnancy and overweight in following way.

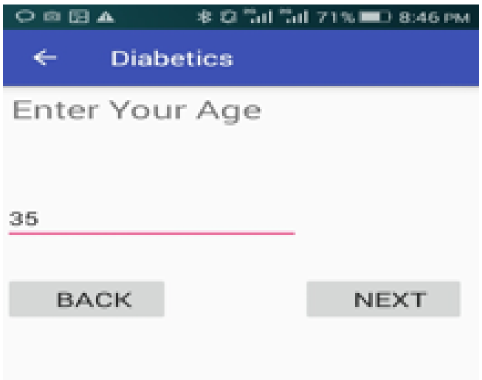


Figure 4. 17: Sample age to determine diabetes type

As we shown in figure 4.17, If the end-user insert the “age”, which is >=35, the system gave priority for diabetes type-2, but now also, not determine specific diabetes type.

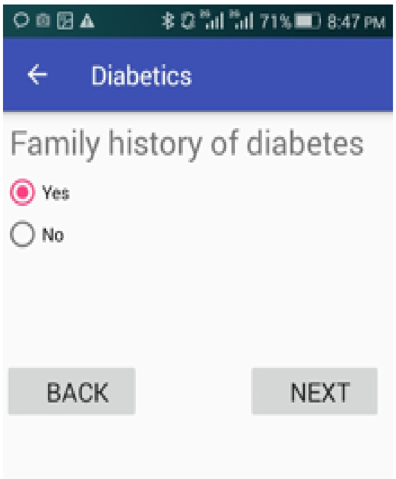


Figure 4. 19: Sample page to determine the existence of family history

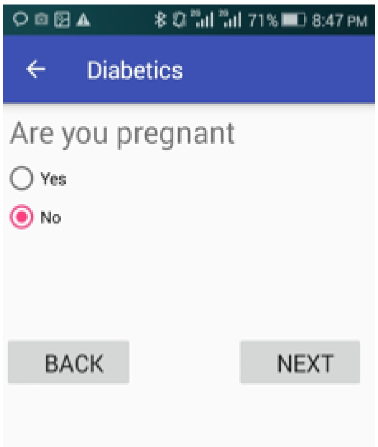


Figure 4. 18: Sample page to determine the existence of pregnancy

As we shown in figure 4.18, and 4.19, the system again requests the end-user to insert the “family history of diabetes” and “pregnancy”. Finally the system conclude “The patient has type-2 diabetes” in the following way.

Figure 4. 20: Sample identifying diabetes type and system explanation

As we shown in fig 4.20, after the system identified the diabetes type, the system offered advices about the diet information, medication, exercise and foods you should eat and foods avoid or limit. Moreover, the system advices the patient to monitor his/her glucose level to live along life with a disease.

4.3. Testing and Evaluation of the Prototype System

After we implemented the prototype system through android studio editor tool and firebase Google platform, we has being evaluated and tested to ensure that whether the performance of the system is accurate and the system satisfy the requirements of end-users.

4.3.1. System Performance Testing of the Prototype System

System performance testing is the process of determining whether the prototype system is correct or not. It confirms whether the right prototype system has been built or not.

In this study, two physicians are selected from Dangla hospital for the purpose of evaluating and testing the prototype system. The selected physicians are different from whom we collected the domain knowledge. The criteria for selecting the evaluators is because of the current availability on working place, and their willingness. Thirty patient's test cases are distributed equally to the evaluators, which is 15 patients' test cases for each evaluator.

In the performance of the prototype system, the domain experts classify correctly and incorrectly diagnosed diabetics cases by comparing the judgments reached by the prototype system with that of the domain experts' judgments reached on the same patient's 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 three class classifier are type-1, type-2, and type-3 diabetes.

Table 4. 1. Confusion matrix of the prototype system

Expert System Offered				
Type 1 diabetes	Type 2 diabetes	Type 3 diabetes	Class names	Experts Offered
8	1	0	Type 1 diabetes	
2	9	1	Type 2 diabetes	
0	0	9	Type 3 diabetes	

As we shown in table 4.1, thirty diagnosed diabetics' cases are offered by experts. From thirty diabetics, they selected 10 diagnosed diabetic's cases from "Type-1 diabetes" based on previous their judgment. As we shown in first column, out of 10 diagnosed diabetics' cases 8 are correctly classified and 2 diagnosed diabetics' case are incorrectly classified. From thirty diabetics, as we shown in second column, experts also selected 10 diagnosed diabetic's cases from "Type-2 diabetes". Out of 10 diagnosed diabetics cases 9 correctly classified as "Type-2 diabetes" and 1 diagnosed diabetic's cases is incorrectly classified. As we shown in third column, 10 diagnosed diabetic's cases are selected by experts from "Type-3 or gestational diabetes" out of 10 diagnosed diabetics' cases 9 are correctly classified as "Type-3 diabetes" and 1 diagnosed diabetic's cases is incorrectly classified. In general, from thirty diagnosed diabetics' cases, 26 diagnosed diabetics' cases are classified correctly, this means 86.7% diabetics' cases are correctly classified and 4 diabetics or 13.3% diagnosed diabetics' cases are classified incorrectly.

As we shown in table 4.2, the performance of the prototype system is calculated thorough by using confusion matrix. The prototype system record 86.7% in diagnosing diabetics, which is a hopeful accuracy result after it has been evaluated by domain experts.

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

In a classification task, the precision for a class is the number of true positives divided by the total number of elements labeled as belonging to the positive class (i.e. Precision =TP/ (TP+FP)). It known as predictive value positive.

Recall in this context is defined as the number of true positives divided by the total number of elements that actually belong to the positive (i.e. Recall= TP/ (TP+FN). It is known as sensitivity.

Measure: A measure that combines precision and recall is the harmonic mean of precision and recall.

Table 4. 2. Detailed accuracy of the prototype system

	TP Rate	FP Rate	Precision	Recall	F-Measure	Class name
	0.8	0.83	0.88	0.8	0.84	Type-1
	0.9	0.55	0.75	0.9	0.82	Type-2
	0.9	0.47	1	0.9	0.95	Type-3
Weight Average	0.866	0.061	0.876	0.866	0.87	

The weighted average precision shows 87.6% of the predicted positive cases that were correctly diagnosed cases which are registered by the expert system judgement. Similarity, the weighted average recall also shows 86.6% of the positive cases among all cases that actually belong to the relevant subset. In system performance testing, the reason why the system registered this number is because of misdiagnosis of all diabetes type made by experts to identify the diabetics' diabetes type and another challenge at back of this problem is lack of modern laboratory facilities., in Ethiopia, the experts attempt to identify the patient's diabetes type by using two or more fast plasma glucose checking and other factors like, age, family history of diabetes, pregnancy, weight, and other symptoms. Those inputs are affected the thirty diabetics' case results which are offered by experts. Different developed countries have used this modern FPG laboratory facilities to measure C-peptide in the blood of diabetic. By using this measurement the expert simply determine the diabetes type.

4.3.2. User Acceptance Testing of the Prototype System

The prototype system, has being testing and evaluating to check whether the objectives of the research are achieved or not. The evaluation and testing issue of the system is summarized by the question "Does the prototype system give acceptable and accurate diagnosing service to all types of diabetes?" as we shown in figure 4.21, user acceptance testing helps to assess the performance of the system from user's perspective based on the ISO 9126 software quality model. These questioners are attached in appendix III.

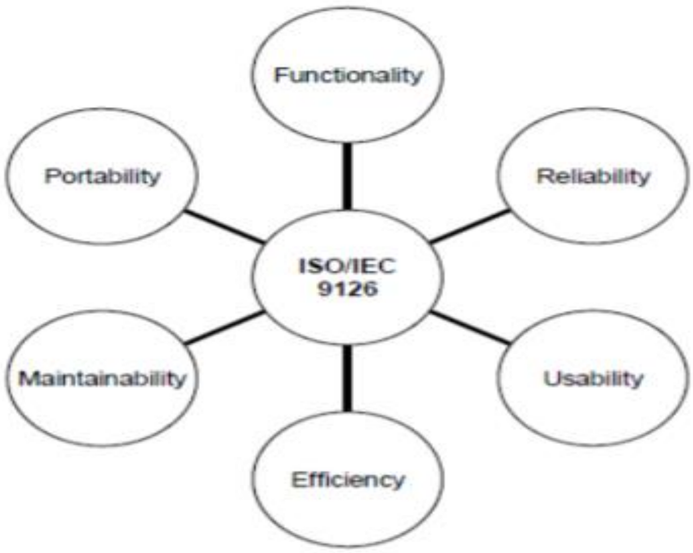


Figure 4. 21: ISO 9126 software quality model

In user acceptance testing nine end-users (diabetics) have participated to evaluate and test the prototype system how accurate the performance measures are, how trustworthy the expert system is, generally how the system satisfies the diabetics needs.

The diabetics assess the accuracy of the prototype system by using the following standards are: simplicity of use and interact with the prototype system, attractiveness of the prototype system, efficiency in time, the accuracy of 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, and the importance of the prototype system in the domain area. These evaluation standards are customized from (Gebremariam, 2013). The adapted questionnaires were modified in the context of all types of diabetes diagnosing and treatment by expert system. There are total of six closed ended questions and nine end-users answered as strongly agree, agree, somewhat agree, disagree, and strongly disagree. We assigned numbers for each word as strongly agree = 5, agree = 4, somewhat agree = 3, disagree = 2 and strongly disagree = 1. The system evaluators gave the value for each closed ended questions. In table 4.3, shows result of analysis of end-users' feedback. For more detail see appendix III.

Table 4. 3. Performance evaluation by end-users

No	Evaluation criteria	Strongly disagree	Disagree	Somewhat agree	Agree	Strongly agree	**Average**
Q 1	Functionality	0	1	2	4	2	**3.78**
Q 2	Reliability	0	1	3	3	2	**3.67**
Q 3	Usability	0	1	2	3	3	**3.89**
Q 4	Efficiency	0	0	2	4	3	**4.11**
Q 5	Maintainability	0	1	2	3	3	**3.89**
Q 6	Portability	0	1	3	3	2	**3.65**
		Total Average					**3.83**

As we shown in table 4.3, the result of analysis of users' feedback analyzing the relative performance of the system based on nine users' evaluation, for instance the end-users answered the closed ended questions as functionality =3.78, means,

$$\frac{2*5+4*4+2*3+1*2+0*}{9} = \frac{34}{9} = 3.78$$

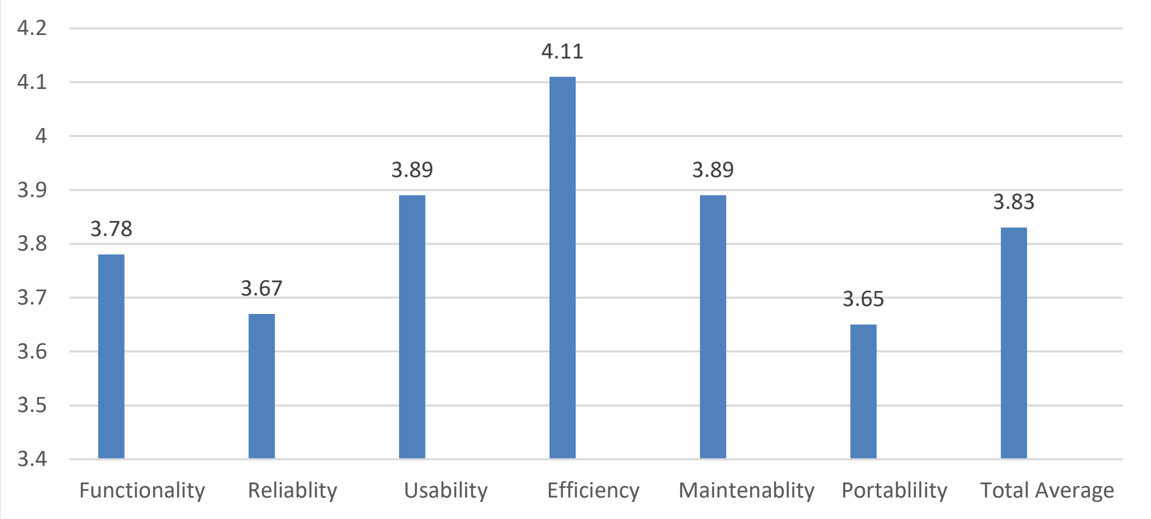


Figure 4. 22: Result of analysis of end-users' feedback towards system

4.3.3. Discussion

As shown in the above table 4.3, 22.22% of the evaluators scored the functionality of the prototype system criteria of evaluation as strongly agree, 44.45% as agree, 22.22% as somewhat agree, 11.11% disagree and 0% strongly disagree. The second evaluation criteria reliability of the prototype system scored 22.22% strongly agree, 33.34% as agree, 33.33% as somewhat agree, 11.11% as disagree, strongly disagree. In the usability and maintainability of the prototype system scored 33.34% as strongly agree, 33.34% as agree, 22.22% as somewhat agree, 11.11% as disagree, and 0% as strongly disagree. The fourth evaluation criteria is efficiency of the prototype system showed a greater rate of attractiveness by the evaluators the majority is scored 33.34 % as % strongly agree, 44.45% as agree, 22.2% as somewhat agree, 0% as disagree and strongly disagree.

As we shown in figure 4.23, the overall performance the prototype system scored 28% strongly agree, 37% as agree , 26 % as somewhat agree, 9% as disagree, and 0% as strongly disagree .

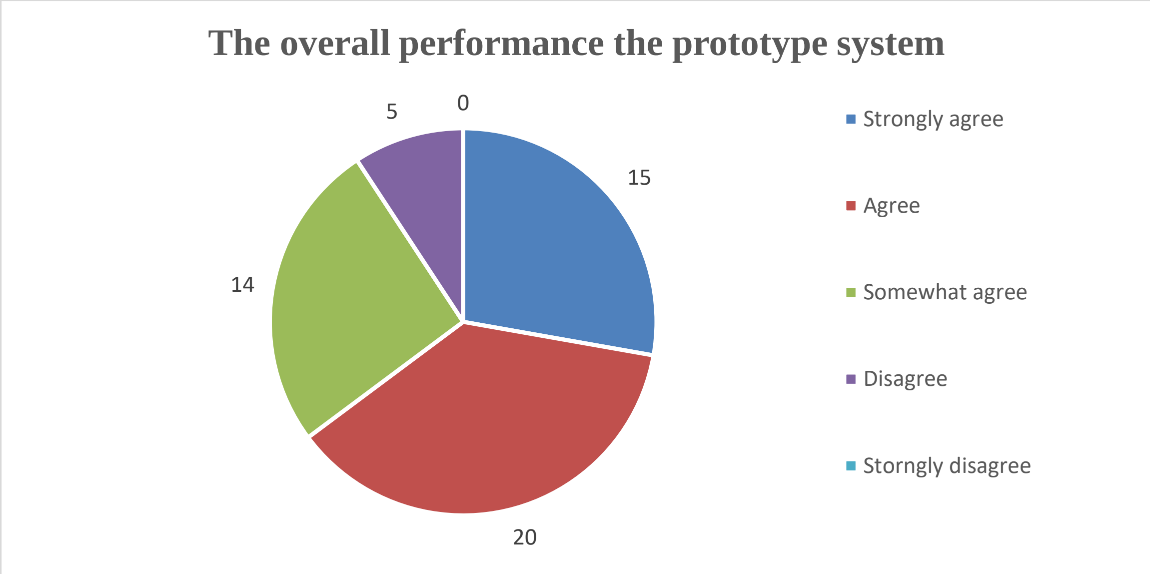


Figure 4. 23: The end-user evaluation result summery on closed questions

As discussed in the above under sections 4.3.1 and 4.3.2, the accuracy of the prototype system is registered as 86.7% and the average evaluation result filled by the domain experts in the domain area is 76.6%. The overall accuracy of the prototype system is 81.65%.

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

- Explanation about the prototype system was given to the domain experts on how the system functions and on how to use and interact with the system. However, from nine evaluators, three of them are not satisfied by the functionality, usability, maintainability, and portability of the prototype system. One evaluator responded that, he/she wants to more explanation about type-3 diabetes, which regard to when the diabetes occurred? Is it before and after pregnancy? Based on this input the system should give advice or recommendation for end-users, in reliability of the prototype system, an integration of expert system, cloud, and mobile intelligence has been reduced the accuracy of the prototype system, he/she wants to insert his/her queries to the user interface without username, password, and an Internet connection to encode the data to cloud had a doubt about the significance of the prototype system to the diabetics who live rural area, he/she wants to modify the size of text on mobile screen to optimize the visibility of texts or recommendations, and he/she also wants to use any mobile phone, but the prototype system didn't offered those requirements. Due to this reason, one evaluator replied as dis agree to the above mentioned evaluation criteria respectively.

- Even though tacit knowledge about the diagnosis and treatments of diabetes is extracted from 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.

In general, the testing and evaluation outcomes of the prototype system have achieved the objectives of the study. However, additional study is needed to bring complete implementation and use of cloud-based expert system using mobile intelligence for diabetes diagnosis and treatment.

CHAPTER-FIVE

CONCLUSIONS AND RECOMMENDATIONS

The earlier chapters have concluded to graceful some significance issues in the design of the prototype mobile-based expert 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 in domain area.

5.1. Conclusions

We have learned from the various sources that diabetes in the world is growing very fast. Nowadays, our country's disease is widespread. In fact, preventing natural defects has improved the scalability, but most importantly, correct treatment on relief will leave the diabetic with the chance to live with the diabetes. Here are the similarities and symptoms of diabetes that we should mention here, such as lack of attention, lack of professionalism, skilled knowledge, and the problems associated with the appointment of diabetes patients and the like are described by experts.

To developed prototype expert system on cloud platform using mobile intelligence for diabetes treatment, first the knowledge was acquired from domain experts and documented sources through the interview and document analysis respectively. The acquired knowledge focuses on concepts and facts of diabetes. These extracted facts and concepts were modeled using a decision tree after verification and validation then the model has been converted into IF-THEN rules of knowledge representation. The development tools applied in this research are android studio 3.2 and firebase. To diagnose and recommend the treatments of diabetes, the system uses hybrid (forward and back warding) chaining inference mechanism. The inference engine first identifies the type of diabetes based on facts or symptoms and the possible recommendation or advice then display the page for the identified disease.

Also in testing and evaluation of the prototype system, thirty (30) cases of diabetics 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 shown, the overall performance of the prototype system registers 81.5%.

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 all types of diabetes, some additional study is needed like updating the rules in the knowledge base of the system automatically in the cloud, a cloud facilities, and optimize the processing time of the system.

The system really contribute in rural areas where a shortage of expert and knowledge lack workers is available who works closer to the diabetics. The significance of the system has been accepted by domain experts, because the system gave accurate and reliable information about the diabetes, and recommend the end-users. By replicating this prototype system, it could reduce the existed knowledge gap observed in remote areas where transferring skilled experts is difficult as well as miss diagnosis rate of diabetes.

5.2. Recommendations

- Diagnosing a disease with the user input instead of only the knowledge base (the system does not learn from experience).
- Designed for cases of diabetes or other complicated diseases.
- Large databases in cloud more than (5MB).
- Data mining tools and techniques

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APPENDICES

Appendix I. Interview Questions

Questions concerning diabetes with selected experts

1. What are the challenges that face the health offices to achieve its stated objectives (diabetes diagnosis)?
2. Describe the type of diabetes specifically in Ethiopia?
3. What are the symptoms of the diseases described in Question No.2?
4. What are the identification techniques and procedures you applied to diagnose the diseases mentioned above (Question No. 2)?
5. Do you use standardized guidelines/manuals to diagnose each diabetes?
6. What are the steps undertaken to diagnose of diabetes mentioned above?
7. What are the major issues covered during the diagnosis process of each diabetes type?
8. After a diagnosis of these diseases, what are the recommendation and treatments you provided?
9. In diagnosis using only signs and symptoms of diabetes, can we say the new patient is diabetic or not?

Appendix II. Applicable of symptoms of the Prototype

Table 5. 1. Applicable symptoms for each diabetes type

S. no.	Symptoms	T 1	T 2	T 3
1	Excessive thirsty	1	1	0
2	Frequent urination in large quantity	1	1	0
3	Excessive hungry	1	1	0
4	Weight reduction	1	0	0
5	Over weight	0	1	1
6	Weight variation	0	1	0
7	Impaired vision	0	1	0
8	Tiredness	1	1	0
9	Impatience	0	1	0
10	Infection	0	1	0
11	Itchy skin	**0**	**0**	**0**
12	Family history	**0**	**0**	**0**
13	Depression and stress	**0**	**0**	**0**
14	Tingling sensation	**0**	**0**	**0**
15	Fruity breath odor	1	0	0
16	Bed wetting	1	0	0
17	Slow-healing wounds	0	1	0
18	The family history of diabetes during pregnancy	0	0	1
19	Previous pregnancy	0	0	1
20	Baby over 9 pounds during previous pregnancy	0	0	1
21	Sleeplessness	1	1	0
22	Trembling	1	1	0
23	Sweating	1	1	0
24	Anxiety	1	1	0
25	Confusion	1	1	0
26	Weakness	1	0	0
27	Mood swings	1	0	0
28	Nausea	1	0	0

29	Vomiting	1	0	0
30	Dry skin	0	1	0
31	Aches and pains	0	1	0
32	Recurrent fungal infection	0	1	0
33	Nightmares	1	1	0
34	Seizures	1	1	0
35	Sadness	1	1	0
36	Unconsciousness	1	1	0
37	Numbness	1	1	0
38	Vaginal mycotic infection	1	1	1
39	Rapid heart beat	0	1	0
40	Recurring gum infections	**0**	**0**	**0**
41	Impotency	1	1	0
42	High blood pressure	0	0	1
43	Sleep walking	1	1	0
44	Making unusual noises	1	1	0
45	leg cramps	1	1	0
46	Slurred speech	1	1	0
47	flushed face	1	1	0
48	Pale skin	1	0	0
49	Loss of menstruation	1	1	0
50	Stomach pain	1	1	0
51	Deep breathing	1	1	0
52	Areas of darkened skin	0	1	0
53	Difficult Concentrating	1	1	0
54	Dehydration	1	1	0
55	Lack of coordination	1	1	0
56	History of heart disease	**0**	**0**	**0**
57	Polycystic ovary syndrome	**0**	**0**	**0**
58	Low blood sugar in the baby immediately after delivery	0	0	1
59	Waist size more than 102 cm in male and 88 cm in female	**0**	**0**	**0**
60	Waist to hip ratio more than 0.9 in male and 0.85 in female	**0**	**0**	**0**

Appendix III: CESDTMI Prototype Evaluation Questionnaire

AKSUM UNIVERSITY

Department of Computing Technology

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY PROGRAM

Cloud-based expert system for diabetes treatment using mobile intelligence (CESDTMI)

Prototype Evaluation Questionnaire

Evaluation Instruction:

I. Read the statement carefully and put "x" on the cell of your choice which you think is the weight of the statement.

Table 5. 2. Prototype Evaluation Questionnaire

Scale	Equivalent
5	Strongly Agree
4	Agree
3	Somewhat agree
2	Disagree
1	Strongly Disagree

<table>
<tr><th rowspan="2">No, Q</th><th rowspan="2">Evaluation criteria</th><th rowspan="2">Functionality of evaluation criteria Contains:</th><th colspan="5">Scale</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td>Q 1</td><td>Functionality</td><td>The system provides adequate functions including:
▪ The ability making the right conclusion and recommendation.
▪ The accuracy of decision to identify all type of diabetes.
▪ The ability to remember the diabetics' history.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Q 2	Reliability	▪ Accuracy of the system to give a decision about diabetes.					
Q 3	Usability	Simplicity to use and interact with the prototype system includes: ▪ Easy to learn and use ▪ Navigation of links are easy to understand. ▪ Importance of the prototype system in domain area. ▪ Significance of the prototype system to the end-users.					
Q 4	Efficiency	▪ Response time of the system					
Q 5	Maintainability	▪ User interface design ▪ Attractiveness of the prototype system.					
Q 6	Portability	▪ Can the system be used in the intended environment?					

Appendix IV: Rules of Knowledge Base

Rule 8:

IF FPG = “have test result”,

AND lab FPG = “≥126 mg/dL”,

AND age = “≤15 years”,

AND weight lost=”doesn’t exist”,

AND overweight =”exist”,

Family history=”doesn’t exist”,

AND obesity =”doesn’t exist”,

AND pregnancy =”exist”,

THEN diabetes type = “Type III diabetes”

Rule 9:

IF FPG = “have test result”,

AND lab FPG = “≥126 mg/dL”,

AND age = “≤15 years”,

AND weight lost=”doesn’t exist”,

AND overweight =”exist”,

Family history=”doesn’t exist”,

AND obesity =”doesn’t exist”,

AND pregnancy =”doesn’t exist”,

THEN diabetes type = “Type I diabetes”

Rule 10:

IF FPG = “have test result”,

AND lab FPG = “≥126 mg/dL”,

AND age = “≤15 years”,

AND weight lost=”doesn’t exist”,

AND overweight =”doesn’t exist”,

Family history=”exist”,

AND obesity =”exist”,

THEN diabetes type = “Type II diabetes”

Rule 11:

IF FPG = “have test result”,

AND lab FPG = “≥126 mg/dL”,

AND age = “≤15 years”,

AND weight lost=”doesn’t exist”,

AND overweight =”doesn’t exist”,

AND family history=” doesn’t exist”,

AND obesity =”exist”,

THEN diabetes type = “Type I diabetes”

Rule 12:

IF FPG = “have test result”,

AND lab FPG = “≥126 mg/dL”,

AND age = “≤15 years”,

AND weight lost=”doesn’t exist”,

AND overweight =”doesn’t exist”,

Family history=”doesn’t exist”,

THEN diabetes type = “Type I diabetes”

Rule 13:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”,

AND age = “>15 AND ≤35 years”,

AND weight lost=”exist”,

AND family history of diabetes = “exist”,

AND obesity =”exist”,

THEN diabetes type = “Diabetes Type II”

Rule 14:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”,

AND age = “>15 AND ≤35 years”,

AND weight lost=”exist”,

AND family history of diabetes = “exist”,

AND obesity =”doesn’t exist”,

THEN diabetes type = “Diabetes Type I”

Rule 15:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”,

AND age = “>15 AND ≤35 years”,

AND weight lost=”exist”,

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

AND obesity =”exist”,

THEN diabetes type = “Diabetes Type I”

Rule 16:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”,

AND age = “>15 AND ≤35 years”,

AND weight lost=”exist”,

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

AND obesity =”doesn’t exist”,

THEN diabetes type = “Diabetes Type I”

Rule 17:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “>15 AND ≤35 years”

AND weight lost=”doesn’t exist”,

AND overweight=”exist”,

AND family history of diabetes = “exist”

THEN diabetes type = “Diabetes Type II”

Rule 18:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “>15 AND ≤35 years”

AND weight lost=”doesn’t exist”,

AND overweight=”exist”,

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

AND obesity=”exist”,

THEN diabetes type = “Diabetes Type II”

Rule 19:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “>15 AND ≤35 years”

AND weight lost=”doesn’t exist”,

AND overweight=”exist”,

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

AND obesity=”doesn’t exist”,

AND pregnancy=”exist”,

THEN diabetes type = “Diabetes Type III”

Rule 20:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “>15 AND ≤35 years”

AND weight lost=”doesn’t exist”,

AND overweight=”exist”,

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

AND obesity=”doesn’t exist”,

AND pregnancy=”doesn’t exist”,

THEN diabetes type = “Diabetes Type II”

Rule 21:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “>15 AND ≤35 years”

AND weight lost=”doesn’t exist”,

AND overweight=”doesn’t exist”,

AND family history of diabetes = “exist”

AND obesity=”exist”,

THEN diabetes type = “Diabetes Type II

Rule 22:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “>15 AND ≤35 years”

AND weight lost=”doesn’t exist”,

AND overweight=”doesn’t exist”,

AND family history of diabetes = “exist”

AND obesity=”doesn’t exist”,

THEN diabetes type = “Diabetes Type II

Rule 23:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “>15 AND ≤35 years”

AND weight lost=”doesn’t exist”,

AND overweight=”doesn’t exist”,

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

AND obesity=”exist”,

THEN diabetes type = “Diabetes Type II “

Rule 24:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “>15 AND ≤35 years”

AND weight lost=”doesn’t exist”,

AND overweight=”doesn’t exist”,

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

AND obesity=”doesn’t exist”,

THEN diabetes type = “check again your glucose”

Rule 25:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “≥35 years”

AND overweight=” exist”,

AND family history of diabetes = “exist”

THEN diabetes type =“Diabetes Type II “

Rule 26:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “≥35 years”

AND overweight=” exist”,

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

AND obesity=”exist”,

THEN diabetes type =“Diabetes Type II “

Rule 27:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “≥35 years”

AND overweight=” exist”,

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

AND obesity=” doesn’t exist”,

AND pregnancy=”exist”,

THEN diabetes type =“Diabetes Type III“

Rule 28:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “≥35 years”

AND overweight=” exist”,

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

AND obesity=” doesn’t exist”,

AND pregnancy=" doesn't exist",

THEN diabetes type ="Diabetes Type II"

Rule 29:

IF FPG = "have test result",

AND FPG = "≥126 mg/dL"

AND age = "≥35 years"

AND overweight=" doesn't exist",

AND family history of diabetes = "exist"

AND obesity="exist",

THEN diabetes type ="Diabetes Type II"

Rule 30:

IF FPG = "have test result",

AND FPG = "≥126 mg/dL"

AND age = "≥35 years"

AND overweight=" doesn't exist",

AND family history of diabetes = "exist"

THEN diabetes type ="Diabetes Type II"

Rule 31:

IF FPG = "have test result",

AND FPG = "≥126 mg/dL"

AND age = "≥35 years"

AND overweight=" doesn't exist",

AND family history of diabetes = "doesn't exist"

AND obesity=”exist”,

THEN diabetes type =“Diabetes Type II“

Rule 32:

IF FPG = “have test result”,

AND FPG = “≥126 mg/dL”

AND age = “≥35 years”

AND overweight=” doesn’t exist”,

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

AND obesity=” doesn’t exist”,

THEN diabetes type =“Check again your glucose “