JIMMA UNIVERSITY

INSTITUTE OF TECHNOLOGY

FACULTY OF COMPUTING AND INFORMATICS

MSc. IN INFORMATION SCIENCE (IKM)

Integration of Rule-Based and Case-Based Reasoning for Diagnosis and Treatment of Eye Diseases

By:

Betsegaw Desalegn

October 2019

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Integration of Rule-Based and Case-Based Reasoning for Diagnosis and Treatment of Eye Diseases

A Thesis Submitted in Partial Fulfillment of the Requirements for Degree of Masters of Science in Information Science (Information and Knowledge Management)

By:

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October 2019

Jimma, Ethiopia

DECLARATION

I declare that this thesis is my original work and it has not been presented for a degree in any other University. All the material sources used in this work are duly acknowledged.

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Betsegaw Desalegn

October, 2019

This thesis has been submitted to the department for examination with our approval as university advisors:

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List of Acronyms

AI:	Artificial Intelligence
CBR:	Case-based Reasoning
CLIPS:	C Language Integrated Production System
GUI:	Graphical User Interface
IDE:	Integrated Development Environment
IEDDTS:	Integrated Eye Disease Diagnosis and Treatment System
JCOLIBRI:	Java Case and Ontology Libraries Integration for Building Reasoning Infrastructures
JDK:	Java Development Kit
JESS:	Java Expert System Shell
JUSH:	Jimma University Specialized Hospital
KBS:	Knowledge-based System
MATLAB:	Matrix Laboratory
MYSQL:	My Structured Query Language
PROLOG:	Programming in Logic
RDBMS:	Relational Data Base Management System
RBR:	Rule-based Reasoning
SWI:	Social Wetenschappelijke Informatica
UTF:	Unicode Transformation Format
WHO:	World Health Organization

Abstract

The prevalence of eye disease is rapidly growing in Ethiopia and the scarcity of experts in the field of ophthalmology is the major problem for early diagnosis and treatment for eye patients. Designing KBS will simplify the medical diagnose processes by emulating human experts. In KBS development case-based and rule-based reasoning are popular techniques of knowledge representation for problem-solving and decision making. The main purpose of this research is to integrate rule-based and case-based reasoning approaches for diagnosing and treatment of eye diseases. The study followed the design science research approach with six steps process model. For problem identification and formulate the objective of the solution, knowledge is acquired by using document analysis, domain expert interviewing and previously solved patient cards form Jimma University Specialized Hospital. The method of integration of rule-base with case-based reasoning is done using a conditional combination model, which has a controller in between RBR and CBR. The controller is developed by Java eclipse programming language. It forwards the query first for rule-based reasoning (RBR) which attempts to recommend a solution for the new query. If RBR doesn't solve the problem, the query is automatically forwarded to the CBR system. The CBR system is developed by JCOLIBRI programming language, where the case retrieval module identifies the most related solution using case similarity measure. In this study, the four RE (Retrieval, Reuse, Revise and retain) cycle are integrated with the CBR system. The knowledge-based system prototype is demonstrated practically for users' acceptance evaluation. Experimental results show that the system achieves 87.5% accuracy with an average Precision and Recall of 94.7% and 90% respectively. For user acceptance testing the selected ten experts are involved for evaluation hereafter, the system scores 85.6%. This shows the system has registered a promising result. However, knowledge acquisition is performed manually which is challenging and incomplete. So, further study has to be done for automatic knowledge acquisition using data mining or machine learning for simplifying learning towards intelligent system design.

Keywords: Case-based Reasoning, Rule-based Reasoning, Knowledge-based System, Eye diseases

CHAPTER ONE

INTRODUCTION

1.1. Background of the Study

Eyes are the visual system of the human body that has the ability to receive and process visual details by absorbing and instantly processing more than ten million pieces of information per second [1]. It's one of the sensory equipment and a unique part of the body that has been described as the window to the human soul to look at the outside world. Through this sense organ, humans understand the surrounding by gathering most of the information they need for decision making [1].

There are many different conditions that can affect the human eye [2]. Some of them are minor and resolved by themselves quickly like viral conjunctivitis, but others could be serious and lead to serious visual impairment, like glaucoma, retinal detached and uveitis. Vision loss or impairment can be sudden or gradual and some serious eye problems can lead to the total loss of vision. A decrease in vision is usually one of the first presenting symptoms and should always be examined [2]. Blindness can be the result of serious untreated eye problems. Common problems which can affect the eye are infections of the eye or eyelid which came from virus, bacteria, parasite or fungi by attacking the surface or interior of the eye. The other thing is genetically inherited eye problems. Sometimes eye injuries or objects in the eye and most of the time eye disorders that are the result of conditions that affect many organs like diabetes or hypertension will cause eye sickness. However, 80% of blindness caused cases are avoidable, if they get early diagnose and well treated before eye problems are more progressed [3].

The majority of eye disease is found in rural areas [4], most of the time, poor ventilation and climate, overcrowding and close proximity to livestock are contributing factors. Women are the most affected group either due to their work in smoky, wood-burning kitchens or because they have less access to eye care than men, due to their place in society. Illiteracy to read instructional materials that slow down education about eye care, lack of adequate clean water and sanitation are other factors for eye diseases. Lack of income is also a factor that can be an obstacle for most people to come to the city for medical diagnosis and treatment. Because, the majority of eye specialists and eye hospitals are live in urban areas [4, 5]. Medical diagnosis is the process of determining the nature of a disease or condition that explains a person's symptoms and signs. The information required for diagnosis is typically collected from a history and physical examination of the person seeking medical care [6]. As it is interpreted, most people delay from giving medical attention because of cost and/or time constraints, dilettantes or inconvenience situations. Early diagnosis and treatment of numerous diseases could keep many patients from reaching the advanced stages of illness [7].

In medicine, the diagnosis and treatment process consists of four major components [8]: cue acquisition, hypothesis generation, cue interpretation, and hypothesis evaluation. The cue acquisition includes patients' history or illness symptoms which means present and past medical history, clinical and laboratory or psychological tests. The hypothesis generation is probable alternative hypotheses that are retrieved from the physician's memory. The cue interpretation is the component in which the data are considered in view of their contribution to the alternative hypotheses. Hypothesis evaluation is the main stage of the reasoning process, in which the data are weighted and combined to determine until one of the diagnostic hypotheses already generated can be confirmed. If not, the problem must be recycled, new hypotheses should be generated and additional data should be collected until the verification is achieved [8].

To simplify the medical diagnosis and treatment process there is a need to develop a knowledge-based system that automates medical diagnosis and advice systems for patients [9]. In the medical field, there are different knowledge-based expert systems developed for most of its areas. Especially the use of the reasoning processes in decision making with the self-learning ability will improve the reliability and accuracy of the system [10].

A knowledge-based system (KBS) is a computer program that reasons and uses a knowledge-base and inference engine to solve complex problems [12]. It is a branch of artificial intelligence that helps to represent the experts' knowledge in simulated ways [11]. It has three basic types of subsystems [12]: a knowledge-base, a user interface, and an inference engine. It can be broadly classified as intelligent tutoring systems, expert systems, hypertext manipulation systems and databases with intelligent user interface [12].

In KBS the knowledge is not just stored; it is also represented by means of formalization to simplify the reasoning process. The purpose of knowledge representation is to organize the acquired and modeled knowledge into a form that a knowledge-based system can readily access for decision making. In practice there are several types of knowledge representation techniques; the most common techniques are rule-based reasoning (RBR) and case-based reasoning (CBR) [17]. In RBR the system uses IF and THEN parts, since the IF part lists a set of conditions in some logical combinations and in the THEN part its problem-solving action is taken. These two parts are also called a condition and an action. In CBR the system uses reasoning methodology that simulates human reasoning by using past experiences to solve new problems [13, 14]. The two approaches have their own advantage and disadvantage on the implementation of KBS. To minimize the limitation of both representation techniques the approach of integrating them is one of the research areas [15].

Approaches integrating rule-based and case-based reasoning have given interesting and effective knowledge representation schemes [16]. The goal of these efforts is to derive an integrated system that increases their positive aspects of the integrated formalisms and simultaneously minimizes their negative aspects. In the approaches integrating rule-based and case-based reasoning are distinguished into two basic categories: efficiency improving and accuracy improving methods [16]. The former concern integration methods in which rules and cases are dependent, meaning that one representation scheme was derived from the other (i.e., rules derived from cases or vice versa), and the efficiency of the integrated scheme exceeds the efficiency that could have been achieved with rules or cases alone. The latter involves approaches in which the two representation schemes are independent and their integration results in improved accuracy compared to each representation scheme working individually [16].

The motivation of this study is, as stated by Prentzas [22], the efforts to combine symbolic rules and cases have yielded advanced knowledge representation formalisms. The effectiveness of those approaches stems from the fact that rules and cases are complementary in representing application domains and solving problems. In addition, previous researchers have found that there are some problem domains that are especially appropriate and can be easily modeled using a rule-based reasoning mechanism, while others seem to be more suitable for a case-based reasoning approach. However, both of these reasoning approaches have their own weaknesses. A case-based reasoning approach cannot easily take advantage of existing domain knowledge and sometimes makes decisions intuitively, while the rule-based reasoning approach requires a complete theory of the domain but suffers from lacking knowledge that could be derived from past experiences [17]. To improve the effectiveness and accuracy of the system the approach of integrating case-based and rule-based reasoning techniques is one of the future research areas [8, 16].

These days there are different studies attempting to design knowledge-based systems for medical diagnosis and treatment. Henok [18] investigated the applicability of a case-based reasoning approach to developing a knowledge-based system for hypertension management. He attempted to provide relevant cases for designing a CBR system that proposes a solution to the new hypertension cases forms already solved cases. But the gap that the researcher put on his study is in CBR there is a lack of knowledge to interpret the outcomes by using cases. Therefore, Henok [18] recommended the need to integrate rule-based reasoning with the aim of improving the performance of the KBS. Berhanu [19], Seblewongel [20] and Tagel [21] also investigated to design a rule-based KBS. But they found limitations like less learning capability of the system and unable to handle the unexpected cases or missing input on RBR. So, they recommend the need to integrate case-based reasoning with rule-based reasoning.

The limitations of the RBR approach are less learning capacity; which means the system will generate the result as per the rules so the learning capacity of the system by itself is much less. In addition, it is complex domains; which means an application that wants to build is too complex, complex pattern identification is also a challenging task in the RBR approach, and it is not handling the unexpected cases or missing input [9].

On the other hand, there are also drawbacks in the CBR approach [55] like; inability to express general knowledge since cases by their nature express specialized knowledge. So, they cannot express general knowledge. Rule-based systems have the advantage of the ability to express general knowledge. Another limitation in CBR is knowledge acquisition problems which means various knowledge acquisition problems may arise when dealing with domains, where cases are either unavailable or are available in a limited amount [22]. In general, to overcome the limitation of both reasoning techniques it is better to implement the integration of RBR with a CBR approach; it improves the system performance and self-learn ability [17, 22].

Therefore, from the previous research gaps, the motivation of this study is to demonstrate the integration of CBR and RBR approaches in knowledge representation to improve the performance of KBS for the case of diagnosis and treatment of eye diseases.

1.2. Statement of the Problem

According to the WHO [23] report, around 253 million people are living with vision impairment in the world, from those 36 million are blind. The vast majority of getting sick is live in developing countries. More specifically, around 50% of the world's blind population resides in Africa [24] which indicated that more affected peoples live in Africa. And also, more than 80% are aged 50 years and above. Approximately 26.3 million people in Africa region have a form of visual impairment. From those 20.4 million have low vision and 5.9 million are estimated to be blind [24].

The prevalence of eye disease in Ethiopia is rapidly growing, more than one million Ethiopians are blind and close to three million have low vision [32]. The country has a high prevalence of eye disease that can result in blindness after years of repeated infection. With these challenges, Ethiopia faces immense difficulties to meet the healthcare needs of its population, particularly in rural areas [24].

In addition to that, in Ethiopia, the number of ophthalmologists in 2015 was 304 and the projection estimation of WHO will be 524 in 2020 [23]. This statistic shows that there is a scarcity of experts in the field of ophthalmology. Most of the medical problems usually occurred in the country are the living style of people, the nutrition system and most of the time an imbalanced number of patients with the number of doctors [3]. The scarcity of physicians becomes an obstacle for people who consult to get the best treatment solution associated with the disease suffered.

Therefore, designing a KBS is critical to fill this gap in order to help patients with the diagnosis and treatment process. It helps health workers to use as a means of reference or guidance. Additionally, it gives high-level medical health care service for eye disease problems and it will play its own role in the field of medical studies and for the newcomers as a means of knowledge transfer tools [25].

There are different researches that have been done on knowledge-based eye diagnosis and treatment systems independently [45]. Jenefa [28] attempted to design a machine doctor that diagnosing the ophthalmology problem. He used neural network algorithms to get the input by using the back propagation algorithm and design the knowledge-based system by using a case-based knowledge representation method. In addition, Munaiseche [29] conducted research to design an expert system for diagnosis of eye diseases and it was a web-based expert system. Naser and Zaiter [27] designed a knowledge-based system to diagnose eye diseases. They conducted research in rule-based knowledge representation by using a forward chaining mechanism. According to Prentzas [12], the rule-based approach to the development of the knowledge-based system has drawbacks such as; it is not possible to draw conclusions from rules when there are missing values in the input data. For a specific rule, a certain number of condition values must be known in order to evaluate the logical function connecting its conditions. In addition, rules do not perform well in cases of unexpected input values or combinations of them. On the other hand, Case-based reasoning has an inability to express general knowledge. Cases, by nature, express specialized knowledge. So, they cannot express general knowledge. This is a disadvantage compared to rule-based systems.

The previous research studies on eye disease diagnosis are done by using rule-based or case-based reasoning independently. As to the researcher's knowledge, there is no study conducted to design KBS by integrating rule-based and case-based reasoning techniques for eye disease diagnosis and treatment. However, Saraiva et al [65] conducted research by a hybrid approach using CBR and RBR to assist healthcare professionals in the early diagnosis of patients with cancer. They use CBR and RBR because rules and cases are complementary and to improve the probability of CBR or RBR to converge the best solution. Azeb [66] on her work combine rule-based reasoning with existing case-based reasoning for Oil Drainage Company. So, on her finding, she stated that the combination of RBR and CBR improves the accuracy of the decisions of the company.

Therefore, the current study aims to explore and design a KBS for eye disease diagnosis and treatment by integrating CBR and RBR knowledge representation techniques for better performance. To the end, this study attempts to explore and answers the following research questions.

- What are the suitable domain knowledge and cases experts' use for the diagnosis and treatment of eye diseases?
- How to integrate CBR and RBR in designing a knowledge-based system?
- What are the proposed system performance and user acceptance of the prototype?

1.3. The objective of the Study

1.3.1. General Objective

The general objective of the study is to integrate case-based and rule-based reasoning approaches for the diagnosis and treatment of eye diseases.

1.3.2. Specific Objectives

To achieve the general objective of this study, the following specific objectives are formulated.

- To acquire the required domain knowledge from the domain experts and previously solved cases from files
- To model and represent rules and cases for designing rule base and case base respectively
- To integrate RBR and CBR to come up with a prototype for diagnosis and treatment of eye diseases
- To evaluate the performance and user acceptance of the proposed prototype system

1.4. Scope and limitation of the Study

The study focuses on integrating rule-based and case-based reasoning for diagnosis and gives medical treatments for eye disease patients and practitioners. There are more than thirty known eye diseases in the world [23,31], but the study focuses only on Cataract, Dry eye syndrome, Glaucoma, Presbyopia, Myopia, Hypermetropia, Astigmatism, Retinal Detached, Conjunctivitis, Strabismus, Diabetic Retinopathy and Uveitis of eye diseases which are frequently occurring eye diseases in Ethiopia [30, 31,32].

The researcher acquired the knowledge from Jimma University specialized hospital doctors, ophthalmologists, and residents as a primary data source. Additionally, previously solved cases from eye patient record files in JUSH, document analysis from different kinds of literature; books, journal articles, conference papers, and the internet have been acquired as the secondary data sources. In the course of designing a KBS, the research follows knowledge acquisition, knowledge modeling, knowledge representation and integration of rule-based and case-based reasoning so as to come up with a knowledge-based system for diagnosis and treatment of eye diseases.

This study has some limitations, due to a shortage of time, this study did not include an advisory facility for providing an explanation of what and how it reaches to decision. The study also has a limitation on designing an integration system of combination that accepts the query, sends the query for both reasoning at the same time, compares the result and selects the most relevant solution as a balanced approach.

1.5. Significance of the Study

The knowledge-based system tries to solve a problem like a human expert by using knowledge of application (expert) and problem-solving techniques. The general objective of this study is to design KBS by integrating rule-based reasoning (RBR) and case-based reasoning (CBR) to reduce the problem of the limited numbers of experts in giving preliminary diagnosis and treatment of eye disease, especially in rural areas.

Thus, the system mainly benefits primary health care workers and health professionals working on the diagnosis and treatment of eye disease. The prototype system could give advisory services for health professionals who have basic skills in health care. Furthermore, it used by physicians as a knowledge sharing tool for stakeholders in the sector especially hospitals, clinics and health extension workers, junior nurses and health officers who do not have deep knowledge about eye diseases and work in remote areas of Ethiopia which have a shortage of professionals. The prototype system is designed by using the knowledge of multiple eye disease domain experts, documentary sources which are used as organizational memory and previously solved cases of patient’s card. Therefore, it gives better advisory services where highly qualified ophthalmologists are not found. So, the study reduces the workload of eye specialists in the field. Finally, it is useful for other researchers in pointing to areas that need further investigation so as to design an intelligent system that can be usable in the medical sector.

1.6. Research Methodology

The research methodology is the systematic, theoretical analysis of the methods applied to a field of study [63]. It comprises the theoretical analysis of the body of methods and principles associated with a branch of knowledge [39]. According to Kumar [63], research methodology is a collection of procedures, techniques, tools, and documentation aids which will help the system developers in their efforts to implement a new information system. The methodology is the general research strategy that outlines the way in which research is to be undertaken and, among other things, identifies the methods to be used in it [55].

1.6.1. Research Design

A research design is a plan, structure, and strategy of an investigation so conceived as to obtain answers to research questions or problems [63]. In this study, a design science research approach is used to design a KBS for eye disease diagnosis and treatment. According to Peffers [35] and Hevner [67] design science is an outcome-based information science research methodology, which offers special guidelines for evaluation and iteration within the research design. As per their recommendation design science is an effective research methodology for artifact design researches. In design science, the process is structured in three main phases which are problem identification, solution design, and evaluation that can interact with each other within the research process [33].

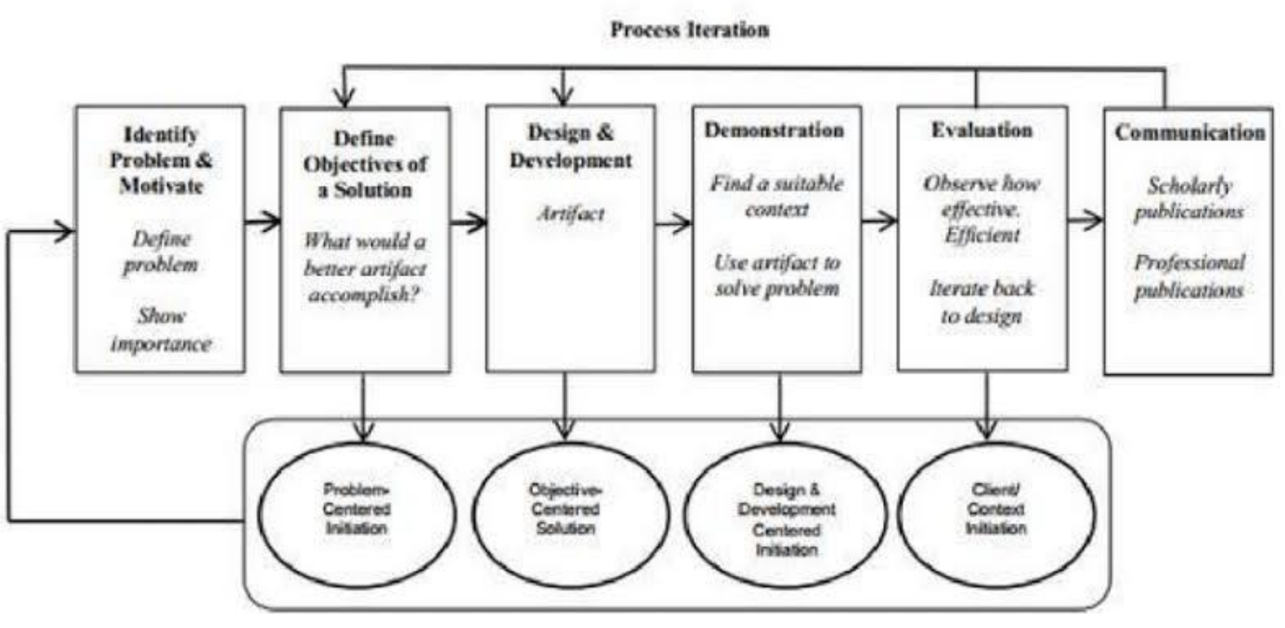


Figure 1.1 Design science processing model [35]

Figure 1.1 shows the process model of design science research methodology, in which each phase is divided into six steps as preferred by Peffers [35]. As a result, this study has followed the design science process model to come with an artifact, the prototype that integrates rule-based reasoning and case-based reasoning.

1.6.2. Identify Problem and Motivation

In this study to identify the problem of the study, the researcher has been done different techniques to achieve the objectives of the study. The study area of this research was Jimma University Specialized Hospital (JUSH) which exists in Oromia regional state of Ethiopia, in the city of Jimma. JUSH is selected as a study area since it is one of the oldest public hospitals in Ethiopia and it gives medical service for all which comes from the west and south region of Ethiopia. So, it has lots of recorded documents than other hospitals in order to get the required knowledge. In addition to that, there are experienced experts because it is an educational hospital in Ethiopia. The populations of this study were eye specialists, resident doctors, and ophthalmologists which have a direct relation with the ophthalmology field of study in Jimma University specialized hospital.

In this study, a purposive sampling technique has been used to select domain experts for knowledge acquisition. Purposive sampling is one of the most common sampling techniques in qualitative research. The criterion to select domain experts for the study was by considering their professions, educational qualification level and years of experience in the diagnosis and treatment of eye diseases.

Initially, to get some overview of eye diseases different interviews were conducted with ten experts that include eye specialists, resident doctors, and ophthalmologists. Among these, five experts were selected purposively for detail discussions using structured and unstructured interviews to discover relevant domain knowledge, for further consultations, system testing and evaluation throughout the study. The rest five experts were consulted in case of selection, in the registration of the patient cases from the card and also in user acceptance evaluation. For the CBR development and system testing, 72 previously solved cases of eye patients from Jimma University Specialized Hospital were collected (see Appendix VI and VII). Even if there is no standard number of cases to be used for CBR system development, the researcher used as a benchmark Salem [34], Saraiva et al. [65], Ethiopia [64] and Henok [18] who used 42, 48, 39 and 45 cases respectively for building and testing their prototype. Also, the data collection is so challenging in terms of time to add more cases.

The researcher has been used in different knowledge acquisition techniques. These are manual knowledge acquisition mechanisms, both interview, and document analysis of other factors as primary and secondary data collection methods to collect the required domain knowledge. One of the data sources for this study is the dataset of previously solved cases and solving experience. The researcher conducted structured and semi-structured interviews with two doctors, two ophthalmologists and one resident who work in JUSH. In document analysis, relevant literature from all possible sources, including the internet, books, journals and articles, different previous researches, prototypes, the guideline for eye diseases was used. In order to get the required information for the research and comments at different stages of experimentation and evaluation unstructured interview was done with purposively selected domain experts at JUSH. Generally, the researcher has acquired knowledge by using different interviewing with domain experts, document analysis and previously solved cases.

1.6.3. Define the Objective of a Solution

After collecting the required knowledge from domain experts, documents and previously solved cases, the next step is defining and setting objectives of the solution. In this study, the researchers used different methods to set the objectives of the solution to identified problems. The first method is modeling the collected knowledge by using a knowledge modeling technique to clarify the structure of knowledge. The next method is presenting that knowledge by using appropriate knowledge representation techniques. For this study, the researcher used case and rule representation methods. After the necessary knowledge is represented the next step is designing architecture for the prototype system. After designing the architecture, the represented knowledge is coded into the computer by using appropriate and efficient knowledge-based system development tools. For this study, the researcher used Prolog, JCOLIBRI, and Java Eclipse programming languages for developing the rule-based system, case-based system, and integration of them.

1.6.4. Design and Development

The design and development of the prototype system involve knowledge acquisition and representation. After that represented knowledge has been coded into a computer by using appropriate and efficient knowledge-based system development tools.

In the process of knowledge-based system development, knowledge modeling is one of the basic steps. Knowledge modeling or conceptual modeling is a technique that helps to clarify the structure of a knowledge concentrated task. The knowledge model of an application provides a specification of the data and knowledge structures required for the application [39]. There are three types of knowledge modeling in KBS which are ladders, network diagrams, and tables and grids. From those modeling tools, the decision tree is widely used [40]. Hence, in this study, the researcher has been used a decision tree knowledge modeling tool to clarify the structure of data, organize and to break down the clusters of data demonstration.

Hereafter knowledge representation is done. Knowledge representation refers to the formalism, both syntax and semantics, used to store knowledge in the architecture [36]. It is also the process of interpreting domain knowledge into computer understandable form using various knowledge representation techniques. The aim of knowledge representation is to express knowledge in a computer tractable form so that it can be used to enable the artificial intelligent agents to perform well [36]. From common knowledge representation techniques, the researcher has been used as a case-based and rule-based reasoning method for this research.

Although there are various case representation methods, like relational database knowledge representation, feature-value case representation, predicate based representation, and soft computing knowledge representation methods which have their own advantages and disadvantages [37], for this research the researcher has been used feature-value case representation. The reason for representing the cases using feature-value representation is that this approach supports the nearest neighbor retrieval algorithm and it represents cases in an easy way [34]. This approach also uses old experiences to understand and solve new problems. It also reuses its solutions and lessons learned for future use. Case retrieval (similarity measurement) usually falls into one of four categories: nearest neighbor, inductive learning, knowledge-guide, and a combination of these [38]. The algorithm that was used to calculate the similarity of cases in a case-base representation for this research is the nearest neighbor retrieval algorithm. The similarity function of the nearest neighbor retrieval algorithm involves computing the similarity between the stored cases in the case-base and the new query.

There are also two major forms of rule-based reasoning; i.e., forward chaining and backward chaining. Forward chaining starts form facts and it applies rules to find all possible conclusions. It is data-driven not goal-oriented [39]. Backward chaining starts with the desired conclusion and works backward to find support in facts and it is also goal-oriented [9]. The algorithms that have been used in rule-based representation are forward chaining for this study.

The rule-based reasoning system has domain knowledge encoded in the form of rules from domain experts. A rule is a conditional statement that links given conditions to actions. In a rule-based reasoning system, a knowledge-base is usually stored in terms of if-then rules which can be used to reach conclusions. Case-based reasoning is a process that uses similar cases to solve the current problem. Rules represent general knowledge of the domain, whereas cases represent specific knowledge. Rule-based systems solve problems from scratch, while case-based systems use pre-stored situations to deal with similar new instances. Therefore, the integration of both approaches turns out to be natural and useful in the system [22].

To design and develop KBS there are various programming tools that are available both freely and commercially. Among this JCOLIBRI, Eclipse and SWI-prolog are the most widely used KBS development tools and known frameworks for teaching and academic research purpose [39]. All of the aforementioned tools have their own capabilities and limitations. Hence, in this study for the development of the prototype system the researcher has been used JCOLIBERI version 1.1 which is an object-oriented framework for CBR development. Java Eclipse Photon 4.8.0 with JDK 8 is also used to develop the combination of RBR and CBR and user interface. SWI-prolog 6.4 is also used for RBR independent system.

1.6.5. Demonstration

In this study system demonstration is used to test and evaluate the full system functionality and user acceptance of the prototype system. Evaluators followed the demo steps of the prototype system in system evaluation and user acceptance testing period. The main interface of the prototype system is designed by using java eclipse programing language, so as the demonstration is prototype-based, users can run it from the source code. After running, the RBR user interface is displayed and it has approximately 22 different signs and symptoms of eye diseases. From the listed symptoms users select the exact sign and symptom that the patient feels by choosing 'yes' and 'no' button. After selecting the symptoms users can click the 'Check' bottom to view the result. There is also the 'Reset' option if users want to re-choose the sign and symptoms again. If the RBR system finds the right disease as per the feelings of the patient, the diagnosis result and treatment will be displayed in the right side of the window, else the system will offer the CBR system to consult. After users click the 'Exit' bottom the CBR system will be opened. The CBR system is developed by using JCOLIBRI programming language, so users select obtain query task option and select the attributes which identify the eye disease diagnosing symptoms. After that, the retrieving tasks which are select working cases task, compute similarity task and select the best task will be done. After users find the best similar eye disease diagnosis result and treatment, they can do reuse, revise and retain options to learn the new case into the system.

1.6.6. Evaluation

Once the prototype is developed and demonstrated, the functionality and user acceptance of the system should be tested. The evaluation processes focus on the performance of the system and user acceptance of the prototype. Five professionals have been selected purposively to evaluate the system and they evaluated the system by using twenty-four (24) prepared test cases. Each case has been selected purposively and used to test the performance of the prototype. Based on that, they evaluate the performance of the system by using close-ended questions. The accuracy value of the system has been calculated based on its retrieval results using recall and precision. The researcher has been tested the user acceptance of the system by using checklist questions (see Appendix II). For this purpose, ten evaluators have been used from previously selected domain experts. The selected individuals evaluate the system effectiveness, error tolerance, efficiency, easiness to learn and easiness to remember [58].

1.6.7. Communication

In the meantime, this research study is submitted for Jimma University Information Science department as the partial fulfillment of the requirements for the degree of Master of Science in Information Knowledge and Management, but for the future, it will be sent for publication on journal articles.

1.7. Operational Definition

- **Integration:** is the process of linking together different computing systems and software applications physically or functionally, to act as a coordinated whole.

- **Combining:** refers to the end result of one system will be used as input for the other sub system.

- **Domain Expert:** - is a person who expertise in his/her domain area. In addition, a network administrator who manages and administers a given network is a domain expert in his domain.
- **Knowledge Engineer**: - is one who gathers knowledge from experts through interview or using automatic knowledge acquisition techniques. The knowledge engineer has to have the knowledge of a knowledge base development technology and should know how to develop an integrated system of Rule based system and Case based system using a development environment.
- **Design Science:** is an outcome based information technology research methodology, which offers specific guidelines for evaluation and iteration within research projects.

1.8. Organization of the Thesis

This thesis is structured into six chapters. The **first chapter** discusses the background to the study, problem area, and statement of the problem, objective of the study, scope and limitation of the study, significant of the study and research methodology. The **second chapter** reviews the conceptual literature review, i.e. knowledge-based system, the architecture of KBS, knowledge acquisition, modeling and representation, KBS evaluation and test technique and KBS development tools. In related literature reviewed discussed different research studies related to this research study. The **third chapter** deals with understanding the methods and processes of the system. The proposed system knowledge acquisition process, knowledge modeling, and knowledge representation technique. The **fourth chapter** deals with the design and development of the prototype system the prototype architecture, building RBR system, Building CBR system, Building integrated RBR and CBR system. The **fifth chapter** deals with the demonstration and evaluation of the developed prototype system and discussion of results. The **sixth chapter** presents the conclusions and recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

This chapter review different kinds of literature on knowledge-based system concept, architecture, knowledge acquisition, knowledge modeling, and knowledge representation methods. Furthermore, it presents KBS development tools and related works done for designing and developing KBS in the medical domain.

2.1. Overview of Knowledge-based System

A knowledge-based system (KBS) is one branch of artificial intelligence, which is a growing research area that uses approaches and techniques of artificial intelligence and expert system in problem-solving processes [11]. It is a software system that contains a significant amount of knowledge in an explicit and declarative form. KBS has been referred to with a variety of names such as expert systems, epistemological systems and design, intelligent assistants and analysis systems. The two terms most popular in common usage, often used synonymously, are KBS and expert systems [41].

KBS emulates the behavior of human experts within a well-defined and narrow domain of knowledge. 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. It contains a knowledge-based that accumulated experience and a set of rules and cases [42].

Different scholars and authors referencing knowledge-based systems in different explanations, from those definitions here are some of them. According to Anand & Jeffrey [43], a knowledge-based system is used to organize and store complex structured and unstructured knowledge such that a computer system can help in decision making. The initial use of the term was in connection with expert systems which were the first knowledge-based systems. Mumine [44] stated that a knowledge-based system is considered as a major branch of artificial intelligence. They are capable of making decisions based on the knowledge residing in them and can understand the context of the data that is being processed. Another scholar [11] also defines a knowledge-based system as, software that attempts to reproduce the performance of one or more human experts, most commonly in a specific problem domain and is a traditional application and/or subfield of artificial intelligence [45].

KBS's are sophisticated interactive computer programs that solve complex problems in that domain which use high quality, specialized knowledge in some narrow problem domain [44]. It also names as expert systems, assistants, epistemological systems and design and analysis systems. Usually, scholars also use KBS and expert systems interchangeably. KBS emulates the behavior of human experts within a well-defined and narrow domain of knowledge. It is a system that draws upon the knowledge of human experts captured and stored in a knowledge-base to solve problems that normally require human expertise [46].

2.2. The architecture of Knowledge-based System

Architecture is a blueprint that is used to indicate the structure of a system [47]. The system architecture is a conceptual model that defines the structure and guidelines of the system. It also helps to describe a set of convections, rules, tools, and standards that should be incorporated in the corresponding systems. The structure of a typical KBS contains components like knowledge-base, inference engine, explanation or reasoning facility, user interface, and self-learning, as shown in figure 2.1. All the different components interact together in simulating the problem solving and decision-making process [47]

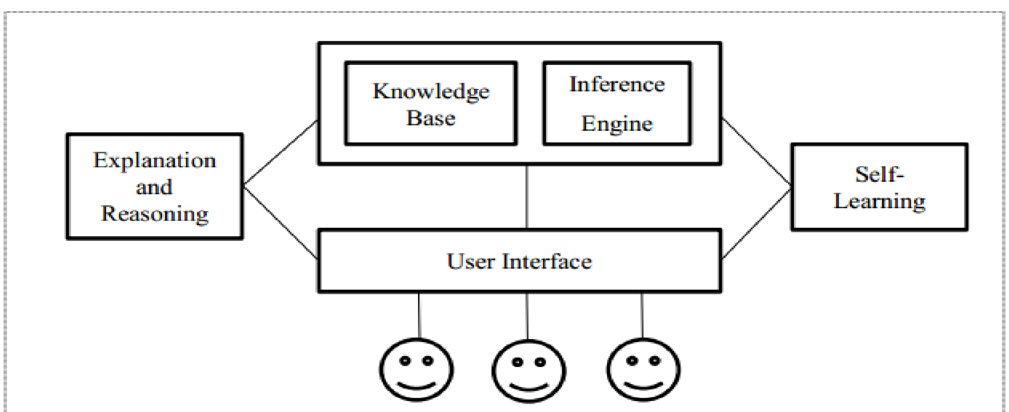


Figure 2.1 Generic architecture of a Knowledge-based System [15]

2.2.1. Knowledge-base

The knowledge-base is the core component of any knowledge-based system or expert system and it represents the repository of knowledge for a specific domain. It contains knowledge acquired from the domain expert that makes humans an accurate expert on a specific domain. In any knowledge-base, there are many facts, rules, and Metaknowledge. This knowledge is extracted from the human experts and encoded in knowledge-based using different knowledge representation techniques. In a knowledge-based system, the main techniques used for representing the knowledge are rule-base and case-base. A rule-base can combine the knowledge of multiple human experts [39], whereas a case base organizes previously solved cases [9].

2.2.2. Inference Engine

The inference engine is the component that provides a methodology for reasoning and formulating conclusions. The inference engine provides directions about how to use the system's knowledge to solve problems. The purpose of the inference engine is to seek information and relationships from the knowledge-base and to provide answers, predictions, and suggestions in the way a human expert would. The inference engine must find the right facts, interpretations, rules and assembles them correctly [48].

2.2.3. Explanation Facility

The explanation subsystem helps in justification of knowledge-based system conclusions by tracing conclusions to their sources and showing how was a certain conclusion reached. One of the key characteristics of a knowledge-based system is the explanation facility. With this capability, it can explain how it arrives at its conclusions. The user can ask questions dealing with the what, how and why aspects of a problem. The knowledge-based system will then provide the user with a trace of the consultation process, pointing out the key reasoning paths followed during the consultation. The explanation facility helps the knowledge-based system to clarify and justify why such a digression might be needed. The explanation facility allows a user to understand how the knowledge-based system arrived at certain results [39, 48].

2.2.4. Learning

Learning is one of the elements of KBS which tries to imitate the learning capability of human beings. It is possible to update the knowledge-base of the KBS either manually, semi-automatically or automatically using machine learning algorithms [15].

According to Akerkar & Sajja [15], "Self-learning is a scientific task that enables the KBS to learn automatically from the inference process, cases executed, and environment. To carry out such tasks, one needs to have a control mechanism that discovers general conjectures and knowledge from specific data and experience, based on sound statistical and computational principles". One of the key characteristics of KBS is the capability to learn and update its knowledge.

According to Castillo & Hadi [49], there are three methods of learning. These are structural learning, parametric learning, and learning by memorization. Structural learning denotes certain features associated with the structure of knowledge such as rules and probability distributions. For example, finding a new related symptom for a certain disease or incorporating a new rule in the knowledge-base. Parametric learning denotes to conjecturing the parameters required to build the knowledge-base. For example, the conjecture of probabilities associated with symptoms or diseases. Learning by memorization denotes the capability of KBS to learn from experience based on the existing data. Using this method, KBS can carry out different activities such as storing or memorizing knowledge and learning from the facts base.

2.2.5. User Interface

The user interface is one of the major components of a KBS which allows bi-directional communication between system and user. It is considered to be a critical part of the success of an expert system. The user interface consists of all screens of interaction between the user and the KBS. The purpose of the user interface is to ease the use of the KBS for developers, users, and administrators [39].

The input/output interface defines the way in which the KBS interacts with the user and other systems. Interfaces are usually graphical with screen displays, windowing, and mouse control. They receive input from the user and display output to the user. Some systems use natural language front ends that accept English-like responses but most use a graphical user interface (GUI) with a mouse device to allow the user to choose from selections in dialog boxes and menu bars [48].

2.2.6. Domain Expert and knowledge engineer

Domain Expert is a knowledgeable and skilled person capable of solving problems in a specific area or domain. This person has the greatest expertise in a given domain. In KBS development, the expertise has been captured in the KBS. Therefore, the expert must be able to communicate his or her knowledge, be willing to participate in the KBS development and commit a substantial amount of time to the program development. The domain expert is the most important player in the KBS development team [50].

The knowledge engineer is someone who is capable of designing, building and testing KBS. The knowledge engineer interviews the expert to elicit his or her knowledge; the knowledge engineer encodes the elicited knowledge for the knowledge-base; 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 KBS; and chooses some development software or KBS shell, or looks at programming languages for encoding the knowledge [48].

2.3. Development of Knowledge-Based System

The main task of designing a knowledge-based system is to transfer the expertise and knowledge acquired from multiple experts and codified materials to a computer program. This task of KBS developers (knowledge engineers) is to carry out such a transformation to the system such that the system can reach the desired level. This step will vary depending on the characteristics of the program, the objectives selected. However, stages depicted in figure 2.2 are normally used in the development of a KBS [39]. The steps in the KBS development process include determining the actual requirements, knowledge acquisition, knowledge representation, knowledge base construction, knowledge modeling, and knowledge verification and validation [15].

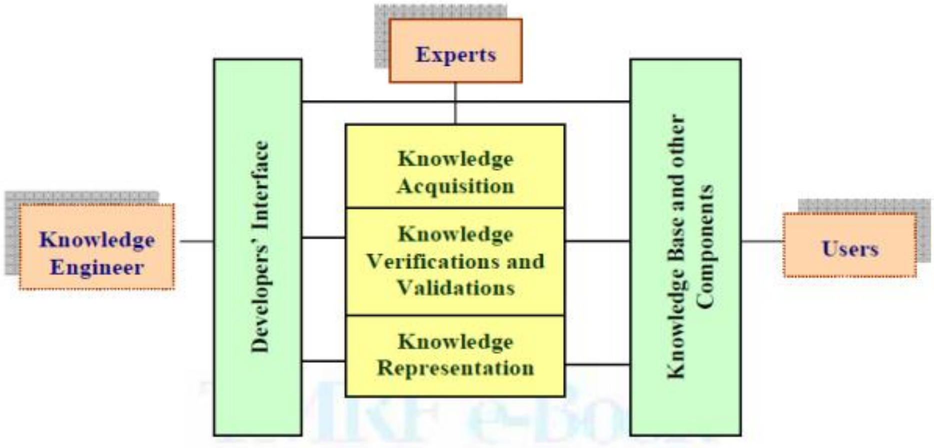


Figure 2.2 Developments of KBS [15]

2.3.1. Knowledge Acquisition

The first task in the development of KBS is knowledge acquisition. Knowledge acquisition is considered as one of the most important phases in the expert system development life cycle [48]. Knowledge acquisition is the process of eliciting, structuring and representing (formalizing) knowledge from some knowledge source in order to construct a KBS. In other words, knowledge acquisition is an important obstacle and time consuming when constructing KBS. It is one of the most difficult and error-prone tasks that a knowledge engineer does while building a KBS [48]. This task of expert system developers (knowledge engineers) is to carry out such a transformation and to the system can reach the desired level. The knowledge acquisition process incorporates different methods such as interviews, questionnaires, record reviews, observation or document analysis to acquire factual and explicit knowledge.

An interview is the most commonly used knowledge acquisition technique from domain experts [51]. It can be in a form such as structured, semi-structured and unstructured interviews [51]. The structured interview is a systematic, goal-oriented process. It forces organized communication between the knowledge engineer and the expert. Therefore, interpersonal communication and analytic skills are important. However, several guidelines, check-lists, and instruments are available that are fairly generic in nature. The semi-structured interview is an interview that has a guide that usually includes both closed-ended and open-ended questions. It is more flexible than a structured one. In these kinds of interviews, the interviewer has a chance to change the order of questions and expand the dimension of questions based on the participant's responses. Unstructured interviews in many knowledge acquisition interview sessions are conducted informally, usually as a starting point. Starting informally saves time; it helps to move quickly to the basic structure of the domain. Usually, it is followed by a formal technique [51].

A questionnaire is a research instrument consisting of a series of questions for the purpose of gathering information from respondents [39]. It has advantages over some other types of surveys in that they are cheap, do not require as much effort from the questioner as verbal or telephone surveys, and often have standardized answers that make it simple to compile data. Questionnaires are also sharply limited by the fact that respondents must be able to read the questions and respond to them [51].

Observation involves direct observation by knowledge engineers or KBS developers while domain expert(s) are performing their tasks. Similar to interviewing, observation may take different forms like on-site observation which means the process of recognizing and noting people, objects and gets the information, discourse analysis which means the study of real language use, by real speakers in real situations and active participation which means the way of working that supports an individual's right to participate in the activities and relationships of everyday life as independently as possible [52].

Document Analysis involves gathering knowledge from existing documentation. Document analysis may involve the interaction with a human expert to confirm or add to the existing information or knowledge. These documents include professional literature, brochures, manuals, guidelines, employee handbooks, reports, glossaries, course texts, and other relevant materials [53].

For this study, the researcher used different interviewing and questionnaire techniques with domain experts for knowledge acquisition and system evaluation. Additional document analysis including recorded compliant file was used in the knowledge acquisition phase.

2.3.2. Knowledge Modeling

Knowledge modeling is a structured representation of acquired knowledge using symbols to represent pieces of knowledge and relationships between them [16]. Knowledge models include symbolic character-based languages like logic, diagrammatic representations such as networks and ladders, tabular representation like matrices and structured text such as hypertext [16]. The model helps to ensure that all stakeholders understand the language and terminology being used and quickly conveys information for validation and modification where necessary. The knowledge models are also great value during cross-validation with other specialists [54].

Knowledge engineers make use of a number of ways of representing knowledge when acquiring knowledge from experts. These are usually referred to as knowledge models. According to Epistemics [40], there are three important types of knowledge models, such as Ladders, Network diagrams, and Tables and Grids. Ladders are hierarchical (tree-like) diagrams. Some important types of ladders are a concept ladder, decision tree ladder, composition ladder, and attribute ladder [40]. Network diagrams show nodes connected by arrows. Depending on the type of network diagram, the nodes represent any type of concept, attribute, value or task, and the arrows show any type of relationship between the nodes. Examples of network diagrams include concept maps, process maps, and state transition networks. Tables and Grids are tabular representations that make use of tables or grids. Three important types are forms, frames, timelines and matrices/grids. For this study, the researcher used the decision tree knowledge modeling technique because it is suitable for modeling both case-based and rule-based reasoning [16].

2.3.3. Knowledge Representation

Knowledge representation is the process of encoding human knowledge in computer understandable form. It is concerned with designing and using systems for storing knowledge [52]. The purpose of knowledge representation is to organize the acquired and modeled knowledge into a form that a KBS can readily access for decision making [15]. It is a means of encoding the domain expert's knowledge in a suitable medium. The common techniques of knowledge representation are frame base, semantic networks, case-based reasoning, and rule-based reasoning [52]. Some of them are described as follows:

Frames Based Technique

If we need to focus on the properties of certain objects, then using frames and objects is a good choice. A frame is a node with the additional structure that facilitates differentiated relationships between objects and properties of objects. It is a collection of concepts, one or more slots, one or more attached procedures, and one or more values that describe some real-world entity [39]. As noted by Abdullah [52], each frame represents a class (set) or an instance (an element of a class). Frames are the application of object-oriented programming for expert systems. The concept of a frame is defined by a collection of slots. Each slot describes a particular attribute or operation of the frame. Slots are used to store values. A slot may contain, a default value or a pointer to another frame, a set of rules or procedures by which the slot value is obtained [52].

Semantic Networks Technique

Semantic networks are an alternative to predicate logic as a form of knowledge representation and it focuses on the relationships between different concepts. The knowledge can be stored in the form of a graph, with nodes representing objects in the world, and arcs representing relationships between those objects. The semantic networks also called Associative Network [52].

Production Based System

In a production system, data and concepts in working memory are associated with data and procedures in long-term memory. Rules are encoded as condition-action pairs: Condition ⇒ Action. The system implements an "inference engine" that operates as a 3-phase cycle [55]. The cycle is also called the "recognize act" cycle. The phases are:

- Match: match facts in working memory to conditions of rules to produce "activations" (associations of WM and rules).
- Select: Select activation for execution.
- Execute: Execute the actions specified in the activation.

In this architecture, each element in working memory is labeled with an index. In each cycle, the conditions part of the rules is matched to the working memory. The association of working memory and rules are stored in an agenda as "activations". One of these activations is then selected for execution. The list of associations of facts and rules are stored in an agenda. One of the associations is selected for execution. There are several different models for how to sort the agenda. The most popular is to use a stack, "Last in First Out" or LIFO [39].

Ontology

In terms of ontology, concepts are formal representations of notions from the real world. To represent the knowledge of concepts and the relationships between them, the following – often together – can be used: logical expressions such as subsumption, equivalence, disjointness, and negation [38].

- Creating the hierarchy of concepts is one of the most common applications of ontology. It is based on the use of subsumption which is defined in description logic in the following way [38]. $B \subseteq A$, where concept A subsumes concept B, this means that concept B is contained in concept A. A subsumption has a transitive nature and thus a classic syllogism takes place [38]: $B \subseteq A \wedge C \subseteq B \Rightarrow C \subseteq A$

- The equivalence or identicalness of concepts appears when individuals who are instances of these concepts are always identical. This is written as follows [38]: $B \equiv A$

- Disjointness of two concepts means that there can be no individual which would simultaneously belong to both of them. Thus, the intersection of the two disjoint concepts is an empty concept ($\bot$), which can be written as [38]: $A \cap B \subseteq \bot$

- Sometimes the easiest way to say what a thing is to point out what it is not. This is one of the possible applications of the structure called the negation of a concept. To write that concept B is not concept A, we will use the following notation [38]: $B \subseteq \neg A$

2.4. Reasoning mechanisms

The reasoning is the process of thinking about things in a logical, rational way. It is considered an innate human ability that has been formalized by fields such as logic, mathematics and artificial intelligence [9]. The process of reasoning is used to make decisions, solve problems and differs in terms of handling uncertainty and partial truths [39]. The most popular reasoning mechanisms used in artificial are rule-based reasoning (RBR) and case-based reasoning (CBR). These emerge as two important and complementary reasoning mechanisms in artificial intelligence. The reasoning architecture of CBR consists of a case library (stored representations of previous experiences/problems solved) and an inference cycle [47]. The important steps in the inference cycle of CBR are to find and retrieve cases from the case library that are most relevant to the problem at hand (input) and adapt the retrieved cases to the current input. The reasoning architecture of rule-based systems has two major components: the knowledge base (usually consisting of a set of (IF … THEN), rules representing domain knowledge) and the inference engine (usually containing some domain-independent inference mechanisms, such as forward and backward chaining) [9].

2.4.1. Case-Based Reasoning

Case-based reasoning is a process that uses similar problems to solve the current problem [9]. It consists of two steps. First, it finds those cases in memory that solved a problem similar to the current problem and then adapts previous solutions to fit the current problem [39]. 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. The solution is tested and if found successful, added to the case library.

Knowledge acquisition is easier in case-based reasoning because of the granularity of knowledge [9]. Knowledge is presented in precedent or resultant cases. Beyond the knowledge representation language (rules, semantic nets, frames, cases), the knowledge engineer needs further aids such as tools to edit the knowledge-base; inference tracers to assist in error detection; and analytical tools to find, update and consistently check the represented knowledge or attributes [39].

Case-Based Reasoning (CBR) system is a reasoning methodology that simulates human reasoning using past experiences to solve new problems. Generally, the problem-solving cycle of the classical CBR model consists of four steps [9, 47]: retrieve, reuse, revise and retain.

a. Retrieve

In CBR, retrieval is remembering previous cases stored in the case-base to solve new problems at hand. The first step which is the most important step in the CBR cycle is the retrieval of previous cases that can be used to solve the target situation (new problem). Given a target problem, retrieve cases from memory that are relevant to solving it. A case consists of a problem description, its solution, and typically annotations about how the solution was derived [55]. In CBR there are different case retrieval algorithms but the two most frequently used are nearest neighbor and induction case retrieval algorithms [56]. These algorithms can be used alone or in combination with each other.

The nearest-neighbor retrieval technique is to measure the similarity between the source case and the case which we are searching for. The nearest neighbor algorithm measures the similarity of stored cases with a new input case, based on matching a weighted sum of features. When a new case doesn't exactly match with old cases then this algorithm will return the nearest match from the CBR library. It is suitable when there are attributes that have numeric (continuous) value. But the retrieval time of this algorithm increases linearly as the case in the case-base increases [56].

Induction retrieval case retrieval algorithms depending on the size of the case-base, the information amount contained in single cases, and the complexity of the used similarity measure, the retrieval step is often a challenging task with respect to computation time. In order to manage this complexity, a large number of different retrieval strategies have been developed. In inductive retrieval, use past cases to extract rules or construct decision. This technique finds target case-based on index source case. Cases are divided into a decision tree structure. Inductive retrieval used to retrieve a set of matched cases and then nearest-neighbor retrieval rank these cases according to their similarity with the target case [55].

b. Reuse/Adapt

This step is responsible for reusing the solution of the most similar case to the new case. It may include the adaptation task in which the solution of the retrieved case is adapted to fit the new case. After selecting one or several similar cases, the reuse step tries to apply the contained solution information to solve the new problem. Often direct reuse of a retrieved solution is impossible due to differences between the current and the old problem situation. Then the retrieved solutions have to be modified in order to fit the new situation. How this adaptation is performed strongly depends on the particular application scenario [56].

c. Revise

This step is responsible for revising the suggested solution for confirmation. Depending on the employed adaptation procedure, the correctness of the suggested solution often cannot be guaranteed immediately. Then it becomes necessary to revise the solved case. How such a revision is performed, strongly depends on the particular application scenario. For example, it might be possible to apply the suggested solution in the real-world to see whether it works or not. However, often a direct application of an uncertain solution is impossible due to the corresponding risks. Then the revision has to be performed manually by a human domain expert or by alternative methods such as computer simulation [55].

d. Retain

This step is responsible for retaining the learned case for future use. If the solved case has passed the revising step successfully, a tested/repaired case will be available representing a new experience that might be used to solve similar problems in the future. The task of the CBR cycle's last step is to retain this new case knowledge for future usage. Therefore, the new case may be added to the case-base. In most cases, the general storage of all generated cases is not always useful. In order to enable better control of the to retain process; various approaches for selecting cases to be retained have been developed [55].

Advantages of case-based reasoning

According to Prentzas [55], some of the advantages of a case-based reasoning approach are discussed as follows:

- Generality: the ability to express specialized knowledge.
- The naturalness of representation: cases are a simple knowledge representation method and very comprehensible to the user.
- Modularity: each case is a discrete, independent knowledge unit that can be inserted into or removed from the case-base, without any problem.
- Easy knowledge acquisition: the process of knowledge acquisition in case-based representations is not usually a problem, due to the fact that in most application domains cases are available.

- Self-updatability: this facilitates the maintenance of the case-base.
- Handling unexpected or missing inputs: a case-based system can handle unexpected cases not recorded in the system or missing input values by assessing their similarity to stored cases and reusing relevant cases.
- Inference efficiency: adapting preexisting cases to handle new problems is usually more efficient than having to solve a problem from scratch as in rule-based.

Disadvantages of case-based reasoning

Case-based reasoning has some drawbacks besides its advantages discussed above. Some of the limitation issues in case-based reasoning are [55]:

- Inability to express general knowledge: cases, by nature, express specialized knowledge. So, they cannot express general knowledge.
- Knowledge acquisition problems: various knowledge acquisition problems may arise when dealing with domains, where cases are either unavailable or are available in a limited amount.
- Inference efficiency problems: the efficiency of the inference process in CBR is not always desirable.

2.4.2. Rule-based reasoning Technique

Rule-based reasoning is the most common and popular knowledge representation method in KBS [9]. Especially, in medical knowledge-based system development, rule-based representation methods have been the dominant knowledge representation scheme [9]. It is a system whose knowledge representation in a set of rules and facts. Symbolic rules are one of the most popular knowledge representation and reasoning methods. The basic forms of a rule, IF<condition> THEN<conclusion>, where <condition> represents premises, and <conclusion> represents associated action for the premises. The condition of the rules is connected between each other with logical connectives such as AND, OR, NOT, etc., thus forming a logical function. A typical rule-based system consists of a list of rules, a cluster of facts and an interpreter [39, 9]. The general forms of rules can be illustrated as [39]:

IF condition 1,
and condition 2,
and condition 3, ..., condition n
THEN action 1,
action 2, ..., action n

IF condition 1, condition 2, condition 3 … condition n is true, THEN action 1, action 2, action 3 ... action n. The conditions (condition 1, condition 2, condition 3, etc.) known as antecedents whereas the actions in the consequents (i.e., action 1, action 2, etc.) are known as consequents. Antecedents are evaluated based on what is currently known about the problem being solved. Such kinds of rules are talking to mean if all antecedents of the rule evaluate to true, the actions in the consequents can be executed. Each antecedent of a rule typically checks if the particular problem instance satisfies some conditions.

Types of rule-based reasoning

The two major forms of reasoning in the rule-based system are forward chaining and backward chaining inference mechanisms [39, 9].

Forward chaining also called data-driven approach, starts from the set of facts (the available data) and then checks if the given rules are satisfied. If there is matching then the rule is executed. This process continues until the goal is found (assuming that just one answer is required), or there are no new facts to be added. It helps in extracting more data until a goal is reached. An inference engine using forward chaining searches the inference rules until it finds one. Here the antecedent is known to be true [39].

Backward chaining also called goal-driven reasoning, works in reverse to forward chaining, and starts from the goal and tries to find data to prove its goal. After starting from the given goal, the search of THEN parts of the given rules (action part) is conducted, and if the rule is found and it's IF part (condition) matches the data in the database, then the rule is executed (fired). Otherwise, if the condition does not match the data (facts) in the database, the inference engine sets the rule that is working on a stack and makes a new sub-goal to prove the condition in the current rule. The knowledge-based keeps looking for rules to prove the sub-goal. The process of stacking the rules is repeated until the knowledge-base has no rules to prove the sub-goal [39].

Advantages of Rule-based Reasoning

Rule-based systems have good features. Sasikumar [9] stated the major advantages of rule-based representation of knowledge-based systems as follows.

- Rule-based systems have an advantage of the ability to express general knowledge.
- Declarative Nature: Rule-based representation method represents the knowledge of the world declaratively in the form of rules and facts.
- Homogeneity: Rule-based representation has uniform syntax. Hence, the meaning and interpretation of each rule can be easily analyzed.
- Simplicity: Rule-based representation has simple syntax. It uses English like human languages to write rules. Therefore, both technical and nontechnical persons can easily understand the rules. As a result, domain experts can often understand the rules without an explicit translation of them.
- Independence: In rule-based representation, a new rule can be added without affecting the existing rules. Each rule is an independent piece of knowledge about the domain.
- Modularity: A rule-based system exhibits a high degree of modularity. Each rule represents an independent piece of knowledge. Therefore, it is possible to add new rules without affecting already existing rules of the knowledge-base.
- Separation of Knowledge from use and control: In the rule-based representation method, there is a clear separation between the knowledge about the domain (facts) and the control (how the knowledge is to be used to solve the problems). In other words, the same inference engine can be used with different rule-bases and a rule-base can be used with different inference engines.

Disadvantages of Rule-based Reasoning

However, according to Prentzas [22], the following are the main disadvantages of rule-based knowledge representation.

  - Knowledge acquisition bottleneck: The standard way of acquiring rules through interviews with experts is cumbersome and time-consuming. The chief reasons are the inability of an expert to express his or her knowledge and the unavailability of experts

- Brittleness of rules: It is not possible to draw conclusions from rules when there are missing values in the input data. For a specific rule, a certain number of condition values must be known in order to evaluate the logical function connecting its conditions. In addition, rules do not perform well in cases of unexpected input values or combinations of them;
- Inference efficiency problems: In certain cases, the performance of the inference engine is not the desired one, especially in very large rule-bases. There are two main kinds of reasoning strategies employed in rule-based systems which include forward and backward chaining mechanism

In this research, the integration of a rule-based and case-based representation approach has been used. The reason to integrate the two approaches is due to their interchangeable nature. Integrating them provides effective knowledge representation, problem-solving power, and exceeding one‘s weakness with the other in different areas of applications.

2.5. Designing Integration of RBR and CBR

There has been enormous interest in integrated systems in the past two decades. Almost every conceivable problem has been approached by using some form of the integration system. Integrated systems are universally better than conventional approaches. The integrated system is intrinsically better as it is used in combination with two different techniques thereby increasing the strength and reducing the weakness [9]. Approaches integrating rule-based and case-based reasoning have given interesting and effective knowledge representation schemes [55].

The main objective of this study is to integrate CBR and RBR for designing a knowledge-based system. According to Khandelwal [61], the integration of rule-based with case-based reasoning is distinguished in three basic categories. The categorization is based on the importance of each of the two-component schemes in the inference process.

The first category includes approaches in which the rule-based component prevails in the inference process, whereas the case-based component plays a complementary role. The approaches belonging to this category usually focus on the rule-based component and invoke the case-based component only when rules are unable to deal with specialized situations. This approach is called rule-dominant approaches.

The second category consists of approaches in which the role of the integrated components is balanced, which means that none of the integrated components plays a supportive role. This approach is called balanced approaches. The approach described in [62] integrates rules and cases in an innovative way. The approach has been applied to a medical domain and more specifically to diabetic patient management.

The third category consists of approaches in which the case-based component plays a more important role and the rule-based component is less significant. In this paradigm, the rules play a supportive role in case-based reasoning, useful for instance when the case library contains a limited number of cases. The approaches belonging to this last category will be referred to as case-dominant approaches.

The goal of these integration efforts is to derive combined representations that augment the positive aspects of the integrated formalisms and simultaneously minimize their negative aspects. In this approach integrating rule-based and case-based reasoning improves efficiency and accuracy. The former concern integration methods in which rules and cases are dependent, meaning that one representation scheme was derived from the other (i.e., rules derived from cases or vice versa), and the efficiency of the integrated scheme exceeds the efficiency that could have been achieved with rules or cases alone. The latter involves approaches in which the two representation schemes are independent and their integration results in improved accuracy compared to each representation scheme working individually [55]. For this study, the researcher used the rule-dominant approaches in which rule-based components play an important role.

2.6. Evaluation and Testing of Knowledge-based System

Evaluation can be generally defined as the process of systematic assessment and endeavor of the worth of a system. Similarly, Anumba and Scott [57] defined knowledge-based system evaluation as "a process of examining the knowledge-based system's ability to solve real-world problems in a particular domain". The evaluation of a knowledge-based system aids to prove whether a system fulfills its specified objectives or not [58].

The knowledge-based system evaluation process involves the assessment of many aspects of a knowledge-based system. An effective knowledge-based system evaluation process, especially medical knowledge-based systems, incorporates both non-human (technical) and human (nontechnical) aspects [57]. Some of the non-human aspects include exploring the code, examining the correctness of reasoning techniques, checking the efficiency and performance of the system and detecting errors in the early age of a system. On the other hand, some of the non-technical issues include systems compatible with users' needs and desires, the easiness of the system for users, the quality of the user interface and the fitness of the system in real working environments of the domain area [58].

According to Abdullah [52], knowledge-based system evaluation may be divided into several phases. In most cases, the evaluation process of the knowledge-based system starts during the development of the system and can be split into verification, validation, and assessment of human factors.

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

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

Performance measures

Precision, Recall, and Accuracy is the common parameters used for measuring the performance of a certain classifier [39]. These parameters are defined in terms of the instances that are relevant and the instances that are correctly classified (or retrieved). The following table 2.1 shows the confusion matrix which can be used to calculate Precision, Recall, and Accuracy of the classifier.

Table 2.1 Metrics for performance evaluation [39]

	Predicted Class		
Actual Class		Class = YES	Class = NO
	Class = YES	TP	FP
	Class = NO	FN	TN

The precision (P) is the proportion of the classified information which is relevant, as calculated using the equation [39]:

$$P = \frac{TP}{(TP+FP)} \qquad (2.1)$$

The recall (R) is the proportion of the classified relevant information versus all relevant information, as calculated using the equation [39]:

$$R = \frac{TP}{(TP+FN)} \qquad (2.2)$$

The F-measure is the harmonic mean of precision and recall, as calculated using the equation [39]:

$$F = \frac{2*P*R}{(P+R)} \qquad (2.3)$$

The accuracy (AC) is the fraction of the total number of predictions that were correct, as calculated using the equation [39]:

$$AC = \frac{TP+TN}{(TP+FP+TN+FN)} \qquad (2.4)$$

From these system performance evaluation techniques, the researcher used accuracy for the purpose of prototype evaluation.

Assessment of Human Factors is a very essential part of the knowledge-based systems evaluation process, but it is the most neglected and forgotten issue by most system developers. This phase helps to answer users' acceptance question, "To what extent the system will be accepted and used by the users?", although a system has been verified and validated, it may be so uncomfortably designed and it cannot be used in real life. Therefore, systems that have been judged acceptable from the knowledge engineers' point of view may not necessarily be viewed positively by potential users [58].

There are varieties of methods to assess human factors of a knowledge-based system. Some of the most commonly used methods include interviews, checklist questions, log studies, reaction studies, and visual interaction. Among these checklists, the most commonly used method allows the experts or domain users to make comments while interacting with the system and hence in this study also the researcher used it for user acceptance system evaluation.

2.7. Tools Used in Knowledge-based System Development

Knowledge-based systems are usually written in special programming languages or tools. The most commonly available tools for the development of KBS are shells. A shell is a piece of software that provides a development framework, containing the user interface, a format for declarative knowledge in the knowledge-base and the inference engine. In KBS development both general-purpose programming languages like java and framework, l.NET and specific purpose readymade utilities of self-learning, explanation and inference, etc., such as Expert System Shell (JESS), CLIPS, Vidwan, prolog, Recall, JCOLIBRI are useful [15]. Some of these programming languages are discussed below.

SWI Prolog

SWI Prolog is the most comprehensive and widely used Prolog development environment. It has excellent development facilities. It supports a graphical debugging environment and a range of libraries that allow for graphical user interface implementation. Moreover, SWI Prolog is well maintained and available for all major platforms such as Windows, Mac OS, Linux, etc. The major advantage of SWI Prolog creates a friendly development environment: the graphical debugger is indispensable, and even the command-line interface offers some goodies like a help system, command completion and command history [13]. In this study, the researcher used the SWI prolog for the development of the rule-based system.

Java Eclipse

Java Eclipse is an integrated development environment (IDE) which is used in computer programming. It contains a base workspace and an extensible plug-in system for customizing the environment. Eclipse is written mostly in Java and its primary use is for developing Java application, but it may also be used to develop the application in other programming languages via plug-ins [60].

In this study, java eclipse is used for integrating the RBR and CBR system and user interface developments.

JCOLIBRI

JCOLIBRI is a technological evolution of COLIBRI and it is an object-oriented framework in Java which is designed for building CBR systems. It is a java-based tool and uses JavaBeans technology for case representation and generation of the user interface. This framework is developed by the GAIA artificial intelligence group at Completeness University in Madrid [59]. The framework is built in two hierarchical levels- upper and lower. The lower level consists of a library of classes (Software modules) for full 4REs CBR cycle (REtrieval, REuse, REvise and REtain), also for the definition of cases, attributes and connectors for access to outer databases. The upper level is the "black box" graphical interface, which allows non-complicated user case-based reasoning application generation based on lower levels modules. It is a non-commercial compatible tool that supports the full CBR cycle (Retrieval, Reuse, Revise and Retain). Using JCOLIBRI is also suitable for developing large scale applications [59]. In this study, JOCLIBRI is used for case-based system development.

2.8. Related works

Different researchers have attempted to apply rule-based and case-based reasoning techniques in medical diagnosis and treatment including eye diseases. The researcher reviews some research works that related to the knowledge-based system, case-based, and rule-based reasoning,

Naser and Zaiter [27] conducted research by using a rule-based reasoning approach for diagnosing eye diseases. The approach is applied to diagnose only four eye diseases such as discharge from the eye, bulging eye, double vision, and drooping eyelid. They used CLIPS language for prototype development and forward chaining mechanism for rule representation and the accuracy of the system is 80%. Because of the less learning capacity of RBR, the system is no self-learnable. For future work, they recommend the issue of self-learning for system improvement by using other knowledge representation techniques. The current study is different from this research with its attempt by integrating CBR with RBR towards designing an intelligent self-learning knowledge-based system.

Jenefa et al. [28] conducted research that can diagnose ophthalmology problems to give advice for rural people and make the machine doctor as user-friendly and cost-effective. They used the neural networks concept to get the input using the backpropagation algorithm. By using this backpropagation algorithm, they can train the network and detect ophthalmology problems and the prototype system scored 79.8% accuracy. According to the researcher's future recommendation training is takes more time and also it needs to correctly train the network if it is not properly trained means it does not provide accurate output. As a result, the current study is different from this research it uses the nearest neighbor retrieval algorithm for similarity measurement. It fluent in computing the similarity between the stored cases in the case-base and the new query to calculate the similarity of cases in CBR because it is not time-consuming to provide accurate output

Munaiseche et al. [29] conducted research on design an expert system application for diagnosing eye diseases using forward chaining. They also focus on extended to 16 types of eye diseases with 41 symptoms of the disease but their work is functioning only by their local language. The aim of the study was to design a web-based expert system that can recognize the type of eye disease in humans based on the symptoms experienced by patients. The researcher used the PHP programming language and MySQL as the relational database management system (RDBMS). The system uses a decision tree for RBR and it was no self-learnable. The system performance is 83.5%. As their recommendation to be able the system self-learns it is better to integrate with other knowledge representation techniques. As a result, the current study is different from this research by integrating CBR with RBR to enhance the system performance and to make the system self-learnable.

Based on the related work reviewed the researcher found that some of the studies used the RBR technique in the design of knowledge representation and others used CBR. However, both RBR and CBR have their own limitations. RBR has less learning capacity by itself, and not handling the unexpected cases or missing input. CBR, on the other hand, has limitations like unexpressed general knowledge. But the integration of RBR and CBR brings into one the strength of both approaches thereby enhancing their positive aspects by minimizing their negative aspects. As to the researcher's knowledge, there is no research that attempts the integration of RBR and CBR for diagnosis and treatment of eye diseases.

To summarize the chapter the researcher found important points from the literature review such as the methodologies and processes used to develop the knowledge-based system, tools used for the implementation purpose, knowledge modeling and representation technique and performance evaluation techniques. From the related works, the researcher found that all are designed by using individual knowledge representation techniques of RBR or CBR for eye disease diagnosis and treatment.

Based on the literature review the researcher used different tools, techniques, and approaches to achieve the objectives of the study. It is also noted by scholars that, the integrated approach is better than a single approach to getting a better result. As a result, this study is initiated to explore the integration of CBR and RBR for designing a better knowledge-based system for eye disease diagnosis and treatment.

CHAPTER THREE

IDENTIFY PROBLEM AND DEFINE OBJECTIVE OF THE SOLUTION

The main goal of this chapter is to acquire knowledge for identifying problems and set objectives for the solution. To do so, it discusses how the domain knowledge is acquired from document analysis, domain experts and patient's history cards of eye disease diagnosis and treatment techniques, as well as modeling the acquired knowledge and knowledge representation is discussed.

3.1. Source of Knowledge Acquisition

Knowledge Acquisition (KA) is the process of acquiring relevant knowledge from domain experts and other sources of information such as books, databases, guidelines, manuals, journal articles and computer files [48]. It is also the process of eliciting, structuring and representing (formalizing) domain knowledge acquired from different sources. The acquired knowledge can be specific to the problem domain, and it can be general or it is meta-knowledge (knowledge about knowledge). Knowledge acquisition is the first step and critical task in the development of a knowledge-based system [39].

The process of knowledge acquisition of this research encompasses some basic activities such as gathering the needed knowledge, analyzing that knowledge, identifying important concepts and symptoms and finally modeling the acquired knowledge using decision tree structure for knowledge representation. In this study to acquire the needed knowledge, both primary and secondary sources of knowledge are used.

In order to elicit knowledge from the domain experts and from eye disease cases in a proper manner, the researcher reviews different relevant documents related to different eye diseases. The researcher collected knowledge from relevant sources such as the internet, books, journal articles, different previous researches, prototypes, the guideline for eye diseases.

3.1.1. Knowledge Acquisition from Domain Experts

The primary knowledge was gathered from various experts in the domain area from Jimma University specialized hospital of ophthalmology department by using structured and unstructured interviews. During the preliminary investigation, two eye specialist doctors, two ophthalmologists, and one resident are included to understand the dimensions of eye disease problems. During this time, the researcher conducted informal kinds of interviews with these experts. Due to this, the researcher selected five experts purposively for extensive discussions using structured and unstructured interviews to discover relevant knowledge. The structured interview questions are attached in appendix I. The experts were principally participating throughout this research work, and they were consulted to confirm the correctness of the acquired knowledge.

The researcher found that the knowledge acquired from documents as well as from interviews is similar and the researcher used the result as data triangulation. The results obtained from the interview and document analysis are presented below.

3.2. Overview of Eye Disease

Eye disease is a blanket term that refers to a host of diseases relating to the function of the eye. It can be any of the diseases or disorders that affect the human eye. Many eye diseases have no early symptoms or they may be painless and no change in the vision until the disease has become quite advanced. Most people have eye problems at one time or another, some are minor and will go away on their own, or are easy to treat at home; others need a specialist's care [2].

3.2.1. Types of Eye Diseases Frequently Occurred in Ethiopia

A number of things can go wrong in any of the structures of the eye, causing visual impairment and blindness. The most common vision problems are refractive errors, more commonly known as nearsightedness, farsightedness, astigmatism, and presbyopia. Many of these deteriorations are due to aging. Common or frequently occurred eye diseases in Ethiopia are described below and the researcher was done the study on these eye diseases for the development of a knowledge-based system [30, 31, 32].

Cataract

A cataract is the clouding of the eye's natural lens, preventing the passage of light to the retina and impairing vision. A cataract may occur in one or both eyes and typically occurs as a result of aging. It is the most common cause of vision loss in people over age 40 and is also the principal cause of blindness in the world [60].

M**ajor symptoms of Cataract include** seeing blurred, clouded or dim vision, difficulty seeing at night, Problem seeing through light and glare, seeing halos around lights, frequently changing contact lens prescription or eyeglasses, Fading or yellowing view of colors, Need for brighter light for reading and other activities.

Detached retina

A detached retina is an emergency, tissue at the back of the eye pulls away from a layer of blood vessels that provide necessary oxygen and nourishment. It occurs when the retina peels away or detaches from its underlying layer of support tissue at the back of the eye. The retina is a thin layer of light-sensitive nerve cells at the back of the eye [32].

Major symptoms of Retinal Detachment include Sudden appearance of floaters (specks drifting through the field of vision) in the affected eye, Sudden appearance of light flashes in one or both eyes, Blurred vision, Steadily receding peripheral or side vision, Presence of a curtain-like shadow through your field of vision and A heavy feeling in the eye.

Dry eye syndrome

Dry eye syndrome is a condition in which a person doesn’t have enough quality tears to lubricate and nourish the eye. It is a common and often chronic problem, particularly in older adults. Tears are necessary for maintaining the health of the front surface of the eye and providing clear vision. With each blink of the eyelids, tears spread across the front surface of the eye, known as the cornea. Tears provide lubrication, reduce the risk of eye infection, wash away foreign matter in the eye and keep the surface of the eyes smooth and clear. Excess tears in the eyes flow into small drainage ducts in the inner corners of the eyelids, which drain into the back of the nose. Dry eyes can occur when tear production and drainage are not in balance. This is caused when tear glands stop making enough tears or produce poor quality tears or the tears evaporate too quickly [60].

Major symptoms of Dry Eye Syndrome include A burning, dryness, scratchy or stinging sensation in eyes, Eye redness, Sensitivity to light, Stringy mucus in or around the eyes, Blurred vision, eye fatigue, Difficulty in wearing contact lenses and Filing like something in the eyes.

Glaucoma

A glaucoma is a group of conditions caused by normal fluid in the eye that hasn't drained properly. This creates pressure that damages the optic nerve connecting the eye to the brain, resulting in sight loss. The increased pressure, called intraocular pressure, can damage the optic nerve, which transmits images to the brain. In most glaucoma cases; the condition develops when too much pressure builds up inside the eye. If the damage continues, glaucoma can lead to permanent vision loss. Without treatment, glaucoma can cause total permanent blindness within a few years. Although it's not clear exactly why this happens, factors such as age, family history, racial background and other medical conditions such as diabetes and short-sightedness can increase the risk. It can affect people of all ages, but it's most common in adults [60].

Major symptoms of Glaucoma include Tunnel or Narrowed vision, Peripheral vision loss, Severe pain in eyes accompanied by nausea and vomiting, Sudden visual disturbance in low light conditions, Seeing halos around lights, Blurred vision and Redness of the eyes.

Presbyopia

Presbyopia is the normal loss of near focusing ability that occurs with age. Most people begin to notice the effects of presbyopia sometime after age 40 when they start having trouble seeing the small print clearly. Also, it wills difficulty in focusing the eye to see close objects [60].

Major symptoms of Presbyopia include Blurry vision and inability to read at normal reading distance, Eyestrain with accompanied headaches and Hold reading material farther away to make the letter clear.

Astigmatism

Astigmatism is a common vision condition that causes blurred vision. It occurs when the cornea called the clear front cover of the eye is irregularly shaped or sometimes because of the curvature of the lens inside the eye. An irregularly shaped cornea or lens prevents light from focusing properly on the retina, the light-sensitive surface at the back of the eye. As a result, vision becomes blurred at any distance. This can lead to eye discomfort and headaches. Astigmatism frequently occurs with other vision conditions like myopia and hyperopia. Together these vision conditions are referred to as refractive errors because they affect how the eyes bend or refract light [30].

Major symptoms of Astigmatism include Distorted and blurry vision at close range as well as at a distance, Difficulty in seeing things at night, Eyestrain, Headaches, Squinting and Eye irritation.

Hypermetropia

Hypermetropia called long-sightedness is where the eye is shorter than normal or the cornea is too flat, meaning that light rays focus behind the retina. It is a common eye condition where nearby objects appear blurred, but the vision is clearer when looking at things further away. Light rays from close objects such as pages of a book cannot be focused on clearly by the retina. Occur when the length of the eye is too short, making it easier to see distant objects and harder to see close ones [30].

Major symptoms of Hypermetropia include Vision getting blurry for objects close by, Need to squint for getting a better vision, Headache hitting after tasks needing your focus on close by objects and an aching or burning sensation around the eyes.

Myopia

Myopia called short-sightedness is the inability to see things clearly unless they are relatively close to your eyes. It occurs when the length of the eye has grown too long front to back, causing light to come to a focus in front of the retina instead of directly on it. Other contributing factors include a cornea that is too curved from the length of the eyeball or a lens inside the eye that is too thick. Myopia typically starts to develop during childhood and can progress gradually or rapidly [30].

Major symptoms of Myopia include Vision getting blurry when looking at distant objects, requiring squinting or partial closing of, the eyelids to get a clear vision of something, Eyestrain leading to headaches and Difficulty viewing objects while driving a vehicle, particularly at night (night myopia).

Strabismus

Strabismus is a condition where the eyes point in different directions. One eye may turn inwards, outwards, upwards or downwards while the other eye looks forward. This usually occurs because the muscles that control the movement of the eye and the eyelid, the extra ocular muscles, are not working together. As a result, both eyes are unable to look at the same spot at the same time. It can also happen because a disorder in the brain means that the eyes cannot correctly coordinate [32].

Major symptoms of Strabismus include Crossed eyes, Double vision, and Eyes' inability to focus on a particular point at the same time, uncoordinated eye movements and loss of depth perception.

Uveitis

Uveitis is a form of eye inflammation in the eye's pigmented layers (iris, ciliary body, and choroid) inside the eye; it affects the middle layer of tissue in the eye wall. The condition can affect one or both eyes, it primarily affects people ages 20 to 50, but it may also affect children. Possible cause of uveitis is an infection, injury or an autoimmune or inflammatory disease most of the time a cause can't be identified. Uveitis can be serious, leading to permanent vision loss [60].

Major symptoms of Uveitis include Blurred vision, Pain in the eye, Light sensitivity, Redness of the eye, Dark, floating spots in the field of vision (floaters) and Decreased vision.

Conjunctivitis or pink eye

Conjunctivitis or pink eye is an inflammation or swelling of the conjunctiva. It is the thin transparent layer of tissue that lines the inner surface of the eyelid and covers the white part of the eye. It is a common eye disease, especially in children. It may affect one or both eyes. Some forms of conjunctivitis are highly contagious and can easily spread. While it is usually a minor eye infection, sometimes it can develop into a more serious problem. A viral or bacterial infection can cause conjunctivitis. It can also develop due to an allergic reaction to air irritants such as pollen and smoke, chlorine in swimming pools, ingredients in cosmetics, or other products that contact the eyes, such as contact lenses [32].

Major symptoms of Conjunctivitis include Redness appearing in the eyelid or through the white of the eye, swelling in the conjunctiva, Excessive tearing, Thick yellowish discharge, mostly covering whole eyelashes, especially after sleep, Itching and burning eyes, Blurred vision and Extra sensitivity to light.

Diabetic retinopathy

Diabetic retinopathy is basically a diabetes complication, which affects eyes by causing damage to the blood vessels spread throughout the light-sensitive tissues of the retina called the back of the eye. Anyone having type 1 or type 2 diabetes can develop this eye condition, especially those who have diabetes for a long time with fluctuating blood sugar levels. Usually, both eyes get affected by diabetic retinopathy [32].

Major symptoms of Diabetic Retinopathy include dark spots or strings floating through your vision (floaters), impaired color recognition, fluctuating vision, blurred vision, vision loss, poor night vision and sudden and total loss of vision.

In addition to the above major symptoms, age, diabetes, hypertension, smoking tobacco, drinking alcohol, previous eye surgery, radiation treatment, medication or drug, hypothyroidism, previous other eye disease or disorder and cardiovascular diseases are taken into consideration during eye disease diagnosis and treatment.

3.2.2. Diagnosis of Eye Diseases

Eye problems can range from mild to severe. Some are chronic, while others may resolve on their own and never to appear again. A variety of tests can be done to confirm the eye diseases or to determine the extent or severity of an eye disorder. Diagnosis of eye diseases is initially based on the person's symptoms, the appearance of the eyes, and the results of an examination. A person with eye or vision problems describes the location and duration of the symptoms and then the ophthalmologist examines the eye, the area around it and possibly other parts of the body, depending on the suspected causes. Hereunder a description of the steps that domain experts follow in diagnosing eye diseases is given.

The first step - Asking the patient about the symptoms

Symptoms that may be asked about by the doctor or ophthalmologist including the following: tearing, blurred vision, loss of vision, injuries to the eye, the presence of floaters, redness and pain in the eye, cloudy vision, flu-like symptoms, sinus infection, sensitivity to light, possibility of being diabetic, swelling or itchiness around the eyes, painful lumps, discharges from the eye, skin irritation around the eye, and the wearing of contact lenses. There will be asking about the medical history and whether there is experienced this particular or any other problem before.

Second step - Looking at the appearance of the eye

Even before closely examining the eye, the doctor will be able to observe certain signs in the physical appearance of the eye. These include droopy eyelids, the bloodshot appearance of the eye, an opaque appearance to the eye, a squint (strabismus), excessive tearing, trauma to the area around the eye, an inverted eyelid, puffiness around the eye, large scratches on the cornea, inflammation of eyelash follicles.

Third step - Actual tests or a close physical examination

- **Refraction test**: is used to assess focusing errors which can lead to visual acuity problems such as nearsightedness or farsightedness
- **Snellen test**: A person's vision is tested by using the Snellen test making them read letters on a chart from six meters away, or a lighted box that displays rows of letters in diminishing sizes.
- **Autorefractor test**: An auto refractor is also used to determine how light is changed when it enters the eye. A phoropter used together with the Snellen test helps to determine which corrective lenses will be most effective.
- **Visual field testing**: is done to see the entire area seen out of each eye. With one eye closed and the patient focusing on the doctor's face., he/she moves an object into the field of vision and makes notes on when the patient reports seeing it.
- **Goldmann perimeter:** is used to test peripheral vision and an Amsler grid to test the central area of vision. Eyes are always tested separately
- **Isihara color plates:** colored dots on a white background are used to test for color blindness. The inability to see certain patterns or numbers amongst the colored dots can point to color blindness.
- **Ophthalmoscope (funduscopy):** is like a flashlight with magnifying lenses. This used to look through the pupil into the eye using a bright light in order to detect changes in the retina or the other structures of the eye, possibly because of conditions such as diabetes or high blood pressure. An indirect ophthalmoscope will give the doctor a three-dimensional view.

3.2.3. Treatments of Eye Diseases

Most treatment of eye diseases is aimed at reducing inflammation, repairing traumatic injuries, and improving or saving eyesight. Sometimes eye problems, such as pain will resolve itself within a few days, but anything causing visual disturbances, or if there has been trauma to the eye, will require immediate medical attention. The treatments of eye diseases here discussed below are gathered from different relevant documents and from the experience of domain experts via interview [60].

Medication treatment

Medication including home treatments and over the counter medicine, it used for the treatment of eye problems diverse. Here are some of the more regularly used medications and treatments: -

- Artificial tears for dry eyes
- Over the counter eye drops to treat short term eyestrain or scratchy eyes
- Antibiotics to treat bacterial infections such as bacterial conjunctivitis, viral conjunctivitis, the most common cause of an acute red eye.
- Corticosteroids can sometimes be used to try and prevent permanent damage to the eye, which could be the result of certain eye diseases, such as uveitis
- Antihistamines can relieve the symptoms of allergic conjunctivitis
- Some home remedies include cold compresses for a black eye and conjunctivitis

Prescription glasses or contact lenses treatment

Lenses have been used for over 800 years to help improve eyesight. Initially, people used single eyeglasses, but this developed into a double frame containing lenses worn in front of both eyes simultaneously. Left and right lenses can differ according to the wearer's requirements. Bifocals, trifocals, and glasses with an adjustable focus followed. And then in the latter part of the twentieth century, the use of contact lenses became widespread, especially with the advent of the first soft contact lenses in 1971, according to the timeline on the site of GP contact lenses. Contact lenses are small plastic discs worn in the eye. These are shaped to correct eyesight problems. Both glasses and contact lenses help to bend light rays and focus an image more sharply on your retina, improving the eyesight, by enabling the brain to receive a clearer picture of what the eyes are observing.

Surgery treatment

Eye surgery is extremely delicate and most of it is aimed at reshaping the cornea, thereby correcting vision problems. This is a field in which there have been many developments in the past few years.

- Refractive surgery, also known as vision correction surgery, can be used to treat both nearsightedness and farsightedness
- Corneal refractive surgery alters the curvature of the cornea to focus light more precisely on the retina
- Lens implants can be done to treat patients for farsightedness if laser surgery is not an option.
- Segments of biocompatible plastic can also be inserted into the edge of the cornea to treat farsightedness.

Surgery is the only way to remove cataracts, glaucoma, etc. Successful eye surgery can eliminate the need for either glasses or contact lenses. Eye surgery can also be necessary to repair the eye after trauma or remove an object from the eye. The surgery procedure includes laser surgery as optional. The following explanations are used by the researcher for the development of KBS as a treatment for selected eye diseases according to the acquired knowledge from experts.

Treatment for Cataract

- New eyeglasses with antiglare sunglasses and magnifying lenses
- Use brighter lighting
- Surgery, if the cataract has affected both eyes for removal and replacement of cloudy lens with an artificial one

Treatment for Retinal Detachment

- The surgery treatment will be decided according to the detachment level after examined by an eye specialist. The surgeries are:
    - Cryotherapy (a freeze treatment) surgery, Laser surgery, Vitrectomy surgery, Scleral Buckle or Pneumatic Retinopexy

Treatment for Dry Eye Syndrome

- Artificial tears, each eye per day, approximately 6 hours apart
- Restasis of eye drops each eye per day for 3 months

- Xiidra, the recommended dosage is two applications in each eye per day, approximately 12 hours apart
- Nutritional supplements - simply drinking more water might help relieve dry eye symptoms. Mild dehydration often makes dry eye problems worse.
- Home remedies for dry eyes - blink more frequently, thoroughly remove eye makeup, clean your eyelids and wear quality sunglasses

Treatment for Glaucoma

- Eye drop treatment
    - Prostaglandins- Xalatan (Pfizer), Lumigan (Allergan), Travatan Z (Alcon) and Rescula (Novartis). Prostaglandins generally work by relaxing muscles in the eye's interior structure to allow better outflow of fluids, thus reducing the buildup of eye pressure. The recommended dosage one drop per day.
- Pills

If eye drops don't bring down the pressure of eyes, pills procedure will be taken. They ease the pressure by slowing the production of fluid in the eyes.

  - Acetazolamide (Diamox) - the recommended dosage of Diamox is 1 capsule (500 mg) two times a day.
  - Methazolamide (Neptazane) - The effective therapeutic dose of Methazolamide varies from 50mg to 100mg, 2 or 3 times daily.
- Laser Surgery
    - It is used when eye drop or pills medications are not lowering the eye pressure enough or are causing significant side effects
- Traditional Surgery
    - When medicated eye drops and laser surgery do not remedy intraocular pressure (IOP), the specialist may recommend conventional glaucoma surgery. The most common surgical option is trabeculectomy, also called filtration surgery

Treatment for Presbyopia

The goal of treatment is to compensate for the inability of eyes to focus on nearby objects. Treatment is optional according to complaints need; it includes wearing corrective eyeglasses (spectacle lenses) or contact lenses, undergoing refractive surgery, or getting lens implants for presbyopia.

- Eyeglasses
    - Most nonprescription reading glasses range in power from +1.00 diopter (D) to +3.00 D.
- Contact lenses
    - People who don't want to wear eyeglasses often try contact lenses to improve their vision problems caused by presbyopia. This option may not work for whom if they have certain conditions related to eyelids, tear ducts or the surfaces of the eyes such as the dry eye.
- Refractive surgery
    - Refractive surgery changes the shape of the cornea. It's like wearing mono-vision contact lenses. Even after surgery, it may need to use eyeglasses for close-up work.
- Lens implants
    - It is the procedure of removing the lens in each eye and replaces it with a synthetic lens.

Treatment for Astigmatism

- Eyeglasses- it contains a special cylindrical lens prescription
- Contact lenses– it’s optional
- Refractive Surgery- aims to change the shape of the cornea permanently and it’s optional

Treatments for Hypermetropia

- Traditional correction: glasses or contact lenses in the form of positive lenses.
- Surgical correction: The two surgical procedures available are: Laser eye surgery and clear leans extraction.

Treatments for Myopia

- Eyeglasses and contact lenses are the best treatment options while nearsightedness is still changing
- Refractive surgery is another option it reduces the need for eyeglasses and contact lenses.

Treatments for Strabismus

- Treatment for Kids: Eye patching, Eyeglasses, Atropine drops, and Eye muscle surgery
- Treatment for Adults: Prism correction or Surgery

Treatments for Uveitis

- Prescription eye drops in combination with anti-inflammatory medications. Corticosteroid
    - For oral dosage form (tablets): Adults and teenagers—25 to 300 milligrams (mg) a day, as a single dose or divided into several doses.

      Children—Dose is based on body weight or size and must be determined by a doctor.
    - For injection dosage form: Adults and teenagers—20 to 300 mg a day, injected into a muscle.

      Children—Dose is based on body weight or size and must be determined by a doctor.
- Ocular anti-inflammatory injections - injections may be to the outside or inside of the eye. This treatment may be uncomfortable, yet very effective in acute episodes of uveitis.
- Systemic or oral administration of steroids, other immunosuppressant or anti-metabolite drugs.
- Surgical procedures may be needed to replace the vitreous (or gel-like area) or to implant a device in the eye for slow-release of corticosteroid medication

Treatments for Conjunctivitis

- Artificial tears, in infected eye per day, approximately 6 hours apart
- Antihistamines or non-steroidal anti-inflammatory drugs: for allergic conjunctivitis, administered topically twice a day or taken once a day by mouth
- Antibiotic eye drops or ointments: for bacterial conjunctivitis, they are typically used three to four times a day for five to seven days.

- Topical steroids: for severe conjunctivitis, which often results from a chemical injury, it may recommend that the use these medications for only a couple of weeks.

Treatments for Diabetic Retinopathy

- Laser treatment – to treat the growth of new blood vessels at the back of the eye (retina) in cases of proliferative diabetic retinopathy, and to stabilize some cases of maculopathy.
- Eye injections – to treat severe maculopathy that's threatening the sight.
- Eye surgery – to remove blood or scar tissue from the eye if laser treatment isn't possible because retinopathy is too advanced.

3.2.4. Knowledge Acquisition from Eye Disease Cases

After the knowledge acquired from relevant documents and domain experts, the researcher was collect different eye disease cases from the patient record file. For CBR knowledge representation technique cases are an important source for system development. All cases are collected from Jimma University specialized hospital. JUSH is selected because of several factors with eye diseases that are well organized and sufficiently available. Different methods were applied to make the result better. Among these methods extraction of previously documented cases was collected with the help of experienced ophthalmologists from this hospital and interviewing more experienced health professionals (nurses and health workers) was mainly be implemented.

The variables that are identified from different eye patient record file, which are important to eye diseases are age, diabetes, hypertension, smoking tobacco, alcohol, previous eye surgery, radiation treatment, medication or drug, hypothyroidism, previous other eye disease or disorder, cardiovascular diseases, viral, bacterial or allergic conjunctivitis. Others are the same variables (symptoms) that are acquired from domain experts in the interview section. These are blurred vision, clouded, difficulty seeing at night, problem seeing through light and glare, seeing halos around lights, frequently changing contact lens prescription or eyeglasses, fading or yellowing view of colors, need for brighter light for reading and other activities, narrowed vision, having vision loss, severe pain in eyes accompanied by nausea and vomiting, sudden visual disturbance in low light conditions, redness of the eyes, burning, dryness, stinging or aching sensation, eye redness, sensitivity to light, stringy mucus in or around the eyes, eye fatigue, filing like something is in the eyes, floaters, vision getting blurry when looking at distant objects, closed objects or at normal distance, squinting, eye strain, eye irritation, double vision, excessive tearing, heavy feeling in the eye. For this study, the research collects 72 cases from previously solved patient history card and all collected cases are used for developing the CBR system and system testing.

3.3. Knowledge Modeling

Knowledge modeling is the heart of the knowledge acquisition phase [16]. It is a crucial step to understand well the problem domain and to prepare for the knowledge representation phase. Before a knowledge-based system can be constructed, knowledge should be identified and collected, and then a model of domain knowledge should be built.

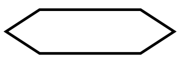
According to Emberey et al. [54], one of the most extensively applied methods of conceptual modeling is called decision tree. The decision tree commonly acts as a key role in the knowledge modeling process. It is used for the search space of a certain problem and presented by a graph. A node in the tree denotes a decision to be attained when finding a solution to a certain problem, and the branches extended from the node show the potential values of the decision. To find the solution of a certain problem, anyone then traces by way of its tree using data of a certain problem to select a branch at every node [54].

In this study, the knowledge used for diagnosis and treatment of selected eye diseases is acquired from domain experts and relevant document analysis. In the following sections, the model of concepts in the diagnosis and treatment of eye diseases is discussed.

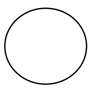
3.3.1. Conceptual Modeling Using Decision Tree

In the diagnosis of eye disease, the domain experts have a concept of symptoms that are used to differentiate the real symptoms of different eye diseases. For those eye diseases, the domain experts have general knowledge about the common sign and symptoms of each eye disease. In the knowledge acquisition time, the domain experts (physicians) explained that there are symptoms that are used for diagnosing the new patient who came for treatment. In addition to that in the patient cards, there are some additional identifying symptoms whether the patient has which kind of eye disease. The possible symptoms used for the domain experts to identify which eye disease is affecting the patient are presented in the following figure 3.1. Therefore, the researcher identified the different signs and symptoms with the help of ophthalmology experts. As it was discussed in the literature review section from different knowledge modeling techniques the researcher used the decision tree knowledge modeling technique because it is suitable for representing in a case-based and rule-based reasoning [16].

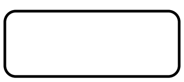
For knowledge modeling using decision tree the following shapes are used. Each shape has the following meanings.



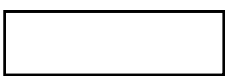
The flowchart diagram shows the sign and symptoms of each eye disease



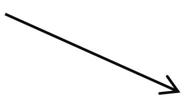
The circle diagram with Alphabets shows the continuity of the diagram in the next page



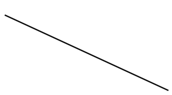
The rounded rectangle diagram shows the diagnose result of eye disease



The rectangle diagram shows the recommended treatment of the disease and other advice to diagnose if the solution is not fined

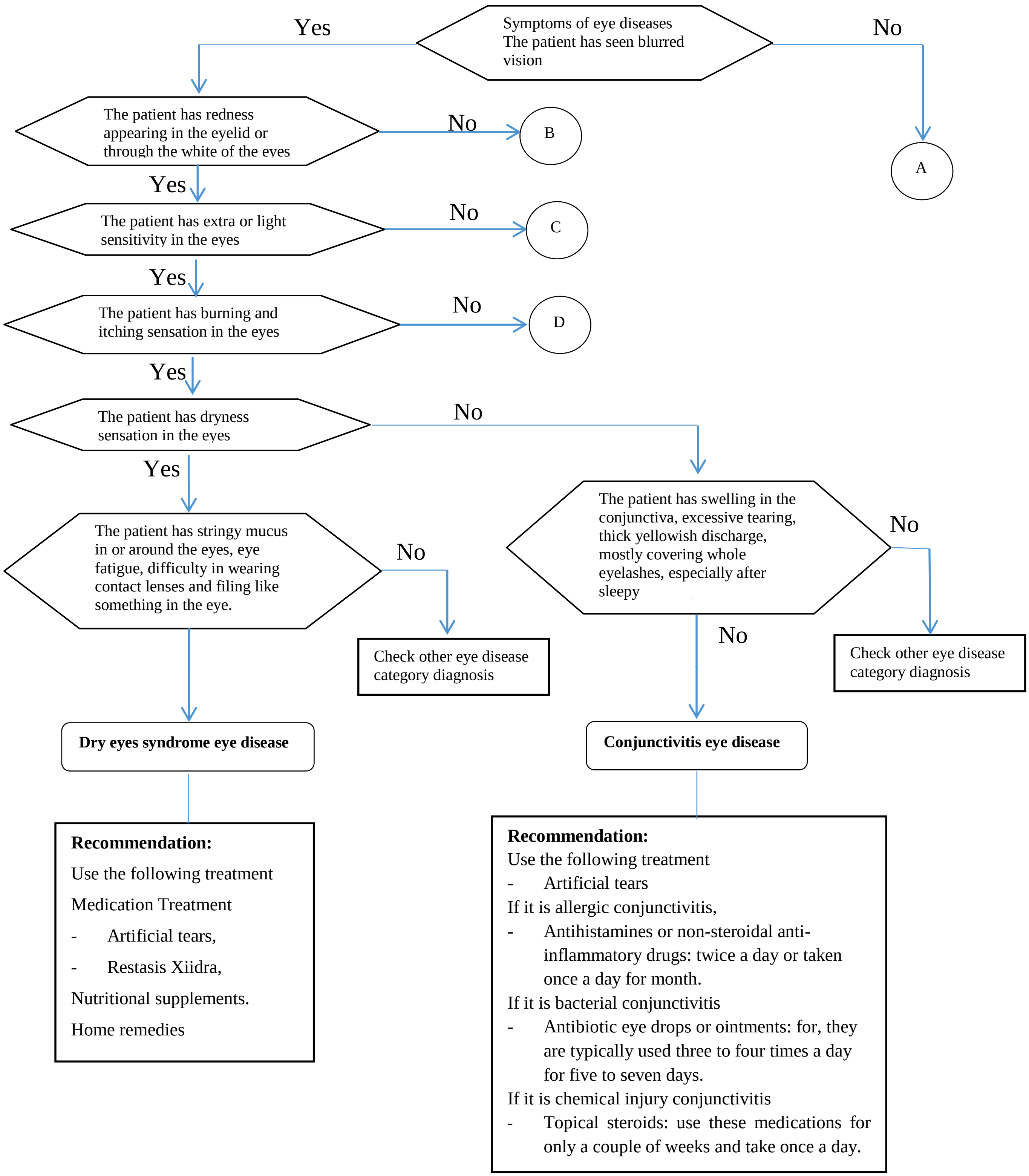


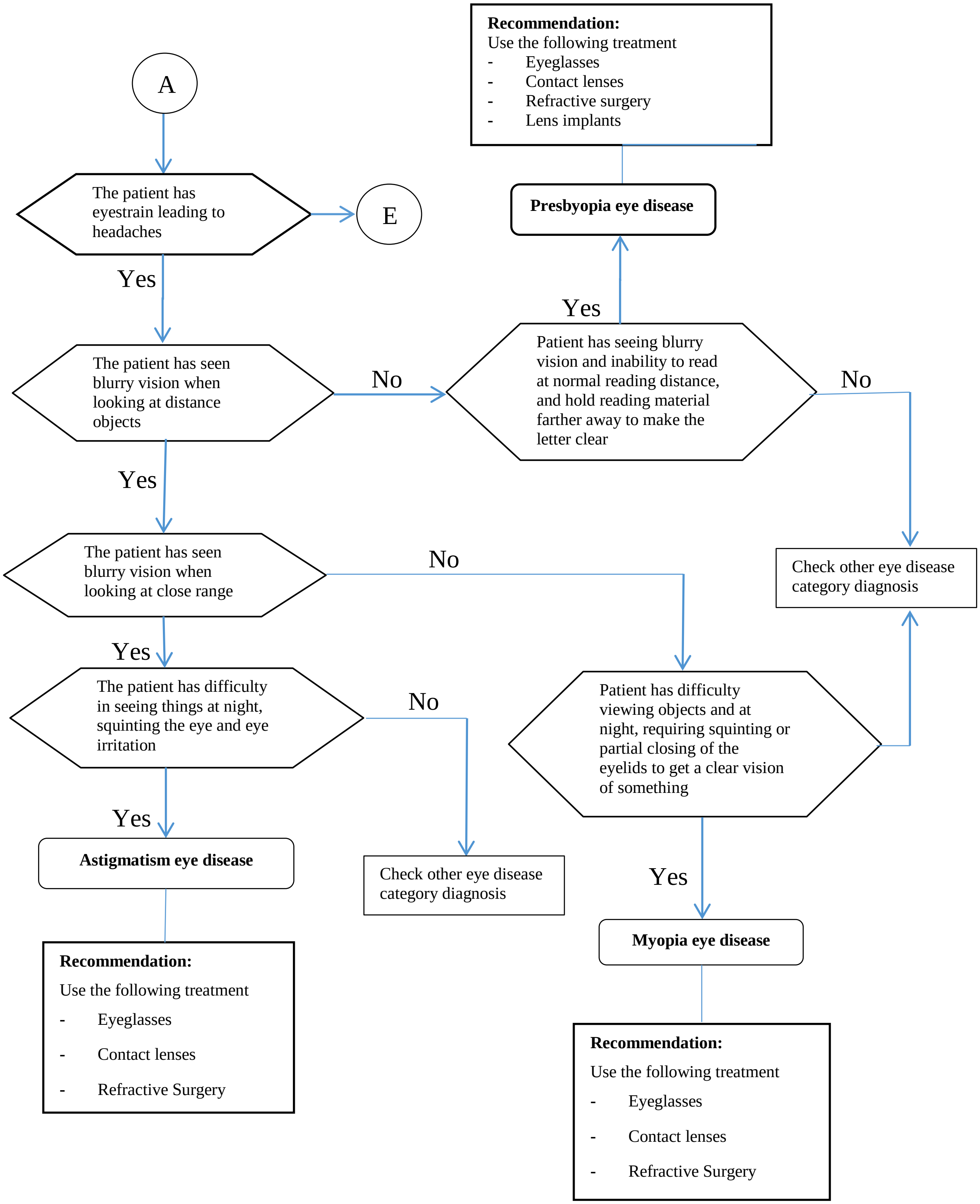
The arrow diagram goes to other options to choose next findings

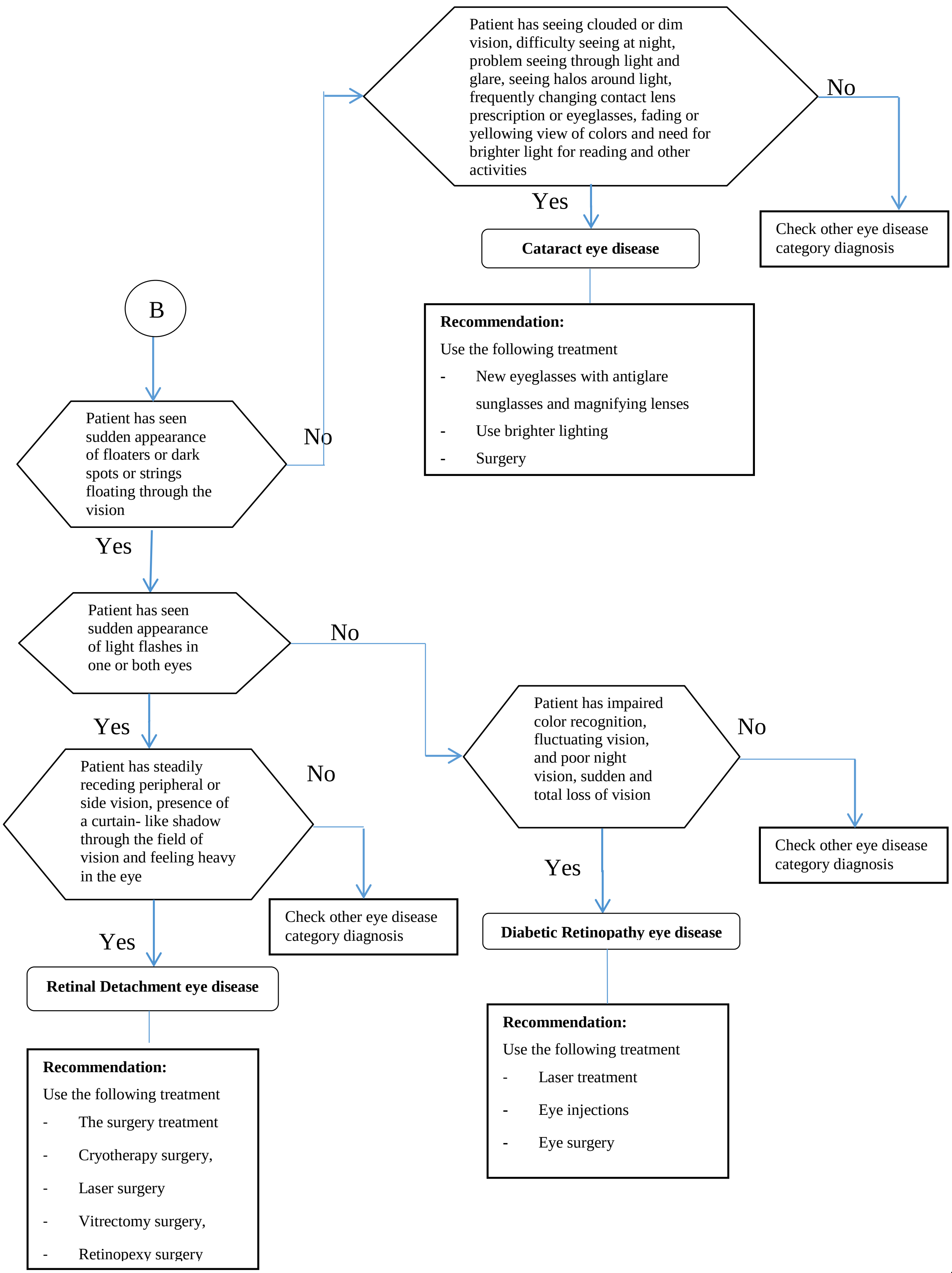


The line diagram goes to the final decision of the system

Figure 3.1 depicts the decision tree used for modeling the procedure followed and conditioned considered in eye disease diagnosis and treatment.


Symptoms of eye diseases The patient has seen blurred vision
Yes
No
A
The patient has redness appearing in the eyelid or through the white of the eyes
No
B
Yes
The patient has extra or light sensitivity in the eyes
No
C
Yes
The patient has burning and itching sensation in the eyes
No
D
Yes
The patient has dryness sensation in the eyes
No
Yes
The patient has stringy mucus in or around the eyes, eye fatigue, difficulty in wearing contact lenses and filing like something in the eye.
No
Check other eye disease category diagnosis
Dry eyes syndrome eye disease
Recommendation:
Use the following treatment
Medication Treatment
- Artificial tears,
- Restasis Xiidra,
Nutritional supplements.
Home remedies
The patient has swelling in the conjunctiva, excessive tearing, thick yellowish discharge, mostly covering whole eyelashes, especially after sleepy
No
Check other eye disease category diagnosis
No
Conjunctivitis eye disease
Recommendation:
Use the following treatment
- Artificial tears
If it is allergic conjunctivitis,
- Antihistamines or non-steroidal anti-inflammatory drugs: twice a day or taken once a day for month.
If it is bacterial conjunctivitis
- Antibiotic eye drops or ointments: for, they are typically used three to four times a day for five to seven days.
If it is chemical injury conjunctivitis
- Topical steroids: use these medications for only a couple of weeks and take once a day.


Recommendation:
Use the following treatment
- Eyeglasses
- Contact lenses
- Refractive surgery
- Lens implants
A
The patient has eyestrain leading to headaches
E
Presbyopia eye disease
Yes
Yes
The patient has seen blurry vision when looking at distance objects
No
Patient has seeing blurry vision and inability to read at normal reading distance, and hold reading material farther away to make the letter clear
No
Yes
The patient has seen blurry vision when looking at close range
No
Check other eye disease category diagnosis
Yes
The patient has difficulty in seeing things at night, squinting the eye and eye irritation
No
Patient has difficulty viewing objects and at night, requiring squinting or partial closing of the eyelids to get a clear vision of something
Yes
Astigmatism eye disease
Check other eye disease category diagnosis
Yes
Myopia eye disease
Recommendation:
Use the following treatment
- Eyeglasses
- Contact lenses
- Refractive Surgery
Recommendation:
Use the following treatment
- Eyeglasses
- Contact lenses
- Refractive Surgery


Patient has seeing clouded or dim vision, difficulty seeing at night, problem seeing through light and glare, seeing halos around light, frequently changing contact lens prescription or eyeglasses, fading or yellowing view of colors and need for brighter light for reading and other activities
No
Check other eye disease category diagnosis
Yes
Cataract eye disease
Recommendation:
Use the following treatment
- New eyeglasses with antiglare sunglasses and magnifying lenses
- Use brighter lighting
- Surgery
B
Patient has seen sudden appearance of floaters or dark spots or strings floating through the vision
No
Yes
Patient has seen sudden appearance of light flashes in one or both eyes
No
Patient has impaired color recognition, fluctuating vision, and poor night vision, sudden and total loss of vision
No
Check other eye disease category diagnosis
Yes
Diabetic Retinopathy eye disease
Recommendation:
Use the following treatment
- Laser treatment
- Eye injections
- Eye surgery
Yes
Patient has steadily receding peripheral or side vision, presence of a curtain- like shadow through the field of vision and feeling heavy in the eye
No
Check other eye disease category diagnosis
Yes
Retinal Detachment eye disease
Recommendation:
Use the following treatment
- The surgery treatment
- Cryotherapy surgery,
- Laser surgery
- Vitrectomy surgery,
- Retinopexy surgery

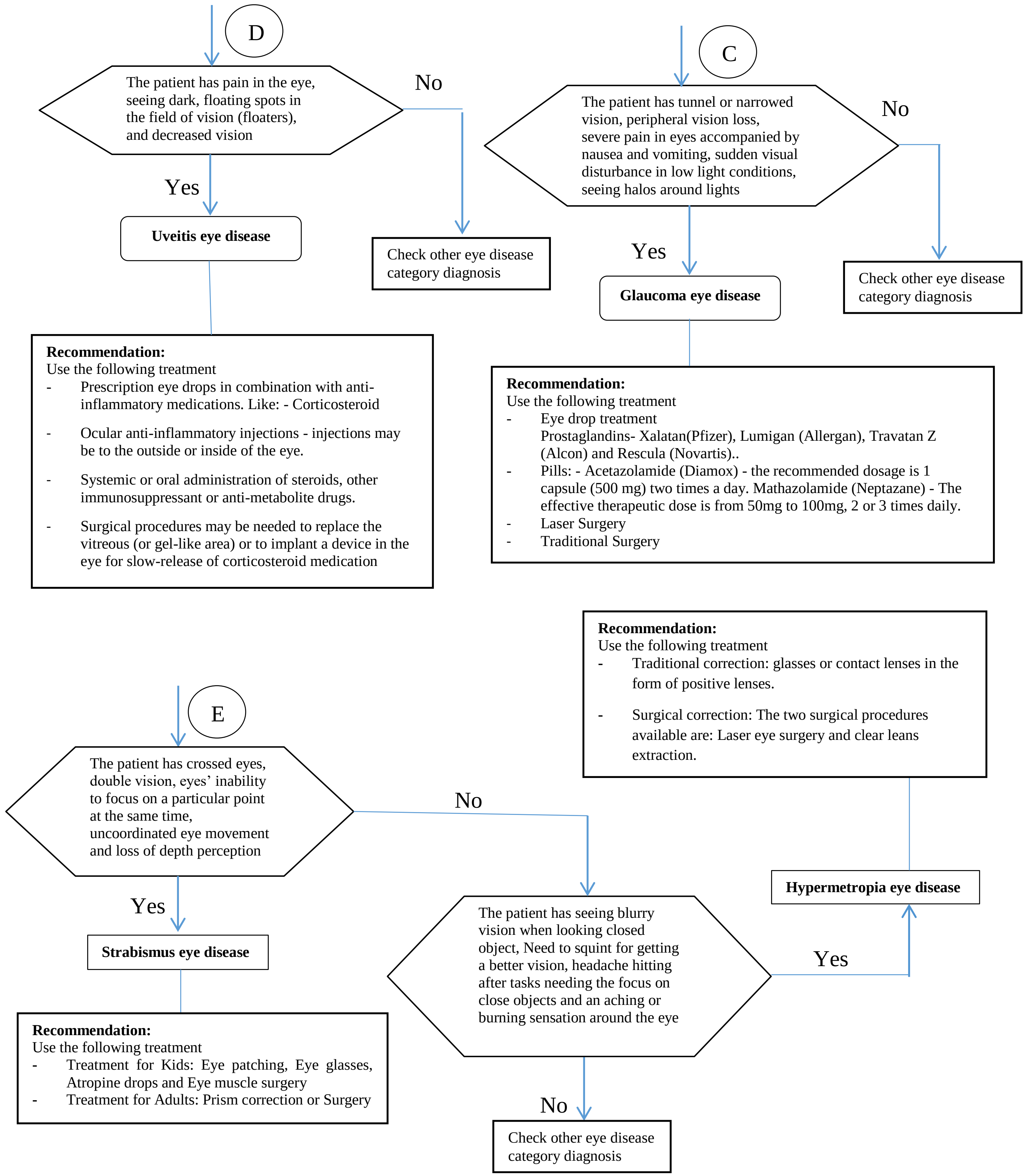


Figure 3.1 Decision Tree for Diagnosis and Treatment of Eye diseases

3.4. Knowledge Representation

Knowledge representation is one of the basic steps in the process of knowledge-based system development [52]. It is the process of interpreting domain knowledge into computer understandable form using knowledge representation methods. In this study, rule-based representation for a rule-based system and case-based representation for the case-based system is used.

3.4.1. Rule-based Representation

A rule is a conditional statement that links the given conditions to actions. Rules in the knowledge-base are constructed based on the decision tree structure on the conceptual model discussed above. The acquired knowledge from document analysis and domain experts represented using the IF-THEN- form. The rules are the base for the construction of KBS [16]. In this study, a rule-based knowledge representation technique and forward chaining inference mechanism are followed for the construction of the rule-based system. The following rules are incorporated into the knowledge base.

Rule 1

IF the patient has seen a blurred vision

AND has redness appearing in the eyelid or through the white or the eyes

AND has extra or light sensitivity in the eyes

AND has a burning and itching sensation in the eyes

AND has dryness sensation in the eyes

AND has stringy mucus in or around the eyes, eye fatigue, difficulty in wearing contact lenses and filing like something in the eye

THEN

Result: The patient has Dry Eye Syndrome Eye Disease

Treatment 1: Artificial tears, each eye per day, approximately 6 hours apart

Treatment 2: Restasis of eye drop each eye per day for 3 months

Treatment 3: Xiidra, the recommended dosage is two applications in each eye per day, approximately 12 hours apart

Treatment 4: Nutritional supplements - simply drinking more water might help relieve from dry eye Syndrome. Mild dehydration often makes dry eye problems worse.

Treatment 5: Home remedies for dry eyes - blink more frequently, thoroughly remove eye makeup, clean your eyelids and wear quality sunglasses

Rule 2

IF the patient has seen a blurred vision

AND has redness appearing in the eyelid or through the white or the eyes

AND has extra or light sensitivity in the eyes

AND has a burning and itching sensation in the eyes

AND has swelling in the conjunctiva, excessive tearing, thick yellowish discharge mostly converting whole eyelashes, especially after sleeping.

THEN

Result: The patient has Conjunctivitis (Pinkeye) Eye Disease

Treatment 1: Artificial tears, in infected eye per day, approximately 6 hours apart

Treatment 2: Antihistamines or non-steroidal anti-inflammatory drugs: for allergic conjunctivitis, administered topically twice a day or taken once a day by mouth

Treatment 3: Antibiotic eye drops or ointments: for bacterial conjunctivitis, they are typically used three to four times a day for five to seven days.

Treatment 4: Topical steroids: for severe conjunctivitis, which often results from a chemical injury, it may recommend that the use these medications for only a couple of weeks.

Rule 3

IF the patient has eye strain leading to headaches

AND has seen the blurry vision when looking at distance objects

AND has seen blurring vision when looking at close range

AND has difficulty in seeing things at night squinting the eye and eye irritation

THEN

Result: The patient has Astigmatism Eye Disease

Treatment1: Eyeglasses- it contains a special cylindrical lens prescription

Treatment2: Contact lenses– it's optional

Treatment3: Refractive Surgery- aims to change the shape of the cornea permanently and it's optional

Rule 4

IF the patient has eyestrain leading to headaches

AND has seen blurry vision and inability to read at normal reading distance, and hold reading material farther away to make the letter clear

THEN

Result: The patient has Presbyopia Eye Disease

Treatment 1: Eyeglasses: - Most nonprescription reading glasses range in power from +1.00 diopter (D) to +3.00 D.

Treatment 2: Contact lenses

Treatment 3: Refractive surgery

Treatment 4: Lens implants

Rule 5

IF the patient has eye strain leading to headaches

AND has seen the blurry vision when looking at distance objects

AND has difficulty viewing objects and at night, requiring squinting or partial closing of the eyelids to get a clear vision of something

THEN

Result: The patient has Myopia Eye Disease

Treatment 1: Eyeglasses and contact lenses are the best treatment options while nearsightedness is still changing

Treatment 2: Contact lenses

Treatment 3: Refractive surgery is another option it reduces the need for eyeglasses and contact lenses.

Rule 6

IF the patient has seen a blurred vision

AND has redness appearing in the eyelid or through the white or the eyes

AND has seen the sudden appearance of floaters or dark spots or strings spots or strings floating through the vision

AND has seen the sudden appearance of light flashes in one or both eyes

AND has steadily receding peripheral or side vision, presence of a curtain-like a shadow through the field of vision and feeling heavy in the eye

THEN

Result: The patient has Retinal Detachment Eye Disease

Treatment1: The surgery treatment will be decided according to the detachment level after examined by eye specialists. The surgeries are: Cryotherapy (a freeze treatment) surgery, Laser surgery, Vitrectomy surgery, Scleral Buckle or Pneumatic Retinopexy

Rule 7

IF the patient has seen a blurred vision

AND has redness appearing in the eyelid or through the white or the eyes

AND has seen a clouded or dim vision, difficulty seeing at night, problem seeing through light and glare, seeing halos around light, frequently changing contact lens prescription or eyeglasses, fading or yellowing view of colors and need for brighter light for reading and other activities

THEN

Result: The patient has Cataract Eye Disease

Treatment 1: New eyeglasses with antiglare sunglasses and magnifying lenses if it is not working surgery will be taken to remove and replace the cloudy lens with an artificial one

Treatment 2: Use brighter light

Treatment 3: Surgery

Rule 8

IF the patient has seen a blurred vision

AND has redness appearing in the eyelid or through the white or the eyes

AND has seen the sudden appearance of floaters or dark spots or strings spots or strings floating through the vision

AND has impaired color recognition, fluctuating vision, and poor night vision, sudden and total loss of vision

THEN

Result: The patient has Diabetic Retinopathy Eye Disease

Treatment1: Laser treatment – to treat the growth of new blood vessels at the back of the eye (retina) in cases of proliferative diabetic retinopathy, and to stabilize some cases of maculopathy

Treatment2: Eye injections – to treat severe maculopathy that's threatening the sight Treatment3: Eye surgery – to remove blood or scar tissue from the eye if laser treatment isn't possible because retinopathy is too advanced

Rule 9

IF the patient has seen a blurred vision

AND has redness appearing in the eyelid or through the white or the eyes

AND has extra or light sensitivity in the eyes

AND has pain in the eye, seeing dark, floating spots in the field or vision (floaters), and decreased vision

THEN

Result: The patient has Uveitis Eye Disease

Treatment1: Prescription eye drops in combination with anti-inflammatory medications. Corticosteroid: For oral dosage form (tablets): Adults and teenagers—25 to 300 milligrams (mg) a day, as a single dose or divided into several doses. Children—Dose is based on body weight or size and must be determined by a doctor. For injection dosage form: Adults and teenagers—20 to 300 mg a day, injected into a muscle. Children—Dose is based on body weight or size and must be determined by a doctor.

Treatment 2: Ocular anti-inflammatory injections - injections may be to the outside or inside of the eye. This treatment may be uncomfortable, yet very effective in acute episodes of uveitis.

Treatment 3: Systemic or oral administration of steroids, other immunosuppressant or anti-metabolite drugs.

Treatment 4: Surgical procedures may be needed to replace the vitreous (or gel-like area) or to implant a device in the eye for slow-release of corticosteroid medication

Rule 10

IF the patient has seen a blurred vision

AND has redness appearing in the eyelid or through the white or the eyes

AND has a tunnel or narrowed vision, peripheral vision loss, severe pain in eyes accompanied by nausea and vomiting, sudden visual disturbance in the low light conditions, seeing halos around lights

THEN

Result: The patient has Glaucoma Eye Disease

Treatment 1: Eye drop treatment: - Prostaglandins- Xalatan (Pfizer), Lumigan (Allergan), Travatan Z (Alcon) and Rescula (Novartis). Prostaglandins generally work by relaxing muscles in the eye's interior structure to allow better outflow of fluids, thus reducing the buildup of eye pressure. The recommended dosage is one drop per day.

Treatment 2: Pills: - If eye drops don't bring down the pressure of eyes, pills procedure will be taken. They ease the pressure by slowing the production of fluid in the eyes. Acetazolamide (Diamox) - the recommended dosage of Diamox is 1 capsule (500 mg) two times a day. Methazolamide (Neptazane) - The effective therapeutic dose of Methazolamide varies from 50mg to 100mg, 2 or 3 times daily.

Treatment 3: Laser Surgery: - It is used when eye drop or pills medications are not lowering the eye pressure enough or are causing significant side effects

Treatment 4: Traditional Surgery: -When medicated eye drops and laser surgery do not remedy intraocular pressure (IOP), the specialist may recommend conventional glaucoma surgery. The most common surgical option is trabeculectomy, also called filtration surgery.

Rule 11

IF the patient has crossed eyes

AND has seen double vision, eyes’ inability to focus on a particular point at the same time, uncoordinated eye movements and loss of depth perception

THEN

Result: The patient has Strabismus Eye Disease

Treatment1: the patient is under age 8, Eye patching with eyeglasses, atropine drops if it is not working eye muscle surgery.

Treatment2: the patient is above age 8, Prism correction surgery will be taken.

Rule 12

IF the patient has seen the blurry vision when looking closed object

AND has to need to squint for getting a better vision, headache hitting after tasks needing your focus on close by objects and an aching or burning sensation around the eyes

THEN

Result: The patient has Hypermetropia Eye Disease

Treatment 1: Traditional correction: glasses or contact lenses in the form of positive lenses.

Treatment 2: Surgical correction: The two surgical procedures available are: Laser eye surgery and clear leans extraction.

3.4.2. Case-based Representation

Cases are the fundamental units of CBR and their structure in effect determines how CBR operates. The acquired cases are represented using one of the different case-based representation methods that are appropriate for the researcher. Case-base representation methods include feature-value case representation, relational database case representation; predicate based case representation and soft computing case representation methods [56].

For this research, the acquired cases are represented using the feature-value case representation method. The reason for representing cases using feature-value representation is the approach supports the nearest neighbor retrieval algorithm and it represents cases in an easy way [34]. This approach also uses old experiences to understand and solve new problems. In addition to this representation of cases, case indexing is another important issue in CBR systems to facilitate the retrieval of cases. Cases are selected and retrieved in a ranked order based on their similarity for the given new case query. For this research, the nearest neighbor retrieval algorithm was used to measure the similarity of the input case with cases in the case-base.

So, for representing the knowledge with feature-value pair format, the case structure was constructed for diagnosis and treatment of twelve eye diseases. The case structure has two important parts: problem descriptions and solutions. Problem description, as part of the case structure, consisted of attributes (symptoms and signs) which described the problems to be solved. The solution part provides the diagnosis result and recommended treatment given to eye disease patients based on the problem descriptions.

After the case structure is constructed the cases that build the case-base are collected from the eye disease patient card history. This stage is a big challenge for the researcher because the patients' history is recorded on paper and the manual record-keeping situation in Jimma University specialized hospital. Since converting cases from paper recorded format to computer understandable format is the other problem that was hard work for the researcher. The patient card histories are converted into cases thought the definition of attribute-value pairs in order to make the case-base of the system. The conversion has done with the help of domain experts (ophthalmologists, health officers, and nurses).

The attributes which were used for diagnosis and treatment of eye diseases as problem description are: Age, Diabetes, Medication or drug, Hypertension, Smoking tobacco, Drinking alcohol, Previous eye surgery, Radiation treatment, Hypothyroidism, Previous other eye disease, Cardiovascular diseases, Seeing blurred vision, Seeing clouded vision, Problem seeing at night, Problem seeing through light and glare, Seeing halos around lights, Frequently changing contact lens or eyeglasses, Seeing fading or yellowing colors, Need for brighter light for reading and other activities, Narrowed vision, Having vision loss, Severe pain in eyes, Nausea and vomiting, Sudden visual disturbance in low light conditions, Redness of the eyes, Burning and Dryness sensation, Stinging or Aching sensation, Sensitivity to light, Stringy mucus in or around the eyes, Eye fatigue, Filing like something is in the eyes, Floaters, Vision getting blurry when looking at Distant objects, Closed objects or at Normal distance, Squinting, Eyestrain, Eye irritation, Double vision, Excessive tearing, Heavy feeling in the eye, have difficulty in wearing contact lenses, thick yellowish discharge, pain in the eye, decreased vision, impaired color recognition, headache, swelling in the conjunctiva. As solution attributes are Diagnosis results and recommended treatment.

Most selected attributes have Boolean data types and some others have a string and an integer value. In general, the attributes (variables) that are needed for diagnosing eye disease cases are many.

However, due to a shortage of time, the researcher used those attributes that have a direct impact on those twelve eye diseases and recorded in eye disease patient's history cards.

To easily show the case representations working mechanisms, the researcher selected randomly selected a case from the notepad plain text connectors.

Sample case representations (Case 2):

case2,62,type2,diuretics,false,false,false,false,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,true,false,true,true,true,true,false,false,false,false,false,false,false,false,false,false,true,true,false,false,false,false,false,false,Dry-Eye-Syndrome,Artificial-tears-each-eye-per-day-approximately-6-hours-apart/Restasis-of-eye-drop-each-eye-per-day-for-3-month/Xiidra-two-applications-in-each-eye-per-day-approximately-12-hours-apart,

In this specific case, the main attributes which have more weight for diagnosis and treatment of eye disease are age which is 62, diabetes of type2 , takes diuretics medication, no hypertension, no smoking tobacco, no drinking alcohol, no previous eye surgery, no radiation treatment, no hypothyroidism, no cardiovascular diseases, have seeing blurred vision, no seeing clouded vision, no difficulty seeing at night, no problem seeing through light and glare, no seeing halos around lights, no frequently changing contact lens or eyeglasses, no seeing fading or yellowing colors, no need for brighter light for reading and other activities, no narrowed vision, no peripheral vision loss, no severe pain in eyes nausea and vomiting, no sudden visual disturbance in low light conditions, have redness of the eyes, have burning and dryness sensation, no stinging or aching sensation, have eye fatigue, have filing like something is in the eyes, have sudden appearance of floaters or dark spots through vision, no vision getting blurry when looking at distant objects, no closed objects or at normal distance, no squinting, no eyestrain, no eye irritation, no double vision, no heavy feeling in the eye, no excessive tearing, have sensitivity to light, have difficulty in wearing contact lenses, no thick yellowish discharge, no pain in the eye, no decreased vision, no impaired color recognition, no headache, no swelling in the conjunctiva. Accordingly, the results show that the patient has dry eye syndrome eye disease. As a result, the treatments are Artificial tears for each eye per day approximately 6 hours apart, Restasis of eye drops each eye per day for 3 months, Xiidra two applications in each eye per day approximately 12 hours apart.

Hence the researcher changed the obtained knowledge into case representations using note pad as depicted in figure 3.2.below.

```
CBRresultTest - Notepad
File  Edit  Format  View  Help
case1,56,type1,antihistamines,false,false,false,false,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,true,
false,true,true,true,true,false,false,false,false,false,false,false,false,false,false,true,true,false,false,false,false,false,false,
Dry-Eye-Syndrome,Artificial-tears-each-eye-per-day-approximately-6-hours-apart/Xiidra-two-applications-in-each-eye-per-day-approximately-12-hours-apart,
case2,62,type2,diuretics,false,false,false,false,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,true,false,
true,true,true,true,false,false,false,false,false,false,false,false,false,false,true,true,false,false,false,false,false,false,
Dry-Eye-Syndrome,Artificial-tears-each-eye-per-day-approximately-6-hours-apart/Restasis-of-eye-drop-each-eye-per-day-for-3-month/Xiidra-two-applications-in-
case3,45,false,antihistamines,false,false,false,false,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,true,
false,true,true,true,true,false,false,false,false,false,false,false,false,false,false,true,true,false,false,false,false,false,false,
Dry-Eye-Syndrome,Artificial-tears-each-eye-per-day-approximately-6-hours-apart/Restasis-of-eye-drop-each-eye-per-day-for-3-month,
case4,71,type2,antidipressants,false,false,false,false,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,true,
false,true,true,true,true,false,false,false,false,false,false,false,false,false,false,true,true,false,false,false,false,false,false,
Dry-Eye-Syndrome,Artificial-tears-each-eye-per-day-approximately-6-hours-apart/Restasis-of-eye-drop-each-eye-per-day-for-3-month/Xiidra-two-applications-in-
case5,27,false,false,false,true,true,false,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,true,false,false,
false,false,false,false,false,false,false,false,false,false,false,false,true,true,false,false,false,false,false,false,true,
Conjunctivitis,Artificial-tears-in-infected-eye-per-day/approximately-6-hours-apart/Antihistamines--falsen-steroidal-anti-inflammatory-drugs-twice-a-day-for
case6,43,false,false,false,true,true,false,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,true,false,false,
false,false,false,false,false,false,false,false,false,false,false,false,true,true,false,false,false,false,false,false,true,
Conjunctivitis,Antihistamines-or-falsen-steroidal-anti-inflammatory-drugs-twice-a-day-or-taken-once-a-day-for-month,
case7,31,false,false,false,false,false,false,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,true,false,
false,false,false,false,false,false,false,false,false,false,false,false,true,true,false,false,false,false,false,false,true,
Conjunctivitis,Antibiotic-eye-drops-or-ointments-for/they-are-typically-used-three-to-four-times-a-day-for-five-to-seven-days,
case8,15,false,false,false,false,false,false,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,true,false,
false,false,false,false,false,false,false,false,false,false,false,false,true,true,false,false,false,false,false,false,true,
Conjunctivitis,Topical-steroids-use-these-medications-for-only-a-couple-of-weeks-and-take-once-a-day/Artificial-tears-in-infected-eye-per-day/approximately-
case9,49,false,false,false,true,true,true,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,true,false,false,
false,false,false,true,false,false,false,false,false,false,false,false,true,true,false,false,true,true,false,false,true,
Uveitis,Oral-dosage-of-Corticosteroid/25to300-milligrams(mg)-a-day,
case10,34,false,false,false,true,true,true,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,
true,false,false,false,false,false,true,false,false,false,false,false,false,false,false,true,true,false,false,true,true,false,false,true,
Uveitis,Oral-dosage-of-Corticosteroid/25to300-milligrams(mg)-a-day,
case11,75,type2,false,false,true,true,true,false,false,false,true,false,false,false,false,false,false,false,false,false,false,
true,true,false,false,false,false,false,true,false,false,false,false,false,false,false,false,true,true,false,false,true,true,false,false,true,
Uveitis,Injection-dosage-of-Corticosteroid/20to300mg-a-day/injected-into-a-muscle/Anti-metabolite/approximately-6-hours-apart,
case12,67,false,false,false,true,true,true,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,true,true,false,false,
false,false,false,true,false,false,false,false,false,false,false,false,true,true,false,false,true,true,false,false,true,
Uveitis,Ocular-anti-inflammatory-injections/anti-metabolite/approximately-6-hours-apart,
case13,49,type2,false,false,false,false,false,false,false,true,true,false,true,false,false,false,false,false,true,true,false,false,true,true,false,false,
false,false,false,true,false,false,false,false,false,false,false,false,true,true,false,false,true,true,true,false,true,
Diabetic-Retifalsepathy,Eye-surgery,
case14,52,type2,false,false,true,true,false,false,false,false,true,false,true,false,false,false,false,false,true,true,false,false,true,true,false,false,
false,false,false,true,false,false,false,false,false,false,false,false,true,true,false,false,true,true,true,false,true,
Diabetic-Retifalsepathy,Eye-surgery,
case15,47,type1,false,false,true,true,false,false,false,false,true,false,true,false,false,false,false,false,true,true,false,false,true,true,false,false,
false,false,false,true,false,false,false,false,false,false,false,false,true,true,false,false,true,true,true,false,true,
Diabetic-Retifalsepathy,Laser-treatment,
case16,58,type2,false,false,false,false,false,false,false,false,true,false,true,false,false,false,false,false,true,true,false,false,true,true,false,false,
false,false,false,true,false,false,false,false,false,false,false,false,true,true,false,false,true,true,true,false,true,
Diabetic-Retifalsepathy,Eye-surgery,
case17,13,false,false,false,false,false,false,false,false,false,false,false,true,false,false,false,false,false,false,false,false,false,false,false,false,
false,false,false,false,false,true,false,false,true,true,false,false,false,false,false,false,false,false,false,false,false,false,
Myopia,Eye-glasses+2.00-diopter-(D)-to+3.00-D,
```

Figure 3.2 Case representations using notepad

To summarize the chapter, the acquired knowledge from human experts, document analysis and patient history card is modeled by using the decision tree knowledge modeling technique. It is helpful to explore the specific attributes which are significant in the process of eye disease diagnosis and treatment. Once the appropriate knowledge is acquired and modeled then it is represented by using rule-based and case-based knowledge representation techniques to develop and integrate the knowledge-based system. To integrate the reasoning system rule dominant approach is settled as a solution of the objective.

CHAPTER FOUR

DESIGN AND DEVELOPMENT OF THE PROTOTYPE

The design and development part of this section includes the real construction of the prototype system for the diagnosis and treatment of eye diseases. After the necessary knowledge is acquired and represented, the next step is coding the represented knowledge into a computer by using appropriate and efficient knowledge-based system development tools.

4.1. Designing the Architecture

Architecture is a blueprint that is used to indicate the structure of the system [47]. The architecture of the prototype system is shown in figure 4.1. The prototype integrates rule-based and case-based approaches for developing a knowledge-based system for diagnosis and treatment of eye diseases.

As presented in Figure 4.1, the knowledge engineer collects knowledge from different sources by using different knowledge acquisition methods. In this study, the researcher acquires knowledge by analyzing different relevant documents and guidelines for diagnosis and treatments of eye diseases. In addition to this, knowledge was acquired by interviewing five domain experts who are well educated and experienced doctors, residents, and ophthalmologists in Jimma University specialized hospital. The final knowledge acquisition method is finding knowledge from previously solved cases from Jimma University specialized hospital patients history recorded card.

After acquiring knowledge, the knowledge engineer has represented this knowledge into an appropriate format which is easily understandable by the computer systems using different knowledge representation methods. For this study, the researcher used rule-based knowledge representation and case-base knowledge representation methods which are the most popular knowledge representation methods in the development of KBS. Besides this, knowledge modeling is done to organize the acquired knowledge for easy and clear knowledge representation. The next step is developing the RBR system and CBR system for manipulating rules and cases represented and stored in a knowledge base.

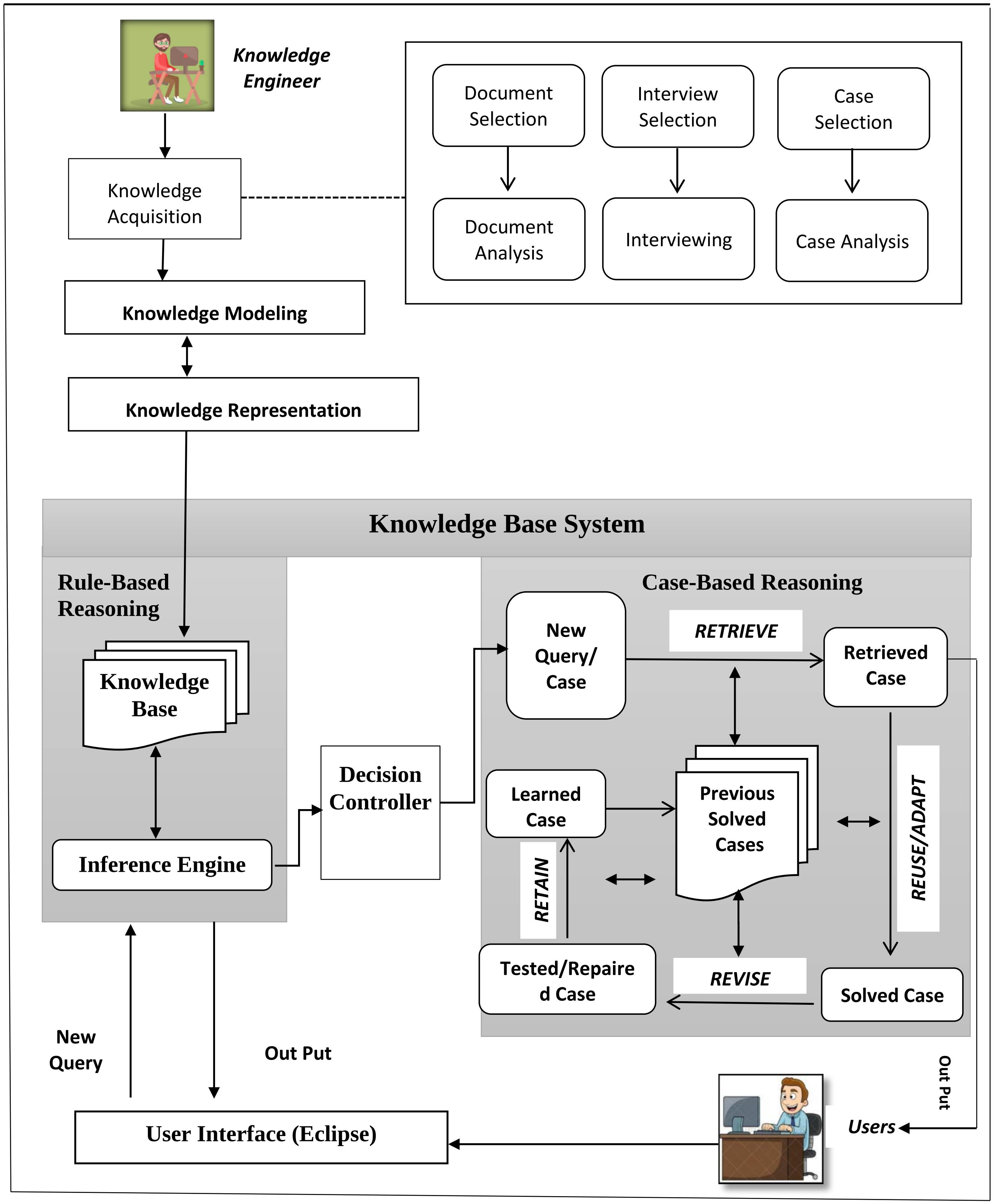


Figure 4.1 System Architecture of Prototype for Diagnosis and Treatment of Eye Diseases

The integrated system starts by accepting the new query from users with the help of the interface. When the new query is entered the integrated reasoning system first uses RBR to search for the rules/facts that match the new query from the rule base. If exact matches found the RBR gives the solution. If not, the query is passed to CBR. The CBR system has the capability of retrieve, reuse/adapt, revise and retain cases. The retrieval task starts with a new case description and ends when the best matching similarity case of sign or symptom of cases found from the case base.

The system searches the best matching cases from the case base and returns the possible solution in ranked order to the problems described in the query. If exact matching occurred in between the query and cases in the case base, users can directly use the solution or if the similarity or matching is partial, then adaptation, revision, and reuse tasks are done to make the proposed solution best for the problem at hand. The final step is modifying the best solution and stored to the case base for future use, thereby the system becomes self-learnable.

4.2. Building Rule-base System

The aim of this study is to integrate RBR and CBR for designing the knowledge-based system. In order to build the RBR system, the basic components of KBS have to be organized. Let us discuss these basic components which are used for the development of the RBR system for diagnosis and treatment of eye diseases.

4.2.1. Knowledge-base

The researcher stores all knowledge that is collected from domain experts and document analysis in the knowledge-based as a set of rules, "IF-THEN" statements using rule-based knowledge representation method. The collected knowledge includes symptoms of eye diseases, how-to diagnose and treat different eye diseases. For this study, the selected sign and symptoms are categorized and generated into 12 rules for the diagnosis of selected eye diseases. The knowledgebase contains one rule for each eye disease with the proper treatment. The RBR system is first developed by using prolog programing language so that, the following (figure 4.2) sample code shows rules generated for the diagnosis of eye diseases.

```
Rule1: hypothesis(Patient,astigmatism) :- symptom(Patient,eyestrain),
symptom(Patient,blurry_distance), symptom(Patient,blurry_close), symptom(Patient,squinting).

Rule2: hypothesis(Patient,dry_eyes_syndrome) :-
symptom(Patient,blurred_vision),symptom(Patient,redness), symptom(Patient,light_sensitivity),
symptom(Patient,burning_itching), symptom(Patient,dryness), symptom(Patient,fatigue).

Rule3: hypothesis(Patient,conjunctivitis) :- symptom(Patient,blurred_vision),
symptom(Patient,redness), symptom(Patient,light_sensitivity), symptom(Patient,burning_itching),
```

Figure 4.2: Sample code using prolog for the diagnosis of eye diseases

Therefore, the RBR system checks rules for diagnosing eye disease. If any of the 12 rules don't validate as true for a certain disease, then that incident is not known in the RBR system.

```
2 ?- start.
What is the name of the patient: zelalem.

Does zelalem have seen blurred vision (y/n) ?y.

Does zelalem have redness appearing in the eyelid or through the white of the ey.

Does zelalem have extra or light sensitivity in the eyes (y/n) ?y.

Does zelalem have burning and itching sensation in the eyes(y/n) ?y.

Does zelalem have dryness sensation in the eyes(y/n) ?y.

Does zelalem have stringy mucus in or around the eyes, eye fatigue, difficulty y.

zelalem probably have dry_eyes_syndrome
```

The above module is the asking module, which helps in creating interaction with the user. The RBR system presents a question to the user using this module. This module is designed in a manner to accommodate any changes in the rules and facts. The questions displayed are based on the contents of rule and fact bases. Whenever a change in knowledge base happens, the question asked also changes accordingly. The RBR system uses forward chaining reasoning mechanisms.

4.2.2. Inference Engine

An inference engine is the brain of the KBS which directs the system to derive conclusions by looking for possible solutions from the knowledge-base and recommend the best possible solution. Since the objective of the proposed knowledge-based system is diagnosis and treatment of eye diseases, the prolog's built-in inference mechanism is forward chaining is used. The whole program written for developing a rule-based reasoning system is attached in Appendix IV.

4.3. Building Case-base System

In order to build a CBR system, selecting the exact and appropriate cases is the first stage. After that, the collected cases can be stored in representational formats. So, the researcher collects the diagnosis and treatment of eye patient's cases/knowledge from the patient recorded card. The acquired cases are used to build a case-based eye diagnosis and treatment system. All the acquired cases are stored as a plaintext file in a feature value representation format to represent cases.

The case-base is presented as a plaintext comprising of n columns representing case attributes (A_1, A_2, A_3, …, A_n) and each m rows representing individual cases C ={C_1, C_2, C3, …,C_m} each attribute has a sequence of possible k values associated to each column attribute A={V_1, V_2, V_3, …, V_k}. The reason for representing cases using feature-value representation is that this approach supports the nearest neighbor retrieval algorithm and it represents the case in an easy way.

4.3.1. Managing the Case Structure in JCOLIBRI

The acquired cases are saved in plaintext file format. All the 49 attributes listed in table 4.1 have a significant impact on the diagnosis and treatment of eye diseases. For building a CBR system the value of the weight for the attributes comes from attribute selection using information gain from experts' feedback. As a result, all attributes are selected from collected cases and weights are given by discussing with experts as it depicts in table 4.1 below.

Table 4.1 Managing the Case Structure in JCOLIBRI

Description Attributes			
Attributes Name	**Data Type**	**Weight**	**Local similarity**
Age	Integer	1.0	Equal
Diabetes	String	0.9	Equal
Medication or Drug	String	0.9	Equal

Attributes Name	Data Type	Weight	Local similarity
Hypertension	Boolean	0.9	Equal
Smoking tobacco	Boolean	0.9	Equal
Drinking alcohol	Boolean	0.9	Equal
Previous eye surgery	Boolean	0.9	Equal
Radiation treatment	Boolean	0.9	Equal
Hypothyroidism	Boolean	0.9	Equal
Cardiovascular diseases	Boolean	0.9	Equal
Seeing blurred vision	Boolean	1.0	Equal
Seeing clouded or dim vision	Boolean	1.0	Equal
Difficulty seeing at night	Boolean	1.0	Equal
Problem seeing through light and glare	Boolean	1.0	Equal
Seeing halos around lights	Boolean	1.0	Equal
Frequently changing contact lens or eyeglasses	Boolean	1.0	Equal
Fading or yellowing view of colors	Boolean	1.0	Equal
Need for brighter light for reading and other activities	Boolean	1.0	Equal
Tunnel or narrowed vision	Boolean	1.0	Equal
Peripheral vision loss	Boolean	1.0	Equal
Severe pain in eyes accompanied by nausea and vomiting	Boolean	1.0	Equal
Sudden visual disturbance in low light conditions	Boolean	1.0	Equal
Redness of the eyes	Boolean	1.0	Equal
Burning and itching sensation	Boolean	1.0	Equal
Stinging or Aching sensation,	Boolean	1.0	Equal
Dryness sensation in eyes	Boolean	1.0	Equal
Stringy mucus in or around the eyes	Boolean	1.0	Equal
Eye fatigue	Boolean	1.0	Equal
Filing like something is in the eyes	Boolean	1.0	Equal
Sudden appearance of floaters or dark spots through vision	Boolean	1.0	Equal
Vision getting blurry when looking at distant objects	Boolean	1.0	Equal
Vision getting blurry when looking at closed objects	Boolean	1.0	Equal
Vision getting blurry when looking at normal distance	Boolean	1.0	Equal
Squinting	Boolean	1.0	Equal
Eyestrain	Boolean	1.0	Equal
Eye irritation	Boolean	1.0	Equal
Double vision	Boolean	1.0	Equal
Heavy feeling in the eye	Boolean	1.0	Equal
Excessive tearing	Boolean	1.0	Equal
Sensitivity to light	Boolean	1.0	Equal
Difficulty in wearing contact lenses	Boolean	1.0	Equal
Thick yellowish discharge	Boolean	1.0	Equal
Pain in the eye	Boolean	1.0	Equal
Decreased vision	Boolean	1.0	Equal
Impaired color recognition	Boolean	1.0	Equal
Headache	Boolean	1.0	Equal
Swelling in the conjunctiva	Boolean	1.0	Equal
Solution Attribute			
Diagnosis result	String	1.0	EqualStringingrecase
Recommended treatment	String	1.0	EqualStringingrecase

4.3.2. Case Attributes

Defining the case structure in JCOLIBRI is done using a simple manage case structure window. It is very easy to define the case structure with JCOLIBRI. Because it is simple to add attributes in the description of case structure and set properties of attributes of metadata of attributes. Metadata of attributes are the data type of attributes, similarity function and weight of attributes. During configuration of case structures, JCOLIBRI creates codes automatically and saved in XML file format. Most significant attributes are set by declaring higher weight as compared to other weights. Descriptive modeling for designing case-based reasoning in eye disease diagnosis and treatment prototype case-base has 47 description attributes and 2 solution attributes. The solution attribute is used after finding the best selected cases, which shows the diagnosis result and gives the recommended treatment. Appendix III shows the description of case attributes regarding name, data type, weight, and local similarity.

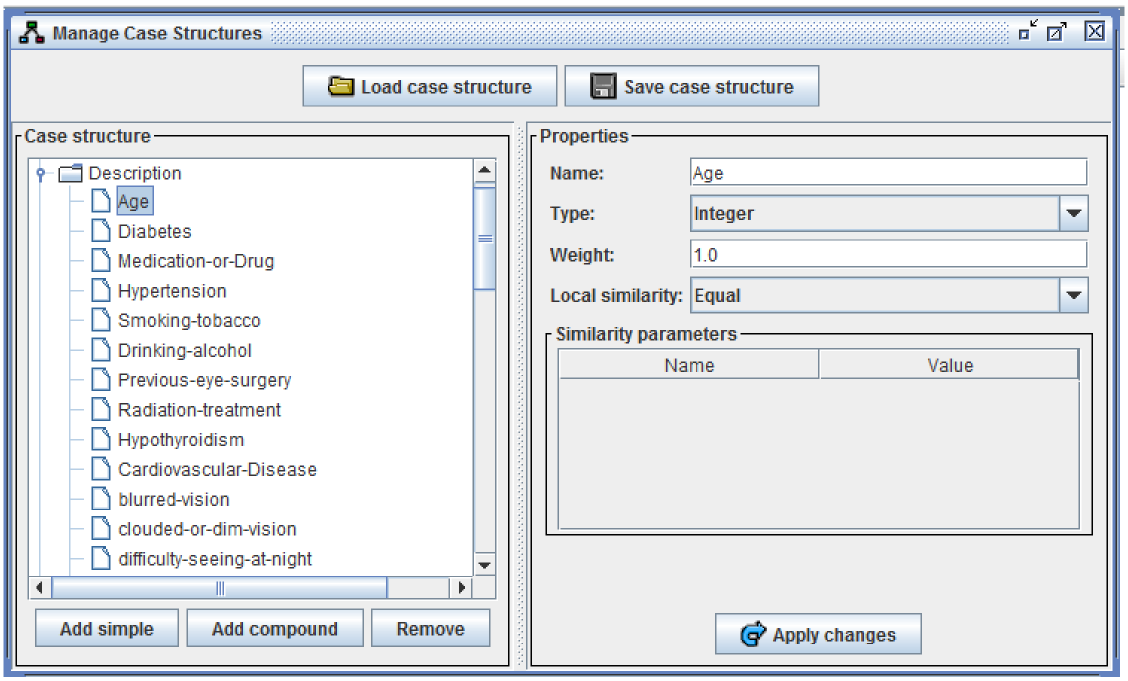


Figure 4.3 Configurations of Case Structures and Similarities

4.3.3. Managing Connectors

Once case structures are configured in JCOLIBRI, the CBR system must access the stored cases in an efficient way. JCOLIBRI splits the problem of case-base management into two separate related concerns: persistency mechanisms through connectors and in-memory organization. A connector is an object which has the ability to access and retrieve cases from a specific case persistency when given the case structure and gives those cases to the CBR system in a standardized way. Because of this, JCOLIBRI can deal with any case persistency as long as a connector is provided.

Connectors are objects that know how to access and retrieve cases from the storage media and return those cases to the CBR system in a uniform way. Therefore, connectors provide an abstraction mechanism that allows users to load cases from different storage sources in a transparent way. As shown in figure 4.4, JCOLIBRI includes connectors that work with plain text files, relational databases, and Description Logics systems.

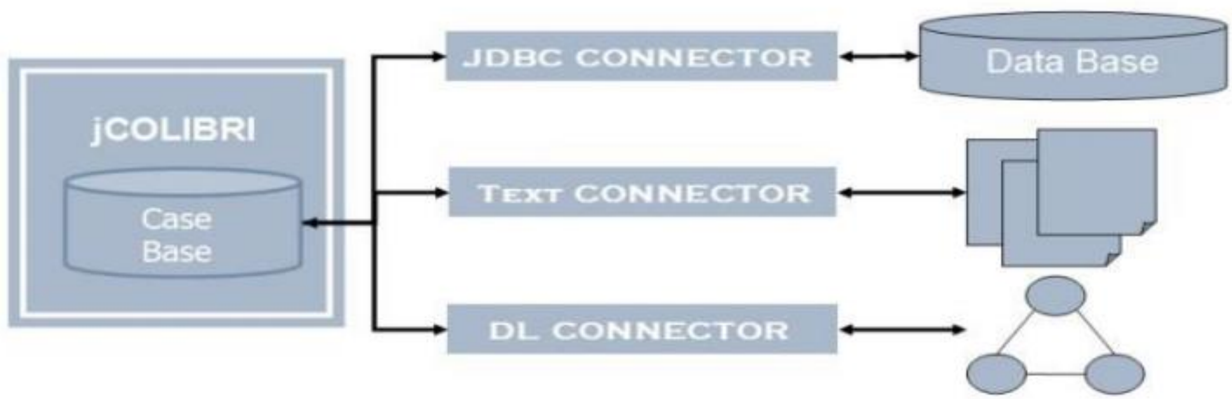


Figure 4.4 The JCOLIBRI Connector Architecture [24]

For the implementation of Case-based, the researcher used plaintext connector because dataset cases are stored in a plaintext file format. Plaintext file case-base connector is used for the persistence of cases. In this connector, the researcher has to specify the path of the case structure and also the path of a text file. All the attributes of a case should be mapped. This is the connector’s responsibility to retrieve data from case-base and return it back to GUI. Like that of the case structure, the connector is also saved in XML format.

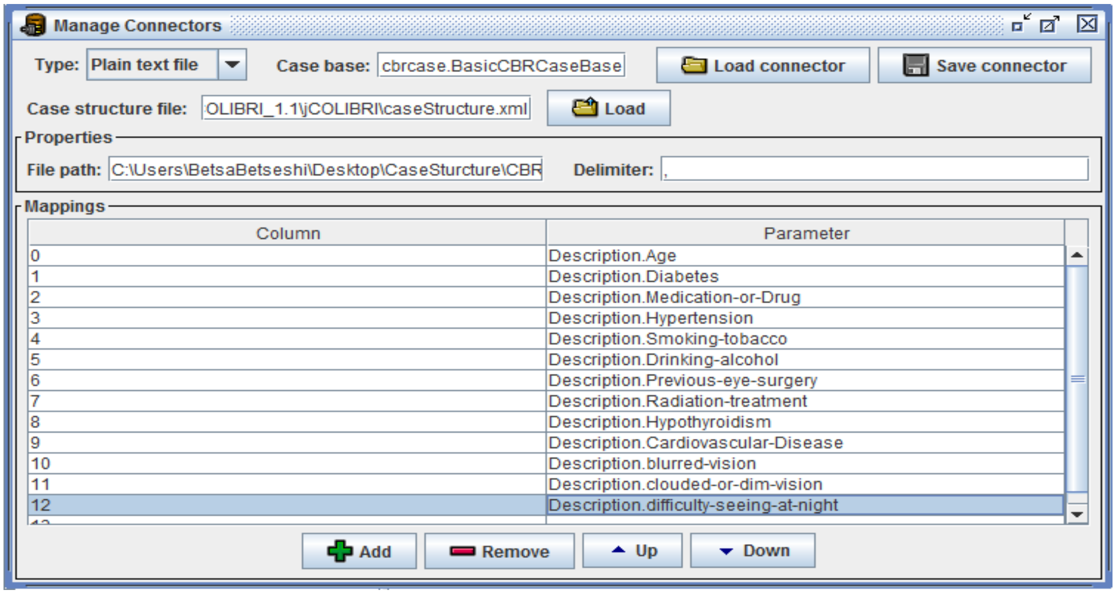


Figure 4.5 Managing Connector Configuration

4.3.4. Manage Tasks and Methods

4.3.4.1. Managing Tasks

For the development of eye disease diagnosis and treatment of a case-based system, the researcher used core package tasks such as Pre-Cycle, main CBR cycle and Post-Cycle [55]. In the first step, the Pre-Cycle task gets all the cases in case-base. Therefore, it is necessary to define the dataset path of the connector in its subtask. There is only one subtask called obtaining case task and it is used to retrieve data from case-base before the execution of the main CBR cycle. The main CBR cycle is the main task of the CBR cycle and it also has sub-tasks. The developer has to give the path of the case structure in it. It knows the number of case attributes that are available. It is called obtain query task. In addition, to obtain a query task, there are other significant tasks under the main CBR cycle. These are retrieved tasks, reuse tasks, revise task and retain tasks [59].

Retrieve tasks used to retrieve case(s) from the stored case-base. Retrieve tasks also decomposed into different subtasks. The subtasks include select working cases task, compute similarity task and select the best case. Select working case tasks, select cases from case-base and stores them into the current context. Compute similarity task compute the similarity of the stored cases with the case entered by the user using the query window. Then select the best case shows the best match of the case(s) after computing the similarity of stored cases against the new case. It means that the number of best-matched case(s) is shown to the user depending on the method used and the threshold.

Reuse tasks enable to reuse of previously-stored cases. It has three subtasks. These subtasks are: prepare cases for adaptation task, automatic reuse task. Prepare cases for adaptation task select cases from case-base and stores them into context. Here also specifying the path of case structure in this method is needed. Atomic reuse tasks should be resolved by reuse the resolution method.

Revise tasks are the evaluation stage about the selected solution in the reuse phase. After selecting the most similar cases from the retrieved results, the solution for the problem should be confirmed and validated before the solution is stored for future use.

Retain tasks also used to CBR case retention on a persistence layer. It has also its own subtasks like select cases to store tasks and store cases task. Select cases to store task give authentication to the user for storing case. The store case task enables to store case(s) into the case-base.

The last task in managing tasks in JCOLIBRI is PostCycle. PostCycle tasks have only one sub-task called close connectors task which is usually executed after the main CBR cycle. Its main task is to close a connection between case-base and GUI.

Case Similarity, Matching, and Ranking

The primary goal of the CBR system is to retrieve the best similar cases by using some similarity assessment of heuristic functions. The similarity function involves computing the similarity between the stored cases in the case-base and the query and selects the nearest similar cases to the query. Therefore, JCOLIBRI uses the nearest neighbor algorithm as a case retrieval technique. This is because JCOLIBRI uses the nearest neighbor algorithm for retrieval tasks. The nearest neighbor algorithm retrieves the case which is nearest to the user`s query by measuring its similarity with the cases. Given a collection of cases and query point in an m-dimensional metric space, find the new case that is closest to the query point. Similar queries are performed by taking a given complex object, approximating it with a high dimensional vector to obtain the query point, and determining the data point closest to it in the underlining feature space.

The nearest neighbor algorithm used to measure the similarity between the stored and the new queries and return the search results within their ranked order. For each attribute in the query and case, local similarity function measures the similarity between two simple attribute values. Based on the matching weighted sum features from those simple attributes, the similarity score between the queries and stored cases for each simple attribute is assigned.

Finally, the average score (global similarity) of each attribute between the case and the query is computed and the result is assigned to the object (the similarity between the stored case and the query). The maximum degree of similarity among the retrieved cases is displayed according to their ranked order.

4.3.4.2. Managing Methods

The method library stores classes that actually resolve the task. These classes can resolve the CBR cycle using programming or using GUI. All tasks that are mentioned above should have their own methods to be assigned in order to achieve the goal of the task. The following are lists of methods that are used to solve tasks for this case-base eye disease diagnosis and treatment application.

LoadCaseBaseMethod: This method returns the whole available cases from the case-base to the designer. This method uses a connector to retrieve case-base.

ConfigurQueryMethod: This method resolves to obtain query tasks. By receiving the case structure as input parameters, it displays a GUI window so that the user can enter a query to retrieve cases from the case-base.

SelectAllMethod: This method allows displaying all the available cases from the case-base to the result window.

SelectSomeMethod: This method resolves to select the best task by choosing the „n" most high similarity value from the returned cases. It requests the number of cases to give as the input gets the best match with the requested input.

NumeriSimilarityComputationalMethod: this is used to calculate the similarity between the query and cases that are stored in the case-base.

NumericProportionMethod: it is the sub-method of reuse task which involves computing numeric proportions between the description attributes and solution attributes.

ManualRevisonMethod: The manual revision method permits users to modify cases in the query window as they need.

RetainChooserMethod: This method allows the user to choose the method. The chosen method will store case-base. User can choose what he/she want this method to store in case-base.

Retain tasks also used to CBR case retention on a persistence layer. It has also its own subtasks like select cases to store tasks and store cases task. Select cases to store task give authentication to the user for storing case. The store case task enables to store case(s) into the case-base. The last task in managing tasks in JCOLIBRI is Post Cycle. Post Cycle task has only one sub-task called close connectors task which is usually executed after the main CBR cycle. Its main task is to close a connection between case-base and GUI. In general, these are some of the methods discussed and used for this research. But there are many other methods available in JCOLIBRI method library. It is the task of the knowledge engineer to choose the most appropriate method during designing the CBR application. Figure 4.6 shows the configuration of tasks and methods.

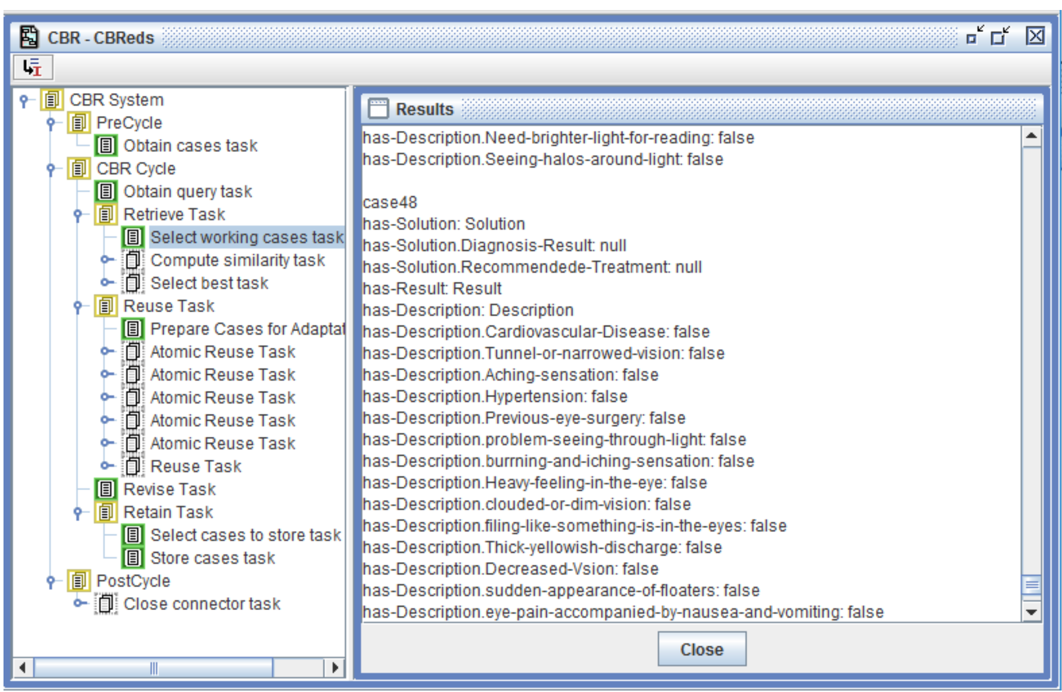


Figure 4.6 Tasks and Methods Configuration

In the configuration window depicted in figure 4.5, the left side shows the tasks and subtask and the right side shows the methods.

4.4. Combining Rule-based and Case-based systems

Once rule-based and case-based reasoning systems are constructed, an experiment is made to decide the order of using them for eye diagnosis and treatment. The main objective of this study is to integrate CBR and RBR for designing a knowledge-based system. According to Prentzas [22], the integration approach of rule-based with case-based reasoning is categorized in to rule dominant, case dominant and balanced approach. The categorization is based on the importance of each of the two-component schemes in the inference process.

The first category, rule-dominant approaches include approaches in which the rule-based component prevails in the inference process, whereas the case-based component plays a complementary role. The approaches belonging to this category usually focus on the rule-based component and invoke the case-based component only when rules are unable to deal with specialized situations. But this is not advisable when there are a large number of rules in the rule library.

The second category, case-dominant approaches consist of approaches in which the case-based component plays a more important role and the rule-based component is less significant. In this paradigm, the rules play a supportive role in case-based reasoning, useful for instance when the case library contains a limited number of cases. The approaches belonging to this category will be referred to as case-dominant approaches.

The third category, balanced approaches consist of approaches in which the role of the integrated components is balanced, which means that none of the integrated components plays a supportive role. The innovative aspect is the ability to dynamically adapt rules belonging to specific classes in order to improve the handling of a new situation. Refinement of the rules is performed with the use of cases and involves certain parameters of the rules, which are too general to deal with the specific situation. General structured knowledge is used to retrieve and adapt cases from the case-base. If no case is found to be applicable for a specific situation (meaning there is a gap in case-based knowledge), inference uses only the rules and the case-base is updated using the produced outcome. Therefore, the rule-based and the case-based components assist each other during inference. The integration makes the system more effective in detecting the patient's problems and making proper prescriptions reducing the time required to resolve the patient's problems. From these three categories of integration approach, the researcher used rule dominant approach because of the experimental results of both rule and case dominant.

According to Khandelwal [61], the combination of the two reasoning techniques is implemented by applying either rule-based or case-based reasoning first and then followed by the other as shown in figure 4.6. In this, if the solution given by the reasoning mechanism used in the first step is accepted, then it is used as a solution to the given problem, otherwise, the other reasoning is consulted.

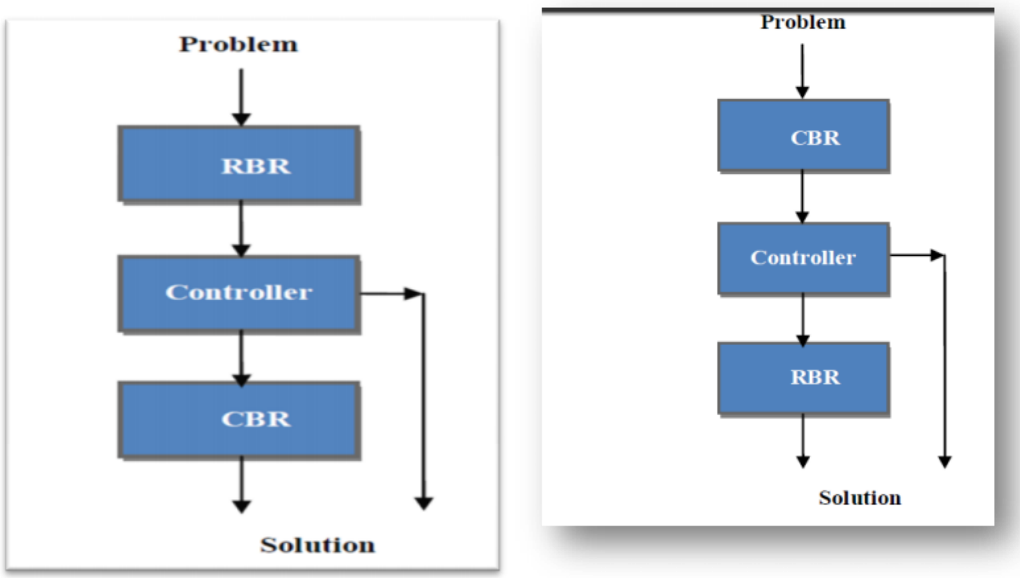


Figure 4.7 Conditional Combination Models of CBR and RBR [61]

To choose which model of combination is more preferable in the eye disease diagnosis and treatment process, an experiment is conducted using the same test dataset and the performance of the individual reasoning model is compared. All the experimental result is discussed in Chapter Five system performance test section. This comparison helps to see what model of combination has to take to enhance the already developed eye disease diagnosis and treatment systems. The experiment is done for: RBR system, CBR system, CBR followed by the RBR system and RBR followed by a CBR system.

Table 4.2 below shows the comparison of the performance of CBR and RBR and their combination in terms of percentage of correctly and incorrectly identified disease diagnosis and treatment.

Table 4.2 Experimental results of CBR and RBR and their combined performance

Reasoning model	% of correctly identified	% of incorrectly identified
RBR	70.8%	29.1%
CBR	75%	25%
CBR-RBR	75%	25%
RBR-CBR	87.5%	12.5%

As clearly seen in table 4.2, the first experiment is undertaken using RBR and CBR independently. From the experiment, the two reasoning gives 70.8% and 75% correctly identified result respectively. The second experiment is undertaken by combining the two reasoning approaches, in which Rule-based Reasoning followed by Case-based Reasoning (RBR-CBR) achieves 87.5% accuracy and Case-based reasoning followed by Rule-based reasoning (CBR-RBR) score 75% accuracy. The experimental result shows that, as compared to the individual performance of CBR and RBR, combining the two reasoning provides better performance. When we look at the two approaches for combining RBR and CBR, RBR followed by CBR outperforms CBR followed by RBR. Hence for designing eye disease diagnosis and treatment system, the researcher used RBR followed by CBR.

As stated by Prentzas [22] and Edwina [62] the following are the advantages of the RBR-Controller-CBR model of combination.

- RBR module uses more general knowledge to solve situations not reflected in CBR. Therefore, to solve problems in a given area, it is common to start with general knowledge.
- RBR is a collection of rules/facts and used exact matching of problems to solve. If the problem matches, the solution will be 100% acceptable or correct, but CBR measures similarity.
- Allows shortcuts in reasoning. If appropriate rules can be found, problems can often be solved in much less time than it would take to generate a solution from cases.

So, in this study, the combination of the RBR system followed by the CBR system is selected and it is used for the implementation of an integrated eye disease diagnosis and treatment system.

To summarize the chapter, in the designing and development phase the architecture of the prototype system is designed. By using the architecture of the prototype system, the researcher developed the integrated system. The rules were constructed in the RBR system with the ‘IF-THEN’ format. The ‘IF-THEN’ format of a prototype is used mainly by depending on the decision tree model, which was discussed in chapter three. To achieve the goals of the system, the inference engine uses a forward chaining reasoning mechanism. The cases were presented in the CBR system as a plaintext comprising by using a feature value representation approach. This approach used the nearest neighbor retrieval algorithm which represents cases in an easy way. Furthermore, the integration of the prototype system is designed by using conditional combination models of the RBR-CBR order. In general, the system is designed by using Java Eclipse and JCOLIBRI knowledge-based system development tools.

CHAPTER FIVE

DEMONSTRATION AND EVALUATION OF THE PROTOTYPE

This chapter presents users' evaluation of the developed system as well as the performance evaluation of the system. While system demonstration is a prototype rough example of the future system, put together as proof of concept with the primary purpose of showcasing the possible applications, feasibility, performance, and method of an idea for a new system [63]. System evaluation is a means of verifying whether the proposed system meets the objectives as set by the researcher based on the requirements of the user [58]. Therefore, to realize the objectives of this study, a manual knowledge acquisition technique was used from document analysis (such as manual, regulation), interviewing Jimma University Specialized Hospital experts and collecting cases from Jimma University Specialized Hospital patients' cards. Then, the researcher constructs the RBR system and CBR system that contains rules and cases for eye diseases diagnosis and treatment. After that, the two systems are connected to come up with an Integrated Eye Disease Diagnosis and Treatment System (IEDDTS). In this chapter, the IEDDTS demo is presented and the performance and user acceptance are also discussed.

5.1. Demonstration of the Prototype

In this study, the conditional combination of CBR and RBR took place by using Java eclipse to combine the two mechanisms. The diagnosis and treatment process is undertaken by interacting with the user through presenting a serious of questions for the user. The system asks the user by displaying yes/no questions for reasoning using the rule-based and case-based systems. The user is expected to reply to the questions, based on which the RBR system starts the first reasoning. Thereby, if the solution exists the RBR diagnoses the disease like cataract, dry eye syndrome, glaucoma, presbyopia, myopia, hypermetropia, astigmatism, retinal detached, conjunctivitis, strabismus, diabetic retinopathy, and uveitis, and displays the result. If the RBR does not identify the solution for the type of disease users ask in the diagnosis process, the query is forwarded to the CBR system.

The user interface facilitates communication between the system and the user. Since the graphical user interface of prolog is not user-friendly, so the researcher preferred to develop the graphical user interface of the proposed system by using eclipse Photon 4.8.0 with JDK 8. In the below figure 5.1, it shows the user interface contained some of the rules generated from a prolog programming language. The attributes are some of the rules used to determine the type of eye disease symptoms which are selected for rule-based development.

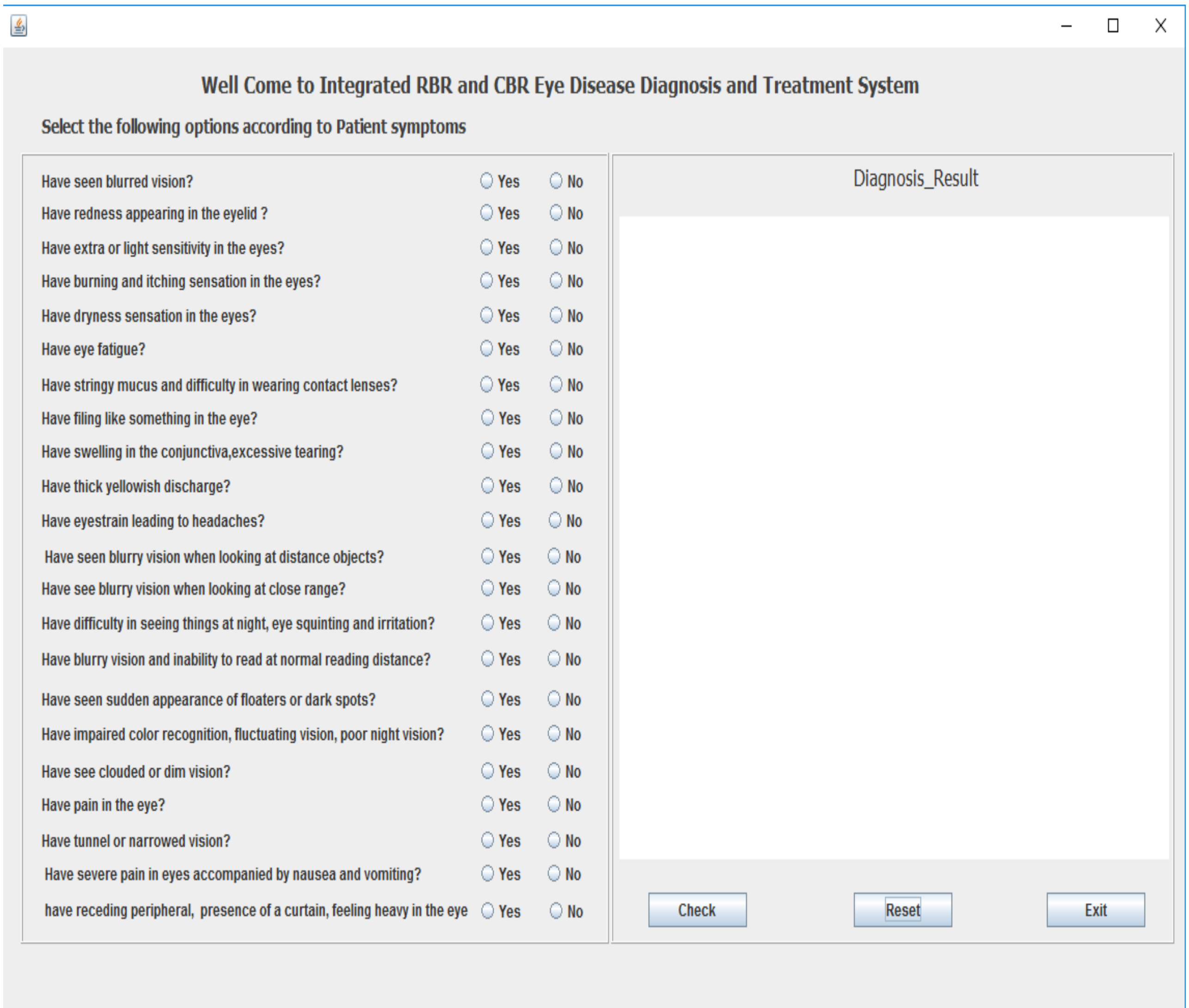


Figure 5.1 User Interface of the integrated RBR and CBR

In the below interface shown in figure 5.2, it allows the user to select the radio button as per the new query and click the radio button, if the condition is satisfied, the type of disease and suggested treatment is displayed at the provided space as shown in figure 5.2.

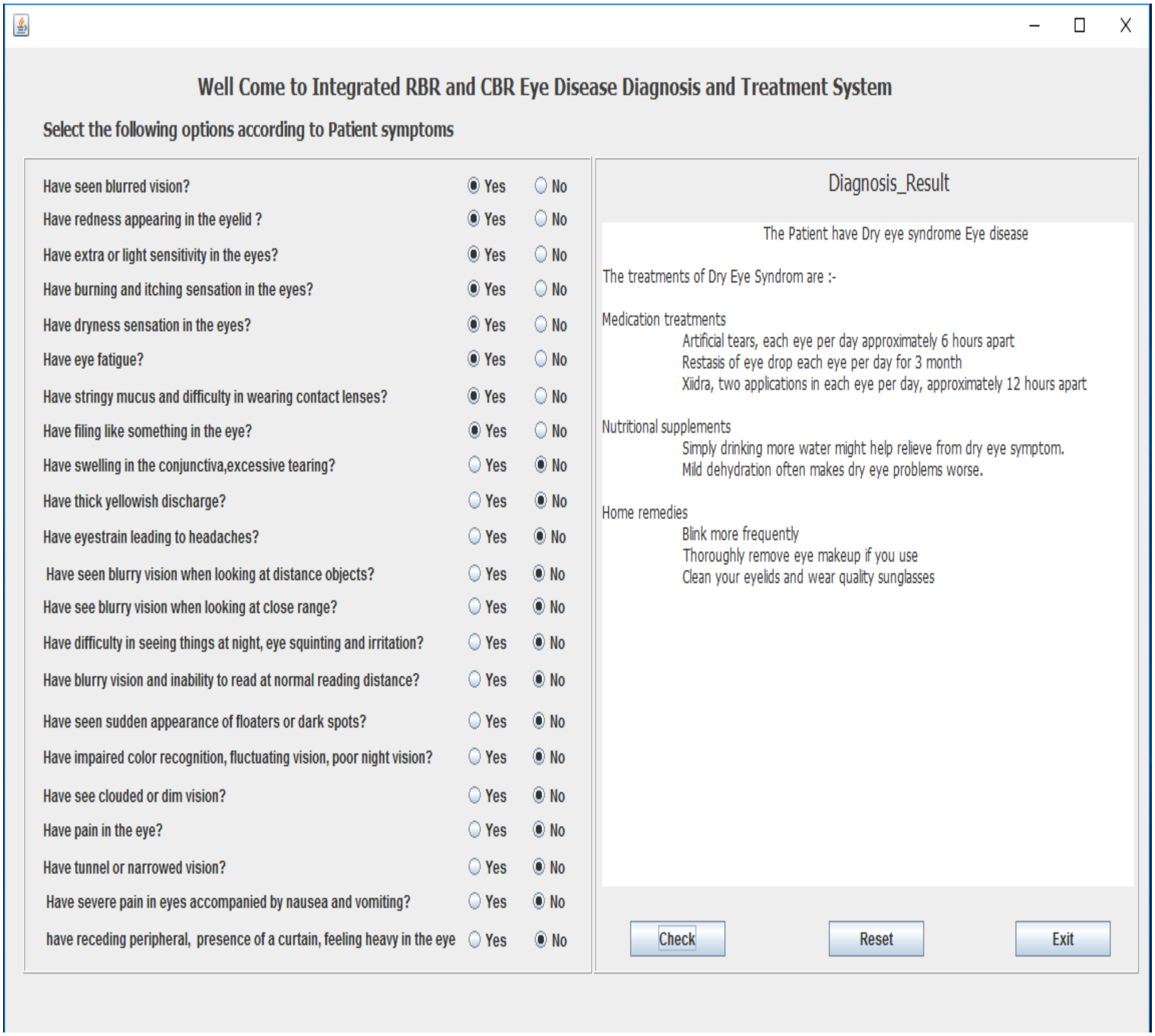


Figure 5.2 User interface of the integrated system diagnosing Dry Eye Syndrome eye disease

In the above figure 5.2, the RBR displays the exact treatment as per the users' selection of symptoms in the provide space after the press ‘Check’ button. If a user wants to select other symptoms to diagnose other types of eye disease, he/she can press the ‘Reset’ button to start again. To leave from the system he/she can press the ‘Exit’ button. If the RBR system does not resolve the question, the CBR will receive the query. The CBR system has the capability of retrieve, reuse/adapt, revise and retain cases.

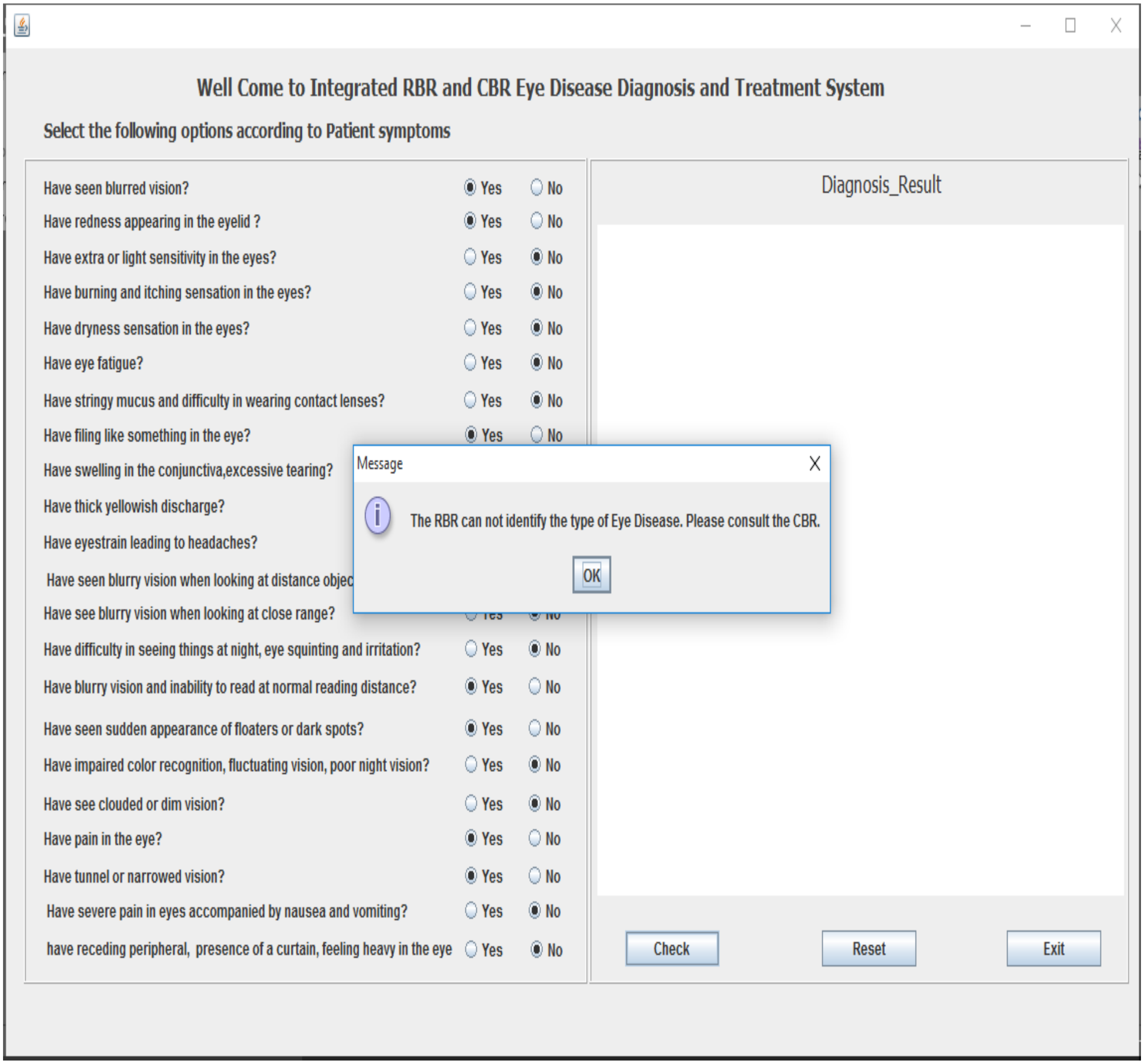


Figure 5.3 RBR system cannot identify the type of disease

As shown in the above figure 5.3, if the selection symptoms are not correctly diagnosed by the RBR system for the exact disease, the RBR displays the message “The RBR is not able to identify the type of eye disease. Please consult the CBR”. Then the case is passed the query to CBR. If the user presses the ‘Ok’ button and the ‘Exit’ button the system automatically goes to the JColibri interface of the CBR. The JColibri interface of the CBR (depicted in figure 5.4) is displayed automatically and users can open the query dialog box for diagnosing the type of disease.

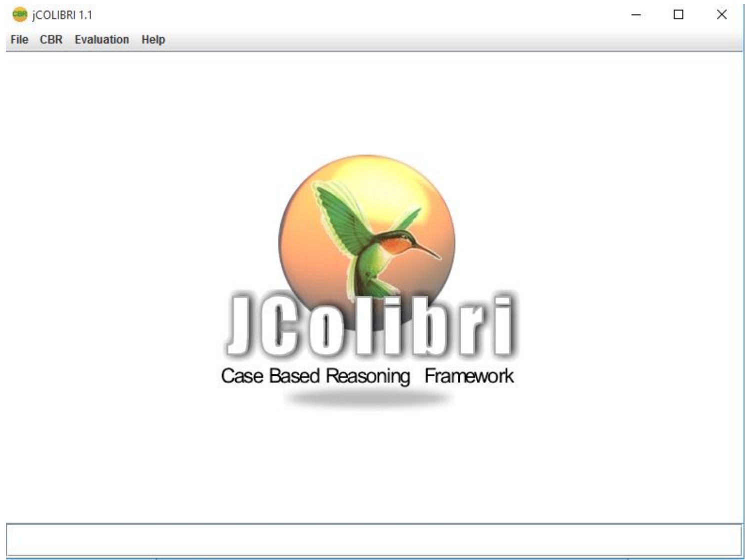


Figure 5.4 JColibri interface of the CBR

As shown in the below figure 5.5, the query interface of CBR will be opened by users. The CBR elements measure similarity, retrieve cases, display result, adopts cases, refine/revise case and retain is done at the end.

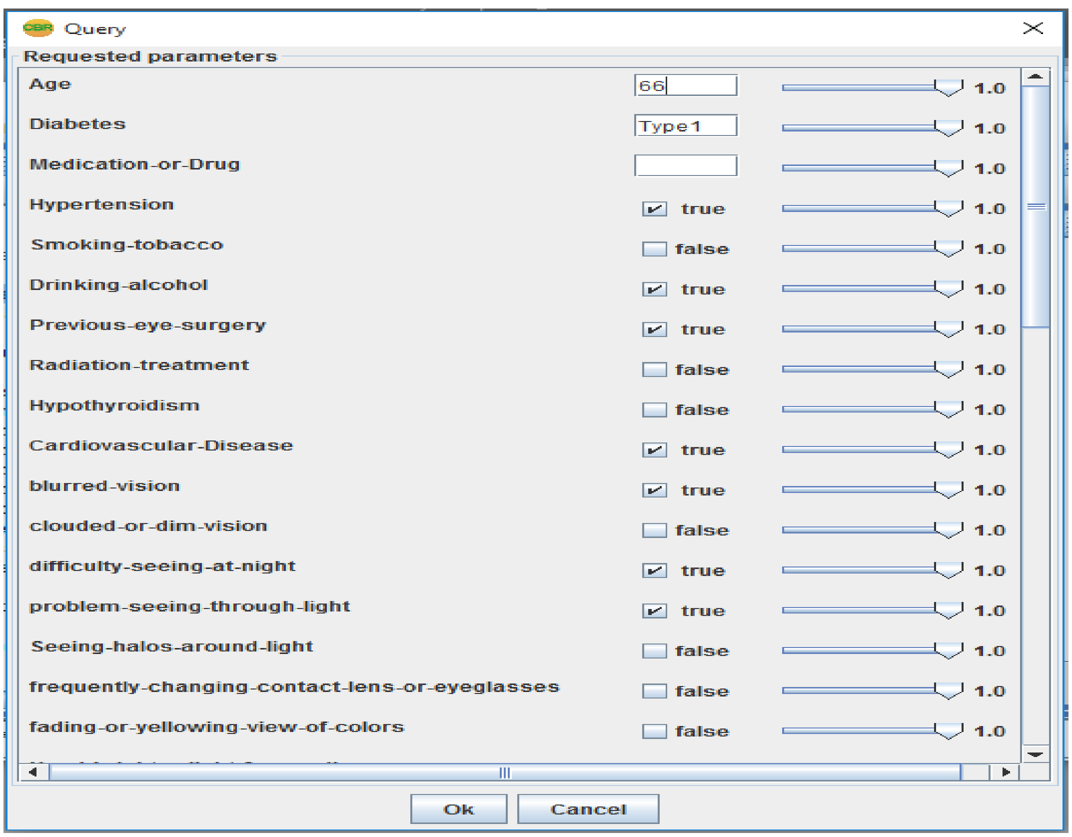


Figure 5.5 The query interface of the CBR

When users entered a new query through this interface, the system searches the best matching cases from the case base and retrieve possible solution in ranked order to the problems described in the query. If the similarity or matching is incomplete, adaptation, revision, and reuse tasks are done to make the proposed solution best for the problem at hand. The final step is modifying the best solution and store in the case base for future use; this makes the system a learning system.

5.2. System Performance Testing

The evaluation of the proposed system was done by selected appropriate test cases with domain expert system evaluators' interaction. Each case is selected purposively to test the performance of the prototype system. Therefore, the accuracy value of the system is calculated based on its retrieved cases.

The researcher prepared a total of twenty-four (24) test cases for evaluating the proposed system. Selection of domain experts is done purposively from Jimma University specialized hospital eye department by considering their professions, educational qualification level and years of experience on eye diseases. The eye department involved two eye specialist doctors, two ophthalmologists, and one resident. As a result, the five experts involved in testing the prototype IEDDTS.

For identification of relevant cases, the test cases are given to the domain expert in order to assign possible relevant cases from the prototype system to each of the test cases. The domain experts use the value of diagnosis results and recommended treatment as the main concept to assign the relevant case to the test cases. The testing method used for evaluating the performance of the prototype system was made by using the precision and recall of the parameter. These two parameters were used in order to measure the accuracy of the prototype system. The recall is defined as the ratio of the number of relevant cases returned to the total number of relevant cases for the new case; whereas precision is the ratio of the number of relevant cases returned to the total number of cases for a given new case [63].

For the purpose of the validation process, the twenty-four (24) test cases were distributed for each of the twelve eye diseases. Then, to perform the test procedure, the selected system evaluators or domain experts checked each of the twenty-four cases and the system can give advice from the stored cases in the knowledge-based system.

The following table 5.1 presents the performance of the proposed RBR-CBR prototype in terms of precision, recall, and accuracy.

Table 5.1 Performance of the proposed RBR-CBR system

Reasoning Model	Precision	Recall	Accuracy
RBR-CBR	0.947	0.90	0.875
CBR-RBR	0.944	0.85	0.833
CBR	0.809	0.894	0.791
RBR	0.761	0.888	0.75

As shown in above Table 5.1, the proposed RBR-CBR system performs with the recall of 90% and a precision of 94.7%. As compared to Recall, the system has performed well in its Precision for diagnosing eye diseases accurately. To sum up, IEDDTS has an accuracy of 87.5% which indicates that the proposed prototype system has a very good performance. In general, as compared to other reasoning options, RBR followed by CBR performs well with an accuracy of 87.5% and the researcher proposed this reasoning approach for eye disease diagnosis. The system performance of RBR-CBR is presented using the confusion matrix in table 5.2 below.

Table 5.2 Confusion matrix of the prototype RBR-CBR system

	Actual correct test cases	**Actual incorrect test cases**
Predicted correct by the prototype system	18	2
Predicted incorrect by the prototype system	1	3
Total	19	5

The result of the prototype system depicted in the above table 5.2 shows that, out of the total 24 tested cases, 87.5% of them are with correct diagnosis results and only 12.5% are with incorrect results. It is clear that the system with RBR-CBR confused by three instances. These three instances which are incorrectly identified as strabismus, hypermetropia, and conjunctiva which are the correct instances was hypermetropia, strabismus, and uveitis respectively as depicted in table 5.3. The reason why the system is confused is they have similar symptoms with each other. To identify correctly more cases and rules have to add in the knowledge base and/or case library. For the rest of 21 instances, the system identified correctly and works effectively.

For further analysis, the detail confusion matrix of the RBR-CBR combination is presented in table 5.3 below. It shows the matrix of test cases evaluation by IEDDTS and test cases. The rows illustrate the evaluation of the test case and the columns illustrate the result of IEDDTS.

Table 5.3 Confusion matrix for the evaluation of IEDDTS compared to test case

		IEDDTS												
	Disease Types	Cataract	Dry eye syndrome	Glaucoma	Presbyopia	Myopia	Hypermetropia	Astigmatism	Retinal detached	Conjunctiva	Strabismus	Uveitis	Diabetic retinopathy	Total
Test case	Cataract	2	0	0	0	0	0	0	0	0	0	0	0	2
	Dry eye syndrome	0	2	0	0	0	0	0	0	0	0	0	0	2
	Glaucoma	0	0	1	0	0	0	0	0	0	0	1	0	2
	Presbyopia	0	0	0	2	0	0	0	0	0	0	0	0	2
	Myopia	0	0	0	0	0	1	1	0	0	0	0	0	2
	Hypermetropia	0	0	0	0	0	1	0	0	0	1	0	0	2
	Astigmatism	0	0	0	0	0	0	2	0	0	0	0	0	2
	Retinal detached	0	0	0	0	0	0	0	2	0	0	0	0	2
	Conjunctiva	0	0	0	0	0	0	0	0	1	0	1	0	2
	Strabismus	0	0	0	0	0	1	0	0	0	1	0	0	2
	Uveitis	0	0	0	0	0	0	0	0	0	0	2	0	2
	Diabetic retinopathy	0	0	0	0	0	0	0	0	0	0	0	2	2
	Total	2	2	1	2	0	3	3	2	1	2	4	2	24

Table 5.3 illustrated that the entry under columns cataract, dry eye syndrome, presbyopia, retinal detached and diabetic retinopathy shows that the system has correctly identified two instances as per each disease type respectively. The entry under column glaucoma and conjunctiva the system has correctly identified one instance per each disease respectively. The entry under column myopia testified that out of two instances, there is no instance is correctly or incorrectly identified as myopia or other. The entry under hypermetropia testified that out of three instances one of the instances is

correctly identified as hypermetropia disease, one instance is also correctly identified as myopia and one instance is incorrectly identified as strabismus. The entry under astigmatism testified that out of three instances two of the instances are correctly identified as astigmatism disease, and one instance is correctly identified as myopia. The entry under column strabismus indicates that the system identified that out of two instances, one of the instances is correctly identified as strabismus and one of the instances is incorrectly identified as hypermetropia. The entry under column uveitis indicates that the system identified that out of four instances, two of the instances are correctly identified as uveitis, one of the instances is correctly identified as glaucoma and one of the instances is incorrectly identified as conjunctiva.

5.3. User Acceptance Testing

User acceptance testing has been conducted by domain experts and end-users of the system. Visual interaction evaluation method allows the domain experts and end-users to directly interact with the system and help them to evaluate the performance of the knowledge-based system. In this study, the questionnaire is used for user acceptance evaluation. The researcher used five parameters for evaluation, such as system effectiveness, error tolerance, efficiency, easiness to learn and easiness to remember [58]. The questionnaire is distributed for the selected five domain experts and also for five end-users which are composed of three nurses and two health extension workers in Jimma University specialized hospital. The evaluators were allowed to rate the options as Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. The summary of the result is presented in table 5.4.

Table 5.4 Result Summary of User Acceptance Testing

No.	Evaluation Parameters	Performance Value					
		SD	**D**	**N**	**A**	**SA**	**Av.**
1	The proposed system is easy to use			1	4	5	4.4
2	The proposed system is attractive for a user’s interaction				1	9	4.9
3	The proposed system could help in the effort to improve the health care service			1	2	7	4.6
4	The responses of the proposed system are in line with your needs			3	4	3	4
5	The proposed system can tolerate errors when you use it			2	3	5	3.3
6	The speed of the proposed system is in time				2	8	4.8
7	Users would learn to use the proposed system very quickly			2	5	3	4.5
8	Users feel very confident using the proposed system		2	5	2	1	3.8
Total Average							4.28

As depicted in table 5.4, for the first question which is about whether the proposed system is easy to use or not, users agree with an average of 4.4. This score indicates that users strongly agree that, the proposed system is easy to use. For the second question concerning the attractiveness of the user interaction, the score is 4.9. This shows that users strongly agree with the attractiveness of the user interface of the proposed system. For the third question, which is about the helpfulness of the system to improve the health care services or not, the score is 4.6. This score indicates users strongly agree with the helpfulness of the system to improve the health care services. For the fourth question which is about the responses of the proposed system are in line with your needs, the score is 4. This score indicates users agree with the responses of the proposed system are in line with their work. For the fifth question which is about whether the proposed system can tolerate errors in the use or not, users agree with 3.3. This score indicates users are agreed with the proposed system can tolerate errors in use. For the sixth question, which is about the speed of the proposed system is in time or not, users agree 4.8. This indicates that users are strongly agreed with the proposed system is in time. For the seventh question which is about whether users would learn to use the proposed system very quickly or not, score 4.5. The score indicates users are strongly agreed that they can learn the proposed system very quickly. For the eighth question which is about whether users feel very confident using the proposed system or not, the score is 3.8. This indicates that users agreed to use the proposed system with very confident.

Finally, based on the evaluation of all the respondents the average performance of the prototype system is 4.28, which means 85.6% evaluators are strongly agreed. This performance result shows the prototype has promising applicability for diagnosis and treatment of eye diseases.

Discussion of Result

This study has three research questions to answer, from these three research questions the specific objectives are listed out. As per the first research question of this study, the researcher attempt to identify the domain knowledge/attributes that experts use to diagnose and treat eye diseases. This is done using interviews with domain experts, document analysis and collecting cases form patient cards. This study finds out that age, diabetes case, some medications, hypertension case, smoking tobacco, drinking alcohol, previous eye surgery, taking radiation treatment, hypothyroidism case, previously happened eye diseases, cardiovascular diseases case, seeing blurred vision, seeing clouded vision, problem seeing at night, problem seeing through light and glare, seeing halos around lights, frequently changing contact lens or eyeglasses, seeing fading or yellowing colors, need for brighter light for reading and other activities, narrowed vision, having vision loss, severe pain in eyes with nausea and vomiting, sudden visual disturbance in low light conditions, redness of the eyes, burning and dryness sensation, stinging or aching sensation, sensitivity to light, stringy mucus in or around the eyes, eye fatigue, filing like something is in the eyes, floaters, vision getting blurry when looking at distant objects, closed objects or at normal distance, eye squinting, eyestrain, eye irritation, double vision, excessive tearing, and heavy feeling in the eye are the main attributes to diagnose eye diseases. Medication, prescription glasses or contact lenses and different surgery like refractive surgery, corneal refractive surgery, lens implants, segments of biocompatible plastic are also the main attributes to treat eye diseases.

To answer the second question, the study integrates CBR and RBR in designing an effective knowledge-based system. To this end, the researcher first developed a Rule-Based system by using the Java programming language. Next, the Case-based system is developed by using JCOLIBRI. The conditional combination of CBR and RBR took place using the Java eclipse interface to combine the two reasoning mechanisms. The user interface contains the rule-base code and case-base connector code. First, the users' query is served in the RBR system by interacting via the user interface. If the RBR system is not correctly providing a diagnosis solution, the query is passed to the CBR. Then the CBR system is displayed automatically and users' can use it by opening the CBR query interface for diagnoses the type of eye disease.

Finally, the evaluation of the performance of the proposed system and user acceptance testing is performed. As the researcher discussed in the evaluation section, the proposed system achieved a promising result with a system performance of 87.5% of accuracy by using twenty-four (24) test cases, with user acceptance of 85.6% using eight open-ended questions, which shows users agree with the proposed system.

As per the hypothesis and experimental result of this research, the integration of RBR and CBR provides a better result for diagnosing and treatment of eye diseases. As reported by Naser and Zaiter [27] and Munaiseche et al. [29], rule-based reasoning performs 80% and 83.5% accordingly. On the other hand, the report of Jenefa et al. [28] proofed that, for eye disease diagnosis and treatment case-based reasoning system scored 79.8% overall performance.

The following table 5.5 shows the comparison of the proposed system in this study with previous research works.

Table 5.5 Comparison of IEDDTS with the previous CBR and RBR System work

Researcher	**Reasoning Technique**	**Performance measurements and results (in %)**			
		Precision	**Recall**	**Accuracy**	**User Acceptance**
Naser and Zaiter(2008)	RBR	Not Specified	Not Specified	80%	Not Specified
Jenefa et al. (2014)	CBR	Not Specified	Not Specified	79.8%	Not Specified
Munaiseche et al. (2017)	RBR	Not Specified	Not Specified	83.5%	83.06%
Integrated system	RBR-CBR	94.7%	90%	87.5%	85.6%

As shown in Table 5.5, the comparison of the above three studies results with the integrated prototype system, the performance and user acceptance of integrated reasoning system for eye disease diagnosis and treatment score 87.56% and 85.6% respectively. This implies that the proposed system is a very good enhancement and improvement for diagnosing and treatment of eye diseases.

Generally, integrating rule-based reasoning followed by a case-based reasoning system for diagnosis and treatment of eye diseases has better performance than CBR and RBR can do independently.

In addition, the attractiveness of user interaction and speed of the proposed system resolve problems in time for diagnosis and treatment of eye disease has achieved an encouraging result and rated by the respondents with the highest rating value. Domain experts assign a lower value compared to others is the proposed system can tolerate errors when users use it and users feel very confident using the proposed system. One interesting feedback provided by the domain experts is adding explanation facilities in the system are very important. According to domain experts, an explanation facility is important for the retrieved solution. If users of the system get a more explanation about the retrieved solution and the disease itself, they can feel very confident in the system. According to the experts, error tolerance of the system is very weak because of less knowledge or cases are in the system. Because of that weakness, the system performance of the prototype system is not near to 100%, which needs further improvement.

To summarize the chapter, the demonstration of the system shows how users can easily use the prototype system for diagnosing and treatment of eye disease. The system performance testing is done by preparing 24 test cases and evaluated by five domain experts. The user acceptance evaluation is also done by using eight questioners and ten evaluators. Finally, the performance and user acceptance of an integrated reasoning system for eye disease diagnosis and treatment score 87.56% and 85.6% respectively.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

6.1. Conclusion

The eye specialist advised that everyone has to examine their eye at least once in a year for a healthy eye condition. Because, vision loss or impairment can be a gradual happening or it can be sudden, besides blindness can be the result of serious untreated eye problems. Nevertheless, without a human expert's involvement, the diagnosing and treatment of eye disease is difficult. Not only that there is also the scarcity of professionals in the field. Therefore, there is a need to design a knowledge-based system for the diagnosis and treatment of eye diseases.

In this study, an integrated reasoning system for knowledge-based eye disease diagnosis and treatment has been designed. The two reasoning systems are Case-based Reasoning (CBR) and Rule-based Reasoning (RBR). Manually recorded patient cards are used to construct cases for a case-based reasoning and document analysis and interviewing are used for generating rules for rule-based reasoning.

The integration of the two-reasoning system is first designed independently as RBR and CBR systems, after that the integration was made by user interface or controller. The user interface is developed by Java eclipse programming language. In this study, based on test result the rule dominant approach is implemented. In rule dominant approach the first reasoning system is RBR which is first treats a new query. If the RBR model gets a rule that exactly matches the new query, it gives solutions and the solution is accepted as a correct solution. If not, it automatically forwards to the CBR system. The CBR system retrieves relevant cases using similarity measures, reuse which allows domain experts to transfer retrieval case solution to suit for the current case, revise which is to test the solution and retain to store the confirmed solution to the case-base for future use.

The performance of the prototype system shows that 87.5% accuracy with an average Precision of 94.7% and Recall of 90% respectively. The user acceptance testing also shows an average of 85.6% which is a very good acceptance. This shows the system has registered a promising result.

The strength of this study is the integration of reasoning systems to diagnose and treat eye diseases. The integrated prototype system scored high result when it compared from independent reasoning system. In the integration of RBR and CBR, due to their interchangeable nature, they provide effective knowledge representation, problem-solving power, and exceeding one‘s weakness with the other. The challenge of designing the proposed system is the scarcity of cases in designing the case library. The major weakness observed in this study is that the system has not included an explanation facility for additional advice.

6.2. Recommendation

Based on the result of the current study, the following recommendations are made as a way forward for further advancement and enhance the coverage of the KBS in the health domain: -

- To solve the problem of getting enough cases and knowledge for designing the KBS, the standard corpus should be prepared as a baseline for future research and measure advancement in implementing an intelligent system.
- The need to integrate data mining techniques for automatic knowledge acquisition for designing the hybrid knowledge-based system which is capable of employing rule-based reasoning and case-based reasoning.
- A combination that accepts the query, sends the query for both reasoning at the same time, compares the result and selects the most relevant solution is also another research issue that needs further investigation.
- Investigate the applicability of natural language processing (NLP) in constructing a user-friendly and localized user interface to enhance the use of a knowledge-based system by the society at large.
- The proposed system has no explanation facility. So, there is a need to include an explanation facility to the system such that the system can answer the what, how and why it suggests a given solution.
- These kinds of systems are also critical for other health domains. So it is recommended for researchers to design a knowledge-based system that provides diagnosis and treatment for other health cases.

REFERENCES

[1] B. Trend, (2010). *Nutrition for Healthy Eyes – Health Engine Blog* [Online]. Health Engine Blog. Available at: https://www.myvmc.com/lifestyles/nutrition-for-healthy-eyes/ [Accessed 23 Nov. 2018].

[2] V. Dullabh, (2015). *What is eye disease?* [Online]. Health24. Available at: https://www.health24.com/Medical/Eye/Overview/What-is-eye-disease-20150421 [Accessed 23 Nov. 2018].

[3] Medbroadcast (2017). *Eye Infections - Causes, Symptoms, Treatment, Diagnosis - MedBroadcast.com* [Online]. Medbroadcast.com. Available at: https://medbroadcast.com/condition/getcondition/ eye-infections [Accessed 24 Nov. 2018].

[4] E. Diaz, (2008). *Impact of reducing indoor air pollution on women's health* [Online]. 1st ed. Norway: University of Bergen, Norway, Available at: https://core.ac.uk/download/pdf/3092 6114. pdf [Accessed 23 Dec. 2018].

[5] J. Meyer, (2016). *There are many obstacles to eye care in Ethiopia, where blindness is prevalent* [Online]. GlobalSistersReport.org. Available at: http://www.globalsistersreport.org/blog/gsr-today/ministry/there-are-many-obstacles-eye-care-ethiopia-where-blindness-prevalent-41391 [Accessed 18 Oct. 2018].

[6] E.R. Robert (2018). *Diagnosis | medicine* [Online]. Encyclopedia Britannica. Available at: https://www.britannica.com/science/diagnosis [Accessed 23 Nov. 2018].

[7] O. Bojovic, M. Medenica, D .Zivkovic, B.G. Rakocevic, Trajkovic, D. Kisic-Tepavcevic, (2018) *Factors associated with patient and health system delays in diagnosis and treatment of tuberculosis in Montenegro, 2015–2016* [Online].PLoS ONE 13(3): e0193997. https://doi.org/10.1371/journal.pone.0193997

[8] B. Evren, D. Sabriye, K. Mehmet-Ali, "*Expert system in medicine and its application at pulmonary diseases",* Istanbul, vol 3(11), pp. 342-349, 2016.

[9] M. Sasikumar, S. Ramani, M. Raman, K. Anjaneyulu, R. Chandrasekar, *A Practical Introduction to Rule-based Expert Systems*. 2nded. New Delhi: Narosa Publishing House, 2007.

[10] J. Singla, D. Grover, A. Bhandari. "*Medical expert systems for diagnosis of various diseases*," International Journal of Computer Applications; vol. 93(7), pp.36-43, 2014.

[11] S. Eds and R. Akerkar, “Advanced knowledge-based systems: Model, applications and research,” USA, vol. 3(1), pp. 1-11, 2010.

[12] J.M. Bullinaria, (2005). *IAI: Production Systems*. Available at: http://www.cs.bham.ac.uk/~jxb/ IAI/w7.pdf [Accessed 26 Nov. 2018].

[13] T. Winstanley and P. Courvalin, “*Expert systems in clinical microbiology. Clinical Microbiology Reviews*”, vol. 24(3), pp. 515-556, 2011.

[14] R. Nohria, *“Medical expert system a comprehensive review.”* International Journal of Computer Applications, vol. 130(7), pp. 44-50, 2015.

[15] R.A. Akerkar and P.S. Sajja, “*Knowledge-Based Systems*”. Jones and Bartlett Publishers, USA, vol, 2. pp 67-80, 2010.

[16] D. Aha, and J.J. Daniels, “*Case-Based Reasoning Integrations*”: Papers from the 1998 AAAI Workshop. Technical Report WS-98-15, AAAI Press 1998.

[17] Y. Melody, “An integrated approach of rule-based and case-based reasoning for decision support”, USA, pp. 255-267, 2014.

[18] B. Henok, “A case-based reasoning knowledge-based system for hypertension management,” MSc thesis, AdiseAbeba University, Addis Abeba, Ethiopia 2011.

[19] E. Birhanu. “Developing Knowledge-based system for coffee disease diagnosis and treatment,” MSc thesis, AdiseAbeba University, Addis Abeba, Ethiopia 2012.

[20] E. Seblewongel, “Prototype knowledge-based system for Anxiety mental disorder diagnosis,” MSc thesis, AdiseAbeba University, Addis Abeba, Ethiopia 2011.

[21] A. Tagle, “Knowledge-based system for premedical triage treatment at Adam University Asella hospital” MSc thesis, AdiseAbeba University, Addis Abeba, Ethiopia 2013.

[22] J. Prentzas and I Hatzilygeroudis, "*Categorizing Approaches Combining Rule -Based and Case-Based Reasoning*," vol. 24, pp. 97-122, 2007.

[23] WHO. (2018). *Blindness and vision impairment* [Online]. Available: https://www.who.int/blindness/ world_sight_day/2017/en/, [Accessed 23 Nov. 2018]

[24] WHO Africa. (2018). *Eye health* [Online]. Available: https://www.afro.who.int/health-topics/eye-health, [Accessed 23 Nov. 2018]

[25] I. Fatimah, B.A. Juliana,J. Fathilah, N.T. Mohd, "*Expert System for Early Diagnosis of Eye Diseases Infecting the Malaysian Population*", Singapore, pp. 430-432, 2001.

[26] T. Varsha, and B. Manisha, "*Localization of Text Editor using Java Programming*", International Journal of Computer Applications, vol.89(12), pp. 49-54, 2014.

[27] S.S. Naser, and A.O. Zaiter, "*An Expert System for Diagnosing Eye Diseases Using Clips*", Indonesia, pp 923-930, 2008.

[28] A. Jenefa, H. Manimala, R. Ravi, *"A machine doctor that diagnosing ophthalmology problems using Neural Networks,"* India, vol 3(2), pp 528-533, 2014.

[29] C.P. Munaiseche, D. R. Kaparang, P. T. Rompas, "*An Expert System for Diagnosing Eye Diseases using Forward Chaining Method*" Indonesia, vol 306, pp. 555- 654, 2017.

[30] L. Bezabih, T.W. Abebe, R.O. Fite, "*Prevalence and factors associated with childhood visual impairment in Ethiopia*", Ethiopia, vol. 11. pp. 1941-1948, 2017.

[31] B. Yemane, W. Alemayehu, B. Abebe, A. Liknaw, A. Wondu, B. Amir, H. Zegeye, A. Allehone, A. Yilikal, G. Teshome, D. Tewodros, W. Emily, W. Sheila, "*National Survey on Blindness, Low Vision and Trachoma in Ethiopia: Methods and Study Clusters Profile"*, vol. 21(3), pp. 185-203, 2017.

[32] T. Thevi, M. Basri, S. Reddy, "Prevalence of eye diseases and visual impairment among the rural population – a case study of Temerloh hospital", Malaysia, vol. 7(1), pp. 6–10. 2013.

[33] O. Philipp, L. Olga, S. Marten, B. Udo "*Outline of a Design Science Research Process, Deutsche Telekom Laboratories,*" German, vol. 6, pp 2-11. 2009.

[34] M. Salem, "A Case-base Experts System for Diagnosis of Heart Disease. International Journal on Artificial Intelligence and Machine Learning," Egypt, vol. 5(1), pp. 33-39. 2005.

[35] K. Peffers, T. Tuunanen, M. A. Rothenberger, S.Chatterjee, "*A Design Science Research Methodology for Information Systems Research*." Journal of Management Information Systems, vol. 24(3), pp. 45-77, 2008.

[36] W. Birmingham and G. Klinker, "*The Knowledge Acquisition Tool with Explicit Problem-Solving Models*". Cambridge Journal, vol. 8(1), pp. 5-25, 2009.

[37] R. Bergman, J. Colodner, E. Plaza, “Knowledge Representation in case-based reasoning. The Knowledge Engineering Review”, vol. 10(0), pp. 1-4, 2005.

[38] C. Adam, and T. Sitek. "*Ontologies vs. Rules—Comparison of Methods of Knowledge Representation Based on the Example of IT Services Management*." Wrocław, Oficyna Wydawnicza Politechniki Wrocławskiej, pp 99-109. 2013.

[39] A. Abraham, “*Rule-based Expert Systems*.” In: Peter, H., Sydenham & Richard T. Handbook of Measuring System Design. Oklahoma, pp. 909-919, 2005.

[40] Epistemics (2013). *Knowledge Models*. [online] Epistemics.co.uk. Available at: http://www.epistemics.co.uk/Notes/90-0-0.htm [Accessed 24 Nov. 2018].

[41] J. Cassandra, S. Leon, H. Krista, H. Christopher, “*Transfusion in the Patient with Sickle Cell Disease: A Critical Review of the Literature and Transfusion Guidelines,”* Elsevier Inc., Journal of Transfusion Medicine Reviews, vol. 21(2), pp. 118-133, 2007.

[42] F. T. Chee, “A Prototype of Knowledge-based System for Fault Diagnosis in Automatic Wire Bonding Machine”, Tubitak, Melaka, Malaysia. 2008.

[43] R. Anand and U.D. Jeffrey, “Mining of Massive datasets”, California, Stanford University, 2010.

[44] K. K. Mumine, “*An Overview: The Impact of Data Mining Applications on Various Sectors,*” Technical Journal, vol. (11)3, pp. 128-132, 2017.

[45] M.J. Berry and G.S. Linoff, “Data Mining Techniques for marketing, sales and customer relationship management” 2nd ed. Indiana: Wiley publishing, 2004.

[46] A. Azevedo and M.F. Santos, KDD, SEMMA AND CRISP-DM: A parallel overview, presented at the Parallel overview, no. ISBN: 978-972-8924-63-8, 2008.

[47] M. Abdulkerim, “Towards, Integrating Data Mining with Knowledge-based System: The Case of Network Intrusion detection,” MSc thesis, Addis Ababa University, Addis Ababa, Ethiopia 2013.

[48] A. Ayman and M. Ahmar, “Rule-based expert system for selecting software development Methodology.” Ajman, pp. 143-148. 2010.

[49] E. J. Castillo and A.S. Hadi, *Expert Systems and Probabilistic Network Models,* Gutierrez Springer, USA, 1997.

[50] D. Poole, A. Mackworth, R. Goebel, "*Computational Intelligence.*" Oxford University Press, USA 1999.

[51] K. Ranjan, P. Rajkishore, A. K. Sinha, "AMRAPALIKA: An expert system for the diagnosis of pests, diseases and disorders in Indian mango." Knowledge-Based System, vol. 2(19), pp. 9-21, 2006.

[52] M.S. Abdullah, C. Kimble, I. Benest, R. Paige, "*Knowledge-based Systems: a reevaluation*". Journal of Knowledge Management, vol. 10(3), pp. 127-142, 2006.

[53] N. Shadbolt, and M. Burton, "Knowledge Elicitation, In: Artificial Intelligence Techniques in Design and Evaluation," pp. 321-345. 2011.

[54] C. L. Emberey, N. R. Milton, J. P. Berends, M. Tooren, S. Els, B. Vermeulen, "*Application of Knowledge Engineering Methodologies to Support Engineering Design Application Development in Aerospace,*" 7th AIAA Aviation Technology, Integration and Operations Conference (ATIO), AIAA-2007-7708, Belfast, Ireland, 2007.

[55] A. Amodt, and E. Plaza, "*Case-Based Reasoning: Foundational Issues, Methodological Variations and System Approach,"* ALCOM- Artificial Intelligence Communication IOS Press, vol. 7(1), pp. 39-59, 1994.

[56] Y. Singh, K. Bhatia, O. Sangwan, *"A Review of Studies in Machine Learning Techniques,"* International Journal of Computer Science and Security, vol. 1(1), pp. 70-84. 2007.

[57]. C.J. Anumba, and D. Scott, "Performance Evaluation of Knowledge-based System for Subsidence Management: Structural survey," MCB University Press, vol. 19(5), pp. 222-232, 2001.

[58] Z. Jeremic, J. Jovanovic, D. Gasevic, "*Evaluating an Intelligent Tutoring System for Design Patterns: the DEPTHS Experience,*" Educational Technology & Society, vol. (12)2, pp. 111–130. 2009.

[59] H. Ashraf and N. Iqbal, "Evaluation of jCOLIBRI," Unpublished Master's Thesis, Maradalen University, Sweden, 2006.

[60] A. Azari and P. Barney, "*A Systematic Review of Diagnosis and Treatment*," vol. 310(16), pp. 1721-1729, 2014.

[61] K. Khandelwal. "*Hybrid Reasoning Model for Strengthening the problem solving capability of Expert Systems.*" (IJACSA) International Journal of Advanced Computer Science and Applications,Jaipur, India 2013.

[62] L. Edwina Rissland and B. David Skalak, "*Combining Case-Based and Rule-Based Reasoning: A Heuristic Approach*", pp 534-530, 2011.

[63] K. Ranjit, "Research Methodology A Step-by-Step Guide for Beginners", 3rd ed. Singapore: SAGE, 2011.

[64] T. Ethiopia, "Application of Case-Based Reasoning for Amharic Legal Precedent Retrieval: A Case Study with the Ethiopian Labour Law", Msc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia. 2010.

[65] R.M. Saraiva, J. Bezerra, M. Perkusich, H. Almeida, C. Siebra, "A Hybrid Approach Using Case-Based Reasoning and Rule-Based Reasoning to Support Cancer Diagnosis: A Pilot Study", Federal Institute of Paraiba, Monteiro, PB, Brazil, 2015.

[66] B. Azeb, "Integrated Case Based and Rule Based Reasoning for Decision Support", Norwegian University of Science and Technology, Department of Computer and Information Science, M.Sc Thesis 2009.

[67] R.A. Hevner, "Design science in information systems research", Vol. (28)1, pp. 75-105, USA, 2009

APPENDICES

APPENDIX I: Interview Questions

JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF INFORMATION SCIENCE

Dear Interviewees,

First of all, the researcher would like to thank you for your willingness to make yourself available for the interview.

The purpose of this interview is to acquire knowledge about Eye diseases. The knowledge that is going to be collected from you will be used to design the Knowledge-based System that gives advice about Diagnosis and Treatment of Eye diseases for health extension workers, junior nurses and health officers who do not have deep knowledge about Eye diseases and work in the remote areas of Ethiopia. Your feedbacks are very important for the success of the research, which is conducted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Information Science!

1. What is Eye disease?
2. How many Eye diseases are there?
3. What are the frequently occurring Eye diseases in Ethiopia?
4. What are the main signs and symptoms for those Eye diseases and which one of them is common to most of the patients?
5. What are the major diagnosing mechanisms and procedures for eye disease?
6. How do you identify the major symptoms of Eye disease?
7. Is there any standard guideline that you use for the diagnosis of Eye patients?
8. What are the treatments for those Eye diseases?
9. What are the major challenges identified during Eye disease diagnosis? How can you manage them?

APPENDIX II: User Acceptance Test

JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF INFORMATION SCIENCE

Dear Evaluators,

First of all, the researcher would like to thank you for your willingness to evaluate the proposed system and give your feedbacks which are very important for the improvement of the proposed system and to make it available for potential users!

The proposed system is the knowledge-based system that gives advice about the Diagnosis and Treatment of Eye diseases for health extension workers, junior nurses and health officers who do not have deep knowledge about Eye diseases and work in the remote areas of Ethiopia.

This questionnaire has 8 questions which the researcher thinks that are relevant to evaluate the proposed system. First, read the questions and choose your answer from the available five options which could best describe your feeling: - Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree

No.	**Evaluation Parameters**	**Performance Value**				
		Strongly Disagree	Disagree	**Neutral**	**Agree**	**Strongly Agree**
1	The proposed system is easy to use					
2	The proposed system is attractive for a user's interaction					
3	The proposed system could help in the effort to improve the health care service					
4	The responses of the proposed system are in line with your needs					
5	The proposed system can tolerate errors when you use it					
6	The speed of the proposed system is in time					
7	Users would learn to use the proposed system very quickly					
8	Users feel very confident using the proposed system					

APPENDIX III: Attribute Description

Attributes Name	Description
Age	The patient age
Diabetes	Whether the patient has Type 1, Type 2 or no diabetes
Medication or Drug	Whether the patient take other medication or not
Hypertension	Whether the patient has hypertension or not
Smoking tobacco	Whether the patient smoke tobacco or not
Drinking alcohol	Whether the patient drink alcohol or not
Previous eye surgery	Whether the patient has taken previously eye surgery or not
Radiation treatment	Whether the patient has taken previously radiation treatment or not
Hypothyroidism	Whether the patient has hypothyroidism or not
Cardiovascular diseases	Whether the patient has cardiovascular disease
Seeing blurred vision	Whether the patient has seen blurred vision or not
Seeing clouded or dim vision	Whether the patient has seen clouded or dim vision or not
Difficulty seeing at night	Whether the patient has difficulty seeing at night or not
Problem seeing through light and glare	Whether the patient has Problem seeing through light and glare or not
Seeing halos around lights	Whether the patient has Seeing halos around lights or not
Frequently changing contact lens or eyeglasses	Whether the patient has Frequently changing contact lens or eyeglasses or not
Fading or yellowing view of colors	Whether the patient has fading or yellowing view of colors or not
Need for brighter light for reading and other activities	Whether the patient need for brighter light for reading and other activities or not
Tunnel or narrowed vision	Whether the patient has tunnel or narrowed vision or not
Peripheral vision loss	Whether the patient has Peripheral vision loss or
Severe pain in eyes accompanied by nausea and vomiting	Whether the patient has severe pain in eyes accompanied by nausea and vomiting or not
Sudden visual disturbance in low light conditions	Whether the patient has Sudden visual disturbance in low light conditions or not

Redness of the eyes	Whether the patient has Redness of the eyes or not
Burning and itching sensation	Whether the patient has Burning and itching sensation or not
Stinging or Aching sensation,	Whether the patient has Stinging or Aching sensation or not
Dryness sensation in eyes	Whether the patient has Dryness sensation in eyes or not
Stringy mucus in or around the eyes	Whether the patient has Stringy mucus in or around the eyes or not
Eye fatigue	Whether the patient has Eye fatigue or not
Filing like something is in the eyes	Whether the patient has Filing like something is in the eyes or not
Sudden appearance of floaters or dark spots through vision	Whether the patient has Sudden appearance of floaters or dark spots through vision or not
Vision getting blurry when looking at distant objects	Whether the patient has Vision getting blurry when looking at distant objects or not
Vision getting blurry when looking at closed objects	Whether the patient has Vision getting blurry when looking at closed objects or not
Vision getting blurry when looking at normal distance	Whether the patient has Vision getting blurry when looking at normal distance or not
Squinting	Whether the patient has Squinting or not
Eyestrain	Whether the patient has Eyestrain or not
Eye irritation	Whether the patient has Eye irritation or not
Double vision	Whether the patient has Double vision or not
Heavy feeling in the eye	Whether the patient has Heavy feeling in the eye
Excessive tearing	Whether the patient has Excessive tearing or not
Sensitivity to light	Whether the patient has Sensitivity to light or not
Difficulty in wearing contact lenses	Whether the patient has Difficulty in wearing contact lenses or not
Thick yellowish discharge	Whether the patient has Thick yellowish discharge or not
Pain in the eye	Whether the patient has Pain in the eye or not
Decreased vision	Whether the patient has Whether the patient has Decreased vision or not
Impaired color recognition	Whether the patient has Impaired color recognition or not
Swelling in the conjunctiva	Whether the patient has Swelling in the conjunctiva or not

APPENDIX IV: Prolog Code

```
start :-
        write('What is the name of the patient: '),
        read(Patient),nl,
        hypothesis(Patient,Disease),
        nl,write(Patient),write(' probably have '),write(Disease),nl,nl,undo,
        treatment(dry_eyes_syndrome,explain1),
        treatment(conjunctivitis,explain2),
        treatment(astigmatism,explain3),
        treatment(presbyopia,explain4),
        treatment(myopia,explain5),
        treatment(retinal_detachement,explain6),
        treatment(diabetic_retinopathy,explain7),
        treatment(cataract,explain8),
        treatment(uveitis,explain9),
        treatment(glaucoma,explain10),
        treatment(strabismus,explain11),
        treatment(hypermetropia,explain12).
symptom(Patient,blurred_vision ) :- verify(Patient,' have seen blurred vision (y/n) ?').
symptom(Patient,redness) :- verify(Patient,' have redness appearing in the eyelid or through the white of the eyes? (y/n) ?').
symptom(Patient,light_sensitivity) :- verify(Patient,' have extra or light sensitivity in the eyes (y/n) ?').
symptom(Patient,burning_itching) :- verify(Patient,' have burning and itching sensation in the eyes(y/n) ?').
symptom(Patient,dryness) :- verify(Patient,' have dryness sensation in the eyes(y/n) ?').
symptom(Patient,fatigue) :- verify(Patient,' have stringy mucus in or around the eyes, eye fatigue, difficulty in wearing contactlenses and filing like something in the eye? (y/n) ?').
symptom(Patient,swelling) :- verify(Patient,' have swelling in the conjunctiva,excessive tearing, thick yellowish discharge,mostly covering whole eyelashes, especially after sleepy (y/n) ?').
symptom(Patient,eyestrain) :- verify(Patient,' have eyestrain leading to headaches (y/n) ?').
symptom(Patient,blurry_distance) :- verify(Patient,' have seen blurry vision when looking at distance objects (y/n) ?').
symptom(Patient,blurry_close) :- verify(Patient,' have see blurry vision when looking at close range(y/n) ?').
symptom(Patient,squinting) :- verify(Patient,' have difficulty in seeing things at night, squinting the eye and eye irritation(y/n) ?').
symptom(Patient,blurry_normal) :- verify(Patient,' have see blurry vision and inability to read at normal reading distance, and hold reading material farther away to make the letter clear (y/n) ?').
symptom(Patient,difficulty) :- verify(Patient,' have difficulty viewing objects at night, requiring squinting or partial closing of the eyelids to get a clear vision of something (y/n) ?').
symptom(Patient,floaters) :- verify(Patient,' have seen sudden appearance of floaters or dark spots or strings floating through the vision  (y/n) ?').
symptom(Patient,sudden) :- verify(Patient,' have seen sudden appearance of light flashes in one or both eyes (y/n) ?').
symptom(Patient,receding) :- verify(Patient,' have steadily receding peripheral or side vision, presence of a curtain- like shadow through the field of vision and feeling heavy in the eye (y/n) ?').
symptom(Patient,clouded) :- verify(Patient,' have see clouded or dim vision, difficulty seeing at night, problem seeing through light and glare, seeing halos around light, frequently changing contact lens prescription or eyeglasses, fading or yellowing view of colors and need for brighter light for reading and other activities  (y/n) ?').
symptom(Patient,impaired) :- verify(Patient,' have impaired color recognition, fluctuating vision, and poor night vision, sudden and total loss of vision (y/n) ?').
symptom(Patient,eye_pain) :- verify(Patient,' have pain in the eye, seeing dark, floating spots in the field of vision (floaters), and decreased vision (y/n) ?').
symptom(Patient,tunnel) :- verify(Patient,' have tunnel or narrowed vision, peripheral vision loss, severe pain in eyes accompanied by nausea and vomiting, sudden visual disturbance in low light conditions, seeing halos around lights (y/n) ?').
symptom(Patient, crossed_eyes) :- verify(Patient,' have crossed eyes, double vision, eyes’ inability to focus on a particular point at the same time, uncoordinated eye movement and loss of depth perception (y/n) ?').
```

```
symptom(Patient,headache) :- verify(Patient,' have see blurry vision when looking closed object, Need to squint for getting a better vision, headache hitting after tasks needing the focus on close objects and an aching or burning sensation around the eye (y/n) ?').
  hypothesis(Patient,dry_eyes_syndrome) :-
    symptom(Patient,blurred_vision),
    symptom(Patient,redness),
    symptom(Patient,light_sensitivity),
    symptom(Patient,burning_itching),
    symptom(Patient,dryness),
   symptom(Patient,fatigue).
  hypothesis(Patient,conjunctivitis) :-
    symptom(Patient,blurred_vision),
    symptom(Patient,redness),
    symptom(Patient,light_sensitivity),
    symptom(Patient,burning_itching),
    symptom(Patient,swelling).
  hypothesis(Patient,astigmatism) :-
    symptom(Patient,eyestrain),
    symptom(Patient,blurry_distance),
    symptom(Patient,blurry_close),
    symptom(Patient,squinting).
  hypothesis(Patient,presbyopia) :-
    symptom(Patient,eyestrain),
    symptom(Patient,blurry_normal).
  hypothesis(Patient,myopia) :-
    symptom(Patient,eyestrain),
    symptom(Patient,blurry_distance),
    symptom(Patient,difficulty).
  hypothesis(Patient,retinal_detachement) :-
    symptom(Patient,blurred_vision),
    symptom(Patient,floaters),
    symptom(Patient,sudden),
    symptom(Patient,receding).
  hypothesis(Patient,diabetic_retinopathy) :-
    symptom(Patient,blurred_vision),
    symptom(Patient,floaters),
    symptom(Patient,impaired).
  hypothesis(Patient,cataract) :-
    symptom(Patient,blurred_vision),
    symptom(Patient,clouded).
  hypothesis(Patient,uveitis) :-
    symptom(Patient,blurred_vision),
    symptom(Patient,redness),
    symptom(Patient,light_sensitivity),
    symptom(Patient,eye_pain).
  hypothesis(Patient,glaucoma) :-
    symptom(Patient,blurred_vision),
    symptom(Patient,redness),
    symptom(Patient,tunnel).
  hypothesis(Patient,strabismus) :-
    symptom(Patient,crossed_eyes).
  hypothesis(Patient,hypermetropia) :-
    symptom(Patient,headache).
```

```
hypothesis(_,'disease. But Im Sorry, I dont seem to be able to diagnose the disease please check other eye disease catagory diagnosis').
  treatment(Disease,explain1) :-
        write('The treatments of '),write(Disease),write(' is '),nl,
        write('Medication treatment'),nl,
        write('     Artificial tears, each eye per day approximately 6 hours apart'),nl,
        write('     Restasis of eye drop each eye per day for 3 month'),nl,
  write('     Xiidra, two applications in each eye per day, approximately 12 hours apart'),nl,
  write('Nutritional supplements'),nl,
        write('    Simply drinking more water might help relieve from dry eye symptom. '),nl,
        write('    Mild dehydration often makes dry eye problems worse.'),nl,
        write('Home remedies'),nl,
        write('        Blink more frequently'),nl,
        write('    Thoroughly remove eye makeup if you use'),nl,
        write('    Clean your eyelids and wear quality sunglasses'),nl,nl,
        write('THANK YOU FOR CHECKING '),nl,nl.
                        % All treatment will be entered like this
ask(Patient,Question) :-
        write('Does '),       write(Patient),write(Question),
        read(N),
        ( (N == yes ; N == y)
   ->
   assert(yes(Question)) ;
   assert(no(Question)), fail),nl.
:- dynamic yes/1,no/1.
verify(P,S) :-
 (yes(S)
  ->
  true ;
  (no(S)
   ->
   fail ;
   ask(P,S))).
undo :- retract(yes(_)),fail.
undo :- retract(no(_)),fail.
undo.
```

APPENDIX V: Java code for integration of CBR and RBR, and Graphical interface

```
public class Integrated_System {
        private JFrame frame;
        private final ButtonGroup buttonGroup = new ButtonGroup();
        private JLabel lblDiagnosis_Res;
        private JTextArea lblTreatment;
        private JButton btnNewButton;
        private final ButtonGroup buttonGroup_1 = new ButtonGroup();
        private final ButtonGroup buttonGroup_2 = new ButtonGroup();
        private final ButtonGroup buttonGroup_3 = new ButtonGroup();
        private final ButtonGroup buttonGroup_4 = new ButtonGroup();
        private final ButtonGroup buttonGroup_5 = new ButtonGroup();
        private final ButtonGroup buttonGroup_6 = new ButtonGroup();
        private final ButtonGroup buttonGroup_7 = new ButtonGroup();
        private final ButtonGroup buttonGroup_8 = new ButtonGroup();
        private final ButtonGroup buttonGroup_9 = new ButtonGroup();
        private final ButtonGroup buttonGroup_10 = new ButtonGroup();
        private final ButtonGroup buttonGroup_11 = new ButtonGroup();
        private final ButtonGroup buttonGroup_12 = new ButtonGroup();
        private final ButtonGroup buttonGroup_13 = new ButtonGroup();
        private final ButtonGroup buttonGroup_14 = new ButtonGroup();
        private final ButtonGroup buttonGroup_15 = new ButtonGroup();
        private final ButtonGroup buttonGroup_16 = new ButtonGroup();
        private final ButtonGroup buttonGroup_17 = new ButtonGroup();
        private final ButtonGroup buttonGroup_18 = new ButtonGroup();
        private final ButtonGroup buttonGroup_19 = new ButtonGroup();
        private final ButtonGroup buttonGroup_20 = new ButtonGroup();
        private final ButtonGroup buttonGroup_21 = new ButtonGroup();
        private final ButtonGroup buttonGroup_22 = new ButtonGroup();
        private boolean seeing_blurred_vision;
        private boolean eye_redness;
        private boolean light_sensitivity;
        private boolean burning_and_itching_sensation;
        private boolean dryness_sensation;
        private boolean eye_fatigue;
        private boolean stringy_mucus_and_difficulty_in_wearing_contact_lenses;
        private boolean filing_like_something_in_the_eye;
        private boolean swelling_in_the_conjunctiva_and_excessive_tearing;
        private boolean thick_yellowish_discharge;
        private boolean eyestrain_leading_to_headaches;
        private boolean blurry_vision_when_looking_at_distance_objects;
        private boolean blurry_vision_when_looking_at_close_range;
        private boolean squinting_the_eye_and_eye_irritation;
        private boolean blurry_vision_and_inability_to_read_at_normal_reading_distance;
        private boolean seen_sudden_appearance_of_floaters_or_dark_spots;
        private boolean impaired_color_recognition;
        private boolean clouded_or_dim_vision;
        private boolean eye_in_pain;
        private boolean tunnel_or_narrowed_vision;
        private boolean nausea_and_vomiting;
```

```
	private boolean headache;
	private String Diagnosis_Result=null;
	/**
	 * Launch the application.
	 */
	public static void main(String[] args) {
		EventQueue.invokeLater(new Runnable() {
			public void run() {
				try {
					Integrated_System window = new Integrated_System();
					window.frame.setVisible(true);
				} catch (Exception e) {
					e.printStackTrace();
				}}});
	}
	/**
	 * Create the application.
	 */
	public Integrated_System() {
		initialize();
		}
		public void clearGroup(){
			buttonGroup_1.clearSelection();
			buttonGroup_2.clearSelection();
			buttonGroup_3.clearSelection();
			buttonGroup_4.clearSelection();
			buttonGroup_5.clearSelection();
			buttonGroup_6.clearSelection();
			buttonGroup_7.clearSelection();
			buttonGroup_8.clearSelection();
			buttonGroup_9.clearSelection();
			buttonGroup_10.clearSelection();
			buttonGroup_11.clearSelection();
			buttonGroup_12.clearSelection();
			buttonGroup_13.clearSelection();
			buttonGroup_14.clearSelection();
			buttonGroup_15.clearSelection();
			buttonGroup_16.clearSelection();
			buttonGroup_17.clearSelection();
			buttonGroup_18.clearSelection();
			buttonGroup_19.clearSelection();
			buttonGroup_20.clearSelection();
			buttonGroup_21.clearSelection();
			buttonGroup_22.clearSelection();}
public String getDiagnosis_Result() throws IOException{
	if(seeing_blurred_vision && eye_redness && light_sensitivity && burning_and_itching_sensation && dryness_sensation && eye_fatigue && filing_like_something_in_the_eye && stringy_mucus_and_difficulty_in_wearing_contact_lenses)
	{
		Diagnosis_Result= "\t\tThe Patient have Dry eye syndrome Eye disease";
		Diagnosis_Result+="\n\nThe treatments of Dry Eye Syndrom are :- ";
	}
```

```
else if(seeing_blurred_vision && eye_redness && light_sensitivity && burning_and_itching_sensation && swelling_in_the_conjunctiva_and_excessive_tearing && thick_yellowish_discharge)
{
		Diagnosis_Result="\t\tThe Patient have Conjuctivitis Eye disease";
		Diagnosis_Result+="\n\nThe treatments of Conjuctivitis Eye disease are :- ";

}
else if(eyestrain_leading_to_headaches && blurry_vision_when_looking_at_distance_objects && blurry_vision_when_looking_at_close_range && squinting_the_eye_and_eye_irritation)
{
		Diagnosis_Result="\t\tThe Patient have Astigmatism Eye disease";
		Diagnosis_Result+="\n\nThe treatments of Astigmatism Eye disease are :- ";

					}
else if(eyestrain_leading_to_headaches && blurry_vision_and_inability_to_read_at_normal_reading_distance && squinting_the_eye_and_eye_irritation)
{
		Diagnosis_Result="\t\tThe Patient have Prosbyopia Eye disease";
		Diagnosis_Result+="\n\nThe treatments of Prosbyopia Eye disease are :- ";
}
else if(seeing_blurred_vision && seen_sudden_appearance_of_floaters_or_dark_spots && impaired_color_recognition)
{
		Diagnosis_Result="\t\tThe Patient have Diabetic_Retinapathy Eye disease";
		Diagnosis_Result+="\n\nThe treatments of Diabetic_Retinapathy Eye disease are :- ";
		}
else if(seeing_blurred_vision && clouded_or_dim_vision)
{
		Diagnosis_Result="\t\tThe Patient have Cataract Eye disease";
		Diagnosis_Result+="\n\nThe treatments of Cataract Eye disease are :- ";
}
		else if(seeing_blurred_vision && eye_redness && eye_in_pain && tunnel_or_narrowed_vision && nausea_and_vomiting)
{
		Diagnosis_Result="\t\tThe Patient have Glaucoma Eye disease";
		Diagnosis_Result+="\n\nThe treatments of Glaucoma Eye disease are :- ";
}
else if(seeing_blurred_vision && seen_sudden_appearance_of_floaters_or_dark_spots && impaired_color_recognition && headache)
{
		Diagnosis_Result="\t\tThe Patient have Retinal_Detachment Eye disease";
		Diagnosis_Result+="\n\nThe treatments of Retinal_Detachment Eye disease are :- ";
}
else if(seeing_blurred_vision && eye_redness && light_sensitivity && seen_sudden_appearance_of_floaters_or_dark_spots && eye_in_pain)
{
Diagnosis_Result="\t\tThe Patient have Uveitites Eye disease";
Diagnosis_Result+="\n\nThe treatments of Uveitites Eye disease are :- ";
}
else if(squinting_the_eye_and_eye_irritation)
{
Diagnosis_Result="\t\tThe Patient have Strabismus Eye disease";
Diagnosis_Result+="\n\nThe treatments of Strabismus Eye disease are :- ";
}
```

```
else if(burning_and_itching_sensation && blurry_vision_when_looking_at_close_range && squinting_the_eye_and_eye_irritation)
{
Diagnosis_Result="\t\tThe Patient have Hypermetropia Eye disease";
}
else if(blurry_vision_when_looking_at_distance_objects && squinting_the_eye_and_eye_irritation && headache)
{
Diagnosis_Result="\t\tThe Patient have Myopia Eye disease";
Diagnosis_Result+="\n\nEyeglasses ";
		}
else {
Diagnosis_Result=null;
OptionPane.showMessageDialog(null, "The RBR cannot identify the type of Eye Disease. Please consult the CBR.");
Process process = Runtime.getRuntime().exec("cmd /c JColibriGUI.bat", null, new File("C:\\jCOLIBRI_1.1\\jCOLIBRI\\"));

				}
				String Stype=Diagnosis_Result;
				return(Stype);
				JLabel lblwell_come = new JLabel("Well Come to Integrated RBR and CBR Eye Disease Diagnosis and
Treatment System");
		lblwell_come.setFont(new Font("Tahoma",Font.BOLD,16));
		lblwell_come.setForeground(Color.DARK_GRAY);
		lblwell_come.setBounds(192, 11, 737, 33);
		frame.getContentPane().add(lblwell_come);

		JLabel lblNewLabel_0 = new JLabel("Select the following options according to Patient symptoms");
		lblNewLabel_0.setFont(new Font("Tahoma",Font.BOLD,14));
		lblNewLabel_0.setForeground(Color.darkGray);
		lblNewLabel_0.setBounds(38, 44, 479, 24);
		frame.getContentPane().add(lblNewLabel_0);

		JButton btnCheck = new JButton("Check");
		btnCheck.addActionListener(new ActionListener() {
			public void actionPerformed(ActionEvent arg0) {
				try {
				//		lblDiagnosis_Res.setText(getDiagnosis_Result());
						lblTreatment.setText(getDiagnosis_Result());
				}catch(IOException e) {
				//		e.printStackTrace();
						System.out.println(e);
				    e.printStackTrace();
				}
				}
			});
		btnCheck.setBounds(623, 610, 95, 25);
		frame.getContentPane().add(btnCheck);

		JButton btnExit = new JButton("Exit");
		btnExit.addActionListener(new ActionListener() {
			public void actionPerformed(ActionEvent arg0) {
				System.exit(0);
			}
		});
```

```
btnExit.setBounds(1007, 610, 95, 25);
frame.getContentPane().add(btnExit);
JLabel lblDiagnosis_Result = new JLabel("Diagnosis_Result");
lblDiagnosis_Result.setFont(new Font("Tahoma", Font.PLAIN, 16));
lblDiagnosis_Result.setBounds(821, 76, 134, 37);
frame.getContentPane().add(lblDiagnosis_Result);
lblDiagnosis_Res = new JLabel(" ");
lblDiagnosis_Res.setVerticalAlignment(SwingConstants.TOP);
lblDiagnosis_Res.setForeground(Color.BLACK);
lblDiagnosis_Res.setFont(new Font("Tahoma", Font.PLAIN, 12));
lblDiagnosis_Res.setBounds(595, 111, 321, 37);
frame.getContentPane().add(lblDiagnosis_Res);

lblTreatment = new JTextArea("");
lblTreatment.setEditable(false);
lblTreatment.setAutoscrolls(true);
lblTreatment.setFont(new Font("Tahoma", Font.PLAIN, 12));
lblDiagnosis_Res.setForeground(Color.BLACK);
lblTreatment.setBounds(595, 122, 530, 464);
frame.getContentPane().add(lblTreatment);

JButton btnReset = new JButton("Reset");
btnReset.addActionListener(new ActionListener() {
        public void actionPerformed(ActionEvent arg0) {
                buttonGroup_1.clearSelection();
                buttonGroup_2.clearSelection();
                buttonGroup_3.clearSelection();
                buttonGroup_4.clearSelection();
                buttonGroup_5.clearSelection();
                buttonGroup_6.clearSelection();
                buttonGroup_7.clearSelection();
                buttonGroup_8.clearSelection();
                buttonGroup_9.clearSelection();
                buttonGroup_10.clearSelection();
                buttonGroup_11.clearSelection();
                buttonGroup_12.clearSelection();
                buttonGroup_13.clearSelection();
                buttonGroup_14.clearSelection();
                buttonGroup_15.clearSelection();
                buttonGroup_16.clearSelection();
                buttonGroup_17.clearSelection();
                buttonGroup_18.clearSelection();
                buttonGroup_19.clearSelection();
                buttonGroup_20.clearSelection();
                buttonGroup_21.clearSelection();
                buttonGroup_22.clearSelection();
                lblTreatment.setText("");
                }
                });
btnReset.setBounds(821, 610, 95, 25);
frame.getContentPane().add(btnReset);
JPanel panel_1 = new JPanel();
```

```
			panel_1.setBorder(new EtchedBorder(EtchedBorder.RAISED, null, null));
			panel_1.setBounds(18, 76, 567, 571);
			frame.getContentPane().add(panel_1);

			JPanel panel_2 = new JPanel();
			panel_2.setBorder(new EtchedBorder(EtchedBorder.RAISED, null, null));
			panel_2.setBounds(587, 76, 543, 571);
			frame.getContentPane().add(panel_2);
			}
		public JLabel getlblDiagnosis_Result() {
			return lblDiagnosis_Res;
		}
		public JButton getBtnNewButton() {
			return btnNewButton;
		}
		public ButtonGroup getButtonGroup() {
			return buttonGroup;
		}
}			}
```

APPENDIX VI: Sample cases used for system design

- A 45-year-old man presents with eye pain. He has type one diabetes, which is controlled with insulin and take a medication of antihistamines. An eye exam reveals that he has seen blurred vision and eye fatigue with burning and itching sensation. The eyelid has filled with red and he has fear of light sensitivity. He can't wear contact lenses and feel like something is in his eyes. He has stringy mucus around his eyes after sleeping. The disease is dry eye syndrome the treatment will be artificial tears each eye per day approximately 6 hours apart. Xiidra two applications in each eye per day approximately12 hours apart.
- A 25-year-old woman has seen blurry vision when looking closed object. She has need to squint for getting a better vision, headache hitting after tasks needing your focus on close by objects and an aching or burning sensation around the eyes. The disease conjunctivitis the treatment will be artificial tears each eye per day approximately 6 hours apart. Antihistamines falsensteroidal and anti-inflammatory drugs twice a day for month.
- A 29-year-old man works in chemical laboratory room. The pain has started before two days. He has fear of extra light sensitivity and his white eyelid is covered by redness. He has burning and itching sensation with excessive tearing in his eyes. He has also thick yellowish discharge mostly converting whole eyelashes, especially after sleepy. The disease is astigmatism the treatment will be eyeglasses range in power from +1.00 diopter (D) to +3.00 D, with special cylindrical lens prescription.
- A 39-year-old woman presented with painless progressive decrease vision of 1-year duration, more the left than the right eye. She was a diabetic on treatment with oral hypoglycemic agents and insulin for 2 years. She has an experience of drinking alcohol and smoking cigarette for 10. She has red eyes and seen blurred vision. She has seen sudden appearance of floaters through her vision. She has also impaired color recognition, fluctuating vision, and poor night vision, the disease is diabetic-retinopathy, the treatment will be Xiidra two applications in each eye per day approximately 12 hours apart and eye surgery.
- A 29-year-old man has eye distorted and blurry vision at close range as well as at a close range. He has type two diabetes, which is controlled with insulin and hypertension. He has eyestrain leading to headaches and eye irritation, and He has difficulty in seeing things at night because of the he squinting the eye, the disease is hypermetropia, the treatment will be Eyeglasses +1.00 diopter(D) to +3.00 D.
- A 33-year-old man has seen blurred vision and has redness appearing in the eyelid or through the white or the eyes. He has extra or light sensitivity in the eyes and has pain in the eye, seeing dark,

floating spots in the field or vision (floaters), and decreased vision. The disease is uveitis, the treatment will be Injection dosage of Corticosteroid 20 to 300mg a day injected into a muscle, Anti-metabolite, approximately 6 hours apart,

- A 61-year-old man has blurry vision and inability to read at normal reading distance. Before 2 years myopia was started on him. He always holds reading material farther away to make the letters clear. To that he has eyestrain which is leading to headaches. The disease is presbyopia; the treatment will be refractive surgery.
- A 72-year-old woman has seen blurred vision and she has redness appearing in the eyelid or through the white or the eyes. She has tunnel or narrowed vision, peripheral vision loss, severe pain in eyes accompanied by nausea and vomiting, sudden visual disturbance in the low light conditions, seeing halos around lights the disease is glaucoma, the treatment will be Xalatan (Pfizer), dosage is one drop per a day traditional surgery.
- A70-years-old man concerned that his vision was blurred. He has troubling to look things at night or darkest place. As well as he cannot see through light and glare. He looks halos around light; frequently he changes contact lens prescription. He saws fading or yellowing colors and needs brighter light for reading or identifying objects. The disease is cataract; the treatment will be eye-glasses +1.00 diopter (D) to +3.00 D, with-antiglare-sunglasses.
- A 22-year-old man has eye distorted with seen blurry vision when looking at distance objects. He has eyestrain which is leads him to headaches. He has difficulty viewing objects at night. To view the object clearly, it requires squinting or partial closing of the eyelids to get a clear vision of something. The disease is myopia the treatment will be eye-glasses +2.00 diopter (D) to +3.00 D.
- An 8-year-old boy has crossed eyes and seeing double vision on objects, his eyes are inability to focus on a particular point at the same time and he has also uncoordinated eye movements and loss of depth perception. The disease is strabismus, the treatment will be eye-patching, Eye glasses+1.00 diopter(D) to +3.00 D, Atropine drops approximately 12 hours apart,
- A 70-year-old man becoming aware of visual field defect in both eyes. He has type 2 diabetics, Hypertension and Cardio vascular diseases. Before 10 years ago he had eye surgery for cataract remove. Now he has red eyes and looks blurred vision. As well as at somewhat he sees sudden appearance of light flashes in his both eyes. He has sudden appearance of floaters and heavy filling on his eyes. The disease is retinal detachment; the treatment will be Scleral Buckle, Pneumatic, Retifalsepexy surgery.

APPENDIX VII: Sample cases used for system testing

- A 50-year-old woman has becoming aware of visual distorted with seeing blurred vision, she has hypertension disease with controlled medication. She has got redness eye in her eyelid. She has seen clouded or dim vision. In the night or low light and she has difficulty to seeing objects. She can't see through light and glare and she seeing halos around light, she made frequently changing eyeglasses, fading or yellowing view of colors. Most of the time she needs brighter light for reading and other activities.
- A 32-year-old man has started seen blurry vision when looking at distance objects. He has eyestrain which is leads him to headaches. He has difficulty viewing objects at night. To view the object clearly, it requires squinting or partial closing of the eyelids to get a clear vision of something.
- A 17-year-old girl has eye pain before 3 days because she was swimming in the pool. She has seen blurred vision and she has redness appearing in the eyelid of her eyes, she has fear of light sensitivity, burning and itching sensation in the eyes, she has swelling in the conjunctiva, excessive tearing.
- A 56-year-old man presented with painless progressive of decrease vision from 2 years ago. He has experience of drinking alcohol and smoking cigarette for 20 years. His examination shows that he has now blurred vision. He saws sudden appearance of dark spots of floating through his vision. His eyelids are so red and sometimes burning and acing sensation feels him.
- A 44-year-old man has seen blurred vision and has redness appearing in the eyelid or through the white or the eyes. He has extra or light sensitivity in the eyes and has pain in the eye, seeing dark, floating spots in the field or vision (floaters), and decreased vision
- A 33-year-old man has eye distorted and blurry vision when looking at distance objects and also blurring vision when looking at close range. He has no diabetes but has hypertension with controlled with hydrochlorothiazide but no other drugs. An eye exam reveals that he has eyestrain, headaches and eye irritation. He has also difficulty in seeing things at night and has partial squinting on his left eye.
- A 72-year-old woman has seen blurred vision and she has redness appearing in the eyelid or through the white or the eyes. She has tunnel or narrowed vision, peripheral vision loss, severe pain in eyes accompanied by nausea and vomiting, sudden visual disturbance in the low light conditions, seeing halos around lights

- A 42-year-old woman has blurry vision and inability to read at normal reading distance. She always holds reading material farther away to make the letters clear. To that she has eyestrain which is leading to headaches. Sometimes she feels burring and aching sensation with excessive tearing.
- A 12-year-old girl has crossed eyes and seeing double vision on objects, his eyes are inability to focus on a particular point at the same time and he has also uncoordinated eye movements and loss of depth perception.
- A 62-year-old man has becoming aware of decreased visual acuity in his left eye. He has seen blurred vision on the affected eye. His eyes have redness appearing in the eyelid through the white part of his eyes. He saws sudden appearance of dark spots of floating through his vision. In the affected eye he saws light flashes and he has steadily receding side vision, presence of a curtain like shadow through the field of vision and he feel like heavy in his eyes.
- A 19-year-old man has seen blurry vision when looking closed object. He has need to squint for getting a better vision, headache hitting after tasks needing your focus on close by objects and an aching or burning sensation around the eyes.
- A 53-year-old woman presents with eye pain. She has taken refractive eye surgery before three year. She has no diabetes but has hypertension or cardiac disease. An eye exam reveals that she has seen blurred vision and excessive tearing with burning and itching sensation. The eyelid has filled with redness and she has no fear of light sensitivity. She can't wear contact lenses and feel like something is in her eyes. She has stringy mucus around her eyes after sleeping.

APPENDIX VIII: Letter of cooperation to collect data

ቁጥር:-ኢ.ሳ/07/49/2011

ቀን፡ 27/07/2011

ከኢንፎርሜሽን ሳይንስ ት/ት ክፍል

ጅማ ዩኒቨርሲቲ

ለጅማ ህክምና ማዕከል የአይን ህክምና ትምህርት ክፍል

ጅማ ዩኒቨርሲቲ

በኢንፎርሜሽን ሳይንስ ት/ት ክፍል የድህረ-ምረቃ ተማሪ የሆነ፡ በፀጋው ደሳለኝ "Integration of Case Based and Rule Based Reasoning for Designing Knowledge Based Diagnosis and Treatment of Eye Disease" በሚል ርዕስ የጥናት ስራዉን ለመስራት በመስሪያ ቤታችሁ መረጃ መሰብሰብ ስላስፈለገው ተገቢው ትብብር እንዲደረግለት በአክብሮት እየጠየቅን፣ ለሚደረግለት ትብብር ሁሉ ከወዲሁ እናመሰግናለን፡፡

ከሠላምታ ጋር

አቶ ሚሳ ዲሪባ

የኢንፎርሜሽን ሳይንስ ት/ት ክፍል