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DEVELOPING A KNOWLEDGE-BASED SYSTEM FOR DIAGNOSIS AND TREATMENT OF HIV/AIDS DISEASE USING RULE-BASED REASONING TECHNIQUE

Yibabie, Getenet

BAHIR DAR UNIVERSITY

BAHIR DAR INSTITUTE OF TECHNOLOGY

SCHOOL OF RESEARCH AND GRADUATE STUDIES

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MSc. Thesis on:

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By

Yibabie Getenet

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Yibabie Getenet

A thesis submitted to Bahir Dar Institute of Technology in Partial Fulfillment of the Requirements for the Degree of Masters of Science in **Information Technology** in the Faculty of Computing.

Advisor: Abrham Debasu (Ass. Pro.)

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SCHOOL OF GRADUATE STUDIES
FACULTY OF COMPUTING

Approval of thesis for defense result

I hereby confirm that the changes required by the examiners have been carried out and incorporated in the final thesis.

Name of Student Yibabie Getenet Signature ______ Date 18/7/2023

As members of the board of examiners, we examined this thesis entitled "**Developing a knowledge-based system for diagnosis and treatment of HIV/AIDS disease using rule-based reasoning technique**" by **Yibabie Getenet**. We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Masters of science in "**Information Technology**".

Board of Examiners

Name	Signature	Date
Name of Advisor: Abrham Debasu		14/01/2016
Name of External examiner: Tibebe Beshah (PhD)		18/7/2023
Name of Internal Examiner: Alemu Kumlachew		14/01/2016
Name of Chairperson: Debas Senshaw (PhD)		14/01/2016
Name of Chair Holder: Abdulkerim M (PhD)		14/01/2016
Name of Faculty Dean: Alemu K		14/01/2016

Faculty Stamp

Bahir Dar University Bahir Dar Institute of Technology Faculty of Computing

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ABSTRACT

The study highlighted the persisting global health crisis of HIV/AIDS and the recent disruptions caused by economic and humanitarian crises along with the COVID-19 pandemic. These factors have troubled the established HIV/AIDS diagnosis and treatment services which are critical steps for preventing the disease. Thus, this study aims to address this challenge and improve the quality-of-service delivery by developing a knowledge-based system which integrates an intelligent counseling and medical data storage and access functionalities with the testing and treatment services of HIV/AIDS.

The task of diagnosis and treatment of HIV/AIDS involves several determinant rules that govern the decision-making process. These rules play a crucial role in identifying and suggesting appropriate treatments. Thus, a rule-based reasoning technique is used to address the problem due to its explicit definition of facts, rules, relationships, actions, and suggestions. It offers a structured framework for decision-making, where predefined rules assist users by providing relevant information and the logical reasoning process for identifying HIV status and recommending appropriate treatments. By using these rules, the model consistently generates the same results for identical scenarios, ensuring reliability in the diagnosis and treatment of HIV/AIDS.

The study followed a qualitative research approach and data collection methods such as semi-structured interviews, and documentation. The required knowledge is acquired from medical experts involved in HIV/AIDS diagnosis and treatment services in the Debre Tabor referral hospital. In addition, governmental strategic documents, guidelines, manuals, and related journals are used as secondary sources of data selected by purposive sampling technique. A content analysis method is used to explore the knowledge, experiences, skills, and processes related to counseling, testing, and treatment services. Graphical decision tree and forward-chaining reasoning techniques are used to model and represent the knowledge respectively. Angular web framework with typescript programming language is used for the implementation.

The findings highlighted the effectiveness of the KBS model in providing counseling, testing, and treatment services. The counseling service offered information and support to individuals undergoing HIV testing, helping them make informed decisions. The testing service accurately analyzed samples of blood test results, aiding in early detection and treatment. The treatment recommendation service suggested antiretroviral therapy regimen types.

Furthermore, the proposed model included medical data storage and access services with the KBS model for retrieval and utilization of diagnosis and treatment-related information. This service contributes to resource management and promotes collaboration in HIV/AIDS diagnosis and treatment tasks. In conclusion, this study presented a promising knowledge-based system model for the management of HIV/AIDS by integrating intelligent counseling services and data storage and accessing capabilities. Thus, it makes a significant contribution to the ongoing fight against the disease.

Keywords: Intelligent counseling, HIV/AIDS testing, HIV/AIDS treatment

ABBREVIATIONS

AIDS:	Acquired Immune Deficiency Syndrome
ART:	Anti-retroviral therapy
CBR	Rule-Based Reasoning
CD4:	Cluster Differentiation 4
CRUD:	Create, Read, Update and Delete
ES:	Expert System
FMOH:	Federal Ministry of Health
HAPCO:	HIV/AIDS Prevention and Control Office
HIV:	Human Immunodeficiency Virus
HIVST:	HIV Self Testing
HTC:	HIV Testing and Counseling
IPD	In Patient Department
KBS:	Knowledge-Based System
MCH	Mother and Child Health
MMI:	Multi-Modal Interactivity
OPD	Out Patient Department
PITC:	Provider initiated Testing and Counselling
PLWHA:	People Living with HIV/AIDS
RBR:	Rule-Based Reasoning
UI:	User Interface
WHO:	World Health Organization
WER:	Word Error Rate
VCT	Voluntary Counselling and Testing

CHAPTER ONE

1. INTRODUCTION

1.1. Background

HIV/AIDS is a serious public health crisis across the world. The burden of the disease is very high in developing countries compared to developed ones. Because the prevention, care, and treatment strategies require high investment in service delivery, training manpower, deploying technologies, and inducing knowledge of the disease (Deribew et al., 2016). According to Mondal & Shitan (2013), half of the annual infections occurred in youths under the age of 25 which is in their most productive years. Thus, the social, cultural, and economic growth of families, communities, and nations will also be affected (Brookmeyer, 2010).

The tasks of diagnosis and treatment for HIV/AIDS are critical steps for preventing the disease. Especially, HIV testing and counseling services are important tasks in identifying and connecting PLHIV to a treatment service. It also provides an important opportunity to strengthen HIV prevention among negative populations (MOH, 2018). Most commonly, KBS is being employed for these tasks. It adopts physicians' knowledge and supports diagnosis and treatment decisions. It is especially useful for experts with no computer experience in building and evaluating complex disease models. It is also important to spread knowledge by providing reasonable explanations and overcoming human limitations.

Recent research by (Oluwakemi et al., 2017), presented a KBS to diagnose HIV infection and manage antiretroviral drug prescriptions that result in a predictive performance of 93.33% accuracy. In situations where there are few medical doctors accessible, the approach aids in lowering mortality rates. Similarly, Afolabi et al. (2017) have developed an expert system that proves its ability to assist doctors in the quick diagnosis of HIV/AIDS disease. On the contrary, other studies revealed that patients want to see doctors in person even if they are able to know their HIV status themselves with the help of such systems. (Simfukwe MacMillan et al., 2014).

The experience of HIV/AIDS patient illness can be changed by providing appropriate counseling, and treatment services that follow professional standards (Uys, 2003). On the other hand, the diagnosis and treatment of HIV/AIDS disease can be greatly affected by how physicians, lab technicians, and nurses who are working on HIV/AIDS disease interact, store, and exchange patients' information (Quinn et al., 2019).

Previous studies on KBS systems for HIV/AIDS diagnosis and treatment did not include counseling, data storage, and accessing services as part of their system. Therefore, this study aimed to address this gap by integrating them into a KBS system designed for diagnosing and treating HIV/AIDS disease. The proposed model is developed using a rule-based reasoning approach.

The counseling service model was designed to provide counseling services for self-tester individuals and guidelines for trained experts. The testing and treatment suggestion model showed promising results in classifying HIV status and suggesting appropriate ART regimen prescriptions. In addition, the data storage and access service support the diagnosis and treatment tasks by enabling a Create, Read, Update, and Delete (CRUD) operation of the database. In general, the developed knowledge-based system showed a promising result in the context of Debre Tabor Referral Hospital, as it addresses a critical need for accurate and effective diagnosis and treatment of HIV/AIDS.

In the introduction section, the research provided information on the study's background, objective, research questions, scope, and significance. The literature review section discussed various topics, including an overview of global and Ethiopian HIV/AIDS status, HIV testing, counseling, treatment, patient data storage, and accessing tools. Additionally, the section presented an in-depth analysis of rule-based and case-based reasoning methods of KBS along with their strengths and limitations. The methodology section detailed the research approach, strategy, knowledge gathering, analysis, modeling, and representation techniques used in the study. Finally, the last sections presented the major findings, model evaluations, conclusions, and recommendation statements.

1.2. Statement of the Problem

HIV/AIDS was discovered for the first time in 1981 in the United States of America. It is still a major health crisis for human beings (Chopra et al., 2019). More than 40.1 million people have died due to Aids-related illnesses over the past 40 years. Until the end of 2020, there were 37.7 million people suffering from HIV/AIDS across the globe. In addition, 1.5 million people have been newly infected with HIV, and 680,000 people passed away in 2020 (UNAIDS, 2021).

Currently, economic and humanitarian crises combined with the covid 19 pandemic have disrupted health services in much of the world. As a result, HIV infection vulnerability is rising and global progress against HIV is slowing over the past two years (UNAIDS, 2022). The report shows that new HIV infections decreased globally in 2021. However, compared to 2020, the drop was only 3.6 percent, which is the smallest annual decrease since 2016. Similarly, before 2020, the number of people on HIV treatment increased by more than 2 million from the previous years. Whereas, the number decreased to 1.47 million only in 2021, the lowest increase since 2009. This shows that the world AIDS response is under threat.

Knowing one’s HIV status is a critical step in preventing the disease. Especially, it is very crucial for young people aged 15-24 years who are engaged in shorter relationships with more partners. HIV-negative people who are aware of their HIV status can make risk-reduction decisions to keep themselves and others healthy. Those who are HIV positive can protect their partners, get access to care, and be treated if they are aware of their status. However, participation in HIV testing all over Ethiopia is slightly coming lower in 2016 than it was in 2011 (EDHS, 2016).

The experience of HIV/AIDS patient illness can be changed by providing appropriate counseling, and treatment services that follow professional standards(Uys, 2003). However, in most African countries, HIV/AIDS counseling is provided with little attention and training. The service is not sufficiently supported by education policy, strategy, and appropriate funds (Richards & Marquez, 2005).

On the other hand, Mavhandu-Mudzusi et al., (2007) shows HIV/AIDS counseling provider experts are facing positive and negative psychological experiences during their work. The study describes as they are frequently exposed to emotionally draining activities such as thoughts, feelings, and immoral behaviors from their clients which makes them more vulnerable to stress (Mavhandu-Mudzusi et al., 2007). Therefore, the counseling task requires well-organized knowledge and skill for providing effective service and appropriate handling of such emotional states.

Similarly, the diagnosis and treatment of HIV/AIDS disease can be greatly affected by how physicians, lab technicians, and nurses interact, store, and share their patient information (Quinn et al., 2019). Hence, the current manual patient information-sharing mechanism is highly vulnerable to medical errors and time delays. Thus, easy accessibility of patient medical information can facilitate linkage, monitoring, and coordination of clients with medical experts and improve the quality of diagnosis, and treatment services for HIV/AIDS disease. In addition, it can reduce resource utilization costs (Shade et al., 2012; Sadoughi et al., 2018).

Without the integration of counseling services into the KBS, there is a risk of suboptimal diagnoses, delayed interventions, and limited understanding of patients' needs and preferences. The absence of patient data storage and access functionality further delays the flow of information and collaboration among healthcare professionals, leading to fragmented care and compromised treatment outcomes.

Therefore, the problem revolves around the need to develop a knowledge-based system for the diagnosis and treatment of HIV/AIDS disease that addresses the gap in integrating counseling services and patient data storage and access functionality. By integrating counseling services, the system can enhance the accuracy and effectiveness of diagnoses, improve patient understanding, and optimize treatment recommendations. Additionally, by incorporating efficient patient data storage and access functionality, the system can facilitate coordinated work among healthcare professionals, enable seamless information exchange, and support patient care.

Overall, the study is relevant to improve the delivery of HIV/AIDS services, enhancing collaboration among healthcare professionals, ensuring information accessibility, and contributing to the advancement of knowledge in the field of HIV/AIDS diagnosis and treatment. By addressing these aspects, it aims to make a positive impact on the lives of individuals affected by HIV/AIDS and contribute to the broader efforts of combating this global health challenge by addressing the following research questions.

- What are the specific information needs and requirements of individuals conducting HIV/AIDS testing and treatment services?
- How can the design and integration of a medical data storage and access services with a KBS model be implemented to facilitate coordination in the diagnosis and treatment of HIV/AIDS?

1.3. Objectives of the Study

1.3.1. General Objective

The general objective of the research is to develop a knowledge-based system for diagnosis and treatment of HIV/AIDS disease using rule-based reasoning technique.

1.3.2. Specific Objectives

- To develop a KBS model that delivers personalized and relevant information and supports the decisions for individuals conducting HIV/AIDS testing and treatment services
- To design and implement a medical data storage and access model integrated with the diagnosis and treatment services of HIV/AIDS disease
- To evaluate the effectiveness and efficiency of the proposed model in delivering diagnosis and treatment services for HIV/AIDS disease

1.4. Scope of the Study

The study focuses on integrating counseling and data storage and access services for the testing and treatment recommendation KBS models.

The counseling service provides information and guidelines related to stigma and discrimination, testing processes, available treatment services, referrals, and emotion-supporting resources. The testing and treatment services provide decision support for diagnosis and treatment recommendation tasks. Parallelly, the data storage and access service provide clients with medical data collection and retrieval functionalities for coordination work in the diagnosis and treatment of HIV/AIDS disease.

The proposed KBS model is designed for clients who are above 5 years aged. However, infants and children below 5 years are not considered in this study. A common graphical user interface, speech synthesis, and recognition modalities in the English language are used for user interaction. Nevertheless, due to technical difficulties and a lack of efficient modeling, a local language user interface is not part of this study.

1.5. Significance of the Study

HIV/AIDS is a significant global health challenge, and effective counseling, testing, and treatment services are essential to reduce its impact on individuals and communities. The development of a knowledge-based system using a rule-based reasoning technique for the diagnosis and treatment of HIV/AIDS is a significant contribution to the field of the health sector.

The counseling service provided by the knowledge-based system can help to address the stigma and discrimination associated with HIV/AIDS while providing relevant information and guidance to clients and medical experts. This service can provide pre and post-counseling for HIV testing with speech modality, enhancing the skills and knowledge of test provider experts in providing counseling service efficiently and effectively.

The testing service provided by the knowledge-based system can support the reasoning of medical experts in diagnosing HIV infection accurately and efficiently. The service analyzes samples of blood test results and classifies HIV status as positive, negative, and inconclusive. Similarly, the treatment service provided by the knowledge-based system can help to improve the quality of care for patients with HIV/AIDS by suggesting appropriate ART regimens and scheduling follow-up appointments.

The service is able to suggest ART regimens for patients based on their medical history and schedule appointment dates for the next subsequent viral load testing date. Parallelly, the data storage and access service integrated with testing and treatment services can help to facilitate coordinated work among medical experts for the diagnosis and treatment of HIV/AIDS. This service is integrated with the testing and treatment services and is used to share patient data among medical experts. Generally, the study has the potential to make a meaningful impact on the lives of individuals with HIV/AIDS by improving the quality of counseling, testing, and treatment services and facilitating coordinated work among medical experts.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Over View of Literature

HIV/AIDS is a serious public health crisis across the world. The burden of the disease is very high in developing countries compared to developed ones. Because the prevention, care, and treatment strategies require high investment in service delivery, training manpower, deploying technologies, and inducing knowledge of the disease (Deribew et al., 2016). According to Mondal & Shitan (2013), half of the annual infections occurred in youths under the age of 25 which is in their most productive years. Thus, the social, cultural, and economic growth of families, communities, and nations will also be affected (Brookmeyer, 2010).

Nowadays, a knowledge-based system is playing a great role in the health sector. In a developing country like Ethiopia, there is a shortage of trained manpower in this sector. On the other hand, a pandemic, such as HIV/AIDS, does not allow for the acquisition of sufficient trained personnel. In this situation, knowledge-based systems are recommended to disseminate physicians' knowledge to low-level experts and facilitate the diagnosis and treatment services (Prentzas & Hatzilygeroudis, 2007).

This section begins by reviewing the status of HIV/AIDS globally and in Ethiopia specifically. The HIV counseling, testing, and treatment service delivery trends are discussed. Consequently, common KBS development approaches and architecture, medical data storage, and access tools for KBS are explored. Finally, after analyzing relevant topical-related works existing gaps are identified.

2.2. HIV/AIDS Status in the World

HIV/AIDS is a serious public health crisis across the world. The burden of the disease is very high in developing countries compared to developed ones. Because the prevention and treatment strategies require high investment in service delivery, training manpower, deploying technologies, and inducing knowledge of the disease (Deribew et al., 2016).

According to Mondal & Shitan (2013), half of the annual infections occurred in youths under the age of 25 which is in their most productive years. WHO has identified adults and adolescents as a key population group for HIV prevalence factors. This group showed an increased risk of HIV infection. This shows that HIV/AIDS primarily affects people in their most productive years. But the social, cultural, and economic growth of families, communities, and nations will also be affected (Brookmeyer, 2010).

The UNAIDS (2021) report showed that there were 37.7 million people suffering from HIV/AIDS across the globe, until the end of 2020. Among these victims, 1.5 million people have been newly infected with HIV, and 680,000 people passed away in 2020. The report added that most of these deaths are due to insufficient access to HIV prevention and treatment services. This shows that HIV/AIDS continues to be a serious challenge in public health.

Sub-Saharan Africa was identified as the region primarily affected by the HIV/AIDS disease, with an estimated 25.6 million persons living with HIV (PLHWA) in that area. The victims in this region also experienced discrimination, stigma, and low acceptance within their communities, as observed in a study conducted by Amuche et al. in (2017). The pandemic's impact across the region resulted in an increased demand for skilled healthcare professionals, heightened levels of poverty, higher costs associated with funeral services and medical expenses, additional responsibilities in caring for children, and reduced birth and fertility rates (Williams et al., 2015).

A study conducted by Rodger et al. (2016), it was found that providing adequate access to Antiretroviral Treatment (ART) services could reduce AIDS-related deaths. Furthermore, this service played a significant role in preventing the further transmission of the disease. The study highlighted that individuals with undetectable HIV viral levels were unable to transmit the disease to others.

2.3. HIV/AIDS Status in Ethiopia

Ethiopia is placed among the 25 nations with the highest numeral of new HIV infections since 2011. The distribution of the pandemic across the nation is characterized as mixed, with regional variations and concentrations in urban areas (Lakew et al., 2015).

The study showed that the national HIV/AIDS prevalence is low among the general population but high among certain sub-populations and geographic areas. For example, people in the richest classes showed higher HIV prevalence rates than those in the poorest classes. Compared to people without education, adults with primary, secondary, and higher levels of education had an increased risk of being HIV positive. Related to age, adults between the ages of 25 and 45 had a higher probability of getting HIV infection than adults between the ages of 45 and 49 years. As well, people living in urban areas had a higher chance of having HIV infection than those living in rural areas.

According to EDHS (2016) data, 1.9 percent of adults in the country were infected with HIV in 2011. In addition, over 20,000 AIDS-related fatalities occurred in 2016. The survey revealed that adults aged between 15 to 49 years are at the epicenter of HIV/AIDS. The young populations, especially never-married sexually active females, face the greatest risk of HIV infection in the country. According to HAPCO (2018), the incidence of the disease appeared to be stabilized in larger towns, while it has been growing in the smaller ones. The institution warned that despite government efforts in prevention and treatment programs, the improvement of communication and transportation infrastructure could lead to increased urban and rural population mixing. This in turn would raise the risk of HIV infection.

2.4. HIV Testing and Counseling Services

HIV testing and counseling is an important first step in identifying and connecting PLHIV to a treatment service. It also provides an important opportunity to strengthen HIV prevention among negative populations (MOH, 2018). The ministry office recommended adhering to the national guidelines, standard operating procedures, and protocols to be followed when providing these services. In addition, the individual’s consent, confidentiality, correct test results, and connection to care, treatment, and prevention services have to be protected. Furthermore, people receiving HTC services have to give informed consent for being tested and counseled. In Ethiopia, two HTC service delivery approaches are implemented across the nation. The first one is the health facility-based HTC model, where both private and public health facilities are responsible for offering counseling and testing services to their clients.

The second model is the community-based HTC approach, which focuses on reaching out to eligible individuals who may not access HTC services at health facilities. This approach aims to enhance public trust, reduce stigma, and address discrimination-related issues. Additionally, the community-based approach plays a crucial role in the early identification of HIV-positive individuals compared to the facility-based approach (MOH, 2018).

As stated by the Ministry of Health, the community-based approach targeted specific subpopulation groups, geographic areas, and workplaces with a significant number of individuals eligible for HTC services. However, in both approaches, it was crucial to follow the national working HTC algorithms while providing these services. The national guidelines emphasized that the provision of mandatory HTC services was considered illegal in the country unless specifically ordered by a court.

The experience of HIV/AIDS patient illness can be changed by providing appropriate counselling, and treatment services that adhere to professional standards(Uys, 2003). However, in most African countries, HIV/AIDS counseling is often provided with little attention and training. The service is not sufficiently supported by education policy, strategy, and appropriate funds (Richards & Marquez, 2005).

On the other hand, Counselors experienced both positive and negative psychological experiences during their work. They are frequently exposed to emotionally draining activities such as thoughts, feelings, and bad behaviors from their clients which makes them more vulnerable to stress (Mavhandu-Mudzusi et al., 2007). Therefore, the counseling task requires well-organized knowledge and skill for providing effective service and handling such emotional states.

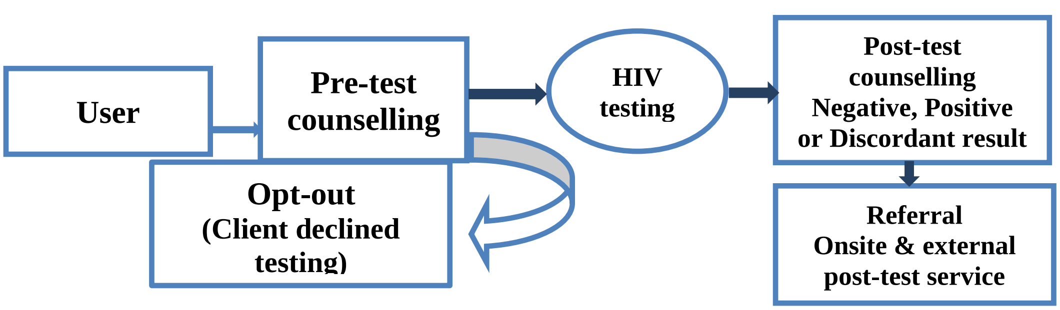

Figure 2-1:Procedure of HTC service delivery adopted from (MOH, 2018)

2.4.1. HIV Self-Test

According to MOH (2018), an HIV self-tester is an individual who conducts an HIV test on themselves using a self-testing kit, without the involvement of a healthcare professional. HIV self-testing kits are designed to be easy to use and can provide results within a short amount of time. Self-testing can be an effective way to increase access to HIV testing, particularly for individuals who may not have easy access to healthcare facilities or who may feel stigmatized or discriminated against when seeking testing services.

However, the author noted that it is not a substitute for medical diagnosis or treatment, and individuals who receive a positive result from a self-test should seek confirmation of their status through further testing and medical evaluation. Additionally, individuals who tested negative but are still at risk of HIV infection has to be counseled on the importance of continued prevention measures such as condom use and regular testing. In addition, this method is practically implemented in two ways. In the first method, people receive direct assistance before or during testing from peers or competent specialists. Hence, the aid provider demonstrates how to conduct the test and evaluate the test results for the individual to be tested. The other is unaided, in which individuals conduct a test on their own and simply follow the guidelines provided with the HIV testing kit (MOH, 2018).

Even though, HIV self-testing is a useful tool for increasing access to testing and reducing stigma and discrimination, it's important to have access to accurate and reliable testing kits, as well as appropriate counseling and support to ensure clients receive accurate results and are linked to appropriate care and treatment services. In a recent study conducted by Ngoc et al. (2023), it was observed that HIV self-testing (HIVST) showed a high level of acceptance and utilization. The findings of the study indicated that HIVST is a feasible and acceptable method, highlighting its potential as an additional option for expert-driven testing. Similarly, Tun et al. (2018) conducted a study that revealed the high acceptability, feasibility, and accuracy of blood-based HIV self-testing. The authors emphasized the critical role of HIVST in boosting the uptake of HIV testing and improving access to crucial HIV prevention and treatment services.

2.5. HIV/AIDS Treatment Services

According to the (MOH, 2018), all PLWHA are eligible for ART and admission to care providers. Anyone with HIV needs to start ART as soon as possible. This helps to decrease HIV transmission, especially mother-to-child transmission. one-third of PLWHA seeking care had chronic HIV illness. Furthermore, many PLHIV who stopped receiving treatment is now returning to care with severe illness. Even after beginning ART, patients with severe HIV illness are still at significant risk of dying because their CD4 cell count is declining.

The Ministry of Health (2014) suggested that clinicians are supposed to conduct a detailed discussion with PLWHA about their consent to start ART, its regimen type, dosage, and schedule. As well as, the benefits, possible side effects, and substitutions for the problematic ART regimens need to be explained for them. While ART medications lower the possibility of HIV transmission, it is important for those taking ART to understand that they cannot be relied upon to keep others from getting infected. They need to be advised on safer sex and the avoidance of other high-risk practices, such as sharing injecting equipment.

Early treatment initiation improves survival and lowers the prevalence of HIV infection in the family and community. It is also connected with clinical and HIV-preventive advantages. Regardless of their WHO clinical stages and CD4 levels, all adults and adolescents with a confirmed HIV diagnosis who are prepared and volunteered should begin ART as soon as possible (MOH, 2018). As maturity levels vary, some younger teens might require parental support and approval. Adolescents with prenatal infections require particular care and support.

2.6. Patient Data Storage and Access tools

Patient data storage and access mechanisms refer to the methods and protocols used to store, retrieve, and manage patient data in healthcare systems (Quinn et al., 2019). These mechanisms are critical for ensuring that patient data is organized, secure, and easily accessible to authorized users. Authentication and authorization mechanisms are used to ensure that only authorized users can access patient data.

Encryption mechanisms are used to ensure that patient data is protected against unauthorized access, theft, or cyber-attacks (Chernenko & Williams, 2021). It enabled healthcare providers to access patient information quickly and efficiently and to facilitate communication and collaboration among those involved in a patient's care. The system typically includes a wide range of information, such as patient demographics, medical history, medication lists, test results, and other clinical information.

However, it is important to note that privacy and security concerns are still major issues with electronic health recording systems, and steps must be taken to ensure that patient information is protected. Once you have defined the patient data to be stored, you need to select an appropriate data storage solution. There are several types of databases that can be used for patient data storage, including relational databases, NoSQL databases, and hybrid databases. The choice of the database depends on factors such as the volume of data, the complexity of the data, and the scalability requirements of the system (Weitzman et al., 2010).

Designing patient data and access mechanisms for a KBS requires a specialized approach that incorporates both the principles of KBS and the requirements for secure patient data management. According to Liu et al. (2019), designing a KBS for patient data management involves several key steps. Firstly, the KBS must be designed to process and organize patient data in a way that facilitates knowledge discovery and decision-making. Secondly, the KBS must be designed to support experts' decision-making by providing real-time access to specific data. This requires the development of algorithms and decision support systems that can analyze patient data and provide recommendations for treatment and care.

Thirdly, the KBS must be designed to ensure the privacy and security of patient data. This includes implementing robust access controls, encryption, and other security measures to prevent unauthorized access and data breaches. To achieve these goals, a variety of technologies can be used, including artificial intelligence, natural language processing, and big data analytics. These technologies should be carefully integrated to provide a seamless and secure experience for both experts and patients.

2.7. Knowledge-Based System

A knowledge-based system is a type of artificial intelligence that is designed to replicate the problem-solving abilities of a human expert in a particular field. It is a computer program that uses knowledge, rules, and logic to solve complex problems that typically require human expertise. The knowledge in a KBS is typically represented in the form of rules, facts, and heuristics that have been derived from the expertise of human experts in a particular domain (Prentzas & Hatzilygeroudis, 2007). The system uses this knowledge to make inferences and draw conclusions that can help it solve problems.

It has the potential to transform the healthcare sector by providing decision support and improving the quality of care for patients. It can help to reduce medical errors, increase efficiency, and improve patient outcomes. However, the development and implementation of KBSs require significant expertise in both the healthcare and technology domains. As well as, data privacy, accuracy of the knowledge base, and ethical considerations are the major challenges that need to be addressed (Giboney et al., 2015).

KBS has many important characteristics that make them useful for a wide range of applications. These characteristics include domain-specificity, flexibility, learning, collaboration, explainability, scalability, accessibility, knowledge sharing, security, and automation. By leveraging these characteristics, KBS can provide decision support, improve efficiency, and accuracy, and promote collaboration tasks in many different domains such as disease diagnosis, weather forecasting, education, manufacturing, aerospace, engineering, security, and others (Bimba et al., 2016)..

Its ability to capture and utilize expert knowledge in a domain is useful in situations where there is a shortage of skilled personnel, or where decisions need to be made quickly and accurately. This can reduce the risk of errors and improve consistency in decision-making, as they follow a predefined set of rules or guidelines. In addition, they can explain their reasoning and decision-making processes to users.

2.7.1. Architecture of Knowledge-Based System

The architecture of KBS is designed to capture and utilize expert knowledge in a specific problem area and provide intelligent reasoning capabilities to users. KBS has the potential to revolutionize decision-making and problem-solving capabilities in many fields. Thus, their architecture and techniques are continuously evolving to improve their effectiveness and usability. Its architecture consists of five major components, such as a knowledge acquisition module, knowledge base, inference engine, working database, and user interface (Prentzas & Hatzilygeroudis, 2007).

The authors explained as KBS components are designed to work together and enable the system to reason out about a particular problem and provide intelligent decision-making capabilities to users. However, the specific implementation of each component can vary depending on the application and the underlying knowledge representation techniques.

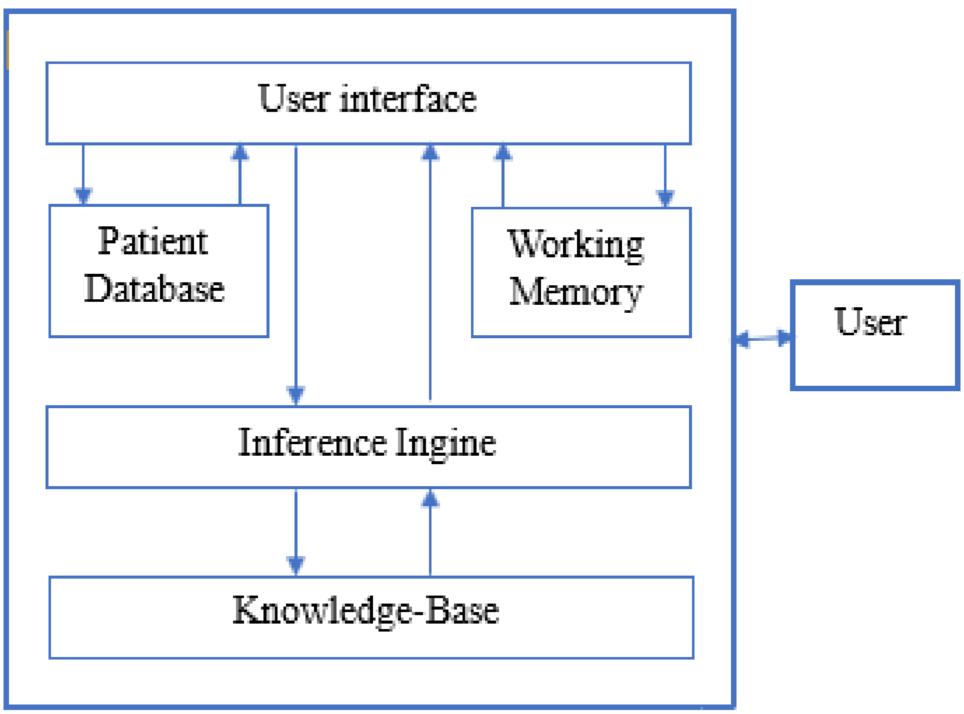

Figure 2-2: Architecture of KBS adapted from (Akter et al., 2009).

- **Knowledge base:** The Knowledge base is a fundamental component of a KBS that stores all the domain-specific knowledge that the system uses to make decisions. It contains all the information required for the KBS to reason about a particular domain, such as symptoms, diseases, and their relationships in a medical (Akter et al., 2009). It is typically created by domain experts, who provide their expertise and knowledge of the domain to the system.

  In a rule-based knowledge-based system (KBS), the knowledge base typically consists of a collection of IF-THEN rules that encode the expert knowledge specific to the domain. On the other hand, in a frame-based KBS, the knowledge base comprises a set of frames or objects that represent entities within the domain along with their associated properties. In the case of an ontology-based KBS, the knowledge base is constructed as a formal ontology, which establishes a standardized vocabulary of concepts and relationships within the domain (Jiang et al., 2017).

  The performance of a KBS is greatly impacted by the accuracy and comprehensiveness of the knowledge base. It is vital to maintain an up-to-date and relevant knowledge base that is well-structured and organized to facilitate efficient reasoning and decision-making processes. Additionally, it is important to validate and verify the knowledge base to identify and rectify any errors or inconsistencies that might hinder the system's performance (Mardani et al., 2019). Thus, quality and organization are essential factors in ensuring the system's success in delivering valuable insights and recommendations.

- **Inference Engine:** The inference engine is a crucial component of a KBS that enables the system to perform complex reasoning tasks and provide valuable insights and recommendations. According to (Prentzas & Hatzilygeroudis, 2007), the choice of inference mechanism depends on the problem domain, the type of knowledge representation used, and the specific requirements of the system. Moreover, its performance can be influenced by the complexity of the problem area and the computational resources available.

  In some cases, the inference engine may require a significant amount of computing power to process the input data and derive conclusions, which can limit its efficiency.

The authors emphasized that an explanation facility is another significant factor when using an inference engine in a KBS. It provides transparency into the reasoning process used by the inference engine and can help users understand how the system arrived at its conclusions or recommendations. This is particularly important for applications where the output of the system has a significant impact on human decision-making. The working database component of a KBS plays a crucial role in the overall system. Parallelly, the working database component needs to be designed carefully, with attention paid to the representation of knowledge, the storage mechanism, and the query and inference engine used (Kowalski & Sadri, 2012).

- **User Interface:** The user interface of a KBS is a critical component that enables users to interact with the system and access its knowledge base. One of the emerging trends in KBS User Interface (UI) design is the incorporation of speech synthesis and recognition technologies, which enable users to interact with the system more naturally and intuitively, which can improve their satisfaction and engagement with the system (Gürkök & Nijholt, 2012). Speech synthesis technology is a process that converts written text into spoken language. It can be used in KBS UI to provide users with auditory feedback and guidance and to enhance the accessibility of the system for users with visual impairments.

  On the other hand, Speech recognition technology is a process that converts spoken language into written text. It can be used in KBS UI to enable users to input commands and queries using natural language, rather than traditional keyboard and mouse input (Rakkolainen et al., 2021). However, the integration of speech synthesis and recognition technologies into KBS UI presents various challenges and opportunities for designers. One of the primary challenges is ensuring that the system can accurately recognize and interpret natural language input from users, which requires sophisticated natural language processing algorithms. As well as, designers must ensure that the system's Text To Speech (TTS) output is clear and understandable to conform to users' preferences and expectations (Karpov & Yusupov, 2018).

2.8. KBS Development Approaches

A KBS can be sorted as rule-based, case-based, frame-based, fuzzy logic-based, and neural network based according to their working principle. The oldest and most commonly used method, for researchers to create KBS are the rule-based and case-based methods. In these methods, people's habits, knowledge, and reasoning are stored and processed separately. When compared to other types of expert systems, the rule-based expert system's speed is not very fast. Because every time a rule is invoked, the complete database's rule set must be scanned (Bimba et al., 2016).

Whereas in frame-based KBS, it can save the search process framework to improve the test direction till we find the most suitable framework (Amer, 2017). In addition, each frame provides data that can allow attribute mismatches to enhance the frame's fault tolerance. Thus, it typically works when the majority of a frame's structure can be matched. A study conducted by (SushilSikchi et al., 2013) showed that a fuzzy logic-based KBS is significant in vague reality representation. It carries out its function by modeling uncertain reasoning.

In addition, the study revealed that the limitations of KBS do not result from their limited computational power but rather from the unavailability of an intellectual interface between medical experts and computers. Due to this reason, many medical experts still do not prefer to use expert systems as diagnostic aids. To bridge this gap, the authors suggested expert systems with intelligent interfaces that understand human thinking patterns, insights, gestures, and moods need to be developed. Neural network-based systems use neural networks to gather knowledge and use large-scale parallel processing to improve the system's reasoning ability. On the contrary, one of its difficulties is still how to make the neural network explain the process of its reasoning (Amer, 2017).

2.8.1. Rule-Based Reasoning

A rule-based reasoning method is a common type of reasoning approach used in the development of KBS. In this method, knowledge is represented in the form of rules, which are conditional statements that describe relationships between different facts. These rules are used to make inferences and draw conclusions based on the available data.

When a set of rules is applied to a set of facts, the system can draw conclusions based on the rules and the facts. This approach is used in a wide range of applications, such as medical diagnosis, financial analysis, and decision support systems (Prentzas et al., n.d.).

The development of a rule-based KBS involves several steps, including knowledge acquisition, rule representation, and inference mechanisms. Knowledge acquisition involves gathering information from domain experts or existing databases. Rule representation involves converting the acquired knowledge into a set of rules that can be used by the system. Inference mechanisms involve the application of rules to the available data to make predictions or draw conclusions. This method has two reasoning techniques called forward and backward chaining (Prentzas & Hatzilygeroudis, 2007).

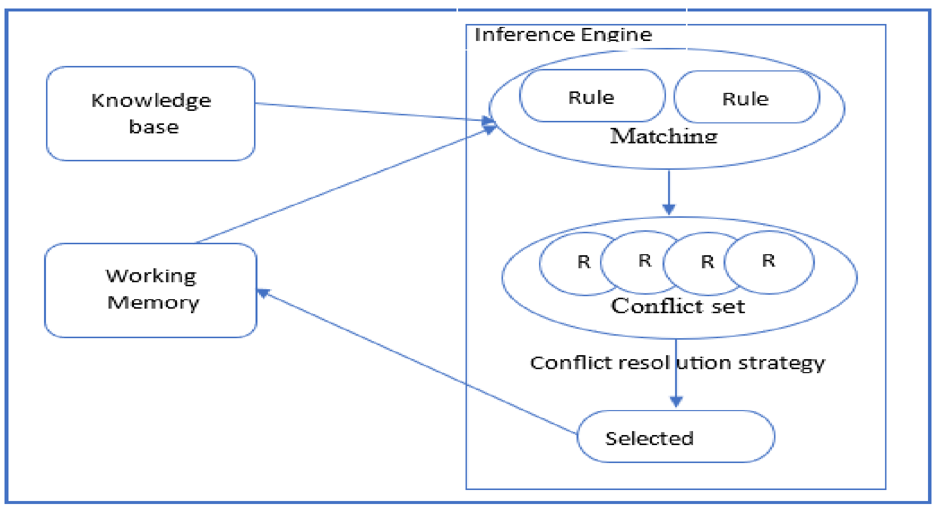

Figure 2-3:Rule Based Reasoning system components and processes adapted from (Prentzas&Hatzilygeroudis, 2007)

- **Forward Chaining Reasoning Technique:** It is a reasoning technique used in rule-based KBS to infer new information from available data. In this technique, the system starts with the available data and applies a set of rules to it to derive new information. This process continues until no further conclusions can be drawn. Its process involves initialization, rule matching, inference, conflict resolution, and updating steps. According to Tan, (2017), it is often used in diagnostic and decision-making applications, where the system needs to make a prediction or recommendation based on the available data.

In addition, it is also used in intelligent tutoring systems, where the system needs to determine the appropriate instructional material to present to the learner based on their current knowledge. It has flexibility, the ability to handle complex problems, uncertainty, and incomplete information. However, it can also be time-consuming and may require significant computational resources, particularly when dealing with large datasets or complex rules.

- **Backward Chaining Reasoning Technique:** Backward chaining is a reasoning technique used in rule-based KBS developments to determine the sequence of events that led to a particular conclusion. It starts with the goal that needs to be proved and then works backward to find the evidence that supports that conclusion. This process continues until all the necessary evidence is identified to support the original goal or conclusion (Amer, 2017).

  It is often used in diagnostic reasoning, where the goal is to determine the cause of a particular problem or symptom. It involves breaking down the problem into a series of smaller sub-problems. The major advantage of this technique is that it can save computational resources by avoiding the need to consider all possible hypotheses or solutions, instead focusing only on those that are relevant to the final goal (Ghani,2004).

2.8.2. Case-Based Reasoning

Case-based reasoning (CBR) is a problem-solving methodology used in the development of KBS. Its approach involves solving new problems by reusing solutions from similar problems solved in the past. The knowledge is represented in the form of cases, where each case contains a problem description, a solution, and a context that explains the relationship between the problem and the solution. When a new problem is encountered, the system searches through the existing cases to find the most similar case and adapts the solution to fit the new problem by considering the differences in the context (Salem et al., 2005). It encompasses four primary stages. Initially, during the retrieving stage, the system performs a search for cases that exhibit similarity to the present problem using a similarity metric.

Subsequently, in the reuse stage, the system adjusts the solution from the retrieved case to suit the current problem. Following that, in the revision stage, the system assesses the solution and incorporates required modifications based on feedback. Lastly, in the retain stage, the system stores the updated solution as a new case in the case base, ensuring its availability for future reuse.

CBR offers several advantages, including its ability to handle incomplete or uncertain information and its adaptability to new situations. It is also capable of managing exceptions and addressing non-linear relationships between variables. However, CBR does have certain limitations. One key challenge lies in selecting the most suitable similarity metric to retrieve relevant cases effectively. Additionally, maintaining the case base poses a difficulty as it can grow large and become cumbersome to manage over time.

According to Saraiva et al., (2015), CBR systems can be developed using knowledge-intensive, data-intensive, or a hybrid approach. The knowledge-intensive approach requires a substantial amount of domain knowledge and expertise to define the problem representation, similarity metrics, and adaptation methods. Whereas, the data-intensive approach utilizes machine learning techniques to automatically learn the similarity metrics and adaptation methods from a large dataset of cases. Additionally, the hybrid approach combines the knowledge-intensive and data-intensive approaches to leverage the strengths of both approaches.

The authors stated that supporting knowledge acquisition and maintenance are the key merits of this approach. When new cases are added to the case base, they can be used to update and refine the similarity metrics and adaptation methods, which can improve the performance of the system over time. It also provides a natural way to capture and organize expert knowledge, which can be shared and reused across different applications. Despite its strengths, it has some limitations and challenges that need to be addressed, such as the selection of appropriate features for problem representation, the definition of appropriate similarity metrics, and the management and technical maintenance of the case base (Salem et al., 2005).

2.8.3. Rule-Based Versus Case-Base reasoning Methods

RBR and CBR are two different reasoning methods in artificial intelligence. Both methods have their own advantages and disadvantages, and the choice between them depends on several factors. According to Saraiva et al. (2015), the nature of the problem, complexity, availability of data, time sensitivity, uncertainty, scalability, and learning capability are the major factors to be considered during the selection of the reasoning technique.

The nature of the problem is most suitable for problems with well-defined rules and constraints, where the solution can be derived by applying a set of rules to the given input. On the other hand, CBR is more appropriate for problems that require reasoning based on past experiences or cases. The complexity of the problem is another consideration. RBR may become too complex and difficult to manage if there are too many rules to apply. CBR, on the other hand, can handle complex problems more effectively by using past cases as a basis for reasoning.

In terms of the availability of data, CBR requires a significant amount of historical data to be effective. If the necessary data is available, then CBR can be a good option. However, if there is not enough data, then RBR may be a better choice. Time sensitivity is indeed an important factor to consider. RBR typically exhibits faster decision-making compared to CBR due to its utilization of pre-defined rules. In contrast, CBR requires time to search for relevant past cases and adapt them to the current problem. When it comes to handling uncertainty, CBR excels in adapting to uncertain variable problems. RBR, on the other hand, is less flexible and may struggle to effectively address such situations. In addition, the study stated interpretability as another aspect to consider. RBR is more interpretable than CBR since the rules used for decision-making are explicitly defined.

CBR, on the other hand, is less interpretable, as it relies on past cases that may not be directly related to the current problem. Furthermore, scalability is a consideration when dealing with large-scale problems. RBR may become less scalable as the number of rules and complexity of the problem increases. CBR, on the other hand, can be highly scalable, as it can effectively store and retrieve a large number of past cases.

2.9. Related Works

The field of healthcare has experienced significant advancements due to rapid technological progress. One notable development is the emergence of expert systems that aim to aid in the diagnosis and treatment of a wide range of diseases. These systems utilize knowledge-based approaches and incorporate medical expertise and decision-making algorithms to deliver accurate and efficient healthcare solutions. The advent of expert systems holds great potential in addressing the challenge of limited access to highly trained medical professionals, particularly in regions where skilled manpower is scarce. By leveraging the power of technology, these systems strive to bridge the gap and provide timely and precise disease diagnosis and treatment options.

One such study conducted by Oluwakemi et al. (2017) focused on creating an expert system specifically tailored for diagnosing and treating HIV/AIDS. The primary objective of this system was to address the challenge of limited access to highly trained medical professionals, particularly in regions where such expertise is scarce. By leveraging the power of knowledge sharing, the system aimed to improve healthcare outcomes and reduce mortality rates associated with HIV/AIDS.

In addition to diagnosing and treating HIV/AIDS, there have been notable endeavors to develop expert systems for HIV screening. Abdulsalami et al. (2015) and Afolabi & A.T (2017) conducted studies that explored the utilization of expert systems in the context of HIV screening. While the specific accuracy rates of these systems were not discussed, the studies indicated that the expert systems supported routine tasks related to HIV screening. This suggests that the systems could play a valuable role in streamlining and enhancing the efficiency of HIV screening processes.

By employing expert systems in the field of healthcare, researchers have sought to address the challenges associated with diagnosing and treating various diseases. Kontagora (2013) conducted a study that aimed to empower individuals to self-diagnose HIV/AIDS. This system was particularly focused on reducing stigmatization, discrimination, and suicide rates among Nigerian individuals living with HIV/AIDS.

Although the study did not include pre-test and post-test counseling services typically associated with HIV infection diagnosis, it recognized the importance of providing self-testing options to minimize the social stigma surrounding the disease. Expanding beyond HIV/AIDS, expert systems have also been developed for other diseases. For instance, Diriba et al. (2016) focused on the diagnosis and treatment of malaria. Their study highlighted the potential of expert systems to reduce both the time and cost associated with diagnosing and treating malaria, contributing to improved healthcare delivery in malaria-endemic regions.

Similarly, Lidya (2017) presented an expert system designed for tuberculosis diagnosis. The study emphasized the significance of knowledge exchange and learning opportunities between lung specialists and medical professionals. By providing clinical data processing, access, and storage facilities, the expert system aimed to enhance the efficiency and accuracy of TB diagnosis, ultimately benefiting both patients and healthcare providers.

Furthermore, Osamor (2014) developed an expert system for screening tuberculosis infection through the internet. This system employed a rule-based approach and unified modeling language to enable individuals without access to medical experts to assess their TB status. By offering online diagnosis systems, especially for health issues associated with discrimination and stigmatization, the study recognized the value of providing accessible and confidential diagnostic tools.

The development of expert systems extends to other diseases as well Choubey et al. (2017) focused on predicting diabetes at an early stage, achieving a high accuracy rate by utilizing a wide range of knowledge sources. Mohammed & Beshah (2018) developed a self-learning knowledge-based system for diagnosing and treating early-stage kidney disease. The system aimed to address the limited access to medical experts, particularly in regions with resource constraints. Similarly, Sanz et al. (2014) aimed to predict the risk of cardiovascular disease through a classifier that provided interpretable results for doctors.

Lastly, (Ghahazi et al., 2014) focused on developing a fuzzy rule-based expert system for the diagnosis of Multiple Sclerosis, an autoimmune disease affecting the myelin sheath.

The study acknowledged the complexities and uncertainties involved in diagnosing Multiple Sclerosis and incorporated fuzzy logic to handle these challenges. By creating an expert system that specifically addressed the uncertainties and vagueness encountered during the diagnostic process, the researchers aimed to assist both neurologists and non-neurologists.

These studies collectively highlighted the advancements in expert systems for disease diagnosis and treatment, emphasizing their potential to improve healthcare outcomes in areas with limited access to medical expertise. The use of various methodologies, including fuzzy logic and rule-based approaches, demonstrated the adaptability of these systems in handling uncertainties and complexities associated with disease diagnosis.

Table 2-1:Topical-Related Works

Source information	**Research objective**	**Problem or gap addressed**	**Findings and conclusions**	**Implications or suggestions for future research**	**How your research can fill the gap**
(Oluwakemi et al., 2017)	- To develop an ES for the diagnoses and management of HIV/AIDS patients	- Individuals remain unaware of their HIV status due to stigma and discrimination	- The system could diagnose patients and categorize them into clinical stages. - Provided personalized treatment recommendations		
(Abdulsalami. et al., 2015)	- To build an expert system for HIV screening	- Customers spend a lot of hours in hospital due to shortage of trained expert.	- rapid prognosis - reduces the hours patients spend in hospitals and boring routine tasks for HIV screening.	- A reporting tool to generate report of all the patients that have used the system	- Designing a data storage and accessing services

Source information	Research objective	Problem or gap addressed	Findings and conclusions	Future research directions	How your research can fill the gap
(Afolabi & A.T, 2017)	- To develop an expert system for HIV/AIDS diagnosis	- Doctors has not a quick reference when they diagnose for HIV infection.	- Able to assist Doctors and provide quality of medical care		- Designing a counseling guideline service
(Kontagora, 2013)	- Designing an ES for diagnosis and treatment of HIV/AIDS	- Individuals are not able to know their HIV status themselves in their home and convenient time	- Allowing non-medical personnel to handle some medical operation with ease.	- Pharmacy stores and testing materials should be available sufficiently in the market	- Implementing multiple modes of interaction for the user interface - Adding counseling and explanation services
(Diriba et al., 2016)	- To develop a KBS for diagnosis and treatment of malaria	- People in rural area is very affected by malaria due to scarcity of medical expert	- Able to give verification to medical expert for diagnosis and treatment of malaria	- Developing in local languages, good interface programming language	- Designing multimodal user interface

Source information	Research objective	Problem or gap addressed	Findings and conclusions	Future research directions	How your research can fill the gap
(Lidya, 2017)	- To develop ES for diagnosis of TB and Support Knowledge Sharing	- There is no knowledge sharing between lung specialists to general physicians or students	- provide facility to store, access, and supporting the complexity of TB diagnosis	- prototype development, including design and construction of every component is the future focus	- Developing multiple mode of user interface
(Osamor, 2014)	- To translate tuberculosis patients' symptomatic data for online pre-laboratory screening.	- People who do not have access to medical experts, are an able to know their TB status.	- An architecture for translating patients' information from the web for use in tuberculosis diagnosis is built		- Designing a data storage and accessing services

Source information	Research objective	Problem or gap addressed	Findings and conclusions	Future research directions	How your research can fill the gap
(Choubey et al., 2017)	- to develop an expert system that can predict diabetes at the early stages	- The absence of a system for early prediction of diabetes	- An ES that able to predict diabetes at early stages		
(Mohammed & Beshah, 2018)	- to develop a self-learning KBS for diagnosis and treatment of the first three stages of kidney disease	- Limited access to chronic kidney disease prevention - Lack of treatment options - Limited access to medical advice for experts	- built a KBS model that could diagnose, suggest treatment recommendations and support medical experts' decisions	Expansion of the system to cover advanced stages of kidney disease	

Source information	Research objective	Problem or gap addressed	Findings and conclusions	Future research directions	How your research can fill the gap
(Sanz et al., 2014)	- To develop a classifier that determines the risk of a cardiovascular disease within the next 10 years	- Lack of a classifier for determining the risk of cardiovascular disease	- A high-performance classifier model is built for determining the risks of cardiovascular disease		
(Ghahazi et al., 2014)	- To develop a fuzzy rule-based ES for the diagnosis of Multiple Sclerosis	- uncertainties and vagueness in the diagnosis process, while considering the person's identity, symptoms, and signs	- a fuzzy rule-based ES is built that could address uncertainties and vagueness in the diagnosis process.		

The research questions are thoroughly discussed in the body section of this chapter. Rule-based and case-based reasoning with semantic knowledge representation is the most common used approach for building a KBS. In addition, neural network and fuzzy logic based reasonings are usually used options for better performance and the treatment of ambiguous datasets, respectively.

According to various research, a mismatch between human expertise and logical thinking on a specific task and its modeling in an expert system raises the performance issue in a KBS system. In addition to that, the low attention given to human factors such as colors, ease of use, modes of interaction in the user interface have posed a major challenge to the acceptance and implementation of a KBS system. There is also the need for a security issue under KBS to ensure the confidentiality of patient's laboratory or clinical results. This issue directly relates to the stigma and discrimination available in the community.

In addition, KBS has to be developed by considering an enterprise architecture model that addresses the business process, data management, integration and interoperability with existing systems, and performance issues of a given model. Based on the literature review conducted, the researcher identified the following research gaps which motivated him to do this research. Firstly, in the diagnosis and treatment of HIV/AIDS, the provision of pre-test and post-test counseling services holds significant importance.

According to the guidelines set forth by the World Health Organization (WHO) and the Ethiopian national guidelines for HIV/AIDS prevention, care, and treatment services, counseling is a crucial component of the diagnostic process. This is particularly crucial for clients utilizing HIV self-testing, as it is essential to provide relevant information and ensure they are well-informed for a successful diagnosis and treatment journey.

Secondly, in the current working environment, the exchange of patient-specific data such as diagnoses and viral load test results between the VCT and ART departments is conducted manually. Consequently, the researcher is motivated to address these challenges, as there has been no prior work integrating intelligent counseling, data storage, and access services into a KBS model designed specifically for the diagnosis and treatment of HIV/AIDS.

CHAPTER THREE

3. METHODOLOGY

3.1. Introduction

In the previous chapter significant amount of topically related literature is discussed in detail. Whereas, this chapter presents the research design, knowledge acquisition, analysis, modeling, and representation methods used to develop the KBS model for HIV/AIDS diagnosis and treatment. In addition, the implementation tools and evaluation methods are discussed. A qualitative research approach and its knowledge acquisition methods such as face-to-face interviews, and literature analysis are used to gather the required knowledge. Moreover, content analysis and rule-based techniques are used for knowledge analysis and representation purposes respectively.

Typescript programming language along with the Angular web development framework is used to build the proposed KBS model under a web-based platform. In addition, NodeJS and JSON web servers are used to provide the web service for the building and testing phase. The performance evaluation of the developed model is conducted using Word Error Rate (WER), precision, recall, f-measure, and accuracy metrics. As well as a unit test and usability evaluations are conducted by developing specific testing cases.

3.2. Research Design

In order to tackle challenges in diagnosis and treatment and improve the quality of services the availability of specialized experts, the information needs for counseling, testing, treatment, and medical data storage and access are assessed. Additionally, the potential of KBS in disseminating information and assisting individuals in making informed decisions are also assessed. Limited access to specialized experts in underserved areas can hinder the ability of low-level or fresh service providers to obtain skilled insights. By implementing KBS, these experts can utilize the specialized experts' knowledge and experience to improve their service delivery. This is particularly valuable during diagnosis and treatment services, as the explaining ability of the system can support decision-making, build trust, and facilitate collaboration.

In addition, the absence of clients' medical data integrated across VCT and ART departments has its own challenges such as the risk of unsuccessful diagnosis, error making, and delayed treatment interventions. Thus, addressing these issues is essential for enhancing decision-making and improving the overall quality of diagnosis and treatment service delivery. Simultaneously, it is crucial to implement robust data privacy and security measures to protect patient information and maintain confidentiality. Another challenge lies in capturing tacit knowledge, which is often difficult but important for effective decision-making.

Furthermore, engaging experts in the system design processes can help integrate this valuable expertise, thereby enhancing the capabilities of KBS and improving decision-making outcomes. Therefore, designing a user-friendly interface that supports a natural way of communication with existing workflows is a vital issue. It ensures domain experts can accurately interpret and apply the recommendations provided by the KBS. By incorporating a user-centric design approach, the system becomes more intuitive and seamlessly integrated into experts' daily routines, ultimately improving the overall effectiveness and efficiency of diagnosis and treatment service delivery.

Thus, a qualitative research approach is followed for the methods and techniques used to gather, analyze, model, and represent the required knowledge for the study. The type of data gathered is the experience and knowledge of medical experts in providing testing, counseling, and treatment services for HIV/AIDS disease. The relevant data used to answer the research questions includes the reasoning skills of laboratory technicians in diagnosing HIV infection, physicians in clinical and psychological treatment, and patients' data storage and access trends. The knowledge acquisition process mainly focused on investigating the recurring structure of data or facts related to counseling, testing, treatment and data storage, and access to HIV/AIDS disease. These facts are constructed from medical experts and works of literature by using a qualitative research data collection method such as interviews and literature analysis.

3.2.1. Knowledge Acquisition Methods and Sampling Techniques

Knowledge acquisition from experts involves explicitly capturing and encoding their knowledge into the model, providing a solid foundation of human expertise. This is especially valuable in diagnosis and treatment tasks where expert knowledge plays a crucial role in accurate decision-making. Thus, the model can utilize the deep understanding and insights possessed by experts and enhances its ability to make informed decisions and handle complex situations effectively.

In the health sector, there may be cases where limited or no historical data is available. This makes knowledge acquisition from machine learning challenging to provide accurate decisions. However, knowledge acquisition from experts allows us to explicitly define rules or principles to handle these unique scenarios. Thus, the model becomes better ready to address complex and unfamiliar situations that may arise. Medical experts who possessed specialization, experience, and roles related to HIV/AIDS are the primary source of the knowledge gathered. Additionally, existing literature is used as a secondary source of knowledge.

By using the expertise of different professionals, a more comprehensive understanding of the problem could be achieved. The study employed a semi-structured face-to-face interview and documentation techniques for knowledge gathering. These techniques are employed to extract valuable insights and knowledge from experts and relevant literature to address the research questions effectively. In addition, the documentation method is used to consolidate ambiguous information gathered through interview.

The general study population for the primary source of data is a group of doctors, lab technicians, nurses, and health informatics experts whose educational background and experiences are related to HIV/AIDS diagnosis and treatment services in the Debre Tabor referral hospital. These medical experts are providing HIV testing services in different departments of the institution such as the Out Patient Department (OPD), In-Patient Department (IPD), Mother and Child Health (MCH), Voluntary Counselling and Testing (VCT), ART, and Youth.

Especially, the VCT and ART departments are dedicated to providing comprehensive services for HIV/AIDS, including counseling, testing, treatment, care, and follow-up. Other departments also offer HIV testing when necessary, and if HIV infection is confirmed, patients are referred to the specialized VCT and ART departments for further management. These departments offer counseling and testing services, manage patient data, and ensure continuous follow-up. The study selected its sample population from these departments due to their critical roles in providing counseling, testing, treatment, and managing patient data.

Thus, seven participants are selected from this department's staff with a purposive sampling technique. The selection is conducted based on their academic qualification, experiences, and the roles they have in counselling, testing, and treatment services. Five of them are qualified for the degree program and the two are at diploma level in their academic's accreditation. This sample population comprises four nurses working on voluntary counseling and testing, two HIT experts who are responsible for managing the SmartCare patient database system, and a medical doctor who is engaged in ART treatment and adherence counseling. Each of them is working on HIV/AIDS services for 8 to 15 years. Whereas, the selection criteria for the documents were focused on recent publications, documents from reputable sources, and those specifically addressing the implementation of KBS models in HIV/AIDS counseling, testing, and treatment.

By considering various sources of knowledge, involving multiple experts, and employing diverse knowledge acquisition techniques, the researcher aimed to enhance the comprehensiveness and reliability of the knowledge base obtained for the study. These measures were taken to address the limitations around the eliciting of tacit knowledge and ensure a deep understanding of the research questions under investigation.

- **Semi-structured interview:** The face-to-face semi-structured interview is one of the methods employed to collect qualitative data in this study. This method was chosen due to its ability to capture rich and in-depth insights from participants, allowing for a comprehensive exploration of their experiences and perspectives regarding HIV/AIDS counseling, testing, treatment services, and medical data storage and accessing trends. Open-ended questions were designed to explore key aspects of the research questions.

A total of, seven participants are involved in a face-to-face interview at their convenient time and place lasting for 20-30 minutes. Informed consent was obtained from all participants, ensuring they were aware of the purpose of the study, their rights, and the confidentiality of their responses. The researcher established an understanding with the participants before the interviews, creating a safe and open environment for discussion. Audio recordings were made with participants' consent to accurately capture their responses and ensure reliable data for later analysis. In addition, documentation is involved by taking detailed notes during the interviews to capture key points, non-verbal signs, and contextual information.

During the interviews, active listening techniques were employed to encourage participants to share their experiences and perspectives freely. Analytical questions were used to elicit further details and clarification when necessary. The semi-structured nature of the interviews allowed for flexibility, enabling participants to expand on relevant topics and express their thoughts in their own words.

- **Documentation:** It is used as the second knowledge acquisition method of the study. The documents utilized in this study included academic papers related to HIV/AIDS counseling services, HIV/AIDS prevention, care and treatment guideline, and patient records (Mall et al., 2013; MOH, 2018; Okech & Kimemia, 2012; Petersen et al., 2014). A systematic literature review was conducted by accessing digital databases such as Google Scholar and Scopus. The search terms used included HIV/AIDS counseling, HIV/AIDS testing, HIV/AIDS treatment, and knowledge-based systems.

  Filters were applied to include studies published within the last ten years and written in English. Additionally, Debre Tabor Referral Hospital was contacted to obtain access to recent guideline documents, manuals, and patient records. Relevant information related to counseling and testing practices, treatment, and data storage and access trends were extracted from these documents. Finally, the data gathered through interviews and literature analysis is further analyzed for the knowledge modeling purpose.

3.2.2. Knowledge Analysis Method

A content analysis technique is used to examine the contents, structure, and process involved in providing counseling, testing, treatment, and patient data storage and access trends. It allowed the analysis of extensive textual documents, and the exploration of subjective experiences, perspectives, or emotions of domain experts embedded within the data. The interview data collected through face-to-face semi-structured interviews were transcribed using Express Scribe tool. In addition, a comprehensive review and analysis of academic papers related to counseling, testing, and treatment services, in the context of HIV/AIDS are conducted. The gathered data through both techniques were analyzed with a content analysis technique by using Microsoft Office Excel and Word 2013.

The content analysis process involved several stages. Initially, familiarization with the data was achieved by thoroughly reading and reviewing the documentation texts and interview transcripts multiple times. This allowed for a deep understanding of the content and context of the data. Next, a set of codes or categories such as HIV/AIDS, counseling, testing, treatment, data storage, and access were established based on the research objectives. In addition, for the codes having distinct aspects, sets of subcodes were created for further detailed analysis under the category or main code. For instance, for the counseling code category, subcodes such as risk assessment, pre-test counseling, post-test counseling, and emotional support are created.

Subsequently, the task of assigning the relevant codes to segments or elements of the content is conducted. Once the coding process was completed, the coded data were, analyzed under each category, and relevant key information, facts, and relationships among them are identified. These sets of facts are later used to build the packages of knowledge base for the proposed KBS model. This methodological approach provided valuable insights into the research questions and ensured the credibility of the study’s findings. Below samples of codes and the analyzed content is presented in Table 3-1 as follows:

Table 3-1:Sample of analyzed data

Source	Main Code	Sub-Codes	Example Analyzed Content
Interview transcribe data, Counselling related articles, HIV/AIDS prevention, care and treatment guideline	Counseling	Risk Assessment	During the counseling session, the experts assessed the client's sexual history, and recent potential exposure to determine their risk of HIV.
		Pre-Test Counseling	The counselor discussed the importance of testing, explained the process, and ensured the client's understanding and consent before proceeding.
		Post-Test Counseling	Upon receiving a positive test result, the counselor provided emotional support, discussed treatment options.
		Emotional Support	The experts empathetically listened to the client's concerns about living with HIV and reassured them that emotional support would be available throughout their journey.
		Testing Methods	The counselor explained the rapid HIV testing procedure,
	Testing	Antiretroviral Therapy	The ART officer explained the prescribed antiretroviral medications, including dosage, possible side effects.
	Treatment	Psychosocial Support	The ART officer offered individual counseling sessions to address the client's emotional well-being, coping strategies, and connecting them to support groups.

Source	Main Code	Sub-Codes	Example Analyzed Content
Interview transcribe data, Counselling related articles, HIV/AIDS prevention, care and treatment guideline	Data Storage Systems	SmartCare HMIS	The healthcare facility implemented a system to store HIV/AIDS patient medical information electronically, allowing for easy access and retrieval.
		Data collection forms	data collection forms such as consent, test result, and profile registration forms are used to capture relevant information during patient encounters.
		Data entry processes and protocols	Trained data entry staff follow established protocols for entering patient data into the system.
	Data Access and Privacy	User authentication and access controls	Access to patient data is restricted through user authentication mechanisms, ensuring only authorized individuals can access the information.
		Role-based access permissions	Access privileges are assigned based on roles and responsibilities, limiting data access to only what is necessary for each individual.
		Report generation and dissemination	collected data is synthesized into comprehensive reports, which are then disseminated to regional and federal bodies for decision-making purposes.

3.2.3. Knowledge Modeling Method

The knowledge modeling task is conducted by organizing and structuring of knowledge gathered through interviews and documentation. It helps to create independent concepts such as test types, testing kits, laboratory results, and HIV status. A combination of these specific concepts builds a knowledge modeling package. This package was later used for conserving, refining, sharing, accumulating, and processing relevant concepts to model medical experts' intelligence. Thus, the study used a manual decision tree technique to formulate a decision-making process for a specific outcome such as HIV status, ART regimen type, viral load level, and treatment schedules.

It allows knowledge engineers to determine the relevant variables, conditions, and outcomes that should be included in the decision tree model manually. As a result, it grants them full control over its structure, conditions, and rules. This facilitates easier validation, explanation, and ease of understanding of the decision-making process. In addition, the manual decision tree technique enables customization to fit the specific requirements and constraints of the KBS. Since Knowledge Engineers have the flexibility to determine the decision nodes, conditions, and specific outcomes to include in the model, it ensures that the decision tree closely aligns with the needs and goals of the KBS.

Another advantage is the iterative knowledge modification and adaptation made possible by manual decision tree construction. As new data and insights become available, knowledge engineers can modify and update the decision tree accordingly. This iterative approach ensures that the knowledge model remains up-to-date and aligned with the evolving knowledge in the domain, leading to improved performance and accuracy of the KBS (Singh et al., 1999).

Architecture of the proposed model: According to the Ethiopian Ministry of Health (2018), HIV counseling and testing services are being provided with the consent of the client. So that a client who comes to testing centers like health stations and hospitals can receive counseling, testing, and treatment services after his or her name and medical record number are recorded. The proposed model was built based on the VCT and Treatment services as shown below in Figure 3-1.

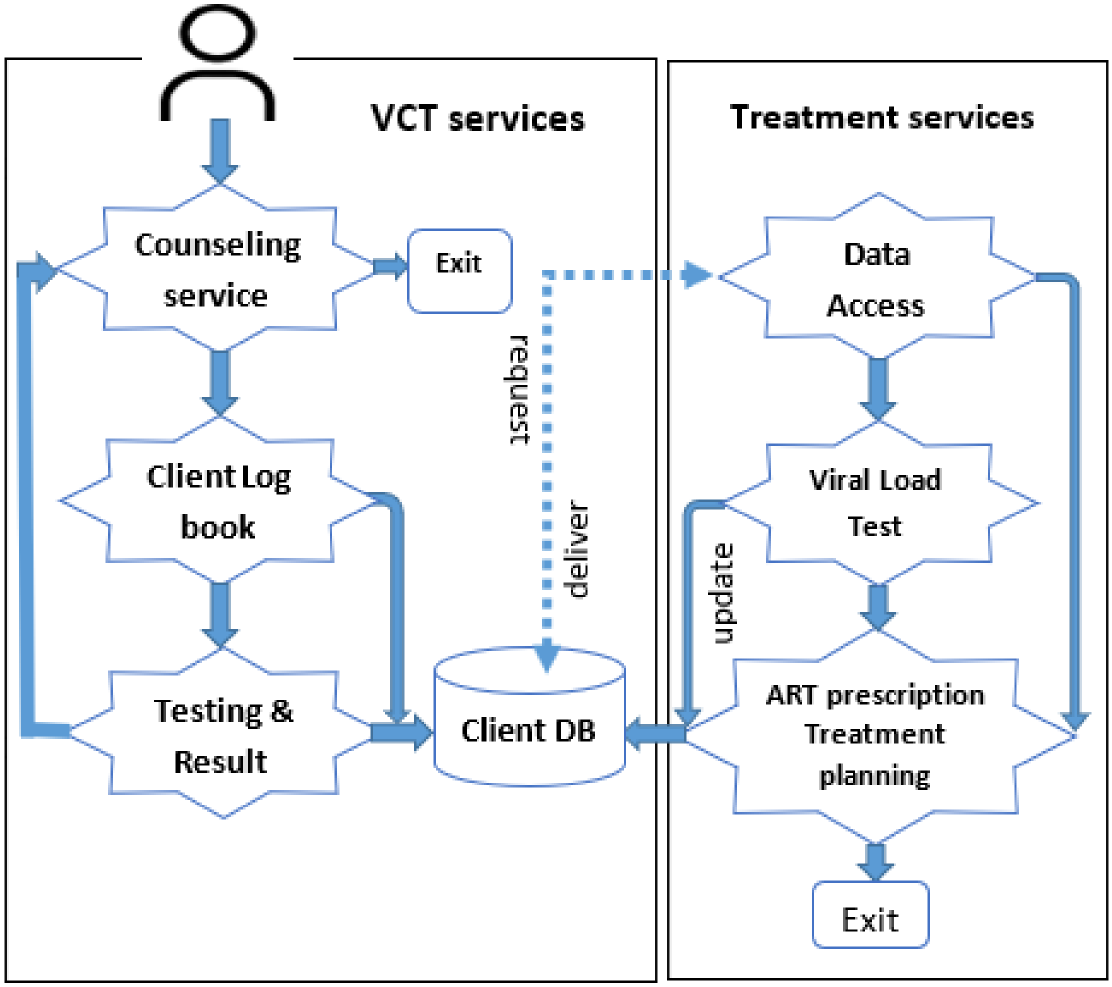

Figure 3-1:Architecture of the proposed model

- **Counseling service:** The decision tree model of counseling services for HIV/AIDS clients, as depicted in Fig 3.2, outlines the steps involved in determining the appropriate counseling service based on the user's profile and service request. The model began by identifying the user as a self-tester or a test provider expert. Once the user type is established, the system prompts the user to indicate whether counseling services are required or not. If the user had confirmed the need for counseling, the requested service is delivered accordingly.

However, in cases where counseling services were not required, the user is guided to the client information recording form, and continues recording the necessary information. Whether counseling was needed or not, the user has the choice to either out from the counseling service or continue with the testing service.

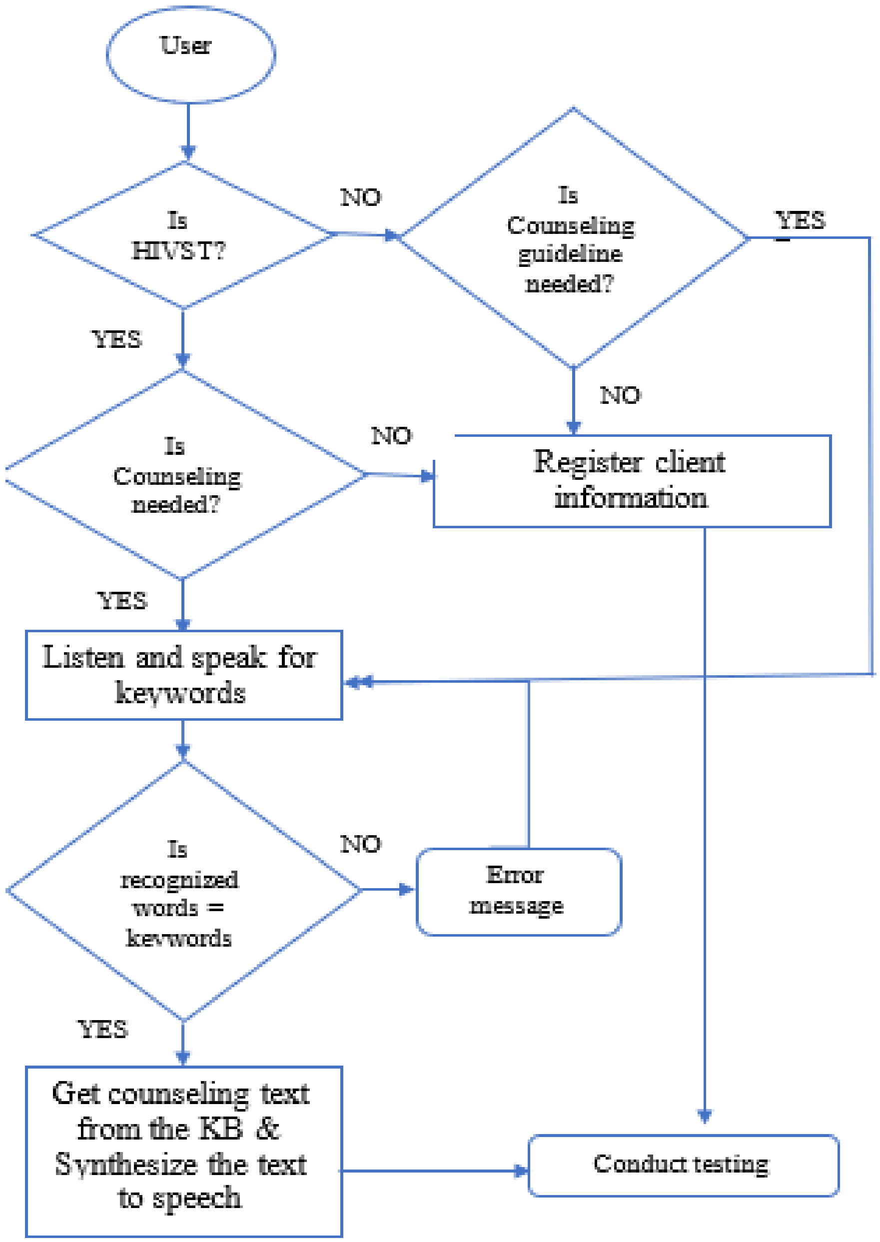

Figure 3-2: decision tree model of counseling services

- **Testing and results:** HIV testing can be conducted either by a trained medical expert or an individual. So that these services enable both types of testers to make an analysis of actual blood sample test results and identify HIV status. Once a client is ready to take a test it can be conducted with either of the two testers. Then the outcome should be explained anonymously with ensuring the individual's privacy.

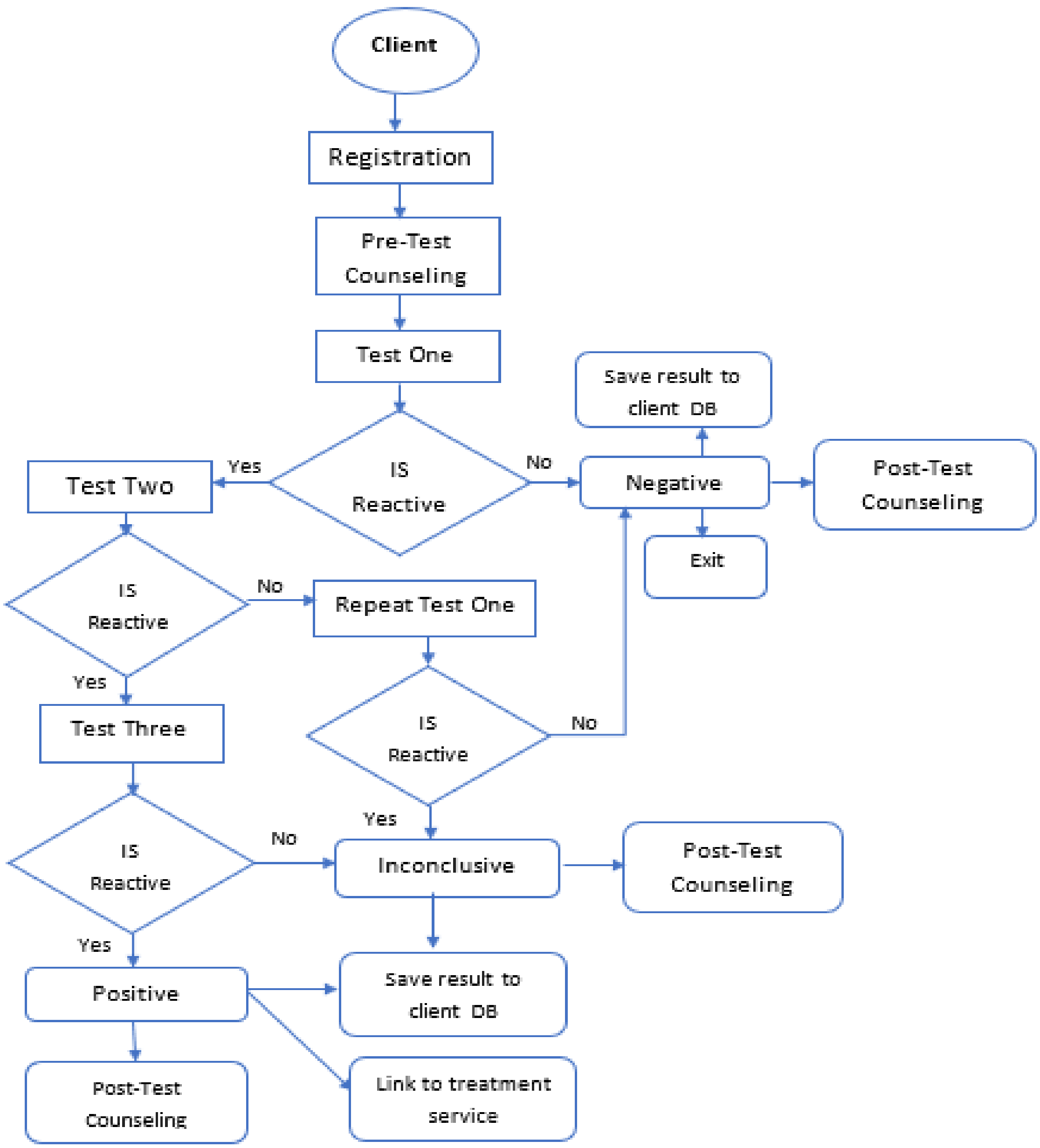

Figure 3-3: A decision tree model of testing service

- **Viral Load Testing, ART Prescription, and Treatment Planning Service:** Once patients are confirmed to have HIV positive, the next step is to link them to care and treatment services. In addition, monitoring patients receiving ART is important to ensure successful treatment, identify problems and determine the need of switching regimens. The developed model analyzed viral load counts and ART initiation dates to suggest ART prescriptions and schedule the treatment plans. For instance, patients were recommended to continue the first-line ART regimen if their ART initiation date matched the detection date, or if it was 6 months or 9 months before, and their viral load was less than or equal to 50 copies per micro-milliliter

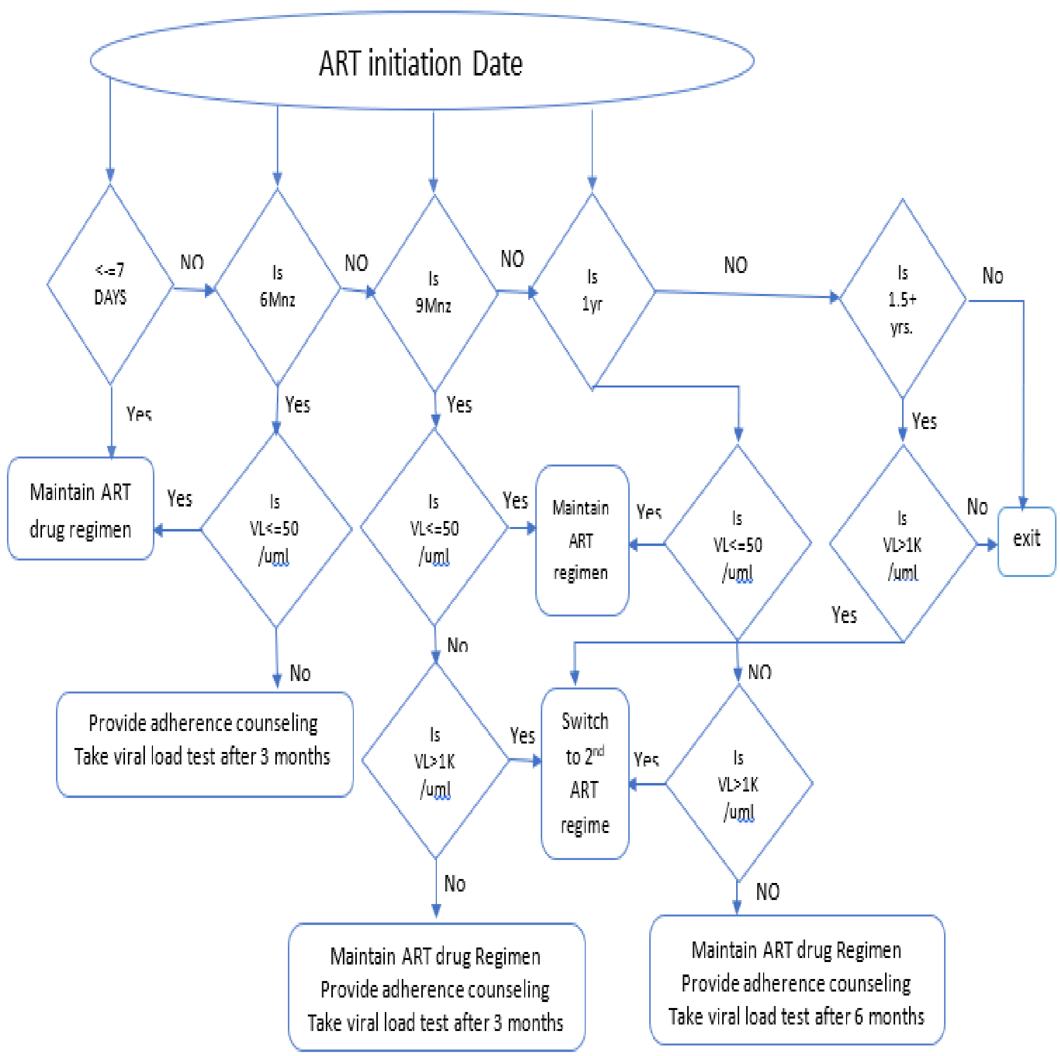

Figure 3-4: Decision tree model of treatment service

- **Data storage and access model:** A decision tree model of data storage and access services for HIV/AIDS disease clients is shown below in Figure 3-5. It stores clients' information and their HIV/AIDS diagnostic results in the database. Once the client was linked to treatment services, the model enabled users to search for confirmed HIV infection data from the database. If the diagnostic result returned positive, it allowed for the provision of treatment services. Otherwise, the system exited the current page and moved to the home page. Finally, the provided treatment services and appointment dates for the current client were updated in the client database.

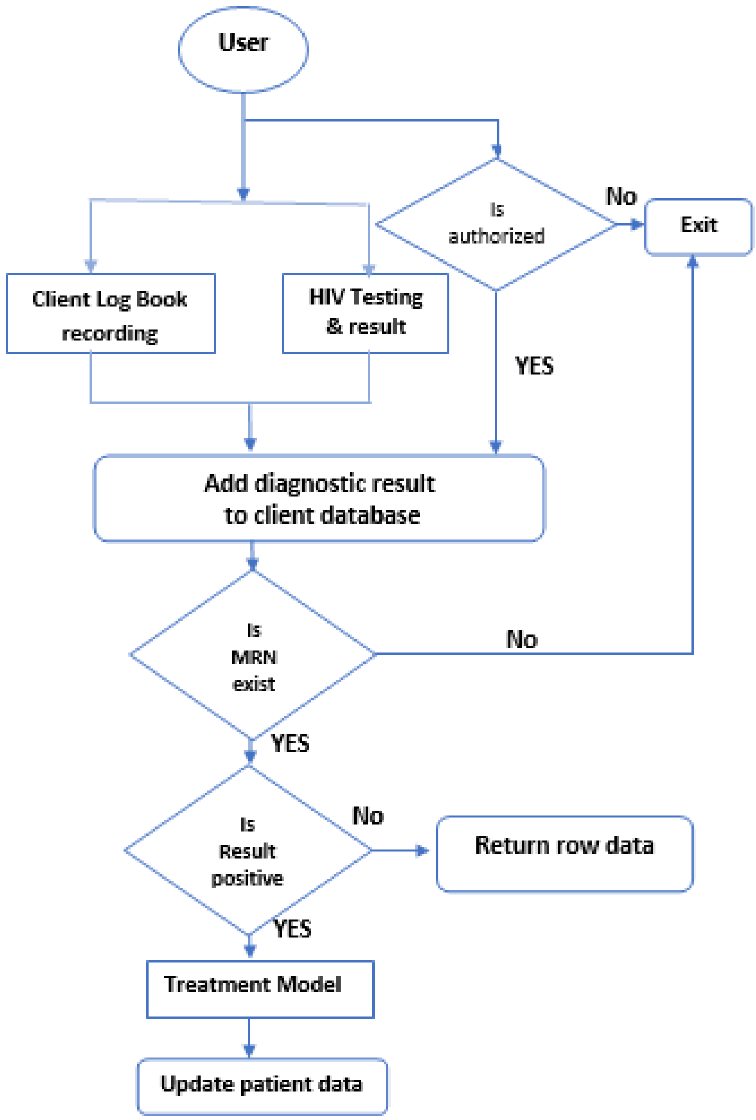

Figure 3-5: Decision tree model of data storage and access service

3.2.4. Knowledge Representation Method

Knowledge representation is one of the fundamental elements of the KBS development process. It is a process of translating acquired knowledge into a format that a computer can understand. The task of diagnosis and treatment of HIV/AIDS involves several determinant rules that govern the decision-making process. These rules play a crucial role in conveying relevant information, identifying HIV infection, and suggesting appropriate treatments. Thus, forward chaining reasoning technique is employed to evaluate these rules based on the current state of the knowledge base. By continuously examining the available data, the system can dynamically derive new information (Tan, 2017). This data-driven approach enables the system to respond on time to changes in the input data, ensuring that the knowledge representation remains up-to-date and relevant.

In addition, rather than conducting a comprehensive search throughout the entire knowledge base, it selectively applies rules based on the available data. This targeted evaluation enables the system to reach conclusions and make decisions quickly. This efficiency is especially advantageous in time-sensitive applications where prompt responses are required. Moreover, forward-chaining reasoning creates a traceable sequence of rule activations and derived conclusions. This traceability enhances the transparency of the system's reasoning process, enabling explanations and justifications for the derived outcomes.

Lastly, this technique enables the system to trigger appropriate actions or recommendations based on the derived knowledge and conclusions. This capability is particularly important in KBS applications where the system needs to support decision-making processes. When multiple rules are applied to a given situation, conflicts may arise due to conflicting conditions or actions. By defining a specific sequence for rule activation, consistent resolution of conflicts is ensured. Rules that are activated earlier in the sequence are given higher priority and are applied before rules are activated later. The order of the rules is conducted based on its relevance to the context of the proposed model. The fact base of the knowledge is organized in the form of JavaScript object notation format and the rule base is organized in the form of if-then rules as shown below.

Sample rules generated from the counselling decision tree model

Rule 1: If user is an HIV self-tester AND

If counseling service is demanded

then

Listen available counseling services and keywords

Speak for keywords

Rule 2: If user is an HIV self-tester AND

If counseling service is not demanded

then

Record clients log book

Navigate to testing model

Rule 3: If user is not an HIV self-tester AND

If counseling guideline service is demanded

then

Listen available counseling guideline services and keywords

Speak for keywords

Rule 4: If user is not an HIV self-tester AND

If counseling guideline service is not demanded

then

Record clients log book

Navigate to testing model

Rule 5: If recognized word is equal to keywords

then

Fetch counselling note from KB

Synthesize the counselling note to speech

Listen to the counselling speech

Sample rules generated from the testing decision tree model

Rule 1: If the Stack-Pack blood test result shows reactive AND

then

Give post-test counseling to the client

The diagnosis result is HIV Negative

Add test result to client database

Rule 2: If the Stack-Pack blood test result shows reactive AND

If the Abon blood test result shows reactive AND

If the SD-Violent blood test result shows reactive

then

Give post-test counseling to the client

The diagnosis result is HIV positive

Add test result to client database

Rule 3: If the Stack-Pack blood test result shows reactive AND

If the Abon blood test result shows Non-reactive AND

If the repeated Stack-Pack blood test result shows non-reactive

then

Give post-test counseling to the client

The diagnosis result is HIV Negative

Add test result to client database

Rule 4: If the Stack-Pack blood test result shows reactive AND

If the Abon blood test result shows Non-reactive AND

If the repeated Stack-Pack blood test result shows reactive

then

Give post-test counseling to the client

The diagnosis result is inconclusive

Add test result to client database

Sample rules generated from treatment decision tree model

Rule 1: If the ART initiation date is the same as the detection date

then

Maintain ART First-line regimen

schedule the next treatment plan six months later

update client database for the regimen type and treatment plan

Rule 2: If the ART initiation date is 6,9,12 or 18 months before AND

If the viral load count is less than or equal to 50 /uml

then

Maintain ART First-line regimen

Viral load level is suppressed

schedule the next treatment plan three months later

update client database for the regimen type, viral load level and treatment plan

Rule 3: If the ART initiation date is 6 months before OR

if initiation date is 9 months before AND ,9,12 or 18 months before

If the viral load is greater than 50 /uml and less than or equal to 1000/uml

then

Viral load label is not suppressed

Maintain ART First-line regimen

schedule the next treatment plan three months later

update client database for the viral load level, regimen type, and treatment plan

Rule 4: If the ART initiation date is 12 months before OR

If the ART initiation date is 18 and above months before AND

If the viral load is greater than 50 /uml and less than or equal to 1000/uml

then

Viral load label is not suppressed

Maintain ART First-line regimen

schedule the next treatment plan six months later

update client database for the viral load level, regimen type, and treatment plan

Sample rules generated from data storage and access decision tree model:

Rule 1: if user is authorized

then

grant access to client database

Search for MRN match

Rule 2: if clients MRN is empty

then

return message 'Enter searching MRN parameter'

Rule 3: if clients MRN is not empty AND

If MRN is exist in client database AND

If clients diagnostic result is positive

then

read client row data

pass MRN to treatment model

navigate to treatment model

update patient's treatment data

Rule 4: if user is not authorized

then

deny access to client database

Rule 5: if clients MRN is not empty AND

If searching MRN exists in client database AND

If clients diagnostic result is not positive

Then

Return row data for the searching MRN

return message 'Client's HIV infection status is not positive!'

Similar procedures have been used for all rules incorporated into the knowledge base. To summarize this section, the transformation process of the acquired knowledge from human experts and document analysis to conceptual modeling is helpful to produce a set of rules.

These sets of rules are used to represent the knowledge gathered for the task of counseling, testing, treatment planning, and data storage and accessing tasks. Once the relevant knowledge is acquired, it is represented in a computer-understandable manner to arrive at the expected goals. As a result, the developed KBS with rule-based reasoning approach is put into action by generating the aforementioned rules.

3.3. Development Tools

Typescript a superset of JavaScript programming language, is used to add dynamism and interactivity to the web pages. Angular 14.2, a JavaScript web framework, was chosen for its ability to create web pages in conjunction with HTML, especially suited for single-page applications with routing capabilities. Node.js, a backend framework, facilitated the management of development-related packages and provided a server-side environment for executing JavaScript code.

JSON server, built on top of Node.js, served as the web server for database interaction and web service provision. HTML was used to create the content and structure of the application, while Bootstrap, a language for describing web page appearance, ensured responsiveness across various devices. Visual Studio Code served as the code editor of choice, offering a comprehensive set of features for writing and editing code. Additionally, Mendeley v.1.19.18 and Microsoft Office Word 2016 were used for citation and writing research reports respectively throughout the development process.

3.4. Testing and Evaluation Methods

In this study performance and usability testing are conducted to evaluate the developed KBS model. Because performance test ensures that the KBS model meets the needs of the end users. Whereas, the usability test is used to identify the model's usability issues such as confusing navigation, inadequate error handling, inconsistent design, in efficient task completion, and long response time the users encountered during the interaction (Nagaraj et al., 2014). Word Error Rate (WER) evaluation metric is used to measure the performance of the counseling model. It is a commonly used evaluation metric in the field of speech recognition. It measures the accuracy of a speech recognition system by comparing the recognized words with the reference transcript.

WER calculates the percentage of words that are incorrectly recognized or substituted, deleted, or inserted by the speech recognition system. To compute WER, the total number of word errors is divided by the total number of words in the reference transcript. The resulting value represents the percentage of word errors in the recognized speech (Ali & Rentals, 2018). Lower WER values indicate higher accuracy and better performance of the system, while higher WER values indicate more errors and lower accuracy. On the other hand, precision, recall, f-measure, and accuracy evaluation metrics are used to assess the performance of testing and treatment service models. They provide relevant information about the effectiveness and correctness of the testing process. This is later used to improve the quality of the system and ensure that it meets the needs of end-users (Vos et al., 2012).

Precision is the ratio of correctly identified positive results to the total number of positive results identified by the testing process. if the precision is high, it means that the testing process accurately identified the defects. Otherwise, it indicates that the testing process is generating too many false positives. If the recall is high, it means that the testing process effectively identified all relevant defects. However, if the precision is low, it may indicate that the testing process is generating too many false positives, while a low recall may indicate that the testing process is missing relevant defects. It measures the accuracy of the positive predictions made by the testing process. It can be calculated as P=TP/(TP+FP).

The recall is the ratio of correctly identified positive results to the total number of actual positive results in the system. It measures the effectiveness of the testing process in identifying all the relevant defects. If the recall is high, it means that the testing process effectively identified all relevant defects. Otherwise, it indicates that the testing process is missing relevant defects. It can be calculated as R=TP/(TP+FN). F-measure is a harmonic mean of precision and recall. It provides a single value that represents both precision and recall, and it is calculated as the weighted average of precision and recall. It is a useful metric to evaluate the overall effectiveness of the testing process. It can be calculated as F=2*P*R/(P+R).

Accuracy measures the overall correctness of the testing process. It is the ratio of correctly identified results of precision and recall to the total number of test cases.

A high accuracy value indicates that the testing process is identifying both true positives and true negatives effectively. It can be calculated as:

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

In addition, to validate the data storage and access model unit testing is conducted by using the Jasmine testing framework with karma test runner to verify the correct data insertion, retrieval, updating, and deletion process is conducted successfully. Jasmine is a framework for testing JavaScript code, including Angular applications. It provides a syntax for writing test cases in a readable and expressive manner (Karma - Spectacular Test Runner for Javascript, n.d.).

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Introduction

In the previous chapter, the research approach, knowledge acquisition, sampling, modeling, and representation techniques used in the study were presented. In this chapter, findings of the research such as counseling, testing, treatment suggestion and data storage, and accessing services and their evaluation reports are discussed in detail. The proposed model is developed under a web-based platform that supports remote access to the system. It has three major sections which are the diagnosis, treatment, and client's data storage and accessing functionality sections.

The diagnosis section includes voluntary counseling and testing services, which are designed by modeling the human experts' HIV counseling and testing intelligence. The counseling services used a pretest and posttest counseling knowledge to model the service. This service is designed to be used by both an HIV self-tester and a trained expert to provide a better understanding of how to proceed HIV diagnosing process. Whereas the testing service used a lab orator sample blood test results to analyze and classify an HIV status as positive, negative, or inconclusive.

The treatment section includes viral load testing, ART prescription, and appointment date scheduling services. The viral load testing service uses the Ethiopian national viral load testing algorithm to label the amount of HIV in a sample of blood as suppressed or not suppressed. The ART regimen prescription services used the viral load test results as an input parameter and suggested ART regimen types.

Whereas the appointment scheduling service used an ART initiation and the current date as input parameter to schedule the next viral load testing date. The last one is the data storage and access section which is integrated with the diagnostic and treatment sections. In this section, a central database is used to store and provide access client wise medical data. Finally, the Word Error Rate (WER) accuracy of the counseling model is examined, for counseling model speech recognition capabilities.

Furthermore, the performance evaluation of the testing and treatment models is discussed, focusing on key metrics such as precision, recall, f-measure, and accuracy. These metrics provide insights into the models' ability to accurately diagnose and treat HIV/AIDS. Similarly, the unit test evaluation of the data storage and accessing model is presented, evaluating its functionality in terms of insertion, retrieval, updating, and deletion operations. This assessment ensures the proper functioning and efficiency of the data storage and accessing functionalities within the KBS. Additionally, the report highlights the user acceptance testing results for the proposed KBS model. This evaluation measures the system's overall acceptance and usability among users, including factors such as ease of use, user satisfaction, and system effectiveness.

4.2. Counseling Model

Counseling service is a critical component of the HIV diagnosis process. It provides clients with information, support, and guidance to make informed decisions about HIV testing and manage the psychological impact of HIV diagnosis. By reducing barriers to testing and improving access to counseling services, more individuals can receive timely HIV testing and care, which leads to better health outcomes and reduced HIV transmission. This service is designed for self-tester individuals and test-provider experts. It allowed providing self-tester users information about the testing process, HIV transmission, prevention, and risk reduction strategies in the pretest counseling session. This helps clients to understand the benefits of testing and make informed decisions about whether to get tested for HIV or not.

Whereas a post-test counseling session allowed to provide clients support and guidance information after receiving their test results. For those who tested negative, it could help to reinforce safe behavior and provide information about risk reduction strategies. For those who tested positive, it provided support for coping with the diagnosis, information about HIV treatment options, referrals to medical care, and emphasized the importance of follow-up. On the other hand, for a test-provider expert, it served as a guideline for providing quality counseling service for clients in pre and post-test counseling sessions. It enabled the expert to maintain a professional and ethical counseling practice. By adhering to these guidelines, counselors could help to build trust and establish a positive and productive healing relationship with their clients.

By incorporating these components, the counseling service enabled users to receive the necessary information, emotional support, guidance, and supporting resources for their overall well-being. The model employed a speech synthesis and recognition modality in addition to the graphical user interface. Users were first asked to identify themselves as either a self-tester or a test provider. As a specific counseling service is demanded by the user, it was delivered to the user in speech modality. Furthermore, users had the option to express their concerns using speech. Subsequently, the service recognized users' speech and provided appropriate responses. For example, samples of the knowledge base, rules, and HIV-self-tester user dialogues for pretest counseling service are presented as follows:

{
"questions": [{"questionText": "*Dear User, are you a trained expert for HIV testing?*",
"explanation":{"expText":"*It just to know if you are a trained expert...*"},
"response": [{"text": "*YES*"}, {"text": "*NO*"}]
},
{"questionText": "*Do you need a*",
"counseling":[{"serviceId":"*pre-test counseling service?*"},…],
"explanation":[{"expText":"*It is to know if you want to take a counseling service*"},…],
"response": [{"text": "*YES*"}, {"text": "*NO*"}]
},
{"questionText": "Good ! please wait for seconds. Service delivery is processing...",
"recognitionword": [{"metadata": "one"}, {"metadata": "two"}, {"metadata": " guideline one "},{"metadata": " guideline two "},{"metadata": "post one"}, {"metadata": "post two"}, {"metadata": "post alpha"}, {"metadata": "post beta"}, …],
"pretestcounseling":[{"serviceId":"I would like to take a moment to introduce you to some of the services that are available to you related to HIV testing, …."},…],
"posttestcounselingpositive":[{ "serviceId":"Thank You! I have learned that your diagnostic result is HIV positive…" },…],
"posttestcounselingnegative":[{ "serviceId":"This is a post test counseling service for HIV negative result. Please speak post alpha, for risk reduction plan and. speak, post beta, to get HIV prevention informations",…},,…]
}}

Sample rules used for HIV self-tester counselling service

```
public currentQuestion: number = 0; //the index of the questions array
public serviceno: number = 0;  //the index of the counselling service array
public note:     string=’’;  //counselling note definition
private recognition = new webkitSpeechRecognition(); //Web speech API

answer( response: any) { //function for counselling service
setTimeout(() => { if(this.currentQuestion===0 && response.text==='NO') //rule-1
{this.currentQuestion=0;}
this.currentQuestion++;
},400)
if(this.serviceno===0 && this.currentQuestion===1 && response.text==='YES') //rule-2
{this.router.navigate(['/pretestcounselingforhivst']);
}
this.recognition.onresult = (event:any) => {  //function for speech recognition
const results = event.results;
const transcript = results[0][0].transcript;
if (transcript.includes('one'))  //rule-3
{
this.note= this.getNotes( 2, 1);
setTimeout(()=>{
this.say(this.note);},500)
this.stopRecognition();
}}};
```

Based on the above knowledge base, the TypeScript compiler evaluated the first rule to determine if the user was either a self-tester or a trained expert. It is used to identify the type of service to be delivered.

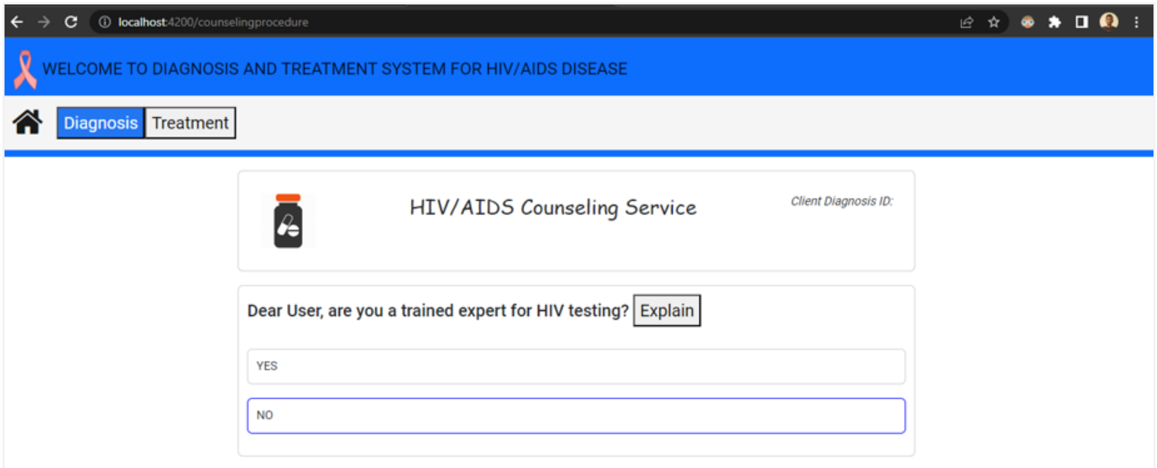

Figure 4-1:counselling model user interaction-1

The user responded as "**NO**" for the above query, indicating that the user belonged to the self-tester category. The compiler proceeded to evaluate the second rule to determine if the user demanded a pre-test counseling service or not.

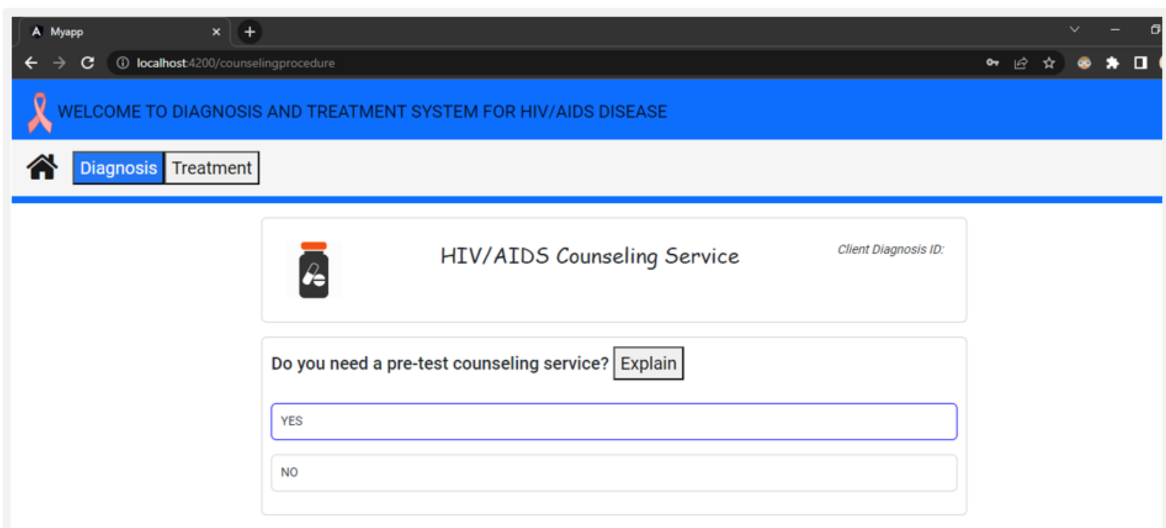

Figure 4-2:Counselling Model User Interaction-2

The user responded as "**YES**," as shown in figure 4-2 above, and a pretest counseling service page was asserted as shown below in Figure 4-3.

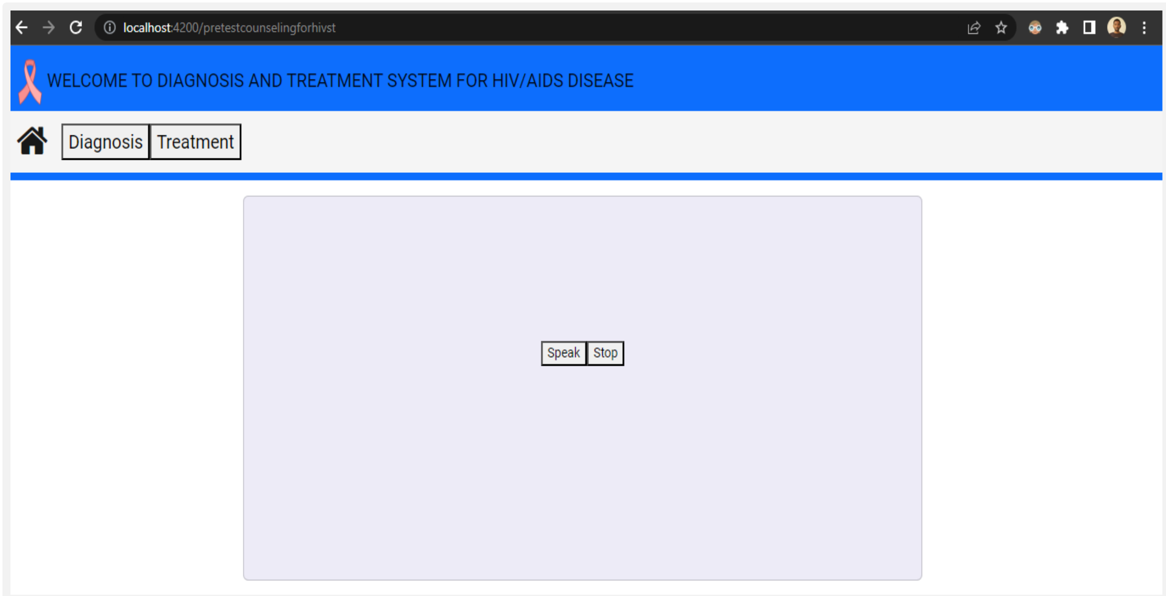

Figure 4-3:COunselling Model User Interaction-3

Finally, the third rule was initiated to introduce the type of service that was going to be delivered and the associated keywords that the user had to speak for specific concerns. For example, according to the aforementioned rule, if the user wanted to know about the testing process that would be conducted, they had to speak the meta word 'one' which represented the counseling note for the test process. Then, the service recognized the spoken word and passed the counseling note to the speak function. Subsequently, other meta words for further counseling services were provided, and the user continued the process of speaking and listening.

4.3. Testing Model

HIV/AIDS testing service is essential in the fight against the HIV/AIDS epidemic. Early detection, prevention, and treatment of HIV are critical in controlling the spread of the virus and reducing the number of new infections. Because people who are aware of their HIV status are more likely to take steps to protect themselves and their partners. Testing services can also help reduce stigma and improve access to care for those who are infected. This model was designed to simulate HIV infection diagnosis for adults and children above five years old. It analyzed subsequent blood sample test results and provided the HIV status of clients as positive, negative, or inconclusive.

Three types of testing kits, namely Stack-Pack, Abon, and SD-Bioline, were utilized to determine the result of each blood sample test. Furthermore, a national working diagnosis procedure, approved by the Ethiopian Ministry of Health, was followed to determine each subsequent test and the final diagnostic results.

When the diagnostic result indicated a positive outcome, it implied that the individual had tested positive for HIV antibodies, indicating an HIV infection. In such instances, if left untreated, the person might progress to develop AIDS. Conversely, a negative diagnostic result indicated the absence of HIV antibodies, suggesting no HIV infection. Nonetheless, it is important to note that diagnostic results could occasionally be inconclusive, meaning that the status could not be definitively determined at that particular time. As for the sample of the knowledge base, rules, and user interface, it is presented as follows:

Sample of testing fact base


```
{
"questions": [{"questionText": "What is the  result of ",
"test":[ {"testKit":"first STACK-PACK blood test ?"},
          {" testKit ":"ABON blood test ?"},
          {" testKit ":"ABON blood test ?"},…],
"explanation":[{"expTextId":"it is to know the result of.."},
                {"expTextId":"exptext"},…],
"response": [{"text": "REACTIVE"},
             {"text": "NON-REACTIVE"} ]
},
{"questionText": "Client's HIV infection diagnostic result is: ",
"hivStatus":[ {"status":"Positive"},
              {"status":"Negative"},…],
"explanation":[{"expText":"please explain this"},
               {"expText":"Explain"},…]
}
}
```

Sample rules used for HIV positive result

```
public currentQuestion: number = 0; //index of questions array

public tkno: number = 0; //index of testKit array

public hivstatusid: number = 0; //index of hivstatusId array

public textExpId: number = 0; //index of explanation array

answer (option: any) {  // function of diagnosis
setTimeout(() =>
{
this.tkno++;
this.textExpId++;
}
},400);
Rule-1: if (this.tkno ===0 && option.text==='REACTIVE'){
this.currentQuestion=0;
}
Rule-2: if (this.tkno ===1 && option.text==='REACTIVE'){
this.currentQuestion=0;
}
Rule-3: if (this.tkno ===2 && option.text==='REACTIVE'){
this.currentQuestion=1;
this.hivstatusid=0;
this.expTextId=this.hivstatusid;
setTimeout(()=>{
this.updateClients(); },1000);
}}
```

Based on the above sample knowledge base, each rule is evaluated in every execution of the function. In addition, the **tkno** is incremented as the function is executed. Thus, in the first execution of the function, **Rule-1** is e selected and evaluated for the first Stack-pack blood test result. The user responded as **Reactive, tkno** became 1, and the query continued as shown below in Figure 4-4..

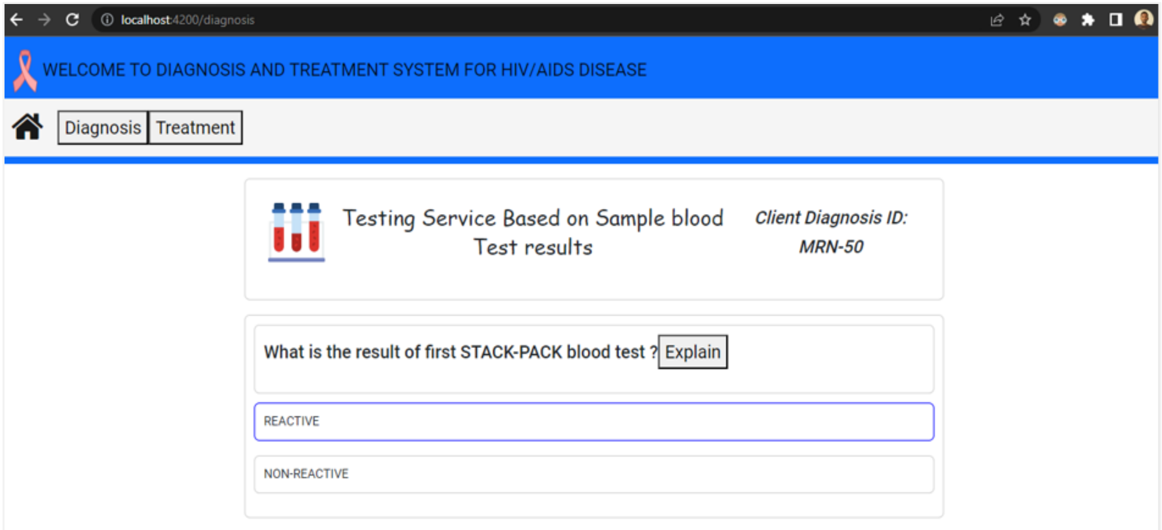

Figure 4-4:Testing Model User interface-1

In the second session of function execution **rule-2** is selected and evaluated for the Abon blood test result. The user responded as **REACTIVE, tkno** became 2, and the query continued as shown below in Figure 4-5.

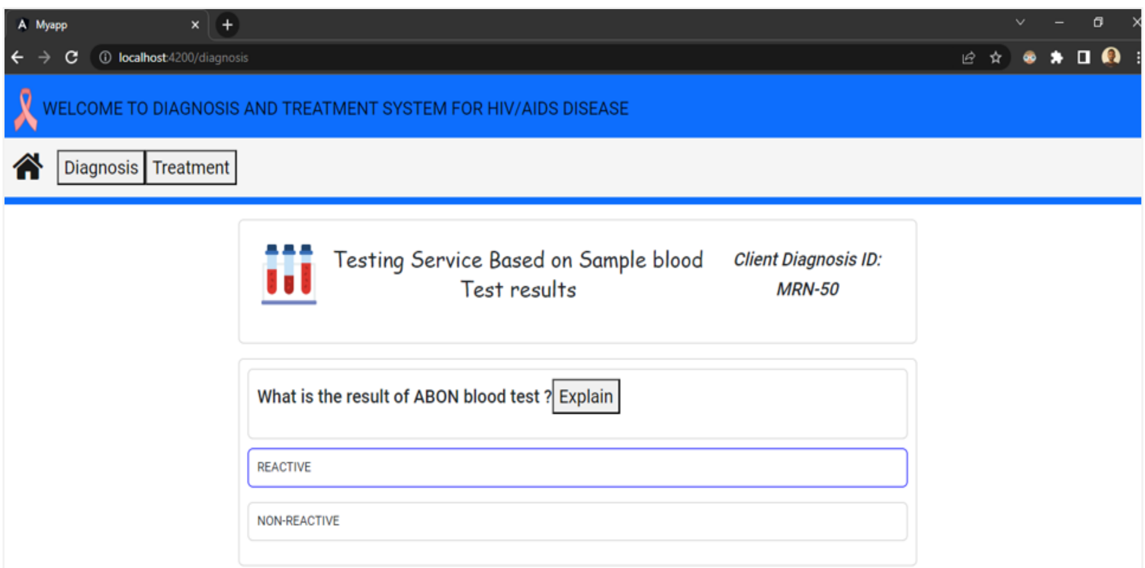

Figure 4-5:Testing Model User Interface-2

In the third session of function execution **rule-3** is selected and evaluated for the SD-Bioline blood test result. The user responded as **REACTIVE, tkno** became 3, and the query continued as shown below in Figure 4-5.

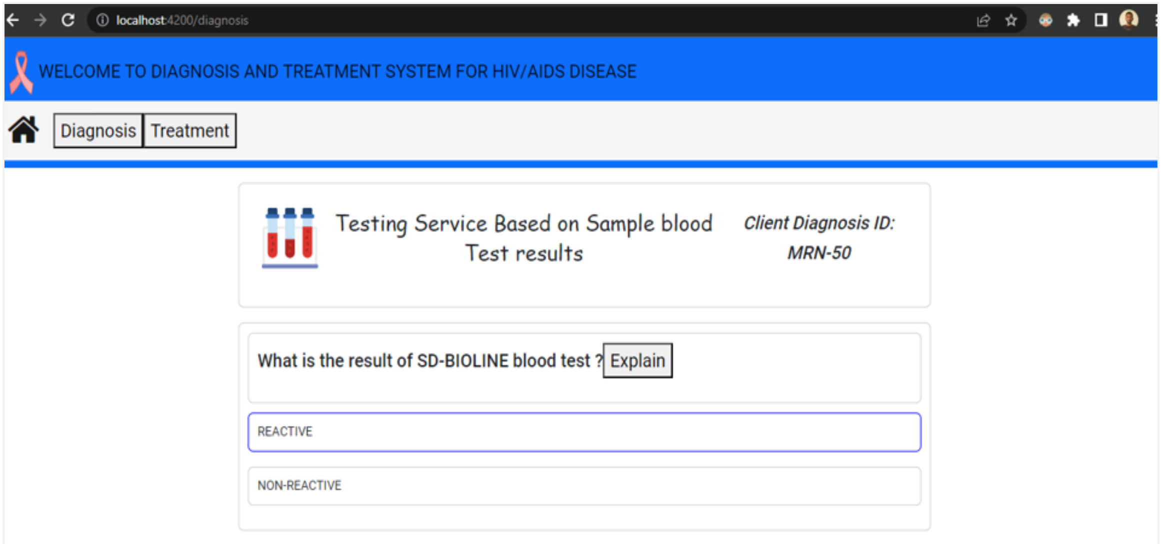

Figure 4-6:Testing Model User Interface-3

Finally, a conclusion for HIV status as Positive is drawn as shown below in Figure 4-7.

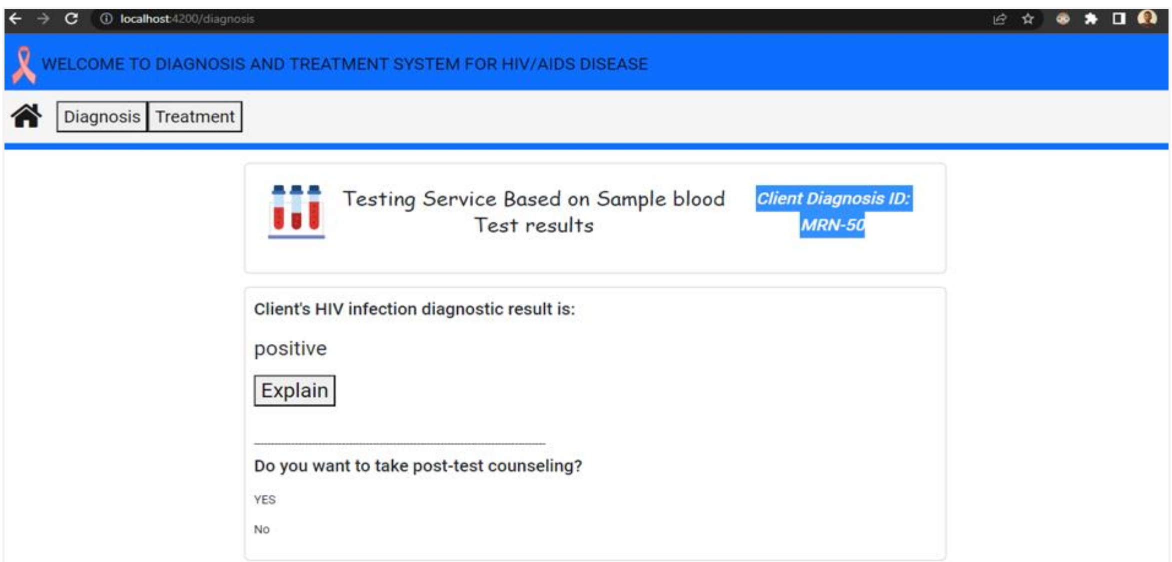

Figure 4-7:Testing Model User Interaction -4

Simultaneously, the service offered an explanation feature for each query stored in the working memory and conclusions derived from them. The explanation text was accessed using the corresponding explanation text index **expTextId**. It provided explanations for "how" and "why" questions when prompted by the user for all queries and derived conclusions. This feature was presented through the synthesis of explanation text into speech.

4.4. Treatment Model

HIV/AIDS treatment services are critical in controlling the HIV/AIDS disease. The provision of these services plays a vital role in reducing the transmission of HIV, improving the health of people living with HIV/AIDS, and reducing the number of AIDS-related deaths. By suppressing the virus in people living with HIV/AIDS, it can reduce the transmission of the disease. When the virus is suppressed to undetectable levels through ART, it is much less likely to be transmitted to another person. This in turn slows down the progression of the disease. This service is used to suggest an appropriate ART regimen and schedule treatment plans.

This model was designed based on test and ART initiation date and viral load count parameters. Initially, ART first-line regimen should be started as soon as possible after an HIV diagnosis is conducted. This is done regardless of the viral load count, to help prevent disease progression and transmission. However, viral load testing is important in determining the effectiveness of ART and adjusting the treatment plan as needed. For example, the sample knowledge base and user interaction are presented as follows:


```
{
"questions": [{"questionText": "Is the patient ART initiation Date: ",
                "duration":[{"dur":"<=7 days ago?"},{"dur":"6 months ago?"}, …],
                "response": [{"text": "YES"}, {"text": "NO "} ]
},
{"questionText": "Is patients Viral load count: ",
                "viralLoadCount":[{"vlc":"<=50?"}, {"vlc":"50<VLC<=1000?"}, …],
                "response": [{"text": "YES"}, {"text": "NO "} ]  },
{"questionText": "Patients viral load count is:  ",
         "viralLoadLabel":[{"vll":"Suppressed"}, {"vll":"Not suppressed"},…]
},
{"questionText": "Your patient is recommended to take:",
        "recommendation":[{"therapyid":"Maintain first line ART regimen"},
                          {"therapyid":"Maintain second line ART regimen"},…],}
}
```

Sample rules used for ART prescription, viral load leveling and treatment planning for 6 months since ART is initiated.

```
public currentQuestion: number = 0;
  public vlcid: number = 0;
  public durid: number = 0;
answer (currentQno: number, option: any)
{
setTimeout(() => {
Rule-1: if (this.currentQuestion===1&&this.vlcid ===0 && option.text==='YES'){
this.currentQuestion=3;
this.vlcid=-1;
this.appointment=this.sixmonthSchedule()
setTimeout(()=>{this.updateClients();},1000)
};
this.durid++;  this.vlcid++ ;}, 400) ;
Rule-2: if (this.currentQuestion===0&&this.durid ===0 && option.text==='YES'){
this.currentQuestion=3;
this.vlcid-=1;
this.appointment=this.threemonthSchedule()
setTimeout(()=>{this.updateClients();},1000)
};
Rule-3: if (this.currentQuestion===0&&this.durid ===1 && option.text==='YES'){
this.currentQuestion=1;
this.vlcid-=2;};};
```

The TypeScript compiler evaluated each rule by deducing from the provided fact base. For instance, during the initial execution of the answer function, **Rule-2** was evaluated if the ART initiation was conducted in the last 7 days.

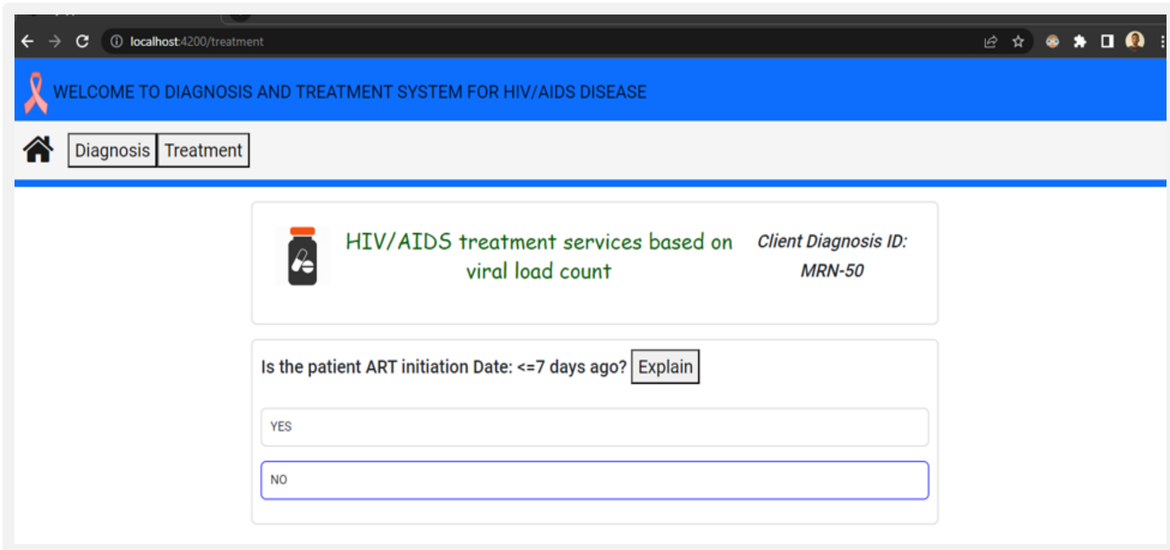

Figure 4-8: Treatment Model User Interface-1

However, the user responded as "**NO**" as shown in Figure 4-8 above. Consequently, **Rule-3** was evaluated if the ART initiation was conducted within the last six months and the user responds as **YES**, as shown below in Figure 4-9.

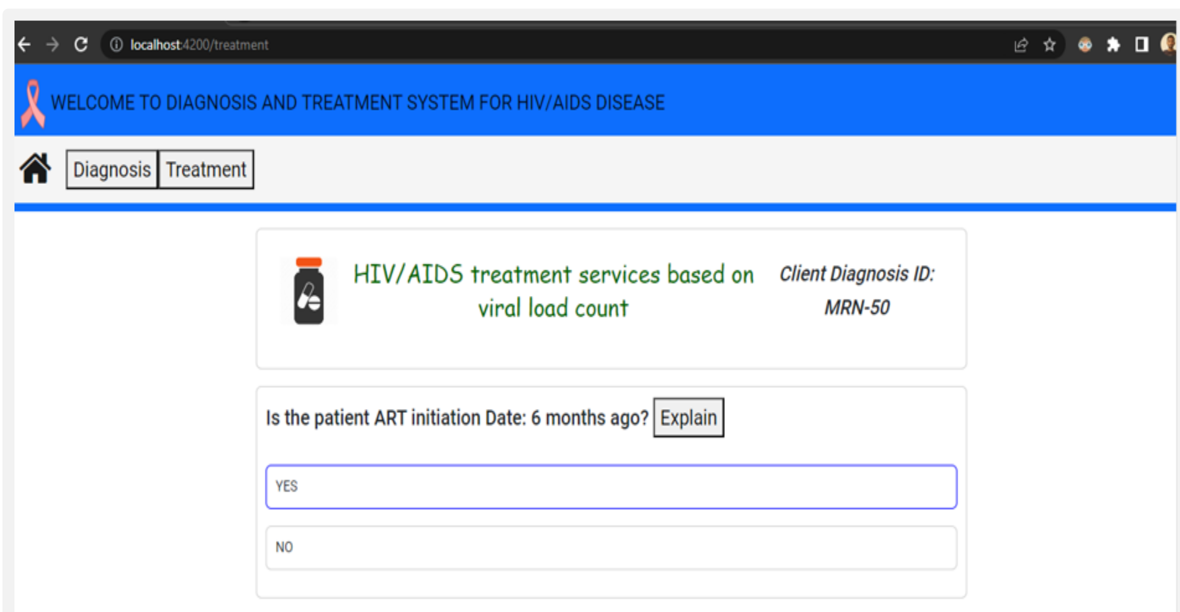

Figure 4-9:Treatment Model User Interface-2

The interaction continued and **Rule-1** is evaluated if the viral load count is less than or equal to 50 and the user responded as "**YES**" for it as shown below in Figure 4-10.

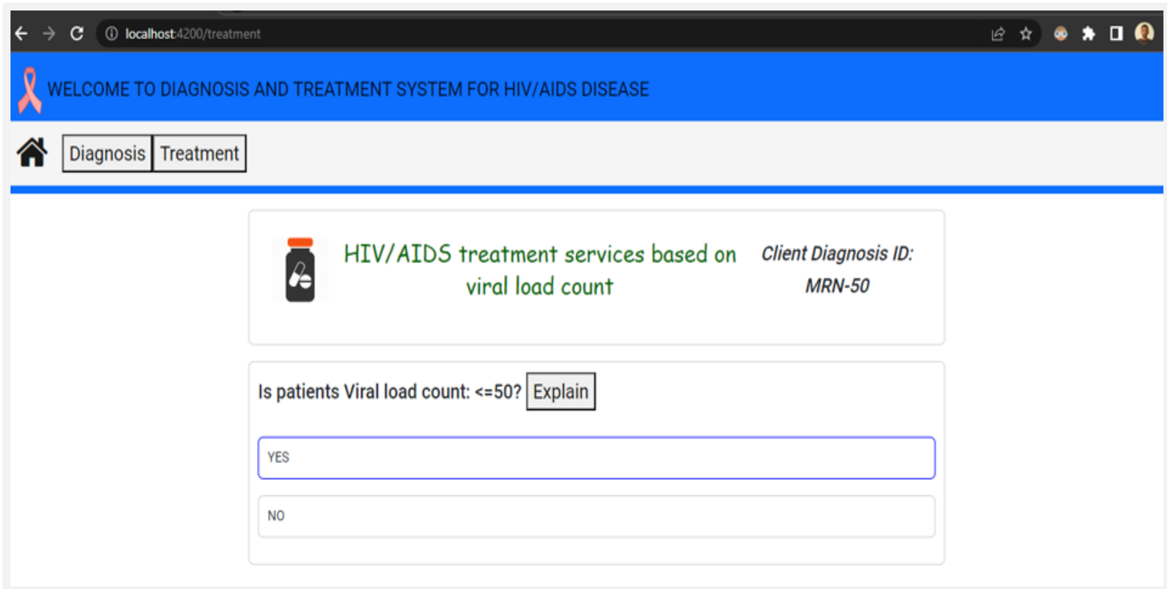

Figure 4-10:Treatment Model User Interface-3

Finally, the first rule reached to a conclusion for treatment recommendation, viral load leveling and scheduling treatment plan. as depicted in Figure 4-11.

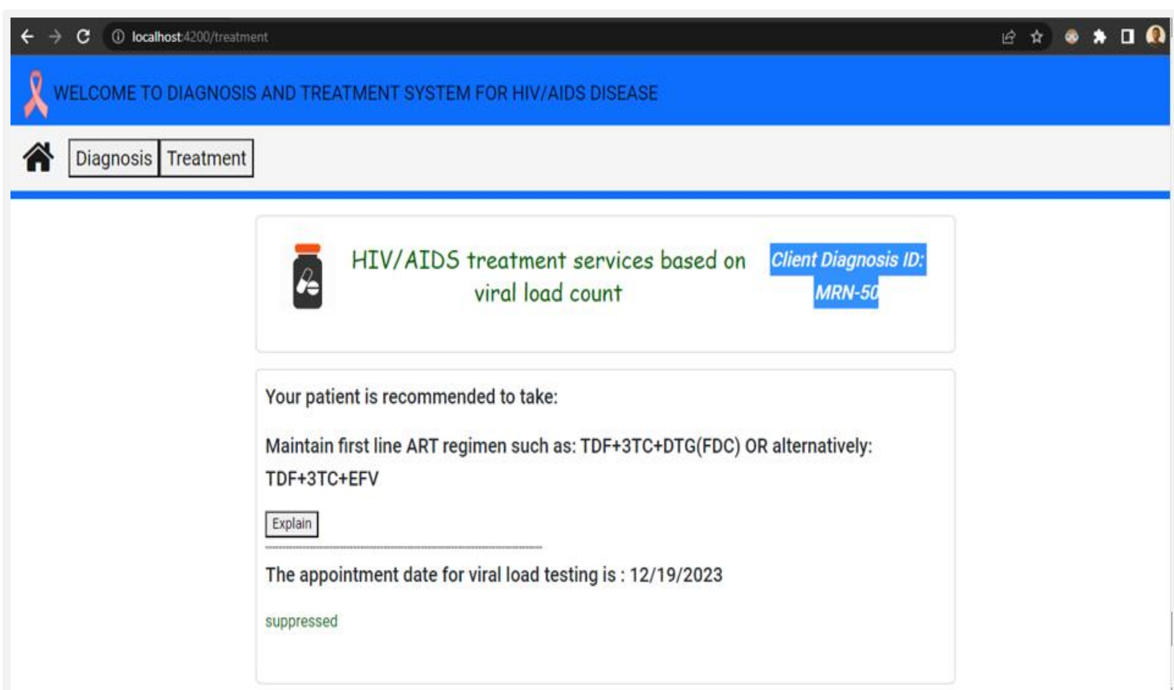

Figure 4-11:Treatment Model User Interface-4

4.5. Data Storage and Access Model

The use of medical data in the diagnosis and treatment of HIV/AIDS services is significant for reducing error-making and identifying trends, patterns of HIV distribution, and high-risk populations. The data storage and access model allowed users to register clients' MRN, first name, middle name, and diagnostic results in the diagnosis process. Likewise, it facilitated access control functionalities for the patient database, enabling users to update the patient's viral load label, ART regimen, and treatment plan during the treatment task.

The model implementation is integrated with the diagnosis and treatment models. As a result, the access control functionality allowed VCT and ART officers to work together in diagnosing and treating HIV/AIDS clients. This in turn helped them to identify patients at risk of treatment failure, intervene early, optimize treatment, monitor disease progression, and evaluate the effectiveness of treatment over time. Samples of fact and rule base and the user interface used for this model are shown as follows:

```
{
"clients" :  [{
"fname" :    " ",
"mname" :  " ",
"MRN" :     "  ",
"result" :     " ",
"viralloadcount" :  " ",
"treatment" :  " ",
"AppointmentDate" :  " ",
}]}
```

```
{
"users": [
{"name": "admin", "password": "admin"},
{"name": "user",     "password": "user"},…
]
```

Sample rules used for storing and accessing client data to and from the database

Rule-1: If (this.tkno ===2 && option.text==='REACTIVE'){

this.hivstatusid=0;

this.expTextId=this.hivstatusid;

setTimeout(()=>{

this.updateClients(); },1000);

}}

Rule-2: If (this.username===data.users.name && this password==data.users.password){

this.router.navigate(['/search]);

}

Rule-3:if (data.result.includes('positive')){

this.router.navigate(['/treatment']);}

Based on the aforementioned sample knowledge base, Rule-1 was found from the testing model. Once it is fired, it drew a conclusion and asserted the HIV status as Positive, as shown in Figure 4-7 above. Simultaneously, it has invoked the updateClients function to store the current client's diagnostic result in the database, as shown below in Figure 4-12.

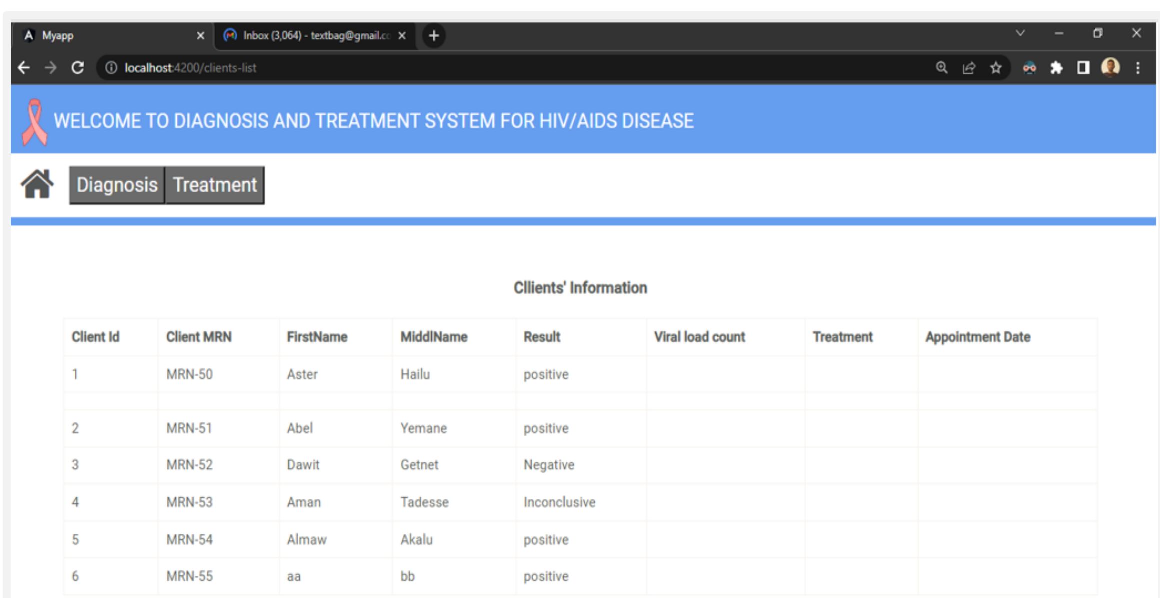

Figure 4-12: Data Storage User Interface-1

When the user tried to access the patient database for treatment purposes, **Rule-2** was selected to authenticate the user. It was evaluated to determine whether the username and password entered by the user were valid or not, as shown below in Figure 4-13.

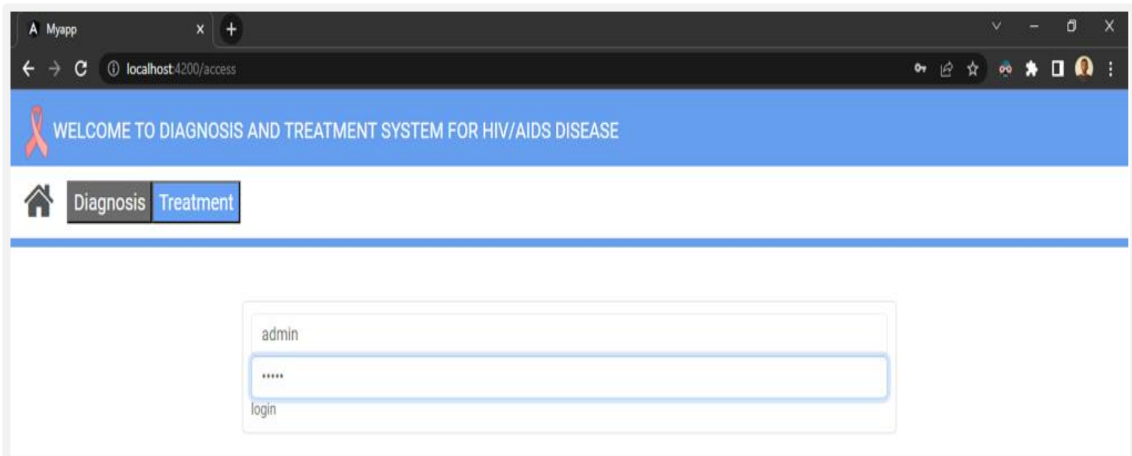

Figure 4-13:Data accessing user interface-2

As the user entered username ‘**admin**’ and password ‘**admin**’ the user got access to the database and proceeded to retrieve patient’s data based on their MRN, as shown below in Figure 4-14.

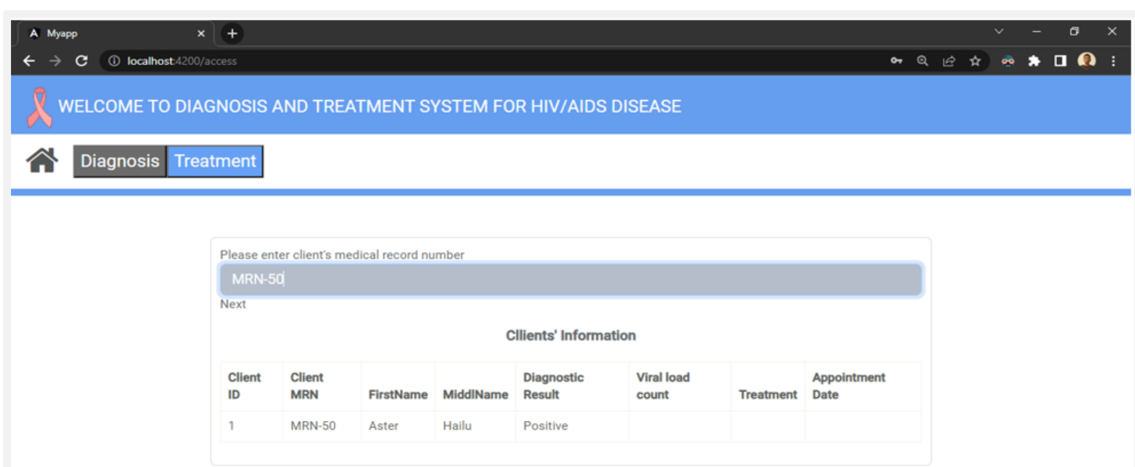

Figure 4-14:Data accessing user interface-3

The search result for **MRN-50** indicated a **positive** diagnosis result. Consequently, **Rule 3** was fired, asserting the treatment service model, and initiating the analysis of user responses for subsequent queries.

Once the treatment model reached a conclusion, as shown in Figure 4-11 above, the client database was updated with the patient's ART regimen, viral load level, and treatment plan, as illustrated below in Figure 4-15.

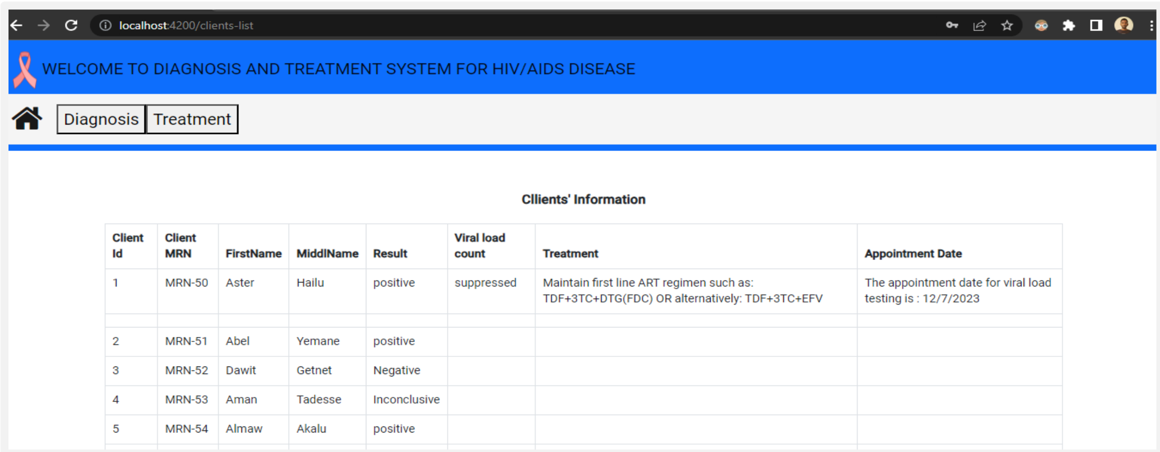

Figure 4-15:Data accessing user interface-4

4.6. Performance Evaluation of the Proposed KBS Model

In this section, an evaluation of the proposed KBS model is presented. The counseling service model is evaluated using a simulated speech data set generated by text-to-speech service. The Word Error Rate (WER) metric is used to evaluate the performance of the model. It is used to measure the percentage of incorrectly recognized words and characters in a given speech recognition event.

On the other hand, the performance of the testing and treatment service models are evaluated in terms of precision, recall, F-measure, and accuracy metrics. The primary objective of these evaluations is to determine the effectiveness of the models in accurately diagnosing and suggesting appropriate treatments for HIV/AIDS. The evaluation helped to identify shortcomings of the model and provided insight into areas that need improvement.

Furthermore, the functionality of the data storage and accessing model is evaluated using Jasmine angular testing framework and karma test runner. The objective of this test is to ensure that this model works as expected and meets user requirements. It is evaluated if the database insertion, appropriate retrieval updating, and deletion operations are successfully conducted or not.

4.6.1. Counseling Model Evaluation

This evaluation aims to measure the speech recognition performance of the model. The objective was to assess the system's accuracy in converting recognized short conversational speech into written text. Test audio dataset was collected from on-the-fly records using a text-to-speech tool and conducted on a laptop computer with an Intel Core i5 processor and 8GB of RAM. it comprised a total of 5000 speech words recorded in 5 voice models.

The recorded audio covered speech in the English language and involved the utilization of five distinct voice models specific to the Google Chrome browser. These models include Google UK English Male, Google UK English Female, Google US English, Microsoft David - English, and Microsoft Mark - English (United States). All recordings were captured through laptop speakers, in a common environment such as a working office and living room background noises.

Finally, the audio dataset was carefully transcribed to text using speech-to-text service and compared to the original reference text for evaluation. WER is the metric used to measure the percentage of incorrect words in the recognized output. It is calculated as WER = (Substitutions + Insertions + Deletions) / Total number of words in the reference * 100. According to the test result shown below in Table 4-1, the counseling model achieved an average WER of 11.57% on the test dataset.

Table 4-1: performance test result for counseling model

Objective	Audio voice types	No. of words	Insertion	Substitution	Deletion	WER in %
To test the accuracy of speech recognition	Google UK English Male	1000	50	56	20	12.6
	Google UK English Female	1000	50	30	30	11
	Google US English	1000	45	55	22	12.25
	Microsoft David - English	1000	40	45	15	10
	Microsoft Mark English-US	1000	60	40	20	12
Average WER						11.57%

4.6.2. Testing Model Evaluation

The objective of this evaluation was to analyze the classification performance of a testing model for distinguishing between HIV-positive, HIV-negative, and inconclusive cases. The evaluation utilized 200 real data test cases, taking into account various factors such as age, sex, test-kit types, and sample blood test results. Precision, recall, F-measure, and accuracy were employed to assess the model's performance on each individual class as well as the overall accuracy of the classification task. The table provides a breakdown of the classification performance for each class and the overall accuracy of classification based on the number of cases identified as True Positive, False positive, True Negative, and False Negative as shown below in Table 4-2.

Table 4-2: performance test result for testing model

Class	TP	FP	TN	FN	Precision	Recall	F-measure	Accuracy
HIV Positive	75	5	117	3	0.94	0.96	0.95	**0.96**
HIV Negative	70	3	122	5	0.96	0.93	0.95	**0.96**
Inconclusive	47	0	150	3	1	0.94	0.97	**0.99**
Over all accuracy=$(TP_{total}+TN_{total}) / (TP_{total}+TN_{total} +FP_{total}+FN_{total})$								**0.97**

4.6.3. Treatment Model Evaluation

The purpose of this evaluation was to assess the classification performance of the treatment model in distinguishing between cases recommended for first and second-line ART regimens. A total of 300 real data test cases were used, considering factors such as viral load count, ART initiation dates, and CD4 levels. Precision, recall, F-measure, and accuracy were utilized to evaluate the model's performance for each class as well as the overall accuracy of the classification task. Table 4-3 presents a detailed breakdown of the classification performance for each class, including the number of cases identified as True Positive, False Positive, True Negative, and False Negative.

Table 4-3: performance test result for treatment model

Class	TP	FP	TN	FN	Precision	Recall	F-measure	Accuracy
First Line ART Regimen	160	10	115	15	0.94	0.91	0.93	**0.91**
Second line ART regimen	115	15	160	10	0.89	0.92	0.90	**0.91**
Over all accuracy=(TP_{total}+TN_{total}) / (TP_{total} + FP_{total} TN_{total} +FN_{total})								**0.91**

4.6.4. Data Storage and Access Model Evaluation

The purpose of this test report is to provide an overview of the unit test conducted for the data storage and access functionalities in the developed KBS model. The unit tests aimed to assess the correctness and reliability of the data insertion, retrieval, updating, and deletion. The unit test was performed using the Jasmine and Karma testing framework, with TypeScript as the programming language. The tests were executed for each functionality.

The test is focused on ensuring the correct data storage and indexing, validating the accuracy of data retrieval, Verifying the proper handling of data updates, and ensuring the integrity of data during the deletion process. The table below summarizes the test cases, their results, and relevant remarks for each functionality as follows.

Table 4-4: Unit test result for data storage and accessing model

Functionality	Test Case	Result	Notes
Data Insertion	Insertion of a new documents with valid data.	Passed	Successfully inserted a new document with valid data.
	Insertion of a document with invalid data.	Failed	Failed to handle insertion of a document with invalid data.
	Insertion of documents with missing or incomplete data fields.	Passed	Inserted a large volume of data without any issues.
Data Retrieval	Retrieval of documents based on a specific searching parameter.	Passed	Retrieved documents based on a specific keyword successfully.
	Handling cases where no matching documents are found for a given search	Passed	Handled cases where no matching documents were found.
	Retrieval of documents based on multiple keywords or search criteria.	Passed	Performance testing for retrieving data from a loaded database.
Data Updating	Updating document attributes.	Passed	Updated document attributes accurately.
	Updating non-existing document attributes	Failed	Failed to handle update request for a non-existing document.
Data Deletion	Deletion of a document.	Passed	The unit successfully removed the specified document from the KBS system, ensuring appropriate cleanup and maintaining the integrity of related information.

4.7. User Experience Evaluation of the Proposed KBS Model

The main objective of this test aimed to assess the model's ease of use, user satisfaction, effectiveness, and performance. Its easiness is assessed based on the evaluation of navigation, interface clarity, task completion efficiency, error prevention and recovery, consistency of design, and overall intuitiveness. Additionally, the users' overall satisfaction with the model is reflected by projecting participants' perceptions of usefulness. The effectiveness of the application was evaluated based on the accuracy of diagnosis, appropriateness of treatment recommendations, appointment scheduling efficiency, and integration of counseling services. Finally, the testing considered system performance, including response time, stability, and data privacy.

The testing involved four representative users who closely aligned with the target audience for the system. They were chosen to ensure that the testing outcomes would accurately reflect the experiences and perspectives of the intended user. Specific test cases were designed to cover various functional areas and represent the typical tasks that users would encounter while interacting with the system. During the testing sessions, participants were encouraged to express their feelings, concerns, and any difficulties they encounter while performing the assigned tasks. This allowed us to capture a real-time understanding of participants' thoughts, decision-making processes, and any challenges encountered during the task completion.

The participants' interactions with the system were observed to capture their actions, comments, and behaviors. This observation provided valuable qualitative data regarding user experiences, preferences, and potential usability issues. To gather feedback, a combination of open-ended questions and rating scales was used. Open-ended questions encouraged participants to provide detailed feedback, express their thoughts, and offer suggestions for improvement. Rating scales allowed participants to quantify their experiences and perceptions using numerical ratings. This combination of feedback collection methods provided both qualitative and quantitative insights into the model's usability, user satisfaction, and overall performance. By employing this testing approach, the evaluation process gathered meaningful feedback and data from representative users.

Table 4-5: usability test case, rating and result matrix

Testing goal	Evaluation Criteria	Rating (1-5)	Comments/Feedback	Result in % = (Rating/5)*100
To assess the easiness of the system to use	Ease of navigation	4.5	The systems navigation is straight forward, but some menus could be better organized.	90
	Clarity of interface	5	The interface is clean and intuitive, with clear labels and icons.	100
	Task completion efficiency	4.5	It takes a few steps to complete certain tasks	90
	Error prevention and recovery	3.7	The system provides helpful error messages and allows users to easily recover from errors for most parts	74
	Consistency of design	5	The design elements are consistent throughout the system, providing a cohesive user experience.	100
	Overall intuitiveness	4.5	Generally easy to use, but a few features could be more intuitive.	90
To assess user satisfaction	User satisfaction	4.5	Users have expressed high satisfaction with the features and functionality.	90
	Perception of usefulness	4.5	Users find the system useful for diagnosing and managing their HIV/AIDS treatment.	90

	Overall satisfaction	4	Users have reported high overall satisfaction, but some have suggested improvements in certain areas.	80
To assess the effectiveness of the application	Accuracy of diagnosis	4.8	The diagnosis feature has a high level of accuracy and aligned with the established guideline	96
	Relevance of treatment recommendations	4.5	The treatment recommendations are aligned well with established guidelines and are personalized to each user.	90
	Appointment scheduling efficiency	5	Appointment scheduling are fully aligned with established guideline	100
	Integration of counseling services	4.5	Users appreciate the seamless integration of counseling services within the system.	90
To assess the performance the system	Response time	4.7	The system responds quickly.	94
	System stability	4.8	The app has exhibited a high level of stability with minimal crashes or disruptions.	96
	Data privacy	4.5	Medical results are presented anonymously	90

4.8. Discussion

According to the counseling model evaluation result shown in Table 4-1 above, the model achieved the highest recognition accuracy with a WER of 10% for the Microsoft David - English voice dataset. This indicates that only 10% of the spoken words were incorrectly transcribed by the system. Similarly, the model showed an 11% WER for the Google UK English Female Voice dataset and slightly higher error rates, ranging from 12% to 12.6% for the Google UK English Male, Google US English, and Microsoft Mark English-US voice dataset. The average WER across the five voice types testing dataset for the model was found to be 11.57%. This suggests that the model has the capability to accurately recognize user concerns and provide personalized information with an accuracy of 88.43%. This result is promising considering the model's limited vocabulary and its design for short conversational speech interactions with minimal background noise.

Based on the testing model evaluation, for the HIV Positive class, the model correctly identified 75 cases as positive and incorrectly classified 5 cases as positive when they were not. It correctly classified 117 cases as negative and missed 3 positive cases. The precision for the HIV Positive class is 0.94, indicating that 94% of the cases classified as positive were correct. The recall is 0.96, indicating that the model identified 96% of the actual positive cases. The F-measure, which combines precision and recall, is 0.95. The accuracy for this class is 0.96, meaning that 96% of the HIV Positive cases were classified correctly.

Similarly, for the HIV Negative class, the model correctly identified 70 cases as negative but misclassified 3 cases as negative when, they were positive. It correctly classified 122 cases as true negative and missed 5 negative cases. The precision for the HIV Negative class is 0.96, indicating that 96% of the cases classified as negative were correct. The recall is also 0.93, meaning that the model identified 93% of the actual negative cases. The F-measure for this class is 0.95, and the accuracy is 0.96.

For the Inconclusive class, the model correctly identified 47 cases as inconclusive but did not classify cases as inconclusive when they were not. It correctly classified 150 cases as either HIV positive or negative and missed 3 inconclusive cases.

The precision for the Inconclusive class is 1, indicating that 100% of the cases classified as inconclusive were correct. The recall is 0.94, indicating that the model identified 94% of the actual inconclusive cases. The F-measure for this class is 0.97, and the accuracy is 0.99. Thus, the model showed an overall accuracy of 0.97, indicating that it correctly diagnosed 97% of the cases.

According to the treatment model evaluation, for the first-line ART regimen class, the model correctly identified 160 cases as belonging to the first-line ART regimen recommendation and incorrectly classified 10 cases as the first-line regimen when they were not. It correctly classified 115 cases as not belonging to the first-line regimen and missed 15 cases that should have been classified as the first-line regimen. The precision for the first-line ART regimen class is 0.94, indicating that 94% of the cases classified as first-line ART regimens were correct. The recall is 0.91, meaning that the model identified 91% of the actual first-line ART regimen cases. The F-measure, which combines precision and recall, is 0.93. The accuracy for this class is 0.91, meaning that 91% of the first-line ART regimen cases were classified correctly.

Similarly, for the second-line ART regimen class, the model correctly identified 115 cases as belonging to the second-line regimen but misclassified 15 cases as the second-line regimen when they were not. It correctly classified 160 cases as not belonging to the second-line regimen and missed 10 cases that should have been classified as the second-line regimen. The precision for the second-line ART regimen class is 0.89, indicating that 89% of the cases classified as second-line regimens were correct. The recall is 0.92, meaning that the model identified 92% of the actual second-line regimen cases. The F-measure for this class is 0.90, and the accuracy is 0.91. Thus, the model showed an overall accuracy of 0.91, indicating that it correctly suggested ART regimens for 91% of the cases. The unit testing conducted for the data storage and accessing model demonstrated positive outcomes, with the majority of test cases passing successfully.

The results indicated that the functionalities for data insertion, retrieval, updating, and deletion are performed correctly and reliably.

On the other hand, in the usability testing evaluation matrix presented in Table 4.5 above, the evaluation showed an average result of 90.6% for usability test cases and participants found the system is easy to navigate, with a clean and intuitive interface. However, some of them suggested improvements in task completion efficiency and certain design elements. Regarding user satisfaction, the evaluation showed an average result of 86.6% for user satisfaction test cases. participants expressed their satisfaction with the features, and perceived it as useful for the diagnosis and treatment of HIV/AIDS disease.

In addition, the effectiveness of the system was assessed through the accuracy of diagnosis, relevance of treatment recommendations, appointment scheduling efficiency, and integration of counseling services. This evaluation showed an average result of 94% and participants found the testing and treatment services have a high level of accuracy, and are aligned with the established guidelines. In terms of performance, the evaluation showed an average result of 93.3 % and participants found the system presented lab results anonymously and responded quickly. Thus, according to the above results, the systems over all user experience with respect to usability, user satisfaction, efficiency, and performance evaluation metrics has shown 91.1% average result.

However, there are some potential limitations to the study. In order to further enhance the validity and generalizability of the findings, it would be beneficial to include additional testing datasets and incorporate different test types. The use of multiple datasets would increase the diversity of the samples and account for potential variations in the data distribution. Speech recognition may not always be completely accurate in complex cases and noisy environments. It could misinterpret or fail to recognize certain words or phrases, leading to inaccurate responses during counseling sessions. This can affect the quality and effectiveness of the service. Complex counseling cases that require specialized expertise may not be effectively handled by an application alone, necessitating referrals to human counselors.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

The study focused on the implementation of a KBS model for the diagnosis and treatment of HIV/AIDS disease. The findings highlighted the effectiveness and significance of the model in addressing the research objectives and improving healthcare outcomes. The counseling model provided information, support, and guidance to individuals undergoing HIV testing, helping them make informed decisions and manage the psychological impact of the diagnosis. The testing model accurately diagnosed HIV status, contributing to early detection, prevention, and treatment of HIV infection. Similarly, the treatment model suggested appropriate ART prescriptions, identified viral load levels, and scheduled treatment plans. This in turn contributes to controlling the spread of HIV/AIDS and improving health outcomes.

In addition, the proposed model, implemented a patient database for medical data storage and access service for users to collect and analyze patient information for accurate diagnosis and treatment planning. The significance of the study lies in its potential to improve healthcare outcomes, enhance efficiency and resource management, advance healthcare informatics, bridge gaps in healthcare collaboration, and contribute to policy development in the field of HIV/AIDS diagnosis and treatment. By addressing these areas, the study aims to make a meaningful impact on the lives of individuals affected by HIV/AIDS and contribute to the overall efforts of combating the disease.

The findings of this study align with existing knowledge on HIV/AIDS diagnosis and treatment. However, the study's unique contribution lies in the development of the KBS model, integrating intelligent counseling services and data storage and access functionalities, which provided a comprehensive solution for HIV/AIDS management. In conclusion, the study findings demonstrated the effectiveness and significance of the proposed KBS model, in addressing the research objectives and contributing to the overall efforts in combating the disease.

5.2. Recommendation

As a recommendation for future research, it is suggested to explore the following areas.

- One potential future research direction is to develop and implement culturally sensitive and accessible counseling services by modeling them to the local language. This approach would ensure that individuals undergoing HIV testing receive information, support, and guidance within their cultural context. By tailoring counseling services to the local language, it becomes easier to address concerns and misconceptions specific to the community, promoting a more effective and personalized counseling experience. Such an approach can contribute to reducing barriers to testing and improve overall engagement with HIV/AIDS services.
- In addition, exploring the integration of additional modalities, such as gesture recognition has a role to enhance the counseling service. By capturing non-verbal cues and body language, gesture recognition technology can provide valuable insights into clients' emotional states and needs. This information can be leveraged to tailor counseling interventions and provide personalized support, leading to more effective and empathetic care for individuals affected by HIV/AIDS. These approaches aim to facilitate informed decision-making and better management of the psychological impact of diagnosis.
- Likewise, the implementation of database backup and recovery, along with additional security measures like encryption, adds an extra layer of protection to safeguard the medical data of patients from disasters and data breaches. The incorporation of these security measures aims to ensure the confidentiality, integrity, and privacy of patient information, thereby enhancing the trustworthiness and reliability of the system.

By adopting these recommendations, the thesis seeks to make a valuable contribution to the enhancement of HIV/AIDS disease diagnosis and treatment.

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APPENDICES

Appendix-1: Open-ended questions in Amharic

For pre-test counseling knowledge

1. በቅድመ-ምርመራ የምክር ክፍለ ጊዜ ለግለሰቦች ብዙ ጊዜ ምን አይነት መረጃዎች ይሰጣሉ?
2. ስለ ኤችአይቪ/ኤድስ ምርመራ ግለሰቦች ሊያጋጥሟቸው ስለሚችሏቸው የተለመዱ ስጋቶች ወይም የተሳሳቱ አመለካከቶች እና በቅድመ-ምርመራ ምክር ጊዜ እንዴት እንደሚፈቱ መወያየት ይችላሉ?
3. ምርመራ ሂደት ውስጥ ግለሰቦች ስለ ሚስጥራዊነት እና ግላዊነት ሊያጋጥሟቸው የሚችሉትን ፍርሃቶች ወይም ስጋቶች እንዴት መፍታት ይቻላል?
4. በቅድመ-ምርመራ ምክር ወቅት ስለ ኤችአይቪ/ኤድስ ስርጭት፣ መከላከል እና ህክምና ለግለሰቦች ትምህርት እና መረጃ እንዴት ይሰጣሉ?
5. በቅድመ-ምርመራ ምክር ወቅት ግለሰቦች ስለ ምርመራው ሂደት ወይም ለኤችአይቪ/ኤድስ ሊገለጡ ስለሚችሉት ማንኛውም አይነት ጥያቄዎች ወይም ስጋቶች እንዴት መፍታት ይቻላል?
6. ከዚህ ቀደም አሉታዊ የኤችአይቪ/ኤድስ ምርመራ ውጤት ካጋጠማቸው ነገር ግን አሁንም ለበሽታ ተጋላጭ ከሆኑ ግለሰቦች ጋር እንዴት ይሰራሉ?
7. አንድ ግለሰብ ለኤችአይቪ/ኤድስ ለመፈተሽ ባለው ፍላጎት ላይ ተጽዕኖ ሊያሳድሩ የሚችሉ ማንኛውንም ባህላዊ ወይም ማህበራዊ ጉዳዮችን እና በቅድመ-ምርመራ ምክር ጊዜ እነዚህን እንዴት እንደሚፈቱ መወያየት ይችላሉ?

For post-test counseling knowledge

1. ግለሰቦች የኤችአይቪ/ኤድስ ምርመራ ውጤታቸውን ከተቀበሉ በኋላ ሊያጋጥሟቸው ስለሚችሉት የተለያዩ ስሜቶች እና ምላሾች እና በዚህ ሂደት እንዴት ሊደግፏቸው እንደሚችሉ መወያየት ይችላሉ?
2. ኤችአይቪ/ኤድስ መያዛቸው የተረጋገጠ ግለሰቦች እንዴት ትምህርት እና መረጃ ይሰጣሉ?
3. የኤችአይቪ/ኤድስ ሁኔታቸውን ለባልደረባዎቻቸው ወይም ለምትወዷቸው ሰዎች ስለመግለጽ ግለሰቦች ሊያጋጥሟቸው የሚችሉትን ፍርሃቶች ወይም ስጋቶች እንዴት መፍታት ይችላሉ?

4. የኤችአይቪ/ኤድስ ምርመራ ውጤታቸውን ከተቀበሉ በኋላ ግለሰቦች ስለወደፊት ጤናቸው እና ደህንነታቸው ሊነሱ የሚችሉትን ማንኛውንም ጥያቄዎች ወይም ስጋቶች እንዴት መፍታት ይችላሉ?
5. ከኤችአይቪ/ኤድስ መመርመሪያቸው ጋር በተያያዘ ተጨማሪ የሕክምና ወይም የአእምሮ ጤና ድጋፍ ለሚፈልጉ ግለሰቦች ማናቸውንም ሪፈራሎች ወይም ግብዓቶች መስጠት ይችላሉ?
6. ከኤችአይቪ/ኤድስ መመርመሪያቸው ጋር በተገናኘ የመንፈስ ጭንቀት፣ ጭንቀት ወይም ሌላ የአእምሮ ጤና ችግር ካጋጠማቸው ግለሰቦች ጋር እንዴት ይሰራሉ?
7. ግለሰቦች ከኤችአይቪ/ኤድስ ጋር የመኖር ስሜታዊ እና ስነ ልቦናዊ ተፅእኖን እንዲቋቋሙ ለመርዳት የምትጠቀምባቸውን ስልቶች ወይም ዘዴዎች መወያየት ትችላለህ?

For HIV testing knowledge gathering

1. የኤችአይቪ ምርመራ በተቋምዎ የሚካሄድበትን ሂደት መግለጽ ይችላሉ?
2. በኤችአይቪ ምርመራ ሂደት የታካሚውን ሚስጥራዊነት እና ግላዊነት ለመጠበቅ ምን እርምጃዎችን ትወስዳለህ?
3. በተቋምዎ ውስጥ ያሉትን የኤችአይቪ መመርመሪያ ኪት ዓይነቶች እና እንዴት እርስ በርስ እንደሚለያዩ መግለጽ ይችላሉ?
4. በተሞክሮዎ፣ ታካሚዎች ስለ ኤችአይቪ ምርመራ ሊያደርጉ ከሚችሉት በጣም የተለመዱ የተሳሳቱ አመለካከቶች ወይም አፈ ታሪኮች መካከል አንዳንዶቹ ምንድን ናቸው?

For treatment model knowledge gathering

1. በኤች አይ ቪ የተያዙ ሰዎች ARTን ለመጀመር የሚመከሩት መመሪያዎች ምንድናቸው?
2. የ ART መድሃኒትን ማክበር ለህክምናው ውጤታማነት ወሳኝ ሚና የሚጫወተው እንዴት ነው?
3. ከኤችአይቪ/ኤድስ ጋር ለሚኖሩ ግለሰቦች የ ART ህክምና የረዥም ጊዜ ጥቅሞች እና ውጤቶች ምን ምን ናቸው?
4. ታካሚዎች የ ART ህክምናን ለማግኘት እና ለማክበር የሚያጋጥሟቸው ተግዳሮቶች እና መሰናክሎች ምን ምን ናቸው?

5. የተለያዩ የ ART መመሪያዎች በመድኃኒት መጠን፣ የመድኃኒት ጥምረት እና የመድኃኒት መስተጋብር እንዴት ይለያያሉ?
6. 9. የ ART ህክምና የኤችአይቪ ስርጭትን ለመከላከል አስተዋፅኦ የሚያደርገው እንዴት ነው?

Appendix-2: Open-ended questions in English

For pre-test counseling knowledge

1. What information is often given to individuals in a pre-diagnosis counseling session?
2. Can you discuss common concerns or misconceptions that individuals may have about HIV/AIDS testing and how they can be addressed during pre-test counseling?
3. How can the fears or concerns that individuals may have about confidentiality and privacy be addressed during the investigation process?
4. How do you provide education and information to individuals about HIV/AIDS transmission, prevention, and treatment during pre-diagnosis counseling?
5. During pre-test counseling, how can individuals address any questions or concerns about the testing process or possible exposure to HIV/AIDS?
6. How do you work with individuals who have previously tested negative for HIV/AIDS but are still at risk?
7. Can you discuss any cultural or social issues that may influence an individual's willingness to be tested for HIV/AIDS and how these can be addressed during pre-test counseling?

For post-test counseling knowledge

1. Can you discuss the different feelings and reactions that individuals may experience after receiving their HIV/AIDS test results and how you can support them through this process?
2. How are individuals who test positive for HIV/AIDS provided with education and information?
3. How can you address the fears or concerns that individuals may have about disclosing their HIV/AIDS status to partners or loved ones?
4. How can you address any questions or concerns that individuals may have about their future health and safety after receiving their HIV/AIDS test results?

5. Can you provide any referrals or resources for individuals who need additional medical or mental health support related to their HIV/AIDS diagnosis?
6. How do you work with individuals experiencing depression, anxiety or other mental health problems related to their HIV/AIDS diagnosis?
7. Can you discuss strategies or tactics you use to help individuals cope with the emotional and psychological impact of living with HIV/AIDS?

For testing knowledge gathering

1. Can you describe the process of HIV testing at your institution?
2. What steps do you take to protect patient confidentiality and privacy during the HIV testing process?
3. Can you describe the types of HIV testing kits in your institution and how they differ from each other?
4. How do you work with patients to develop personalized plans for HIV prevention, including testing, treatment, and risk reduction strategies?

For treatment knowledge gathering

1. What are the recommended guidelines for starting ART for HIV-positive people?
2. How does adherence to ART medication play a critical role in treatment effectiveness?
3. What are the long-term benefits and outcomes of ART treatment for individuals living with HIV/AIDS?
4. What are the challenges and barriers patients face in accessing and adhering to ART?
5. How do different ART guidelines differ in dosage, drug combinations, and drug interactions?
6. 9. How does ART contribute to preventing the spread of HIV?

Appendix-3: Typescript Code for Counseling Model

```
import { Component, OnInit } from '@angular/core';
import { QuestionService } from '../service/question.service';
import { RestApiService } from '../shared/rest-api.service';
declare var webkitSpeechRecognition: any;
@Component({
  selector: 'app-pretestcounselingfor-hvst',
  templateUrl: './pretestcounselingfor-hvst.component.html',
  styleUrls: ['./pretestcounselingfor-hvst.component.css']
})
export class PretestcounselingforHVSTComponent implements OnInit
{
private recognition = new webkitSpeechRecognition();
public  note:any=[];
public  pcp:any=[];
public  pcn:any=[];
public  pci:any=[];
public messages: string[] = [];
public questionList: any = [];
constructor(private questionService:QuestionService, public restApi: RestApiService)
{
this.recognition.continuous = true;
this.recognition.interimResults = false;
this.recognition.lang = 'en-US';
//To provide counseling service
this.recognition.onresult = (event:any) => {
const results = event.results;
const transcript = results[0][0].transcript;
if (transcript.includes('one')){
this.note= this.getNotes(2,1);
setTimeout(()=>{this.say(this.note);},500);
```

```
this.stopRecognition();
}
if (transcript.includes('two')){
this.note= this.getNotes(2,2);
setTimeout(()=>{this.say(this.note);},500);
this.stopRecognition();
}
if (transcript.includes('three')) {
this.note= this.getNotes(2,3);
setTimeout(()=>{this.say(this.note);},500);
this.stopRecognition();
}
if (transcript.includes('four')){
this.note= this.getNotes(2,4);
setTimeout(()=>{this.say(this.note);},500);
this.stopRecognition();
}
if (transcript.includes('five')) {
this.note= this.getNotes(2,5);
setTimeout(()=>{this.say(this.note);},500);
this.stopRecognition();
}
if (transcript.includes('six')){
this.note= this.getNotes(2,6);
setTimeout(()=>{this.say(this.note);},500);
this.stopRecognition();
}}}
//when the component is loading
ngOnInit(): void {
this.note= this.getNotes(2,0);
setTimeout(()=>{this.say(this.note);},500);}
```

```
//To start recognition service
public startRecognition() {
this.recognition.start();
}
//To stop recognition service
public stopRecognition() {
this.recognition.stop();
}
//Explanation function
private say(message: any){
const speech = new SpeechSynthesisUtterance(message);
speech.lang = 'en-US';
window.speechSynthesis.speak(speech);
}
//To fetch counceling notes from the counceling fact base
public getNotes=(i:number,j:number)=>{
this.questionService.getCounselingJson()
.subscribe(res=> {
this.questionList=res.questions;
 return(this.note=this.questionList[i].pretestcounseling[j].serviceId)
})
}
}
```

Appendix-4: Typescript Code for Testing Model

```
import { Component, Input, OnInit } from '@angular/core';
import { QuestionService } from '../service/question.service';
import { RestApiService } from '../shared/rest-api.service';
import { ActivatedRoute, Router, TitleStrategy } from '@angular/router';
import { findIndex, Observable } from 'rxjs';
import { concatMap, map, take, takeUntil } from 'rxjs/operators';

//Diagnosis component (class)
export class DiagnosisComponent implements OnInit {
@Input() public mrn:any;
public message:string=' ';
public questionList: any = [];
public currentQuestion: number = 0;
public tkno: number = 0;
public hivstatusid: number = 0;
pulic idd:any;
public  clientDetails:any= {id:", fname: ", mname: ", MRN:",lname: ",sex: ", age: ",
address: ",email: ", phone: ", result: ",viralloadcount: ", treatment: "};
public clientlist :any=";
public domvalue:any=[];
public id:any= 0;
public objid:any =";
public objfname:any =";
public objmname:any=";
public objmrn:any=";
constructor(private questionService:QuestionService, private restApi:
RestApiService,public actRoute: ActivatedRoute,public router: Router) { }

//when the component is loading MRN will pass from counceling to testing service
ngOnInit(): void {this.restApi.currentValue.subscribe(msg => this.mrn = msg);
this.getAllQuestions(); }
```

//To update the diagnostic result of a client

```
public getId(): Observable<any> {
return this.restApi.getClients().pipe(map(res => {
this.clientlist = res;
const len = this.clientlist.length;
for(let i = 0; i < len; i++){
if(this.mrn === this.clientlist[i].MRN){
this.objmrn = this.clientlist[i].MRN;
this.objid = this.clientlist[i].id;
this.objfname = this.clientlist[i].fname;
this.objmname = this.clientlist[i].mname;
return this.objid;}}
throw new Error(`No client found with MRN ${this.mrn}`);
}));}
```

//To update HIV diagnosis result of a client

```
updateClients() {
this.getId().subscribe(() => { this.domvalue =
document.getElementsByClassName('id00')[0].getElementsByTagName('h1')[0].textCon
tent; this.clientDetails.result = this.domvalue;
this.clientDetails.fname = this.objfname;
this.clientDetails.mname = this.objmname;
this.clientDetails.MRN = this.objmrn;
this.clientDetails.id = this.objid;
this.restApi.updateClient(this.objid, this.clientDetails).subscribe(() => {
this.router.navigate(['/diagnosis']);
});});}
```

//To fect testing facts from the KB

```
getAllQuestions(){
this.questionService.getQuestionJson().subscribe(res => {this.questionList=res.questions;
})}
```

//diagnosis function

```
answer(currentQno: number, option: any) {
setTimeout(() => {
this.tkno++;
if(this.tkno ===2 && option.text==='NON-REACTIVE'){
this.tkno=3;
}}, 400)
if(this.tkno ===0 && option.text==='NON-REACTIVE'){
this.currentQuestion=1;
this.hivstatusid=1;
setTimeout(()=>{this.updateClients();},1000)
}
if(this.tkno ===3 && option.text==='NON-REACTIVE'){
this.currentQuestion=1;
this.hivstatusid=1;
setTimeout(()=>{this.updateClients();},1000)
}
if(this.tkno ===3 && option.text==='REACTIVE'){
this.currentQuestion=1;
this.hivstatusid=2;
setTimeout(()=>{this.updateClients();},1000)
}
if(this.tkno ===2 && option.text==='NON-REACTIVE'){
this.currentQuestion=1;
this.hivstatusid=2;
setTimeout(()=>{this.updateClients();},1000)
}
if(this.tkno ===2 && option.text==='REACTIVE'){
this.currentQuestion=1;
this.hivstatusid=0;
setTimeout(()=>{this.updateClients();},1000)}
```

```
if(this.currentQuestion===1 && option.text==='YES'){
this.router.navigate(['/posttest']);
}else if((this.currentQuestion===1 &&
option.text==='No')){this.router.navigate(['/home'])}
};

//To fetch questions from the fact base
this.getAllQuestions()
this.currentQuestion = 0;
}

//Explanation function
private say(message: any){
const speech = new SpeechSynthesisUtterance(message);
speech.lang = 'en-US';
window.speechSynthesis.speak(speech);
}
}
```

Appendix-5: Typescript Code for Treatment Model

```
import { Component, OnInit,Input } from '@angular/core';
import { QuestionService } from '../service/question.service';
import { ActivatedRoute, Router } from '@angular/router';
import { RestApiService } from '../shared/rest-api.service';
import { Client } from '../shared/client';
import { Observable, tap } from 'rxjs';

//Treatment component(class)
export class TreatmentComponent implements OnInit {
@Input() public mrn:any;
public name: string = "";
public questionList: any = [];
public currentQuestion: number = 0;
public vlcid: number = 0;
public durid: number = 0;
public dateid: number = 0;
public duridd: number = 0;
public  appointment:any=''
public  clientDetails:any= {id:'', fname: '', mname: '', MRN:'',lname: '',sex: '', age: '',
address: '',email: '', phone: '', result: '',viralloadcount: '', treatment: '', appointment:''};
public clientlist :any='';
clients:Client[]=[];
firstName:string=''
public domvalue:any=[];
public id:any= 0;
public objid:any ='';
public objfname:any ='';
public objmname:any='';
public objmrn:any='';
public objresult:any=''
```

```
public objtreatmeent:any=''
public objvirallc:any=''
public objappointment:any=''

constructor(private questionService:QuestionService, public router: Router, public
restApi:RestApiService, public actRoute: ActivatedRoute) {}

//when the component is initiated clients data is loaded from the DB
ngOnInit(): void{
this.getAllQuestions();
this.loadClients();
this.restApi.currentValue.subscribe((msg: any) => this.mrn = msg);
}

// To fectch clients data from the database
loadClients(): Observable<any> {
return this.restApi.getClients().pipe(tap((data: any) => {
this.clients = data;
}));}

//To get the clients data from the database
getId(): Observable<any> { return this.restApi.getClients().pipe(tap((res: any) => {
this.clientlist = res;
var len = this.clientlist.length;
for (var i = 0; i < len; i++) {
if (this.mrn === this.clientlist[i].MRN) {
    this.objmrn = this.clientlist[i].MRN;
    this.objid = this.clientlist[i].id;
    this.objfname = this.clientlist[i].fname;
    this.objmname = this.clientlist[i].mname;
    this.objresult = this.clientlist[i].result;
    this.objtreatmeent = this.clientlist[i].treatment;
    this.objappointment = this.clientlist[i].appointmentdate;      }}}));}
```

//To update clients treatment data to a database

```
updateClients() {this.getId().subscribe(() => {
   this.objtreatmeent =
document.getElementsByClassName('id000')[0].getElementsByTagName("h3")[1].textC
ontent;
this.clientDetails.treatment = this.objtreatmeent;
this.objappointment =
document.getElementsByClassName('id000')[0].getElementsByTagName("h3")[2].textC
ontent; this.clientDetails.appointmentdate = this.objappointment;
this.objvirallc =
document.getElementsByClassName('id000')[0].getElementsByTagName("h3")[3].textC
ontent; this.clientDetails.viralloadcount = this.objvirallc;
   this.clientDetails.MRN = this.objmrn;
   this.clientDetails.id = this.objid;
   this.clientDetails.fname = this.objfname;
   this.clientDetails.mname = this.objmname;
   this.clientDetails.result = this.objresult;
   setTimeout(() => {
   this.restApi.updateClient(this.objid, this.clientDetails).subscribe(data => {
   this.router.navigate(['/treatment'])
   })}, 200);
  });}
```

//To fetch the treatment fact base

```
getAllQuestions(){
this.questionService.getTreatmentJson().subscribe(res => {
this.questionList=res.questions;
})}
```

//To suggest treatment, viral load classification and scheduling appointment dates

```
answer(currentQno: number, option: any) {
```

```
setTimeout(() => {if(this.currentQuestion===1&&this.vlcid ===2 && this.duridd===4
&& option.text==='YES'){
        this.currentQuestion=3;
        this.vlcid=0;
        this.appointment=this.oneyearSchedule()
        setTimeout(()=>{this.updateClients();},1000)
}
if(this.currentQuestion===1&&this.vlcid ===1 &&this.duridd===4 &&
option.text==='YES'){
        this.currentQuestion=3;
        this.vlcid=-1;
        this.appointment=this.threemonthSchedule()
        setTimeout(()=>{this.updateClients();},1000)
}
if(this.currentQuestion===1&&this.vlcid ===1 &&this.duridd===3&&
option.text==='YES'){
        this.currentQuestion=3;
        this.vlcid=-1;
        this.appointment=this.threemonthSchedule()
        setTimeout(()=>{this.updateClients();},1000)
      }
if(this.currentQuestion===1&&this.vlcid ===1 &&this.dateid===0&&
option.text==='YES'){
        this.currentQuestion=3;
        this.vlcid=-1;
this.appointment=this.threemonthSchedule()
        setTimeout(()=>{this.updateClients();},1000)
}
If (this.currentQuestion===1&&this.vlcid ===2 &&this.dateid===0&&
option.text==='YES'){
        this.currentQuestion=3;
```

```
        this.vlcid=0;
        this.appointment=this.threemonthSchedule()
        setTimeout(()=>{this.updateClients();},1000)
}
if(this.currentQuestion===1&&this.vlcid ===2 && this.durid===1 &&
option.text==='YES'){
        this.currentQuestion=3;
        this.vlcid=2;
this.appointment=this.threemonthSchedule()
        setTimeout(()=>{this.updateClients();},1000)
}
If (this.currentQuestion===1&&this.vlcid ===1 && this.durid===1 &&
option.text==='YES'){
        this.currentQuestion=3;
        this.vlcid=2;
        this.appointment=this.threemonthSchedule()
        setTimeout(()=>{this.updateClients();},1000)
}
if(this.currentQuestion===1&&this.vlcid ===2 && option.text==='YES'){
        this.currentQuestion=3;
        this.vlcid=2;
        this.appointment=this.threemonthSchedule()
        setTimeout(()=>{this.updateClients();},1000)
}
if(this.currentQuestion===1&&this.vlcid ===1 && option.text==='YES'){
        this.currentQuestion=3;
        this.vlcid=2;
        this.appointment=this.threemonthSchedule()
        setTimeout(()=>{this.updateClients();},1000)
}
```

```
if(this.currentQuestion===1&&this.vlcid ===1 &&this.dateid===0&&
option.text==='YES'){
            this.currentQuestion=3;
            this.vlcid=-1;
            this.appointment=this.threemonthSchedule()
            setTimeout(()=>{this.updateClients();},1000)
}
if(this.currentQuestion===1&&this.vlcid ===0 && option.text==='YES'){
          this.currentQuestion=3;
          this.vlcid-=1;
          this.appointment=this.threemonthSchedule()
          setTimeout(()=>{this.updateClients();},1000)
        }
        this.durid++
        this.vlcid++
          }, 400)
if(this.currentQuestion===0&&this.durid ===0 && option.text==='YES'){
            this.currentQuestion=3;
            this.vlcid-=1;
            this.appointment=this.threemonthSchedule()
            setTimeout(()=>{this.updateClients();},1000)
  }
      if(this.currentQuestion===0&&this.durid ===1 && option.text==='YES'){
            this.currentQuestion=1;
            this.vlcid-=2;
}
if(this.currentQuestion===0&&this.durid ===2 && option.text==='YES'){
            this.currentQuestion=1;
            this.vlcid-=3;
            this.dateid=0;
}
```

```
if(this.currentQuestion===0&&this.durid ===3 && option.text==='YES'){
        this.currentQuestion=1;
        this.vlcid-=4;
        this.dateid=0;
        this.duridd=3
}
if(this.currentQuestion===0&&this.durid ===4 && option.text==='YES'){
        this.currentQuestion=1;
        this.vlcid-=5;
        this.dateid=1;
        this.duridd=4;
    };

//To explain the queries
public explain(message: any) {
const speech = new SpeechSynthesisUtterance(message);
speech.lang = 'en-US';
window.speechSynthesis.speak(speech);
}

//To calculate appointment schedules
public threemonthSchedule(){
const  today=new Date();
today.setMonth(today.getMonth()+3)
return today.toLocaleDateString();
}
public sixmonthSchedule(){
const  today=new Date();
today.setMonth(today.getMonth()+6)
return today.toLocaleDateString();
}
```

```
public oneyearSchedule(){
const  today=new Date();
today.setFullYear(today.getFullYear()+1)
return today.toLocaleDateString();
}
}
```

Appendix-6: Typescript Code for Data Accessing Model

```
import { Component, OnInit,Input } from '@angular/core';
import { Client } from '../shared/client';
import { RestApiService } from '../shared/rest-api.service';
import { ActivatedRoute, Router } from '@angular/router';
//Data access class
export class AccessComponent implements OnInit{
clients:Client[]=[];
public firstName:any='';
mName:any='';
result:any='';
treatment:any='';
message:string="";
public mrn: string="";
public user: string="";
public passwrd: string="";
public approvalmrn:string=''
public  clientDetails :any= { fname: '', mname: '', MRN:'', username:'', password:'', lname:
'',sex: '', age: '', address: '',email: '',     phone: '', result: '',viralloadcount: '', treatment: ''};
constructor(private restApi: RestApiService,public actRoute: ActivatedRoute, public
router: Router) {}
ngOnInit() {
this.restApi.currentValue.subscribe(msg => this.mrn = msg);
this.loadClients(); }
```

```
// To fectch clients data from the database
loadClients() {
return this.restApi.getClients().subscribe((data:any)=> {
this.clients=data;
})}
//To filterout a client data
searchfilter() {
if (this.mrn == ' ') {}
else {
this.clients = this.clients.filter(data => {
return data.MRN.toLocaleLowerCase().includes(this.mrn.toLocaleLowerCase());
}); }}
searchfilter1() {
if (this.mrn === '') {
this.message = '';
}
else {
this.searchfilter();
const positiveResult = this.clients.some(data => data.result.includes('positive'));
const negativeResult = this.clients.some(data => data.result.includes('Negative'));
const inconclusiveResult = this.clients.some(data => data.result.includes('Inconclusive'));
if (positiveResult)
{
this.router.navigate(['/treatment']);
this.approvalmrn = this.mrn;
this.restApi.updateInitValue(this.approvalmrn);
}
else if (negativeResult)
{
this.message="Client\'s HIV infection status is  negative!"
}
```

```
else if (inconclusiveResult) {
this.message="Client\'s HIV infection status is  inconclusive!"
}
else {
this.message = 'There is no a record for such MRN';
}}}
//Access controll function
accessControl() {
if (this.user === '' || this.passwrd === '')
{
this.message = 'Please enter username or password';
}
else {
const authorizedUser = this.clients.find(data => data.username === this.user &&
data.password === this.passwrd);
if (authorizedUser)
{
this.mrn = authorizedUser.MRN;
this.searchfilter1();
this.approvalmrn = this.mrn;
this.restApi.updateInitValue(this.approvalmrn);
}
else {
this.message = 'You are not an authorized user!';
}
}
}
}
```