Decision Tree Multi-agent based system for HIV

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DECLARATION

This project, as presented in this report, is my original work and has not been presented for any other institutional award.

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This project has been submitted as part fulfilment of the requirement for Masters of Science in Computer Science with my approval as the University Supervisor

Signature: …………………… Date ……………………

Mr. Andrew Mwaura

School of Computing & Informatics

DEDICATION

I dedicate this research project and all the work that has gone into it to my darling wife Gladys Muthoni

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Key Terms

Agent can be defined as autonomous software characterized by autonomous, mobility, reactivenes, proactiveness and intelligence, whereby, it's capable of performing a set of specialized operations to achieve a given task on behalf of their users

CD4 A type of protein molecule in human blood, sometimes called the T4 antigen that is present on the surface of 65% of immune cells. The HIV virus infects cells with CD4 surface proteins, and as a result, depletes the number of immune system cells (T cells, B cells, natural killer cells, monocytes) in the individual's blood.

Human immunodeficiency virus (HIV) A transmissible retrovirus that causes AIDS in humans.

Immune-deficient A condition in which the body's immune response is damaged, weakened, or is not functioning properly.

Methodology: is a body of methods employed by a discipline .A methodology helps the researcher to implement the solution by specifying some of the steps of the process.

Method: is a procedure for attaining something.

Multi- agents can be described as a set of agents that are able to interact with each other through cooperation, negotiation and are able to coordinate together. They are able to deal with complex problems

Opportunistic infection: An infection by organisms that usually do not cause infection in people whose immune systems are working normally.

Pneumonia (PCP): An opportunistic infection caused by a fungus that is a major cause of death in patients with late-stage AIDS.

Retrovirus A virus that contains a unique enzyme called reverse transcriptase that allows it to replicate within new host cells.

Healthcare Professionals Healthcare providers with patient care responsibilities, including physicians, advanced practice nurses, physician assistants, nurses, psychologists, emergency care providers, home health providers, definitive care providers, pharmacists, and other licensed and credentialed personnel involved in treating patients.

Providers: Can include Healthcare system as well as Licensed Individuals; provide services, Provider Organizations that are engaged in or support the delivery of healthcare like Hospitals.

Decision Analysis: Systematic, explicit quantitative way of decision making under conditions of uncertainty

Abstract

While previous work show that healthcare systems have been used in helping healthcare providers in electronic medical record management specifically clinical operations and tracking treatment outcome, there is little sharing of such or even usage of such data across many hospitals in resolving numerous challenges involved in supporting HIV patients. In this research we use JADE to provide an explicit diagnostic framework where decision trees are used to models temporal and logical flow of clinical problems associated with supporting such patients. We describe the process involved in designing and testing the healthcare system. Several healthcare providers are involved during the design and testing of the healthcare system whereby questionnaires are later used to evaluate the system.

Through functionality and usability evaluation we show how the healthcare system adds value to the health providers by eliminating conflict revolving around numerous treatment variables and enhancing quality of decision while supporting HIV patients. The healthcare providers are pleased with the system with 90% recommending for implementation of the system.

Chapter 1:

1.0: INTRODUCTION

Healthcare providers supporting HIV patients usually encounter complex clinical problems that usually require understanding various factors that affect patient's lifestyle and choosing options that maximises the overall benefit to a patient by prolonging their healthy life. HIV by nature being a infectious disease poses a challenge whereby the clinician may not be certain of prevalent opportunistic infections and Method to support the large number of patients given numerous variables and uncertainty involved in HIV medication process. Basically, when faced with such problems, healthcare providers turn to various sources of information for reference including consulting with other experts, reading biomedical databases and other research materials. This approach has certain limitations due to the limited nature of human being capability to support data collection and integrate the very complex data into a rational and consistent decision (1) creating need for high-quality information management system to ensure that each patient can be identified and traced, individual health status is monitored effectively, that results from clinical laboratory tests are well monitored and communicated to doctors, and that quality drug provisions is available always while needed.

Multi agent is vital in ensuring this system significantly advance collection, aggregation and reporting of data from various hospitals databases either hosted on local server or remote server, Agents support provision of health care through integrating Electronic medical data and clinical data to healthcare system to ensure that patient information is available across various medical institutions for continuity of care. The information may include the problem the patient is encountering, list of alternative actions, how actions alter subsequent events and the outcome based on respective actions. The research focus on symptoms and associated opportunistic infection, recurrence of such cases medication given and treatment outcome based on the medication. Coordination of development, deployment, implementation and maintenance of this functionality within the healthcare systems is fundamental to their success in the health sector.

In this case once the information is available in the knowledge base, we can use decision trees to improve the quality of care since it can provide a structured and consistent approach to solving complex problems surrounding uncertainty in dealing with HIV cases, the basic assumption is that a proper decisions leads to decline in clinical complications, disease states, and deaths, consequently prolongs quality-healthy years increasing life span. Decision analysis using decision trees in HIV related cases focuses not just on the outcome but provide a systematic, explicit analytical framework of making decision by evaluating trade-off among various alternative under conditions of uncertainty in relation to desired outcome leading to both enhanced communications about clinical controversies and betters decision (2) in addressing HIV patients.

A decision tree main objective is to offer the HIV patient an administration option that is likely to result in the greatest expected value in terms of quality health, complication, allergies and other factors. Decision analysis in this case is meant to be prescriptive, not descriptive (3). It supports healthcare providers in deciding what action to take under a given set of conditions, therefore the choice taken will be dependable on the existing data, assumptions made and outcomes measured.

This project aims to address the limitation of information and resources encountered by healthcare providers while making decision. The numerous variables treatment outcomes based on existing opportunistic infections are difficult to understand, tiresome, lengthy and involve too much simplification and unnecessary accuracy in predicting outcome. Healthcare providers usually have doubt on some of the results that are expressed in utilities and that the probability estimates used to obtain these results are not acceptable by all hence creating a conflict.

The quality of a good decision analysis is a decision tree that makes it easy for healthcare providers to understand the alternatives being evaluated, consequently indicate how the outcome is achieved. The Agents has reduced the amount of time taken to collect data, aggregate it, analyze and use cooperation strategies to eliminate conflict associated with tiresome decision making processes.

1.1 Background information

Human immunodeficiency virus (HIV) is associated with the retrovirus family that causes acquired immunodeficiency syndrome (AIDS), a state in humans in which progressive breakdown of the immune system allows life-threatening opportunistic infections and cancers to flourish. An individual can be infected with HIV by the transfer of blood, semen, vaginal fluid, pre-ejaculate, or breast milk. Contained by these bodily fluids, HIV is present as both free virus particles and virus inside infected immune cells. Main ways of spreading the disease include unsafe sex, contaminated needles, breast milk, and spread from an infected mother to her baby at birth

While HIV infection is required to develop AIDS, AIDS is the development of a low CD4 cell count (<200 cells/mm3) or any one of a extended record of problems of HIV infection ranging from a range of opportunistic infections like cancers, neurological symptoms, and wasting syndromes, consequently, a person can be infected with HIV for many years before AIDS develops.

The CD4 cell count and HIV viral load (RNA level) are closely related to HIV-related illness and mortality, and are the laboratory measures that are followed in clinical practice; both are the two markers that provide information on the degree of current immune-compromise and the risk of disease progression. Whereas the **CD4 count** is an indicator of immune system function, the **HIV viral load (RNA level)** gives predictive information on how fast the CD4 count is expected to decline and, as a result, the risk of disease progression Patients with high HIV viral loads generally demonstrate a faster decline in CD4 count and progression to AIDS-related illnesses, whereas those with low viral loads will usually have higher CD4 counts and remain asymptomatic for prolonged periods.

Many patients are unaware of their HIV infection and seek medical care when an OI becomes the initial indicator of their disease (6)". This poses a major challenge leading to the need for optimal strategies for awareness, prevention and management of OIs to provide comprehensive high-quality care for these patients, thereby dire need for advanced intervention in research and incorporation of technology to aid in HIV management.By bridging the current gap in lack of vital healthcare information on HIV patients, technology facilitate collection, storage and utilisation of efficient, safe and quality medical information that plays a great role in making choices, whether personally by affected patients or medical practitioner. Patients achieve a sense of power over their own health and increase survival; therefore, it is vital to develop strategies for providing greater availability of medical literature, expert medical opinion, standardized drug databases in the area of Hiv- Antiviral, standard medical terminology and understanding of personal medical information such as patients specific alerts/ warnings based on analysis as well as persistence test results, current/ past medical conditions, allergies and current or previous medications which will place patients in a position of greater responsibility, consequently, promoting patients in following treatment protocols and making healthy choices recommended by their doctor.

Decision trees have been developed by both machine learning and statistical communities respectively (4) and consequently used in medical diagnosis (5). Structurally, a basic decision model is created from a decision node(square) which represent a decision point , chance node(circle) which represent occurrence of a chance events given the choices made, and values of each terminal node or outcome(boxes) representing the utilities of ending up in each particular outcome state.

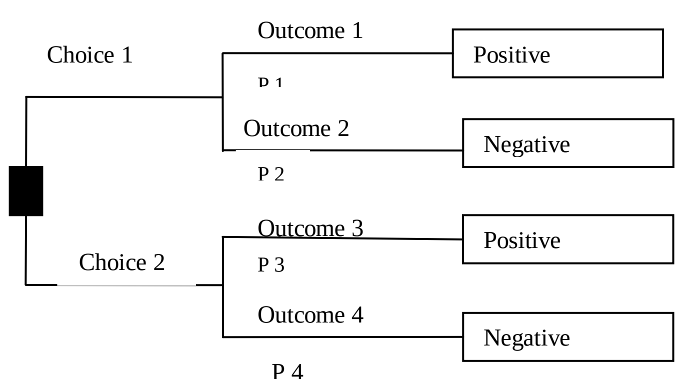


Figure 1: Simple decision tree

Decision trees are a reliable and effective decision making technique that provide high classification accuracy with a simple representation of gathered knowledge and they have been used in different areas of medical decision making (7). In medical decision making (classification, diagnosing, etc.) there are many situations where decision must be made effectively and reliably. Conceptual simple decision making models with the possibility of automatic learning are the most appropriate for performing such tasks.

Letourneau et al used a decision tree approach in decision making for chronic wound care (8). Data were collected from two groups of home care nurses in large urban centres. One group was measured after initial contact with the decision tree, and the other group was measured two years after implementation of the decision tree. The chronic wound management decision tree (CWMDT) was used, in combination with pictorial case studies.

They conclude that a decision tree can assist with decision making by guiding the nurse through assessment and treatment options. Although decision models can provide a formal foundation or guideline development and clinical decision support, their widespread use is often limited by the lack of platform independent software that geographically dispersed users can access and use easily without extensive training.

To address these limitations Sanders et al developed a World Wide Web based interface for previously developed decision models(9). They describe the use and functionality of the interface using a decision model that evaluates the cost effectiveness of strategies for preventing sudden cardiac death. The system allows an analyst to use a web browser to interact with the decision model and to change the values of input Variables within pre-specified ranges, to specify sensitivity or threshold analyses, to evaluate the decision model, and to view the results generated dynamically. The system demonstrates a method for providing distributed decision support to remote users such as practicing Healthcare providers. The web interface provides platform-independent and almost universal access to a decision model. This approach can make distributed HIV healthcare decision support both practical and economical, and has the potential to increase the usefulness of decision models by enabling a broader audience from various Hospitals to incorporate systematic analyses into both policy and clinical decisions while aiding HIV patients.

1.2 ***Problem statement***

The numerous variables treatment outcomes based on existing opportunistic infections are difficult to understand, tiresome, lengthy and involve too much simplification and unnecessary accuracy in predicting outcome. Healthcare providers usually have doubt on some of the results that are expressed in utilities and that the probability estimates used to obtain these results are not acceptable by all hence creating a conflict.

The few available clinicians cannot manage to fully furnish individually the huge number of patients with individual detailed information for health support. This is due to the fact that in a given patient the virus changes into an almost endless variety of forms hence Individuals react differently to different medicines. The medications interact in so many different ways that the clinician can't easily keep them in head with accuracy. Our inability to process numerous variables simultaneously is compounded by the fact that none of us can intuitively estimate probabilities accurately. In this regard, simple decision rules may offer advantages over medical decision

The quality of a good decision analysis is a decision tree that makes it easy for healthcare providers to understand the alternatives being evaluated, consequently indicate how the outcome is achieved. The Agents reduces the amount of time taken to collect data, aggregate it, analyze and use cooperation strategies to eliminate conflict associated with tiresome decision making processes.

Considering the multiple combinations including "boosted" protease inhibitor hybrids that make selection process hard, when a change in HIV therapy is necessary, the system looks at all the possible ways of treating a patient, eliminates those that are contraindicated, and sorts the remainder from the most to the least fit by using thousands of filtration rules. To keep these things sorted out and optimized is a real challenge." Indeed, the body of knowledge required to make a good choice; keeping the pill burden light, avoiding bad drug interactions and exploiting good ones, sidestepping drug toxicities.

1.3 ***Objectives of the study***

The purpose of undertaking this study is to identify the problems associated with the healthcare system to aid in Designing, building and testing an agent based system that uses decision trees to help in supporting the healthcare providers in treatment administration.

Some elements can be notable in treatment decision analysis. This include definition of the problem and the medical starting point, secondly we have choices, which are the events which are controlled by the healthcare provider, Then we have the events that occur by chance, that is, they are not within the control of the healthcare provider. Finally we have the outcome; these are the results to be considered in the analysis.

Several requirements gathering approaches are conducted during which medical processes and individual functional requirements by the system are defined and analysed. In addition, the preliminary requirements gathering approach serves to refine the original project goals and objectives as well as to revise the overall project schedule, if necessary.

1.4 ***Significance of the study***

The paper tries to unlock the role of agent by investigating the acceptable mechanism in aiding HIV patients to achieve quality healthcare.

1. Agents can help us handle complex situations, Agents are not meant to replace doctors but to be a complementary. Agent based healthcare system can be defined as an explicit quantitative diagnostic framework that systematically considers the trade-off between management options under conditions of uncertainty (3). They provide timely solutions by overcoming barriers in clinical decisions, flexibility in information technology facilitate rapid sharing of data, making it possible to generate results vital in guidance and maintenance of health.
2. The explicit diagnostic framework uses decision trees that are models of the temporal and logical flow of clinical problems (10) associated with HIV. Integration of prevention and control activities will aid health worker performing clinician duties in acquiring vital information and facilitate tracking patients in HIV program.
3. The basic assumption is to offer the HIV patient a medical option that is likely to give the patient the greatest value, lower risks and complications. The system is intended to assist healthcare providers in deciding what should be done under a set of conditions, so that the decisions will be consistent with the available data, assumption made and available data.
4. Decision trees can allow healthcare providers to ascertain whether their decisions in complex situation are compatible with their own knowledge, belief and preference (10).

1.5 ***Scope and Limitation***

- The system proposal incorporates information garnered and documented from expert's opinion and other medical literature as a system requirement to facilitate capturing vital functionalities. Based on limited authorization the system developer fails to have an opportunity to experience the end product in a clinical setting. This may create a gap between what the users need the system to do, what it actually does or how it does it.

- The system will be developed and tested in a controlled environment hence it may not be easy to use the system in the context of the actual environment life without facing interruptions and changing work priorities.
- In scope with controlled environment and budget
    a) Clinical decision support
    b) Agent based healthcare system

c) Reports

- In scope without budget and licence

a) System integration in actual environment

1.6 *Summary*

This paper proposes an Agent based systems using decision trees approach usable in HIV and opportunistic disease management as a tool to improve the quality of health care because it can provide a structured and consistent approach to solving complex problems. Opportunistic disease complication, survival rate and other health effects can be used as outcome measure, therefore decision analysis in not just a consideration of a given state in treatment stage, but provide the healthcare provider with a systematic, reproducible analytical framework that considers the trade-off among options under conditions of uncertainty in relation to a desired outcome.

The first step is pre-processing of data where the agent collects, clean and store data useful in generating indicators. In the second phase, indicators are used by the agent based system to generate its classification pattern. Thirdly, the system review and classify the patterns to determine the outcome, further revising them to obtain reports.

Chapter 2

2.0 LITERATURE REVIEW

Literature review is an essential and in depth assessment of previous research, the study explores the information from other sources pertaining the area of study and gives an evaluate report on concepts and ideas adopted by various researchers.

In order to get a good insight, this chapter explores healthcare sector specifically healthcare systems currently in use for HIV patient management. Prerequisite information for clear understanding of HIV and AIDS, methods of transmitting the virus, HIV stages, and preventing the opportunistic infections related with the disease are analysed.

Further study is taken to understand the concepts used by the existing system including their strength and shortcoming in dealing with HIV related cases. An insight is focussed on decision trees since they are clearly visible as a powerful tool in medical field to aid in achieving our goal of handling uncertainty any numerous variables. Decision trees have been applied in a number of systems like the chronic wound management decision tree.

The above information forms a foundation in evaluating milestone attained by the various systems, reviewing their achievement and limitation. The concepts derived from the evaluation of the healthcare system are re-evaluated on how they can be improved with the help of agents to enhance their functionality in management of healthcare.

In the final part of the chapter the study gives a brief review of agents, multi- agents and agent architecture on how optimal to achieve cooperation through agents to achieve the objectives discussed in the first chapter.

2. 1 Healthcare Sector

Countless factors are converging to compel the use of Agent based health solutions to the forefront of 21st century healthcare. Countries around the world are under pressure to manage the rising costs of healthcare; especially the costs of HIV related opportunistic diseases (11). The visible realization of standard healthcare information systems create a platform to input, analyze and share data across the healthcare field. The focus on preventative care and the increased investments in decision based systems make active intervention and relations with patients outside clinical decisions.

Improvements in technology provide the infrastructure to support exchange of extensive variety of information at anytime, consequently, the progress toward patient based healthcare initiates both patients and healthcare providers to centre on two-way information exchange with the individual as a driver of motivation, control and responsibility for managing their own health.

Standard health information systems incorporate : Well defined data entry process; Direct digital capture of laboratory test results or clinical diagnoses; well-organized data merge capabilities from numerous data sources; computerized information quality checks; Rapid search, retrieval, and visualization capabilities, Early warning alerts for potential disease threats and disease outbreaks.

Regardless of vast development in factors motivating decision based systems, the goal is in improving patient's outcome and attaining quality health improvement still remain unproven in most cases. What are needed are solutions, but there are few that have been developed and implemented to date.

Technology refers to simple use of agent based technology to address HIV related health issues. A good instance is the use of decision trees o offer the HIV patient an administration option that is likely to result in the greatest expected value in terms of quality health, complication, allergies and other factors. While making a decision the healthcare provider encounters numerous variables treatment outcomes based on existing opportunistic infections. They are difficult to understand, tiresome, lengthy and involve too much simplification and unnecessary accuracy in predicting outcome. Decision tree makes it easy for healthcare providers to understand the alternatives being evaluated, consequently indicate how the outcome is achieved. The Agents reduces the amount of time taken to collect data, aggregate it, analyze and use cooperation strategies to eliminate conflict associated with tiresome decision making processes. Therefore, use of decision trees will probably have slight visible impact in addressing complicated medical situations and improving health outcomes.

To a great extent, systems categorized as healthcare systems are electronic medical systems for enhancing quality checks by motivating and informing healthcare providers to monitor and trail medical performance and associated activities. Many of these systems fail to address events surrounding patient's outcome.

Achievements of healthcare systems is heavily weighted by implementation of solutions that combine systems to provide information and data in a form that can be consumed and acted on by healthcare providers

These solutions involve explicit quantitative diagnostic framework that systematically considers the interactions between healthcare providers and patients, with escalation of interaction as needed.

They provide information that supports decisions that determines outcome consequently showing alternatives considered to achieve the same

This project aims to unravel the initiative concerning the use of Agents and decision trees on HIV patient's management information systems to offer more and effective services, whereby, the system should provide a degree of decision support that would not only help healthcare providers improve the quality of patient care but also be able to understand the alternatives considered while determining outcome.

2.1.1 <u>Human immunodeficiency virus (HIV) and Acquired immune deficiency syndrome (AIDS)</u>

Aids stands for acquired immune deficiency syndrome. *Acquired* means that it does not crop up naturally in our bodies, it's received by our bodies from some infected place. *Immune deficiency* means that the immune system- the body natural protection against germs – weakens and stops performing as it should be. *Syndrome* refers to a collection of infections, cancers and other illnesses that can take place in individuals with immune deficiency.

Aid's is caused by the human immunodeficiency virus (HIV). It can spread from one person to another. Once inside the body, HIV infects and destroys vital immune systems cells called CD4 + cells. These are essential cells since they commune with other important immune systems cells in the body. If too many CD4+ cells are destroyed the immune system losses its ability to fight germs thereby being origin of illness. These germs and illnesses are known as opportunistic infections (OI, s). This is because they have the opportunity to grow and cause disease as inside the body because the immune system is no longer functioning properly. Individuals usually don't get unwell or die of AIDS.

Rather, they get unwell and die from the OI's associated with AIDS. Preventing these OI, s or treating them if they occur , is the most effective way to keep HIV-positive people alive longer and healthier.

2.1.2 How HIV is transmitted and best ways to prevent from infection

The table below lists some of the ways HIV can be transmitted and the best way to avoid the infection. (*Source: National Aids Control Council)*

Transmission	Rate	Protection
Sexual intercourse(vaginal or anal) with an HIV + person without using a condom	Very high risk	1 Don't have sex with anyone or if you do, only have sex with one partner who does not have HIV
		2 If you don't know your sexual partner's HIV status, always use a condom for sexual intercourse
Sharing drug injection equipment (needles and / or syringes) with an HIV + person	Very high risk	1 Don't use injection drugs
From a needle - stick injury involving a patient who is HIV +	Low risk	2 If you do use injection drugs never share your needles or other injection equipment with anyone else and don't share their needles or equipment
		3 If you do use injection drugs always use a clean needle and syringe each time you inject
From an HIV + woman to her unborn child(either in vitro or during delivery)	Medium risk	
From unprotected oral sex(not using a latex barrier such as dental dam) with an HIV + woman during menstruation	Medium risk	Do not have oral sex when you or your partner is having period or when you or they have sores or abrasion on your genitals

2.1.3 HIV Stages ,

The table below highlights the stages of HIV detailing the four stages, the problems to watch in each stage and consequently, medication to be followed up.

	Description	Problems to watch	Required Medication
Stage 1	This is the earliest stage of HIV infection.	Swollen lymph nodes. Lymph nodes are immune system glands scattered throughout the body. Can become swollen or feel hard	Clinical check up every six months
	Even though HIV is reproducing and causing damage, the number of CD4 + cells remains high and the immune is still strong		Women should have a pap smear every year
	HIV + people do not have any symptoms of AIDS		Have flu shots every year, preferably before flu season comes around

			Having safer sex, eating right and taking multivitamin daily
Stage 2	immune system start showing signs that it is not functioning properly		Clinical check up every six months.
	HIV + people usually feel fine and have no problem keeping up with their daily responsibilities. However , they may experience problems that may require medical attention	Weight loss, Minor skin problems including dry or itchy skin, infection under the nails or sores in and around the mouth. Recurrent head or chest colds or Herpes zoster (shingles) which causes painful blisters, usually on one side of the body	Women should have a pap smear every year
			Have flu shots every year, preferably before flu season comes around
			Having safer sex, eating right and taking multivitamin daily
			Start taking cotrimoxole to prevent PCP and toxoplasmosis
Stage 3	HIV + people may start to feel ill and may stay in bed longer than they normally would because they are not feeling well. The immune system becomes slightly more damaged and, as a result, certain OI' s can occur	*More profound weight loss* - patient lose noticeable amount of weight that is more than 10% of his ideal weight.	Clinical check up every three months. A patient should also visit the clinic in case a new problem arises or have not succeeded in resolving earlier problems.
		Chronic diarrhoea- germs including HIV itself can cause loose stool. Diarrhoea that lasts longer than a month can be serious and indicates that the immune system is not acting as it should	Women should have a pap smear every year
		Fever- Running a temperature for longer than a month	Have flu shots every year, preferably before flu season comes around
		Oral Candiasis - it's a common fungal infection on the mouth. It can cause a sore throat, pain when swallowing, nausea, and loss of appetite.	Having safer sex, eating right and taking multivitamin daily
		Oral Candiasis - it's a common viral infection on the mouth. Can cause discomfort in the mouth and may interfere with eating	Start taking cotrimoxole to prevent PCP and toxoplasmosis
		Tuberculosis: it's a serious infection on the lungs. Can make people with damaged immune systems very sick and must be treated.	

		Severe bacterial infections- Severe breathing problems and cough. Pneumonia is a common bacteria infection.	
		Vaginal candiasis- *s*evere yeast infection which can last more than a month	
Stage 4	At this level the patient is quite ill and usually not well enough to work, care for themselves, or spend a lot of time out of bed	*Profound weight loss*	Clinical check up every month or three months. A patient should also visit the clinic in case a new problem arises or have not succeeded in resolving earlier problems.
	Immune system is seriously damaged and the person is at risk for a number of dangerous OI' s	*Severe lung infections*- Most common problem is Pneumocystis carinii pneumonia (PCP)	Women should have a pap smear every year
		Infection of the brain.- common types are *toxoplasmosis (*a protozoa infection), *cryptococcus (*a fungal infection), *progressive multifocal leukoen cephalopathy (*a viral infection), and *encephalopathy(* often caused by HIV itself)	Have flu shots every year, preferably before flu season comes around
		Infection of the gut that cause severe diarrhoea and weight loss- This include cryptosporidiosis and isosporiasis	Having safer sex, eating right and taking multivitamin daily
		Herpessores- iCaused by the herpes simplex viruses 1 and 2 (HSV-1; HSV - 2), usually occurs around the mouth or genitals. People with damaged Immune systems may have a difficult shaking off these sores and may see them spread to other parts of the body.	Start taking cotrimoxole to prevent PCP and toxoplasmosis
		Severe bacterial or fungal infections- Some types of bacteria and fungi can spread throughout the body and cause serious illness.	Visit different clinics and doctors depending on the OI'S.
		Cancer- When the immune system stops functioning properly; it loses the ability to remove harmful cells from the body. These cells can become cancers, such as Kaposi's sarcoma (KS) and lymphoma.	If seriously ill visit a hospital to receive the medication and care you need

2.1.4 ***Initial Evaluation of a Newly Diagnosed HIV-Positive Patient***

Psychotherapy of individual patients and their sexual partners, including screening of patients' close kin, is done depending with consent of the patient. This entails;

1. Undertaking a detailed history, clinical examination, and assessment of the patient's social and economic circumstances.
2. Careful assessing presence of AIDS-related complications, in particular, existence or nonexistence of TB is determined prior to assessing the patient's immunologic status and deciding whether or not, and when, to start ART.
3. Undertaking tuberculin test, a chest radiograph, and, if a cough is present, three consecutive microscopic examinations of sputum for acid-fast bacilli.
4. Erythrocyte sedimentation rate is performed in the workup.
5. Measurement of CD4 count.
6. Supplementary laboratory exams include a pregnancy test for all women of childbearing age, a serologic test for syphilis, complete blood count (CBC) (or Hct alone) and hepatic transaminase enzymes if available, and a pelvic exam that includes screening for gonorrhea and chlamydia. Lastly, a Pap smear for the screening of cervical cancer.

   The record has a modular structure and is programmed in Microsoft Access

2.2.0 ***Milestones in existing systems***

In our review, we found that HIV related healthcare system is a developing field therefore less historical information associated with it. These systems have been productive in monitoring and managing HIV patient's performance, administering medications and empowering most patients to live healthy. Just a sample of them includes:

Mosoriot Medical Record System (MMRS) developed by Moi University School of Medicine Eldoret, Kenya, and Indiana University School of Medicine in USA has a modular structure and is programmed in Microsoft Access, it is deployed in several healthcare centres in several rural parts of Eldoret, the system supports outpatients HIV/AIDS care. Demographic, clinical, and HIV risk data, diagnostic test results, and treatment information are recorded on paper visit forms which are later taken for entry at central database by trained health workers. The central database gives summary reports, reminders for testing and correct treatment in addition to a central area for conducting research. Another initiative is IQCare which have a robust, fully relational back end database designed on .Net platform, the key to IQCare is the robust back end database. All of the core platform components are freely available or freely downloadable as part of any standard computer setup running the Windows operating environment and MSOffice. Basically, IQCare is a data capture and reporting system with patient management tools designed to measure patient outcomes. Having the ability to analyze data and then use the resulting analysis to provide improved care is the end goal of IQCare. IQCare has all of the key features needed to collect clean data and to do patient and facility analysis and reporting.

IQCare offers three modules: Pre-ART and ART clinical form sets, flexible PMTCT forms and a form builder. Users can create their own forms and modules for any kind healthcare area and run custom reports from the data of one or more all areas. This highly flexible approach works well for facilities of varying sizes and country locations. The pre-ART and ART clinical forms can be used in a paperless mode for clinics/hospitals seeking to reduce paper use and increase staff efficiency.

IQCare can be implemented in a single stand-alone configuration for smaller sites and in networked configuration with multiple simultaneous data entrants for higher volume sites. The application is highly configurable and provides sophisticated ad hoc and pre-defined reporting capabilities.

Another system is **OpenMRS** application which offers support to delivery of healthcare in developing countries. Its genesis is dire need to Scale up treatment of treatment of HIV; basically it was an electronic medical record system that could support the full range of medical treatments. OpenMRS is based on a "concept dictionary" that describes all the data items that can be stored in the system such as clinical findings, laboratory test results or socio-economic data. This approach avoids the need to modify the database structure to add new diseases for example, and facilitates sharing of data dictionaries between projects and sites. Its modular construction allows the programming of new functions without modifying the core code. OpenMRS is web based but can be deployed on a single laptop or on a large server and runs on linux, windows or Mac OS X. It uses the MySQL database though it can be ported to other databases. It is programmed in Java incorporating tools for data export and reporting. The system supports open standards for medical data exchange including HL 7, LOINC and IXF.

Evaluation upon MMRS, IQ Care and Open MRS revealed various problems with the software's including: Variable levels of functionality and data security, Variable reporting functionality, Issues with long-term sustainability, Limited feedback of data in EMR systems for patient care and Limited ability to exchange information between systems

Based on the above evaluation, need for EMR that facilitate information sharing between different users emerged. This inter-operability and data exchange is vital for the success of the health information system enterprise architecture; it entails a patient management system capable of sharing relevant patient-level data with a pharmacy or laboratory information system and vice versa, it should provide a degree of decision support that would help clinicians improve the quality of patient care.

TherapyEdge HIV, a Web-based decision support system for the treatment of HIV with a knowledge-based system for the treatment of chronic diseases graphically tracks and automatically processes a patient's clinical data including medical conditions, medications, genetic tests for drug resistance, drug efficacy and toxicity data through an extensive knowledge base of pharmacological and clinical information created and maintained in collaboration with expert HIV clinicians and researchers. The system utilizes an AI engine and knowledge base to assess a patient's current status and generate patient-specific, optimized treatment alternatives for a clinician to review and compare. In this way, the system can be used to generate comprehensive, individualized treatment plans for patients.

TherapyEdge's real-time, intelligent alerting system automatically checks for drug interactions, medical conditions or side-effect issues, as well as abnormal lab results and drug dosing. Additionally, the system de-identifies patient data and provides a longitudinal database that can be queried for drug efficacy data, clinical outcomes and quality of care information. The system therefore supports the validation of effectiveness of health services and therapeutic interventions.

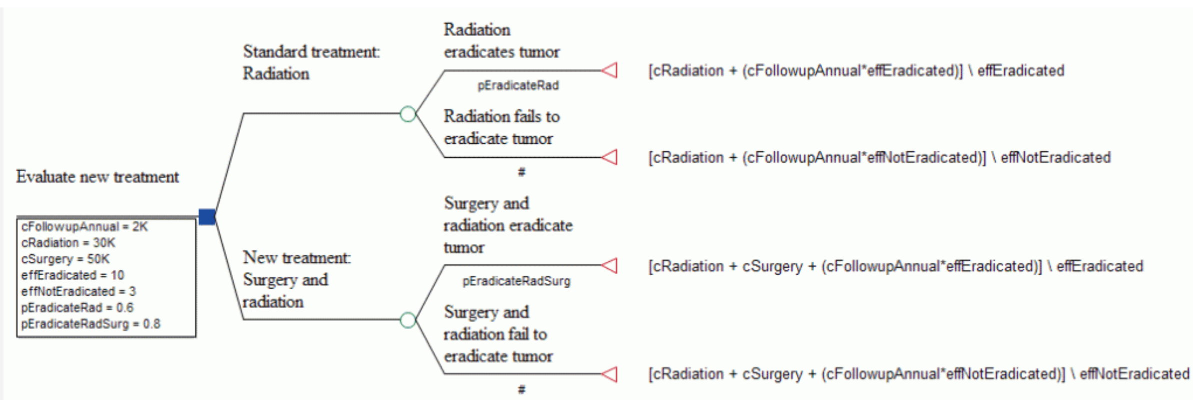
The system heavily relies on HIV sequencing by developing a database enabling HIV sequences submission, analysis and storage. Management of HIV nucleotide sequences is not easy as current database systems do not offer tools to handle genetic information. Another shortfall of Therapy edge is its ability to use information from other healthcare systems in deriving its outcome.

2.2.1 Decision trees based healthcare model

Healthcare models usually begin with a decision node with a branch for each treatment option for a specific health condition. The subtree for each treatment option follows the condition through treatment, including any number of possible outcomes.

A good example is TreeAge Pro that allows you to build large and complex decision tree and Markov models. It uses its analysis tools to compare treatment strategies, examine uncertainty and run individual patient simulations. TreeAge Pro is widely accepted by the scientific community and regulatory agencies as a standard modeling platform (11).

The model presented below includes two strategies for treating a specific tumor designed using Treeage Pro (11). Each strategy has a different likelihood of eradicating the tumor. At each terminal node, a value for cost and effectiveness associated with that outcome.



Simple Healthcare Tree

Figure 2: Simple healthcare tree

Healthcare decision trees are normally much more complicated and often include a Markov model for each treatment option. More complex healthcare trees may have many Markov models included in each strategy.

Although decision models can provide a formal foundation or guideline development and clinical decision support, their widespread use is often limited by the lack of platform independent software that geographically dispersed users can access and use easily without extensive training.

2.2.1.1 **Decision Analysis**

Decision analysis is a systematic, explicit quantitative way of decisions making under condition of uncertainty in healthcare that can lead to both enhanced communication about clinical controversies and better decisions (2).

The process is designed to help healthcare providers think evidently regarding various element of complex decisions, such as: the range of possible consequences of actions (or inaction), preferences among different sets of consequences, the impact of complex, unpredictable systems and processes .

2.2.1.2 **Modeling**

Using decision analysis, a complex medical problem can be subdivided into smaller problems and elements, which are simpler to handle. These components are then employed in building a model of the problem's essential elements. First, a set of alternatives is determined. After that, events and other factors influencing outcome of an alternative are identified. Any feature whose impact on the final diagnostic outcome is indefinite at the time of the decision is termed to as an uncertainty. Based on the healthcare provider objectives, one or more attributes are selected to quantify preferences for the range of possible final diagnostic outcomes.

Decision tree consists of tests or attribute nodes linked to two or more sub-trees and leafs or decision nodes labelled with a category which means the decision. A test node work out various outcome based on the attribute values of an instance, in these case potential outcome is linked with one of the subtrees. An instance is classified by starting at the root node of the tree. If this node is a test, the Outcome for the instance is determined and the process continues using the appropriate subtree. When a leaf is eventually encountered, its label gives the predicted class of the instance.

The judgment of a result with the aid of decision trees commence by preparing a set of solved cases. The whole set is then categorised into 1) a training set, which is used for the generation of a decision tree, and 2) a testing set, which is used to verify the truthfulness of acquired result.

Foremost, the entire attributes defining each case are pointed up (input data) and among them one attribute is selected that represents a decision for the given medical problem (output data). For all input attributes specific value classes are defined. If an attribute can take only one of a few discrete values then each value takes its own class; if an attribute can take various numeric values then some characteristic intervals must be defined, which represent different classes. Each attribute can represent one internal node in a generated decision tree, also called an attribute node or a test node (Figure 1). Such an attribute node has exactly as many branches as its number of different value classes. The leaves of a decision tree are decisions and represent the value classes of the decision attribute – decision classes (Figure 1). When a decision has to be made for an unsolved case, we start with the root node of the decision tree and moving along attribute nodes select branches where values of the appropriate attributes in the unsolved case matches the attribute values in the decision tree until the leaf node is reached representing the decision. Usually the members of a set of objects are classified as either positive or negative instances (for example ill and healthy patients), for the generality purpose this approach has to be extended with multi-class decision making, enabling one to differentiate between various decision classes.

2.3 Agent model

The Agent Management System is the agent that exercise supervisory control over access to and use of the platform; its main objective is to keep a register of local agents and for management of their life cycle. The Agent Communication Channel gives the trail for necessary contact between agents within and remotely to the platform; it is the default communication methods tasked with providing reliable, organized and correct message routing service to achieve inter-operability with other compliant agent platforms. The Directory Facilitator is the agent that provides address listing services to the agent platform.

Agents with emergent functionalities are crucial in software development and are currently being given a lot of attention in artificial intelligence. Medical field is integrating aspects of computer science for adoption of systems that works with composed agents that support co -operation in interaction between multiple and diverse interactions and processes in the healthcare management. The body of knowledge required to make a good choice through optimization by reviewing possible ways of treating a patient entices then researchers to develop adoptive agents to deal with open and complex agent problems.

2.3.1 What is an Agent?

An agent can be defined as autonomous software characterized by autonomous, mobility, reactivenes, proactiveness and intelligence, whereby, it's capable of performing a set of specialized operations to achieve a given task on behalf of their users. An agent is able to portray some of these features:

a) Autonomy: agents can work independently without human intervention and still maintain control over their actions.
b) Adaptation- agents can learn new techniques to enhance their performance
c) Reactivity: agents can observe and interact with their surroundings consequently responding to environmental changes;
d) Proactiveness: are able to act out of their on their own initiative to achieve goals through exploiting opportunities.
e) Social ability: individual agent's acts in an organized way while interacting with other agent through negotiation and cooperation to achieve their goals.

2.3.2 Multi Agent systems

Multi- agents can be described as a set of agents that are able to interact with each other through cooperation, negotiation and are able to coordinate together. They are able to deal with complex problems

2.3.3 Agent Architectures

Maes defines agent architecture as: "A particular methodology for building agent. It specifies how the general problem can be decomposed into the construction of a set of components modules and how these component modules should be made to interact. Architecture encompasses techniques and algorithms that support this methodology.
Agent architecture is a general methodology for designing particular modular decompositions for particular task, In this case we can have explicit logical reasoning in order to decide what to do, being reactive to percepts or combining both aspects

2.4 Why Multi agent Systems for Healthcare support

The key characteristics of agents to associate with include; *autonomous*, whereby, an agent is able to act independently to accomplish a given task amidst various complexities, at the same time being *adoptive* in order to learn new techniques. In this case, Each Agent is an active process which performs several important functions:

1. Verification, interpretation and explanation of patient data collection, relevant facts or medical plans.
2. Recommendations with the acquired experience and patient's preferences.
3. Feasibility study, regarding the medical effectiveness, diagnostics cost and therapeutic planning.
4. Patient's health progress monitoring.
5. Communications with other service provider's software agents.
6. Education, information and support to the patient.

In this case, the healthcare provider needs information regarding the drugs, nutrition, available programs among other information. To achieve the following, all these functions mentioned above help to improve the medical diagnosis quality, increase the patient's commitment and reduce the disease effects and medical errors.

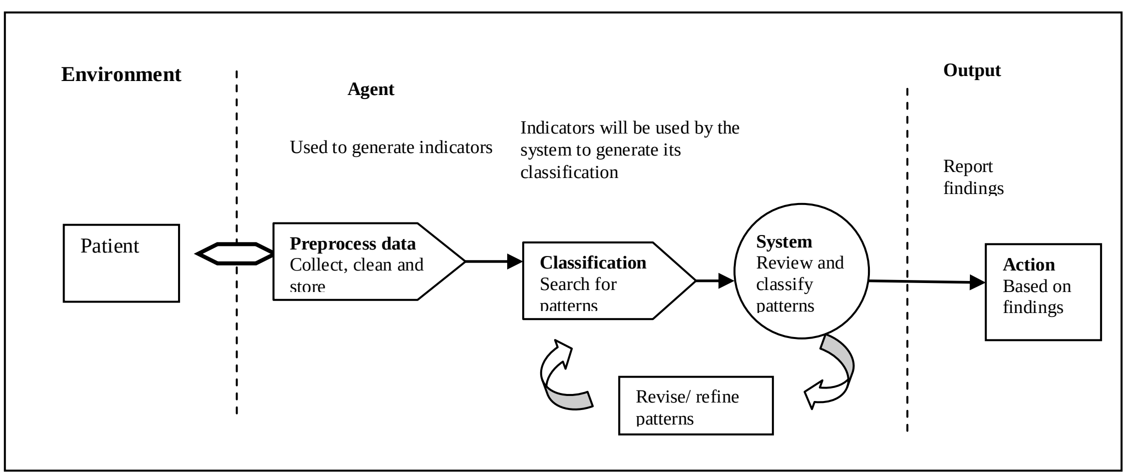


Figure 3: Data processing diagram

2.5 Clinical Systems basic functionality

2.5.1 Basic Demographic and Clinical Health Information

To illustrate the system, we must be able to capture basic patient-related information including patient identification information, clinic attendance or encounter information. This entails

1. Collecting and displaying important demographic patient information such as: name, birth date, gender, etc.
2. Managing patients problem / diagnosis list: coded diagnosis, onset date, history, chronicity, date resolved
3. Collecting and displaying patient medication
4. Collecting and displaying patient allergies
5. Collecting and displaying test results
6. Accepting encounter clinical data: vital signs, weight, height, calculate BMI
7. Accepting clinical notes in structured format and in free text format

2.5.2 Clinical Decision Support

Medical world being a complex environment is rather complex and extremely involving field to medical practitioner, their key focus usually entail generating revenue and patient care leaving less room for usage of technology unless noticeable value addition is evident. A clinical decision support comes in place to work in a similar way with a medical expert; thinking, delivering relevant information in an appropriate manner thereby reducing medication errors and improving patient safety.

This involves

1. Highlighting abnormal test results.
2. Alerting provider of abnormal vital signs and latest laboratory results.
3. Alerting provider if a known allergic drug is prescribed or if a known drug interaction is likely to occur
4. Providing reminders of recommended care due such as next laboratory tests due and medication/pharmacy appointment.
5. Managing patient's follow-ups including SMS alerts for next appointment.

2.5.3 Order Entry and Prescribing

Health care worker electronically enters instructions for the care and treatment of patients under his or her care, in this case systems plays a role in:

1. Allowing providers to enter orders with required details
2. Accepting prescription orders
3. Ordering and administering immunizations: capturing dose and the location given
4. Managing referral orders with details of referring provider and referred-to provider.

2.5.4 **Health Information and Reporting**

A quality systems improves the reporting and use of health information by

1. Generating reports from clinical data to support quality improvement
2. Generating aggregate reports for submission to health ministries and patients.

2.5.5 **Security and Confidentiality**

Privacy of patient data using strong data system encryption according to international patient privacy laws is of vital concern, that is:

1. Having access control functions that limit access to health data to selected individuals, based on defined and document roles
2. Maintaining detailed audit trails of all events within the system
3. Following defined standard practices on logins and passwords
4. Ensuring data protection by meeting requirements regarding data backup, recovery and documentation of systems
5. Incorporating technical security functions in line with requirements regarding encryption and data transmission.

2.5.6 **Exchange of Electronic Information**

Medical systems inter-operate with other similar hospital systems including laboratory systems and pharmacy systems whereby they communicate and exchange information to improve efficiency and provide quality patient care. This can be achieved by using web services, HL7 and other international standards:

1. Receiving patient information as a clinical document using a recognized standard.
2. Generating patient summary information as a clinical document using a recognized standard.
3. Generating aggregate clinical care information using a recognized standard.

2.6 **Agent based decision support system**

Agent-based technologies are considered the most promising means to deploy enterprise-wide and worldwide applications that often must operate across corporations and continents and inter-operate with other heterogeneous systems. It is because they offer the high-level software abstractions needed to manage complex applications and because they were invented to cope with distribution and interoperability (14).

The diagram below will highly aid in the design and implementation of the system.

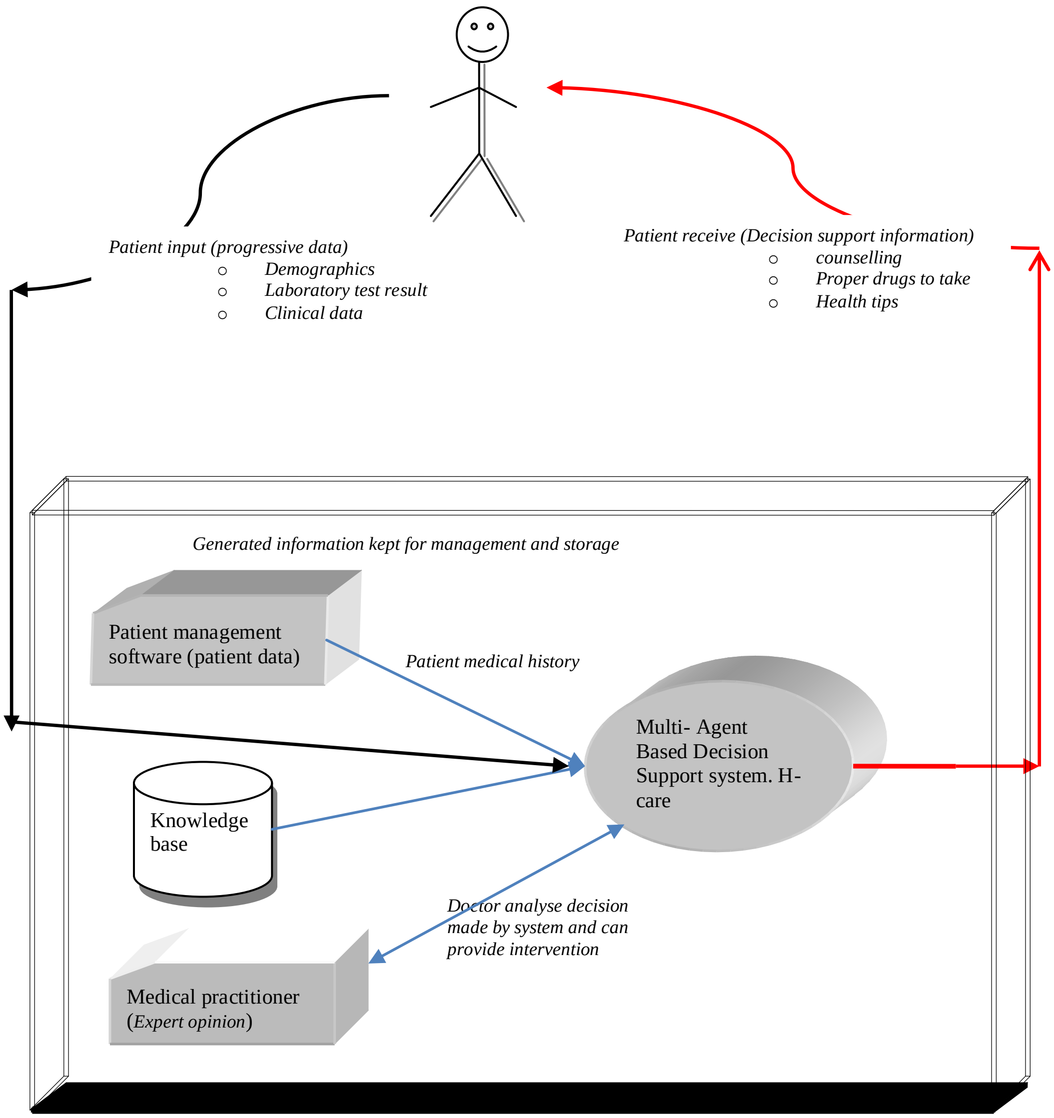


Figure 4: System overview diagram

2.7 JADE

JADE - Java Agent Development Framework is a framework to develop multi-agent systems, it's a middleware that facilitates the development of multi-agent systems (14). It provides basic middleware-layer functionalities which are independent of the specific application and which simplify the realization of distributed applications that exploit the software agent abstraction (Wooldridge and Jennings, 1995). It includes (14).

1. A **runtime environment** where JADE agents can "live" and that must be active on a given host before one or more agents can be executed on that host.

a. Distributed Agents platform - While appearing as a single entity to the outside world, a JADE agent platform is itself a distributed system, since it can be split over several hosts with one among them acting as a front end for inter-platform IIOP communication. A JADE system is made by one or more *Agent Container*, each one living in a separate Java Virtual Machine and communicating using Java RMI. IIOP is used to forward outgoing messages to foreign agent platforms. A special, *Front End* container is also an IIOP server, listening at the official agent platform ACC address for incoming messages from other platforms.
b. Agent communication model is peer-to-peer though multi-message context is provided by interaction protocols and conversation identifiers. On the other hand, JADE uses transport technologies such as RMI and event dispatching which are typically associated with reactive systems.

2. A **library** of classes that programmers have to/can use (directly or by specializing them) to develop their agents.
3. A suite of **graphical tools** that allows administrating and monitoring the activity of running agents.

2.7.1 AGENT COMMUNICATION – THE ACLMESSAGE CLASS

One of the most important features that JADE agents provide is the ability to communicate. The communication paradigm adopted is the **asynchronous message passing**. Each agent has a sort of mailbox (the agent message queue) where the JADE runtime posts messages sent by other agents. Whenever a message is posted in the message queue the receiving agent is notified. If and when the agent actually picks up the message from the message queue to process it is completely up to the programmer however.

2.7.2 The ACL language

Messages exchanged by JADE agents have a format specified by the ACL language defined by the FIPA international standard for agent interoperability. This format comprises a number of fields and in particular:

1. The ***sender*** of the message
2. The list of ***receivers***
3. The communicative intention (also called "***performative***") indicating what the sender intends to achieve by sending the message. The performative can be REQUEST, if the sender wants the receiver to perform an action, INFORM, if the sender wants the receiver to be aware a fact, QUERY_IF, if the sender wants to know whether or not a given condition holds, CFP (call for proposal), PROPOSE, ACCEPT_PROPOSAL, REJECT_PROPOSAL, if the sender and receiver are engaged in a negotiation,and more.
4. The ***content*** i.e. the actual information included in the message (i.e. the action to be performed in a REQUEST message, the fact that the sender wants to disclose in an INFORM message …).

5. The content ***language*** i.e. the syntax used to express the content (both the sender and the receiver must be able to encode/parse expressions compliant to this syntax for the communication to be effective).
6. The ***ontology*** i.e. the vocabulary of the symbols used in the content and their meaning (both the sender and the receiver must ascribe the same meaning to symbols for the communication to be effective).
7. Some fields used to control several concurrent conversations and to specify timeouts for receiving a reply such as ***conversation-id***, ***reply-with***, ***in-reply-to***, ***reply-by***.

A message in JADE is implemented as an object of the jade.lang.acl.ACLMessage class that provides get and set methods for handling all fields of a message.

CHAPTER 3:

3.0: METHODOLOGY

System development methodology is a framework that is used to structure, plan, and control the process of developing the agent based decision support system. This chapter presents the research activities that were adopted in this research in order to achieve the objectives outlined in chapter one.

1. Literature review
2. Design the system
3. Elaborate user interface prototypes
4. Test and validate user interface prototypes
5. Review outcome
6. Collect data

3.1 Literature review

The research adopted literature review and the result was an evaluative report that gave a clear understanding on concepts used by other researchers in implementation of existing healthcare management systems in supporting HIV patients. During the process some formative activities including contextual inquiry, task analysis, risk assessment, expert review were used in the investigating existing information.

3.2 System design

The research is designed using Adelfe methodology, whereby, Adelfe is described as "framework for developing software with emergent functionality" (Adelfe, 2003), (Bernon et al., 2003), (Henderson-Sellers & Giorgini, 2005) and was developed to deal with open and complex agent problems. These systems work with composed agents that have cooperative interactions with each other and are called Adaptative Multi-Agent Systems (AMAS).

The preliminary and final requirements aimed at establishing user's requirement and generating a strategic report to guide in development of the project are defined. An entity in Adelfe is an actor classified as passive or active. An active entity can act in an autonomous and dynamic way with the system. A passive entity is considered a resource of the system that can be used or modified by active entities.

Define context (6b) is an activity that analyses the environment through the interaction among entities and the system by defining sequence and collaboration diagrams. The information flow of passive entities and the system are expressed by collaboration diagrams, while interactions among active entities and the system are described by sequence diagrams.

The Adelfe methodology defines these diagrams based on the result of the previous step (6-1) where the entities were pre-defined with the support of the set of keywords provided in (4).

The work definition 3.2.1 and 3.2.2 below describe the process involved.

3.2.1 WD_1 (Work Definition) 1: Preliminary Requirements

1. Define user requirements
2. Validate user requirements
3. Define consensual requirements
4. Establish keywords-set
5. Extract limits constraints

3.2.2 WD_2 (Work Definition) 2: Final Requirements

6. Characterize environment
    a. Determine entities
    b. Define context
    c. Characterize environment
7. Determine use cases
    a. Draw inventory of use cases
    b. Identify cooperation failures
    c. Elaborate sequence diagrams

3.3 Elaborate user interface prototypes

The implementation of the healthcare support system is done using JADE to simulate agent behavior.

3.4 Test and validate user interface prototype

Test data is fed in the system and results analyzed with aid of a professional healthcare provider.

3.5 Review outcome

System usability is conducted throughout design and system evaluation is conducted throughout product development. During the design and development process, formative usability activities are carried out in support of defining the application, namely; Understanding the user and user workflow, making iterative improvements to the healthcare support system.

The data gathered during these activities tend to be more qualitative and descriptive. The findings from formative usability activities are meant to describe and define users and user needs and product features, as well as have an impact on the design of the product’s user interface.

Some of Formative usability activities include contextual inquiry, task analysis, risk assessment, expert review and One-on-one usability testing. Summative usability activities are carried out afterwards during the development process to refine the healthcare system. Each activity has specific goals which they appropriately address and consequently the data gathered during these activities tend to be more quantitative and objective though some activities may be subjective. Summative usability activities include expert reviews as a means to validate usability introduce subjective expert input.

3.6 Collection of data

Primary data and secondary data were key in research process. Primary data was mostly obtained using questionnaires, observation and interviews to medical practitioners. The data collected was vital in extensive understanding of existing concepts and guided in deriving new concepts.

3.6.1 Data collection techniques

i. Survey was done through conducting individual interviews and meeting focus groups with help of a healthcare provider regarding desired functionality of the system, content validity and possible barriers to encounter.

ii. Preparation of a detailed system evaluation form. This was generated from discussions with medical practitioners and study investigators on the merits of specific system features. Each feature was evaluated on and comments

iii. An intensive examination of medical journals, health technology journals and the internet for relevant materials supporting similar systems that provide key functionality associated with primary care for HIV patients

iv. Review of features of relevant medical systems based on live demonstrations, working copy of the systems and self-running demonstrations with manuals. Demonstrations helped with questionnaire ratings and feedback on key areas of interest within the system including: user interface, usability, customizability and overall impression of their functionality and acceptability.

v. Detailed discussion with medical experts regarding functionality of the sample demonstration systems, their shortfalls and how to resolve them at the same time incorporating comments from the interviews, evaluation forms and journals.

3.7 Summary

The researcher was able to understand existing healthcare systems using data collection techniques defined in these chapter, the existing systems formed a foundation for the improved system. Concepts used in defining the existing systems are also weighed to determine the suitable approach to achieve the objective of our study.

Chapter 4

4. Analysis and system design

The healthcare provider has information that require support in attending the patient in the medical process, This entails the HIV stage, specific infection including related problems to watch, the number of cases, recurrence, outcome and treatment status. As a start the healthcare provider gets information crucial in understanding the HIV stage, whether it's early stage, middle stages or advanced stage. Then the healthcare provider needs information to identify and classify the specific symptoms associated with given infection, recognize existence of opportunistic infection or allergies if any. Thirdly, they require information regarding the number of cases notable in relation to the prevailing opportunistic infection. The healthcare provider needs also to be acquainted with the rate of occurrence for such opportunistic infections and the outcome of previous medications, whether the case was improved, resolved or not successful. Finally, the healthcare provider needs information on whether the treatment was positive or not depending on allocated drugs, nutrition taken and programs followed.

The patient requires maximum health success enhancing personal wellbeing and living longer out of the benefit provided through quality decision.

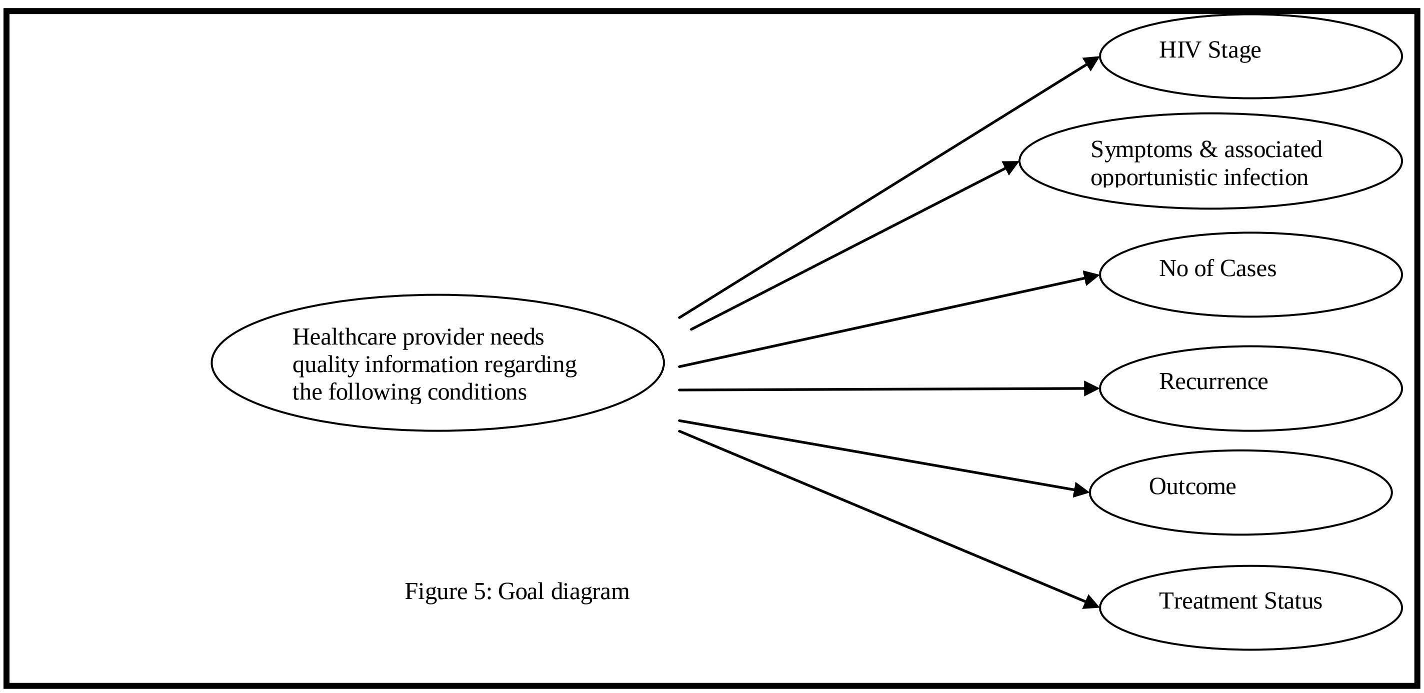


Figure 5: Goal diagram

4.1.1 The target of the system

a) Functional requirements defined in the preliminary requirements phase entail healthcare provider desires to make different query to health databases, communicate with other local and remote medical systems, monitor the progress of the patient health conditions and the effect of the treatment, expose the gathered data from secondary sources to user contributing enough background understanding to the user involved and lastly categorize illnesses and diseases in a hierarchal structure using decreasing levels of severity, in order to make possible to apply together different techniques to the patients. Above contributory goals leads to achievement of overall target

b) The agents are cooperative entities that portray the basic requirement, that is, autonomy requirement as well as goals and interaction with other entities. Entities which exhibit characteristics such as autonomy, goals, interaction with other entities, perceive its environment and the capacity to negotiate are considered as possible agents. In this case, The cooperation Diagrams for passive entities and the Sequence Diagrams for the active Entities illustrating standardized approach to get Patient's management to achievable is identified as shown below:

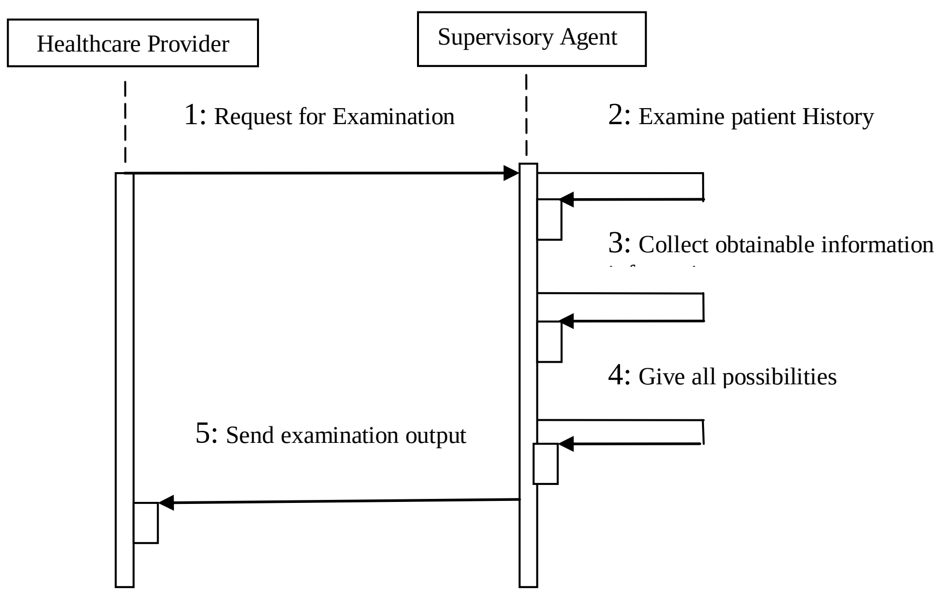


Figure: 6 Sequence diagram: Standardized approach to get Patient's management achievable

c) Non-functional requirements also defined in preliminary phase include: system ability to store physical and logical information using an enormous data volume, multi-tasking ability to respond to numerous data request simultaneous at a certain average time, to be conceptually distributed (the small parts inside inhabit all the same environment, however they represent, separately, concepts and well distinct parts) and to allow the adaptation and evolution of its components.

4.1.2 Actors of the system

The main actors in the healthcare system based on environment characterization activity are classified as passive or active. An active actor can act in an autonomous and dynamic way with the system. A passive actor is considered a resource of the system that can be used or modified by active actor, they include;

i. Patient **as the central actor** of the support-agent, whereby a patient has potential to trigger events in any situation that will be convenient, dynamically interacting with the system.
ii. **The Healthcare provider actor** has the power to trace treatment plans, to request examinations and to prescribe medicines, can also modify the patient treatment routine depending on the treatment results and satisfaction degree, being able to dynamically interacting with the system.
iii. **The support-agents** can be seen as “processing cells" of the system that interact dynamically in accordance with the recurrently perceptions of the environment.
iv. **Passive actor’s** are World Wide Web, Knowledge base, medical session, disease Information and Therapy while **Active actors** are: Patient, Health Professional and Hospital.

4.1.3 Specialization of the actors

i. Control agents - aimed at fetching medical and treatment data which require analyses, interpretation and understanding of patient’s outcome from local/ remote source.
ii. Supervisory agents- aimed at monitoring/inspection of specific states in the system.
iii. Cooperation agents – aimed at reduction and treatment of Non-Cooperative Situations. The Cooperation agent is responsible for using its "negotiation" together with supervisory skills to determine the priorities of the agent’s execution.
iv. Worker - the basic processing cell with the physical operations required to modify Data/state of the system.

4.1.4 Activity within the healthcare system based on environment description consists of;

i. Remote because several users can be logged and they can modify data at anytime.

ii. Continuous because the healthcare providers are free to make their own actions.

iii. Non-deterministic because the prescription of a treatment can be different for the same disease in different patients, and Dynamic because the system depends on the environment and that cannot be predicted by the system.

4.1.5 The use case diagrams were defined and mapped as shown below

The design agent activity refines the cooperation agents identified earlier, the various modules of agents are identified, their representation, characteristics, interaction languages.

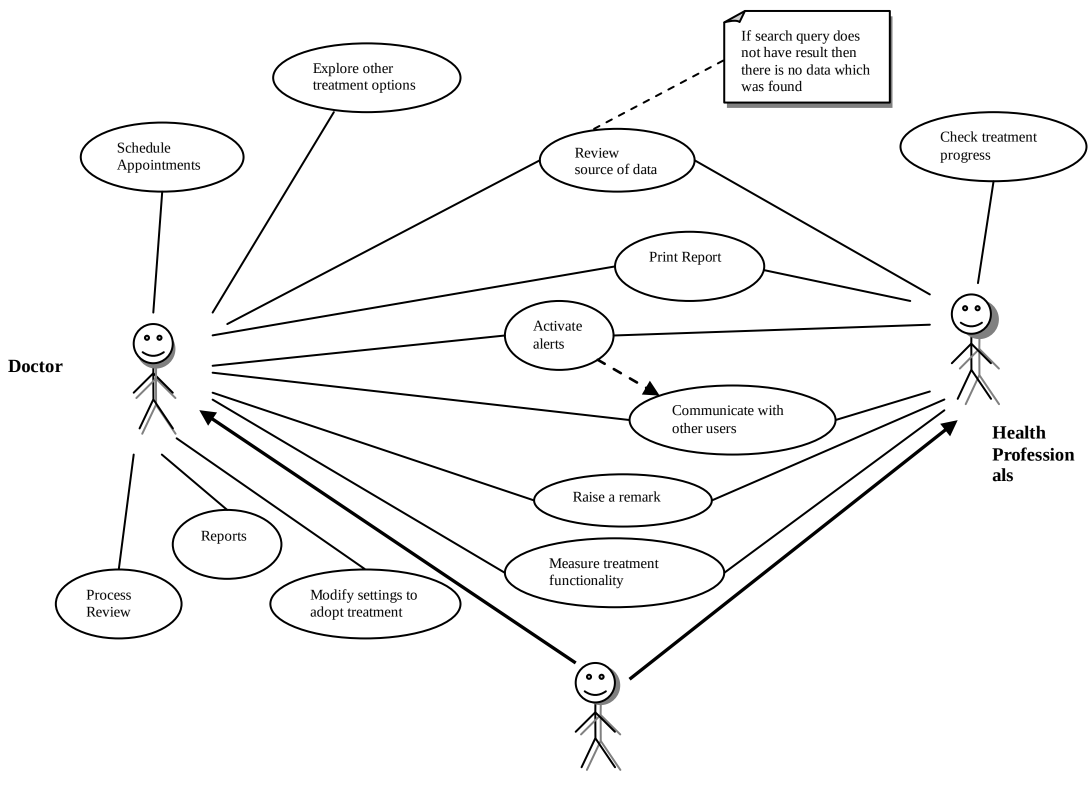


Figure 7: Use case

4.1.6 Non – Cooperation model

From Figure 7 above, Agents were defined and how they affect cooperative agent, a reviewing of how individual agents perceive and react to the environment and other entities is done, its notable to highlight some agent are susceptible to cooperation failures. These failures are marked as non-cooperative situations at the agent level, the entities meeting all these criteria will be identified as agents and the classes related to them marked as agents.

	Support Agents	Description
1	Autonomy:	Has autonomy because can make decisions based only on its knowledge
2	Local Goal:	The local goal is to perform a task that was assigned to it.
3	Interactions with other Entities:	Interact with other Support agents and Patient.
4	Environment Partial Overview:	Limited overview of the system
5	Negotiation Abilities:	Capable to Negotiate with other entities.

Table 3: Non Co- Operation model

4.1.7 System description

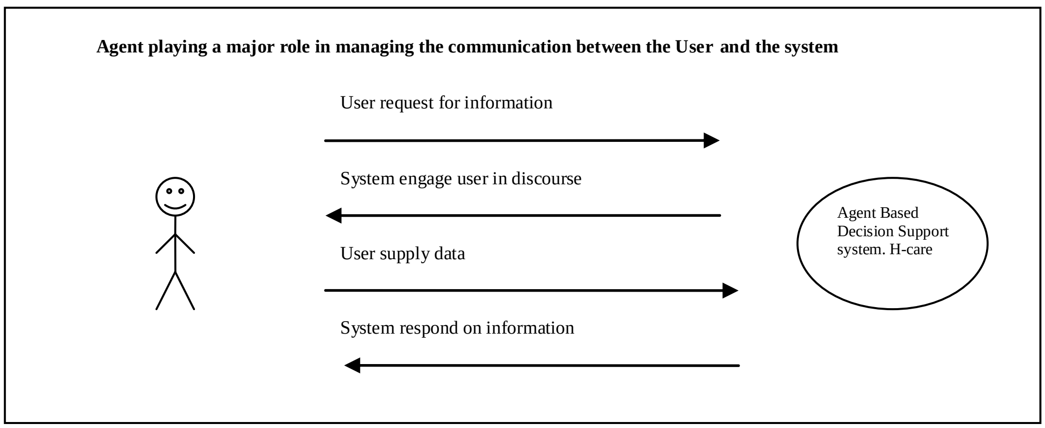


Figure 8: System description

Percepts

a) The System requests healthcare provider to provide some details.
b) Healthcare provider undertakes clinical tests to the patient and inputs the information.
c) The agent captures the information

Actions

a) The agent searching for helpful information relating to HIV stages, opportunistic infections, number of cases, recurrence, outcome and the treatment having high success rate.
b) Reporting on results achieved.

4.1.8 State chart diagram

The attributes and methods are defined to express the agents' state, conditions and actions. The state chart diagram illustrates the dynamic behaviors and the main intention is to mirror various changes of an entity state when it is interacting with others.

Name:	prompting for patients problem (CD4 Count, symptoms, allergies)
Description:	Enables system to get data on patient situation
Percept:	CD4 Count, symptoms, allergies
Message Sent:	Request opportunistic infection details
Actions:	Inputs infection results on the system
Data used:	Knowledge base
Interactions:	HIV stage knowhow through symptoms and opportunistic infection severity.
Goal:	HIV stage/ Opportunistic infection

Name:	Sending request for diet, medication and program request.
Description:	Enables healthcare provider get clinical decision support information.
Percept:	Diet, medication and program
Message Sent:	Request Diet, medication and program
Actions:	Inputs results on the system
Data used:	Knowledge base
Interactions:	Treatment outcome
Goal:	Treatment Success

Table 4: State chart diagram

4.2 Architectural design

The HIV Health Care agents are created inside containers that exist across different computers. These computers are networked together and all the containers connect or register to one main container thereby creating a distributed agent platform. The main container acts as the controller. It has two special agents:

1. Agent Management System (AMS) is the most authoritative agent in the platform. It performs management roles including
    - i. Creation and termination of agents
    - ii. Starts and stops the platform. Other agents can only requests AMS to do so.

iii. Ensure unique naming of agents e.g. KenyattaHospital@HIVHealthCare where KenyattaHospital is an agent sitting on HIVHealthCare platfrom.

2. Directory Facilitator (DF)

DF provides a Yellow Pages like function where by agents register their service. Agents like KenyattaHospital or Rift Valley District Hospital would register "hiv-healthcare" services that they provide. An agent requesting such services would ask the DF to provide a list of agents offering the service(s)

Ordinary containers hold service agents across the platform. e.g. NairobiHospital_Agent would reside at Nairobi Hospital while KiambuHospital_Agent dwells at Kiambu District Hospital. Any container may hold multiple agents providing various services. The main container can also hold HIV Health Care agents just as ordinary containers do.

Agent Type	**Responsibilities**
HIV Search Agent	Search for Agents offering HIV Healthcare services
HIV Subscription Agent	Register Agents offering HIV Healthcare services to the directory facilitator.
HIV Healthcare Agent	Queries patient information regarding diet, medicine and programs from local/remote database. Controls other local/remote agents Consolidates patient information from various data sources into the knowledge base Analyse data in the knowledge base using the decision trees

Table 5: Architectural design

4.3 Protocol diagram

Protocol diagram to define how agents communicate between themselves in order to exchange information is described. For each support agent the characteristics, res presentation, individual abilities and aptitude are identified.

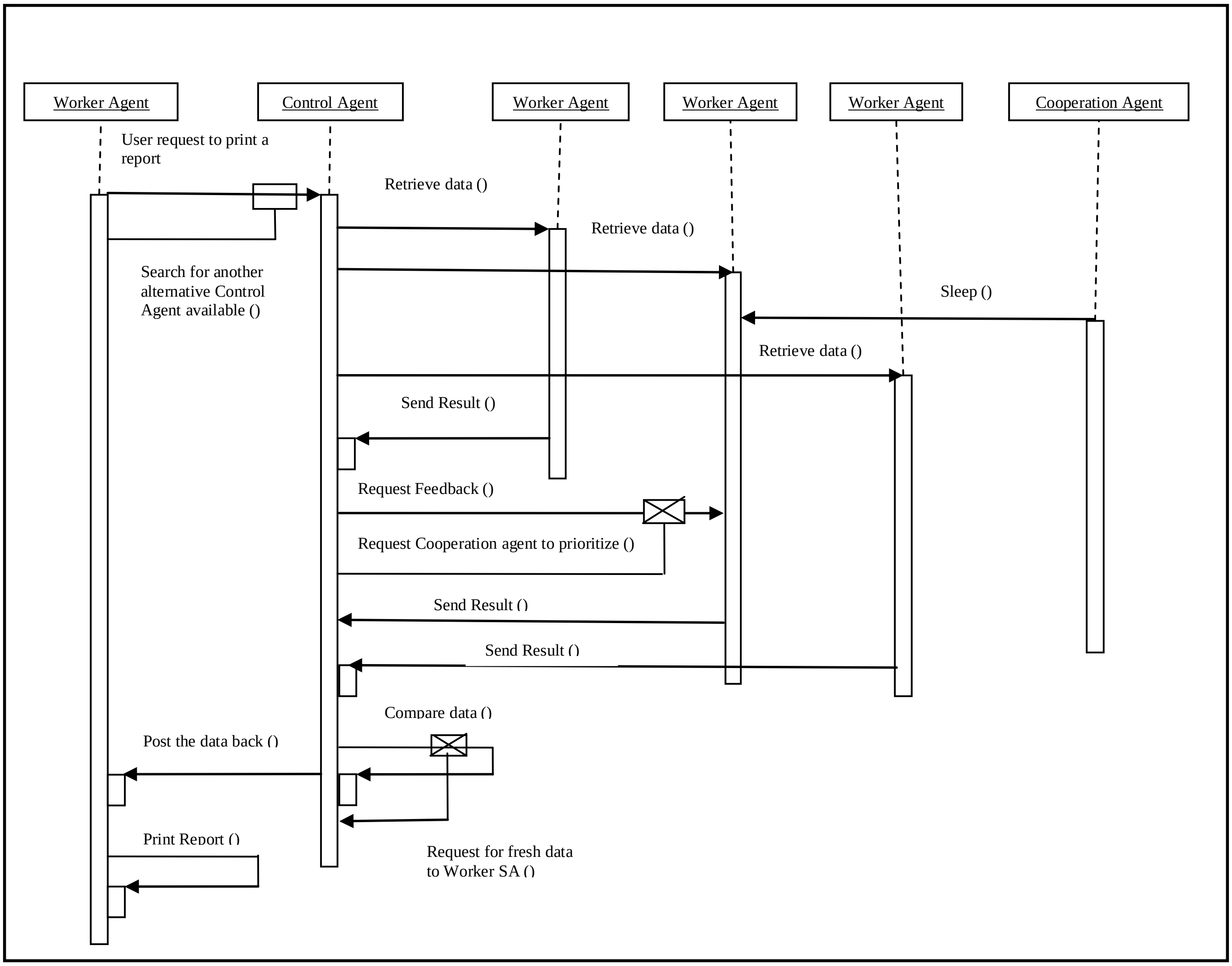


Figure 9: Protocol diagram

Chapter 5

5.1 IMPLEMENTATION OF THE SYSTEM

The system has been implemented using a combination of frameworks and APIs

(i) The front end has been developed in Java Enterprise Edition (J2EE)

(ii) The back end has been implemented using:

a. OpenEMR electronic health system. OpenEMR provides HIV patients medical information. It is a web application developed in PHP language and MySQL database.

b. MySQL database used for the Health Care knowledge base

(iii) The Multi Agent System has been implemented using JADE 4.3.0. The agents are distributed across a network of computers.

5.2 SAMPLE CODE OF THE IMPLEMENTATION

5.2.1 SERVICE SUBSCRIPTION AGENT

```
/**
 * This subscribes to the DF agent in order to be notified each time a given
 * service is published in the HIV Register.
 */
public class ServiceSubscriptionAgent extends Agent {
private static final long serialVersionUID = 1L;

    protected void setup() {
        // Build the description used as template for the subscription
        DFAgentDescription template = new DFAgentDescription();
        ServiceDescriptiontemplateSd = new ServiceDescription();
        templateSd.setType("hiv-healthcare");
        template.addServices(templateSd);
    …
        addBehaviour(new SubscriptionInitiator(this,
                DFService.createSubscriptionMessage(this, getDefaultDF(),
                        template, sc)) {
                    private static final long serialVersionUID = 1L;

            protected void handleInform(ACLMessage inform) {
                Master.log("Agent " + getLocalName()
                        + ": Notification received from DF", false);
newServiceSearchAgent(inform);
            }
        });
    }
}
```

5.2.2 SERVICE SEARCH AGENT

```
/**
 * This searches for hiv-healthcare services provided by other agents and
 * advertised in the hiv register managed by the DF agent.
 */
public class ServiceSearchAgent extends Agent {
	ACLMessage notification;

	publicServiceSearchAgent(){
	}
		publicServiceSearchAgent(ACLMessagemsg) {
		this.notification = msg;
	}
	protected void setup() {
		addBehaviour(new Search(this, 5000, new String[]{}));
	}
	class Search extends TickerBehaviour {
		private Agent agnt;
	public Search(Agent a, long period, String[] args) {
			super(a, period);
			this.agnt = a;
		}
		protected void onTick() {
			try {
				Master.log("Agent " + getLocalName()
						+ " searching for services of type \"hiv-healthcare\"", false);
				…
							DFAgentDescription[] results;

				if (notification != null) {
					results = DFService.decodeNotification(notification
							.getContent());
				} else {
					// Build the description used as template for the search
					DFAgentDescription template = new DFAgentDescription();
					ServiceDescriptiontemplateSd = new ServiceDescription();
					templateSd.setType("hiv-healthcare");
					template.addServices(templateSd);
					…
					results = DFService.search(agnt, template, sc);
				}

				Master.log("Agent " + getLocalName()
							+ " found the following hiv-healthcare services:",
							false);
								for (int i = 0; i <results.length; ++i) {
					DFAgentDescriptiondfd = results[i];
					AID provider = dfd.getName();
					Iterator it = dfd.getAllServices();
					while (it.hasNext()) {
						ServiceDescriptionsd = (ServiceDescription) it.next();
						// Retrieve only agents offering hiv-healthcare services
						if (sd.getType().equals("hiv-healthcare")) {
								agent.Master.HIVAGENTS.add(provider);
							String host = provider.getName();

							Master.log("Service \"" + sd.getName() + "\" found,
provided by " + provider.getName() + " (host: " + host + ")", false);
```

```
                        }
                    }
                }
            } catch (FIPAExceptionfe) {
                fe.printStackTrace();
            }
        }
    }
}
```

5.2.3 HEALTHCARE AGENT

```
/**
* This agents coordinates all other agents. It requests for hiv-healthcare services and updates the local knowledge base
 */
public class HealthCareAgent extends Agent {
    protected void setup() {
        String serviceName = "hiv-healthcare";
        ...
            addBehaviour(new UpdateKnowledgeBase(this, 3600000)); //Every 1 hour
            ...
    }
    classUpdateKnowledgeBase extends TickerBehaviour {
        private Agent agt;
        publicUpdateKnowledgeBase(Agent agent, long time) {
            super(agent, time);
            this.agt = agent;
        }
        protected void onTick() {
            Master.log("Agent " + getLocalName()
                    + " seeking to update the \"hiv-healthcare\" knowledge base",
                    false);
            try {
                Master.log("Number of \"hiv-healthcare\" agents found: " + agent.Master.HIVAGENTS.size(), false);
                    DFAgentDescription[] results = DFService.decodeNotification("hiv-healthcare");

                if (results.length> 0) {
                    Master.log("Agent " + getLocalName()
                            + " found the following hiv-healthcare services:",
                            false);
                    for (int i = 0; i <results.length; ++i) {
                        DFAgentDescriptiondfd = results[i];
                        AID provider = dfd.getName();
                        Iterator it = dfd.getAllServices();
                                while (it.hasNext()) {

….
                            agent.Master.requestPatientInfo(provider);
….
                        }
                    }
                } else {
                    Master.log("Agent " + getLocalName()
```

```
                                        + " did not find any hiv-healthcare service", false);
                        }
                } catch (FIPAExceptionfe) {
                        fe.printStackTrace();
                }
        }
    }
}
```

5.2.4 DECISION TREE ALGORITHM

```
public class DecisionTree {
    privateLinkedHashSet<String> attributes;
    private Map<String, Set<String>> decisions;
    private Examples examples;
    private Attribute rootAttribute;
    private Algorithm algorithm;
…
    private void setDefaultAlgorithm() {
        setAlgorithm(new ID3Algorithm(examples));
    }

    publicDecisionTreesetAttributes(String[] attributeNames) {
        ...
        for (int i = 0; i <attributeNames.length; i++)
            attributes.add(attributeNames[i]);
        return this;
    }
    publicDecisionTreesetDecisions(String attributeName, String[] decisions) {
        ...
        return this;
    }
    publicDecisionTreeaddExample(Map<String, String> attributes,
            boolean classification) throws UnknownDecisionException {
        ...
        examples.add(attributes, classification);
        return this;
    }
    publicboolean apply(Map<String, String> data) throws BadDecisionException {
        compile();
        returnrootAttribute.apply(data);
    }
    ...
}
```

5.2.5 ID3 ALGORITHM

```
public class ID3Algorithm implements Algorithm {
    private Examples examples;
    public ID3Algorithm(Examples examples) {
        this.examples = examples;
    }
    /**
     * Returns the next attribute to be chosen.
     */
    public Attribute nextAttribute(Map<String, String>chosenAttributes,
            Set<String>usedAttributes) {
        doublecurrentGain = 0.0, bestGain = 0.0;
```

```
		String bestAttribute = "";
		/*
		 * If there are no positive examples for the already chosen attributes,
		 * then return a false classifier leaf. If no negative examples, then
		 * return a true classifier leaf.
		 */
		if (examples.countPositive(chosenAttributes) == 0)
			return new Attribute(false);
		else if (examples.countNegative(chosenAttributes) == 0)
			return new Attribute(true);
		for (String attribute : remainingAttributes(usedAttributes)) {
			// for each remaining attribute, determine the information gain
			currentGain = informationGain(attribute, chosenAttributes);
			if (currentGain>bestGain) {
				bestAttribute = attribute;
				bestGain = currentGain;
			}
		}
		if (bestGain == 0.0) {
			boolean classifier = examples.countPositive(chosenAttributes) > 0;
			return new Attribute(classifier);
		} else {
			//Create new non-leaf attribute
			return new Attribute(bestAttribute);
		}
	}

	private Set<String>remainingAttributes(Set<String>usedAttributes) {
		Set<String> result = examples.extractAttributes();
		result.removeAll(usedAttributes);
		return result;
	}
	private double entropy(Map<String, String>specifiedAttributes) {
		doubletotalExamples = examples.count();
		doublepositiveExamples = examples.countPositive(specifiedAttributes);
		doublenegativeExamples = examples.countNegative(specifiedAttributes);
		return -nlog2(positiveExamples / totalExamples)
				- nlog2(negativeExamples / totalExamples);
	}
	private double entropy(String attribute, String decision,
			Map<String, String>specifiedAttributes) {
		doubletotalExamples = examples.count(attribute, decision,
				specifiedAttributes);
		doublepositiveExamples = examples.countPositive(attribute, decision,
				specifiedAttributes);
		doublenegativeExamples = examples.countNegative(attribute, decision,
				specifiedAttributes);

		return -nlog2(positiveExamples / totalExamples)
				- nlog2(negativeExamples / totalExamples);
	}
	private double informationGain(String attribute,
			Map<String, String>specifiedAttributes) {
		double sum = entropy(specifiedAttributes);
		doubleexamplesCount = examples.count(specifiedAttributes);
		if (examplesCount == 0)
			return sum;
```

```
            Map<String, Set<String>> decisions = examples.extractDecisions();
            for (String decision : decisions.get(attribute)) {
                doubleentropyPart = entropy(attribute, decision,
                                specifiedAttributes);
                doubledecisionCount = examples.countDecisions(attribute, decision);
                sum += -(decisionCount / examplesCount) * entropyPart;
            }
            return sum;
    }
    private double nlog2(double value) {
            if (value == 0)
                return 0;
            return value * Math.log(value) / Math.log(2);
    }
}
```

5.2.6 KNOWLEDGE BASE

```
public class KnowledgeBase {
    public static DecisionTreegetTree() {
            DecisionTree tree = new DecisionTree().setAttributes(new String[] {
                        "Type", "Issue", "Recurrence", "Outcome" });
            ...
            ResultSetrs = conn.statement
                        .executeQuery("SELECT * FROM knowledge_base");
                        String[] instance = null;
            boolean classification;
            while (rs.next()) {
                instance = new String[] {
                        rs.getString("type"),
                        rs.getString("issue"),
                        rs.getInt("cases"),
                        String.valueOf(rs.getInt("recurrence")),
                        String.valueOf(rs.getInt("outcome"))
                };
                try {
                        tree.addExample(instance, (rs.getInt("outcome") == 1 || rs.getInt("outcome") == 2) ? true : false);
                } catch (UnknownDecisionException e) {
                        e.printStackTrace();
                }
            }
                        return tree;
    }
    public static booleanapplyInstance(DecisionTree tree,
                Map<String, String> instance) {
            boolean res = false;
            try {
                res = tree.apply(instance);
            } catch (BadDecisionException e) {
                e.printStackTrace();
            }
            System.out.print("Predicted classification: " + res);
            return res;
    }
}
```

Chapter 6

6 DISCUSSION OF RESULTS

6.1 RESULTS FOR INFORMATION ANALYSIS FOR THE HEALTHCARE SYSTEM.

The information on problems associated with HIV, basically symptoms and their associated opportunistic infection, Specific cases affecting patients, Rate of recurrence of such cases, Outcome based on a given treatment and medication are identified during the system analysis phase. The treatments offering positive results are analysed using decision trees and acknowledged for use in guidance to the healthcare provider.

Patient medical information is captured using OpenEMR electronic medical record system and stored in MySQL database at various hospitals. The database holds patients personal details, medication history, drugs, HIV programs, opportunistic infections details among others. Agent based Healthcare system queries and store helpful information in local HealthCare knowledge base for use either locally or remotely by other HealthCare systems. Decision analysis using decision tree eliminates inconsistency associated with numerous variables

6.2 OUTCOME OF THE AGENT BASED HEALTHCARE SYSTEM

The HIV HealthCare system is created using agents integrated within containers that exist across different computers. These computers are networked together and all the containers connect or register to one main container thereby creating a distributed agent platform. The HIV Healthcare Agent queries patient information regarding diet, medicine and programs from the associated MySQL local database, the information gathered is shared across with other Agents. In this case, the main container controls other local/remote agents consequently consolidating patient information from various data sources into the knowledge base.

Further data analysis within the knowledge base is undertaken using the decision trees to offer the healthcare provider the optimal result. The various drug results together with recommended diet and programs as gathered by the agents are evaluated by the decision tree to determine which option gives the highest quality.

Agent in the healthcare system are launched by an administrator by using the RMA (Remote Monitoring Agent) GUI; Arguments are embedded within parenthesis and can be passed to each agent. The main-container hosts Agent Management System (AMS), Directory Facilitator (DF) and RMA. The other containers, instead, connect to the main container and provide a complete run-time environment for the execution of any set of JADE agents.

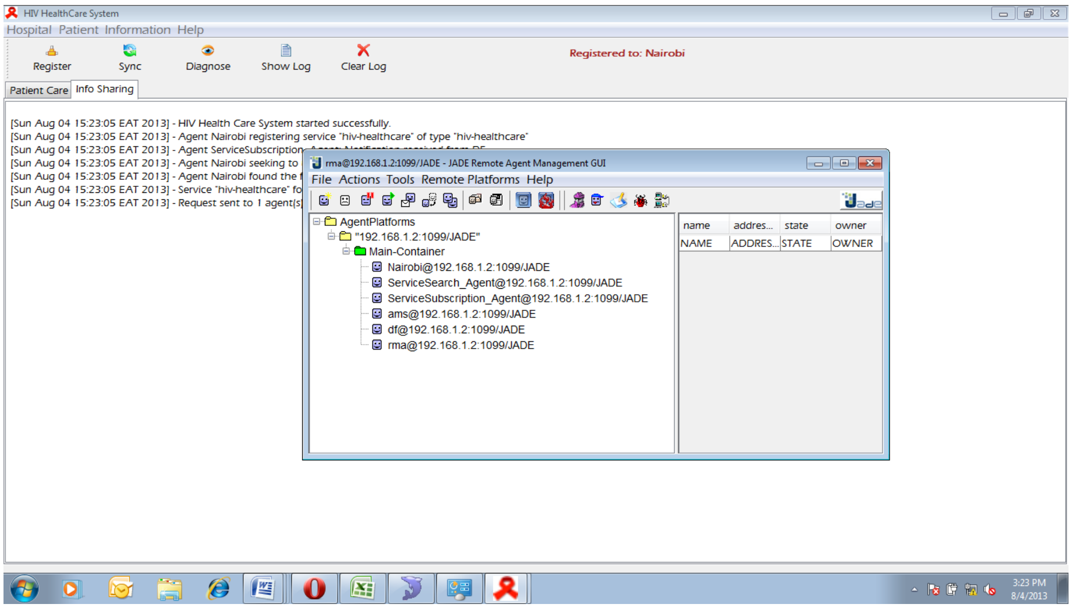


Figure 10. Healthcare Agent system main container at Nairobi Hospital

At the same time the Healthcare system is being launched, Respective Electronic Management record system is activated, in this case the research has narrowed down to OpenEMR.

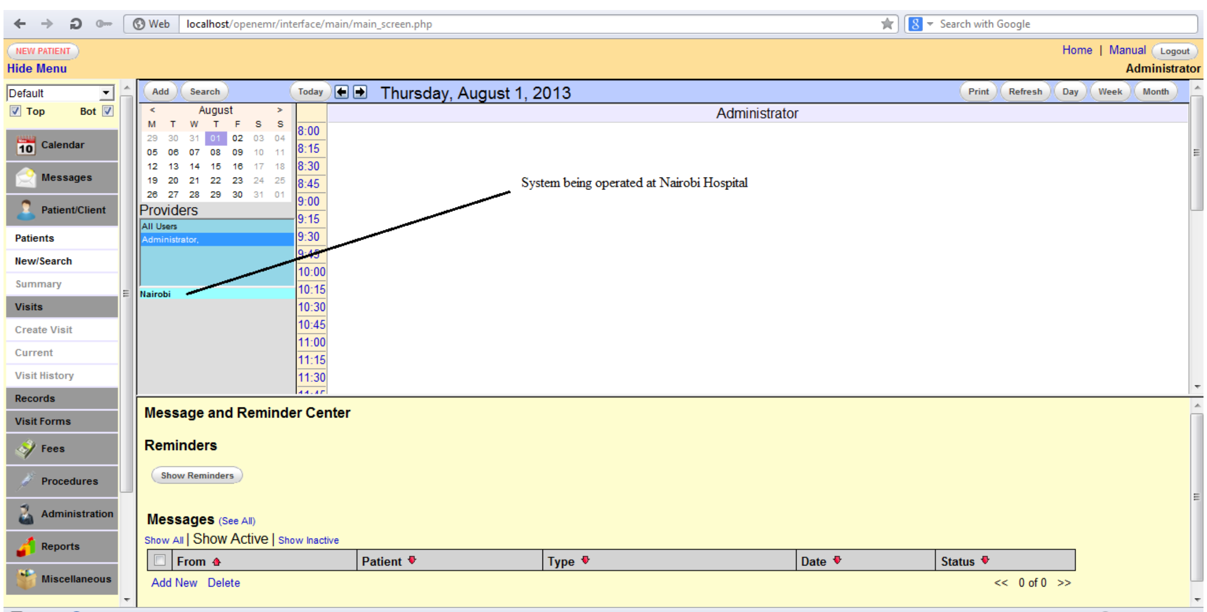


Figure 11: OpenEMR running on a local host

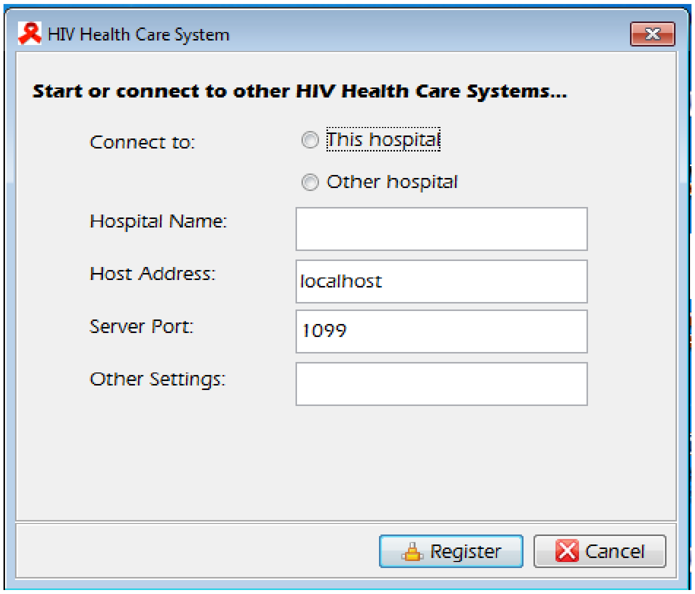


Figure 12 : Healthcare system Establishing connection

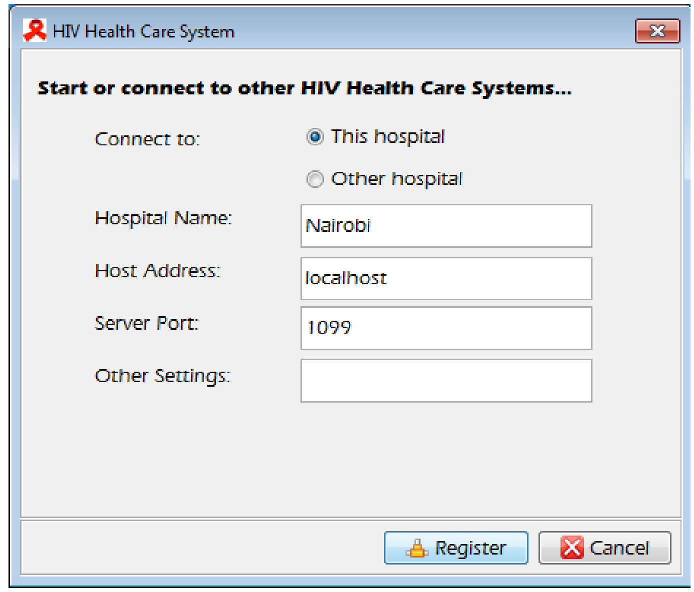


Figure 13: Healthcare system connecting to Nairobi Hospital

In Figure 12, the healthcare provider need to establish connection to a given hospital, the initial connection must be linked to the host hospital (Figure 9) where the main container is contained; In this case the system connects to Nairobi Hospital. Subsequent connection to other hospitals can be added as shown below.

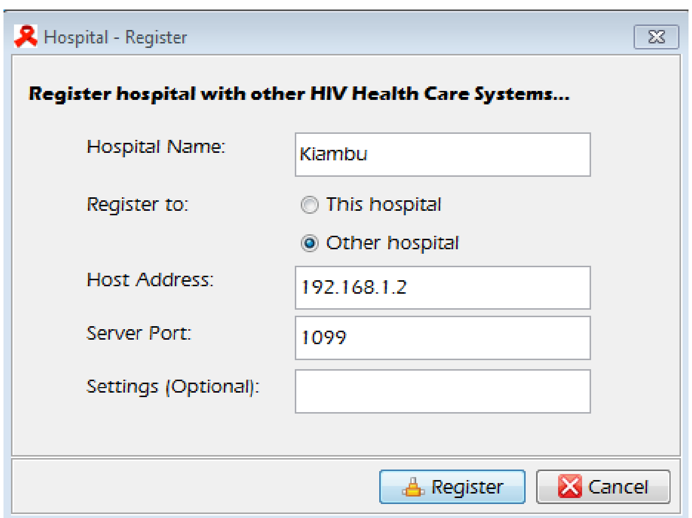


Figure 14: Healthcare system with main container at Nairobi Hospital being connected to additional container (Kiambu hospital)

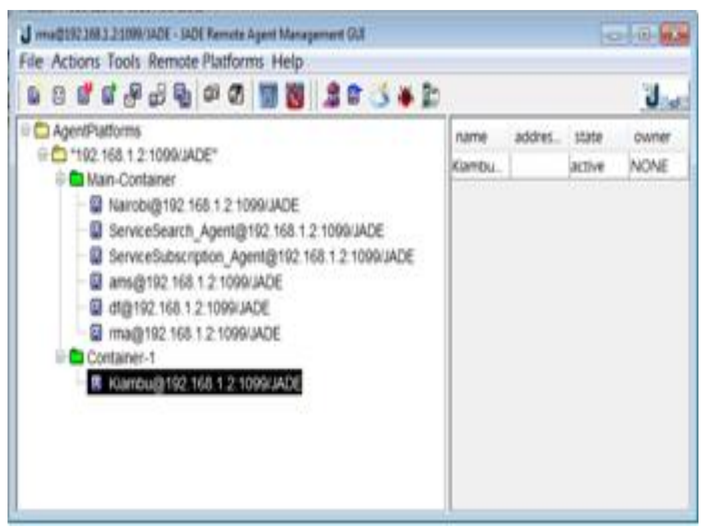
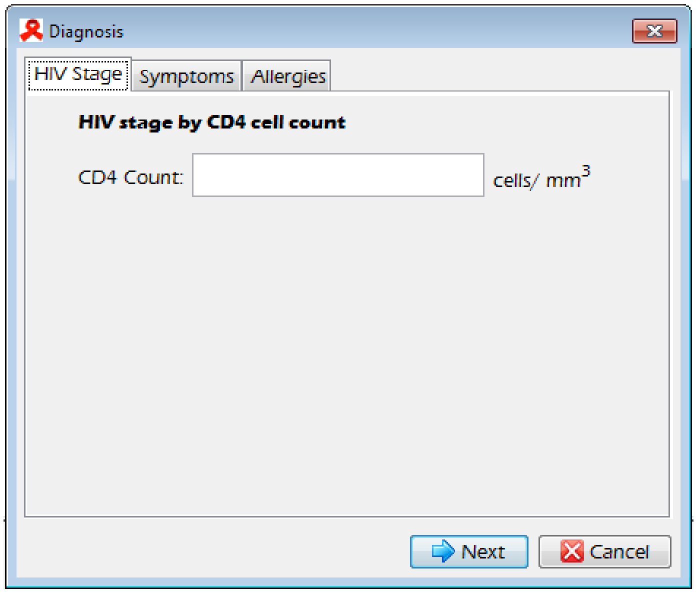


Figure 15 : Healthcare system Establishing connection to remote hospital at Kiambu (Kiambu District Hospital)



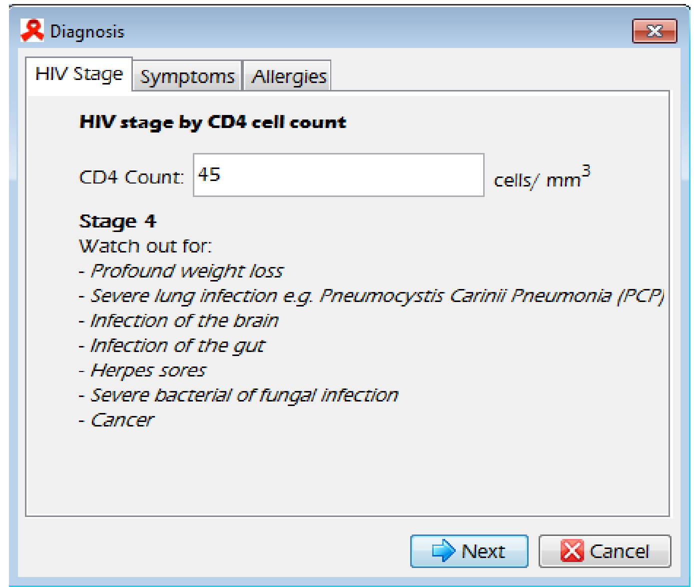


Figure 16: *System Requirement - CD4 Check*

Figure 17 : *Advice on Symptoms review*

Whereas Electronic Medical systems (OpenEMR) focuses on capturing patient demographic details, medical history and clinical data , The HIV healthcare systems primarily focuses on collecting HIV information from all the EMR and aggregating the same to aid in decision support. Based on this the, the second main requirement is to provide the patient CD4 Count to help in identifying the degree of infection. On providing the CD4 Count a request is sent to the knowledge base and the healthcare provider get support on the common symptoms to test and verify from the patient.

Respective Vitals and triage are conducted to test the medical problems associated with the reflected symptoms. At the third stage; the agent request for patients medical symptoms from the clinical database and update the knowledge base whereby the healthcare provider is supported with a list of medical problems and their associated symptoms. We can have one symptoms or a multiple combination of symptoms. The main category of symptoms in HIV patients include General problems like weight loss and fatigue, Skin problems like rashes and sores, heent like swollen lymph nodes and headache, Cardiovascular like short breath and heart attack. More details on table 6.

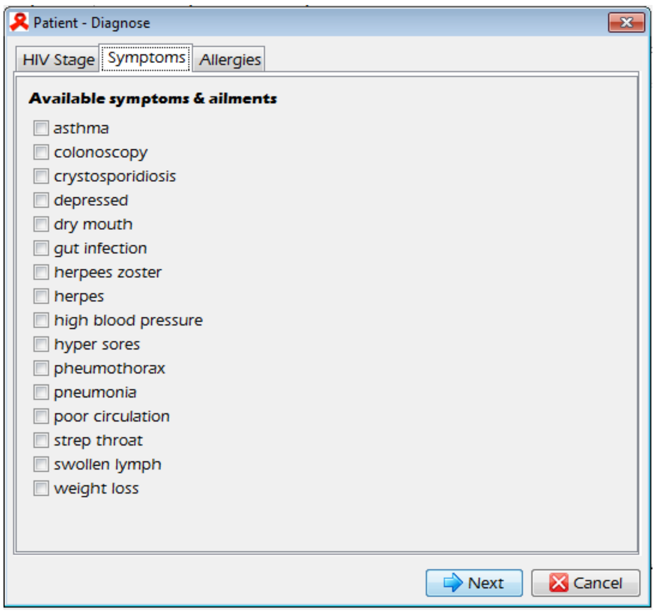


Figure 18: Symptoms noted

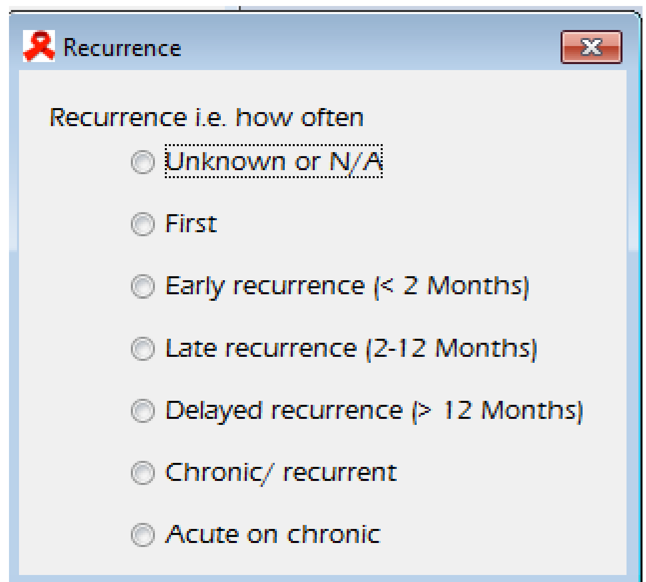


Figure 19: Rate of recurrence for each symptom

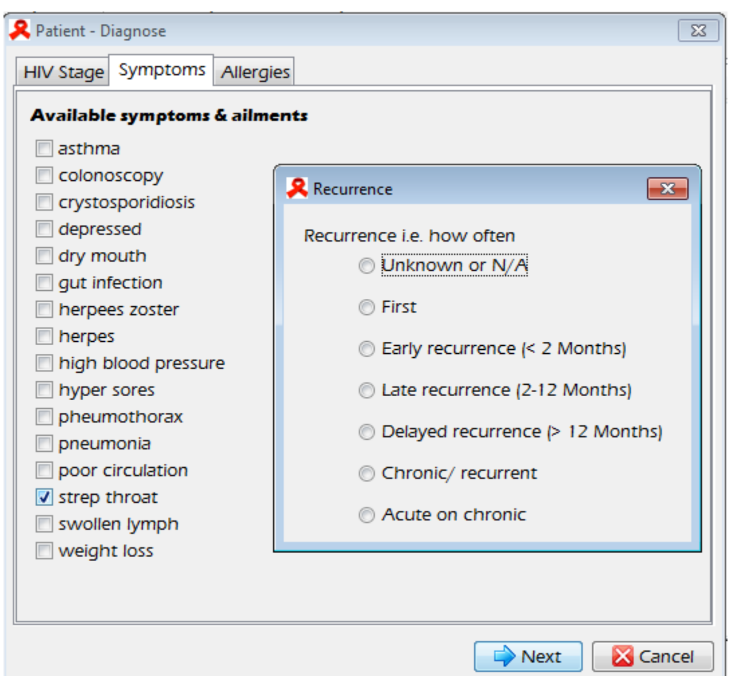


Figure 20: Symptoms and rate of recurrence

Diverse patients react differently to various medications hence the healthcare provider need support in identifying allergic medications; in this case the healthcare systems support the healthcare provider with knowledge of existing and emerging allergies resultant from reaction with medications or other causes. The Service search agent identifies other agents offering HIV service and sends a request for information on noted allergies, information on identified allergies is collected to the knowledge base for analysis. Medications causing allergic reaction should be given low priority or not issued at all in prescription.

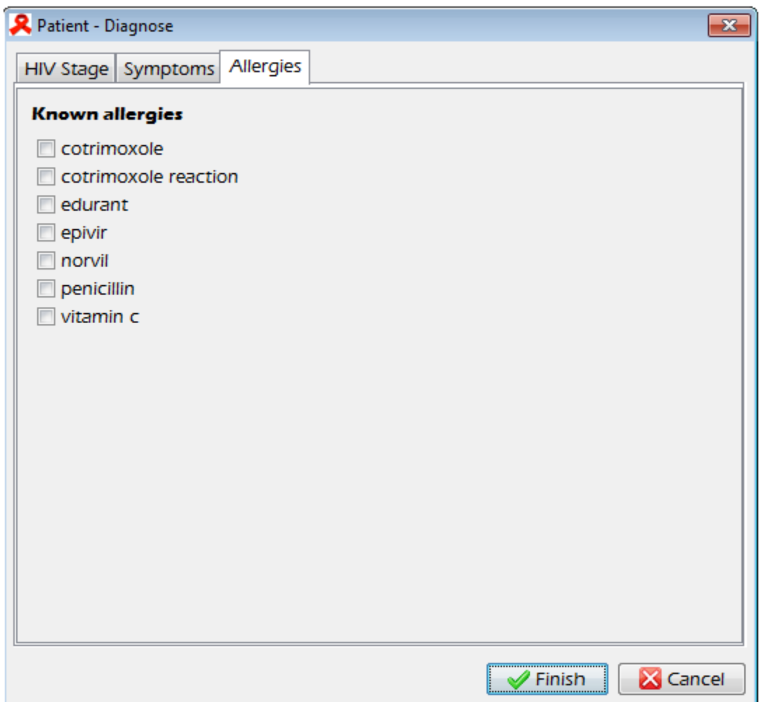


Figure 21: Allergies

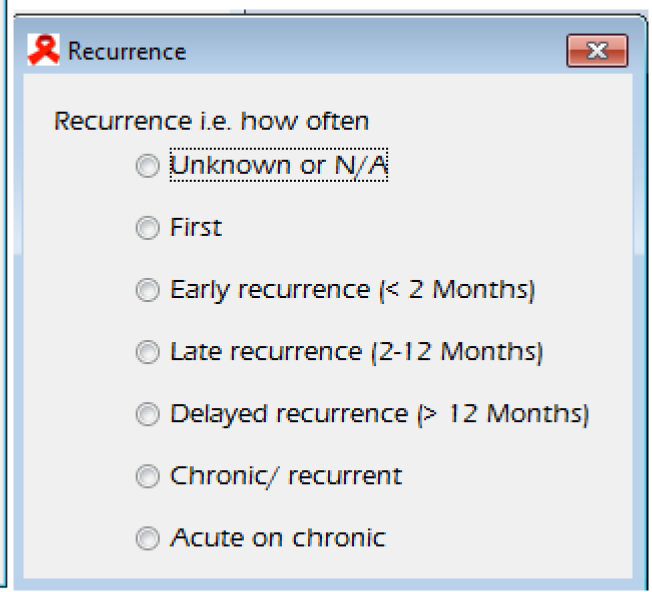


Figure 22: Recurrence of allergies

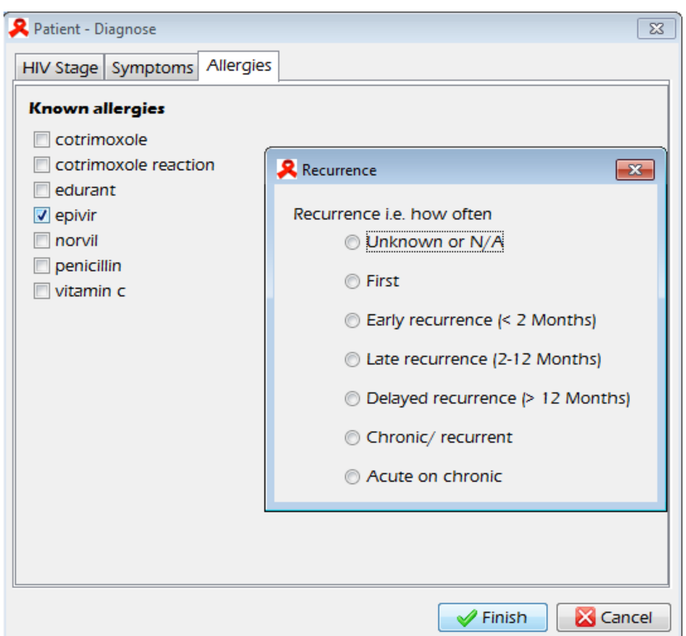


Figure 23: Allergies and rate of recurrence

The agent based healthcare system finally gives the healthcare provider information on the noted opportunistic infection and medication which had the positive outcome. The agent search for all data related to HIV, then narrow down to specific issues based on symptoms, recurrence and allergic reaction. Once the information is received at the knowledge base, decision trees perform analysis to identify the treatment which is highly recommended.

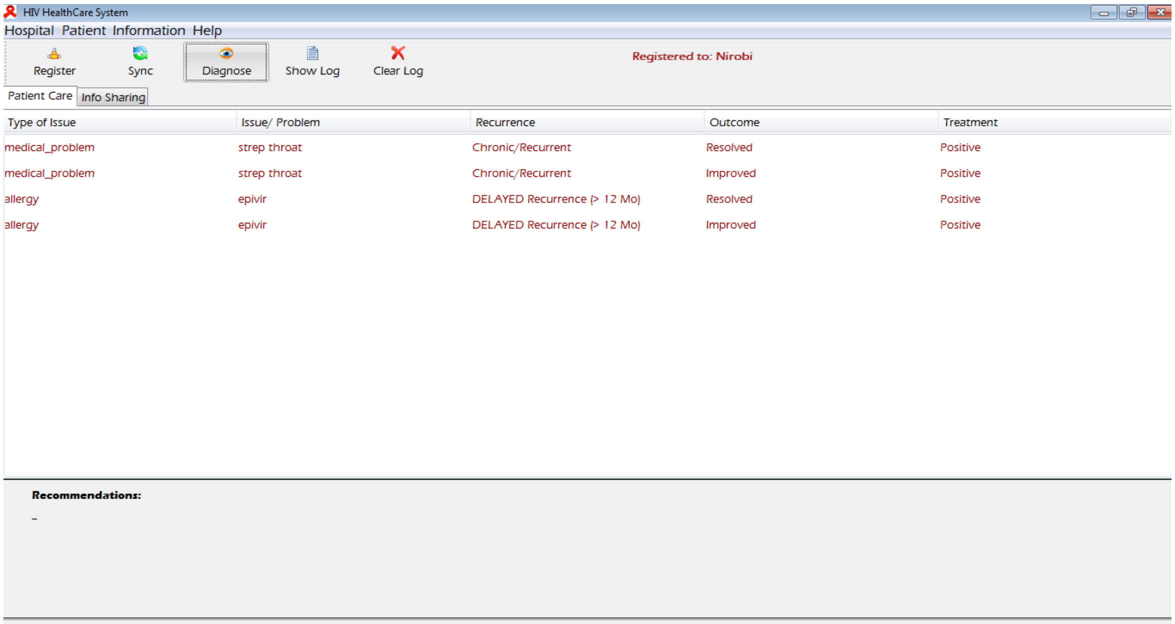


Figure 24: Healthcare system results

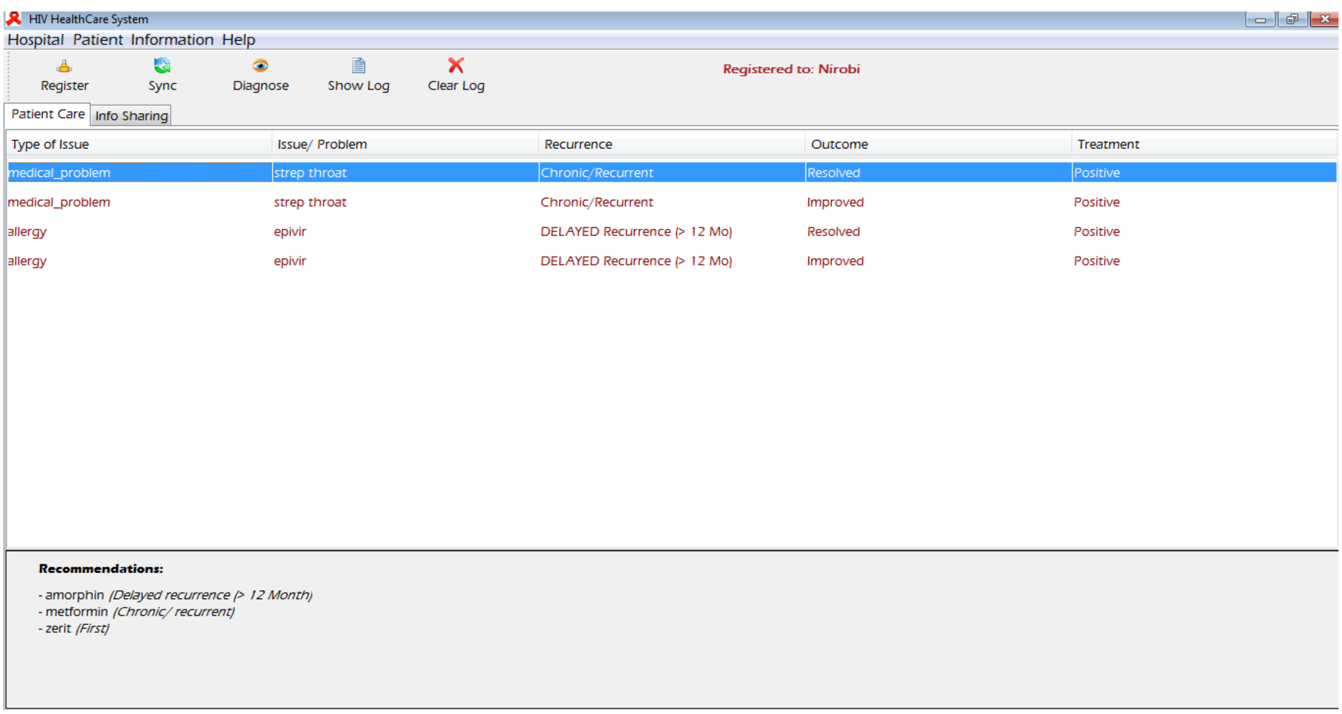


Figure 25 Healthcare system recommendation

6.3 EVALUATION RESULT

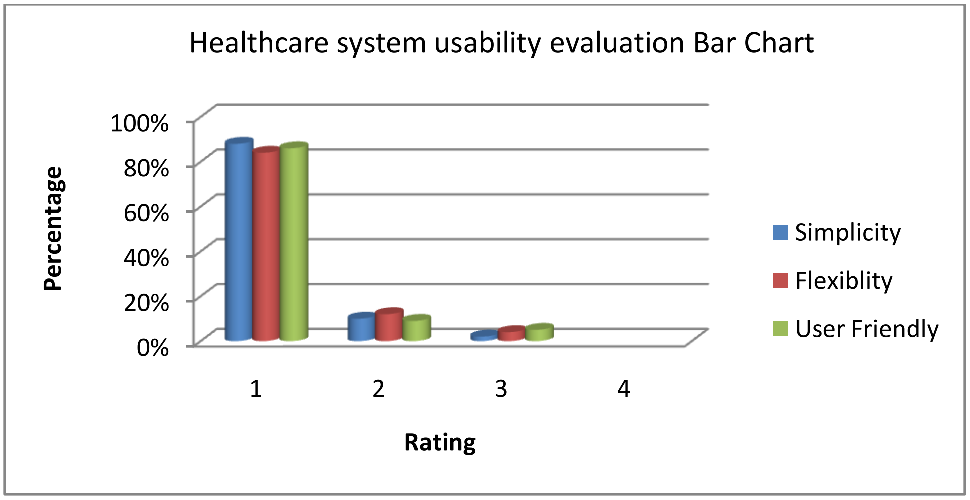


Figure 26: System Usability chart

After engaging several respondent 78% were comfortable with simplicity of the system, 18% rated it fair and 4% were to the opinion that usability is low. 80% of the respondent rated the system simplicity as good, 18% fair and 18% low. In terms of System flexibility 80% of the respondent rated the system as good, 21% fair and 4% low. Finally, on user friendliness 78% of the respondent rated the system simplicity as good, 18% fair and 4% low.

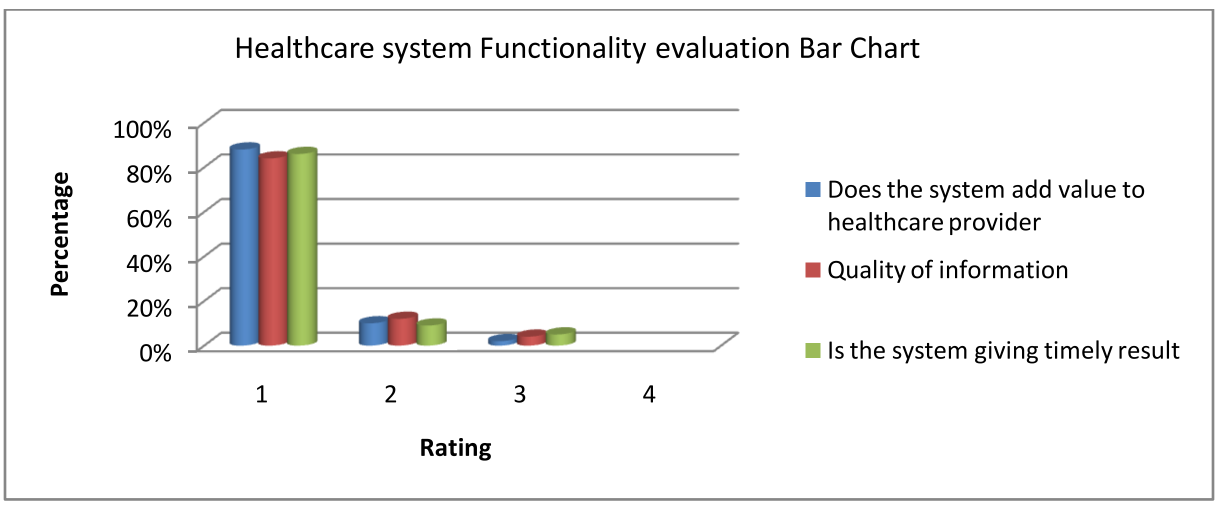


Figure 27: System Evaluation chart

88% of the respondent agreed the healthcare system is adding value to healthcare providers, 84% were satisfied with nature of information provided and 86% were happy with the rate in which the system was searching, analysing and giving result. In average 86% of the respondent agreed the healthcare system functionality is good, 10% rated the system functionality as fair and 4% didn't comment on the system.

Chapter 7

7.1 Conclusion

The healthcare system is targeted to bridge the gap of healthcare provider incapacity to process numerous variables treatment outcomes based on existing opportunistic infections. The research have aimed to add value to healthcare providers by using Agents to reduces the amount of time taken to collect data, aggregate it, analyze by using cooperation strategies to eliminate conflict associated with tiresome decision making processes. Decision trees have been integrated into the system to offer the HIV patient an administration option that is likely to result in the greatest expected value in terms of quality health, complication, allergies and other factors.

The research is undertaken by using JADE to design agents and application is demonstrated by incorporating OpenMRS to provide patient management system and clinical data records. Training data was used in learning and performance reviewed to enhance system usability.

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Opportunistic infections

	General	Skin	HEENT	Cardiovascular	Endocrine	Pulmonary	Genitourinary	Gastrointestinal	Musculoskeletal
1	Fever	Rashes	Cataracts	Heart Attack	Insulin Dependent Diabetes	Emphysema	Kidney Failure	Discharge From Urethra	Osetoarthritis
2	Chills	Infections	Cataract Surgery	Irregular Heart Beat	Non-Insulin Dependent Diabetes	Chronic Bronchitis	Kidney Stones	Stomach Pains	Rheumotoid Arthritis
3	Night Sweats	Ulcerations	Glaucoma	Chest Pains	Hypothyroidism	Interstitial Lung Disease	Kidney Cancer	Peptic Ulcer Disease	Lupus
4	Weight Loss	Pemphigus	Double Vision	Shortness of Breath	Hyperthyroidism	Shortness of Breath	Kidney Infections	Gastritis	Ankylosing Spondlilitis
5	Poor Appetite	Herpes	Blurred Vision	High Blood Pressure	Cushing Syndrome	Lung Cancer	Bladder Infections	Endoscopy	Swollen Joints
6	Insomnia		Poor Hearing	Heart Failure	Addison Syndrome	Lung Cancer Surgery	Bladder Cancer	Polyps	Stiff Joints
7	Fatigued		Headaches	Poor Circulation		Pheumothorax	Prostate Problems	Colonoscopy	Broken Bones
8	Depressed		Ringing in Ears	Vascular Surgery			Prostate Cancer	Colon Cancer	Neck Problems
9	Hyperactive		Bloody Nose	Cardiac Catheterization			Kidney Transplant	Colon Cancer Surgery	Back Problems
10	Exposure to Foreign Countries		Sinusitis	Coronary Artery Bypass			Sexually Transmitted Disease	Ulcerative Colitis	Back Surgery
11			Sinus Surgery	Heart Transplant			Burning with Urination	Crohn's Disease	Scoliosis
12			Dry Mouth	Stress Test				Appendectomy	Herniated Disc
13			Strep Throat					Diverticulitis	Shoulder Problems
14			Tonsillectomy					Diverticulitis Surgery	Elbow Problems
15			Swollen Lymph Nodes					Gall Stones	Wrist Problems
16			Throat Cancer					Cholecystectomy	Hand Problems
17			Throat Cancer Surgery					Hepatitis	Hip Problems
18								Cirrhosis of the Liver	Knee Problems
19								Splenectomy	Ankle Problems
20									Foot Problems

Table 6.0 Opportunistic Infections

Sample Usability evaluation form

Name

Attributes	Components to be evaluated	Measurements methods	Indicators		
Usefulness	Did you use the systems when registering patients?	Data validation/ Observation of Clinical system/ User friendly	Good	Fair	Low
Simplicity	Are you able to collect all information from the patient as needed?	Data validation	Good	Fair	Low
Flexibility	Are the data collection tools modifiable?	Healthcare system	Good	Fair	Low
Additional comments					

Functionality evaluation form

Attributes	Components to be evaluated	Measurements methods	Rating		
Data quality	Is patient information entered correctly	Data validation/ Quality of information	Good	Fair	Low
Acceptability	Do you feel the healthcare system is useful?	Staff Survey/ does the system add valu	Good	Fair	Low
Timeliness	How long it take to assist a patient?	Time-flow analysis/ Is the system giving timely result	Good	Fair	Low
Additional comments:					

Tutorial

1. How to "Register" a hospital

HIV Health Care is a networked system. The system may either register with itself or with other hospitals.

   i. Run the application or click on "Hospital > Register"
   ii. Type the name of the hospital
   iii. Select which hospital to register with i.e. this hospital of other
   iv. Input the host and port address of the hospital to register with
   v. Input any optional settings
   vi. Click "Register"
   vii. If you register with "this hospital" 2 main GUI will show i.e. HealthCare and Jade RMA.
   viii. If you register with "other hospital", a notification will be identified on the other end (hospital).

2. How to diagnose a patient
   i. Click on "Patient > Diagnose"
   ii. Enter patient's CD4 cell count. Observe the HIV stage symptoms indicated to watch.
   iii. Click "Next". Select patient's symptoms and ailments. For each item, select "Recurrence".
   iv. Click "Next". Select patient's known allergies. For each item, select "Recurrence".
   v. Click "Finish"
   vi. Results will show on the main window on a grid.
   vii. Click on each grid item to view "Recommendations" for particular issues.

3. How to "Sync" data with other hospitals

   This can be achieved in 2 was

   i. Click on "Sync"
   ii. Or wait for agents to do this on timer

4. How to view action log
   i. Click on "Information > View Log"
   ii. Click on "Information > Clear Log" to clear