Fuzzy Model For Management Of Hiv/Aids Patients

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Abstract

HIV/AIDS represents major public health problems in Nigeria. The harmful effects of HIV virus to the human body cannot be underestimated. In this research, a fuzzy model for the management of HIV/AIDS (FMMHIV) was presented for providing decision support platform to HIV/AIDS researchers, physicians and other healthcare practitioners in HIV endemic regions. The developed FMMHIV composed of four components which include the Knowledge base, the Fuzzification, the Inference engine and Defuzzification components. Triangular membership function was used to show the degree of participation of each input parameter (CD4+ and Viral Load) and the defuzzification technique employed in this research is the Centre of Gravity (CoG). The fuzzy expert system was designed based on clinical observations, medical diagnosis and the expert's knowledge. We selected 30 patients with HIV positive from HIV clinic Federal Teaching Hospital Gombe and computed the results that were in the range of predefined limit by the domain experts. The result of the model was tested using confusion matrix and found 87.1% accurate with 12.9 percentage error. HIV careers with tuberculosis (TB) and pregnant women are not considered in this work.

Keywords: *Fuzzification; Fuzzy Logic; Fuzzy Model; Fuzzy System; HIV/AIDS Patients*

I. INTRODUCTION

One of the problems that characterized the traditional method of medical diagnostic is inaccuracy and imprecision which has cause many lives. The advent of computer has led to the development of several algorithms, models and technologies to ensure accuracy and precision and this has greatly reduced the numbers of patients that dead daily in the hospitals and one of such technologies is Fuzzy logics which is a branch of artificial intelligence. Nowadays, medical diagnostic processes are carried out with the aid of computer-related technologies, which are on the increase daily. These systems are mostly based on the principles of artificial intelligence and are designed not just to diagnose based on symptoms but also prescribe treatments based on such (Awotunde et al, 2014). According to Ahmed, et al (2011), "in the medical field, many decision support systems (DSSs) have been designed, such as Aaphelp, Internist I, Mycin, Emycin, Casnet/Glaucoma, Pip, Dxplain, Quick Medical Reference, Isabel, Refiner Series System and PMA which assist medical practitioner in their decisions for diagnosis and treatment of different diseases". The proposed Medical Post-Diagnostic System (PMDS) is meant to post-diagnose HIV/AIDS patient in an expert system such as this. Fuzzy logic is chosen as the artificial intelligence tool employed in the proposed system because it is one of most efficient qualitative computational methods.

A fuzzy expert system is a form of artificial intelligence that uses a collection of membership functions (fuzzy logic) and rules (instead of Boolean logic) to reason about data. The mathematical representation of fuzziness based on such terms as tall, old and hot. While classical logic operates with only two values 1 (true) and 0 (false), Lukasiewicz introduced logic that extended the range of truth values to all real numbers in the interval between 0 and 1. He used a number in this interval to represent the possibility that a given statement was true or false, which is called possibility theory (Lukasiewicz, 1930). Zadeh extended the work on possibility theory into a formal system of mathematical logic, and even more importantly, he introduced a new concept for applying natural language terms. This new logic for representing and manipulating fuzzy terms was called fuzzy logic (Zadeh, 1965).
In recent years, computational intelligence has been used to solve many complex problems by developing intelligent systems. And fuzzy logic has proved to be a powerful tool for decision making systems, such as expert systems and pattern classification systems. Fuzzy set theory has already been used in some medical expert systems (Nguyen, 2000).

Klaus (2015), Patient-specific diagnostic and therapeutic decision support will become a part of every medical information system in the near future. Hospital information systems are being equipped with rule firing mechanisms to automatically generate intelligent alerts, warnings, and recommendations to the attending

physician. A rule editor with access to medical data dictionaries allows the user to define rules on contraindication alerts, drug interaction warnings, diagnostic and treatment recommendations, etc. Due to the inherent fuzziness of linguistic concepts in medicine, first, the data-to-concept conversion step and, second, any modeling of knowledge in medicine can employ fuzzy set theory and its derived theories to model interpreted medical entities such as recounted patient history items, perceived physical signs, interpreted laboratory measurements, pathophysiological states, diagnostic, therapeutic, and prognostic concepts as type-n fuzzy sets. Any n-ary relationship between these fuzzy concepts that is used to model medical knowledge may itself be fuzzy (Klause, 2015).
Elaine Rich defined Artificial Intelligence as the study of how to make computers do things at which, at the moment, people are better. Humans are still better in many fields (e.g. understanding pictures, learning ability) likewise Computers are already better in many fields (e.g. playing chess) (Elaine Rich, 2013). According to the father of Artificial Intelligence John McCarthy, it is "The science and engineering of making intelligent machines, especially intelligent computer programs" (John McCarthy,1955).

Modern automatic control systems in manufacturing or process industries face Increasing demands regarding performance, product quality, energy, and material consumption. On the one hand, these demands have led to a stronger integration of the processing stages and subsystems, on the other hand to plant-wide hierarchical information and control systems with various man–machine interfaces integrating control, scheduling, supervision, fault detection, and diagnosis. Consequently, the processes to be controlled as well as the control systems have become far more complex. In addition, nonlinear behavior and time-varying characteristics of the processes have to be taken into account. Furthermore, especially on the higher level of automation systems, information is partly incomplete, vague, and imprecise. For automatic control in consumer products, transportation systems, machines, and so on, analog trends can be observed.

Fuzzy systems, along with the related computational intelligence techniques, promise to be a powerful tool for solving automation tasks characterized by the problems mentioned. This should be especially the case when the process to be controlled is not amenable to conventional modeling techniques, information of different sources and character has to be combined, or human expertise is to be modeled. However, a fuzzy system is only a part of an automation system applied for a particular task. It can be found in different structures, and it may replace, complement, or supervise existing subsystems. Fuzzy systems use linguistic descriptions for the variables and linguistic rules for the input– output behavior. Numerical input quantities are mapped to numerical output quantities by using fuzzification, inference, and defuzzification procedures. As a consequence, fuzzy systems can be regarded as knowledge-based and as nonlinear systems. Since the 1980s, many applications of fuzzy systems in different fields, especially in automatic control, have been reported. Nowadays, fuzzy systems are an accepted technology in automatic control. They are used for control problems in nonlinear and complex systems and for various tasks on the different levels of automatic control systems (Jens, 2002).
Expert systems (ES) are a branch of applied artificial intelligence (AI), and were developed by the AI community in the mid-1960s. The basic idea behind ES is simply that expertise, which is the vast body of task-specific knowledge, is transferred from a human to a computer. This knowledge is then stored in the computer and users call upon the computer for specific advice as needed. The computer can make inferences and arrive at a specific conclusion. Then like a human consultant, it gives advices and explains, if necessary, the logic behind the advice (Shu, 2004). ES provide powerful and flexible means for obtaining solutions to a variety of problems that often cannot be dealt with by other, more traditional and orthodox methods.

A multi-agents system is a system that contains a set of agents that interact with communications protocols and are able to act on their environment. Different agents have different spheres of influence, mainly because of their control (or at least an influence) on different parts of the environment. In some cases, these spheres of influence may overlap which causes dependency of reports between the agents (Wooldridge, 2002).
Agent-based systems technology has generated a lot of excitement in recent years because of its promise as a new paradigm for conceptualizing, designing, and implementing software systems. This promise is particularly attractive for creating software that operates in distributed and open environments such as the internet. Recently, the great majority of agent-based systems consist of a single agent. However, with technological advancement in the Agent-based systems and the increasing demand to address complex applications, the need for systems that consist of multiple agents which communicate in a peer-to-peer fashion are becoming apparent. This Multi-Agent based System can be used in different application areas such as e-commerce and distributed information systems.

It is interesting to note that not all problems require agent based approach. Some problems need other approaches other than the agent based. Among the most important characteristics of problems that may require agent or multi-agent approach include: cases in which knowledge required to solve a problem is spatially distributed in different locations; the solution of a problem involves the coordination of the effort of different individuals with different skills and functions; the problems are quite complex and finding standard software engineering solution for them is difficult. In addition, Multi-Agent based approach can be employed in a situation where accessing the most relevant information as easily, flexibly and timely as possible becomes necessary (Moreno, 2003).

HIV causes disease by the progressive destruction of the immune cells which it infects. These are the CD4-T cells which are central to maintaining and measuring a healthy immune system. Without a strong immune system, we become vulnerable to opportunistic infections and HIV which normally we could fight off easily. We call these infections 'opportunistic' because HIV gives these germs an opportunity to cause disease. Gupta *et al* (2011) stated that there are different kinds of studies for data mining techniques in healthcare databases, where we can identify application fields such as Diagnosis, Prognosis, and Treatment of several diseases. Medical diagnosis is considered as an intricate task that needs to be carried out precisely and efficiently. The automation of the same would be highly beneficial. Clinical decisions are often made based on doctor's intuition and experience.

Data mining techniques have the potential to generate a knowledge-rich environment which can help to significantly improve the quality of clinical decisions. One of which is the staging and prognosis of cancer disease which can be done by transformation of qualitative data in form of text based (i.e. the biopsy report) to a quantitative one. Therefore, predicting the outcome of a disease is one of the most interesting and challenging tasks where to develop data mining applications. The human immunodeficiency virus (HIV) has changed the social, moral, economic and health fabric of the world in a short span. Today HIV/AIDS is the greatest health crisis faced by the global community. As per the 2008 UNAIDS Report this pandemic has till date killed nearly 25 million people. More than 30 million people are living with HIV, and an additional 7400 are added to this pool every day. It is expected that, if not treated, three million people will die of HIV/AIDS every year. It is estimated that of the millions of people living with HIV/AIDS (PLWHA) in developing countries, 6.7 million people require antiretroviral therapy (ART). Most of these are in 34 high-burden countries of Africa and Asia, (WHO, 2009).

Statement of the Research Problem

As a result of the scarcity of the medical personnel and resources, standard health care delivery is still a challenge in many of the developing countries like Nigeria as it is not accessible and affordable and where it is, a lot need to be done to improve it.

Although there are various Medical Diagnosis Systems that take care of early stage of patients, most of the systems are not capable of managing and monitoring patient online. Hence there is need to develop a fuzzy based model system that will also be able to manage patient and update the doctor with the patients progress for patient suffering from chronic diseases such as HIV/AIDS.

Apart from the above mentioned problem, the approach is associated with other challenges as follows:

i. The approach is associated with too much time consumption, both the pathologist and the oncologist spent much time on a single report, as such few patients are consulted.

ii. There is tendency for biasness to play a role during the interpretation (by the oncologist).

iii. Data redundancy, as for every patient, a report (on a paper) is obtained.

iv. Data inconsistency, reports/results could easily be misplaced.

v. Lack of confidentiality due to less or absence of data security.

vi. Many patients feel shy to come for the Anti-Retroviral Therapy (ART).

However, the concept of fuzzy model technique will be employed to ascertain a comprehensive interpretation of laboratory report to determine the stage and predict the prognosis of HIV/AIDS patients using Fuzzy Logic.

Research Questions:

In line with the above problem statement, the research intends to investigate and answer the following questions:

a). Could fuzzy logic be able to interpret a laboratory report more accurately to obtain an optimal management of HIV/AIDS disease?

b). For which type of tasks are fuzzy systems an appropriate means?

c). . What are the specific prerequisites and advantages of the application of fuzzy systems?

d). . How could fuzzy logic technique be used to project the state and post-diagnosis of HIV/AIDS patients?

Aim and Objectives of the Study

The primary aim of the research is to obtain an effective model that predicts the stage of HIV/AIDS patient through laboratory report and correlate it to the treatment to be administered of that patient.

Apart from this fundamental objective, the research will look at the following supplementary objectives and attempt to answer the questions in (1.3):

i. Analyze the existing and current system used in hospital.
ii. Harmonize the WHO clinical staging system with Center for Disease Control (CDC) with regard to HIV/AIDS.
iii. To develop a fuzzy model that manages HIV/AIDS patient based on the above diagnosing methods by prescribing appropriate treatment/management.
iv. To come up with a system that will serve as a global repository of information regarding HIV patients.
v. Simulate the fuzzy model prototype in other to generate reports that can aid decision making.

Significance of the Research

The traditional method of medical diagnostic is characterized with the problem of precision and accuracy. This negative impact of imprecision and inaccuracy has on the populace geared this research (Awotunde et al, 2014). It is hoped that the tools and the concepts that will be obtained from the research will lead to effective management of HIV/AIDS with lower health care cost and more importantly enable better quality of life for people living with HIV, it will also help health care workers, more specifically HIV clinic in presenting a comprehensive report. Furthermore, the study will provide basic frame work for further improvement in medical diagnosis and staging of HIV careers and finally, the research will pave a way for further academic researches, as research is a continuous process.

Contribution to Knowledge

The major contribution of this research is to develop a fuzzy model for management of HIV patients (FMMHIV). The reason for choosing fuzzy logic is to address uncertainty and vagueness that characterized traditional medical post-diagnostic practice. The system is tailor to be used in management of HIV/AIDS patients and to test the ability of fuzzy logic in managing HIC patients.

II. LITERATURE REVIEW

Fuzzy Systems

A fuzzy expert system is a form of artificial intelligence that uses a collection of membership functions (fuzzy logic) and rules (instead of Boolean logic) to reason about data. An expert system is a form of artificial intelligence that uses Boolean logic to reason about data. Boolean logic can only handle two decisions, low (0) and high (1) or only True or False, it cannot handles vague and ambiguous terms. This is the drawback of an ordinary Expert System.

An expert system approach can integrate expertise from many fields, reduce the cost of query, lower the probability of danger occurring, and provide fast response (Riley,1989). How can we represent expert knowledge that uses vague and ambiguous terms in a computer? Can it be done at all? Yes, by exploring the fuzzy set theory (or fuzzy logic), all the incapability of the expert system would be solved. Considering the philosophical ideas behind fuzzy logic and its apparatus and then consider how fuzzy logic is used in fuzzy expert systems.

Fuzzy Logic

Let consider this statement: fuzzy logic is not logic that is fuzzy, but logic that is used to describe fuzziness. Fuzzy logic is the theory of fuzzy sets, sets that calibrate vagueness. Fuzzy logic is based on the idea that all things admit of degrees. Temperature, height, speed, distance, beauty all comes on a sliding scale. Fuzzy Logic make used of words like: really hot, very tall, not very fast, average and so on. Fuzzy logic reflects how people think. It attempts to model our sense of words, our decision making and our common sense. As a result, it is leading to new, more human, intelligent systems.

Fuzzy, or multi-valued logic was introduced in the 1930s by Jan Lukasiewicz, a Polish logician and philosopher (Lukasiewicz, 1930). He studied the mathematical representation of fuzziness based on such terms as tall, old and hot. While classical logic operates with only two values 1 (true) and 0 (false), Lukasiewicz introduced logic that extended the range of truth values to all real numbers in the interval between 0 and 1. He used a number in this interval to represent the possibility that a given statement was true or false. For example, the possibility that a man 181cm tall is really tall might be set to a value of 0.86. It is likely that the man is tall. This work led to an inexact reasoning technique often called Possibility Theory.

Zadeh (1965), extended the work on possibility theory into a formal system of mathematical logic, and even more importantly, he introduced a new concept for applying natural language terms. This new logic for representing and manipulating fuzzy terms was called fuzzy logic. Zadeh became the Master of fuzzy logic. The following figure indicates the range of logical values in Boolean and Fuzzy Logic.

Medical fuzziness is impreciseness: a fuzzy proposition may be true in some degree. The word “crisp” is used as meaning “non-fuzzy”. Standard examples of fuzzy propositions use linguistic variables such as age with possible values young, medium, old or similar. The sentence “the patient is young” is true in some degree, the lower the age the more the truth. Truth of a fuzzy proposition is a matter of degree. "Fuzzy logic" in medicine has two different meanings – wide and narrow (Nguyen, 2000).

According to Klir (2012), if the knowledge of a specialism can be expressed through linguistic variables and rules of thumb that involve imprecise antecedents and consequents, then we have a basis of a *knowledge-base*.

• In this knowledge-base 'facts' are represented through linguistic variables and the rules follow fuzzy logic.

grade of their elements in the set. Larger values denote higher degrees of set membership. A set defined by membership functions is a fuzzy set. The most commonly used range of values of membership functions is the unit interval [0, 1].

The membership function of a fuzzy set *A* is denoted by: μ_A

$$\mu_A : X \longrightarrow [0,1]$$

A fuzzy set is capable of providing a graceful transition across a boundary, as shown in Figure 2 below:

		Degree of membership	
Name	Height, cm	Crisp	Fuzzy
Chris	208	1	1.00
Mark	205	1	1.00
John	198	1	0.98
Tom	181	1	0.82
David	179	0	0.78
Mike	172	0	0.24
Bob	167	0	0.15
Steven	158	0	0.06
Bill	155	0	0.01
Peter	152	0	0.00

Figure 1.2

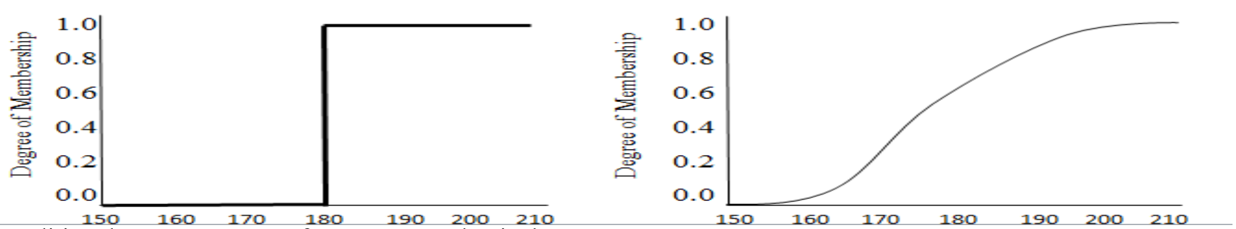


Figure 1: (a) Height, cm (Crisp) (b) Height, cm (Fuzzy)

• In traditional expert systems facts are stated crisply and rules follow classical propositional logic. The operation of a fuzzy expert system depends on the execution of FOUR major tasks:

I. Fuzzification,
II. Inference,
III. Composition,
IV. Defuzzification.

Knowledge Representation & Reasoning: The Air-conditioner Example

Recall that the rules governing the air conditioner are as follows:

RULE#1: IF TEMP *is* COLD
THEN SPEED *is* MINIMAL
RULE#2: IF TEMP *is* COOL
THEN SPEED *is* SLOW
RULE#3: IF TEMP *is* PLEASANT
THEN SPEED *is* MEDIUM
RULE#4: IF TEMP *is* WARM THEN
SPEED *is* FAST
RULE#5: IF TEMP *is* HOT
THEN SPEED *is* BLAST

Fuzzy Set

According to Klir (2012).A membership function: Values assigned to the elements of the universal set fall within a specified range and indicate the membership

HIV/AIDS

What is HIV?

According to Overview of HIV Infection, (2015). Many people see HIV and AIDS as being the same thing, and therefore assumes that someone who is HIV positive could die tomorrow. This is not true. It is important to distinguish between HIV and AIDS. HIV stands for Human Immunodeficiency Virus.

- Human: Infecting human beings
- Immunodeficiency: Decrease or weakness in the body's ability to fight off infections and illnesses
- Virus: A pathogen having the ability to replicate only inside a living cell

The 4 Stages Of HIV Disease (WHO, 2009):

1. Primary HIV infection, the asymptomatic or 'silent' stage
2. Early HIV symptomatic disease
3. Medium-stage HIV symptomatic disease
4. Late-stage HIV symptomatic disease (AIDS).

At normal circumstance, a healthy person that if free from HIV has cells free of virus (HIV). After infection, the virus will come into a cell and accommodates itself in the cell and keep replicating in the cell, after some times the hosting cell will burst up and the rate of the virus will increase in the human body and attack other free cells. As illustrated in Figure 2, The first is a model for the interaction between replicating virus and host cells. In this case there are three variables: uninfected cells *n*, infected cells *i*, and free virus particles *v*. infected cells are produced from uninfected cells and free virus at rate *βnv*and die at rate *bi*. Free virus is produced from infected cells at rate *ki*and declines at rate *sv*. Uninfected cells are produced at a constant rate, *r*, from a pool of precursor cells and die at rate *an*.

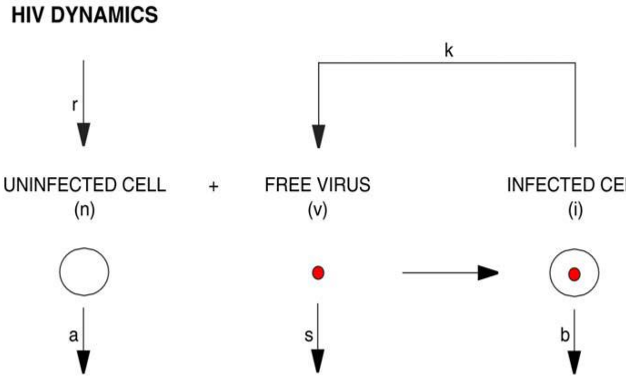


Figure 2: Microscopic models of HIV virus dynamics

When HIV reaches the bloodstream, it attacks mainly the lymphocyte T of the *CD*4+ type. The amount of cells *CD*4+ in periferic blood has prognostic implications in infection evolution by HIV. Nowadays, the amount of immunecompetence cells is the most clinically useful and acceptable measurement for the treatment of infected individuals by HIV, although it is not the only one. We may classify the amount of *CD*4+ cells ml−1 in the peripheral blood in four ranges.

Application of Fuzzy Systems on Medical Fields

From the application point of view, fuzzy systems can be referred to as knowledge-based systems on the one hand and nonlinear systems on the other hand. A fuzzy system describes relations between variables using a set of if–then rules, such as if the control error is positive small and the change of error is negative small, then the manipulated variable should be approximately zero. The values of the variables, here, control error, change of error, and manipulated variable, are specified by linguistic terms (values) here, such as positive small, approximately zero, which receive their meaning from the associated fuzzy sets (Jens, 2002).

Klaus (2015), has developed a FuzzyTempToxopert that interprets toxoplasmosis serology test results obtained in the course of screening for ***Toxoplasma gondii***infections in pregnant women. The antibody tests are performed at the toxoplasmosis laboratory of the Department of Pediatrics and Adolescent Medicine in the Vienna General Hospital. FuzzyTempToxopert interprets them in the course of time and automatically provides a diagnostic interpretation and, most importantly, therapeutic recommendations to avoid fetal damage or subsequent harm to the child.

Awotunde, et al (2014), developed a medical diagnostic system using fuzzy logic; so as to enhance the accuracy and precision of medical diagnosis. The medical diagnostic system was developed using Visual Prolog Programming language. The system proffers solution to the enormous responsibilities of the diagnostic process carried out by medical personnel using fuzzy logic. More advance medical diagnosis system can be designed to help in the area like drugs prescription, registering of patients as well as keeping of patients' details and records in the medical sector. A number of medical diagnostic systems have been developed based on fuzzy logic model and have been employed in the diagnosis and treatments of diabetes, cancer and many more. For example, a system called DIAGAID has been developed by Turku University Hospital and the system is based on fuzzy logic. Fuzzy logic has been used variously in the field of medicine; some of the recent research works in the area of medicine using fuzzy logic are as follows: 1. Fuzzy logic controller (FLC): This is used in medical devices as the control unit 2. Fuzzy logic has also been used in data analysis to evaluate facial expression and the behaviour of human.

Rodolf et al (2004). The first *c*omputer-*a*ssisted *diag*nostic system based on two-valued logic in 1968 with the collaboration between physicians and mathematicians, and engineers constructed. One year later Gangl, Grabner, and Bauer published their first experiences with this system in the differential diagnostics of hepatic diseases. In 1976, the second generation of the system was developed on the basis of three valued logic. Here, in addition to symptoms and diagnoses being considered to be .present. or .absent., .not examined. or .not investigated. symptoms and .possible. diagnoses are also included. For this system known as CADIAG-I (*C*omputer- *A*ssisted *DIAG*nostis, version I).

DanijelaTadić, et al (2010), developed a new fuzzy model (FMOTPD2) to evaluation and Management of therapeutic procedure in Diabetes mellitus on individual level for patients with type 2 diabetes is presented. The advantages of developed model according to literal sources are: criteria according to which a drug is being evaluated, criteria according to which a state of health of each patient is being determined, the relative importance of defined criteria, possible drugs and possible therapeutic procedures according to Clinical Guidelines for Diabetes and values of uncertain criteria. They determined the rank of considered therapeutic procedures for each treated patient and flexible according to the possibility of number change, kind of optimization criteria change and importance of optimization criteria change. The proposed fuzzy model is suitable for software development.

A research delineates a model of a fuzzy expert system, dedicated to Parkinson's disease diagnosis. The proposed system proves to be fast, efficient, and non-invasive and can be used by both physicians and patients at home, as well.

The fuzzy expert system was designed, by using FIS Tools of MATLAB. In the fuzzy expert Systems, the achieved accuracy of diagnosing the Parkinson's disease was of 95.46%. OanaGeman (2011).

Hassan Zarei, et al (2011),present study proposes a fuzzy mathematical model of HIV infection consisting of a linear fuzzy differential equations (FDEs) system describing the ambiguous immune cells level and the viral load which are due to the intrinsic fuzziness of the immune system's strength in HIV-infected patients. The immune cells in question are considered CD4+ T-cells and cytotoxic T-lymphocytes (CTLs). The dynamic behavior of the immune cells level and the viral load within the three groups of patients with weak, moderate, and strong immune systems are analyzed and compared. Moreover, the approximate explicit solutions of the proposed model are derived using a fitting-based method. In particular, a fuzzy control function indicating the drug dosage is incorporated into the proposed model and a fuzzy optimal control problem (FOCP) minimizing both the viral load and the drug costs is constructed. An optimality condition is achieved as a fuzzy boundary value problem (FBVP). In addition, the optimal fuzzy control function is completely characterized and a numerical solution for the optimality system is computed.

Wajiga, et al (2011), came up with a fuzzy expert system for the management of malaria (FESMM) and was presented for providing decision support platform to malaria researchers, physicians and other healthcare practitioners in malaria endemic regions. The fuzzy expert system was designed based on clinical observations, medical diagnosis and the expert's knowledge. The authors believe that the approach proposed in this study, if used intelligently, could be an effective technique for diagnosing malaria. Furthermore, implementation of FESMM will reduced doctors' workload during consultation and eased other problems associated with hospital consultations. Finally, the system found so accurate.

Rosana et al, (2004), introduced a model for the evolution of positive HIV population and manifestation of AIDS (Acquired Immunodeficiency Syndrome). The focus is on the nature of the transference rate of HIV to AIDS. Expert knowledge indicates that the transference rate is uncertain and depends strongly on the viral load and the $CD4+$ level of the infected individuals. Here, we suggest to view the transference rate as a fuzzy set of the viral load and $CD4+$ level values. In this case the dynamic model results in a fuzzy model that preserves the biological meaning and nature of the transference rate λ. Its behavior fits the natural history of HIV infection reported in the medical science domain. The adherence of the transference rate is very significant. It gives medical science better estimates to control the AIDS evolution.

Ahmad E. et al (2012), in their paper, a clinical application of fuzzy logic was considered for cancer treatment by developing a fuzzy correlation model. This model act as prediction model and track the moving targets, placed in lung and abdomen regions of patient body. For this aim the internal-external markers data were utilized for fuzzy model generation (pre-treatment), operation & updating (during the treatment). Fuzzy model structure and different steps of model performance were explained graphically for a real case. Finally, a comparative investigation was preformed between fuzzy model performance and two different correlation models based on Artificial Neural Network and State model. The analyzed results represent that the fuzzy model performance is the best with less error and negligible executive time among the modelers. In general, fuzzy model features make it robust for modeling some systems that are too complex to be modeled by means of conventional mathematical techniques. The application of the fuzzy logic is also highly recommended whenever the available dataset is not qualitatively perfect or has a large degree of variability. Kantesh Kumar Oad&XuDeZhi (2015), proposed system "Fuzzy Rule Based Support System" modelled to predict heart disease intelligently and efficiently, and to replace manual efforts. Experts system can be more proficient and fast so it can be more accurate then manual work. Our system modelled to diagnosis and detecting cardiovascular diseases, the system involves two major phases, one that performs classification and diagnosis, the other one that detects the rate of risks of the respiratory diseases. For this system we have used mamdani inference system. In final this system tested and compared with Neural Network and J48 Decision Tree model to check performance of the system.

III. METHODOLOGY

Fuzzy Logic Technique and Architecture

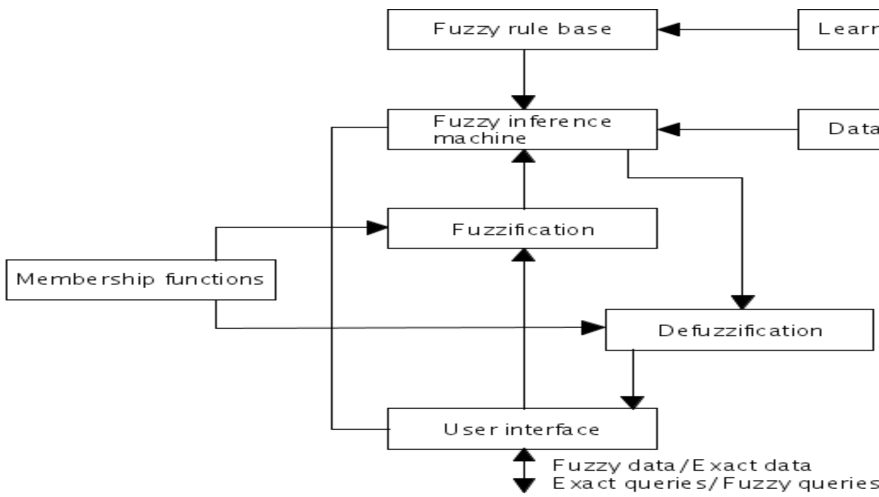
The concepts of fuzzy logic will be employed in the realization of this research. However, current fuzzy systems have the following general limitations.

1. They have no common framework from which to deal with different kinds of problems; in other words, they are problem-dependent.

2. Human experts play a very important role in developing fuzzy expert systems and fuzzy controllers.

Most fuzzy controllers and fuzzy expert systems can be seen as special rule-based systems that use fuzzy logic. A fuzzy rule-based expert system contains fuzzy rules in its knowledge base and derives conclusions from the user inputs and the fuzzy reasoning process (Kandel , 1992).

Figure 3: Typical fuzzy system



Zadeh (1965), states that Fuzzy logic is determined as a set of mathematical principles for knowledge representation based on degrees of membership rather than on crisp membership of classical binary logic. This powerful tool to tackle imprecision and uncertainty was initially introduced by Zadeh to improved tractability, robustness and low-cost solutions for real world problems. Fuzzy sets have been applied in many fields in which uncertainty plays a key role. Medical diagnosis is an excellent example of vagueness and uncertainty. Fuzzy set theory is a response to the demand for ideas and approaches for handling non statistical uncertainty. A fuzzy set is a set with fuzzy boundaries. Defined fuzzy sets or classes for each variable allows intermediate grades of membership in them, which means each set could have elements that belongs partially to it; the degree of belonging is called membership functions ranging from 0 to 1. If X is the Universe of discourse and its elements are denoted as *x* , in contrast with crisp set, then the fuzzy set A of X has characteristics function associated to it. The fuzzy set is represented by a membership function, defined as follows:

$$\mu_A : X \longrightarrow [0,1] \qquad (1)$$

$\mu_A(X) = 1$ if *x* is totally in A

$\mu_A(X) = 0$ if *x* is not in A

$o < \mu_A(X) < 1$ if *x* is partially in A.

$\mu_A(X)$ expresses to which the value *x* belongs to the fuzzy set A. The value 0 corresponds to the absolute non-membership and the value 1 corresponds to the absolute membership. Therefore, a fuzzy membership function $\mu_A(X)$ indicates the degree of belonging to some element *x* of the universe of discourse X. It maps each element of X to a membership grade between 0 and 1 in various shapes such as Triangular, Trapezoidal, Sigmoidal and Gaussian. Triangular membership function which is widely used will be used in this research. Triangular membership function can be calculated as follows:

$$\mu_A(X) = \begin{cases} 0 & \text{if } x \le a \\ \dfrac{x-a}{c-a} & \text{if } x \in [a, c] \\ \dfrac{b-x}{c-b} & \text{if } x \in [b, c] \\ 0 & \text{if } x \ge c \end{cases} \qquad (2)$$

Where *a, b,* and *c* have been defined by experts doctors. Figure 2 below shows a crisp and a fuzzy representation of a fuzzy set defined by triangular membership function of the attribute age of a patient.

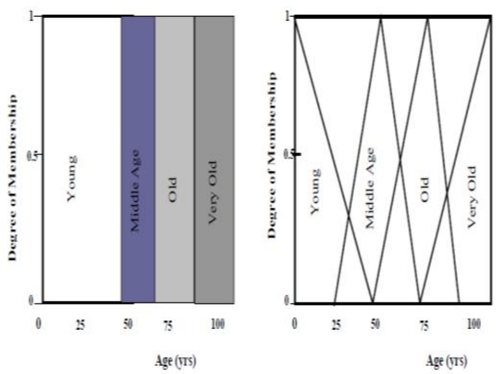


Figure 4: (Crisp and Fuzzy set of Patients' Age with their Linguistics Variables) (Wajiga, et al, 2011)

For the linguistics variable young, the values a, b, and c are 25, 50 and 75 respectively. Ability to represent linguistic variables is a prominent feature of fuzzy logic model since they can convert numeric values to linguistic variables which are highly understandable to final system users.

Fuzzy logic is usually used for building fuzzy rules that can be easily understood by humans. Therefore, it is common to describe fuzzy variables as linguistic variables. The linguistics variables that we will use in this research are mild, moderate, severe and very severe for both the input and output parameters in the fuzzy model. By using those linguistic variable, fuzzy if-then rules which are the main output of the fuzzy system would be set up: generally presented in the form of: if x is A then y is B where x and y are linguistic variables and A and B are linguistic values, determined by their fuzzy sets. The first part of the rule is called the antecedent, and can consist of multiple parts with the operators AND or OR between them. The latter part is called the consequent, and can also include several outputs.

Fuzzy Model for the Management of HIV/AIDs (FMMHIV) (Rule based)

The success of a Fuzzy Expert System depends upon the opinion of the domain experts on various issues related to the study. The domain experts identified were from Federal Teaching Hospital Gombe in Nigeria. The developed model, launched "Fuzzy Model for the Management of HIV/AIDS (FMMHIV)" has an architecture presented in figure 5 below. The development of FMMHIV involves fuzzification, inference engine and defuzzification. FMMHIV is a Rule Based model that uses fuzzy (approximate) logic rather that Boolean logic. It was developed based on the following key components:

- Knowledge Base component
- Fuzzification Component
- Inference Engine Component
- Defuzzification Component

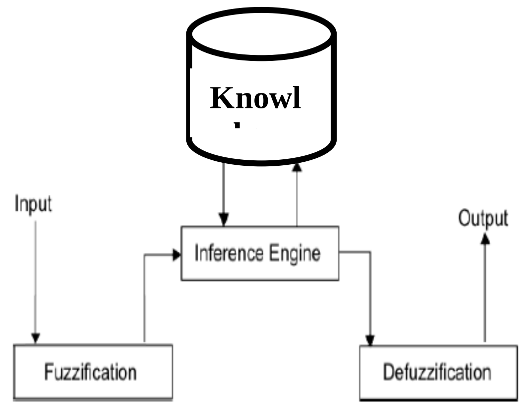


Figure 5: Architecture of FMMHIV

Linguistic variables and rule base. As we have seen, fuzzy sets are a way to represent imprecise information and knowledge. In practice, precise values of the transference rate/ stage from HIV infected to AIDS manifestation are rare, but experts do know how to evaluate the transference rate from their perception of the relationships between c, v, and λ. The estimation of the transference rate/stage $\lambda = \lambda\ (v,\ c)$ is based on linguistic medical information in the form of fuzzy if-then rules. Therefore we adopt a fuzzy rule-based modeling approach assuming, as it is the case with medical knowledge, that the viral load (v), the level of $CD4+$ (c), and the transference rate/ stage (λ) are linguistic variables denoted by V, $CD4+$ and $\wedge$, respectively.

Fuzzy rule-based systems (FRBS) have four components: an input processor, a collection of fuzzy rules called rule base, a fuzzy inference machine, and an output processor. These components process real-valued inputs to provide real-valued outputs as follows.

Fuzzification and Membership Function

Fuzzification is a process of fuzzifying all inputs and output. Determine the degree to which these inputs and outputs belong to each of the suitable fuzzy sets.

CD4+ count:

What are CD4 T lymphocytes?

Cellular components of blood comprise red blood cells and white blood cells. Two populations of leucocytes constitute the latter — the granulocytes and non-granulocytes, including the lymphocytes. Surface receptors of the lymphocytes provide identity to sub-populations of lymphocytes which differentiate into unique clusters. This property gives the subtypes of lymphocytes a nomenclature of clusters of differentiation followed by the number of the unique subtype (CD1, CD2, CD3, CD4…). CD stands for cluster of differentiation; CD numbers are now used to identify cell surface antigens that can be distinguished by monoclonal antibodies. CD4 T lymphocytes (CD4+ T-cells), commonly known as T helper cells, play a vital role in maintaining the integrity of the human immune system (WHO, 2009).

We have actually separated CD4+ count cells into fuzzy sets (law, Medium, High medium and High) and ranges of these fuzzy sets are determined in Table (1). We have used triangular Membership function for fuzzy sets as shown below from (2).

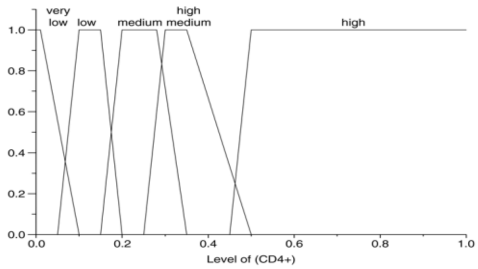
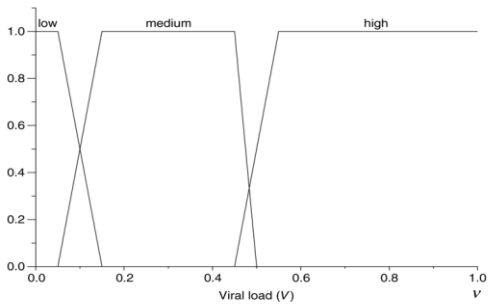


Figure 6: Membership function for CD4+ Level (c)

Viral Load:

The lower limit of detection with the standard kit is 400 RNA copies/ml and the upper limit is 750 000 RNA copies/ml. The Amplicor ultra-sensitive kit detects down to 50 copies/ml of plasma (WHO, 2009).

We have actually classified viral load into fuzzy sets (law, Medium and High) and ranges of these fuzzy sets are determined in Table (1). The triangular Membership function for fuzzy sets as shown below from (2).



Range of Fuzzy Values

Input	**Range (mm)**	**Fuzzy Sets**
COUNT	CD4+ <0.1	Very low
	0.1≤ CD4+<0.2	Low
	0.2≤ CD4+<0.35	Medium
	0.35≤ CD4+ < 0.5	High medium
	CD4+ > 0.5	High
Viral Load	V< 10,000	Law
	10,000≤VL<100,000	Medium
	VL > 100,000	High

Input	**Range (mm)**	**Fuzzy Sets**
CD4+ COUNT	CD4+ <100	Very low
	100≤ CD4+<200	Low
	200≤ CD4+<350	Medium
	350 ≤ CD4+ < 500	High medium
	CD4+ > 500	High
Viral Load	V< 10,000	Law
	10,000≤VL<100,000	Medium
	VL > 100,000	High

Table 1: Risk factors and Ranges

Fuzzification begins with the transformation of the raw data using the functions that are expressed in equations (3) below. During the process, linguistic variables are evaluated using triangular membership function and are accompany by associated degree of membership ranging from 0 to 1 as shown in equations (3) below. These formulae are determined by aid of both the expert doctors in the field of HIV and literature.

$$\mu_{CD+}(X) = \begin{cases} 0 & \text{if } x \leq 0.1 \\ \frac{x - 0.1}{0.1} & 0.1 \leq CD4+ < 0.2 \\ \frac{0.2 - x}{0.15} & 0.2 \leq CD4+ < 0.35 \\ 1 & CD4+ > 0.5 \end{cases} \quad (3)$$

Rules Evolution

In Fuzzy Rule Base System, rules play an important role in the prediction. The rules deliver/provide a sense to linguistic variables and MF (membership function). So we have occupied these fuzzyfied inputs in antecedent part of the rules. In this research, we have actually utilized fifteen (15) rules to HIV management is a patient. In our system antecedent part of the rule consist of only single part that will opinion result of antecedent development. Fuzzy logic will govern risk level and this prediction indeed relies on rules that we have made.

Fuzzy Rule base for HIV/AIDs

Viral load *V* has its values in {*low, medium, high*}, *CD4+* in {*very low, low, medium, high medium, high*}, and transference rate/ Stage $\wedge$in the term set {*weak, medium weak, medium, strong*}. The membership functions that specify the meaning of the linguistic variables are shown in Figs. (5) and (6) for *CD4+ level*, and *viral load* respectively. The rule bases that encode the relationships between *c*, *v*, and λ suggested by expert medical knowledge are as follows:

No. of Rule	Viral Load (v)	CD4+ (C)	Stage(∧)	Conclusion
1	Low	Very low	Strong	Stage IV
2	Low	Low	Medium	Stage III
3	Low	Medium	Medium	Stage III
4	Low	High Medium	Weak Medium	Stage II
5	Low	High	Weak	Stage I
6	Medium	Very low	Strong	Stage IV
7	Medium	Low	Strong	Stage IV
8	Medium	Medium	Medium	Stage III
9	Medium	High Medium	Weak Medium	Stage II
10	Medium	High	Weak	Stage I
11	High	Very low	Strong	Stage IV
12	High	Low	Strong	Stage IV
13	High	Medium	Medium	Stage III
14	High	High Medium	Medium	Stage III
15	High	High	Medium	Stage III

Table 2: Rule base for HIV/AIDS

The rules can be interpreted as follows:
1. If *V* is *low* and *CD4+* is *very low* then ∧is *strong*.
2. If *V* is *low* and *CD4+* is *low* then ∧is *medium*.
3. If *V* is *low* and *CD4+* is *medium* then ∧is *medium*.
4. If *V* is *low* and *CD4+* is *high medium* then ∧is *weak medium*.
5. If *V* is *low* and *CD4+* is *high* then ∧is *weak*.
6. If *V* is *medium* and *CD4+* is *very low* then ∧is *strong*.
7. If *V* is *medium* and *CD4+* is *low* then ∧is *strong*.
8. If *V* is *medium* and *CD4+* is medium then ∧is *medium*.
9. If *V* is *medium* and *CD4+* is *high medium* then ∧is *weak medium*.
10. If *V* is *medium* and *CD4+* is *high* then ∧is *weak*.
11. If *V* is *high* and *CD4+* is *very low* then ∧is *strong*.
12. If *V* is *high* and *CD4+* is *low* then ∧is *strong*.
13. If *V* is *high* and *CD4+* is *medium* then ∧is *medium*.
14. If *V* is *high* and *CD4+* is *high medium* then ∧is *medium*.
15. If *V* is *high* and *CD4+* is *high* then ∧is *medium*.

Staging System for HIV/AIDS

HIV/AIDS has been categorized based on two dimensions: CDC and WHO as follows:

I. Center for Disease Control (CDC): This body has classified HIV/AIDS disease based on Viral load and CD4+ laboratory test into two:

(a) First line: HIV/AIDS patient would be on this line if his/her CD4+ count cells is greater than 350mm^3 (CD4+>350mm^3).

(b) Second Line: A patient will be on second line if his/her CD4+ is less than 350mm^3 (CD4+ < 350mm^3).

II. World Health Organization (WHO) Clinical Staging System: WHO classified HIV/AIDS into four (4) categories based on signs and symptoms as follows:

(a) Clinical Stage 1

• Asymptomatic
• Persistent generalized lymphadenopathy

(b) Clinical Stage 2

• Unexplained persistent hepatosplenomegaly
• Papular pruritic eruptions
• Extensive wart virus infection
• Extensive molluscumcontagiosum
• Fungal nail infections
• Recurrent oral ulcerations
• Unexplained persistent parotid enlargement
• Lineal gingival erythema
• Herpes zoster
• Recurrent or chronic upper respiratory tract infections (otitis media, otorrhoea, sinusitis or tonsillitis)

(c) Clinical Stage 3

• Unexplained moderate malnutrition not adequately responding to standard therapy
• Unexplained persistent diarrhoea (14 days or more)
• Unexplained persistent fever (above 37.5°C intermittent or constant for longer than one month)
• Persistent oral candidiasis (after first 6–8 weeks of life)
• Oral hairy leukoplakia
• Acute necrotizing ulcerative gingivitis or periodontitis
• Lymph node tuberculosis
• Pulmonary tuberculosis
• Severe recurrent bacterial pneumonia
• Symptomatic lymphoid interstitial pneumonitis
• Chronic HIV-associated lung disease including brochiectasis
• Unexplained anaemia (< 8 g/dL), neutropaenia (< 0.5 × 109 per litre)
• And/or chronic thrombocytopaenia (< 50 × 109 per litre)

(d) Clinical Stage 4

• Unexplained severe wasting, stunting or severe malnutrition not responding to standard therapy
• Pneumocystis pneumonia
• Recurrent severe bacterial infections (such as empyema, pyomyositis, bone or joint infection or meningitis but excluding pneumonia)
• Chronic herpes simplex infection (orolabial or cutaneous of more than one month's duration or visceral at any site)
• Extrapulmonary tuberculosis
• Kaposi sarcoma
• Oesophageal candidiasis (or candidiasis of trachea, bronchi or lungs)
• Central nervous system toxoplasmosis (after one month of life)
• HIV encephalopathy
• Cytomegalovirus infection: retinitis or cytomegalovirus infection affecting another organ, with onset at age older than one month
• Extrapulmonarycryptococcosis (including meningitis)
• Disseminated endemic mycosis (extrapulmonaryhistoplasmosis, coccidiomycosis)
• Chronic cryptosporidiosis
• Chronic isosporiasis 42

• Disseminated non-tuberculous mycobacterial infection
• Cerebral or B-cell non-Hodgkin lymphoma
• Progressive multifocal leukoencephalopathy
• Symptomatic HIV-associated nephropathy or HIV-associated cardiomyopathy
• HIV-associated rectovaginal fistula (WHO, 2009)

When HIV reaches the bloodstream, it attacks mainly the lymphocyte-T of the *CD*4+ type. The amount of cells *CD*4+ in peripheral blood has prognostic implications in infection evolution by HIV. Nowadays, the amount of immune competence cells is the most clinically useful and acceptable measurement for the

$$x(t) = e^{-\lambda(v,c)t}$$

$$y(t) = 1 - e^{-\lambda(v,c)t}, \qquad t > 0.$$

treatment of infected individuals by HIV, although it is not the only one. We may classify the amount of *CD*4+ cells ml−1 in the peripheral blood in four ranges (Brazilian Ministry of Health, 2004). After going through the patient's history, discussions with professionals in field and review of literatures, we framed the boundaries (ml) of the model as follows:
1. *CD*4+ >0.5 cells ml−1: Stage of infection by HIV, with very low risk of developing disease.
2. *CD*4+ between 0.35 and 0.5 cells ml−1: Stage characterized by the appearance of signs and shorter symptoms or constitutional alterations. Low risk of developing opportunist diseases.
3. *CD*4+ between 0.2 and 0.35 cells ml−1: Stage with **medium** possibility of developing opportunist diseases.
4. *CD*4+ 0.1 and 0.2 cells ml−1: High medium risk of being overwhelmed by opportunist diseases.
*5. CD*4+<0.1 cells ml−1: Highrisk of being overwhelmed by opportunist diseases such as Kaposi's sarcoma. High death risk and low survival chances.
On the other hand, low HIV viral load does not destroy all the lymphocyte *CD*4+ in the organism. Thus, antibodies have chances to act against opportunist diseases. In contrast, high viral load destroys large quantities of lymphocyte *CD*4+ and the immunologic system may lose its function. In the beginning (or when change of anti-retroviral therapy occurs), literature recommends viral load exams within one to two month period to evaluate treatments. The results should be interpreted as follows:
1. Viral load below 10.000 copies of RNA per ml: low risk of disease progression.
2. Viral load between 10.000 and 100.000 copies of RNA per ml: moderate risk of disease progression.
3. Viral load above 100.000 copies of RNA per ml: high risk of disease progression.
The identification of the disease's stages and its

$$\frac{dx}{dt} = -\lambda(v,c)x \qquad x(0) = 1$$

$$\frac{dy}{dt} = \lambda(v,c)x = \lambda(v,c)(1-y) \qquad y(0) = 0.$$

respective treatment is based on the relationship between viral load and *CD*4+ level. The control of the viral load and *CD*4+ cells level can interfere in the control transference rate λ. Thus, the conversion from an asymptomatic individual to a symptomatic individual depends on the individual characteristics, as measured by the viral load *(v)* and level of *CD*4+ (*c*). Therefore, we suggest the following model:
(4)

From equation (4), the parameter $\lambda = \lambda(v, c)$ and the values of v and c are found using microscopic model information. This assumption has a clear biological meaning and thus is a more faithful characterization of λ. Therefore, we notice that (4) provides a macroscopic modeling approach that uses microscopic information to determine the parameters v and c of the transference rate λ. From the mathematical point of view, (4) can be seen as a parametric family of systems. It seems reasonable that λ, and consequently the population of infected individuals y, could be controlled via v and c. From (4) we have

Monitoring of disease progression and ART

i. Virological

ii. Immunological and Haematological

iii. Opportunistic infections

iv. Adverse drug reaction

Monitoring Laboratory area

•Resistance to antiretroviral drugs
• CD4 T lymphocytes count
• Total lymphocyte counts
• Occurrence of new opportunistic infections
• Recurrence of treated opportunistic infections
• Antimicrobial susceptibility of bacterial pathogens
• Reactivation of TB
• Liver and kidney function tests
• Viral load

•Haematological parameters

Implementation and Discussion of Results

The proposed Fuzzy Model for the Management of HIV/AIDS (FMMHIV) patients

This model is designed to manage the infected population with HIV by accepting the laboratory result (CD4+ count and Viral Load) of a patient based on degree of membership function to minimize the imprecision of the current manual system of managing the patients.

The model attempted to harmonize between the CDC and WHO staging systems and diagnosing. Whereby CDC system consider CD4+ less than 350mm^3 and above which is vague. And that of WHO is based on symptoms which was categorized in four 4 stages.

The model accepts two inputs, CD4+ count and viral load using their degree of membership by the use of equation (2) and give out one output as weak, weak medium, medium and strong stages equals to the WHO staging system stage I, II, III and IV respectively. After providing the stages, the model will prescribe regimens to the patients and give appropriate guidance and council tips on the adherence of the medication.

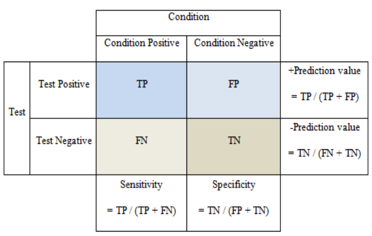


Figure 4: Illustrates how the Positive Predictive Value, Negative Predictive Value, Sensitivity, and Specificity are related

In this model (FMMHIV), we attempt to harmonize between the Center for Disease control and World Health organization HIV staging systems.

The Model Prototype

A total number of thirty (30) HIV clinic reports of patients suffering from HIV/AIDS were obtained from PCR of the Federal Teaching Hospital Gombe. These laboratory reports were interpreted by the model and the HIV stage of each of the patient was obtained and the model's result was compared with the professional (Doctors) of the clinic (table 3) to know and calculate the accuracy of the model if implemented.

Comparison between the Model's results and the professional's

No. of Patient	Viral Load (v)	CD4+ (C)	Model Result	Doctor's Result
01	High	Low	Strong	Strong
02	High	Very Low	Strong	Strong
03	High	Low	Strong	Medium
04	High	Low	Strong	Medium
05	Low	High medium	Weak medium	Weak
06	Low	High	Weak	Weak
07	High	Very Low	Strong	Strong
08	Low	High	Weak	Weak
09	Low	High	Weak	Weak
10	High	Very Low	Strong	Strong
11	High	Very low	Strong	Strong
12	Medium	Very Low	Strong	Strong
13	Low	High	Weak	Weak
14	Low	High Medium	Weak Medium	Weak medium
15	Low	High	Weak	Weak
16	Medium	Very low	Strong	Medium
17	Low	High	Weak	Weak
18	Medium	High medium	Weak medium	Weak
19	Low	High	Weak	Weak
20	Low	High	Weak	Weak
21	Low	High	Weak	Weak
22	Low	High	Weak	Weak
23	Low	High medium	Weak medium	Medium
24	Low	High	Weak	Weak
25	Low	Medium	Medium	Medium
26	Low	Low	Medium	Weak medium
27	Low	High	Weak	Weak
28	Low	Medium	Weak	Weak medium
29	Low	High medium	Weak medium	Weak medium
30	Low	High	Weak	Weak

Table 3: Comparison between the Model's results and the professional's

System Testing

To compare the performance of our model with the professionals, we have examined it through efficiency/performance is usually matched in term of sensitivity, specificity and accuracy. These terms normally took advantage of diagnostic approaches to enhance analysis results.

Sensitivity = TP / (TP + FN)

Specificity = TN / (FP + TN)
Accuracy = (TP+TN) / (TP+TN+FP +FN)
We use specificity to analyze and assess the amount of true positives predicted accurately. Specificity analyses and measure the amount of true negative predicted accurately. Accuracy can be obtained by sum of True Positive and True Negative divided with the total number of instances.

All the four (Strong, Medium, Weak Medium and Weak) instances are calculated as follows:

- **Strong**
  Sensitivity = TP/(TP+FN) = 5/(5+1) *100 = 83.3%
  Specificity = TN/(FP+TN) = 21/21+3)*100 = 87.5%
  Accuracy = (TP+TN) / (TP+TN+FP +FN) = 25/30*100 = 86.7%

Medium:

  Sensitivity = TP/(TP+FN) = 1/(1+4) *100 = 20%
  Specificity = TN/(FP+TN) = 24/(24+1)*100 = 96%
  Accuracy = (TP+TN) / (TP+TN+FP +FN) = 25/30*100 = 88.3%
- **Weak Medium**
  Sensitivity = TP/(TP+FN) = 2/(2+2) *100 = 50%
  Specificity = TN/(FP+TN) = 23/(23+3)*100 = 88.7%
  Accuracy = (TP+TN) / (TP+TN+FP +FN) = 25/30*100 = 88.3%
- **Weak**
  Sensitivity = TP/(TP+FN) = 13/(13+2) *100 = 86.7%
  Specificity = TN/(FP+TN) = 14/(14+1)*100 = 93.3%
  Accuracy = (TP+TN) / (TP+TN+FP +FN) = 27/30*100 = 90%
- **The overall system test result is:**
  Sensitivity = TP/(TP+FN) = 58.7%
  Specificity = TN/(FP+TN) = 91.4%
  Accuracy = (TP+TN) / (TP+TN+FP +FN) = 87.1%
- **Positive Predictive Value is: TP/(TP+FP) = 21/29 = 0.72**
- **Negative Predictive Value: TN/(TN+FN) = 82/91 = 0.90**

Result Evaluation

TP	21
TN	78
FP	8
FN	9
Accuracy	0.87
Sensitivity	0.59
Specificity	0.91
Positive predictive value	0.72
Negative predictive value	0.90
Percentage error from the model	100-87.1= **12.9%**

Table 5: Evaluation of results

CONCLUSION

We have made an attempt to implement the concept of Fuzzy Rule Based Systems that incorporated fuzzy techniques in simplifying the management of HIV. A fuzzy model for the management of HIV (FNNHIV) was developed. In the fuzzy logic implementation, the selection of fuzzifier, rule base and inference engine determined the output of FMMHIV. We choose triangular fuzzifier, the rule base was designed based on knowledge of domain experts (three medical doctors). Fuzzy logic was utilized to remove uncertainty, ambiguity and vagueness inherent in medical diagnosis. The study evaluated the diagnosis of thirty patients using fuzzy methodology and the results gotten were in the range of the pre-defined limits by the domain experts. The essence of the study was to ascertain the degree to which fuzzy methodology represents the exact diagnosis of the patient as compared with those of medical doctors. The model was tested using confusion matrix and found 87.1% accurate with 12.9% percentage error. On the basis of all presentations, it can be concluded that there is no doubt whether Fuzzy Expert Systems should be applied for medical purpose. The use of fuzzy logic for medical diagnosis provides an efficient way to assist inexperienced physicians to arrive at the final diagnosis of malaria more quickly and efficiently. The developed FMMHIV provides decision support platform to assist HIV researchers, physicians and other health practitioners in HIV endemic regions. The authors believe that the approach proposed in this study, if used intelligently, could be an effective technique for managing HIV. Furthermore, implementation of FMMHIV will reduce doctors' workload during consultation and ease other problems associated with hospital consultations.

REFERENCES

[1] Ahmed, E.B., A.E.S., Sherif, and A A.B.A., Ahmed, (2011). "A Fuzzy Decision Support System for Management of Breast Cancer, (IJACSA)".International Journal of Advanced Computer Science and Applications, Vol. 2, No.3, March 2011.

[2] Ahmad EsmailiTorshabi, Marco Riboldi, Andera Pella, Ali Negarestani, MohamadRahnemaand Guido Baroni (2012)." A clinical Application of fuzzy Logic". Department of Electrical & Computer, Kerman Graduate University of Technology, Kerman, Iran. Pp. 1-15.

[3] Awotunde1 J. B., O.E. Matiluko, O.W Fatai, (2014). "Medical System Diagnosis Using Fuzzy Logic".Computer Science Department, Faculty of CIS, University of Ilorin, Ilorin, Nigeria, Center for Systems and Information Services, Landmark University, Omu-Aran, Nigeria. pp. 1-8.

[4] DanijelaTadić, PredragPopović, AleksandarĐukić, (2010). "A Fuzzy Approach to Evaluation AndManagement Of Therapeutic Procedure In Diabetes Mellitus Treatment". Yugoslav Journal of Operations Research Volume 20 (2010), Number 1, 99-116 10.2298/YJOR1001099T.

[5] Elaine R. (2011). Introduction to Artificial Intelligence, Updated 2013.

[6] Gupta, S., Kumar, D. and Sharma, A. (2011). Data Mining classification Techniques AppliedforBreast Cancer Diagnosis and Prognosis. Indian Journal of Computer science and Engineering, 2 (2), 188-195.

[7] G. M. Wajiga, X.Y. Djam1, Y. H. Kimbi and N.V.Blamah, (2011), "A Fuzzy Expert System for the Management of Malaria". Int. J. Pure Appl. Sci. Technol., 5(2) (2011), pp. 84-108. International Journal of Pure and Applied Sciences and Technology ISSN 2229 – 6107.

[8] Hassan Zarei, Ali VahidianKamyad and Ali Akbar Heydari (2012) "Fuzzy Modeling and Control of HIV Infection". Hindawi Publishing Corporation Computational and Mathematical Methods in Medicine Volume 2012, Article ID 893474, 17 pages doi:10.1155/2012/893474.

[9] Jens Jäkel and Georg Bretthauer, (2002). Fuzzy Systems Application: CONTROL SYSTEMS, ROBOTICS AND AUTOMATION – Vol. XVII. Institute of Applied Computer Science, Forschungszentrum Karlsruhe, Germany.Pp 2-4.

[10] John McCarthy (1955). Introduction to Artificial Intelligence.

[11] Kandel A. (1992). Fuzzy Sets and Systems 84 (1996) 33 -47 (revised I August 1995). Department of lnformutionManagement. Kaohsiung Polytechnic Institute. Kuohsiung 84008.Tailcon.Taiwun. ROC.

[12] Kantesh Kumar Oad&XuDeZhi (2015). "A Fuzzy Rule based Approach to Predict RiskLevel of Heart Disease". Global Journal of Computer Science and Technology: C Software & Data Engineering Volume 14 Issue 3 Version 1.0 Year 2014 Type: Double Blind Peer Reviewed. International Research Journal Publisher: Global Journals Inc. (USA) Online ISSN: 0975-4172 &Print ISSN:0975-4350

[13] Klaus-Peter Adlassnig, (2015). Fuzzy Systems in Medicine. Department of Medical Computer Sciences Section on Medical Expert and Knowledge-Based Systems University of Vienna Medical School Spitalgasse 23, A-1090 Vienna, Austria: pp 1-4.

[14] Klir G. J., B. Yuan, (2012). Fuzzy Sets and Fuzzy Logic Theory and Applications.

[15] Lukasiewicz, J. (1930). Philosophical remarks on many-valued systems of propositional logic. Reprinted in Selected Works, L. Borkowski, ed., Studies in Logic and the Foundations of Mathematics, North-Holland, Amsterdam, 1970, pp. 153–179.

[16] Moreno, A. (2003). Medical Applications of Multi-Agent Systems. CiteSeerX.

[17] Nguyen Hoang Phuong andVladikKreinovich, (2000). Fuzzy Logic and its Application in Medicine.Department of Computer Science, University of Texas at El Paso. Published in Proc. of Asian Pacific Medical Informatics Conference APAMI-MIC'2000,;, Hong Kong, September 27-30, 2000, pp. 1-11; full version published in International Journal of Medical Informatics, 2001, Vol. 62, No. 2-3, pp. 2-3.

[18] OanaGeman (2011), "A Fuzzy Expert Systems Design for Diagnosis of Parkinson's Disease", Proceedings of the 3rdInternational Conference on E-Health and Bioengineering - EHB 2011, 24th-26th November, 2011, Iasi, Romania.

[19] Overview of HIV Infection, WHO Module 1, (2015). pp. 1-4.

[20] Riley G.(1989). Fuzzy Sets and Systems 84 (1996) 33 -47 (revised I August 1995). Department of lnformution Management.Kaohsiung Polytechnic Institute.Kuohsiung 84008.Tailcon.Taiwun.ROC.

[21] Rosana M. J., Laecio C., B., Rodney C. B., Fernando G., (2004), "Fuzzy Modeling in Symptomatic HIV Virus Infected Population", Faculty of Mathematics, Federal University of Uberlˆandia, Uberlˆandia, MG, Brazil, Bulletin of Mathematical Biology (2004) 66, 1597–1620.

[22] Rudolf Seising1, Christian Schuh and Klaus-Peter Adlassnig, (2004). Medical Knowledge, Fuzzy Sets, and Expert Systems.Ludwig Boltzmann Institute for Expert Systems and Quality Management in Medicine, Spitalgasse 23, A-1090 Vienna, Austria.

[23] Shu-Hsien Liao, (2004). Expert system methodologies and applications—a decade review from 1995 to 2004. Department of Management Sciences and Decision Making, Tamkang University, No. 151, Yingjuan Rd, Danshuei Jen, Taipei 251, Taiwan, ROC. 2-3.

[24] WHO, (2009). "Guidelines for HIV Diagnosis and Monitoring of Antiretroviral Therapy". SEA-HLM-382(Rev.2)

[25] WHO, (2010). "Clinical Guidelines for the Management of HIV & AIDS in adults And adolescents" national department of health South Africa.

[26] Wooldridge, M. (2002). An Introduction to Multi-Agent Systems. Wiley & Sons.

[27] Zadeh, L. (1965). Fuzzy sets, Information and Control, 8(3), pp. 338–353.