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# Human Immunodeficiency Virus (HIV) Diagnosis Using Neuro-Fuzzy Expert System

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## ABSTRACT

The world is at a crucial point in its development of effective strategies on the prevention, care and control of HIV/AIDS at the national and provincial levels. Given the necessary resources and expertise, it may be possible to keep the epidemic at bay in most parts of the World, and to considerably reduce the negative impacts of the disease on individuals and society. Early detection of HIV has the potential to reduce mortality and morbidity. There are many diagnostic technologies and tests to diagnose HIV. However many of these tests are extremely complex and subjective and depend heavily on the experience of the clinician. This paper made significant contribution to the ongoing worldwide research on the lasting solution to this enemy of man-HIV. It uses a synergistic combination of neural network (NN) and fuzzy inference systems (Neuro-Fuzzy) to generate a model for the detection of the risk level of patients with HIV. The user friendliness and accuracy rate of HIV diagnosis using neuro-fuzzy system makes its output an interesting one. using neuro-fuzzy system is one of the best ways to deal with the vagueness and imprecision of data in the health care sector, and no doubt will exploit tolerance for imprecision, uncertainty and partial truth to achieve tractability, robustness, low solution cost and better report with reality in medical diagnosis.

Key words: Neural network, Fuzzy logic, HIV/AIDS, Neuro-fuzzy and inference system.

#### INTRODUCTION

Recent advances in the field of artificial intelligence have led to the emergence of expert systems for medical applications. Moreover, in the last few decades computational tools have been designed to improve the experiences and abilities of physicians for making decisions about their patients. Major initiatives to improve the quality, accuracy and timelines of healthcare data and information are improving all over the world with the integration of expert system into the healthcare data analysis.

In this study, a neuro-fuzzy system (a combination of artificial neural network and fuzzy logic) is designed for the diagnosis of HIV. This neuro-fuzzy system will provide a self-learning and

adaptive system that is able to handle uncertainties and imprecise data in the medical diagnosis of this life threatening disease.

The Human Immunodeficiency Virus (HIV) is a retrovirus that infects cells of the immune system, destroying or impairing their function (Imianvan et al 2011). As the infection progresses, the immune system becomes weaker, and the person becomes more susceptible to infections. As early as 2-4 weeks after exposure to HIV (but up to 3 months later), people can experience an acute illness, often described as "the worst flu ever." This is called acute retroviral syndrome (ARS), or primary HIV infection, and it's the body's natural response to HIV infection. During primary HIV infection, there are higher levels of virus circulating in the blood, which means that people can more easily transmit the virus to others. After the initial infection and sero-conversion, the virus becomes less active in the body, although it is still present. During this period, many people do not have any symptoms of HIV infection. This period is called the "chronic" or "latency" phase. This period can last up to 10 years-sometimes longer. When HIV infection progresses to AIDS, many people begin to suffer from fatigue, diarrhea, nausea, vomiting, fever, chills, night sweats, and even wasting syndrome at late stages.

HIV is a very dangerous disease that sees no race, no color, no gender, no economic background and not even a specific age group (Venkat et al, 2011). It can affect anyone, at any time if they put themselves in a situation where they could be at risk. In the 30 years since HIV/ AIDS was first discovered, the disease has become a devastating pandemic, taking the lives of 30 million people around the world (Edward, 2012). In 2011 alone, HIV/AIDS killed 1.7 million people, 1.2 million of whom were living in sub-Saharan Africa. Though life-saving antiretroviral treatment is available, access is not yet widespread; of the estimated 14.8 million HIV-positive individuals in need of treatment, nearly 6 million are not currently able to access it. Even more troublesome, new HIV infections continue to outpace those added onto antiretroviral treatment. More than 330,000 infants and children were newly infected with HIV in 2011, and 2.5 million total new HIV infections occurred in the same year-a rate that has held relatively constant since 2006 (UNAIDS 2012). Sub-Saharan African remains the region hardest hit by HIV/AIDS with 23.5 million HIV positive people in 2012, about 69% of the global total with over 1.2 million AIDs related death. Children in Africa are the worst hit by HIV/AIDS and its accompanying challenges. Current data from (UNAIDS 2012) shows that 3.3 million children under age 15 are living with HIV/AIDS which presents great challenges in the future. The Neuro-fuzzy expert system combines the individual advantages of these soft computing technologies to provide quick and accurate diagnosis of this incurable and life threatening disease. This helps in the reduction of deaths and segmentation associated with this viral disease.

Since the early 1950s, Information technology has developed from the curiosity of a few researchers to a valuable tool to support humans making decisions (Michael, 2005). This has been demonstrated by the growing number of successful applications of expert systems and Computational Intelligence used to support the diagnosis of man's disease

Latha *et al*, (2007) in a study developed an Intelligent Heart Disease Prediction System using the Coactive Neuro-Fuzzy Inference System (CANFIS) and Genetic Algorithm, which combined the neural network adaptive capabilities and fuzzy logic qualitative approach integrated with genetic algorithm to diagnose the presence of the disease. The objective of the study was to develop a prototype Intelligent Heart Disease Prediction System with CANFIS and genetic algorithm using historical heart disease database to make intelligent clinical decisions which traditional decision support system cannot. The result showed a better accuracy in data analysis than the diagnosis carried out using traditional methods.

In another study (Imianvan and Obi 2012), a Neuro-Fuzzy Expert Systems for the Probe and Prognosis of Thyroid Disorder was developed using sets of fuzzified data set incorporated into neural network system. It was an interactive system that tells a patient his/her current position as regards Thyroid disease. Again, Imianvan *et al* (2011) developed an Expert system for the Intelligent Diagnosis of HIV using Fuzzy Cluster Means Algorithm. The focal point of this research was to describe and illustrate the application of Fuzzy Cluster means system to the diagnosis of HIV. The system eliminates the uncertainties often associated with analysis of HIV test data. The two studies concluded that appropriate rule-base could be constructed to diagnose complex cross-domain diseases, which often lack standardized diagnostic rule sets

Neuro-fuzzy system for early prediction of Heart Attack by (Obanijesu and Emuoyibofarhe, 2012) was able to show the risk level of patient classified into four different risk level: very low, low, high and very high. This system was used as a supportive tool for the diagnosis of Heart disease. In agreement, Ephzibah and Sundarapandian (2012) designed a Neuro-Fuzzy Expert System for Heart Disease Diagnosis. This system uses the genetic algorithms for feature selection so that diagnosis can be done with limited number of tests. This expert system helped Doctors to arrive at a conclusion about the presence or absence of heart diseases in patients. It is an enhanced system that accurately classifies the presence of that heart disease. This research derived its roots from the success of the aforementioned designs.

#### Methodology

The process for the medical diagnosis of HIV starts when an individual consults a physician and presents a set of complain. The physician then requests further information from the patient or from others close to him who know about the patient's symptoms in severe cases. From the symptoms presented by the patient, the physician narrows down the possibilities of the illness that corresponds to the apparent symptoms and makes a list of the conditions that could account for the patient's condition. These are usually graded as low, Moderate and high.

Neuro-Fuzzy inference procedure, which combines the learning procedure of NN and the appropriate human reasoning capabilities of FL, overcoming the individual limitations of these two soft computing techniques to produce accurate medical report based on the patient complaint to the physician on this incurable and deadly disease, is applied to the diagnosis of HIV.

### **Software Requirement**

- Windows Operating System
- Microsoft .Net frame work4.0
- C# programming language
- Structured Query Language 2008 for the design of the database

This program was designed using Microsoft .net frame work 4.0, which is an integral part of many applications running on windows and provides common functionality for the application to run. The .net frame work provides comprehensive and consistent programming model for building applications that have visually stunning user experiences and seamless and secure communication. C# is an object-oriented programming language by default and was designed by Microsoft in year 2000. It was chosen primarily because of its ability to switch between loose typing and strong typing. Again, C# is platform independent and easy to learn.

Imianvan *et al*, (2011) noted the following symptoms of HIV/Aids:

P01	Headache,
P02	Chronic cough,
P03	Diarrhea,
P04	Swollen glands,
P05	Lack of energy,
P06	Loss of appetite,
P07	Weight loss,
P08	Frequent fever
P09	Frequent yeast infection,
P10	Skin rashes,
P11	Pelvic/abdominal cramps,
P12	Sores on certain parts of the body
P13	Short term memory loss

#### Analysis of System under study

The proposed expert system comprises neural network for the training of the above symptoms to behave in a particular way, using the back propagation. The training involves adjusting the weight between the input layer and output layer. After the training, the results are fed into a fuzzy logic knowledge base for the diagnosis of the illness. Figure 1.0 shows the model of Neuro-Fuzzy system, indicating how the input, in this case, the HIV symptoms must be feed into the neural network so that it can be trained to yield a particular output and thereafter fed into the knowledge base which acts as the database. The trained symptoms are retrieved by the inference engine in order to make a decision

## **Knowledge Base**

Knowledge is a key factor in the performance of intelligent systems (Michael, 2005). Knowledge base is a special kind of database for knowledge management which provides a means for information to be collected, organized, shared, searched and utilized. The knowledge base consists of the database containing the above 13 basic parameters. The values of the parameters are often vague (fuzzy) and imprecise hence the adoption of fuzzy logic in the model as means of analyzing these data. These parameters therefore constitute the fuzzy parameter of the knowledge base. The fuzzy set of parameters is represented by 'P', which is defined as P= {P1, P2..., Pn} where Pi represents the jth parameter and n is the number of parameter (in this case n=13).

#### **Linguistic Variables**

By linguistic variables, we mean variables whose values are words or sentence in a natural or artificial language. The linguistic variables used in this study are Low, Moderate and High and very High. By using these linguistic variables, fuzzy IF THEN RULES which are the main output of the fuzzy system would be set up and generally presented in the form of: IF x is a THEN y is b.

We create fuzzy logic membership functions that define the value of input/output terms used in the rules. Membership functions are

Table. 1: linguistic variable with fuzzy ranges

Linguistic variable	Fuzzy value
Low	0.1≤ x<0.3
Moderate	0.3 <u>&lt;</u> x<0.6
High	0.6 <u>&lt;</u> x<0.8
Very high	0.8 <u>≤</u> x≤1.0

graphical representation of the magnitude of the preparation of each input that is processed, as shown in figure 2.0

### **Fuzzy Inference Engine**

An inference engine is a computer program that tries to derive answers from a knowledge base (Michael, 2005). It is the "brain" that expert systems use to reason about the information in the knowledge base for the ultimate purpose of formulating new conclusions. In fuzzy inference engine, fuzzy inputs are mapped into their respective weighting factors and their associated linguistic variables to determine their degree of membership. The aggregation operator is used to calculate the degree of fulfillment or firing strength of a rule.

In this paper, the fuzzy logical AND is used to evaluate the composite firing strength of the rules. In practice, the fuzzy rules sets usually have several antecedents that are combined using fuzzy logical operators, such as AND, OR and NOT, though their definitions tend to vary: AND simply uses minimum weight of all the antecedents, while OR uses the maximum value. The NOT operator subtracts a membership function from 1 to give the "complementary" function. The inference engine technique employed in this paper is the Root of Sum of Square (RSS). RSS is given by the formula:

$$\sqrt{\sum R^2} = \sqrt{R_1^2 + R_2^2 + \ldots + Rn^2}$$
 ...(1)

The  $R_1^2 + R_2^2 + \dots + R_n^2$  are values of different rules which have the same conclusion in the fuzzy rule base, that is, R = value of firing rule. RSS combines the effects of all applicable rules, scales the functions at their respective magnitudes and compute the "fuzzy" centroid of the composite area. Neural networks provide the structure for the parameters, which serves as a platform for the inference engine. The inference engine consists of reasoning algorithm. There are 12 input variables in this inference engine for the HIV diagnosis which are the HIV symptoms.

#### Defuzzification

The defuzzification is the process of converting the fuzzy output from the inference

engine to a crisp value (Imianvan and Obi 2012). That is, the output from the inference engine in this work using root sum square (RSS) is defuzzified to get the level of the illness. The input to the defuzzification process is a fuzzy set while the output of the defuzzification process is a single number (crisp output). The output from the fuzzy rule is a fuzzy value which must then be defuzzified using centriod of gravity or also called center of area to get a crisp value. This technique was developed by Sugeno in 1985. This is the most commonly used technique and is very accurate and simple. The formula of centriod of gravity is given below;

$$\mathbf{x}^* = \frac{\int \mu_i(\mathbf{x}) \mathbf{x} \, d\mathbf{x}}{\int \mu_i(\mathbf{x}) \, d\mathbf{x}} \qquad \dots (2)$$

## System Algorithm Design

In the design of the diagnosis process, we simulate a set of rules which serves as the algorithm of the proposed system. The symptoms have been trained by the neural network in such a way that a particular combination yields a particular result. The symptoms of the disease are combined using fuzzy logical AND operator which uses the lowest minimum value in each rule; the antecedent of the rule will be computed using RSS to get a fuzzy value which must be defuzzified to get a crisp value and this tells the HIV risk value of a patient. Tables 2.0 and 3.0 show the simulated rule-base for HIV and their translations into crisp values.



## **Rules interpretation**

R1 If headache = moderate and chronic cough = moderate and diarrhea = very high and swollen gland = very high and lack of energy = very high and loss of appetite = very high and weight loss = very high and frequent fever = very high and frequent yeast infection = very high and skin rashes = high and pelvic/abdominal cramp = low and scores on certain part of the body = moderate and short-term memory loss = low then HIV = very high

R2 If headache = moderate and chronic cough = low and diarrhea = high and swollen gland = high and lack of energy =low and loss of appetite = high weight loss = low and frequent fever = moderate and frequent yeast infection = high and skin rashes = low and pelvic/ abdominal cramp = high and scores on certain parts of the body = moderate and short-term memory loss = low then HIV = very high

R3 If headache = very high and chronic cough = very high and diarrhea = low and swollen gland = low and lack of energy = low and loss of appetite = low and weight loss = low and frequent fever = low and frequent yeast infection = low and skin rashes = low and pelvic/abdominal cramp = low and scores on certain parts of the body = low and short term memory loss = low the HIV = low

R4 if headache = low and chronic cough = low and diarrhea = low and swollen gland = low and lack of appetite = low and weight loss = moderate and frequent fever = low and frequent yeast loss = moderate and skin rashes = moderate and pelvic/abdominal cramp = moderate and scores on certain parts of the body = moderate and short term memory loss = low then HIV = moderate

R5 if headache = low and chronic cough = low and diarrhea = moderate and swollen gland = moderate and lack of energy = moderate and loss of appetite = high and weight loss = high and frequent fever = moderate and frequent yeast loss = low and skin rashes = high and pelvic/ abdominal cramp = very high and scores on certain parts of the body = very high and short term memory loss = very high the HIV = high

R6 if headache = low and chronic cough = low and diarrhea = low and swollen gland = low and lack of energy = low and loss of appetite = low and weight loss = low and frequent fever = low and frequent yeast infection = low and skin rashes = low and pelvic/abdominal cramp = low and scores on certain parts of the body =low and short term memory loss = low then HIV = low

R7 if headache = moderate and chronic cough = moderate and diarrhea = moderate and swollen gland = moderate and lack of energy = moderate and loss of appetite = moderate and weight loss = moderate and frequent fever = moderate and frequent yeast infection = moderate and skin rashes = moderate and pelvic/abdominal cramp = moderate and scores on certain parts of the body =moderate and short term memory loss = moderate then HIV = moderate

R8 if headache = very high and chronic cough = low and diarrhea = high and swollen gland = moderate and lack of energy = high and loss of appetite = low and weight loss = very high and frequent fever = low and frequent yeast infection = low and skin rashes = high and pelvic/abdominal cramp = low and scores on certain parts of the body =moderate and short term memory loss = high then HIV = moderate

R9 if headache = very high and chronic cough = moderate and diarrhea = moderate and swollen gland = high and lack of energy = high and loss of appetite = high and weight loss = high and frequent fever = moderate and frequent yeast infection = low and skin rashes = low and pelvic/abdominal cramp = low and scores on certain parts of the body =low and short term memory loss = high then HIV = high

R10 if headache = high and chronic cough = high and diarrhea = high and swollen gland = high and lack of energy = high and loss of appetite = Very high and weight loss = high and frequent fever = high and frequent yeast infection = high and skin rashes = high and pelvic/abdominal cramp = high and scores on certain parts of the body =high and short term memory loss = high then HIV = high

R11 if headache = high and chronic cough = very high and diarrhea = low and swollen gland = low and lack of energy = low and loss of appetite = low and weight loss = low and frequent fever = low and frequent yeast infection = low and skin rashes = high and pelvic/abdominal cramp = high and scores on certain parts of the body =high and short term memory loss = high then HIV = low

R12 if headache = high and chronic cough = high and diarrhea = high and swollen gland = very high and lack of energy = very high and loss of appetite = high and weight loss = very high and frequent fever = very high and frequent yeast infection = high and skin rashes = high and pelvic/abdominal cramp = low and scores on certain parts of the body =moderate and short term memory loss = low then HIV = very high

R13 if headache = very high and chronic cough = very high and diarrhea =very high and swollen gland = very high and lack of energy = very high and loss of appetite = very high and weight loss = very high and frequent fever = very high and frequent yeast infection = very high and skin rashes = very high and pelvic/abdominal cramp =low and scores on certain parts of the body = high and short term memory loss = moderate then HIV =very high

R14 if headache = very high and chronic cough = very high and diarrhea =very high and swollen gland = very high and lack of energy = very high and loss of appetite = very high and weight loss = very high and frequent fever = very high and frequent yeast infection = very high and skin rashes = very high and pelvic/abdominal cramp =very high and scores on certain parts of the body = very high and short term memory loss = very high then HIV =very high

R15 if headache = high and chronic cough = low and diarrhea = very high and swollen gland = high and lack of energy = high and loss of appetite = high and weight loss = high and frequent fever = high and frequent yeast infection = high and skin rashes = high and pelvic/abdominal cramp = high and scores on certain parts of the body =low and short term memory loss = high then HIV = high

R16 if headache = high and chronic cough = high and diarrhea = high and swollen gland = high and lack of energy = moderate and loss of appetite = moderate and weight loss = moderate and frequent fever = high and frequent yeast infection = high and skin rashes = low and pelvic/abdominal cramp = low and scores on certain parts of the body =high and short term memory loss = high then HIV = high

R17 if headache =very high and chronic cough = low and diarrhea = high and swollen gland = high and lack of energy = high and loss of appetite = high and weight loss = high and frequent fever = high and frequent yeast infection = high and skin rashes = high and pelvic/ abdominal cramp = low and scores on certain parts of the body =moderate and short term memory loss = low then HIV = very high

R18 if headache = very high and chronic cough = high and diarrhea = high and swollen gland = moderate and lack of energy = moderate and loss of appetite = moderate and weight loss = moderate and frequent fever = high and frequent yeast infection = high and skin rashes = high and pelvic/abdominal cramp = low and scores on certain parts of the body =low and short term memory loss = low then HIV = moderate

R19 if headache = low and chronic cough = low and diarrhea = very high and swollen gland = very high and lack of energy = very high and loss of appetite =very high and weight loss =very high and frequent fever = very high and frequent yeast infection = low and skin rashes = low and pelvic/abdominal cramp = high and scores on certain parts of the body =high and short term memory loss = low then HIV = very high

R20 if headache = high and chronic cough = very high and diarrhea = moderate and swollen gland = moderate and lack of energy = moderate and loss of appetite = moderate and weight loss =moderate and frequent fever = moderate and frequent yeast infection = moderate

Rule						If								Then
8	Headache	Chronic	Diarrhea	Swollen	Lack of	Loss of	Weight	Frequent	Frequent	Skin	Pelvic/	Scores on	Short-term	Conc-
		cough		gland	energy	appetite	loss	fever	yeast	rashes	abdominal	certain parts	memory	lusion
									infection		cramp	of the body	loss	
001	Moderate	Moderate	Very high	high	Low	Moderate	Low	very high						
002	Moderate	Low	high	High	low	High	Low	Moderate	High	Low	high	Moderate	Low	Very high
003	Very high	Very high	low	Low	Low									
004	Low	Low	wo	Low	low	Low	Moderate	Low	moderate	Moderate	moderate	Moderate	Low	moderate
005	Low	Low	moderate	Moderate	Moderate	High	High	Moderate	Low	High	Very high	Very high	Very high	high
900	Low	Low	Very High	Low	Low	Low								
007	Moderate	Moderate	moderate											
008	Very high	Low	high	Moderate	high	Low	Very high	Low	Low	High	Low	Moderate	High	moderate
600	Very high	Moderate	moderate	High	high	High	High	Moderate	Low	Low	Low	Low	High	high
010	High	High	high	High	high	Very high	High	High	High	High	high	High	High	high
011	High	Very high	low	High	high	Moderate	High	Low						
012	High	High	high	Very high	Very high	High	Very high	Very high	High	High	Low	Moderate	Low	very high
013	Very high	Low	High	Moderate	very high									
014	Very high	Very high	very high											
015	High	Very high	high	High	high	High	High	High	High	High	high	Low	High	High
016	Very high	High	high	High	Moderate	Moderate	Moderate	High	High	Low	Low	High	High	High
017	Very high	Low	high	Low	Moderate	Low	Very high							
018	Moderate	High	high	Moderate	Moderate	Moderate	Moderate	High	High	High	Low	Low	Low	Moderate
019	Low	Low	Very high	Low	Low	high	High	Low	very high					
020	High	Very high	moderate	High	Very high	High	Very high	Moderate						
021	High	High	high	Very high	Very high	Very high	Moderate	Moderate	Moderate	Moderate	Low	Low	Low	High
022	Very high	Very high	low	High	Very high	Low								

Table 2: Simulated Rule Base For HIV

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Rule						<b>=</b>								Then
8	Headache	Chronic	Diarrhea	Swollen	Lack of	Loss of	Weight	Frequent	Frequent	Skin	Pelvic/	Scores on	Short-term	Conc-
		cough		gland	energy	appetite	loss	fever	yeast	rashes	abdominal	certain parts	memory	lusion
									infection		cramp	of the body	loss	
001	0.5	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.75	0.25	0.5	0.25	very high
002	0.5	0.25	0.75	0.75	0.25	0.75	0.25	0.5	0.75	0.25	0.75	0.5	0.25	Very high
003	1.0	1.0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	Low
004	0.25	0.25	0.25	0.25	0.25	0.25	0.5	0.25	0.5	0.5	0.5	0.5	0.25	Moderate
005	0.25	0.25	0.5	0.5	0.5	0.75	0.75	0.5	0.25	0.75	1.0	1.0	1.0	High
900	0.25	0.25	1.0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	Low
007	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	Moderate
008	1.0	0.25	0.75	0.5	0.75	0.25	1.0	0.25	0.25	0.75	0.25	0.5	0.75	Moderate
600	1.0	0.5	0.5	0.75	0.75	0.75	0.75	0.5	0.25	0.25	0.25	0.25	0.75	High
010	0.75	0.75	0.75	0.75	0.75	1.0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	High
011	0.75	Very high	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.75	0.75	0.5	0.75	Low
012	0.75	0.75	0.75	1.0	1.0	0.75	1.0	1.0	0.75	0.75	0.25	0.5	0.25	very high
013	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	0.25	0.75	0.5	very high
014	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	very high
015	0.75	1.0	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.25	0.75	High
016	1.0	0.75	0.75	0.75	0.5	0.5	0.5	0.75	0.75	Low	>	0.75	0.75	High
017	1.0	Low	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.25	0.5	0.25	Very high
018	0.5	0.75	0.75	0.5	0.5	0.5	0.5	0.75	0.75	0.75	0.25	0.25	0.25	Moderate
019	Low	Low	1.0	1.0	1.0	1.0	1.0	1.0	0.25	0.25	0.75	0.75	0.25	very high
020	0.75	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.75	1.0	0.75	1.0	Moderate
021	0.75	0.75	0.75	1.0	1.0	1.0	0.5	0.5	0.5	0.5	0.25	0.25	0.25	High
022	1.0	1.0	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	High	Very high	Low

Table .3: Translated simulated fuzzy rules

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and skin rashes = high and pelvic/abdominal cramp = very high and scores on certain parts of the body =high and short term memory loss =very high then HIV = moderate

R21 if headache = high and chronic cough = high and diarrhea = high and swollen gland =very high and lack of energy = very high and loss of appetite = very high and weight loss = moderate and frequent fever = moderate and frequent yeast infection = moderate and skin rashes = moderate and pelvic/abdominal cramp = low and scores on certain parts of the body =low and short term memory loss = low then HIV = high

R22 if headache = very high and chronic cough = very high and diarrhea = low and swollen gland = low and lack of energy = low and

MainWindow				×
Logout Ab	out			
N	EUR	O-FUZZY H	IV EXP	ERT
Headache	Moderate	•	Frequent Fever	Moderate 🗸
Chronic Cough	High	•	Frequent Yeast Infection	Low 🗸
Diarrhea	Low	•	Lack of Appetite	High 🗸
Swollen Gland	Very High	•	Pelvic/Abdominal Cramp	Low
Lack of Energy Skin Rashes	Moderate Low	•	Sores on Certain Parts of Body	High 🔹
Weight Loss	High		Short-term Memory Loss	Very High 🛛 🗸
Diagno	ose	Clear	HIV RISK LEVE	

Fig. 3: Designed neuro-fuzzy input

MainWindow	
Logout About	
NEURO-FU	ZZY HIV EXPERT
Headache	Frequent Fever
Chronic Cough	Frequent Yeast Infection
Diarrhea 🗸	Lack of Appetite
Swollen Gland	Pelvic/Abdominal Cramp
Lack of Energy	Sores on Certain Parts of Body
Weight Loss	Short-term Memory Loss
Diagnose Clear	HIV RISK LEVEL

Fig. 4: Neuro-Fuzzy Interfaces

loss of appetite = low and weight loss = low and frequent fever = low and frequent yeast infection = low and skin rashes = low and pelvic/abdominal cramp = low and scores on certain parts of the body =high and short term memory loss = very high then HIV = low.

#### Input Design

Data entered or to be entered into the computer are the inputs. The input specified what data is collected, how they are collected, validated and how they are stored for later use. This design also specifies how users can interact with the system and the level of access each user has. The input in this case is the patient symptoms and the severity of a patient HIV status.

#### **Interface Design**

The interface deals with the visible design which serves as a channel through which the user interacts with the system (Michael, 2005). This design specifies what the user sees on the screen and how he interacts with the system. The interface in this paper was designed and coded in C# environment. The interface contains each of the aforementioned HIV symptoms, a button called DIAGNOSE which when clicked, displays the risk level of a patient with HIV, and a CLEAR button that erases any symptoms that have been chosen and diagnosed or wrongly chosen.

## **Output design**

The end products of any system are its outputs. System analysis and design concentrates primarily on the outputs of a system. These are information the user gets as response from the system. The output design is aimed at displaying accurate result from input fed into the system.

## CONCLUSION

Accurate medical diagnosis is one of the major ways to sustain good health and long live. In this paper, an attempt has been made to design a Neuro-Fuzzy Expert System for the diagnosis of HIV. This is one of the best ways to deal with the vagueness and imprecision of data in the health care sector, and no doubt will exploit tolerance for imprecision, uncertainty and partial truth to achieve tractability, robustness, low solution cost and better report with reality in medical diagnosis. This in turn helps to reduce mortality rate in cases where limited medical doctors are available, as it provides very rapid method of diagnosis with much accuracy and reduces the hours patients spend in hospitals. This expert system is user-friendly and carries out diagnosis based on patients' complain (symptoms) to medical expert.

MainWindo	<b>W</b>			×
Logout	About			
Logout	About			
	IFLIRO	-FI177V	HIV FXP	FRT
Headache	Moderate 🗸		Frequent Fever	Very High 👻
Chronic Cou	igh Very High 🗸 🗸		Frequent Yeast Infection	Moderate 🗸
Diarrhea	Moderate 🗸		Lack of Appetite	High
Diamica			Luckon Appende	
Swollen Gla	nd Low			High
			Pelvic/Abdominal Cramp	
Lack of Ener	gy Very High 🛛 🗸		Sores on Certain Parts of Body	Low
Skin Rashes	High 🗸			
Weight Loss	Very High -		Short-term Memory Loss	Low
weight Loss	very ringir			
1				
Diag	nose Cle	ar		
(c				

Fig. 5: Neuro-Fuzzy Output for a patient with MODERATE HIV status

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