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ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM FOR HIV/AIDS DIAGNOSIS, CLINICAL STAGING AND REGIMEN PRESCRIPTION

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Abstract
HIV/AIDS is one of the life threaten diseases in the society today, which has resulted into loss of many lives in the world. Despite the deadly nature of the disease and the availability of effective treatment, most people still do not know their HIV status, largely because of lack of privacy, stigmatization and discrimination that exist in the community. To bridge these gaps identified, an adaptive neuro-fuzzy Inference system is efficiently developed to diagnose and manage patients by placing them into appropriate clinical stages as recommended by the World Health organization (WHO) and prescribing to them the life-saving Antiretroviral drugs through a standardized set of rules that will enable efficient use of scarce resources, encourage testing and lead to overall better treatment outcome for patients.

Keywords*: Adaptive neuro-fuzzy inference system, Diagnose, Antiretroviral drugs, HIV/AIDS.*

1. Introduction

Human Immunodeficiency Virus (HIV) / AIDS (Acquired Immunodeficiency Syndrome) is a pandemic disease that has resulted into high mortality of children and adults in Nigeria attested to by [1] stating that Nigeria bears 10% of the global burden of HIV/AIDS. As an outcome of the enormous tragedy that HIV has wrecked on all aspects of human development in Nigeria and other parts of the world, policy makers, stakeholders and health experts have declared HIV the most important health challenge in recent times [2]. In order to improve survival of patients with HIV, guidelines on voluntary counseling and testing, enrolment into care, diagnosis, consultation and placement on treatment have been provided by the ministry of health in Nigeria to assist healthcare workers in managing them.

However, HIV being a chronic illness requires consistent visit to clinic s for monitoring and management of side effects. Across all these level of patient management, lots of personnel are involved ranging from records officers, doctors, nurses, pharmacist, laboratory scientists and support staffs. Although the scaling-up of antiretroviral therapy for HIV patients has been the strategy for HIV care in developing countries, however, one of the main obstacles to scale-up of antiretroviral therapy has been the workforce shortage [3]. Currently in Nigeria, health professionals rely on the use of manual and paper based tools in the management of their HIV positive patients

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but this becomes a challenge considering the large number of HIV patients in the country, coupled with the shortage of health care worker [4], as well as non-documentation of patient's detailed information and mutilations suffered by the records kept [5]

Nigeria's HIV diagnosis and treatment scale-up has stressed pre-existing inadequacies in the paper-based health information system [6]. So, the country needs to develop innovative ways to maximize the few health professionals at her disposal by developing intelligent e-health system that will help provide information to PLHIV (People Living with HIV) as well as help the workers in managing HIV / AIDS patients in the country. E-health is a concept based on the use technologies such as internet, artificial intelligence, remote servers, networking and others to improve the quality of care and its advances have allowed both patients and medical professional gain access to a variety of resources to make healthcare more efficient and cost effective [7].

There are seemingly an endless number of possible applications of information technology to healthcare service management and every level of management of HIV patients can benefit from such applications [8]. The pressure on our health system are intense and will likely increase in the future considering the number of new infections recorded per year (220, 000 people were newly infected with HIV in Nigeria in 2014, according to Joint United Nations Programme on HIV/AIDS and this shows that we need e-health systems to face significant challenges that the increasing prevalence of HIV brings to HIV care and management. Fortunately, recent advancement in medicine has seen to the development of several lifesaving Antiretroviral drugs which has now modified the disease outcome and made it more of a chronic disease than a deadly disease. This lead to the need to develop innovative ways of helping the health system and the already few over-stretched health workers in managing these large pool of patient to execute outlined plans, testing and treatment program.

HIV/AIDS staging have been acknowledged as a critical tool for tracking and managing of HIV/AIDS patients [9]. This enables efficient access to Antiretroviral Drugs (ARVs) and treatment. Moreover, there are several barriers to individuals, testing for this disease as well as efficient management, such as, stigmatization [10] discriminatory attitudes of Healthcare workers [11], social norm [12] and other factors. Blood tests are the most common ways to diagnose HIV/AIDS. As such early testing is crucial with HIV. This paper presents an Adaptive Neuro-Fuzzy Inference System for HIV/AIDS Diagnosis, determines the Clinical Stage and Treatment guide, in a bid to encourage individuals to take the test and also help in decision making of HIV experts.

Clinical Diagnosis and Staging of HIV Infection

Clinical staging of the HIV/AIDS Disease is based on the patient's clinical presentation at the time of initial assessment with the healthcare provider. The most advanced symptoms at the time of evaluation represent the initial clinical stage of HIV infection. Clinical staging serves as a guide in making decision as regards when to start ART or cotrimoxazole prophylaxis. The symptoms are shown in table 1

Table 1. Table showing Symptoms and Clinical Staging of the HIV/AIDS Disease

Clinical Stage 1
Lymphadenopathy: a disease affecting the lymph nodes (Swollen Groin/Gland) Muscle Aches, Chills, Tiredness, Headache, Loss of Appetite, Memory loss
Clinical Stage 2
Persistent Weight Loss (Weight loss, <10% of body weight) Fungal Nail Infections Shingles (a painful acute inflammation of the nerve ganglia, with a skin eruption often forming a girdle around the middle of the body. It is caused by the same virus as chickenpox.), Chronic Cough (Recurrent Upper Respiratory Tract Infection), Frequent Yeast

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Infection
Clinical Stage 3
Persistent Diarrhea > 1 month (a condition in which faeces are discharged from the bowels frequently and in a liquid form), Recurrent Oral Thrush which is a mucous membrane disorder characterized by white patches, especially on the cheek, tongue. Persistent Night Sweat + Chronic Cough
Clinical Staging 4
Severe persistent weight loss, severe oral thrush (oropharyngeal candidiasis), performance scale 4, cancerous and extensive skin rash (Kaposi Sarcoma)

2. Review of Related works

Adaptive neuro-fuzzy inference system (ANFIS) is a system with membership function parameters adjusted by neuro-adaptive learning techniques related to those used in training neural networks [13]. This technique has been engaged widely as an approach for providing solutions to different problems in health care domains, such as in control, diagnosis and management of several diseases. Some of the related works identified in the course of this study are:

[14] came up with a desktop based expert system. The system was built using the proactive Neuro-Fuzzy Expert System Model. The expert system was developed using a first order sugeno fuzzy model, triangular membership function. The inference engine uses a forward chain mechanism to search the knowledge base for the symptoms of the disease, the centre of gravity is the deffuzzification technique used. The administrator of the system uses the system to diagnose the ailment experienced by the patient by inputting symptoms provided by the patient, thereafter the decision for treatment is made for ailment diagnosed

[15] developed an HIV/AIDS expert system using a combination of neural network and fuzzy inference system to generate a model for the detection of risk levels of patients living with HIV. The back propagation learning rule was used to train listed symptoms to behave in a particular way; the trained symptoms were retrieved by the inference engine in order to make a decision. A set of rules which serves as the algorithm of the system was designed. Both the symptoms and the signs were combined using the AND operator which uses the lowest minimum value in each rule, the antecedent of the rule was computed using the RSS to obtain a fuzzy value which was deffuzified to get a crisp value to determine the risk value of an HIV patient.

A hybrid Neuro-Fuzzy system was designed by [16] on window XP operating system, Visual Basic, Microsoft Excel and Microsoft Access as database to help in diagnosis of thyroid disorder using a set of symptoms, the system designed tells a patient his current thyroid condition.

A skin cancer recognition expert system was developed by [17], using image processing techniques, a neural Network System and a Fuzzy Inference System. An expert system to provide general information on HIV and AIDS to the general public using Botswana as a case study was developed by employing the use of an information portal accessible through mobile phones [18]. In combating the spread of HIV and AIDS, acceptability of a stage-matched expert system intervention to increase condom use among women at high risk of HIV infection in New York City was developed [19].

3. Methodology

(a) Proposed ANFIS Architecture for Diagnosis, Clinical Staging and the HIV Regimen prescription.

This work employed Adaptive Neuro-Fuzzy Inference method, which uses the various advantages of fuzzy logic such as good modeling capabilities of real life applications, efficient knowledge representation and also the intriguing learning capability of neural networks in

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overcoming their individual limitations in recommending accurate medical report based on patient's symptoms and complaints to the physicians, in diagnosis, staging and treatment of HIV/AIDS. Datasets used in this study were obtained from ART Clinician in an HIV/AIDS clinic and the Nigerian National Guideline for HIV/AIDS Counseling with that of the treatment and Care, in building the inputs to this system, the signs and symptoms about the disease where formed in to fuzzy rules, using information from the HIV Clinician in the clinic. The rules were further implemented in the system using the ANFIS model and the resulting outcomes are the HIV/AIDS Risk, the Clinical stage, and the Treatment recommendation based on the level of the Clinical Staging. (Stage 1, Stage 2, Stage 3, Stage 4 and the HIV/AIDS).

The diagnosis, clinical staging and treatment of HIV/AIDS based on the ANFIS architecture consist of five layers which are: Layer 0 (input layer), Layer 1 (hidden layer) also known as the membership function layer, Layer 2 (rule layer), Layer 3 (norm layer), Layer 4 (norm layer) and Layer 5 the output layer. The application also employs the hybrid learning algorithm for the ANFIS system in tuning the parameters of a sugeno type fuzzy inference system using a mix of the least squares and gradient descent methods to model a training set, the ANFIS model is validated by using checking data set to test for over fitting in the dataset used in training the system.

The Adaptive Neuro-Fuzzy Inference system developed comprises of neural network for the training of the HIV/AIDS symptoms. 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 and staging of the illness. Figure 1 shows the model of an Adaptive 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 symptoms of the HIV/AIDS Inference System includes Persistent Fever, Rash, Night Sweat, Muscle Aches, Chronic Cough, Sore of Genitals Neck or Armpit, Fungal Nail Infection, Persistent Weight Loss, Tiredness, Swollen Groin/Gland, Oral Thrush, Shingles, Persistent Diarrhea, Pneumonia, Chills, Loss of Appetite, Headache, Memory Loss, Frequent Yeast Infection. The trained symptoms are then retrieved by the inference engine in order to make a decision.

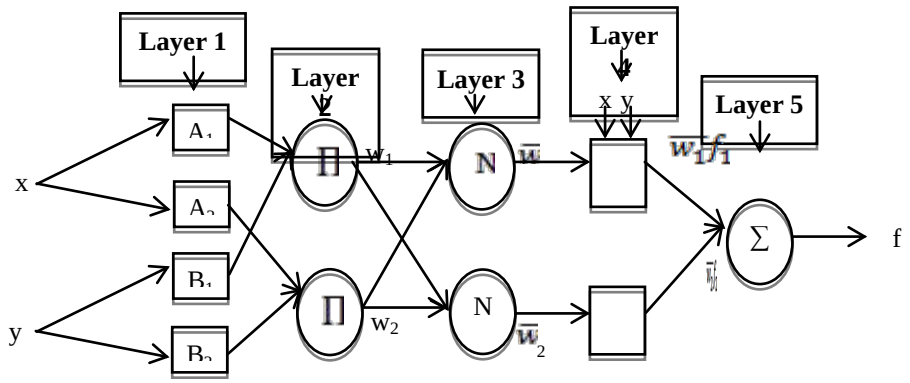

Figure 1: Five Layers ANFIS Architecture

(b) Adaptive Neuro-Fuzzy Inference System Architecture

(i) Fuzzification

Fuzzification is the first step in the fuzzy inferencing process. It involves a domain transformation where crisp inputs are transformed into fuzzy inputs. For the developed system, the linguistic variable was based on the HIV/AIDS domain expert's knowledge, the input and output parameters selected were described with four linguistic variables (mild, moderate, high and very high). The Linguistic variables were evaluated using the triangular membership function as illustrated in table 2.

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Table 2. Table showing the Linguistic Variables Used

Linguistic Variables	Fuzzy Values
Mild	$0.1 \leq x \leq 0.25$
Moderate	$0.25 \leq x \leq 0.50$
High	$0.50 \leq x \leq 0.75$
Very High	$0.75 \leq x \leq 1.0$

For the triangular membership function chosen for mild x takes values [0, 0.125, 0.25], for moderate [0.25, 0.325, 0.50], for High [0.50, 0.625, 0.75] and for Very High [0.75, 0.825, 1.0].

(ii) Fuzzy Reasoning

The second layer forms a major part of the fuzzy reasoning phase, which generates the firing strength. The firing strength combines the degree of compatibility with respect to the antecedent membership functions in a rule using fuzzy AND or OR operators to form a firing strength that indicates the degree to which the antecedent part of the rule is satisfied. The degree of compatibility is comparing known facts with the antecedents of fuzzy rules to find closeness with respect to each antecedent membership function. In this study the AND operator was chosen to create a firing strength to indicate the degree to which the antecedent part is satisfied. There are 23 (twenty-three) rules formed from the dataset gotten from the clinician out of 300 rules (three hundred) based to build the initial rule base of the fuzzy inference system.

(iii)The Inference Mechanism (Fuzzy Inference System)

The Inference Mechanism forms the third layer of the ANFIS architecture. In this study, the fuzzy control rules were formulated using the expert experience. The core of the decision making is done in this phase. The HIV/AIDS Inference system uses the rules in the knowledge base to derive conclusions by using a forward chaining mechanism to search the symptoms by looking up the membership values in the condition of each rule. The membership functions are trained in order to adjust the weight to the desired target output. The inference engine uses a forward chaining mechanism to search the knowledge base for the symptoms of the disease. For each rule, the inference mechanism looks up to the membership values in the condition of the rule. Fuzzy inputs are mapped out in their respective weighting factors and their associated linguistics variables to determine their degree of membership. The membership functions are then trained in order to adjust the weight to the desired target output. The clinical staging of HIV/AIDS were obtained in this study based on the several rules generated as shown table 2.

Rules interpretation

R01 If Persistent Fever = very high and rash = mild and night sweat = mild and muscle aches = very high and chronic cough = mild and sore of genital/neck/armpit = mild and fungal nail infection = mild and persistent weight loss = very high and tiredness = mild and swollen groin/gland = mild and oral thrush = very high and shingles = mild and persistent diarrhoea is = mild and pneumonia = mild and chills = mild and loss of appetite = high and headache = high and memory loss = very high and frequent yeast infection = high then HIV/AIDS Risk = very high.

R02 If Persistent Fever = mild and rash = very high and night sweat = mild and muscle aches = mild and chronic cough = very high and sore of genital/neck/armpit = mild and fungal nail infection = high and persistent weight loss = mild and tiredness = moderate and swollen groin/gland = mild and oral thrush = mild and shingles = high and persistent diarrhoea = mild and pneumonia =

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mild and chills = moderate and loss of appetite = mild and headache = mild and memory loss = very high and frequent yeast infection = high then HIV/AIDS Risk = high.

R03 If Persistent Fever = mild and rash = mild and night sweat = mild and muscle aches = very high and chronic cough = mild and sore of genital/neck/armpit = mild and fungal nail infection = mild and persistent weight loss = very high and tiredness = mild and swollen groin/gland = high and oral thrush = mild and shingles = mild and persistent diarrhoea = mild and pneumonia = mild and chills = high and loss of appetite = moderate and headache = mild and memory loss = moderate and frequent yeast infection = moderate then HIV/AIDS Risk = Moderate.

R04 If Persistent Fever = very high and rash = mild and night sweat = mild and muscle aches = mild and chronic cough = mild and sore of genital/neck/armpit = very high and fungal nail infection = mild and persistent weight loss = very high and tiredness = mild and swollen groin/gland = mild and oral thrush = mild and shingles = moderate and persistent diarrhoea = mild and pneumonia = mild and chills = very high and loss of appetite = moderate and headache = very high and memory loss = mild and frequent yeast infection = high then HIV/AIDS Risk = high.

R05 If Persistent Fever = high and rash = very high and night sweat = mild and muscle aches = mild and chronic cough = high and sore of genital/neck/armpit = very high and fungal nail infection = mild and persistent weight loss = moderate and tiredness = moderate and swollen groin/gland = high and oral thrush = high and shingles = high and persistent diarrhoea = moderate and pneumonia = moderate and chills = very high and loss of appetite = moderate and headache = high and memory loss = very high and frequent yeast infection = mild then HIV/AIDS Risk = high

R06 If Persistent Fever = moderate and rash = mild and night sweat = moderate and muscle aches = moderate and chronic cough = high and sore of genital/neck/armpit = high and fungal nail infection = very high and persistent weight loss = very high and tiredness = mild and swollen groin/gland = moderate and oral thrush = mild and shingles = high and persistent diarrhoea = very high and pneumonia = mild and chills = very high and loss of appetite = mild and headache = very high and memory loss = mild and frequent yeast infection = high then HIV/AIDS Risk = high.

R07 If Persistent Fever = mild and rash = mild and night sweat = moderate and muscle aches = mild and chronic cough = moderate and sore of genital/neck/armpit = mild and fungal nail infection = mild and persistent weight loss = mild and tiredness = moderate and swollen groin/gland = mild and oral thrush = mild and shingles = moderate and persistent diarrhoea = mild and pneumonia = high and chills = very high and loss of appetite = moderate and headache = high and memory loss = very high and frequent yeast infection = mild then HIV/AIDS Risk = mild.

R08 If Persistent Fever = moderate and rash = moderate and night sweat = very high and muscle aches = high and chronic cough = very high and sore of genital/neck/armpit = mild and fungal nail infection = very high and persistent weight loss = mild and tiredness = mild and swollen groin/gland = moderate and oral thrush = moderate and shingles = moderate and persistent diarrhoea = very high and pneumonia = very high and chills = moderate and loss of appetite = high and headache = moderate and memory loss = very high and frequent yeast infection = mild then HIV/AIDS Risk = moderate.

R10 If Persistent Fever = high and rash = moderate and night sweat = moderate and muscle aches = very high and chronic cough = moderate and sore of genital/neck/armpit = high and fungal nail infection = very high and persistent weight loss = high and tiredness = moderate and swollen groin/gland = mild and oral thrush = very high and shingles = high and persistent diarrhoea = high and pneumonia = moderate and chills = high and loss of appetite = mild and headache = moderate and memory loss = very high and frequent yeast infection = moderate then HIV/AIDS Risk = Very high.

R11 If Persistent Fever = high and rash = very high and night sweat = mild and muscle aches = very high and chronic cough = mild and sore of genital/neck/armpit = mild and fungal nail infection = moderate and persistent weight loss = high and tiredness = mild and swollen groin/gland = moderate and oral thrush = very high and shingles = high and persistent diarrhoea = mild and

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pneumonia = very high and chills = mild and loss of appetite = moderate and headache = very high and memory loss = very high and frequent yeast infection = high then HIV/AIDS Risk = very high.

R12 If Persistent Fever =moderate and rash = moderate and night sweat = moderate and muscle aches = high and chronic cough = moderate and sore of genital/neck/armpit = very high and fungal nail infection = very high and persistent weight loss = high and tiredness = mild and swollen groin/gland = moderate and oral thrush = very high and shingles = mild and persistent diarrhoea = very high and pneumonia = high and chills = moderate and loss of appetite = high and headache = very high and memory loss = high and frequent yeast infection = mild then HIV/AIDS Risk = very high.

R13 If Persistent Fever = mild and rash = very high and night sweat = very high and muscle aches = moderate and chronic cough = very high and sore of genital/neck/armpit = mild and fungal nail infection = mild and persistent weight loss = high and tiredness = high and swollen groin/gland = high and oral thrush = moderate and shingles = moderate and persistent diarrhoea = moderate and pneumonia = high and chills = high and loss of appetite = mild and headache = high and memory loss = moderate and frequent yeast infection = very high then HIV/AIDS Risk = high.

R14 If Persistent Fever = mild and rash = moderate and night sweat = moderate and muscle aches = high and chronic cough = mild and sore of genital/neck/armpit = very high and fungal nail infection = moderate and persistent weight loss = very high and tiredness = moderate and swollen groin/gland = very high and oral thrush = high and shingles = moderate and persistent diarrhoea = very high and pneumonia = mild and chills = mild and loss of appetite = moderate and headache = moderate and memory loss = high and frequent yeast infection = mild then HIV/AIDS Risk = high.

R15 If Persistent Fever = high and rash = high and night sweat = high and muscle aches = high and chronic cough = high and sore of genital/neck/armpit = high and fungal nail infection = high and persistent weight loss = high and tiredness = high and swollen groin/gland = high and oral thrush = high and shingles = high and persistent diarrhoea = high and pneumonia = high and chills = high and loss of appetite = high and headache = high and memory loss = mild and frequent yeast infection = mild then HIV/AIDS = high.

R16 If Persistent Fever = very high and rash = very high and night sweat = very high and muscle aches = very high and chronic cough = very high and sore of genital/neck/armpit = very high and fungal nail infection = very high and persistent weight loss = very high and tiredness = very high and swollen groin/gland = very high and oral thrush = very high and shingles = very high and persistent diarrhoea = very high and pneumonia = very high and chills = very high and loss of appetite = mild and headache = mild and memory loss = mild and frequent yeast infection = mild then HIV/AIDS Risk = very high.

R17 If Persistent Fever = mild and rash = moderate and night sweat = moderate and muscle aches = mild and chronic cough =mild and sore of genital/neck/armpit =high and fungal nail infection = very high and persistent weight loss = mild and tiredness = moderate and swollen groin/gland = mild and oral thrush = mild and shingles = mild and persistent diarrhoea = high and pneumonia = high and chills = high and loss of appetite = high and headache = mild and memory loss = moderate and frequent yeast infection = high then HIV/AIDS Risk = mild.

R18 If Persistent Fever = moderate and rash = very high and night sweat = mild and muscle aches = moderate and chronic cough = very high and sore of genital/neck/armpit = very high and fungal nail infection = mild and persistent weight loss = very high and tiredness =mild and swollen groin/gland =high and oral thrush = moderate and shingles = moderate and persistent diarrhoea =high and pneumonia = very high and chills = moderate and loss of appetite = moderate and headache = moderate and memory loss = high and frequent yeast infection = high then HIV/AIDS Risk = very high.

R19 If Persistent Fever = very high and rash = mild and night sweat = mild and muscle aches = very high and chronic cough = mild and sore of genital/neck/armpit = mild and fungal nail infection = very high and persistent weight loss = very high and tiredness = mild and swollen groin/gland = mild and oral thrush = mild and shingles = mild and persistent diarrhoea = mild and

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pneumonia = mild and chills = mild and loss of appetite = high and headache = high and memory loss = very high and frequent yeast infection = high then HIV/AIDS Risk = very high.

R20 If Persistent Fever = mild and rash = very high and night sweat = mild and muscle aches = mild and chronic cough =very high and sore of genital/neck/armpit = mild and fungal nail infection = very high and persistent weight loss = mild and tiredness = moderate and swollen groin/gland = mild and oral thrush = mild and shingles = high and persistent diarrhoea = mild and pneumonia = mild and chills = moderate and loss of appetite = mild and headache = mild and memory loss = mild and frequent yeast infection = mild then HIV/AIDS Risk = high.

R21 If Persistent Fever = mild and rash = mild and night sweat = mild and muscle aches = very high and chronic cough = mild and sore of genital/neck/armpit = mild and fungal nail infection = very high and persistent weight loss = very high and tiredness = mild and swollen groin/gland = high and oral thrush = mild and shingles = mild and persistent diarrhoea = mild and pneumonia = mild and chills = high and loss of appetite = moderate and headache = mild and memory loss = moderate and frequent yeast infection = moderate then HIV/AIDS Risk = moderate.

R22 If Persistent Fever =mild and rash = mild and night sweat = mild and muscle aches = very high and chronic cough =very high and sore of genital/neck/armpit = mild and fungal nail infection = mild and persistent weight loss = mild and tiredness = mild and swollen groin/gland = mild and oral thrush = mild and shingles = mild and persistent diarrhoea = mild and pneumonia = mild and chills = very high and loss of appetite = moderate and headache = mild and memory loss = mild and frequent yeast infection = mild then HIV/AIDS Risk = mild.

R23 If Persistent Fever =moderate and rash = mild and night sweat = moderate and muscle aches = very high and chronic cough =very high and sore of genital/neck/armpit = moderate and fungal nail infection = very high and persistent weight loss = moderate and tiredness = mild and swollen groin/gland = mild and oral thrush = mild and shingles = mild and persistent Diarrhoea = very high and pneumonia = moderate and chills = very high and loss of appetite = moderate and headache = moderate and memory loss = mild and frequent yeast infection = mild then HIV/AIDS Risk = mild.

Table 3: shows the conditions and clinical staging

Condition	**Clinical Stage Level**
If condition = Moderate	Stage 1 or Stage 2
If condition = High	Stage 3
If condition = Very High	Stage 4
If condition = Mild	HIV not likely

The Fourth Layer calculates the consequents based on the consequent parameters, by applying the firing strength to the consequent membership function of a rule to generate a qualified consequent membership function.

(iv) Defuzzification Interface

The fifth layer of the ANFIS architecture forms the overall output of the ANFIS system, by using the process of defuzzification to transform each rule fuzzy results into a crisp output. Defuzzification involves the process of turning the fuzzy set output of a fuzzy inference system into a non-fuzzy (crisp) output, which is the way a crisp value is extracted from a fuzzy set as a representative value. There are several methods employed in achieving this, which includes centre-of-area/gravity, centre of sums, centre-of-largest-area, first-of-maxima, and the weighted average method. The weighted average method of deffuzification was employed because all output

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membership functions must be the same type which is either linear or constant in an ANFIS architecture, in this study the output membership functions was chosen as constant.

3.1 Algorithm for Adaptive Neuro-Fuzzy Diagnosis, Staging and Treatment of HIV/AIDS

Step 1: Capture Patients (individual's) personal information into the database
Step 2: Input signs and symptoms of patient's complaint into the system.
Step 3: Assign fuzzy values to variables identified to be causative symptoms
Step 4: Search the knowledge base for the signs and symptoms identified
Step 5: Search the associated degree of intensity, that is Very High, High, Moderate and Mild.
Step 6: Apply fuzzy rules
Step 7: Map fuzzy inputs into their respective weighing factors to determine the degree of membership
Step 8: Use neural network to represent the membership functions
Step 9: Train the neural network
Step 10: Determine the rule base evaluation
Step 11: Determine the firing strength of the rules
Step 12: Calculate the degree of truth of each of the rules by evaluating the non-zero minimum value
Step 13: Compute the HIV Risk,
Step 14: Compute the staging of the disease
Step 15: Compute the Regimen based on Patient's record.
Step 16: Output Neuro fuzzy HIV/AIDS Risk, clinical staging and the respective regimen
Step 17: Stop

3.2 Dataset for Adaptive Neuro-Fuzzy Inference System

The dataset used for training is specified with a matrix with n+1 columns, where n represents input data into the fuzzy inference system and the final column indicate the output data for the system. The input data in this study are the symptoms which are 19 (nineteen) attributes in number, with 2 (two) final columns of the HIV/AIDS risk and the clinical stage: HIV Status Conclusion and Clinical Stage Interpretation The HIV Status conclusion was further classified into: Normal and Smurf, while the clinical stage interpretation was also grouped into two classes: Normal and Smurf. The Nineteen Attributes of the datasets are as follows: Persistent Fever, Rash, Night Sweat, Muscle Aches, Chronic Cough, Sore of Genitals Neck or Armpit, Fungal Nail Infection, Persistent Weight Loss, Tiredness, Swollen Groin/Gland, Oral Thrush, Shingles, Persistent Diarrhoea, Pneumonia, Chills, Loss of Appetite, Headache, Memory Loss, Frequent Yeast Infection.

4. Results and Discussion

The steps employed to construct the ANFIS model are discussed as follow:

a. The data obtained was split into two parts, 70 % of the dataset was used for training and 30% for testing. The 70% of the data was supplied to the ANFIS so as to create a learning process for the Neuro-Fuzzy system as it will help the system to keep good experimental knowledge while the remaining 30% was used for validating the system.
b. The dataset was loaded into the ANFIS model by supplying the input variables loaded through the Matlab workspace. A total number of nineteen attributes and one group label was loaded into the ANFIS model. The parametric setting of the fuzzy inference system was done using the subtractive clustering method.

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c. A total number of 66 Rules was generated by the subtractive clustering method. The rules generated are shown in figures 2 and 3

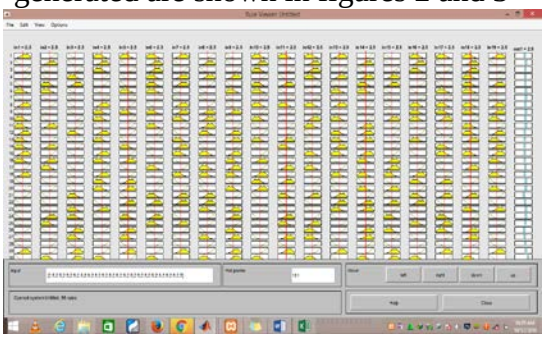

Figure 2: Generated Rules

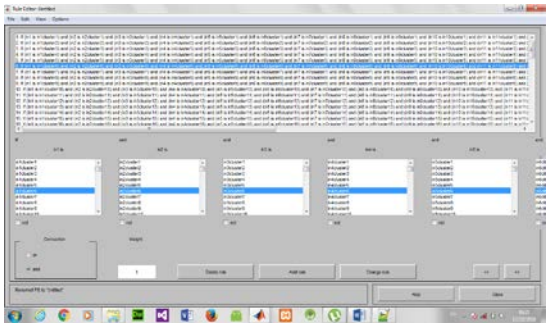

Figure 3: Generated Rules

d. Generation of the membership functions as shown in figure 3 and figure 4 shows the fuzzy inference structure with a total number of nineteen inputs, sugeno engine and one output.

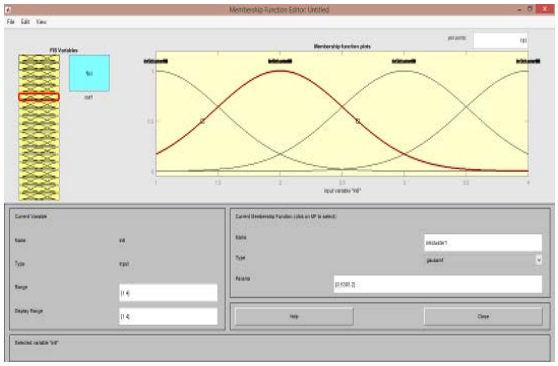

Figure 4: Generated Membership Functions

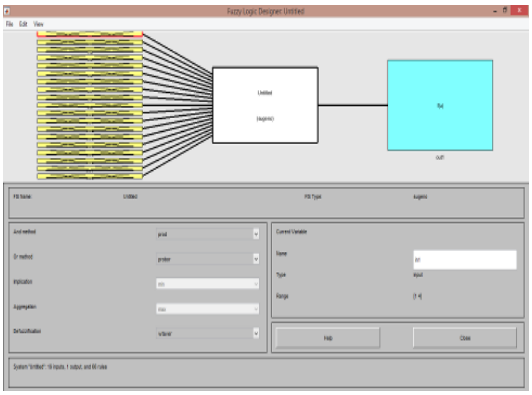

Figure 5: Fuzzy Inference

Structure

e. Figure 6 shows the generated structure of the ANFIS model. It gives a graphical illustration of the number of 19 inputs, the clustering of the membership's functions, the synchronization of the 66 rules and 66 output membership functions.

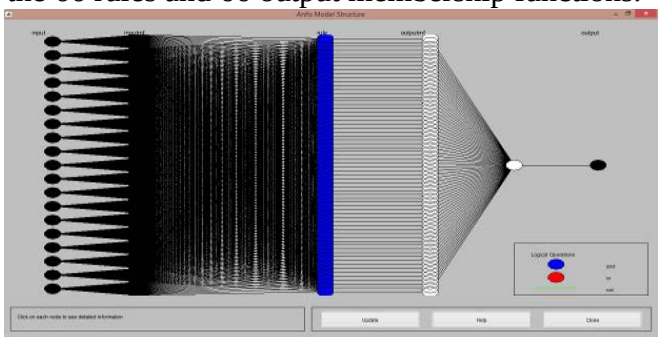

Figure 6: Adaptive Neuro-Fuzzy Inference System Model Structure

f. The loading of the datasets and the training error values generated after the training of the datasets were obtained in this phase, which is an indication of the performance of the trained

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model. A very low mean square error of 7.7268 X 10 $^{-8}$ was obtained, this indicates that the model memorized or learned well.

g. The experimental results was applied to compare the target which is the expected output to the predicted output of the model as indicated in figure 7. A total number of 75 dataset was used to test and the model was able to classify correctly 70 and classified 5 incorrectly. Confusion matrix and system evaluation was conducted to illustrate the variations between the predicted output by the ANFIS model and target (Expected output). The result shows a true positive rate of 0.93333 and false negative rate 0.6667 with 93.33% of data classified correctly and 6.667 % of data classified incorrectly by the ANFIS model as shown in figure 8.

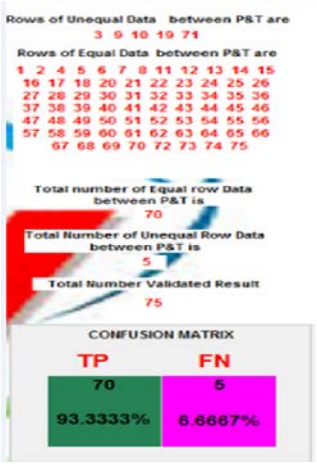

Figure 7: Test Dataset Validation

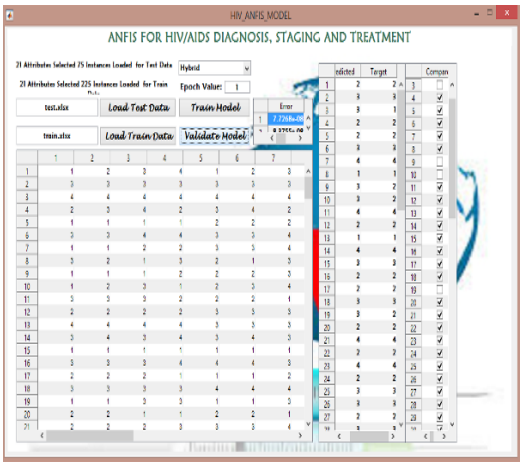

Figure 8: Confusion Matrix

Patients Clinical staging

At this stage the user enters the patient's registration number and the specific symptoms unique to the user and saves it into the database. The existing patient's data in the database can be queried by clicking on the search button and supplying the patient's registration number to retrieve his or her personal information. The diagnostic report of the HIV/AIDS risk of the patient, the clinical stage, and the treatment advice for the patient will be displayed after the user has selected the symptoms peculiar to the patient. Figure 9(a), 9(b), 10(a), 10(b), 11(a), 11(b), 12(a) and 12(b) shows the patient HIV/AID diagnosis, clinical stage and regimen prescription based on the selected symptoms

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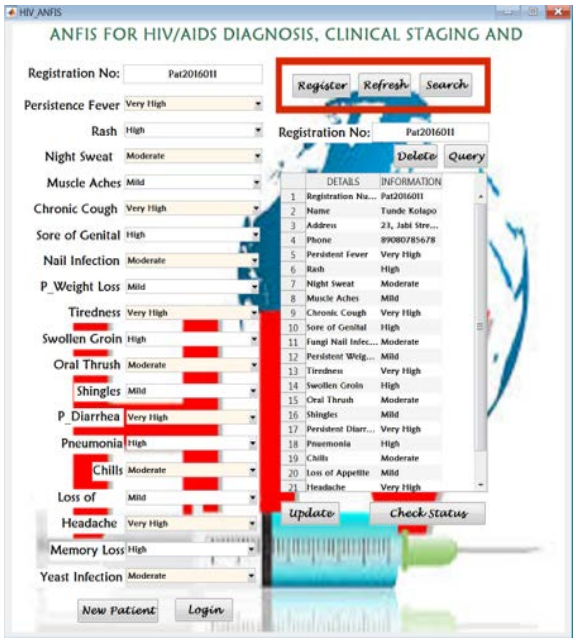


Figure 9(a): Selected Symptoms for patient 1

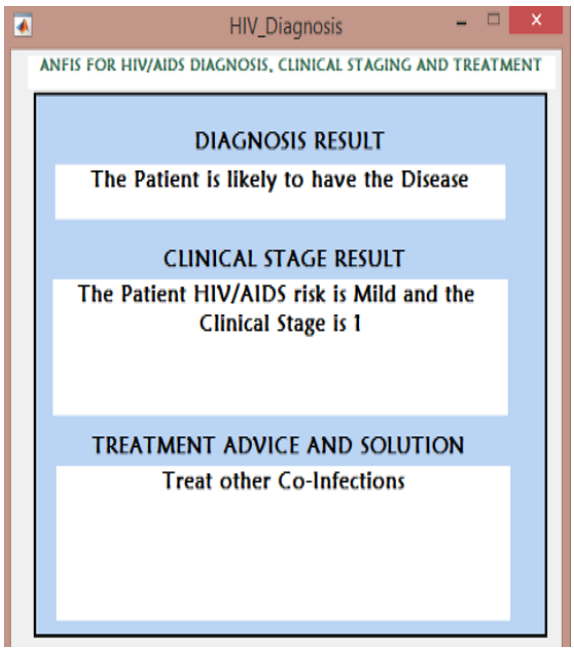


Figure 9(b): HIV/AIDS Status for Patient 1

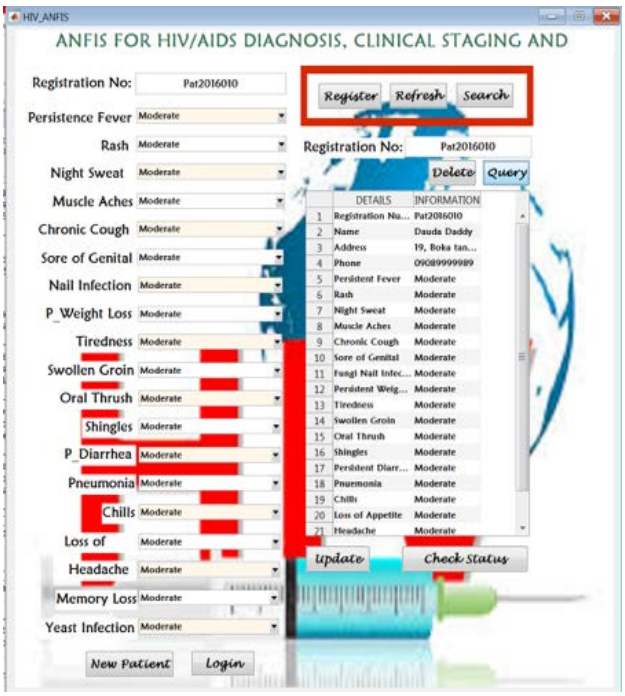
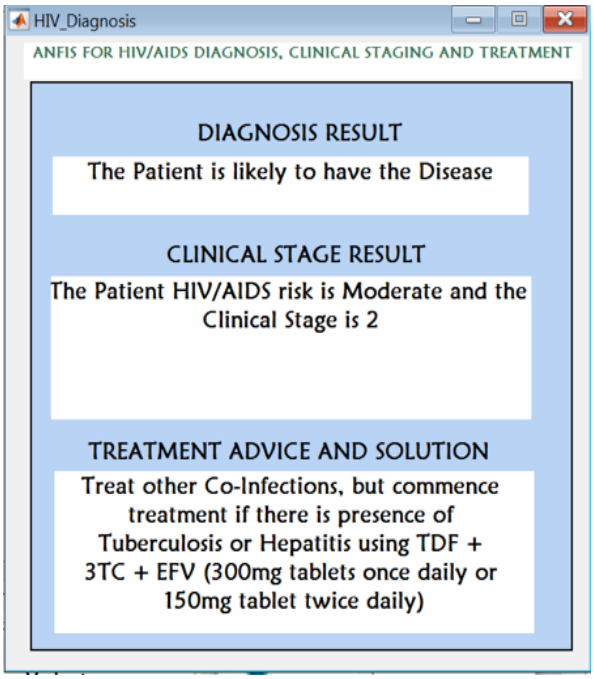


Figure 10(a): Selected symptoms for Figure



10(b): Figure HIV/AIDS status for Patient 2

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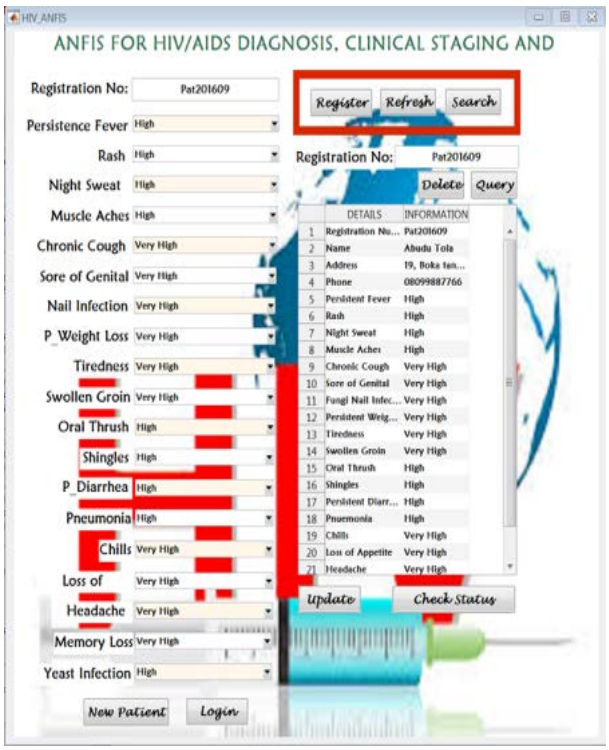


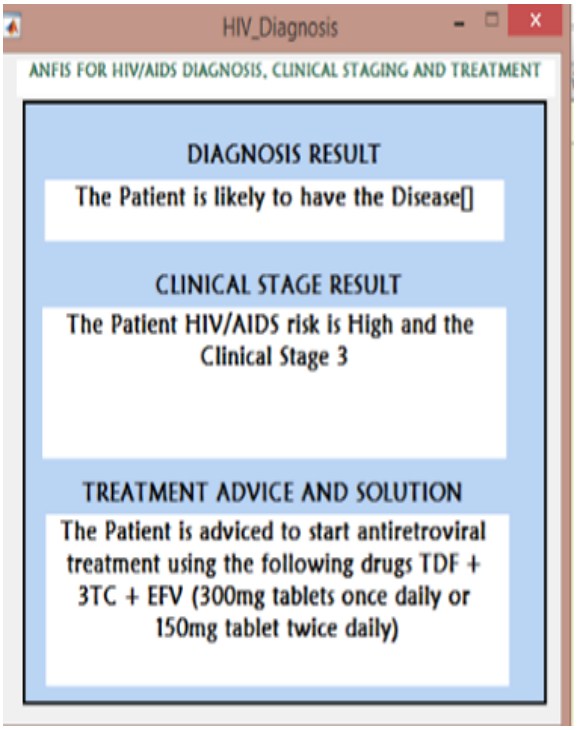
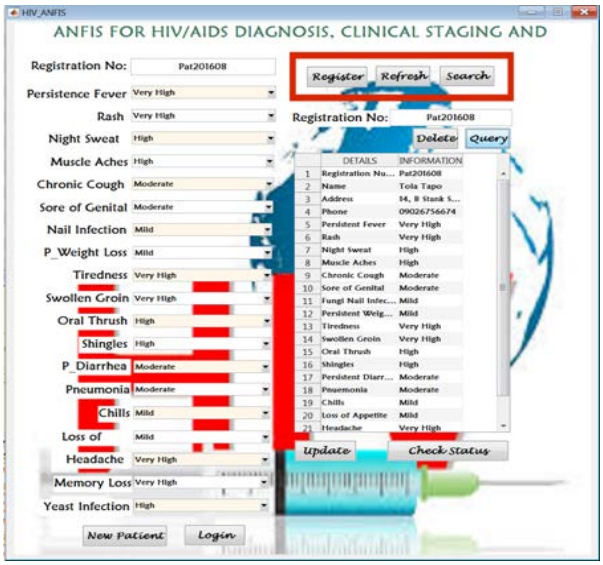


Figure 11(a): Selected symptoms for patient 3

Figure 11(b): HIV/AIDS status for Patient 3



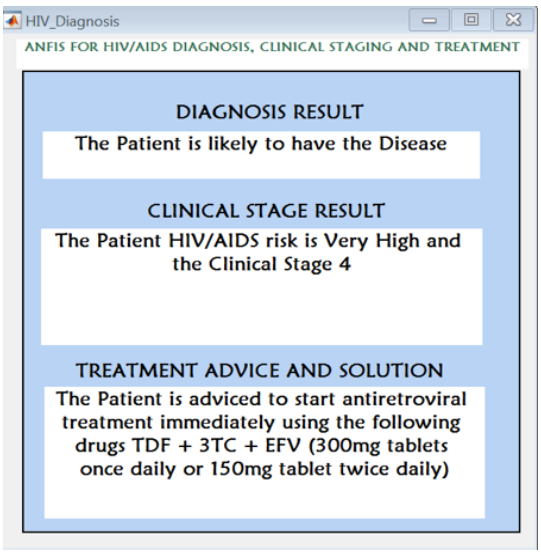


Figure 12(a): Selected symptoms for patient 4

Figure 12(b): HIV/AIDS status for patient 4

5. Conclusion & Recommendation

The need for modeling and implementation of a system that would assist doctors in medical diagnosis and staging of HIV/AIDS has become imperative and hence cannot be over emphasized. This study applies an adaptive neuro fuzzy system to help in HIV/AIDS diagnosis, Clinical staging

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and treatment recommendation using a set of symptoms demonstrates the hands-on application of ICT (Information and Communication Technology) in the area of diagnostic pattern evaluation and staging by determining the extent of membership of individual symptoms to bring about effectiveness and efficiency in the health care management of individuals with the HIV/AIDS disease.

One of the major challenges faced today in under developed country is access to quality and fast health facilities which poses a big threat to the health conditions of patients. Accurate medical diagnosis is one of the major ways to sustain good health and live long. In this study, Adaptive Neuro-Fuzzy Inference system was developed by means of the adaptive neuro-fuzzy inference model using the combination of nineteen attributes (symptoms) and outputs namely diagnosis and staging of the HIV/AIDS disease as well as treatment recommendations based on the stages. HIV/AIDS Dataset used was obtained from HIV/AIDS medical expert, this was used to build the system, not only was the system built but an evaluation performance was done on so as to determine the level of predictive and explanatory power of the developed system. The resulting test carried on the systems shows a very good predictive model with an accuracy of 93.33%.

The results obtained from the adaptive neuro fuzzy inference system shows that the system can be adopted for the diagnosis and staging of HIV/AIDS as this will in turn help to reduce mortality rate in cases where limited medical doctors are available, as it provides very rapid method of diagnosis and staging with much accuracy and reduces the number of hours patients spend in hospitals. This inference system is user-friendly and carries out diagnosis and staging of the HIV/AIDS disease based on patients' complaints (symptoms) to the medical expert.

References

1. Federal Ministry of Health, A., Nigeria. (2014). Integrated Guidelines for HIV Prevention, Treatment and Care.
2. Parker, R. (2002). The Global HIV/AIDS Pandemic, Structural Inequalities, and the Politics of International Health. *American Journal of Public Health, 92*(3), 343-347.
3. Rasschaert, F., Philips, M., Van Leemput, L., Assefa, Y., Schouten, E., & Van Damme, W. (2011). Tackling health workforce shortages during antiretroviral treatment scale-up--experiences from Ethiopia and Malawi. *J Acquir Immune Defic Syndr, 57 Suppl 2*, S109-112. doi: 10.1097/QAI.0b013e31821f9b69.
4. HIMAN, H. i. M. A. o. N. (2016). Development of Medical Records Keeping in Nigeria.
5. Abdulkadir, A. (2011). Medical record system in Nigeria: observations from multicentre auditing of radiographic requests and patients' information documentation practices. *Journal of Medicine and Medical Science, 2*(5), 854-858.
6. Chaplin, B., Meloni, S., Eisen, G., Jolayemi, T., Banigbe, B., Adeola, J., . . . Kanki, P. (2015). Scale-up of networked HIV treatment in Nigeria: creation of an integrated electronic medical records system. *Int. J. Med. Inform, 84*(1), 58-68. doi: 10.1016/j.ijmedinf.2014.09.006.
7. Oh, H., Rizo, C., Enkin, M., & Jadad, A. (2005). What is eHealth (3): a systematic review of published definitions. *Journal of medical Internet research, 7*(1), e1.
8. Osunyomi, B. D., & Grobbelaar, S. S. S. (2015). Integrating eHealth in HIV/AIDS intervention programmes in South Africa. *SA Journal of Information Management, 17*(1), 10 pages.
9. AETC. (2014). HIV Classification: CDC and WHO Staging Systems. *AIDS Education and Training Centers National Coordinating Resource Center*.
10. Monjok, E., Smesny, A., & Essien, E. J. (2009). HIV/AIDS - Related Stigma and Discrimination in Nigeria: Review of Research Studies and future directions for Prevention Strategies. *African journal of reproductive health, 13*(3), 21-35.

ISSN 1512-1232

11. Reis, C., Heisler, M., Amowitz, L. L., Moreland, R. S., Mafeni, J. O., Anyamele, C., & Iacopino, V. (2005). Discriminatory attitudes and practices by health workers toward patients with HIV/AIDS in Nigeria. *PLoS Med, 2*(8), e246.
12. Babalola, S. (2007). Readiness for HIV testing among young people in northern Nigeria: the roles of social norm and perceived stigma. *AIDS and Behavior, 11*(5), 759-769.
13. Toosi, A. N., & Kahani, M. (2007). A new approach to intrusion detection based on an evolutionary soft computing model using neuro-fuzzy classifiers. *Computer communications, 30*(10), 2201-2212.
14. Oladele Tinuke, & Sanni Y. (2015). Dental Expert System.
15. Ojeme B. O, & Maureen A. (2014). Human Immunodeficiency Virus (HIV) Diagnosis Using Neuro-Fuzzy Expert System. *Oriental Journal of Computer Science and Technlology*.
16. Agboizebeta, I. A., & Chukwuyeni, O. J. (2012). Application of neuro-fuzzy expert system for the probe and prognosis of thyroid disorder. *International Journal of Fuzzy Logic Systems (IJFLS) Vol, 2*.
17. Masizana-Katongo, A., Leburu-Dingalo, T., & Mpoeleng, D. (2009). *An expert system for HIV and AIDS information.* Paper presented at the Proceedings of the World Congress on Engineering.
18. Salah, B., Alshraideh, M., Beidas, R., & Hayajneh, F. (2011). Skin cancer recognition by using a neuro-fuzzy system. *Cancer informatics, 10*, 1.
19. Brown-Peterside, P., Redding, C. A., Ren, L., & Koblin, B. A. (2000). Acceptability of a stage-matched expert system intervention to increase condom use among women at high risk of HIV infection in New York City. *AIDS Education and Prevention, 12*(2), 171.

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