Diagnosing Skin Diseases Using an Artificial Neural Network

L. G. Kabari and F. S. Bakpo, *Member, IEEE*

Abstract—**Development of medical expert systems that use artificial neural networks as their knowledge bases appears to be a promising method for predicting diagnosis and possible treatment routine. This paper deals with the construction and training of an artificial neural network for Skin Disease Diagnosis (SDD) based on patients' symptoms and causative organisms. The artificial neural network constructed using a feed-forward architectural design is shown to be capable of successfully diagnosing selected skin diseases in the tropical areas such as Nigeria with 90 percent accuracy. The work may in the future serve as a knowledge base for an expert system specializing in medical diagnosis, testing evaluation, treatment evaluation, and treatment effectiveness. The work serves as the first component of a much larger system that will assist physicians facilitate the reasonable ordering of tests and treatments and minimize unnecessary laboratory routines while reducing operational costs.**

Index Terms -**Artificial Neural Networks, Patients, Knowledge base, symptoms, Feed-forward.**

I. Introduction

THE use of expert system as a mean of conducting medical diagnosis and recommending successful treatments has been a highly active research field in the past few years. Development of medical expert system that uses artificial neural networks (ANN) as knowledge base appears to be a promising method for diagnosis and possible treatment routines. One of the major applications of medical informatics has been the implementation and use of expert systems to predict medical diagnoses based upon a set of symptoms [1]. Furthermore, such expert systems serve as an aid to medical professionals in recommending effective laboratory tests and treatments of diseases. An intelligent computer program assisting medical diagnosis could provide easy access to a wealth of information from past patient data. Such a resource may help hospitals reduce excessive costs from unnecessary laboratory test and ineffective patient treatment, while maintaining high quality of medical care. In [2], Klerfors argued that, so far these expert systems only served as aids to the physician and are not 100% reliable. Current expert systems do not provide enough value to the physician to justify their large-scale implementation. One major drawback of conventional medical expert systems is the use of static knowledge base developed from a limited number of cases and a limited population size, demographics, and geographic location. The knowledge base is inherently not dynamic and is not routinely updated to keep up with emerging trends such as the appearance or increased prevalence of unforeseen diagnoses. The result is that, after a given period of time this inflexibility limits the use of the knowledge base as it no longer reflects the current characteristics of the population at risk. Given these points, the development of a knowledge base using artificial neural network technology naturally lends itself towards the task of predicting medical diagnosis. In addition, the technology appears to be a promising method for recommending possible treatment routines. It offers flexible and quick means of designing dynamic expert systems that consider different decision variables in their predictive routines. With its dynamic nature and on-line learning capability, a neural network knowledge base can also be updated with more recent patient data. Thus, once an initial knowledge base has been set up, it can never become obsolete with time. In this way, the system can effectively capture varying ailment trends in a given population while retaining its previous knowledge. One of the most important problems of medical diagnosis, in general, is the subjectivity of the specialist. Human being always makes mistakes and because of his limitation, errors do occur during diagnosis. It has been noted, in particular in pattern recognition activities, that the experience of the professional is closely related to the final diagnosis [3]. This is due to the fact that the result does not depend on a systematized solution but on the interpretation of the patient's signals. Brause [4] pointed out that almost all physicians are confronted during their formation by the task of learning to diagnose. Here, they have to solve the problem of deducing certain diseases or formulating a treatment based on more or less specified observations and past experience. Principally, humans can recognize patterns or objects very easily but fail when probabilities have to be assigned to observations. In [4], Brause gave, an example of a study in the year 1971 that showed these basic facts in the medical area. The study showed that humans have many limitations in diagnosis. In this paper, we presented an underlying infrastructure for diagnosing skin diseases using a technique of neural network.

Manuscript received June 26, 2009. This work was supported in part by Olivet Clinic, Port Harcourt in Nigeria.

L. G. Kabari is with Computer Science Department, Rivers State Polytechnic, Bori, Rivers State, Nigeria: Phone: +234 8037055369; e-mail: Lekabs@yahoo.com

F. S. Bakpo is with Computer Science Department, University of Nigeria, Nssuka, Nigeria: Phone: +234 8034401289; e-mail: fbakpo@yahoo.com.

978-1-4244-3523-4/09/$25.00©2009 IEEE

II. SKIN DIAGNOSTIC ANALYSIS AND ARTIFICIAL NEURAL NETWORK DESIGN

Skin diseases are diseases that may originate inside the body and manifest on the skin or start from the skin and manifest on the skin [5]. This session presents the analysis of these diseases. It also presents the structure of an artificial neural network for handling skin diseases diagnosis.

A. ANALYSIS OF SKIN DISEASE DIAGNOSTIC SYSTEM

The human expert performs the diagnosis of skin diseases by collecting patient records and complaints. This list of patient complaints and observed skin conditions is then expanded into several Boolean symptoms. The symptoms are further subjected to knowledge matching with the knowledge already possessed by the human expert (knowledge base-experience). If there is a match, the doctor recommends the disease as a possible skin disease. In some cases, the human expert may subject the patient to further laboratory tests in order to ascertain the causative agent of the skin condition. The test could serve as a confirmatory test if the disease diagnosed is actually caused by microorganism such as bacteria, warts, virus, fungi, etc. When the human expert is inexperienced or has not come across such skin condition, he uses trial and error to diagnose. This is done by the combination of all the possible conditions, comparing them with known conditions and narrowing the judgment. During this process, learning is said to have taken place if the skin condition is properly diagnosed and treated. Thus, the human expert depends largely on his experience and the patient complaint interpretation. Figure 1 illustrates the stages of this analysis.

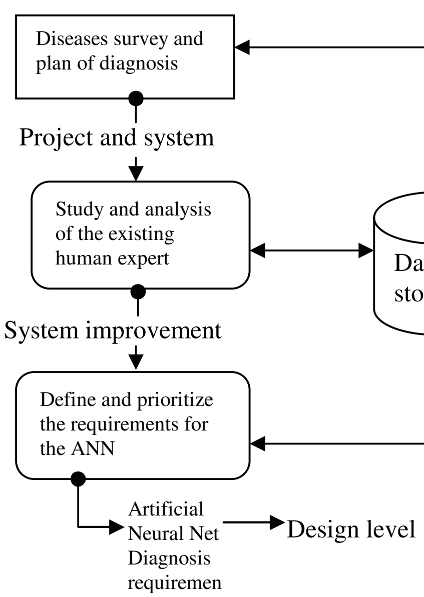

Fig.1 Skin Disease Diagnostic System Analysis

In figure 1, disease survey includes the general collection and listing of the skin diseases that is studied and used in the process of system development. This includes complaint, observation and lab test.

B. SKIN DISEASE DATA INPUT DESIGN

The data used for the diagnostic system consist of the following components: Patient vital signs, Patient verbal complaints, Patient demographics and Presence of specific symptoms. The elements of each of the components serve as an input variable to the network. Thus, the task of the artificial neural network is to draw a correlation between the patient's presentation, using self-reported symptoms and vital sign. While patient demographics and vital signs are a key element in providing clues to an ailment, it has been observed that the patients' complaints provide greater insights for predicting medical diagnoses. However some skin conditions have to rely heavily on good scanning machines for an accurate prediction [6]. Expanded complaint input variables are shown in Table 1.

Table 1 Expanded complaint input variables (*Source, [6]*)

Compliant type	**Compliant type**
Itching	Burous
Pus dripping	Inflamed
Hard inside	White striae
Painless	Sore
Painful	Warm
Rash	Redness
Irritation	Macerate
Swelling	Peeling
Bleeding	Blistering

Table 1, shows a list of input variables created by the expansion of the symptom string. The goal is to create an automated data processing system capable of taking as input a set of these records and using it to arrive at a correct diagnosis. The symptom input variables were created to draw a correlation between a specific complaint and the possible skin disease.

C. NEURAL NETWORK STRUCTURE FOR SKIN DISEASE DIAGNOSTIC

The design and architecture of ANN selected for the skin diseases is based on the feed - forward network. This means that the artificial neurons are organized in layers, and send their signals "forward", (i.e., from input to output) and then the errors are propagated backwards.

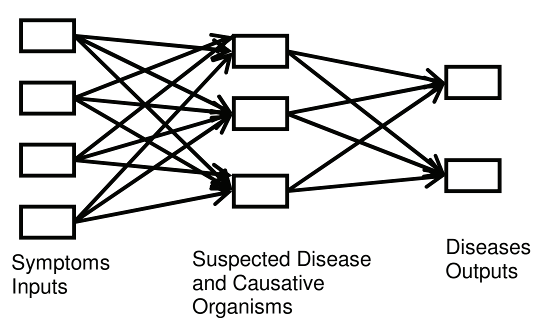

Figure 4: ANN structure for skin disease

The network receives input symptoms by neurons in the input layer, and the output of the network is given by the neurons on an output layer. There may be one or more intermediate hidden layers. The backpropagation algorithm uses supervised learning, which means that we provide the algorithm with examples of the inputs and outputs we want the network to compute, and then the error (difference between actual and expected results) is calculated. The idea is to reduce this error, until the ANN learns the training data. The training begins with random weights, and the goal is to adjust them so that the error will be minimal. The activation function of the artificial neurons in ANNs implementing the backpropagation algorithm [7] is given as follows:

$$A_j(\bar{x}, \bar{w}) = \sum_{i=0}^{n} x_i . w_{ji} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

The output function uses the sigmoidal function:

$$O_j(\bar{x}, \bar{w}) = 1/[1 + e^{A_j(\bar{x}, \bar{w})}] \ldots\ldots\ldots\ldots\ldots (2)$$

We defined the error function for the output of each neuron as:

$$E_j(\bar{x}, \bar{w}, d) = \Sigma(O_j(\bar{x}, \bar{w}) - d_j)^2 \ldots\ldots\ldots\ldots (3)$$

The weights are adjusted using the method of gradient descent:

$$\Delta w_{ji} = -\eta(\partial E/\partial w_{ji}) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

Where: x_i are the inputs, w_{ij} are the weights, $O_j(\bar{x}, \bar{w})$ are the actual outputs, dj are the expected outputs and η - learning rate.

For the skin diagnostic system, we defined the following firing rules: take a collection of symptoms for a disease to a node, the presence of which causes it to fire (the 1-taught set of patterns) and the absence prevents it from firing (the 0-taught set). If there is a tie in symptoms, then the ANN remains in the undefined state (1/0). For instance, in scabies, which have 4 - input symptoms, the neuron is taught to fire (i.e., output 1), when the input (tiny bumps-X_1, itching-X_2, scaly-X_3 and on fingers-X_4) is 1111 or 0111 or 1101 and will not fire ((i.e., output 0) when the input is 0000 or 1010 or 1110. The firing rule is depicted in table 2.

Table 2 Truth table for the skin disease firing rule

X1:	0	0	0	0	0	0	0	0
X2:	0	0	0	0	1	1	1	1
X3:	0	0	1	1	0	0	1	1
X4:	0	1	0	1	0	1	0	1
OUTPUT	0	1/0	1/0	1/0	1/0	1/0	1/0	1
X1:	1	1	1	1	1	1	1	1
X2:	0	0	0	0	1	1	1	1
X3:	1	0	1	1	0	0	1	1
X4:	0	1	0	1	0	1	0	1
OUTPUT	1/0	1	0	1/0	1/0	1	0	1

It is important to note that the decision concerning each firing rule was derived directly from the Scabies condition. This condition specifies that: Scabies occurs only on the hand has to be Itchy. These conditions are weighed higher than other conditions. The values 1111 or 0111 or 1101, implies that all conditions must be met or at least there is either tiny bumps or scaly skin to meet the 50% threshold mark required for firing. This is a very important rule formulation trick, which also requires some higher level knowledge of the disease for which rule is formulated. The rule provides a greater degree of flexibility for determining whether scabies is a skin disease or not. This is particularly true for a case where the patient has used cream to make the skin less scaly. Omission of the scaly symptom will not affect the decision of the neural network in determining whether to suspect scabies or not. This is a more realistic situation which definitely makes the neural network more desirable. The firing rule gives the neuron a sense of similarity and enables it to respond 'sensibly' to symptoms not seen during training.

III. SYSTEM IMPLEMENTATION

Once the system algorithm has been specified the coding of the system follows. The coding to a large extent is guided by the algorithm. Since the program is object oriented with classes, its implementation may not necessarily be procedural. The program coding is implemented in c++. Testing of the system was done module by module, code segment by code segment. Once a segment is in good order another segment is merged with it until the module is complete. In the testing, codes that are retested and proven correct were reused for system development. The stubs were tested on individual member functions; the main program, subroutine or subprogram. In this process the lower level modules were simulated to allow the test of the higher level modules. The diagnostic modules for instance were simulated to test the neural network selection of its actions when the selected operation is called in the main program module where the object is instantiated. When the response was proved correct the diagnostic modules itself was fully developed. This testing method made the program to work when they were merged into a single program. After the testing and merging, all the modules that have been coded and stub tested were retested as an integrated single unit.

A. TRAINING OF THE ARTIFICIAL NEURAL NETWORK

The learning process proceeds by way of presenting the network with a training set composed of input patterns together with required response pattern. By comparing the actual output with the target output for given pattern, the error is computed using equation (3). The error can then be used to alter the connection strengths between layers in other to achieve a better network's response to the same input pattern in subsequent iterations. In the proposed ANN structure, a weight of 10 was initially assigned to all the symptoms, while a threshold of 50, was chosen for the first layer. In the next stage a threshold of 70, was chosen and weights were assigned based on some probabilities.

The network was trained and the result was not satisfied, although some diseases were diagnosed correctly. Following this, a threshold of 50 was reversed and weights assigned based on its peculiarity (but, all not 10 this time). Finally, a threshold value of 70 was chosen again, while higher weights are assigned based on its exclusiveness. Scabies was chosen as a test case because it has a large number of input symptoms which matches with the ANN structure implemented.

B. RESULTS

Table 3, presents the results of testing the system. The result showed cases where suspected and diagnosed based symptoms were supplied to the system. From Table 3, a critical analysis of the results in test 1 to 4, clearly illustrates the effect of weight adjustments in the result of the diagnosis of the skin disease. In test 1, all the symptoms were used and the system confirmed with scabies. In test 2, tiny bumps symptom was dropped and the weight at 50 confirmed that bacteria is present in scabies. This was also true for test 3. However, in test 4 a symptom was dropped and the weight was below 50, indicating that an important symptom has been dropped. Thus the diagnosis indicated that bacteria are the causative organism of scabies.

C. SUCCESS RATING OF THE ANN SYSTEM

In testing the SDDSD, twenty different tests were carried out at random using various symptoms combination the results matched with the expected result of the SDDSD. Where there was a match, success was recorded. In situations where there was no match failure were recorded. The total number of success = 18. Total number of failure = 2. Total number of test was 20.

$$Percentage\ Success = \frac{18}{20} \times 100 = 90\ \%$$

$$Percentage\ Failure = \frac{2}{20} \times 100 = 10\ \%$$

IV. CONCLUSION

The paper presented a framework for diagnosing skin diseases using artificial neural networks. The proposed system was able to achieve a high level of success using the artificial neural network technique. A success rate of 90% was achieved. This infers that ANN technique is an effective and efficient method for implementing diagnostic problems. The features of the ANN provided learning capability, which makes the system opened ended to new disease conditions or variation of a known skin disease due to the mutation of the causative organism. This provides great flexibility in the diagnostic system and makes the system to be opened ended. With this flexibility in the system, the level of coverage of skin conditions by the diagnostic system is limitless. This makes the application to be useful in many conditions even in unforeseen instances.

V. RECOMMENDATION

This work is recommended to human experts and dermatologist who specializes in diagnosing and treatment of skin and related diseases. The human experts will find it useful as an aid in the decision making process and confirmation of suspected cases. Also, a non-expert will still find the work useful in areas where prompt and swift actions are required for the diagnosis of a given skin diseases listed in the system. Medical practitioners who operate in areas where there are no specialist (dermatologist) can also rely on the system for assistance. The skin diseases covered include scabies, Acne, Vulgari, Impetigo, Lieshmaniasis, Atopic Dermatitis, Syringoma, Benign, Skin Turmour, Leprosy, and Diaper Candidiasis. Others are Folliculities, Soborrhocic Dermatitis, Xantherlasma, Malasma, Urtticaria and Ichen simplex. All these diseases can be handled using the system developed in this research. The research work can also act as a pedestal for the advancement of research in neural network applications in medical diagnostic researches. The work is also recommended for developers of object-oriented system and decision-support systems.

REFERENCES

[1] D. Eugene, R. Bubak, and Z. Derek, "Diagnosis Prediction using an Artificial Neural Networks Knowledge Base," Centre for optimization and Semantic Control. Department of System Science and Mathematics. Washinton University in St Louis. (1997) .http://www.cosc. Wustle.edu/mediinfo/html

[2] D. Klerfors, "Artificial Neural Networks", Annuals of Internal Medicine, vol. 104, 1998, pp 410 – 471

[3] N. Salim, "Medical Diagnosis Using Neural Network", Generation5article, (2004).

[4] R. W. Brause, "Medical Analysis and Diagnosis by Neural networks", Computer Science Department, Franfurt a.M., Germany. Proc. IEEE Int. Conf. On Neural Networks, Vol II: pp 481 – 472, 2001.

[5] P. K. Buxton, "ABC of Dermatology. Jolly & Barber Ltd, Great Britain. Pp 1-30, 1991.

[6] National Skin Center (NSC), Singapore, available: www.nsc.gov.sg sponsored by UNESCO/US Foreign AID), 2005.

[7] S. Haykin, "Neural Networks: A comprehensive Foundation". New York Macmillian College Publishing, 842p,1994.

Table 3 Results of ANN system

Test #	Symptoms used	Causative organism	Diseases (Result)
1	Itching, tiny bumps, Scaly, fingers	Bacteria	Scabies (Success)
2	Itching, scaly, fingers	Bacteria	Scabies (Success)
3	Itching, tiny bumps, finger	Bacteria	Scabies (Success)
4	Itching, tiny bumps, scaly	Bacteria	Scabies (Success)
5	Face spot, pus, red	None	Disease not covered (Fail)
6	Face spot, red	None	Disease not covered (Success)
7	Tiny bumps, face spot, pus	None	Acne Vulgar (Success)
8	Tiny bumps, face spot	Bacteria	Acne Vulgar(Fail)
9	Tiny bumps, face spot, pus	Fungi	Acne Vulgar(Success)
10	Harmless growth, dark sketch, rough and greasy skin	Bacteria	Benign (Success)
11	Soft, dark, smooth surface	Fungi	Disease not covered (Success)
12	Dry, thick skin, red rash hypersensitive, hereditary	None	Atopic Dematitis(Fail)
13	Blister, dark patches, peeling	Fungi	Eczema (Success)
14	White dusty scales, red patchy scap	Fungi	Dandruff (Success)
15	Tiny colored growth on eyelid, underdeveloped sweat gland, enlarged skin gland.	None	Syringoma(Success)
16	Thick skin on spot, sores and loss of feelings, disease on limbs	None	Leprosy (Success)
17	Warm Skinny, painful breast lumps, harmless growth on skin	None	Mastitis (Success)
18	Lighter patches, colorless skin around mouth or legs	None	Vitiligo (Success)
19	Maceration from urine, diapers with oozing	None	Diapercandi (Success)
20	Blistering, darker patches, skin peeling	None	Ecema (Success)