IJCSE International Journal of Computer Sciences and Engineering Open Access
Research Paper Vol. 9, Issue.11, November 2021 E-ISSN: 2347-2693

Lupus Suspection Expert System Using Artificial Neural Networks (ANN)

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DOI: https://doi.org/10.26438/ijcse/v9i11.1923 | Available online at: www.ijcseonline.org

Received: 10/Nov/2021, Accepted: 17/Nov/2021, Published: 30/Nov/2021

Abstract—Lupus, often detected as a chronic disease, is beyond any measure of cure. ANN (Artificial Neural Network) is used to suspect lupus disease in this research paper. If treated in an early stage, this disease can be controlled. Early diagnosis of lupus is required to treat it properly. It is very difficult to diagnose lupus manually by observing various symptoms. An approach is given to diagnose lupus in an efficient way with the help of ANN. An ANN has been designed here to suspect lupus based on laboratory test reports. Lupus is a chronic disease. The ANN consists of many neurons associated with weights. Each test report is dependent on the existence of each neuron. The present paper aimed at designing an Artificial Neural Network model to diagnose the stage of Lupus. Here the data has been collected from North Bengal Medical College for training the network. The proposed ANN used here is a supervised type, where different patterns represent different status of patient.

Keywords— SLE, Hematocrit, WBC, SLT

I. INTRODUCTION

Lupus, a chronic disease, tends to effect blood vessels and connected tissues [6]. There are mainly two variants of Lupus erythematosus, one is the cutaneous, that was earlier called discoid lupus, that causes disfigurement of skin, darkening, itchiness, redness on skin or scalp, thinning and wrinkling of skin[1]. The other, Systemic Lupus Erythematosus or SLE, the most common form, like the name suggests, involves the systems of heart, lungs, kidneys, and brain. It is more common in younger women [6]. In this research paper the stage of lupus is suspected using Artificial Neural Networks. The ANN consists of many neurons associated with weights. perceptron learning rule is used to train the neural network. Single layer perceptron is used here for the teaning purpose. Each neuron represents a test report. Seven test reports have been considered in this neural network as parameter. Here outcome of lupus can be categorized into four sections-normal, mild, moderate, severe. The paper is divided into the following sections; related work, Objective, background, methodology, experimental analysis, result, discussion and future scope.

II. RELATED WORK

During the time of this research work it was observed that research work has already been done to suspect various diseases like cancer, dengue etc using ANN. G.K.W. Lam, M.Petri worked on lupus disease. Payel Saha et al have used ANN to detect dengue disease[4]. Farhad Soleimanian Gharehchopogh et al have used ANN to diagnose thyroid disease[1]. Dey et al [2] has used ANN techniques to diagnose Diabetes disease. The applied data in this paper have been collected from Sikkim Manipal Institution of Medial Science Hospital which includes 530 patients. The output includes 2 classes of 0 or 1. They suggested two feed forward ANN architectures where the first one includes the number of neurons in three layers (6-10-1) and the second one involves two hidden layers and the number of neurons in (6-14-14-1) layers. F.S.Gharehchopogh et al. have used ANN to diagnose heart disease34]. They used MLP ANN with 60 nodes in input layer, 4 nodes in hidden layer and 2 nodes in output layer which is back propagation learning algorithm.

III. OBJECTIVE

The aim of the research work is to develop an expert system which can suspect lupus disease in an early stage. The development of the expert system at the early stage of lupus will help the doctors to treat and manage this disease in an efficient way. This will minimize the chances of organ damage and also increases the survival rate. The objective here is to develop a single layer perceptron which can be customized to take test data as inputs. The overall approach of this research work is to predict the stage of lupus of the patient.

IV. BACKGROUND

SUSPECTION OF LUPUS STAGES BY ANALYSING LABORATORY TEST REPORTS

Doctors suspect lupus on the basis of some test reports [6].Now every category will have four variants depending

upon their nature of impact. Here variants are considered as normal, mild, moderate and severe. Each category of test report normal SLE, mild SLE, moderate SLE, and severe SLE. Each variant depends upon the output of the test result as given in the following table:

Laboratory Test

Table 1: Laboratory Test

Category of Report	Laboratory Test						
	Hematocrit (mg/dl)	White blood cell count (per mm^3)	Lymphocyte Count (per mm^3)[6]	Platelet Count (x 1000 per mm^3)	Westergren ESR (mm/hr) [6]	Serum Creatinine (mg/dL) or creatinine clearance (% normal)	Urine Analysis (24 hour Urine Protein) (mg/L)
Normal	>35	>3500	1500-4000	>150	<25	0.5-1.3 or 80-100%	42-224
Mild	30-35	2000-3500	1000-1499	100-149	25-50	1.4-2.0 or 60-79%	225-499
Moderate	25- 29	1000-1999	500-999	50-99	51-75	2.1-4.0 or 30-59%	500-3500
Severe	<25	<1000	<500	<50	>75	>4.0 or <30%	>3500

CONCEPTUAL DIAGRAM OF SLT-NET

Table 2: Matrix Representation of Test report

Category of Test report	Matrix Representation of Test report
Normal	[1 -1 -1 -1]
Mild	[-1 1 -1 -1]
Moderate	[-1 -1 1 -1]
Severe	[-1 -1 -1 1]

If the results of all test reports are normal then [1 -1 -1 -1; 1 -1 -1 -1; 1 -1 -1 -1; 1-1 -1 -1; 1 -1 -1 -1; 1 -1 -1 -1; 1 -1 -1 -1] is taken as input pattern. If the results of all test reports are mild then [-1 1 -1 -1 ; -1 1 -1 -1 ; -1 1 -1 -1; -1 1 -1 -1; -1 1 -1 -1; -1 1 -1 -1; -1 1 -1 -1] is taken as input pattern. If the results of all test reports are moderate then [-1 -1 1 -1; -1 -1 1 -1; -1 -1 1 -1; -1 -1 1 -1; -1 -1 1 -1; -1 -1 1 -1; -1 -1 1 -1] is taken as input pattern. If the results of all test reports are severe then [-1 -1 -1 1; -1 -1 -1 1; -1 -1 -1 1; -1 -1 -1 1; -1 -1 -1 1; -1 -1 -1 1; -1 -1 -1 1] is taken as input pattern. For these input patterns there are four target output values -1 -1 (Normal), -1 1 (Mild), 1 -1 (Moderate), 1 1 (severe) respectively.

There are so many possibilities in input pattern except the above four. In any combination if there exists any negative result then the most negative result will be considered as the target output. If we consider an input pattern like [1 -1 -1 -1; -1 1 -1 -1 ; 1 -1 -1 -1; 1 -1 -1 -1; 1 -1 -1 -1; 1 -1 -1 -1; -1 -1 -1 1] i.e. [normal mild normal normal normal severe] the target output value will be severe for this input pattern.

Table 3: Output of Test Report

Output Of Laboratory Test								
Hematocrit (mg/dl)	White blood cell count (per mm^3)	Lymphocyte Count (per mm^3)[6]	Platelet Count (x 1000 per mm^3)	Westergren ESR (mm/hr) [6]	Serum Creatinine (mg/dL) or creatinine clearance (% normal)	Urine Analysis (24 hour Urine Protein) (mg/L)	Target Output	Remarks
Normal	Normal	Normal	Normal	Normal	Normal	Normal	**Normal**	All the test reports are same.
Mild	Mild	Mild	Mild	Mild	Mild	Mild	**Mild**	All the test reports are same.
Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	**Moderate**	All the test reports are same.
Severe	Severe	Severe	Severe	Severe	Severe	Severe	**Severe**	All the test reports are same.
Normal	Normal	Mild	Normal	Normal	Severe	Normal	**Severe**	Most negative report is considered
Normal	Normal	Normal	Normal	Moderate	Normal	Normal	**Moderate**	Most negative report is considered
Normal	Mild	Normal	Normal	Mild	Normal	Normal	**Mild**	Most negative report is considered

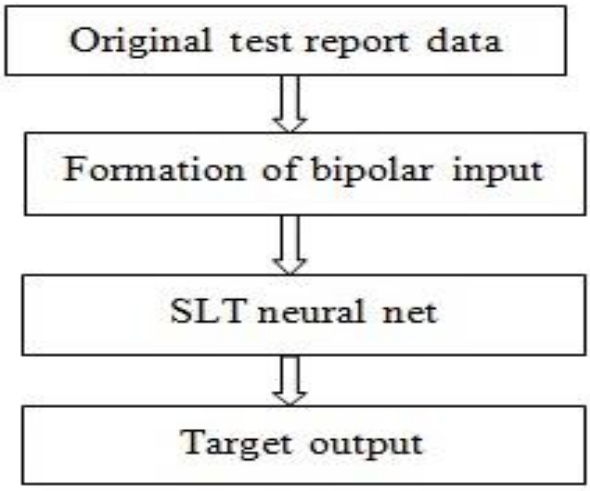

Figure 1: Conceptual diagram of SLT net

ARCHITECTURE OF THE SLT-NET

A SLT(Suspecting Lupus by test report) net consists of two layers of neurons. Layer1 consists of input neurons consisting of input vectors {Hc_no,Hc_mi,Hc_mo,Hc_se}, {Wbc_no,Wbc_mi,Wbc_mo,Wbc_se}, {Lc_no, Lc_mi, Lc_mo, Lc_ se}, {Pc_no, Pc_mi, Pc_mo, Pc_se}, {Esr_no,Esr_mi,Esr_mo,Esr_se},{Sc_no,Sc_mi,Sc_mo,Sc _se},{Up_no,Up_mi,Up_ mo,Up_se}. Hc_no represents Hematocrit normal condition, Hc_mi represents Hematocrit mild condition, Hc_mo represents Hematocrit moderate condition, Hc_se represents Hematocrit severe condition. Wbc_no represents wbc normal condition,

Wbc_mi represents wbc mild condition, Wbc_mo represents Wbc moderate condition, Wbc_se represents Wbc severe condition. Lc_no represents Lymphocyte count normal condition, Lc_mi represents Lymphocyte count mild condition, Lc_mo represents Lymphocyte count moderate condition, Lc_se represents Lymphocyte count severe condition. Pc_no represents Platelet count normal condition, Pc_mi represents Platelet count mild condition, Pc_mo represents Platelet count moderate condition, Pc_se represents Platelet count severe condition and so on.

This SLT net consist of single layer of neuron. It has four output probabilities Lp_no, Lp_mi, Lp_mo,Lp_se. Lp_no represents Lupus stage normal, Lp_mi means Lupus stage mild, Lp_mo means lupus stage moderate, Lp_se means lupus stage severe. The value of Y1 and Y2 defines the stage. If the value of Y1,Y2=-1,-1 then it represents Lp_no. If the value of Y1,Y2=-1,1 then it represents Lp_mi. If the value of Y1,Y2=1,-1 then it represents Lp_mo. If the value of Y1,Y2=1,1 then it represents Lp_se.
There is one weight layer of SLT net. Weight Layer represented by vector W is present between the Input Layer and Output Layer.

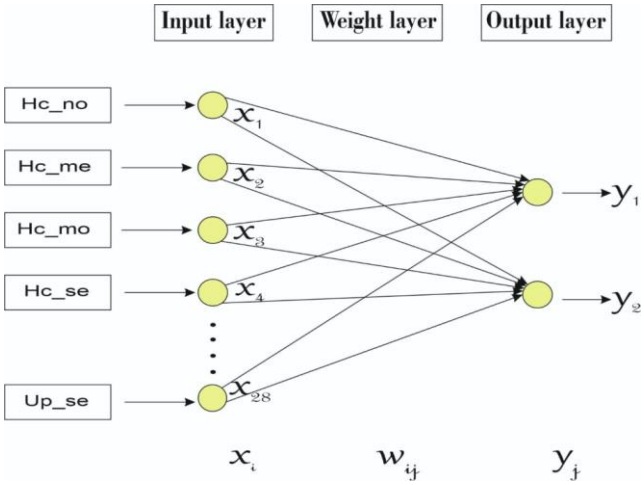

Fig 2: Neural Network Suspecting Lupus

V. METHODOLOGY

Number of all possible tests are 7. These are Hematocrit, white blood cell count, Lymphocyte count, Platelet count,ESR,Serum Creatinine,Urine Protein[1]. For each section of one test 1 is taken as weight. If the value of Hematocrit test report is greater than 35 then Hc_no is considered as input vector .If the value of Hematocrit test report is between 30 & 35 then Hc_mi is considered as input vector. If the value of Hematocrit test report is between 25 & 29 then Hc_mo is considered as input vector. If the value of Hematocrit test report is less than 25 then Hc_se is considered as input vector . In this same way the value of wbcc, Lc,pc,Esr,Sc,Up are taken. The value of Y1,Y2=-1,-1 then "Lupus is normal". If the value of Y1,Y2=-1,1then "lupus is mild". If the value of Y1,Y2=1,-1 then "lupus is moderate",if the value of Y1,Y2=1,1 then "lupus is severe".

In the proposed method seven test report values have been considered as input. After that binary patterns have been designed from this input data set. Then the proposed ANN has been trained by these patterns.The ANN consists of 28 input neurons "x_1", "x_2",…"x_{28}". The 28 input neurons are connected to two output neurons y_1 and y_2 through weight links. Each test report has four outcomes,normal,mild,moderate,severe. Each outcome includes various ranges of test report. This range of values is taken as inputs to a neuron.Among these 7 outcomes if any one of the value is severe the patient will be considered as severe condition.

In this method perceptron learning rule is used for training the ANN.

$$\mathbf{y\_out_i = \sum x_i w_{ij} (where\ i = 1\ to\ n)}$$

The function $f(y\_out_j)$ takes the following values depending upon the values of y_out_j[13].

$$f(y_{out_j}) = \begin{cases} 1 & \text{if } y_{out_j} > \Theta \\ 0 & \text{if } -\Theta \le y_{out_j} \ge \Theta \\ -1 & \text{if } y_{out_j} < -\Theta \end{cases}$$

Here Θ is the threshold value. The value of Θ is taken randomly. Here 0.2 is taken as theta value. For each training input pattern, the ANN will give the required output. The weight has been updated according to the formula.

$$\mathbf{w_{ij}(new) = w_{ij}(old) + \alpha t_i x_i}$$

α is learning rate. Here the value of α is considered as 1 and tj is the target value. For this matter 4 target values have been used. The value of y_j is compared with t_j. The process continues until the value of y_j becomes equal to t_j.

VI. CONTRIBUTION OF THIS RESEARCH WORK

Though SLE is one type of complicated disorders, So it is very difficult for the medical experts to diagnose the diseases on time by analyzing huge set of test reports. In this research work an ANN model has been designed which can accept a huge set of test results and on the basis of the results it is capable of suspecting the disorder efficiently and on time. It also assists the doctor to diagnose the disease easily and helps the doctors serving at far flung areas to suspect SLE disorder. In future such expert systems can be developed using this approach.

VII. EXPERIMENTAL ANALYSIS

MATLAB software has been used to design the ANN. Here input vector and weight vectors are used.
The following data set has been used to train neural network.

Clinical Report Details of Lupus Patient

Case	Test	Value	Normal	Mild	Moderate	Severe
1	Hematocrit	23.2	-1	-1	1	-1
2		23.8	-1	-1	1	-1
3		22	-1	-1	-1	1
4		21.2	-1	-1	-1	1
5		37.5	1	-1	-1	-1
1	WBC	7540	1	-1	-1	-1
2		7200	1	-1	-1	-1
3		10600	1	-1	-1	-1
4		2400	-1	1	-1	-1
5		6000	1	-1	-1	-1
1	Lymphocyte count	23.2	-1	-1	1	-1
2		23.8	-1	-1	1	-1
3		22	-1	-1	-1	1
4		21.2	-1	-1	-1	1
5		37.5	1	-1	-1	-1
1	Platelet Count	467	1	-1	-1	-1
2		749	1	-1	-1	-1
3		170	1	-1	-1	-1
4		130	-1	1	-1	-1
5		158	1	-1	-1	-1
1	Westergren ESR	null	-1	-1	-1	-1
2		40	-1	1	-1	-1
3		16	1	-1	-1	-1
4		null	-1	-1	-1	-1
5		12	1	-1	-1	-1
1	Serum creatinine or creatinine clearance	0.7	1	-1	-1	-1
2		0.3	1	-1	-1	-1
3		0.66	1	-1	-1	-1
4		1.5	-1	1	-1	-1
5		86%	1	-1	-1	-1
1	Serum creatinine or creatinine clearance	0.7	1	-1	-1	-1
2		0.3	1	-1	-1	-1
3		0.66	1	-1	-1	-1
4		1.5	-1	1	-1	-1
5		86%	1	-1	-1	-1
1	24 hour Urine protein	null	-1	-1	-1	-1
2		null	-1	-1	-1	-1
3		null	-1	-1	-1	-1
4		2760	-1	-1	1	-1
5		553	-1	-1	1	-1

Fig 3: Glimpse of the clinical dataset used in the study

The formula for whole network becomes

$y\_out_j = \sum x_i w_{ij}$ (where i =1 to n) for n=28

So, $\mathbf{y\_out = x_1w_1 + x_2w_2 + x_3w_3 + \ldots + x_{28}w_{28}}$

Case 1: x= [1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1];

Y1, Y2= -1,-1

Here 1 represents presence of that section and -1 represents absence of that section.

Case 2: x= [-1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1];

Y1, Y2=-1, 1

Here 1 represents presence of that section and -1 represents absence of that section.

Case3: x= [-1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1];

Y1, Y2=1,-1

Here 1 represents presence of that section and -1 represents absence of that section.

Case 4: x= [-1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1];

Y1, Y2=1, 1

Here 1 represents presence of that section and -1 represents absence of that section.

If Y1, Y2=-1,-1 then “Lupus is normal”

If Y1, Y2=-1, 1 then “Lupus is mild”

If Y1, Y2=1,-1 then “Lupus is moderate”

If Y1, Y2=1, 1 then “Lupus is severe”

The following parameters are used in this experiment.

Number of input neurons = 28

Number of input pattern segments=4

Dimension of weight matrix for each segment =2 X 28

Dimension of input matrix=4 X 28

Dimension of target matrix=4 X 2

Training Algorithm used =Single layer perceptron

Number of Epoch =2 , Θ=0.2, α=1

VIII. RESULT & DISCUSSION

The results achieved by the proposed model are shown in the following figure.

```
X_test1=[1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1];


for k=1:2
    Y_IN1(k)=0;
    for j=1:28
     Y_IN1(k)=Y_IN1(k)+X_test1(j) *W1(j,k);
    end
end
```

```
Command Window

Y1 =

    -1    -1
```

```
X_test2=[-1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1];


for k=1:2
    Y_IN1(k)=0;
    for j=1:28
     Y_IN1(k)=Y_IN1(k)+X_test2(j) *W1(j,k);
    end
end
```

```
Command Window

Y1 =

    -1     1
```

```
X_test4=[-1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1];


for k=1:2
    Y_IN1(k)=0;
    for j=1:28
     Y_IN1(k)=Y_IN1(k)+X_test4(j) *W1(j,k);
    end
end
```

```
Command Window

Y1 =

     1     1
```

Fig 4: Glimpse of result of the experiment

The experiment gives satisfactory result. The test accuracy is adequate. This model is very helpful for patient and doctors both by acting as an early diagnosing expert system.

IX. COMPARISON

This method has been tested for the data set taken from North Bengal Medical College. It was found that for all the records the accuracy rate is satisfactory. After comparing with other models it was found that satisfactory result was achieved by using the simple proposed model.

Sl. No	Name of Method	Methodology	Findings	Accuracy	Research Gap
1	Recursive neural network	The model outputs predicted fatigue and rash levels.	Too small SLE patient data set is used for training the model.	20%	Too small SLE patient data set is used for training the model.
2	Back propagation network	Authors have used redundancy analysis in which a correlation matrix predicted missing data	To predict lupus nephritis in SLE patients.	65.28%	Using analog data coding instead of binary coding for complement provided that they could find homogeneity among values from different medical laboratories.
3	Single layer perceptron (proposed model)	Bipolar pattern will be formed from raw data set. Then proposed model will be trained by that data set.	To suspect the stage of SLE patient based on test report.	75%	There is a scarcity of SLE data.

Table 4: Comparative Result

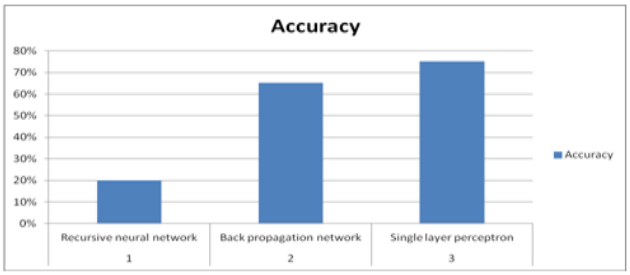

Fig 5: Comparative Diagram for accuracy of RNN, BPN & SLP

X. CONCLUSION

The purpose of this paper is to use Artificial Neural Network to suspect the stage of lupus disease by analyzing the laboratories test report on a year recorded data. The proposed neural network enables one to detect the stage of lupus. This method is tested for some sample test reports. This can be initial step towards digital medical system. It will facilitate the older patient who will not be able to meet doctors on time. This research paper leaves scopes for further research in the areas which include comparison between different neural networks. In future, researchers are advised to explore the detection of lupus disease by using different symptoms using ANN.

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