

An Artificial Neural Network based Model to Analyze Malarial Data and Predict Organ Failure

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Abstract

Health Care Management is one of the most important and most important research areas of the new millennium. The main purpose of this work was to analyze the data on malaria patients in India using the artificial neural networks such as Brainmaker and statistical analysis software (SAS). This data is known that SOFA (Sequential Organ Failure Assessment) score and this information useful in providing the condition of the organ and based on this, the patient's survival rate can be estimated. In this analysis, the same individual SOFA score of different organ systems (esp. the ones which are used to calculate the overall SOFA score) for 753 patients admitted in an hospital in India with malaria were trained using artificial neural networks to provide better predictions of the survival rate compared to the overall SOFA scores. Using the statistical analysis tools like SAS, the statistical aspects of this data was studied. Also, using SAS, analysis was done on the data of the Indian malaria patients and the interested outcomes were projected in the figures at the end of this paper.

The results show that the artificial neural network turns out to be an efficient predictor of survival rate and the results were comparable to the SOFA scoring system where the same variables used for calculating the overall SOFA score were used for training the neural network.

Keywords: Artificial neural networks, SOFA, malaria, organ failure, statistical analysis

1.0 INTRODUCTION

Currently available prediction models such as the Acute Physiology and Chronic Health Evaluation (APACHE) II, Simplified Acute Physiology Score (SAPS), and Mortality Probability Models (MPM) use values taken within the first 24 hrs of an ICU stay. However, these scores ignore the many factors that can influence patient outcome during the course of an ICU stay beyond the first 24 h. The Sequential Organ Failure Assessment (SOFA) assesses patients for organ dysfunction not only at ICU admission but serially during the ICU stay and was first developed to evaluate morbidity. Although this scoring system was developed to describe and quantify organ function and not to predict outcome, the obvious relationship between organ dysfunction and mortality has been demonstrated in several studies. These SOFA scores do not predict the exact rate of morbidity every time but provide meaningful result most of the times.

Nowadays although we have many scoring systems like APACHE II, SAPS, MPM etc, researchers never stop working on creating a better system compared to the other which always happens in a continually developing field such as medicine. This work was done in an attempt to find such system which is efficient compared to the standard system like SOFA score.

Determining the patients survival chance based on these scoring systems is very critical in an Indian hospital environment. In this study two different methods of predicting the hospital mortality were reviewed. One was using these SOFA scores, doing the statistical analysis on the available data to see how accurate are these scores in predicting the mortality while the other one is using the neural networks to predict the mortality rate. Later these two results were compared to see which method is better in predicting the mortality.

This work was done in an attempt to develop an efficient method compared to the standard method. It was observed that the neural networks were as efficient as the traditional SOFA scoring system in predicting the mortality of the patients.

2.0 OBSERVED ORGAN FAILURE DUE TO MALARIA

Most of the patients with malaria have a pre-existing organ dysfunction or failure or develop organ failure during the progress of the disease sometimes which may lead to death of the patient. Organ dysfunction is associated with high rates of hospital morbidity and mortality and as such accounts for a high portion of ICU budget. Recently developed organ failure scores such as Sequential organ failure Assessment (SOFA) can help assess organ dysfunction or failure over time and are useful to evaluate morbidity.

Malaria occurs in 300–500 million individuals annually, resulting in 1.5–2.7 million deaths. Most deaths occur due to *Plasmodium falciparum* infection, which produces life threatening cerebral, renal, hepatic, and hematologic dysfunction in about 1% of cases. This causes infected red blood cells (RBCs) to adhere to capillary and venular endothelium, noninfected erythrocytes, and platelets, resulting in circulatory obstruction. The brain is the most common organ to be involved in severe malaria. Up to 45% of cerebral capillaries may be occluded at postmortem examination because the receptors to which infected RBCs adhere are maximally expressed on cerebral capillary endothelium. Coma also may result from interference with synaptic transmission by nitric oxide from vascular endothelium, raised intracranial pressure due to vasodilatation, and increased capillary permeability. A combination of microcirculatory occlusion, cytokine activation, and nitric oxide-mediated changes in vascular tone are believed to cause organ dysfunction that characterizes severe malaria. However, malaria is not well recognized in critical care literature as a cause of multiple organ dysfunction syndrome.

3.0 NEURAL NETWORKS BASED MODEL

Artificial neural networks are computational paradigms based on mathematical models that unlike traditional computing have a structure and operation that resembles that of the mammal brain. Neural networks lack centralized control in the classical sense, since all the interconnected processing elements change or “adapt” simultaneously with the flow of information and adaptive rules. The commonest learning mechanism in artificial neural networks is the back-propagation algorithm, wherein the system predicts the outcome for each patient based on past experience (memory) and compares this with actual outcome.

The advantage of neural networks over conventional programming lies in their ability to solve problems that do not have an algorithmic solution or the available solution is too complex to be found. Neural networks are well suited to tackle problems that people are good at solving, like prediction and pattern recognition. Neural networks have been applied within the medical domain for clinical diagnosis, image analysis and interpretation, signal analysis and interpretation, and drug development

4.0 DATA ANALYSIS AND KNOWLEDGE DISCOVERY

The development phase of the neural network began with the conception of a study protocol which involved the comparison of the morbidity rates predicted by APACHE II and Artificial neural networks. Several models of artificial intelligence techniques have been used in the ICU. One such technique suited to predict mortality is the artificial neural network. The main goal of this paper is to compare neural networks with an already validated and commonly used outcome prediction model. The question remains whether a model such as SOFA scoring is better at predicting hospital outcome than a model derived from Indian patients treated in an Indian hospital. It was therefore attempted to compare the predictive accuracy of artificial neural networks derived from Indian patients with the SOFA scoring system.

The variables which were used to train the neural network were similar to the ones used for predicting the overall SOFA score. The sofa scores used were those of the six different organ systems estimated during the first 48hrs of the patient’s admission in the hospital.

Sequential Organ Failure Assessment (SOFA)[4]					
Organ Function	0	1	2	3	4
Respiratory (PaO ² /FiO ²)(mm/Hg)	>400	≤ 400	≤ 300	≤ 200 ^b	
Renal(creatinine -mg/dl)	<1.2	1.2-1.9	2.0 – 3.5	3.6 – 5.0	
Hepatic (mg/dl)	<1.2	1.2-1.9	2.0 – 6.0	6.1- 12.00	
Cardiovascular	No Hypotention	MAP < 70 mm Hg	Dopamine≤5 or dobutamine (any dose) ^a	Dopamine ≥ 5 or epinephrine ≤ 0.5 ^a	Dopamine ≥ 15 or epinephrine ≤ 0.1 ^a
Hematologic (platelet count-103/mm3)	>150	≤ 150	< 100	≤ 50	≤ 20
Neurologic : Glasgo Coma Score	15	13 - 14	10 - 12	6 - 9	< 6
^a Adrenergic agents administered for at least one h (doses given are in microgram/ kg/min)					
^b With ventilatory support					

Figure 1 Sequential Organ Failure Assessment Data

The network training was done using *Brainmaker professional and Netmaker Professional*. The data which has been worked on was that of 753 patients who were suffering from malaria in an Indian hospital. Out of this, data on 553 patients was used to train the network and that of 200 patients was used to test the network. The results were then read in to a text file.

Using *SAS (Statistical Analysis Software)*, the frequency bar charts was drawn for survival and SOFA scores. The SOFA Scores were then recoded to six different ranges and the table analysis was done with these ranges and survival. This table analysis gives

the percentage of patient's corresponding to each different SOFA range. The correlation procedure was done to find the correlation between SOFA score and survival.

Using *Excel 2002*, graphs were drawn for the output acquired from neural network to see the percentage of people survived and also graphs were drawn on these 200 patients used for testing the neural network to see the actual percentage of people survived. Then both of these results were compared to see predictive capability of the trained network.

Using *Access 2002*, queries were written to compare the real survival rate with that of the output acquired from neural networks. Also data was queried to find if the SOFA score ranges actually predict the mortality rate comparable to that of the real data. Then those data of patients whose SOFA range is not consistent with the survival/mortality rate were compared to the prediction done by ANN's and it was found that the survival rate for these patients was predicted accurately by ANN's.

5.0 EXPERIMENTAL RESULTS

(i) USING NUERAL NETWORKS:

After training the data using Brainmaker, the least RMS error and Average errors were determined and the plot of the output is shown in the figure 2.

Some of the data were used to validate the model. The trained model behaved very well and the accuracy of the model was over 88%. It was found that the performance of the model of neural networks was significantly better than that of the SOFA score model when applied to the given data set.

The SOFA range 4 had the patients who both survived as well as died which explains that SOFA scoring system also has its inadequacies. When this SOFA range (SOFA range=4) was further analyzed using Microsoft Access 2002 to check the individual values present in this range, it was observed that 3 patients survived and 3 patients died. Surprisingly, it was also observed that the 3 patients out of which 2 people survived and 1 died had the same SOFA score of 16. This doesn't explain the fact how 2 persons with the same SOFA score can show distinct Survival capabilities. When these 6 patients who had the SOFA range of 4 was compared to the results predicted by Brainmaker, it was observed that the Neural network (Brainmaker) gave the correct prediction rates for these patients.

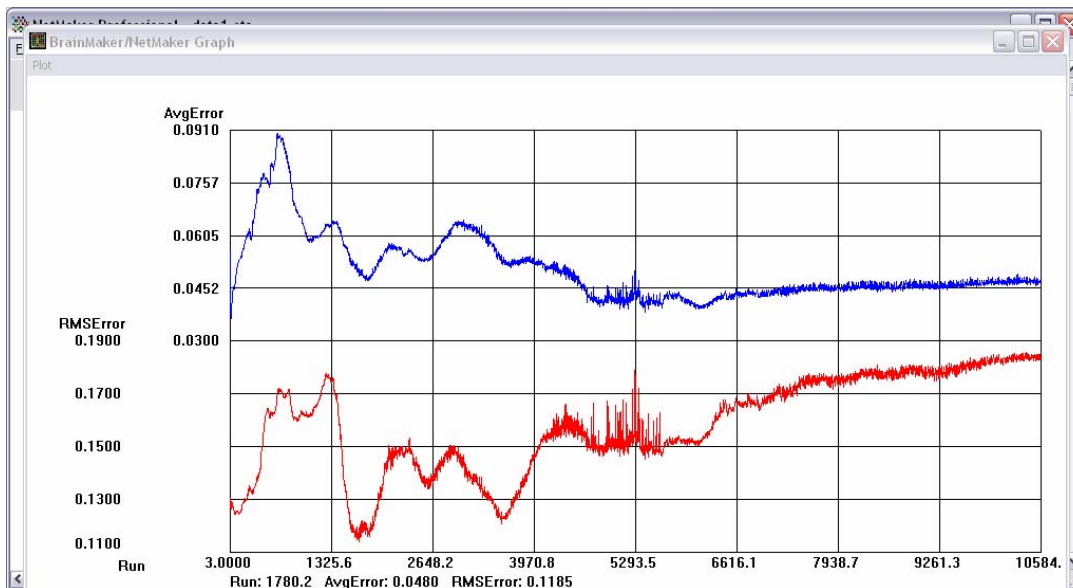


Figure 2

(ii) Statistical analyses of the data using SAS:

The correlation procedure was performed on the test data (200 patients) on SOFAMAX and the SURVIVAL. It was observed that the parameters have very good correlation as seen in figure 3. These SOFAMAX values were then recoded in to ranges to better predict the variations in survival for different SOFA score ranges. The table analysis of these SOFAMAX ranges with SURVIVAL was done indicating the percent of patients in each SOFAMAX range as shown in figure 4.

The histograms for these SOFAMAX ranges was plotted for both survivors and non-survivors indicating the total number of survivors/non survivors for each SOFAMAX range as shown in figure 5 and 6.

The frequency plot of the non-survivors with different SOFA score ranges is supposed to show that the percentages of people with higher SOFA score are supposed to have higher rate of mortality. But its observed that there is a decline in the graph level which suggests that the rate of mortality is lesser in the SOFA range 6 (10 patients) compared to the Percentage of mortality with SOFA range 5(11 patients). This percentage decline with increase in SOFA range leads to an ambiguous condition.

When results of the tested network were checked with the original data (Using Microsoft Access 2002), it was observed that the trained network produced accurate results for 198 patients out of this 200 patients which shows that it gave 99% of the exact results (the results for 2 patients was out of range). The reason for being so accurate in prediction might have the possibility that the data used for training and testing is very low. Most of the times in the real world situations the data sets may be so large that the neural network is not trained as good as it was in this case and also the results may not be as accurate as it was in this case.

6.0 CONCLUSION

This project was aimed at making the peoples life in Medical field (like physicians, nurses) easier while assisting by providing them with tools which have been created with the improving technology to make the complex decisions easier. Such systems not only help them to predict the outcomes but are much efficient in cutting costs of the hospital due to early discovery of this knowledge. This project also aims at such embedded technology into the field of medicine to make the complex decision easier and foresee the outcome most of the times.

This work has been successful in achieving its objective. The results are reliable. Based on the results above still it can be said that it is an efficient neural network which works as good as the standard SOFA scores and is also little efficient compared to the standard SOFA scoring system here.

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The CORR Procedure

2 Variables: SOFAMAX SURVIVED						
Simple Statistics						
Variable Label	N	Mean	Std Dev	Sum	Minimum	Maximum
SOFAMAX	200	9.04500	5.34282	1809	1.00000	24.00000
SOFAMAX						
SURVIVED	200	0.87500	0.33155	175.00000	0	1.00000
SURVIVED						

Pearson Correlation Coefficients, N = 200		
Prob > r under H0: Rho=0		
	SOFAMAX	SURVIVED
SOFAMAX	1.00000	-0.83650
SOFAMAX		<.0001
SURVIVED	-0.83650	1.00000
SURVIVED		<.0001

Figure 3: Correlation Procedure

Table of SURVIVED by SOFAMAX_recoded2

SURVIVED(SURVIVED)		SOFAMAX_recoded2(Recoded Ranges of SOFAMAX)						
Frequency		1	2	3	4	5	6	Total
Row Pct								
0	0	0	0	0	4	11	10	25
		0.00	0.00	0.00	16.00	44.00	40.00	
1	121	36	16	2	0	0		175
		69.14	20.57	9.14	1.14	0.00	0.00	
Total		121	36	16	6	11	10	200

Figure 4: Data analysis of SURVIVAL and SOFAMAX ranges

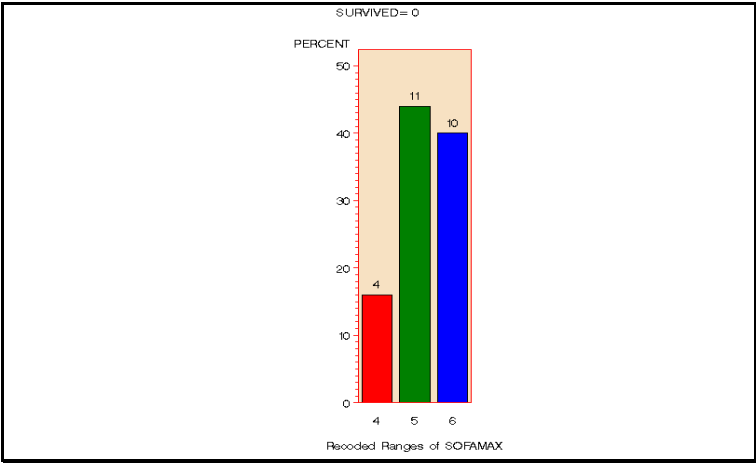


Figure 5: Bar Chart of non-survivors for different SOFAMAX ranges

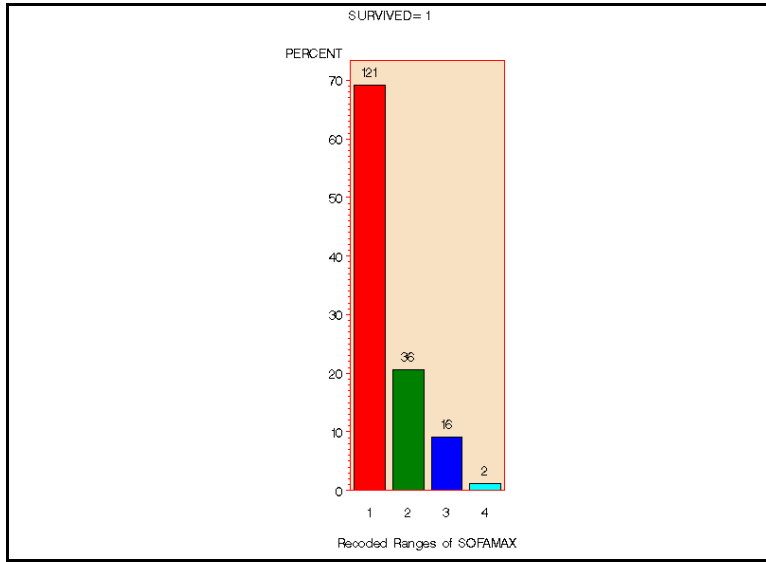


Figure 6: Bar chart of survivors for different SOFAMAX ranges

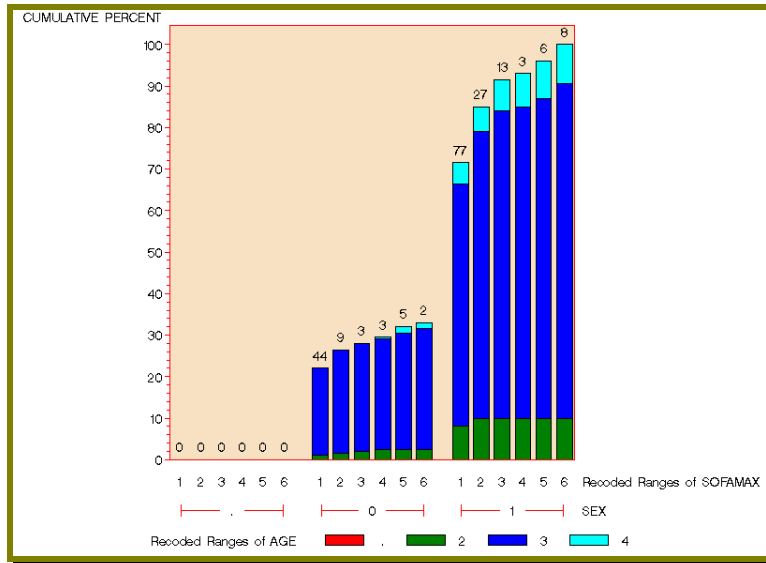


Figure 7: Graphical representation of SOFARANGES based on Age and Gender