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Accelerated Plethysmography based Enhanced Pitta Classification using Artificial Neural Networks

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Abstract: Accelerated Plethysmography uses the second derivative of photoplethysmography waveform to even out the baseline and to isolate the components more visibly as compared to the first derivative. The purpose of this research is to design a High Pitta Classifier and to find the features that may relate to the intensified pitta level. Artificial Neural Network approach has been used for classifying the Accelerated Plethysmography signal into two separate classes. Comparative Group 1 classifies high Pitta on the basis of effect of Mid-day only. 81.30% accuracy is achieved using Artificial Neural Network having 2 neurons in the hidden layer.Comparative Group 2 classifies on the basis ofmid-day as well as digestion following the consumption of meals.87.5% accuracy is achieved using Artificial Neural Network having 2 neurons in the hidden layer. This indicates that the consumption of meals also have some role in the enhanced Pitta level. Comparative Group 3 classifies on the basis of digestion following the consumption of meals.75% accuracy is achieved using Artificial Neural Network having 6 neurons in the hidden layer. From this study it has been concluded that (i)Pitta detection using Photoplethysmography is feasible (ii) Effect of mid-day is prominent (iii)Effect of consumption of meals is also there (iii) Effect of mid-day is more as compared to consumption of meals.

Keywords- Accelerated Plethysmography (APG), Photoplethysmography (PPG), Artificial Neural Network (ANN).

1. INTRODUCTION

Ayurveda, a well-established medical system originated around 5000 years ago. The three body constituents: Vata i.e. nervous system, Pitta i.e. enzymes, andKapha i.e. mucus represent the human health. The coordination of these three constituents influence the health of the human body and disharmony leads to disease[1]. Amongst these three constituents, we have emphasized on the Pitta Dosha. All the metabolic activities, digestive activities and energy exchanges are being managed by the Pitta Dosha[2].Earlier questionnaireswere analyzed for the detection of human constituents[3-6]. In early study uniqueness of finger pulse profile was validated and it was established that it can be used an alternative biometric parameter [7-8]. Earlier research indicates that a substantial relation exists between finger pulse features and the level of pitta in the human body [9-12]. Also second derivative of finger pulse profile has been used to detect the pitta level [13-14].

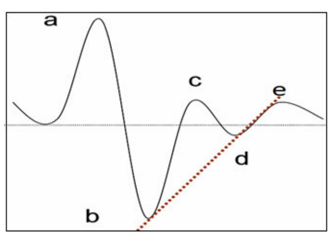

Figure 1: Accelerated Photoplethysmography waveform

For the identification of intensified pitta level we have examined the features extracted from the Accelerated Plethysmography (APG). APG gives the knowledge about heart rate variability and is obtained by differentiating finger pulse profile ofPhotoplethysmography (PPG) twice [15-16].A PhotoPlethysmogram is a volumetric measurement of an organ, obtained optically through apulse oximeter which illuminates the skin and measures the variations in absorption of light[17].An accelerated plethysmography waveform is shown in Figure 1.

2. DATA USED

A PPG signal of 25 healthy subjects was collected from the three fingers i.e. index, middle and ring fingerusing MP150BIOPAC system and Acknowledge software.Furtheran APG wasderived from the recorded finger pulse PPG signal. An APG consists of four systolic peaks i.e. a, b, c and d and a diastolic peak e. The amplitude ratios i.e. b/a,

c/a d/a and e/a were attained. Further average and standard deviation for each ratio was found.Thus a total of 48 features were attained for each subject [18]. These 48 features are referredto as **"Gross Feature Set"** [19].
To reduce the complexity and load on the system these features are reduced optimally. The data is divided into three Comparative groups. Fisher linear discriminant analysis has been employedon each Comparative group to obtain **"Truncated Feature Set"**. Further, in the truncated feature set, correlation of each feature with other features is found to obtain **"Reduced Feature Set"** and **"Super Reduced Feature Set"**. Thebrief description of features obtained after selectionis given below in Table 1 [19].

Table 1:Features selected for enhanced Pitta Detection

Feature Set	**Number of Features**		
	Comparative Group 1	**Comparative Group 2**	**Comparative Group 3**
Gross Feature Set	48	48	48
Truncated Feature Set	17	18	18
Reduced Feature Set	12	12	9
Super Reduced Feature Set	7	8	4

3. PROBLEM DEFINITION

The objective of this research is to develop a classifier that can detect intensified level of Pitta in the human body. For this purpose we shall be considering different sets of features as mentioned in Table 1,which will be classified usingArtificial Neural Networks. The objective of our research shall also include suitability of "Truncated Feature Set", "Reduced Feature Set" or "Super Reduced Feature Set" of features for the best results.

4. CLASSIFICATION

For the classification of different feature sets of each Comparative Group, ANN classifier has been used. Earlier LIBSVMhas been used for the classification purpose [20]. The three comparative groups are[19]:

- Comparative Group1 of After Breakfast (Class A) and Before Lunch (Class B)
- Comparative Group2 of After breakfast (Class A) and After lunch (Class C)
- Comparative Group3 of Before Lunch (Class B) and After Lunch (Class C)

4.1 ARTIFICIAL NEURAL NETWORKS

Artificial Neural networks are the biological structureswhich are inspired by the functioning of human nervous system. These have wide range of applications in the field of classification, pattern recognition etc.[21].The ANN classifier has been developed using Network Pattern Recognition(nprtool) andNeural Network toolbox(nntool) in MATLAB. The basic structure of ANN is shown in Figure 2.

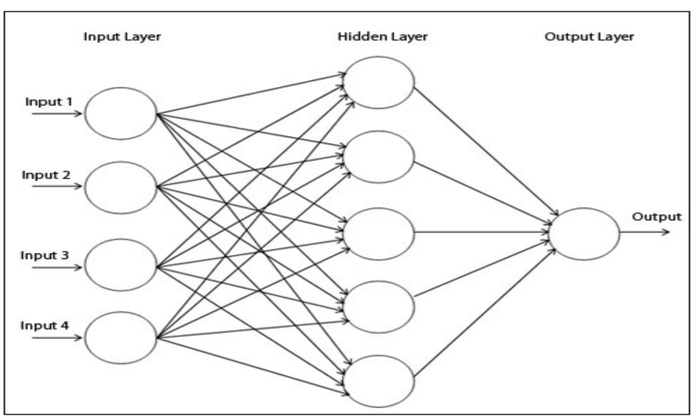

Figure 2:Basic Structure of ANN [22]

A feed-forward back Propagation Network type has been used while developing a classifier.To obtain the forward propagation a training pattern is being applied to the ANN and is propagated through the network to obtain the continuous value of output. This output value has been compared to the required value of the pattern and an error value has been generated. The synaptic weights of the neurons are adjusted by back propagating the error value [23].

The data of 25 healthy subjects have been considered for classification, thus each comparative group consists of 50 samples. The network has been trained using 34 samples and a separate 16 samples are kept to test the performance of the network.The number of neurons in the input layer correspond to the number of input features.Since it is a binary classification,output layer consists of two neurons which represents the two classes namely: High Pitta and Low Pitta. The number of hidden layers have been varied. The number of neurons in the hidden layers arealso varied. Sigmoid transfer function has beenchosen for all the layers.

5. RESULTS AND DISCUSSION

Firstly, we designed the network using three layers i.e. input layer, hidden layer and an output layer.The number of neurons in the hidden layer has been increased one by one to obtain the best results.The number of input neurons arevaried for each feature set of Comparative Groups.However the number of neurons in the output layer are fixed. Table 2, Table 3 and Table 4 shows the results of classification for each comparative group, obtained by varying the number of neurons. The graphical representation of accuracies achieved for each feature set are shown below in Figure 3, Figure 4 and Figure 5.

Table 2: Accuracies obtained by using Truncated Feature Set

Number of Neurons	**Accuracy**		
	Comparative Group 1 (%)	**Comparative Group 2 (%)**	**Comparative Group 3 (%)**
2	81.30	81.30	68.80
3	75	75	68.80
4	75	68.80	68.80
5	68.80	68.80	75
6	68.80	81.30	75
7	68.80	81.30	68.80

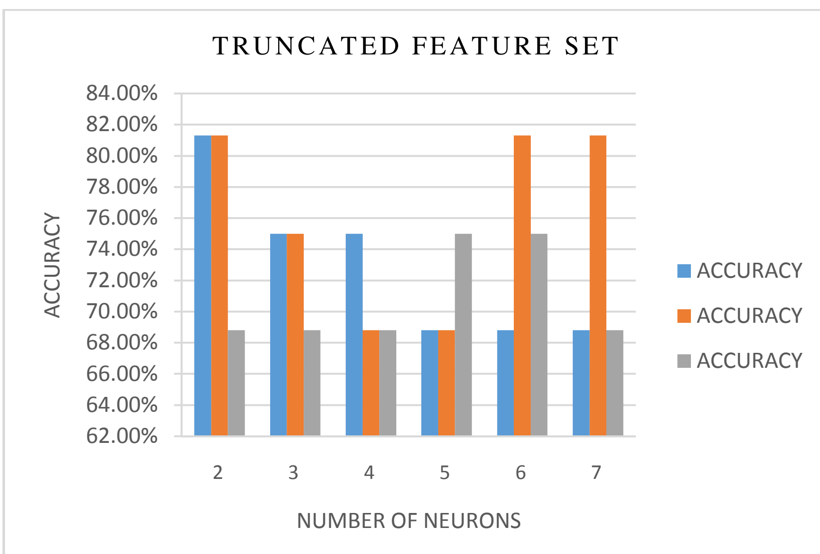

Figure 3: Graphical representation of accuracies obtained by truncated feature set

Table 3:Accuracies obtained by using Reduced Feature Set

Number of Neurons	Accuracy		
	Comparative Group 1 (%)	**Comparative Group 2 (%)**	**Comparative Group 3 (%)**
2	81.30	87.50	68.80
3	75	87.50	68.80
4	81.30	75	68.80
5	75	81.30	68.80
6	68.80	81.30	75
7	75	75	75

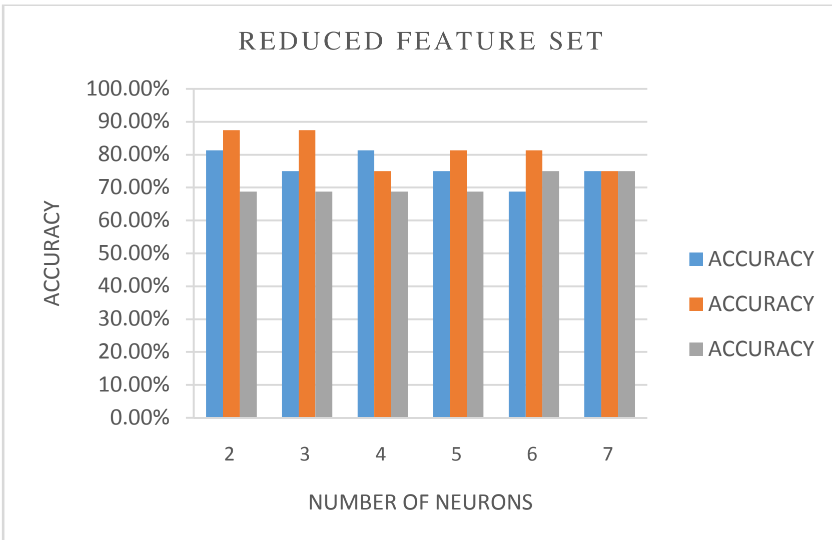

Figure 4:Graphical representation of accuracies obtained by reduced feature set

Table 4: Accuracy obtained by using Super Reduced Feature Set

Number of Neurons	Accuracy		
	Comparative Group 1 (%)	**Comparative Group 2 (%)**	**Comparative Group 3 (%)**
2	81.30	81.30	62.50
3	75	75	62.50
4	75	81.30	62.50
5	68.80	68.80	68.80
6	81.30	68.80	68.80
7	75	75	68.80

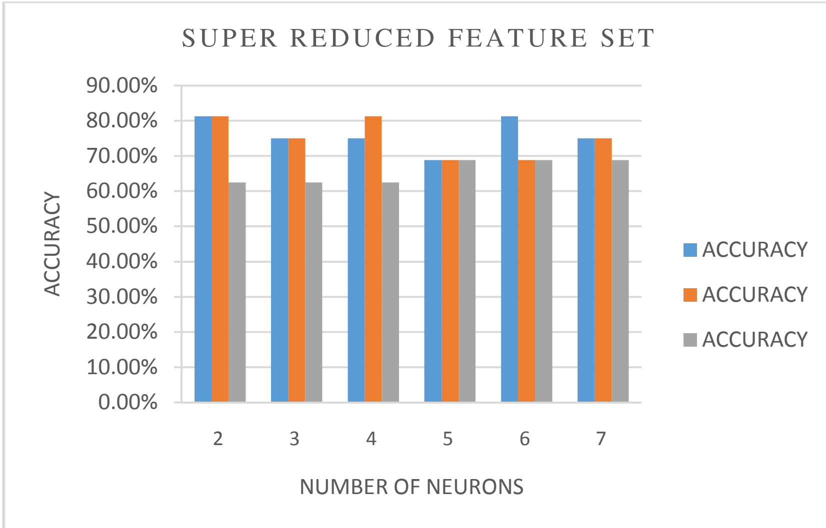

Figure 5:Graphical representation of accuracies obtained by super reduced feature set

It has been observed that the Comparative Group 1 and Comparative Group 2 are classified easily whereas Comparative Group 3 is not easily classified. The number of neurons used in hidden layers while classifying Comparative Group 3 aremore as compared to the neurons used while classifyingComparative Group 1 and Comparative Group 2.Also it is found that the best results are attained while classifying "Reduced Feature Set". Thus, the featuresof this feature set may be used for further consideration.Further, the number of hidden layers areincreased to two, and the number of neurons are varied in each hidden layer. The results so obtained for each feature set are shown below in Table 5,Table 6 and Table 7. The graphical representation of the accuracies achieved is shown below in Figure 6, Figure 7 and Figure 8.

Table 5:Accuracy obtained by using Truncated Feature Set

Number of Neurons	**Accuracy**		
Hidden layer (1,2)	**Comparative Group 1(%)**	**Comparative Group 2(%)**	**Comparative Group3(%)**
2,4	62.50	68.80	68.80
2,5	68.80	62.50	56.30
2,6	62.50	50.00	56.30
3,5	75.00	56.30	68.80

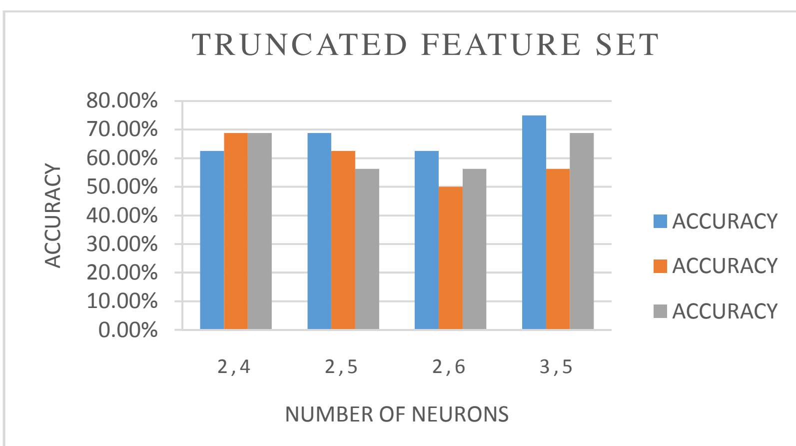

Figure 6: Graphical representation of accuracies obtained by truncated feature set

Table 6:Accuracy obtained by usingReduced Feature Set

Number of Neurons	Accuracy		
Hidden layer (1,2)	**Comparative Group 1(%)**	**Comparative Group 2(%)**	**Comparative Group 3(%)**
2,4	75.00	75.00	62.50
2,5	62.50	68.80	56.30
2,6	62.50	62.50	62.50
3,5	50.00	62.50	56.30

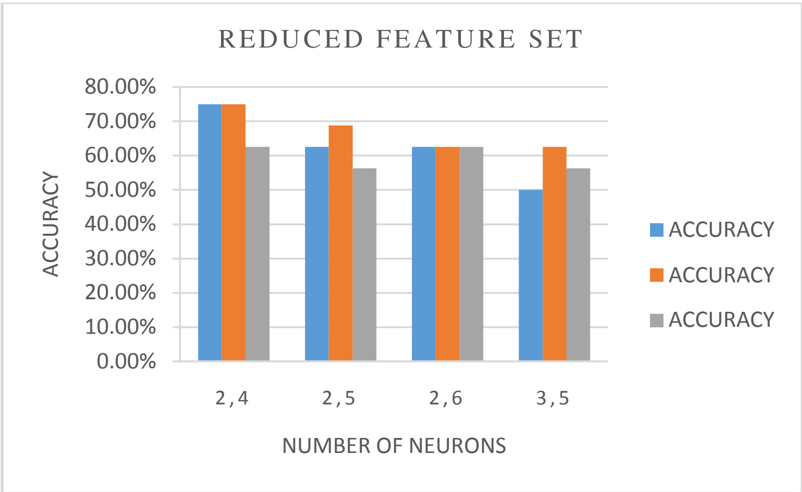

Figure 7:Graphical representation of accuracies obtained by using reduced feature set

Table 7:Accuracy obtained by using Super Reduced Feature Set

Number of Neurons	Accuracy		
Hidden layer (1, 2)	**Comparative Group 1(%)**	**Comparative Group 2(%)**	**Comparative Group 3**
2,4	43.80	62.50	56.30
2,5	62.50	56.30	62.50
2,6	68.80	75.00	56.30
3,5	75.00	62.50	62.50

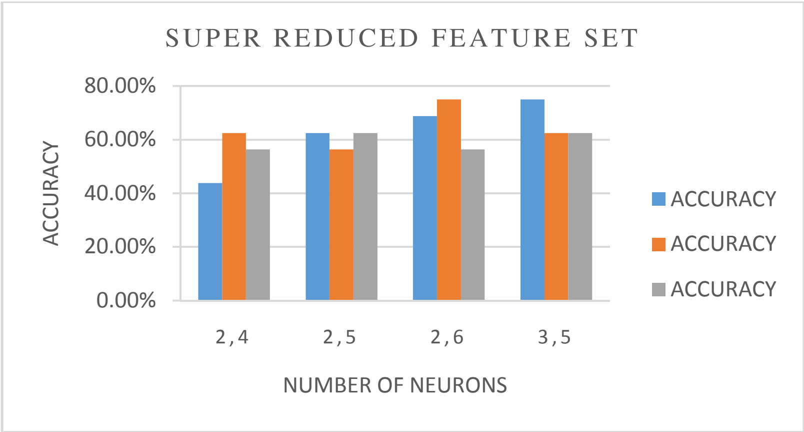

Figure 8:Graphical representation of accuracies obtained by using super reduced feature set

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The accuracy of the network decreased when number of hidden layers areincreased. Since the network is trained effectively using a single hidden layer there is no need to increase the complexity of the system by increasing the number of layers.Thus, considering all the above results it has been observed that the best results are obtained while classifying "Reduced Feature Set".An accuracy of 81.30 % is achieved using 2 neurons in a hidden layer while classifying Comparative Group 1, 87.50% using 2 neurons in the hidden layers while classifying Comparative Group 2 and 75% using 6 neurons in the hidden layer while classifying Comparative Group 3.

Table 8: Best Accuracies Achieved

Comparative Groups	Number of Hidden Layers	Number of Neurons	Accuracy Achieved (%)
Comparative Group 1	**1**	**2**	**81.30**
Comparative Group 2	**1**	**2**	**87.50**
Comparative Group 3	**1**	**6**	**75**

Confusion Matrix

The Confusion Matrix showing best results attained while classifying Reduced Feature Set of the three Comparative Groups is formulated. It informs about the number of false positive (FP), false negative (FN), true positive (TP) and true negative (TN). Accuracy, sensitivity and specificity can be calculated using this matrix, thus analyzing the efficiency of algorithm suitably. The confusion matrix is represented below in Figure 9.

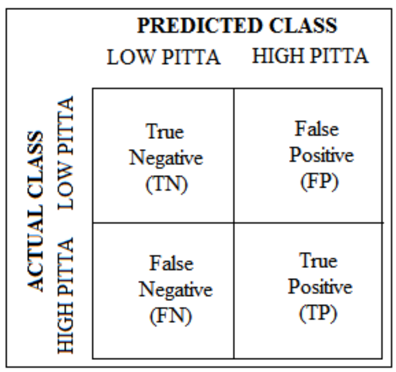
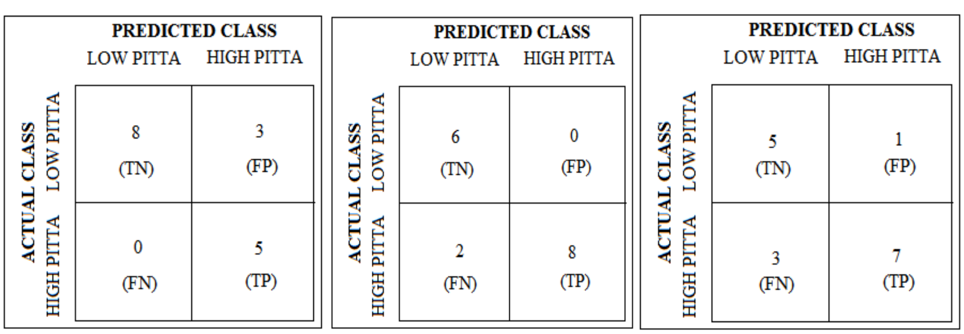


Figure 9: Formulation of Confusion Matrix

The values of accuracy, sensitivity and specificity in terms of true negative, true positive, false negative and false positive are given below in Table 9.

Table 9: Accuracy, Sensitivity and Specificity Parameters from Confusion Matrix

Accuracy	TN+TP/(TP+TN+FP+FN)
Sensitivity	TP/(TP+FN)
Specificity	TN/(TN+FP)



(a) (b) (c)

Figure 10: (a) Confusion Matrix (Comparative Group 1) (b) Confusion Matrix (Comparative Group 2) (c) Confusion Matrix (Comparative Group 3)

The confusion matrix of the best trained network for the three Comparative Groups is illustrated in Figure 10. The values of accuracy, sensitivity and specificity achieved are listed below in Table 10.

Table 10: Classification Results with Reduced Feature Set

Classification Results	Comparative Group 1	Comparative Group 2	Comparative Group 3
Accuracy(%)	81.25	87.5	75
Sensitivity (%)	100	80	70
Specificity (%)	72.72	100	83.33

6. CONCLUSION

After comprehensive exercise to develop ANN based enhanced Pitta classifier, the following points emerged:

(i) Since we have obtained best accuracy of 87.5% for high pitta detection, we may conclude that Pitta classification using APG is feasible

(ii) Since the best results were obtained while classifying Reduced Feature Set, this feature set is best suitable for detection of intensified pitta level

(iii) Single layer network is the most appropriate network

(iv) Effect of mid-day is prominent

(v) Effect of consumption of meals is also there

(vi) Effect of mid-day is more as compared to consumption of meals as the classification of Comparative Group 3 requires more number of neurons and gives less accuracy

(vii) Classification using Artificial Neural Networks is more efficient than usingLIBSVM

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