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Design & Development of a System for Nadi Pariksha

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***Abstract*- The population in the world is increasing enormously and so the people suffering from cardiovascular diseases. In future there is a need for introduction of system which can help in early diagnostics of human health. Now-a-days in medical field there are different methods to examine the pulse of a patient but their basic concepts, clinical methods and practices are not identical. These concepts are arrived from our own ayurvedic practices.**

The main aim of this research is to design a non-invasive system based on ancient diagnostic technique of Nadi Pariksha (Pulse Detection) to assist doctors in routine diagnostic procedures. Nadi Pariksha is one of the ancient medical technologies, originated in India and China. This technique is derived from Ayurveda. Wrist pulse analysis for identification of health status is found in ancient Indian as well as Chinese literature. This project presents the portable prototype of Nadi Pariksha Yantra for pulse reading and analysis which is normally used by an ayurvedic practitioner. This would also be helpful to other physicians who are not well trained to this ancient technique and will be useful in prognosis of the cardiac disorders.

Keywords—Nadi pariksha, Radial Artery, Pre-processing, Data acquisition, Classification, LabView.

I. INTRODUCTION

The design of wearable physiological measurement systems has been a growing research interest due to the potential applications in medicine, security and sports. With the increase in the size of the elderly people in the world, as well as the emergence of chronic diseases because of the changes in the lifestyle of people, there has been a need to monitor the health status of indivisuals in their daily routine at home to prevent fatal disorders[4]. The adoption of mobile health care technology is promising to enhance the quality of life[6]. There are a number of health issues whose treatment benefits from continuous vital sign monitoring. Portable, wirelessly enabling these devices provides greater mobility and improves the efficiency.

A. Pulse Diagnosis Technique

The classical way of pulse examination by the Ayurvedic Practitioner is in the same manner as it was centuries ago. The subjects Radial Pulse is examined by right hand's three finger tips first, middle and third finger, by applying slight pressure on the radial pulse at Radial Fossa. The excruciating nature of the pulse is mentally observed by the ayurvedic practioner or vaidhya. Vata is observed from the index finger tip, Pitta is observed from the second (middle) fingertip and Kapha is observed from the third (ring) fingertip. The standard position to obtain Pulse is through a "pulse waveform" obtained on a wrist with the index, middle and the third fingers respectively [7] as shown in fig 1. The doshas will change with the phases of life. Joshi et al. described the changes in pulse waveform depending upon the age [2]. Childhood (0-16 Years) is dominated by a disturbance of Kapha, the adults (16-50 Years) are facing a disturbance of Pitta and elderly people (over 50) a disturbance of Vata.

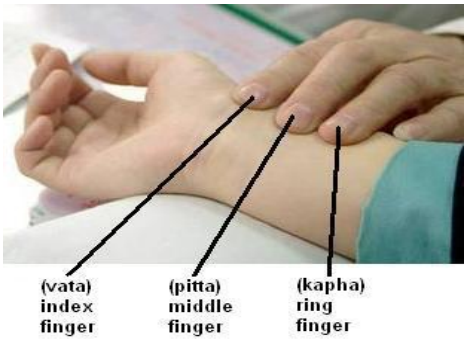

Fig 1. Standard positions to obtain pulse signals
With three fingers

In Ayurveda they have mentioned that every living thing in the earth is made up of five elements as mentioned in [7]. In persons, these five elements correspond to the five senses:

Earth or Prithvi = Smell
Water or Apa = Taste
Fire or Tejas = Sight
Air or Vayu = Touch
Space or Akash = Hearing

Vata types are made up of Akasha and Vayu elements. Vatas tends to be slender with dry hair and cool dry skin. Vatas are prone to headaches, abdominal gas, hypertension, irregular heart rhythms, muscle spasms, diarrhea, constipation and lower back pain.

Pitta types are made up of Teja and Apa. Pittas body is of medium size and strength, and they can easily maintain their weight. Pitta types will suffer from problems like acne, anemia, skin cancer, liver disorders, insomnia, rashes or inflammations of the skin and gallbladder.

Kapha types are made up of Apa and Prithvi. They have strong, solid, hefty body and smooth hair and skin, soft voice with large soft eyes. They have a very strong immunity but even they are susceptible to colds, respiratory problems, atherosclerosis, congestion, painful joints obesity, sinus headaches and allergies.

Table 1. **S**tandard pulse readings for various classes

Newborn (0-3 months old)	Infants (3-6 months)	Infants (6-12 months)	Children (1-10 years)	Children over 10 years & adults, including seniors	Well-trained adult athletes
100-150	90-120	80-120	70-130	60-100	40-60

Table 2. Characteristics of different Doshas (disorders) [5].

DOSHA	SIGHT AT NADI	FINGER	NATURE OF PULSE MOVEMENT	EXAMPLE
Vata	Anterior	Index	Vakra	Leech, Snake
Pitta	Middle	Middle	Chanchal	Crow, frog
Kapha	Posterior	Ring	Manda	Swan, pigeon

The three doshas (disorders) will have different characteristics as shown in Table 2, which shows the sight, nature of the pulse and so on.

Based on different Prakruti, the body type of the person changes from one person to other. Table 3.2.2 shows the body types based on Vata, Pitta and Kapha signals.

Table 3. Body Type based on the Vata, Pitta and Kapha Disorders.

Observations	Vata	Pitta	Kapha
Body size	slim	medium	heavy
Body weight	low	medium	overweight
Chin	thin, angular	tapering	rounded
Cheeks	wrinkled, sunken	smooth, flat	rounded, plump
Eyes	small, dry, active, black, brown, nervous	sharp, bright, gray, sensitive	big, beautiful, blue, calm
Nose	uneven shape	long printed	short, rounded
Lips	dry, cracked	red, inflame	smooth, oily
Skin	thin, dry, cold, rough, dark	smooth, oily, warm	thick, oily, cool, white
Hair	dry, black, brown	warm, straight, oily	curly, thick, oily, waxy

II. Related Work

The conventional method of Nadi Pariksha is to examine the radial pulse using the three fingers by an Ayurvedic practioner for diagnosis of different disorders. The diagnosis of the different disorders is based on the three signals Vata, Pitta & Kapha. These three signals contain most important information for primary diagnosis of diseases related to all the parts of the body. This technique requires extensive practice and experience by the physician.

A. Non-invasive system

The system which is present is capable of detecting the Atherosclerosis. The parameters considered for Atherosclerosis detection are Pulse Wave Velocity (PWV) and Cardio Ankle Vascular Index (CAVI). The system is a non-invasive and it is named as Nadi Shastra. There is another method, where the Pulse Transit Time (PTT) is used to measure Blood Pressure for a period of time. This method is suitable for continuous Blood Pressure Measurement (BPM). Since, it is cuff-less and also non-invasive. It is comfortable for the patient.

B. Bayesian networks

A quantitative method for automatic identification of human pulse signals and extraction of characteristic parameters to construct the recognition model based on Bayesian networks. To distinguish the strength and shape, which cannot be represented by one or several parameters and are hard to recognize, the main time-domain feature parameters are computed based on the feature points of the pulse signal. Then the extracted parameters are taken as the input and five models for automatic pulse signal identification are constructed based on Bayesian networks.

III. PROTOTYPE DESIGN AND DEVELOPMENT

This research work proposes the design of Nadi Pariksha Yantra for the diagnosis of pulse. The pictorial representation of the proposed system is as shown in fig 2.

A. Design of the Nadi Pariksha Yantra

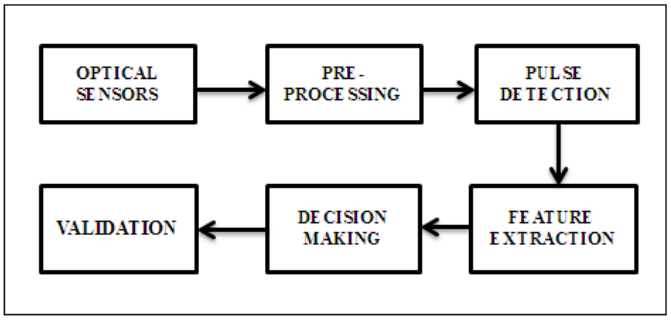

Fig 2. Proposed block diagram for human pulse based system.

Optical pulse sensors shown in fig 3 are used to acquire the pulse signals from the subject. The sensor works on the Principle of Photoplethysmography. The sensor has a LED that shines light into the capillary tissue and the ambient sensor reads the amount of light that bounces back from the tissue. The difference between the incident and reflected light is measured to calculate the pulse signal at that point.

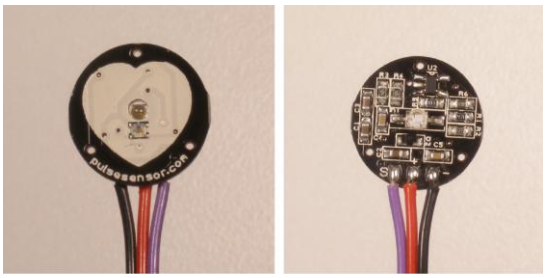

Fig 3: Pulse sensor front and back side respectively

The pulse sensors are placed side-by-side on the radial artery on radial fossa in the position of the fingers shown in fig 1. The pulse sensor positioning is done carefully. If the sensors are positioned incorrectly then the signals may not be reflected efficiently. The misplaced sensors will give incorrect output. This will lead to erroneous decision in the final decision making of the pulse signals. So, placing the sensors in the right position is an important measure in Nadi Pariksha.

The acquired pulse signals from the sensors are then given to the microcontroller for further processing. This data is used for displaying the signals on the LabVIEW software.

B. *Pre-processing the pulse signals*

Pre-processing of the acquired signals is important as the received pulse signals may contain noise due to interaction of the pulse signals with the skin and muscles during the time of signal acquisition. Hence, the design of suitable filter for noise removal is the necessary step of pre-processing module. The software filter designed is Butterworth Low-pass Filter, which has a flat frequency response with following specifications:

- Lower cutoff frequency – .0.125Hz
- Upper cutoff frequency – 180Hz
- Order- 8th order

The maximum frequency of pulse signals are approximately 160Hz. So, the cut-off frequency of the filter is set as 180Hz.

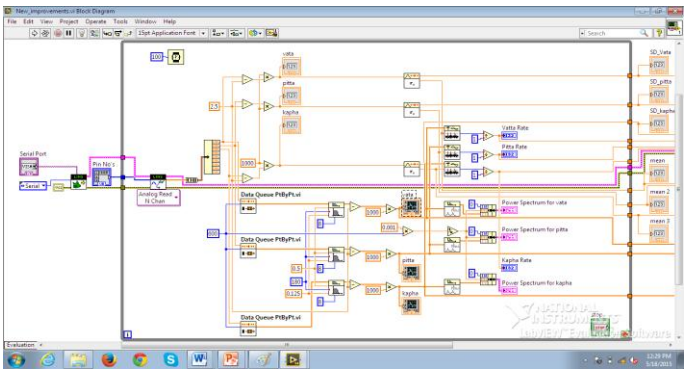

Fig 4. Design of Butterworth Low-pass Filter using LabVIEW Software

Selecting the Order of the Filter is an important parameter in filter design. The Order of the filter used in all instrumentation used for Biomedical signals are 6th or 8th. In this work, we have used the filter of order 8. Since, it is suitable for this work. The filter design of the Butterworth filter using LabVIEW is shown in fig 4.

The output of the pre-processing module is the Pulse signals which are of interest. These signals are further processed for feature extraction.

C. *Microcontroller ATMEGA328*

In this prototype Microcontroller used is ATMEGA328 which is available in Arduino Uno as shown in fig 5.

The analog pulse signals are converted into digital pulse signals by the Analog-to-Digital Converter present in the Arduino Uno. This digitized data is used for further processing.

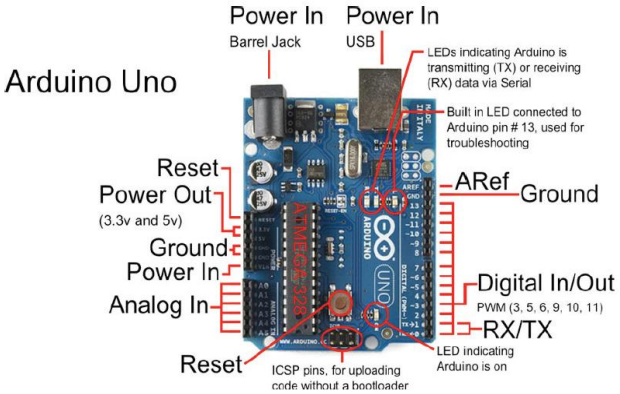

Fig 5. Arduino Uno Board

D. *Database creation*

The pilot developed system has been used to collect data in the presence of expert Ayurvedic practitioner. The protocol has been developed by the expert in order to create sufficient database.

The data of 100 subjects has been collected and the features are extracted from this, which is used for classification. The obtained results are compared with the Ground-truth labeling of the expert and further classification is done for this samples.

E. *Feature Extraction*

The features such as Pulse Repetition Rate, Frequency, Amplitude, Mean and Standard Deviation are considered. These features can be used for further classification of the signal into Vata, Pitta and Kapha.

1. Pulse Repetition Rate: The Pulse Repetition Rate is the number of pulse signals that will occur in one minute. The pulse rate varies from person to person and it is an important parameter in Nadi Pariksha. The Ayurvedic practitioners consider it as a vital parameter in primary diagnosis. Therefore, Pulse Repetition Rate is considered as an important feature for classification of pulse signals.

   The pulse rate is measured by using the peak detection algorithm where the mean of the signal is used as the Threshold value for the algorithm.

2. Pulse Frequency: The Pulse Frequency is measured using the Power Spectrum of the signal. The peak value of the power spectrum is considered as the frequency of that pulse signal. The frequency is another important feature of the pulse signals.

3. Pulse Amplitude: The maximum amplitude of the signal is extracted from the acquired signal. The amplitude of the signal also contains important information in the Pulse signals. If the amplitude reduces this indicates reduced blood flow in the body.

4. Mean Value of the signal: The mean value of the signal is measured for the acquired signal.

$$\bar{X} = \Sigma X / N \quad (1)$$

Where, **N** is the number of samples, **ΣX** is the input data values and $\bar{X}$ is the mean of all the values.

5. Standard Deviation of the signal: The Standard Deviation of the signal is measured for the acquired signal.

$$S = \sqrt{\frac{\Sigma (X - \bar{X})^2}{N}} \quad (2)$$

Where, **S** is the Standard Deviation, **N** is the number of samples, **ΣX** is the input data values and $\bar{X}$ is the mean of all the values.

F. Neural Network based Classification

The extracted features are used to classify the data into three classes Vata, Pitta and Kapha. The target classes are represented in Binary format for classification using Neural Network. Table 4 shows the Binary values for the three classes Vata, Pitta and Kapha.

Table 4 Assignment of Binary values to the three classes

DOSHA	CLASS	BINARY VALUE
VATA	Class 1	100
PITTA	Class 2	010
KAPHA	Class 3	001

The different features are used for classification of the pulse signals into Vata, Pitta and Kapha. Based on the results the best features are selected for Classification.

The dataset has been divided into three groups for Training, Validation and Testing. Out of 100 data samples, 60 samples are used for training the network, 20 samples are used for validation and remaining 20 samples are used for Testing.

The performance analysis for different number of layers and neurons is tabulated as shown in the Table 5.

Table 5 Performance for the Best features for different number of neurons.

No. Of Layers	No. of Neurons	Performance
1	2	0.297
1	3	0.113
1	4	0.160
1	5	**0.008**
1	6	0.174
1	7	0.128
2	5-5	0.268
2	5-6	0.139

The acquired signals are successfully classified into Vata, Pitta & Kapha. The performance of the network is high for 5 hidden layer neurons and it will decrease as the number of neurons increases due to the network complications.

G. Vaildation

The validation has been performed by comparing obtained results with the gold standard. Based on this, the signals are classified into their respective classes. The signal with maximum value in any of the class is considered to be prominent among the three and considered as PRAKRUTI OF AN INDIVIDUAL. The performance of the proposed system has been analysed in terms of sensitivity in classifying samples to anyone of the class. Sensitivity can be calculated as

$$\textbf{Sensitivity} = TP / (TP+FN) \quad (3)$$

Where, TP - True positive
FP - False positive

IV. EXPERIMENTAL RESULTS

Fig 6 represents the real-time pulse signal acquisition, pulse rate measurement and Feature Extraction of the Pulse signals. The three pulse sensors are placed on the wrist on the radial artery and the sensors are connected to the microcontroller for further processing.

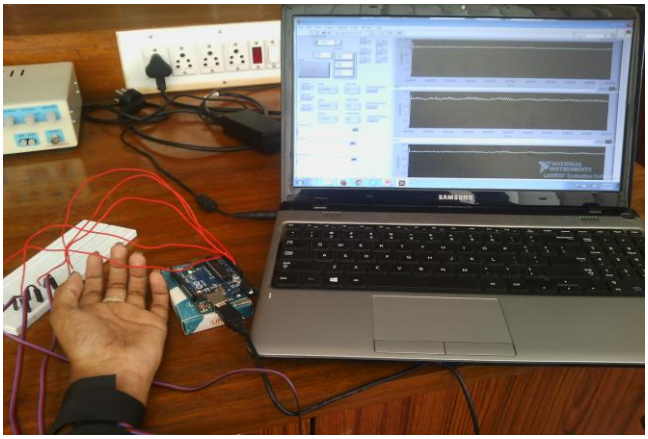

Fig 6. prototype of the proposed system.

Fig 7 shows the Raw Pulse signals acquired from the pulse sensors using LabVIEW.

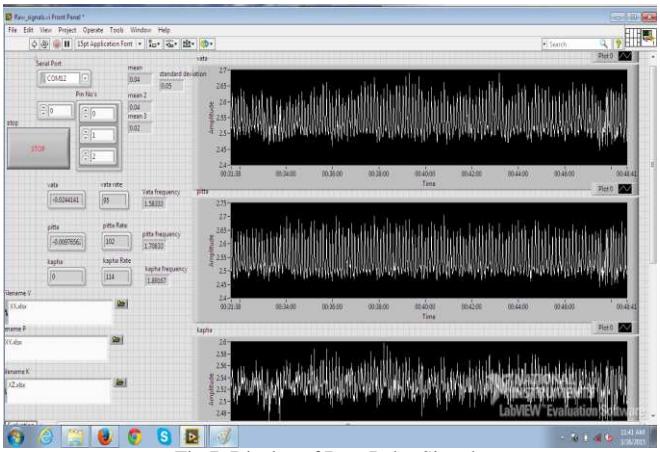

Fig 7. Display of Raw Pulse Signals

The raw pulse signals are filtered and scaled suitably for further processing and feature extraction. The filtered output is shown in fig 8.

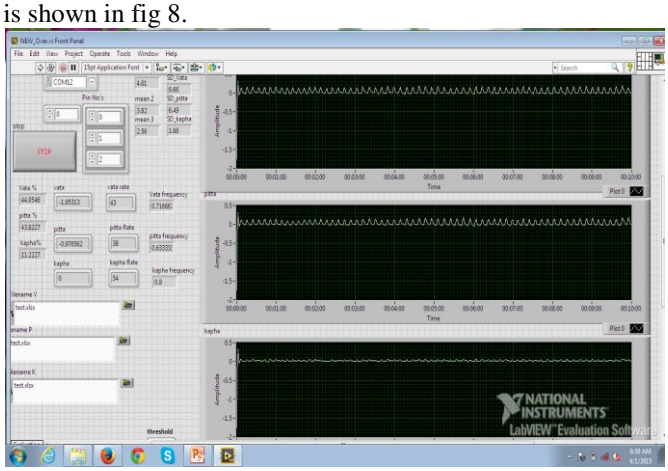

Fig 8. Filtered Output of Pulse Signals

Fig 9,10 and 11 shows the predominant Vata, Pitta & Kapha signals using LabVIEW. This output helps to view the signals based on the output obtained from the sensor. These signals are used for feature extraction.

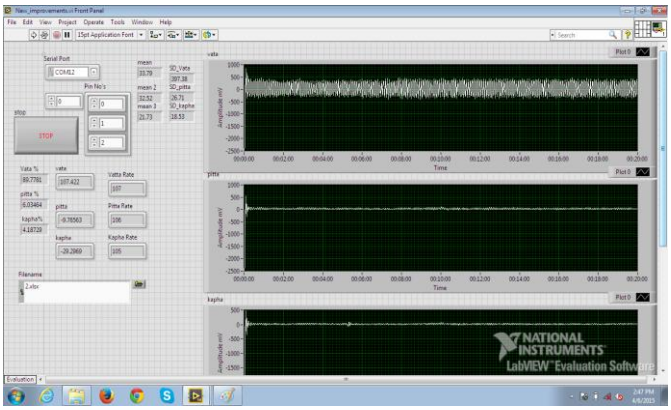

Fig 9. LabVIEW Output for Vata signal

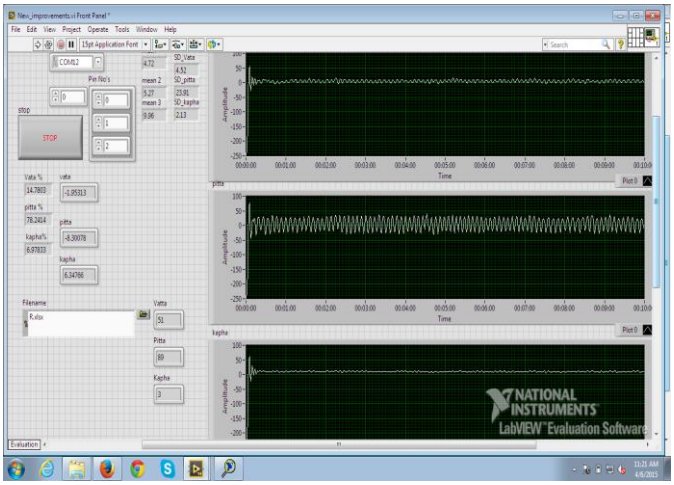

Fig 10. LabVIEW Output for Pitta signal

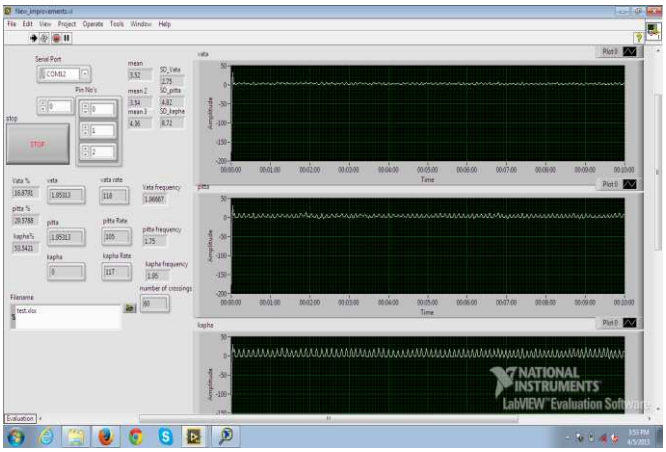

Fig 11. LabVIEW Output for Kapha signal

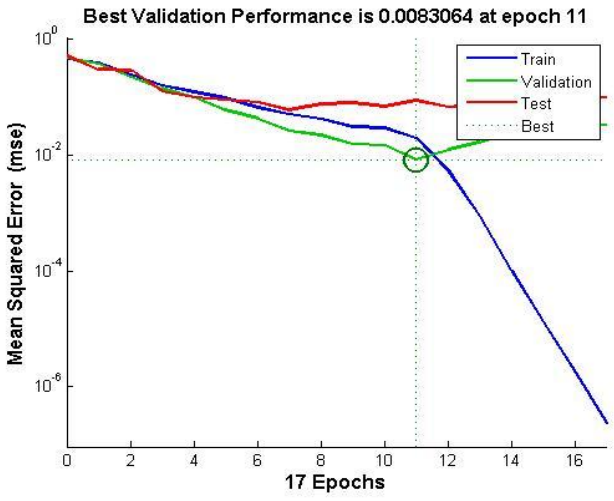

Fig 12. Performance graph for Neural Network

The confusion matrix is plotted for both test and blind data, as shown in fig 13 and 14 and the sensitivity of the system is 80% and 100% for test data and blind data respectively.

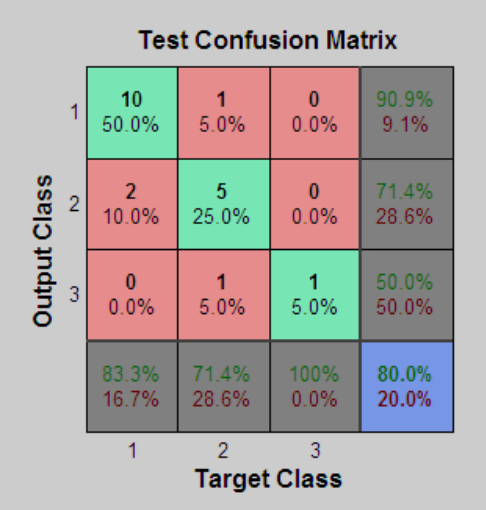

Fig 13. Confusion matrix for Test data

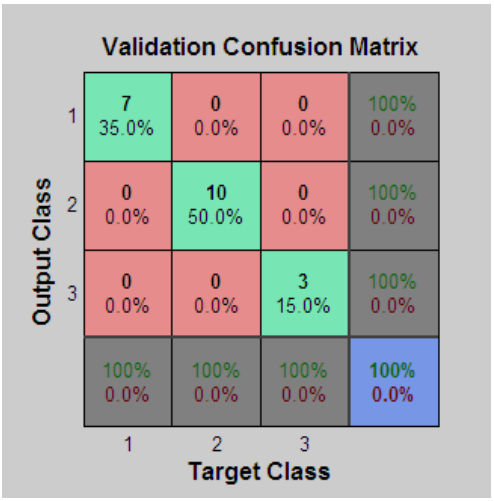

Fig 14. Confusion matrix for Blind data

Table 6 Performance analysis for Test Data

Neural Network	Predicted as class 1	Predicted as class 2	Predicted as class 3	Sensitivity
Class 1	10	1	0	80%
Class 2	2	5	0	
Class 3	0	1	1	

Table 7 Performance analysis for Blind Data

Neural Network	Predicted as class 1	Predicted as class 2	Predicted as class 3	Sensitivity
Class 1	7	0	0	100%
Class 2	0	10	0	
Class 3	0	0	3	

V. CONCLUSION

This work presents a design and development of Nadi Pariksha Yantra for pulse signal analysis. The system has designed with three optical sensors which are positioned on radial artery in order to get three pulse signals Vata, Pitta and Kapha. In order to remove the noise induced due to the signal interaction with the skin and muscles, Butterworth filter of suitable order has been designed.

The developed system has been used in real-time data collection. Further the collected data has been classified into Vata, Pitta and Kapha based on the features extracted. This system will help the physicians who are not trained for Nadi pariksha and further diagnosis and the prognosis of cardiac related disorders. It also acts as a Portable Wearable device for home based health monitoring.

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