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An ANN based SpO2 Measurement for Clinical Management Systems

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Abstract

Pulse oximeters are ubiquitous in modern medicine to noninvasively measure the percentage of oxygenated hemoglobin in a patient's blood. Pulse oximeters are well adapted, simpler and quite easy to measure. In this paper, An ANN based model using LabVIEW is proposed to measure and estimate the SpO2 present in the blood. Infra red (IR) and red LED lights are passed through the fingers and the ratio of transmission characteristics (R value) is calculated through LabVIEW system. Based on the R value the oxygen saturation SPO2 is calculated. This study is done through aNETka, which is an ANN work system designed in LabVIEW. Finally the result is compared with both fuzzy logic and linear regression based methods. The proposed method shows that ANN can be efficiently used in clinical management systems and also proved its consistency and accuracy.

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Keywords: Pulse oximeter, SPO2, artificial neural network (ANN)

1. Introduction

A pulse oximeter is widely used for in-respiratory monitoring. It is basically a non-invasive type measurement device used to measure the percentage of oxygen inside a human body. The knowledge of level of oxygen is

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Nomenclature

SpO2	Saturation oxygen level in blood in percentage
A	Total amount of blood
B	Amount of oxygenated blood
R	Ratio value

necessary, so as to diagnose and monitor several diseases like sleep apnea, asthma, bronchitis and several cardio pulmonary diseases [1, 3]. Since pulse oximeters are reasonably accurate than the other methods in measuring SpO2, this could be coupled with other instruments, helping in clinical management like monitoring intensive care units (ICU) and anaesthesia administration during surgery [10].

$$SpO2 = \frac{B}{A} X 100 \tag{1}$$

The pulse oximeter measures the arterial blood percentage (SPO2). Generally a normal person should have Spo2 value ranging from 92% to 100%. If the Spo2 value goes below 85% then immediate medical attention is required. Artificial neural Network (ANN) has been used extensively in the field of biomedical applications because of its accuracy and quick learning ability. It is a soft computing technique in which the system is trained to adapt to the input changes and produce the optimal results. Considering the complexities involved in the measurement of body parameters and the level of dependency on the biomedical device for saving a human life, the artificial neural network is seen as a promising area to use in biomedical applications in future to produce the accurate results.

2. Pulse Oximeter Design

Many invasive and non-invasive techniques were proposed for blood oxygen saturation measurement. Almost all are designed based on the different light-absorbing characteristics of deoxyhemoglobin and oxyhemoglobin and the pulsating nature of blood flow associated with heartbeat [1]. The basic principle of pulse oximetry is taken from Beer-Lambert's Law [1, 2]. Pulse oximeters have two input channels called as photoplethysmogram (PPG) signals, one is red light (660nm) and another one is infrared-IR (940nm). Different heart beat rates may affect the intensity of light either I_{IR} or I_{RED}. Each channel of input signals contains a constant component of current DC_{RED} and a pulsating component of current $AC_{RED,}$ similarly DC_{IR} and AC_{IR} for the infrared, respectively. Since DC_{RED} and DC_{IR} values are constant they are ignored for the calculation of R.

$$R = \frac{ln(IR)}{ln(Red)} \tag{2}$$

The generalized block of the pulse oximeter is shown in the fig.1. First one is a sensor; a well grove type RED and IR LEDs set up made to capture the transmission characteristics of a blood sample passed through the finger. Here the specifications are selected based on the reference paper [1]. Second block used here is a signal conditioning circuits like filters and amplifiers For this study there are two filters (low pass and high-pass) used. Low-pass filter is designed with 5 Hz cut-off frequency and usually filter out the noise in the received signal. Same way a high-pass filter is added with a cut-off frequency of 0.5Hz to filter out the DC components [1]. Also, this filter has a pre-amplifier in the inverting entrance.

2.1. ANN based Pulse Oximeter using LabVIEW

In our study, mainly focuses on practicing artificial neural network method in LabVIEW environment and make measurement process simpler [2]. Same way fuzzy logic and linear regression methods are also tried in above said environment. Here the values obtained from the sensors, post filtering and amplifying, have been tunneled to determine the value of R (ratio). Further the value of R is given as an input to all these three methods. These systems will measure the accurate and reliable results. General notions and characteristics for each method have been briefly illustrated below.

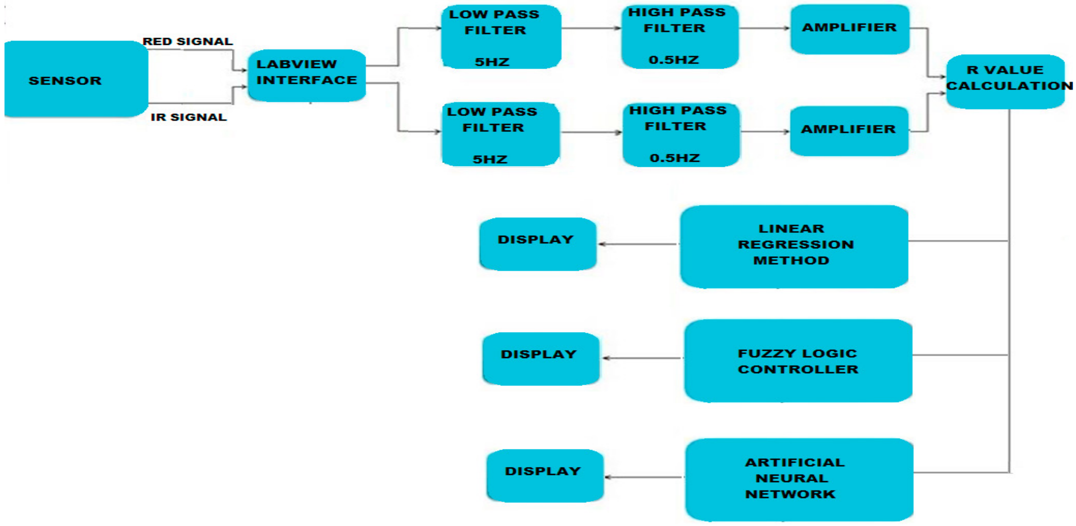

Fig.1 Generalised block diagram of LabVIEW based Pulse Oximeter

One of the simplest ANN's is a feed-forward network. Such a network consists of one input layer, hidden layers (possibly more than one) and one output layer. In most cases all subsequent layers are connected in such way that all previous layer nodes are connected to all next layer nodes. The input layer acts as a buffer to the complete network without one is called as aNETka [8]. Programs in aNETka are written in LabVIEW for acquisition and measurement so it was a natural choice to implement the ANN also in LabVIEW. aNETka consists of three main programs and the library of subprograms. The most complex part of aNETka is the ANN core and the back-propagation algorithm. Those two parts are kept separate in the code. Moreover, the core and back-propagation could not be enclosed within subprograms because they are executed hundreds of times in each iteration and that would slow down the execution. The ANN core and back-propagation look very complicated at the first sight, but mathematically they perform exactly the ANN calculating and training [12]. The Artificial Neural Network Based Pulse-Oximeter is not critical to the execution, are made as subprograms in order to simplify the diagram. All data handling is performed automatically during the execution.

2.2. Fuzzy based Pulse Oximeter using LabVIEW

For this study Mamdani model has been taken. All the concepts behind this are referred by [1]. While R (ratio) value has been used as the input value, SPO2 value has been used as the output value in fuzzy logic. Fig.2 illustrates the flowchart of used fuzzy logic. The input value R and the output value SpO2 are illustrated as triangle membership functions (mf) consisting 21 members. The reason behind 21 member ship functions is that getting of high SpO2 values for low R values. Fuzzy has been loaded in to LabVIEW as a specific program and its file is saved as a unique fuzzy program file which is supposedly called from the main program for its initiation as a controller.

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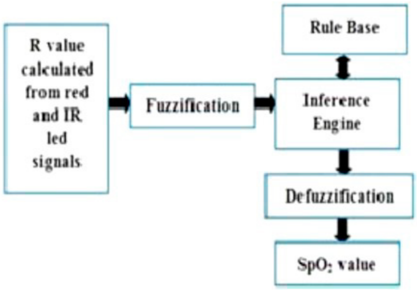

Fig.2 Flowchart of fuzzy logic control

2.3. Linear regression based Pulse Oximeter using LabVIEW

Linear regression is a commonly used statistical model to estimate the expected output using a dependent variable [1]. Linear regression model and application are already discussed in [1]. Based on this the model is adapted and shown in equation (3).

$$SpO2 = -22.60 * R + 95.82 \tag{3}$$

3. Experimental setup

The signals obtained from respective photodiodes are interfaced to PC using NI DAQ USB-6008 device. The obtained signals are given to a low pass filter of cut off frequency 5Hz in order to eliminate the ambient light noises. The filtered signals are given to a high pass filter of cut off frequency 0.5 Hz to eliminate the effect of DC. The signals are then amplified and used to obtain the ratio R using equation (1). The block diagram built in LabVIEW is given in fig.4.

3.1 Artificial neural network set-up (aNETka) in LabVIEW

Neural network is trained initially by using the train VI program in aNETka by using a training file [8]. The train program allows the user to determine the number of iterations, range learning rate and activation function. The system is a single input single output system. The trained system is shown in figure.3. Once the system is trained, the trained file is called into the main program. The calculated R value is given as input to ANN. The single recall program of aNETka is implemented here, wherein the R value is given as input to the neural network.

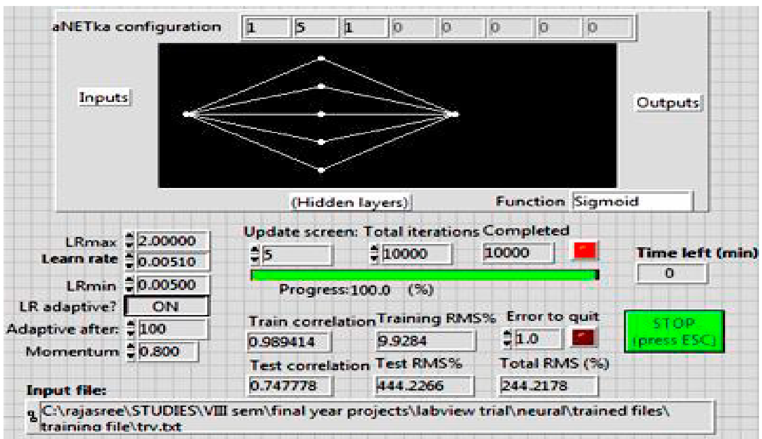

Fig 3 Training of neural network in LabVIEW

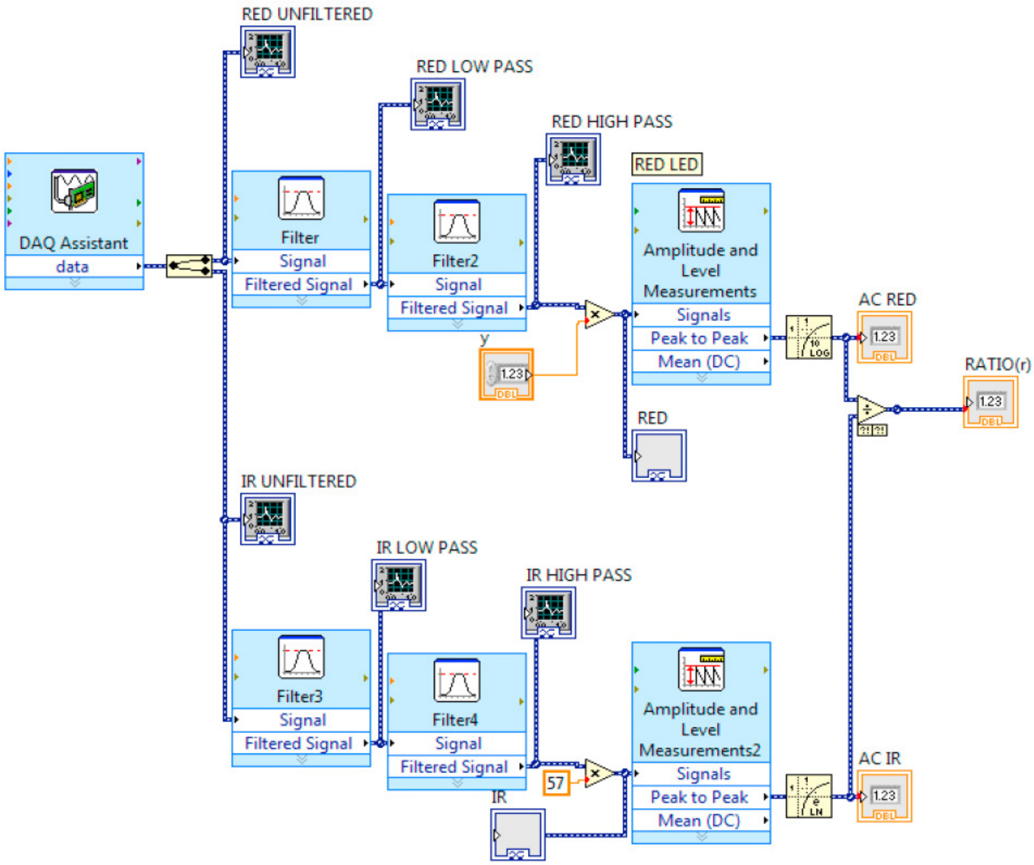

Fig.4 R value calculation in LabVIEW

3.2 Fuzzy logic and linear regression set-up in LabVIEW

The fuzzy system is designed with respect to the inverse linear relationship that exists between the R value and Spo2 value. The ratio R is given as input to the fuzzy logic while the output of fuzzy logic is Spo2. The input R is triangle membership function with 21 membership functions (depicted in Figure.5) and the Spo2 value is also triangle membership function with 21 membership functions(depicted in Figure.6). The rules are constructed such that as the R value decreases the oxygen saturation value increases.

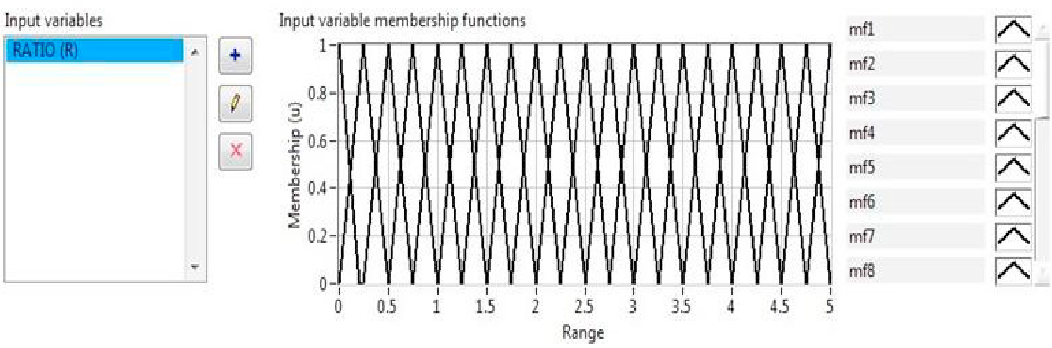

Fig. 5 Membership functions representing R value

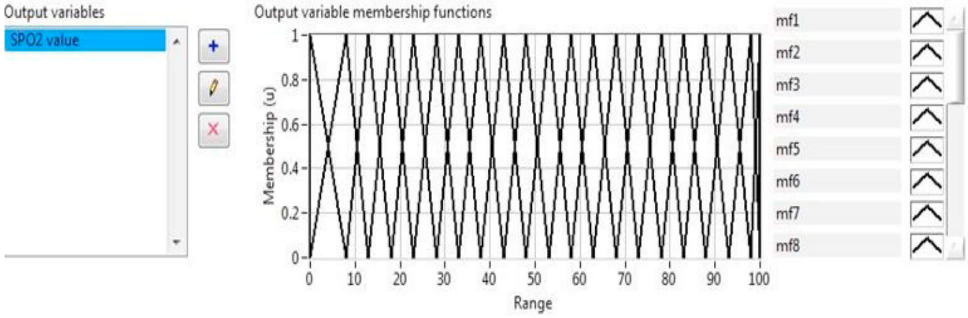

Fig. 6 Membership function representing SPo2

The fuzzy system is called into the main program where the input is given and output indicator is placed [1]. The LabVIEW block diagram for the same is given in figure.7.

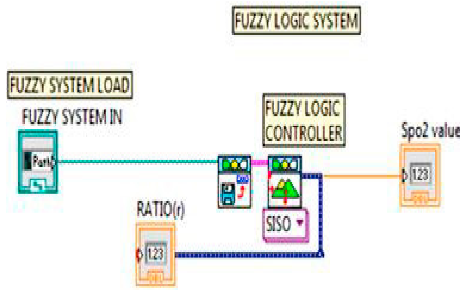

Fig. 7 Fuzzy calling block diagram in LabVIEW

The linear regression method is also implemented by using the relationship equation between R value and Spo2 value obtained in the paper by using Fig. 8 shows the LabVIEW block diagram for calculation of Spo2 using linear regression by utilizing the calculated ratio R [1].

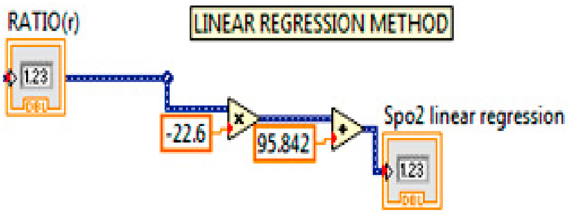

Fig. 8 Linear Regression model in LabVIEW

4. Results and Analysis

Artificial neural network, fuzzy logic and linear regression methods were used for calculating the oxygen saturation in blood content. The waveform obtained from the RED and IR LEDs is shown in fig.9. This experiment is tested with about 50 subjects to check the consistency of the proposed method. Subjects are selected based on their medical condition from normal to minor medical issues specially having breathing problem. Experiments are repeated to get good consistency. Results of 20 subjects are shown in table.1. In this, linear regression method shows poor capturing ability. ANN and Fuzzy based methods are show quite consistent values, but ANN captures accurate value than Fuzzy logic based.

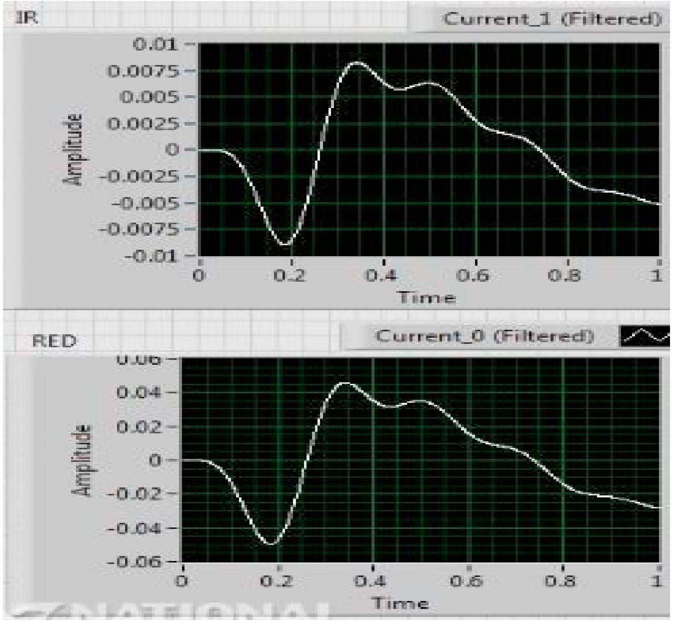

Fig.9 Resultant waveforms generated from RED and IR LEDs

Table 1 Comparison of SpO2 Values generated by ANN, Fuzzy and linear regression based methods

Subjects	R Value	ANN	Fuzzy Logic	Linear Regression
1	0.100	99.26	97.10	93.59
2	0.250	96.83	96.72	90.19
3	0.140	98.65	96.81	92.67
4	0.220	97.37	96.69	90.87
5	0.270	96.50	96.22	89.74
6	0.160	98.34	96.74	92.26
7	0.110	99.11	97.02	93.35
8	0.230	97.19	96.71	90.64
9	0.249	96.87	96.75	90.21
10	0.290	96.15	95.74	89.29
11	0.154	98.43	96.75	92.36
12	0.102	99.23	97.08	93.53
13	0.275	96.41	96.10	89.62
14	0.170	98.18	96.71	92.00
15	0.262	96.64	96.43	89.92
16	0.245	96.94	96.75	90.30
17	0.160	98.34	96.74	92.22
18	0.132	98.78	96.86	92.85
19	0.210	97.53	96.66	91.09
20	0.249	96.87	96.75	90.21

5. Conclusion

Observation of many parameters of an ICU patient is very much important during emergency treatment. Such situations pulse oximeters could be associated with other parameters like pulse rate, blood glucose level, blood pressure etc to supplement the patient with appropriate medicinal level. In that case reliability of pulse oximeters could be increased with ANN model. From this study, it can be observed that the measurement of oxygen saturation in human blood using neural network is possible and it is quite competitive than the existing methods. And also this is more dynamic and reliable. This study can be extended to patients who are in intensive care units, so that the effect of SpO2 level on the poor health can be analysed. The ANN based pulse oximeters can be combined with other biomedical instruments to study the overall clinical management in hospitals.

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