# Aortic Insufficiency Diagnosis tic through STFT & Wavelet Algorithm and Their Comparison through Fuzzy Logic and Neural Network

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*Abstract*—**Phonocardiogram is one of the most unstable signals; therefore phonocardiogram is included of frequency and timing information. Within present study we obtained vast features through STFT and Wavelet algorithm. Our main focus is on signals analysis which shows Aortic Insufficiency diagnosis, then utilized fuzzy logic and neural network to compare two methods.**

***Index Terms***—**STFT, wavelet algorithm, fuzzy logic, neural network.**

## I. Introduction

Clinical PCG signal analysis and determining their properties is of more significance, because this signal, serve vast useful and practical information related to different situation of heart and its diseases. Most of the different methods such as sound spectrograph, Fourier technique, time representative, Frequency and wavelet have been widely utilize to diagnose PCG signals but we don t have any practical comparison between this methods. Mentioned methods are related to times and frequency domain in PCG processing, Aortic Valve narrowing is result of congenital defect or chronic edema of its valve [1].

## II. PCG Signal

Heart Echo (phonocardiogram) provides valuable diagnosis tic information about heart valves and blood dynamic as a invasive method. Heart base point is placed normally within Sternum in 3rd space of chest. Generally, heart apex located in 4th and 6th place of chest near or inside left Mioclavclivlar. Heart beat senses or touches in apex with most intensively. [2]A little blood by the end of uterine systole which because of quick drop of uterine internal pressure, return to the uterine from lung artery and aorta. Aorta valve coincides to internal pressure drop i.e. from lung artery and aorta returns to uterine. In same time of internal pressure drop i.e. reach to lesser value of systolic pressure of aorta artery and lung artery and temporary blood return and contraction operation, aortic valve will be closed. Resulting vibration of said event will provide 2nd phonocardiogram (S2) by the end of systolic operation. ECG, will record time and range of heart electrical activities but could not be able to reflect mechanical events which in this case PCG is required. S1 normally would be occurred after QRS complex and S2 after T wave. [3] While Heart sound resulting from short vibration of systole start and stop, Cardiac murmurs would be occur by group of long vibration within systole or diastole or both. Cardiac murmurs like other heart sounds have audible characteristics, and these special characteristics will be defined based on heart passing blood volume and velocity. Heart abnormal phonocardiogram in addition to 1st sound of S1,and 2nd sound of S2, may included of Cardiac murmurs which developed because of Heart and Vessel systems different defects. These deviations will bring to human hearing system to make mistake and cause to being unclear of heart main sound. Heart sound is very unstable, therefore in heart sound analysis, there is many frequency and time information, in addition, Heart sounds have frequency quick and transitional tolerances, and in this case we utilizes STFT and Wavelet algorithm to reach our targets.

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## III. STFT Algorithm

If we required some information including frequency content tolerances of a time series, we would utilize short term Fourier series, so single dimensional signal will be transferred into 2D signal with two elements of time and frequency. Our accuracy within test method is related to selected window dimensions.[4] If selected window consider too small, frequency tolerances, high frequency will be specified by time wholly and vice versa. Our main problem with PCG signal analysis, is to find measured signal spectra of XC+1 as well as provide information about time interval which match to particular frequency. Utilized Short time Fourier transform (STFT) is as follows:

Multiple X(t) which would be analysis to the window of $\gamma*(t-\tau)$ , then assess window signal of Fourier transformer .

$$\xi_x^y(\tau,w)=\int_{-\infty}^{+\infty}x(t)\gamma(t-\tau)e^{-jwt}\,dt \tag{1}$$

$\gamma*(t-\tau)$ will cause elimination of X(t) out of particular context and Fourier Transformer , will show its local spectra. [5] Applying Transferring principle and modulation to Fourier Transformer we will have :

$$\begin{aligned}&\gamma(t)=\gamma(t-\tau)e^{jwt}\ \Leftrightarrow\\&T(o)=\int_{-\infty}^{+\infty}\gamma(t-\tau)e^{(o-w)}dt\\&=T(o-w)e^{-j(o-w)\tau}\end{aligned} \tag{2}$$

From Parseval relation we will have :

$$< x, \gamma_{r,w} > = \int_{-\infty}^{+\infty} x(t)\gamma^*(t-\tau)e^{-jwt}dt$$

$$= \frac{1}{2\pi} < x, T_{r,w} = \frac{1}{2\pi}\int_{-\infty}^{+\infty} x(v)T(o-w)e^{s(o-w)T}do \quad (3)$$

This relation shows that windowing in time domain simultaneously $\gamma^*(t-\tau)$ resulting to windowing in spectra domain with window of $T(G-w)$ thus reconstruction of $x(t)$ from $\xi(\tau - w)$ is so that possible [5].

$$x(t) = \frac{1}{2}\int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty} \xi_x^y(\tau - w)g(t-\tau)e^{jwt}dtdw \quad (4)$$

By this window, $g(t)$ synthesis should have following conditions :

$$\int_{-\infty}^{+\infty} \gamma^*(t)g(t)dt = 1 \quad (5)$$

In several real situations, available signals will be detoured by noises. It would be a non linear method to reduce noises as follows:

Its model is as follows:

$$y(t)=x(t)+n(t) \quad (6)$$

Considering that there is Fourier transformer for $y(t)$, we will have in frequency domain

$$Y(w)=x(w)+N(w) \quad (7)$$

Since being statistical dependency of signal and noise we have:

$$|Y(w)|^2 = |X(x)|^2 + |N(w)^2| \quad (8)$$

Assume that $E\{|N(w)^2|\}$ is known, so we have :

$$|X(x)|^2 = |Y(w)|^2 - E\{|N(w)^2|\} \quad (9)$$

Therefore, signal without noise in frequency domain is equal to :

$$\hat{X}(w) = |\hat{X}(w)| \angle Y(w) \quad (10)$$

## IV. Fuzzy Systems

Fuzzy system, is system which is based on knowledge or rules. In this way, the heart is a fuzzy system of a knowledge which comprises based on if-then rules. Main problem with respect to fuzzy system is that, its input and output is included of fuzzy complexes, while input and output in engineering systems are real parameters [2],[6].

## V. Method

At first, heart signals have been collected from Milad hospital that is located in Tehran and verified by dr.sheykhani and dr.shojayi. This signals are included of normal (intact) signal and abnormal (aortic insufficiency), then loaded themintoMATLAB software.

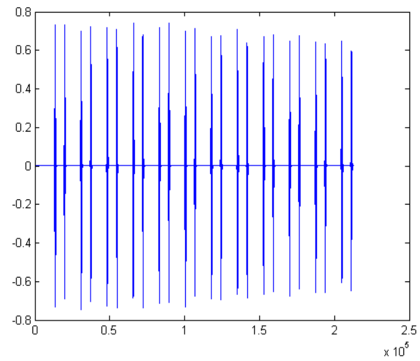

Fig. 1. Normal signal figure

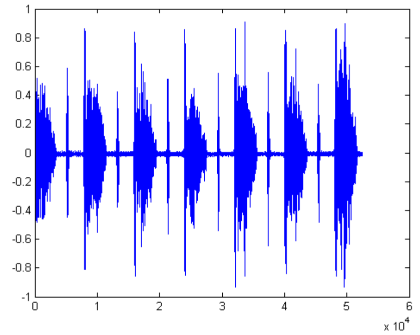

Fig. 2. Aortic insufficiency signal figure

First, to more accurate analysis, normalize by their amplitude, then their calculate their STFT

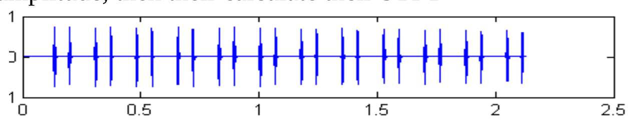

Fig. 3. Normalized normal signal

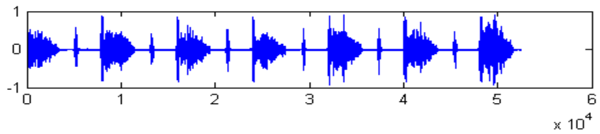

Fig. 4. Normalized aortic insufficiency signal

Then process these signals. From their STFT it could be found that, PCG signals in addition to instability have different power within varied frequency bands throughout heart cycle. Vitally, there is a sound of S1 and different power within Normal signal and aortic insufficient signal, which is proper character to distinguish normal signal and abnormal ones, so to show their distinction, fuzzy logic has been utilized. To utilize last processing into fuzzy logic, first we transformed calculated STFT from previous processes, utilizing their total and depth into 4 distinct levels to apply them as inputs. Since PCG signal has elements up to frequency of 400 Hz, therefore we transformed them to 4 levels of 100 Hz each.

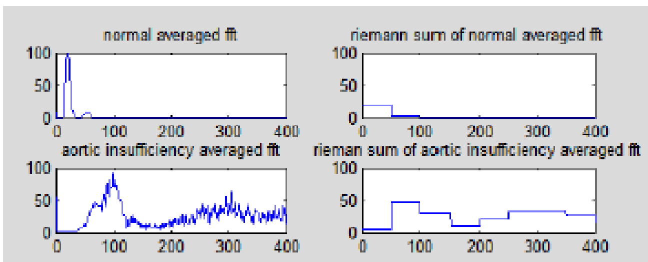


Fig. 5. Signal figure along with its Riemann.

We did said operation on Noraml and abnormal signals. In next steps, we defined these 4 levels of frequency as 4 distinct inputs to fuzzy system. Correlation selected function is as Gaussian one and their cause for selection is based on knowledge achieved from STFT algorithm and also they are as per observation, said correlation function yield considered as ascendant which finally tend to one based on type of input signal to the non fuzzy section of defuzzification. Therefore, fuzzy resultant engine considered as Mamadani engine.

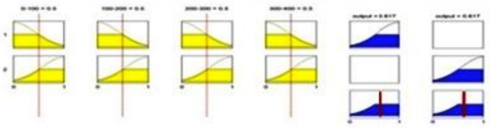

Fig. 6. Fuzzy network

To better realization of bar charts, we allocated them for normal and abnormal signal respectively.[7]

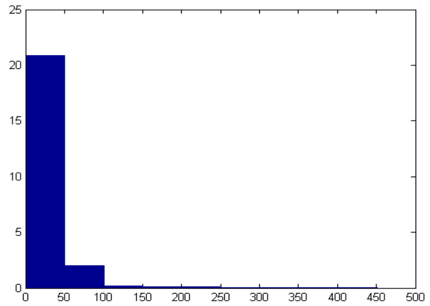


Fig. 7. bar chart for normal signal

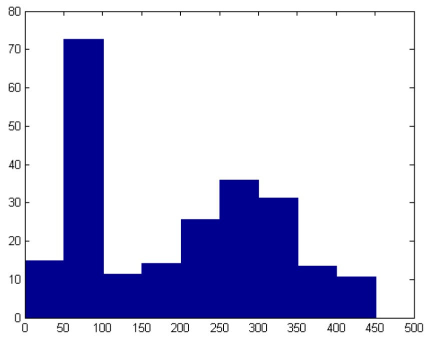


Fig. 8. bar chart for abnormal signal

## VI. Wavelet Transforming

Within STFT technique, small part of signal has been utilized in simultaneously, so it so called as signal windowing technique. But mentioned situation are strictly related to size of selected window, which would be of its weak point, whereas most of signals needs for flexibility to select time window size. Within wavelet analysis, it would be utilize details and approximations which are considered as elements of low and high frequency of signals which identify the signal.[ 8 ] First we did filtering process through Low and high pass filter, then to resolve duplication of our signals we performed down sampling which caused to provide wavelet Transformer coefficient. After analysis of signals which caused to receive valuable information, to conduct primary signal reconstruction we did up sampling. Our aim to utilize wavelet transformer within present study is to achieve features from our data, which are not able at first stage. Since at first stage we are not able to calculate wavelet for total of our data, we have no alternative but to divide our data to windows in which for this purpose we utilize Gaussian neighboring including 50% overlap, and calculate wavelet for each of them separately. Then, we calculated average value of each which represents a feature to us. It allows us to distinguish patients based on differences in features.[9],[10]

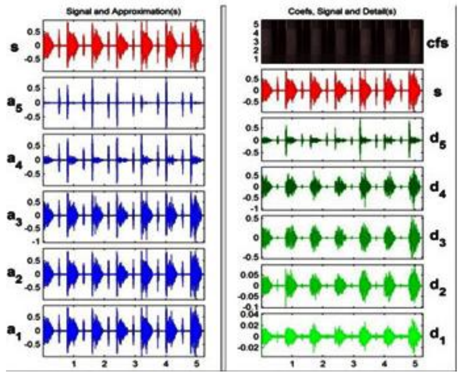


Fig. 9. Signal approximation and signal details

## VII. Signal Details

As it has shown on the figure, left side represent signal approximation and right side represent signal details. To categorization of data, we utilized wavelet analysis using information including normal and abnormal signal, so the required coefficient has been calculated, and mean and standard deviation are calculated through following equation which has beem considered as identification vector including a $10 \times 1$ matrix. Our date is including of 20 types of each signal, so we calculate said identification for each signal which resulting to $10 \times 20$ matrix. This matrix representing arrhythmic information which we considered them as neural network input to train our network.

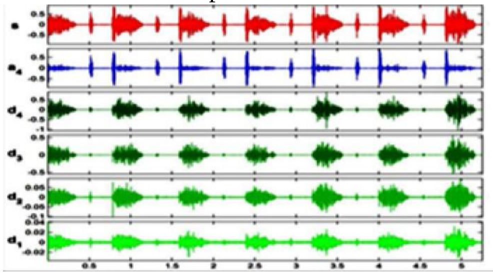

Fig. 10. signal coefficient

Then we allocated a target vector to each normal or abnormal signal yielding to a matrix of $5 \times 1$. The numbers of hidden layers are 5, and applied function within this layer is logsing, and utilizes trainlm function for training.

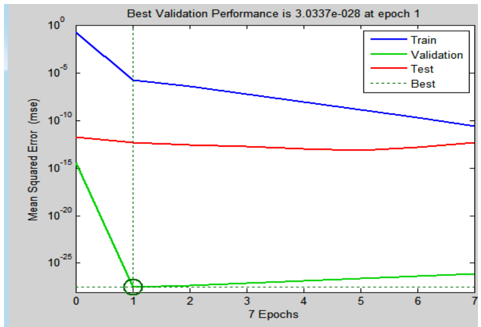


Fig. 11. Neural network error

## VIII. CONCLUSION

TABLE I: AORTIC INSUFFICIENCY SIGNAL

| **Aortic Insufficiency** | **Normal** |
|---|---|
| 0.9855 | 0. 0120 |
| 0.9858 | 0. 0120 |
| 0.9885 | 0. 0145 |
| 0.9889 | 0. 0125 |
| 0.9999 | 0. 0859 |
| 0.9758 | 0. 0859 |
| 0.9585 | 0. 0999 |
| 0.9259 | 0. 0845 |
| 0.9952 | 0. 0745 |
| 0.9958 | 0. 0859 |
| 0.9754 | 0. 0156 |
| 0.9851 | 0. 0556 |
| 0.9841 | 0. 0125 |
| 0.9526 | 0. 0178 |
| 0.9120 | 0. 0953 |
| 0.8025 | 0. 0854 |
| 0.9748 | 0. 0569 |
| 0.9845 | 0. 0452 |
| 0.9854 | 0. 0125 |
| 0.9859 | 0. 0087 |

TABLE II: NORMAL SIGNAL

| **Aortic Insufficiency** | **Normal** |
|---|---|
| 0.0056 | 0.8859 |
| 0.0205 | 0.9859 |
| 0.0125 | 0.9652 |
| 0.0956 | 0.9251 |
| 0.0526 | 0.9226 |
| 0.0648 | 0.9854 |
| 0.0263 | 0.9152 |
| 0.0458 | 0.9021 |
| 0.0102 | 0.9023 |
| 0.0458 | 0.9256 |
| 0.0745 | 0.9903 |
| 0.0852 | 0.9215 |
| 0.0962 | 0.9152 |
| 0.0203 | 0.9745 |
| 0.0102 | 0.9152 |
| 0.0415 | 0.9625 |
| 0.0796 | 0.8956 |
| 0.0158 | 0.9028 |
| 0.0785 | 0.9856 |
| 0.0999 | 0.9874 |

Utilized signal are 20 ones from normal people and 20 ones for disease ones. The results shows that systems are able to distinguish input signals and predict aortic insufficiency whether through STFT or wavelet method. But as it could be observed on following results wavelet algorithm have a high ability with this job so utilizing of this method is strictly recommended. Now our output is included of 2 digits in range of [0,1] which is showing normal or aortic insufficiency signal.

While Semi conductor technology development, new race of complexes circuit have been entered into market known as Neuro-Fuzzy Chip and mentioned system are able to implement on them easily.

## REFERENCES


[1] B. Kamath and W. Thornton, “Auscultation of the Heart,” *Review of clinical signs*, pp. 33-43, September 2010.

[2] P. Wang, Y. Kim, and L. H. Ling, “First Heart Sound Detection for Phonocardiogram Segmentation,” in *Proc. of the IEEE Engineering in medicine and biology 27th Annual Conf*, pp. 5519-5522,2005

[3] J. Chebil and J. A1-Nabulsi, “Classification of Heart Sound Signals Using Discrete Wavelet Analysis,” *International Journal of soft Computing*, pp.37-41,2007

[4] K, O. Lib, Y. C. Liew, and C. Hoh, “Analysis of Mitral and Aortic Valve Vibration and their Role in the production of the first and second Heart Sound,” *Journal of Phisics in medicine and Biology*, pp. 727-733, 2006

[5] M. B. M. Kamarulafizam, “Heart Sound Segmentation Algorithm Based on Instantaneous Energy of Electro Cardiogram,” in *Proc. of the IEEE Conf. on computer in cardiology*. pp. 327-330, 2003

[6] S. Goutam and P. Kumar; “An Efficient Heart Sound Segmentation Algorithm for Cadiac Diseases,” *1st India annual conference*, in Proc. of the IEEE INDICON , pp. 344-348, 2004

[7] V. Kudriavtsev, V. Polyshuk, and D. L Roy, “Heart energy signature spectrogram forcardiovascular diagnosis,” *Biomedical Engineering Online* 2010, vol. 6, no. 16.

[8] J. G. Webster, *Medical Instrumentation Applicatio and Design*, 3 ed.1998 ohn Wiley and Sons, Inc.

[9] N. B. Eugence, “Biomedical Signal Procesing and Signal Modeling,” *John Wiley and Sons*, 2001

[10] N. Shamsuddin, M. N. Mustafa, S, Husin, and M. N. Taib, *Classification of Heart Sounds*.