2012 4th International Conference on Bioinformatics and Biomedical Technology
IPCBEE vol.29 (2012) © (2012) IACSIT Press, Singapore

Utilization of Fuzzy Logic for Classification of Heart Diseases

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Abstract. Phonocardiogram is one of the most unstable signals which is included frequency and timing information because of that we choose STFT algorithm , within present study we obtained vast features through STFT algorithm and their Riemann ,then for categorizing signals we used Fuzzy Logic system which as the result is able to recognize the malady with the best accuracy .

Keywords: STFT — fuzzy logic – Phonocardiogram

1. Introduction

PCG signal analysis and determining their properties is very important in clinical diagnosis , because this signal, serve vast useful and practical information related to different situation of heart and its disease. Most of different methods such as Sound Spectrograph, Fourier technique, Time –Frequency showing , and wavelet have been widely utilized to diagnose PCG signals. Mentioned methods are related to times and frequency domain in PCG processing. The mail purpose of recording PCG signal is to make an important data base which we can refer to that for recognizing the sounds of heart and murmurs.[2]

Heart Echo (phonocardiogram) provides valuable diagnosis information about heart valves and blood dynamic as a invasive method. Heart bottom 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 Mioclavcliular. Heart beat senses or touches in apex with most intensively. 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 coincide 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, aorta valve will be closed. Resulting vibration of said event will provide 2nd phonocardiogram (S2) by the end of systolic operation. [3]

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. 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 timing information, in addition, Heart sounds have frequency quick and transitional tolerances, and in this case we utilizes STFT to reach our targets.

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2. 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. 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 γ*(t-τ), then assess window signal of Fourier transformer .

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

γ*(t-τ) will cause elimination of X(t) out of particular context and Fourier Transformer , will show its local spectra. 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 Parsoal relation we will have :

$$\begin{aligned}&< x, \gamma_{r,w} >= \int_{-\infty}^{+\infty} x(t)\gamma^*(t-\tau)e^{-jwt}\,dt\\ &= \frac{1}{2\pi} < x, T_{r,w} = \frac{1}{2\pi}\int_{-\infty}^{+\infty} x(v)T(o-w)e^{s(0-w)T}\,do\end{aligned} \tag{3}$$

This relation shows that windowing in time domain simultaneously to γ*(t-τ), resulting to windowing in spectra domain with window of T*(G-w), thus reconstruction of x(t) from Є (τ-w) is so that possible.

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

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

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

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:

$$y(t)=x(t)+n(t) \tag{6}$$

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

$$Y(w)=x(w)+N(w) \tag{7}$$

Since being statistical dependency of signal and noise we have:

$$|Y(w)|^2 = |X(x)|^2 + |N(w)^2| \tag{8}$$

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

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

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

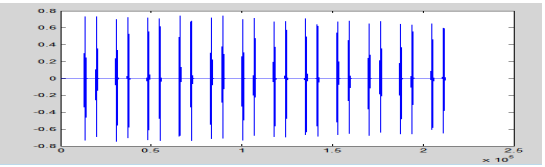
$$\hat{X}(w) = |\hat{X}(w)|\angle Y(w) \tag{10}$$

3. Fuzzy Systems

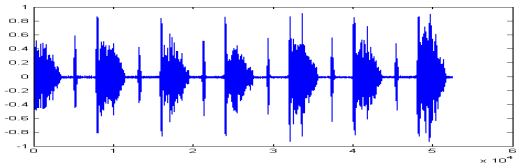
Fuzzy system, is system which is based on knowledge or rules. In this way, the heart is a fuzzy system of a knowledge which comprises based on if-then rules. Main problem with respect to fuzzy system is that, its input and output is included of fuzzy complexes, while input and output in engineering systems are real parameters.[5]

4. Method

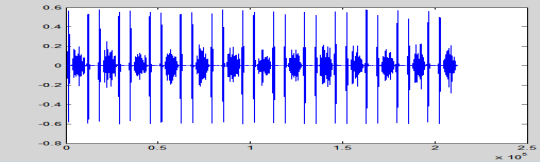
At first heart signals have been collected from Milad hospital ,which Is included of normal (intact) signal and abnormal (aortic insufficiency, mitral stenosis, pulmonary stenosis), we used 36 signals of patient, then loaded them into MATLAB software.



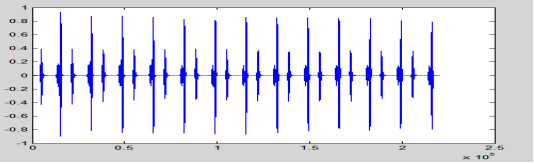
Normal signal figure



Aortic insufficiency signal figure

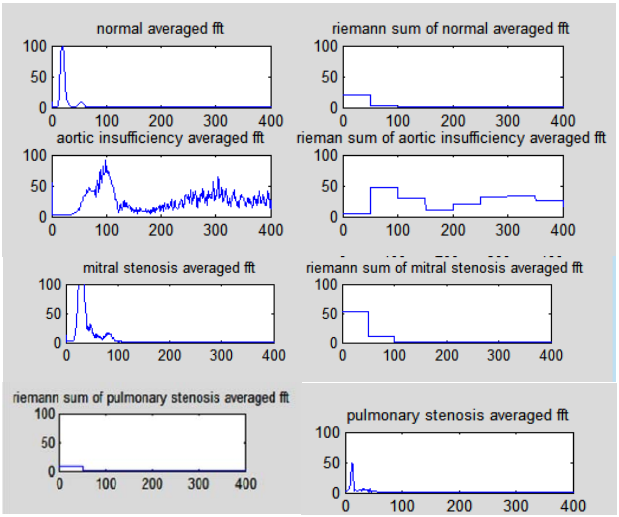


Mitral stenosis signal



Pulmonary stenosis signal

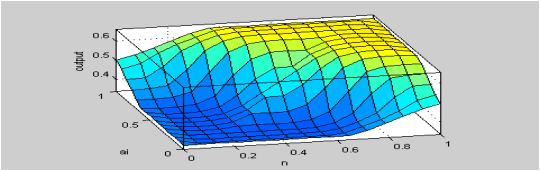
First, to more accurate analysis, normalize by their amplitude, then calculate their STFT and process these signals. From their STFT it could be found that, PCG signals in addition to instability have different power within varied frequency bands throughout heart cycle. Vitally, there is a sound of S1 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.



Signal figure along with its *Rayman*

We did said operation on Normal and abnormal signals. In next steps, we defined these 4 levels of frequency as 4 distinct inputs to fuzzy system. Correlation selected function is Gaussian and their cause for selection is based on knowledge achieved from STFT algorithm and also they are as per observation, said correlation function yield better results. Output correlation functions considered as ascendant function 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.

Fuzzy network



Surface of output

5. Conclusion

Utilized signal are 9 ones from normal people and 27 ones for disease ones. The results show that systems are able to distinguish input signals and predict heart diseases through STFT. Now our output is included of 4 digits in range of [0,1] which is showing normal or other signals.

Normal signal

Mitral stenosis	Pulmonary stenosis	Aortic insufficiency	normal
00652	0.0854	0.0012	0.9859
0.0885	0.0985	0.0502	0.9856
0.0159	0.0854	0.0895	0.9658
0.0774	0.0158	0.0958	0.9958
0.0526	0.0154	0.0658	09859
0.0258	0.0236	0.0578	0.8999
0.0614	0.0258	0.0125	0.9265
0.0215	0.0711	0.0014	0.9895
0.0895	0.0145	0.0158	0.8585

Aortic insufficiency signal

Mitral stenosis	Pulmonary stenosis	Aortic insufficiency	normal
0.0015	0.0145	0.9999	0.0085
0.0174	0.0547	0.9996	0.0625
0.0954	0.0854	0.9025	0.0458
0.0165	0.0258	0.9854	0.0128
0.0148	0.0985	0.9851	0.0749
0.0851	0.0562	0.9855	0.0214
0.0745	0.0158	0.9858	0.1201
0.0148	0.0148	0.9899	0.0010
0.0850	0.0174	0.9102	0.0125

Mitral stenosis

Mitral stenosis	Pulmonary stenosis	Aortic insufficiency	normal
0.9415	0.0102	0.0748	0.0851
0.9250	0.0120	0.0541	0.0012
0.9859	0.0258	0.0254	0.0136
0.9851	0.0265	0.0125	0.0145
0.9810	0.0120	0.0785	0.0855
0.9810	0.0584	0.0157	0.0545
0.9856	0.0157	0.0120	0.0168
0.9154	0.0145	0.0854	0.0021
0.9850	0.0451	0.0625	0.0521

Pulmonary stenosis

Mitral stenosis	Pulmonary stenosis	Aortic insufficiency	normal
0.0859	0.9258	0.0254	0.0136
0.0851	0.9265	0.0125	0.0145
0.0810	0.8920	0.0785	0.0855
0.0895	0.9145	0.0158	0.0585
0.0856	0.9157	0.0120	0.0168
0.0614	0.9258	0.0125	0.0265
0.0215	0.9711	0.0014	0.0895
0.0148	0.9148	0.0899	0.0010
0.0885	0.9985	0.0502	0.0856

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.

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