Heart Sound Recognition by Analysis of wavelet transform and Neural network.

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Abstract

This paper presents the application of the wavelet transform analysis and the neural network method to the phonocardiogram (PCG) signal. Heart sound is a acoustic signal generated by cardiac valves, myocardium and blood flow and is a very complex and nonstationary signal composed of many source. Heart sound can be discriminated normal heart sound and heart murmur. Murmurs have broader frequency bandwidth than the normal ones and can occur at random position of cardiac cycle. In this paper, we classified the group of heart sound as normal heart sound(NO), pre-systolic murmur(PS), early systolic murmur(ES), late systolic murmur(LS), early diastolic murmur(ED).

And we used the wavelet transform to shorten artifacts and strengthen the low level signal.

The ANN system was trained and tested with the back-propagation algorithm from a large data set of examples-normal and abnormal signals classified by expert. The best ANN configuration occurred with 15 hidden layer neurons. We can get the accuracy of 85.6% by using the proposed algorithm.

1. Introduction

Noninvasive study (diagnosis) methods, such as phonocardiogram(PCG) and electrocardiogram(ECG), offer the useful information of the functional heart. In auscultation, the listener tries to analyze the heart sound components separately and then synthesize the heart features. Heart sound analysis by auscultation highly depends on the skills and experience of the listener. Therefore, the recording of heart sounds and analyzing them by a computerizes and objective way would be most desirable

The basic purposes of phonocardiography were to provide the physician with a complementary tool to record the heart sounds and murmurs during auscultation, to obtain the specific measurements on their timing, and to get better understanding of the basic mechanisms behind genesis. Although the development of the intracardiac phonocardiography at the beginning of the 1959's and Doppler echocardiography have provided new approach to investigate the basic mechanisms involved in the genesis of the heart sounds and murmurs, heart auscultation is rhe first easy and useful clinical aid tool. But heart sound analysis by auscultation is the qualitative and insufficient method to diagnose some heart diseases. Abnormal heart sounds may contain, in addition to the first sound S1 and the second sound S2, murmurs and aberrations caused by the different pathologies of the cardiovascular system. These aberrations confuse the human ear, obscuring the main sound of the heart. So the analyst cannot obtain both the qualitative and quantitative characteristics of a phonocardiogram.

In this paper, for more accurate recognition of heart sound , we applied the wavelet transform and the neural network method.

2. Analysis of Heart Sound

The most widely accepted theory on the genesis of the heart sound is described by Rushmer and states that heart sound consists of four components[2].Heart sound is an acoustic signal generated by cardiac valves, myocardium and blood flow and is a very complex and nonstationary signal composed of many sources. Normal heart sound consists of four sounds called the first heart sound(S1), the second heart sound(S2), the third heart sound(S3) and fourth heart sound(S4). The first heart sound (S1) occurs at the beginning of ventricular contraction during the closure of the mitral and tricuspid valves. It indicates the beginning of ventricular systole. The second heart sound(S2) marks the end of ventricular systole and the beginning of ventricular relaxation, following the closure of the aortic and the pulmonary valves. The third sound(S3) is caused by the oscillations of the blood between the root of the aorta and the ventricular wall. The last sound(S4) is caused by the turbulence of the ejected blood. The third and fourth heart sound (S3 and S4) caused by the sudden termination of the ventricular rapid-filling phase, after isovolumetric relaxation, and the displacement of blood caused by arterial contraction, respectively[6]. The identification of systole and diastole is important in determining other heart sound and murmurs[1],[5]. Murmurs have more broad frequency bandwidth than normal and can occur at random position of cardiac cycle. The timing of murmur generation is closely related to heart motion and can be classified normal heart sound(NO), pre-systolic murmur(PS), early systolic murmur(ES), late systolic murmur(LS), early diastolic murmur(ED). Thus recognition of heart sound means classification of murmurs.

3.Wavelet Transform

The wavelet transform is a theory integrated many techniques of various signal processing application and lately is widely used in biomedical signal –nonstationary signal-processing. The Wavelet Transform(WT) is also used to analyze the heart sound in time and frequency domains.

Discrete wavelet system are generated from a single scaling function or wavelet by simply scaling and shifting, then wavelet function $\phi(\cdot)$ and scaling function $\psi(\cdot)$ are expressed to exq.(1),(2)

$$\phi(n) = \sum_k g(n)\phi(2n-k) \quad (1)$$

$$\psi(n) = \sum_k h(n)\psi(2n-k) \quad (2)$$

In analysis algorithm of discrete wavelet transform, wavelet filter coefficient $h(n)$ is a highpass filter coefficient and scaling filter coefficient $g(n)$ is a lowpass filter coefficient.

Discrete wavelet transform to j=J stage in discrete signal x(n) is defined to exq.(3)

$$x(n) = \sum_{j=1}^{J}\sum_{k\in Z} g_j(k)\psi_{2^j}(n-2^j k) + \sum_{k\in Z} h_j(k)\phi(n-2^J k) \quad (3)$$

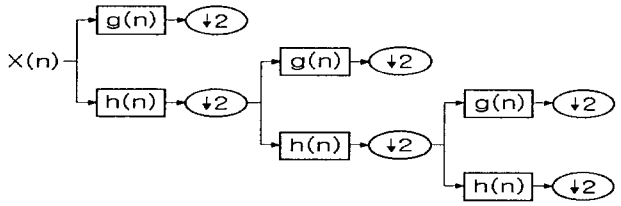

Figure 1. Repetitive filter bank of wavelet transform

4. Neural Network

Neural Network technology gave a computer system an amazing capacity to actually learned from input and output data. Artificial Neural Networks have provided solutions to problems normally requiring human observation and thought processes. A Neural Network can be thought as a functional approximator that fits the input and the output data with a high-dimensional surface. The major difference between conventional statistical methods and ANNs was in the activation functions that were used. Standard functional-approximation techniques used complicated sets of orthogonal basis functions. In this paper, we used a back propagation algorithm which is the most generalized neural network. A Back-Propagation algorithm took multilayer perceptron and generalized delta learning rule. Multilayer perceptron used to overpass the limit of perceptron constructed of single-adjustable layer was consisted of input layer, output layer, and at least one hidden the limit of perceptron constructed of single-adjustable layer the limit of perceptron constructed of single-adjustable layer was consisted of input layer, output layer, and at least one hidden layer. A Back-Propagation Network as shown graphically in Figure 2, was a fully connected, layered, feedforward Neural Network. Activation of the network flew in one direction only: from the input layer through the hidden layer, then on to the output layer. A Back-Propagation network might contain multiple hidden layers.

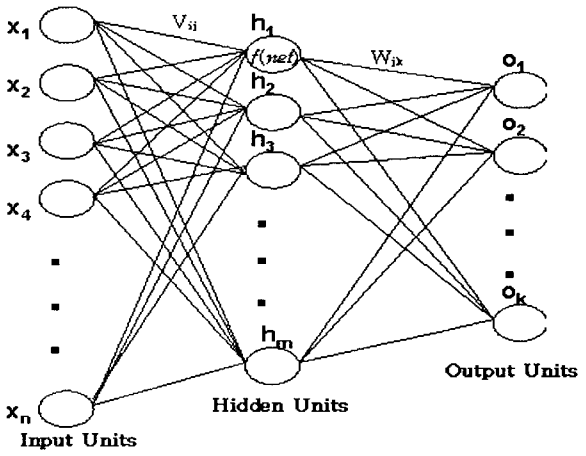

Figure 2. Back propagation net

Multilayer neural network training is demanded longer training time than single-layer network and in some cases, may be failed. Thus, for training faster multiplayer network we have to consider a first connection intensity, training rate, numbers of hidden units.

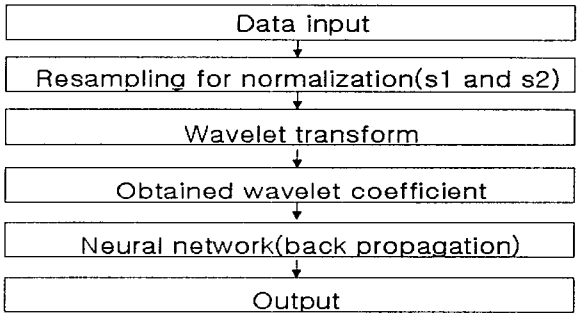

Figure 3. Flowchart of suggested algorithm

5. Experiment and Result

(1) Data acquisition

Heart sounds are obtained by using MP100system in Biopac Co., contact microphone TSD108 as input microphone, DAQ100 as amplifier. For algorithm confirmation, we used data base(8kz,16bit) which Frontiers in Bioscience and Westen univ.. held. Heart sounds and murmurs can be classified by generation time. Each S1 and S2 is generated when systolic period start and diastolic period start. If the factor gets weaker in this period murmur, it is classified as normal heart sound.

Signals are classified into normal heart sound(NO), pre-systolic murmur(PS), early diastolic murmur(ES), late systolic(LS), early diastolic murmur(LD) as figure 4.

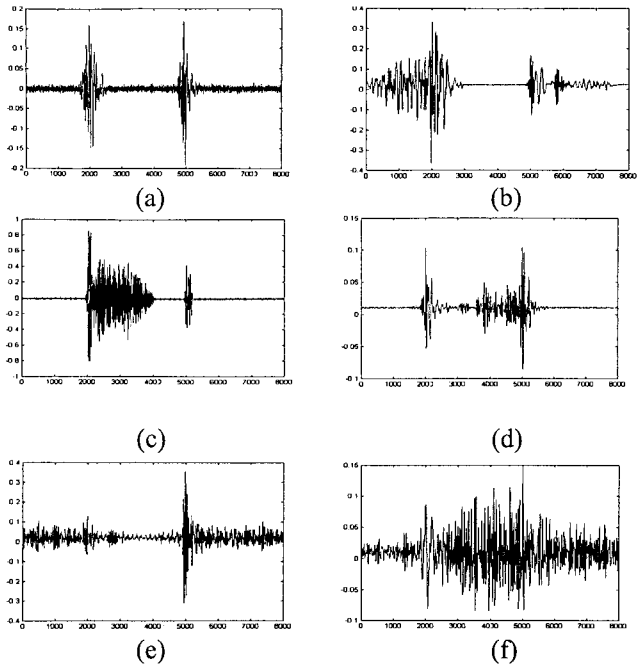

Figure 4. (a)normal heart sound(NO) (b) pre-systolic murmur(PS) (c)early systolic murmur(ES) (d)late systolic murmur(LS) (e)early diastolic murmur(ED) (f)etc.

(2) Resampling

Because each cardiac cycle is different, the interval between S1 and S2 is also different. This is the factor that shorten recognition rate in neural network method. In this paper, for normalize the interval between S1 and S2, we proposed the new resampling method. Firstly, the interval S1 and S2 of each data are obtained and calculated the least common multiple(LCM) with its targets. Then we increased numbers of the sampling data to LCM, executed filtering for distortion prevention. Next, we remove sampling data from each data for target interval and executed filtering again.

(3) Wavelet transform

For heart sound signals, the low-frequency content is the most important part. In this paper, wavelet level 3 for the characteristic field (0-1000hz) of heart sound is used. Much higher part than 1000hz is almost noise. In discrete wavelet analysis, signals are divided into approximation and detail.

In this experiment, the approximation to level 3 is used as input vector of neural network.

(4) Neural network training.

Signals analysed by wavelet method become inputs of neural network with characters of heart sound preserved and numbers of data are reduced. When we reduce training time and processing time, it is essential to reduce numbers of network input node.

A back propagation algorithm consists of three layer of input, hidden, output. To optimize neuron numbers of input and hidden layer, we controlled node numbers and detected the value to get the most accurate detection rate. First, we discriminated normal and abnormal signals. Then, we tried to detect four parts of PS,ES,ED,LD among abnormal signals

The learning rate of neural network was fixed as 0.01, numbers of output node 1, the threshold of mean square error (the average squared error between the network outputs and the target outputs) fixed as 0.05. The change of detection rate depending on the number of node in hidden layer is showed in table 1. Table 1 is the percentage of the value about the learning rate. When numbers of node in hidden layer are 15, we obtained the best result.

Table 1. The change of detection rate depending on the number of node in hidden layer

The number of node in hidden layer	Detection rate	The number of node in hidden layer	Detection rate
10	81.42	18	82.9
11	82.3	19	76.5
12	82.3	20	75.5
13	82.05	21	80.45
14	84.3	22	79.1
15	86.2	23	78.1
16	85.1	24	79.06
17	81.6	25	78.75

Table 2. shows the detection rate of heart sound data classified. We classified the heart sound into normal and abnormal data, then abnormal data into pre-systolic murmur, early systolic murmur, late systolic murmur and early diastolic murmur. When we observe recognition rate about each classfication, the recognition rate of normal data was 100%, pre-systolic murmur was 78%, early systolic murmur was 94%, late systolic murmur 90%, early diastolic murmur 66%. The total recognition rate was 85.5%.

Table 2. Result of heart sound recognition.

Section	Symptom	Rate(%)
Normal	Normal(NO)	100
Abnormal	Pre-systolic murmur(PS)	78
	Early systolic murmur(ES)	94
	Late systolic murmur(LS)	90
	Early diastolic murmur(ED)	66
Total		85.6

5. Conclusion

In this paper, we proposed the recognition method which extracts feature of heart sound on full cycle and classifies heart sounds. Heart sounds are classified into normal, pre-systolic murmur, early systolic murmur, late systolic murmur, early diastolic murmur.

For improving the diagnostic techniques of the heart diseases in cost-effective approaches, this proposed recognition algorithm introduced wavelet transform and neural network. Wavelet transform is used to emphasize important area of frequency band in heart sound signal and to reduce numbers of data.

The neural network with back propagation method

which shows prominent approximation of function was used. We selected the best constructure in controlling the number of node in hidden layer. We can verify our algorithm is useful from the results which show the average recognition rate of heart sounds is 85.6 percent. Recognition error was occurred mainly in early diastolic murmur and pre-systolic murmur. The expected problem in clinical application is the recognition about the heart sounds of which abnormal rate is weak.

Cardiac auscultation has been recognized as a primary and fundamental diagnostic tool for a long time. However, now it is recognized as a insufficient method for more accurate the analysis of the cardiac disease

Using more various signal-processing method, we will study some automatic classification method for phonocardiogram screening. And we will try to get the more accurate classification rates and faster the detection time.

Reference

[1] E.v. Vollenhoven and J. G. J. Chin, "Phonocasrdiography. Past, present and future", Acta Cardiologica, pp.337-344, 1993

[2] M.S.Obaidat, "Phonocardiogram signal analysis: techniques and performance comparison." Journal of medical Engineering & Technology, Volume 17, Number 6(November/December 1993), pages 221-227

[3] L. G. Durand and P. Pibarot, "Digital signal processing of the phonocardiogram-Review of the most recent advancements", CRC Critical Reviews Biomedical Engineering, vol.23, no.3, pp. 163-219, 1995

[4] Endre Bodnar, "prediction of value failure: Statistical modeling and pattern recognition", J.Heart Value Dis., voi.2, no. 5, pp.490-92, 1993

[5] Fausett D., "strictly Local Backpropagation", IEEE Int. Joint Conf. On neural network, Vol. 3, pp. 125-130, 1990

[6] R. M. Rangayyan and R.J. Lehner, "Phonocardiogram signal analysis: A review", CRC Critical Review Biomedical Engineering, vol.15, pp. 211-236, 1998

[7] Louis-Gilles Durand and Philippe Pibarot. "Digital signal processing of the phonocardiogram: Review of the most recent advancements." Critical Reviews™ in biomedical engineering." 23(3/4), pages 163-219

[8] Z. Guo, L. G. Durand, H. C. Lee, L. Allard, M. C. Grenier and P. D. Stein, "Artificial neural networks in computer-assisted classification of heart sounds in patient-assisted classification of heart sounds in patients with porcine bioprothetic valves", Medical & Biological Engineering & Computing, vol. 32, pp. 311-316, 1994

[9] A.J. Gobor, and M.Seyal, "Automated interictal spike detection using artificial neural network.", Electroenceph. Clin. Neurophysiol. Vol. 14 No. 2, pp. 160-166, March/April, 1995