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The Signal Processing of Heart Sound from Digital Stethoscope for Identification of Heart Condition Using Wavelet Transform and Neural Network

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***Abstract*—The ordinary stethoscope that is called acoustic stethoscope can detect heart sound and plung in order to know their health condition. However, the doctor diagnostics result depends on sensitivity of his hearing and experience. Also, it couldn't be saved as patient's medical history. Therefore, these researches have designed and developed a digital stethoscope with modify from the ordinary stethoscope which can produce heart sound via audio and graphics also the result can be saved in computer memory with addition of heart condition identification. The advantages of this research are very cheap production, portable, produce audio and graphics data, able to data saving and identify patient heart condition. The digital stethoscopes built from the ordinary stethoscope using sensor of the condenser microphone for convert analog signal become digital signal. The next process is signal processing such as amplification and low pass filter where frequency region below of 940 Hz, cause the heart sound produce sound between 0 and 940 Hz. These hardware systems connect to sound card in the computer or tablet for several processes of display to monitor, sound to speaker, recording and identification of heart condition using neural network. All of these software processes use matlab 2014.The experiment showed the best network architecture is used at number of neuron in second layer with each layer of 75 neuron. This architect produces highest accuration, the accuration is 82,14 % and need learning time fast enough compare with another one, time is 96 second. And wavelet type that suitable is wavelet db3 with 10 decomposition level. Highest accuration to identify the heart condition with murmur aorta regurgitation and trikuspid regurgitation, of 100 %, then mitral regurgitation with accuration of 83,3 %, mitral stenosis with accuration of 75 % and lowest accuration for normal heart with accuration of 70 %.**

Keyword: heart sound; stethoscope; digital; cheap; identification

I. INTRODUCTION

Nowadays, instrument to heart sound diagnosis is acoustic stethoscope. Mostly, medical doctors around more than 90 % use stethoscope for patient diagnosis [1]. Heart with unnormal condition produces sound addition which called murmur [2]. The operation of ordinary stethoscope has several lack of diagnosis. The problems of the acoustic stethoscope usage are environment noise, low sensitivity, low amplitude and no variation of the sound pattern. The diagnose's doctor depend on ear sensitivity's doctor and his experience. Another disadvantage is the heart sound can't save as heart history's patient and for matter of discussion by among doctors. Another word, conventional stethoscope is tool let behind and very inaccurate. Therefore, important thing to develop stethoscope become digital instrument. Recent, there are digital stethoscope, however it is still very expensive and can't save the data's patients. In this research, we design and produce the smart digital stethoscope with some advantages such as very cheap production, portable, produce audio and graphics data, able to data saving and identify patient heart condition. Hence, this instrument can be used by all people to first diagnose before go to doctor to next diagnosis.

II. THEORY

Heart sound produces two different sounds using stethoscope tools, there are sound of 'lub' and 'dubs'. The first sound (S1) or sound of 'lub' is caused by closing triskupid and mitral valves. The flood flows from auricle to chamber of heart and stop the opposite direction. The second sound (S2) or sound of 'dub' is produced at end of systole and first of diastole, and is raised by closing aortic and pulmonic valves. The flood leaves heart to body and lungs.

Sounds of S1 and S2 are showed at figure 1 (a). The disease because heart valve can't work as usually. If valve can't open widely so only a little flood can flow it. Opposite, if valve can't close completely, so that flood can flow oppositely, which is like to show figure 1 (b).

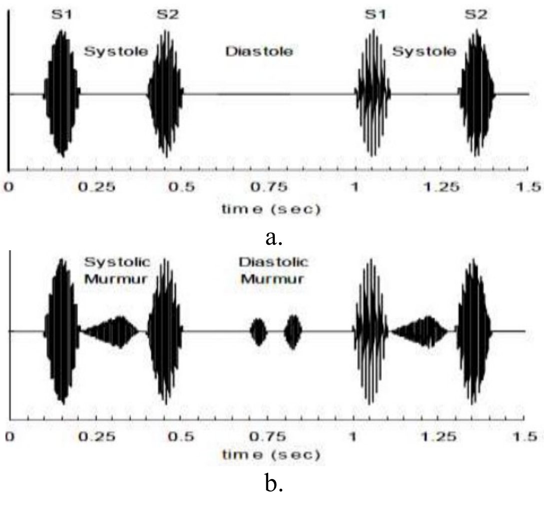

Fig. 1. The heart sound (a) normal and (b) with mur systolic and diastolic [3]

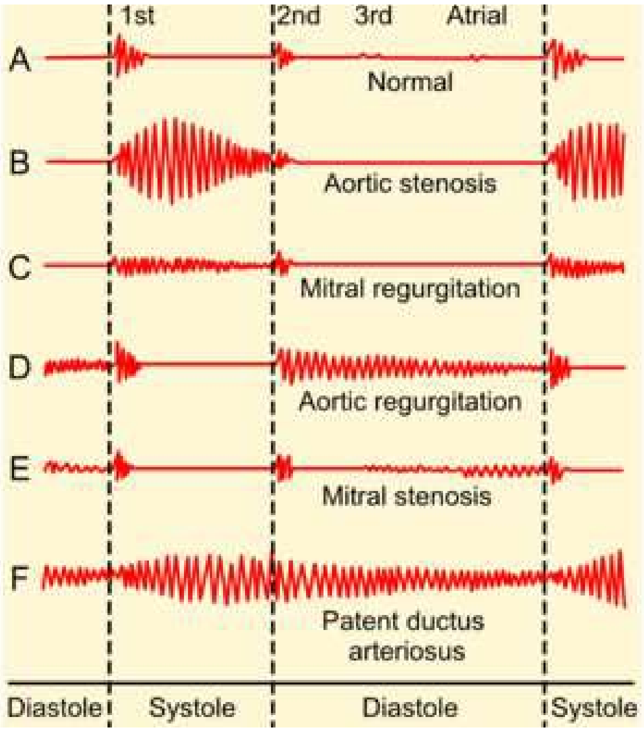

Fig. 2. The heart sound of normal and abnormal [4]

Frequency range of the normal heart sound is between 20 Hz and 400 Hz. However, the frequency range of the abnormal heart is less than 1000 Hz. Murmur is sound that heard as continuously for periods of systolic, diastolic or the both. Murmur can be classified become murmur of systolic and diastolic depend on the phases [3]. Figure 2 shows some sample of murmur signals.

The murmur of systolic is sound that heard continuously between S1 and S2. The murmur of diastolic is sound that heard continuously between S2 and next S1. The early murmur diastolic starts from S2 and culminates at the first phase of three phases of diastole period. This is because S2 is difficult to be heard, however S1 can be heard easily[4].

III. METHODS

The design of the research instrument is used as recording process of the heart sound signal.

The steps of the research are:

1. Design of instruments such as chest piece, microphone condenser, filter, and pre-amplifier.
2. Display of graphics visual from the heart sound signal.
3. Recording process of the digital signal and activation of heart sound via computer speaker.
4. Data acquisition from patient with variety heart condition.
5. Separate the signal graphics become a frame block for a heart sound.
6. Extract the signal characteristics from a heart sound period using Wavelet Transformation with some processes, such as rectifying, enveloping, differentiation, and thresholding.
7. Identification process of the heart sound using backpropagation neural network.

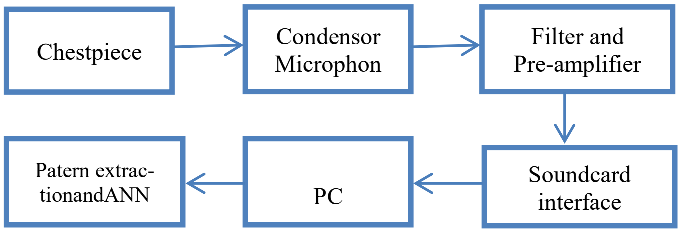

Fig. 3. Diagram block of the digital stethoscope design

The data acquisition process starts from the chest piece sensor placed at the patient's auscultation point. When the chest piece sensor is affixed, the sound or the heart noise vibrates the chest piece sensor, creating acoustic wave pressure propagating up to the rubber tube. Condenser microphones mounted on the ends of the rubber hoses are also covered by the acoustic waves. Sound waves coming into the microphone vibrate this diaphragm component. The diaphragm is placed in front of a disc and the arrangement of this element is formed capacitor. High low sounds coming into the microphone will cause variations from inside the space between the diaphragm and the backplate. This occurs because of the diaphragm movement relative to the backplate as a result of the pressure on the diaphragm. From the movement, an electrical signal will be generated which then goes to the filter. After the signal is filtered, the signal will be forwarded to the amplifier section. This amplifier circuit is a microphone pre-amplifier circuit that serves to amplify the input signal coming from the microphone before entering the laptop soundcard.

Research sample for heart that has murmur in patient in dr. Kariadi hospital. While for normal heart samples can be obtained from all respondents who heart normal. The type and number of samples for the heart that has murmurs depends on the patient's murmur patient in dr. Kariadi hospital. Each respondent will be recorded heart sound using a digital stethoscope. Recording will be done at all points auscultation, either on the respondent who have or not have murmurs.

In this study, heartbeat data acquisition was conducted for 18 seconds and produced 144000 data every 1 time the data retrieval process. Each recorded signal is captured / recorded one beat at 4 beats and the data size is equalized by data by using the command in the program

IV. RESULT AND DISCUSSION

In this research, it is used low pass filter with frequency cut off 940 Hz, according to the heart sound frequency between 20 – 940 Hz. The process after filter, the signal will pass to pre-amplifier unit. The pre-amplifier unit function is to amplify input signal from microphone before to enter computer soundcard. The testing is gotten the signal response graphics can be seen at figure 4.

4.1. Wavelet Transformation

Process of characteristics extraction for each the heart sound signal is done with some processes, such as rectifying, enveloping, differentiation, and thresholding. The process of wavelet transformation is done with convolution of signal with filter data. In this process, the input signal pass to two filters complementer (low-pass H and high-pass G) and down sampling with delete the second data, so that get coefficient approximation of c A

a. Rectifying

In rectifying process, the result of the heart sound signal is displayed in wave shape and be taken the absolute number. The process is occurred in order to get no negative data so that next process is easy. The result of rectifying process is showed at figure 5.

b. Enveloping

The enveloping process is process to get top data number from output of rectifying process, or another word, this process will take outer unit from the heart sound signal which recorded from output of rectifying process. This process uses wavelet transformation. The input signal is decomposed using the daubechies wavelet method. This research used db3 and db6 with each wavelet process using 7 and 10 decomposition levels.

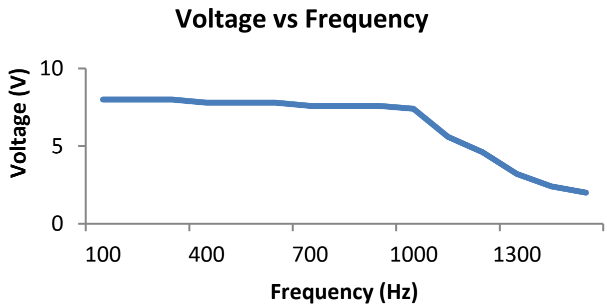

Fig. 4. The graph of signal response in low pass filter frequency

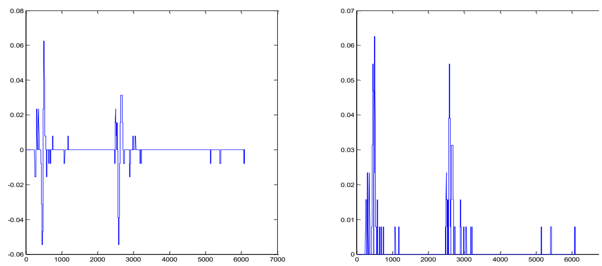

Fig. 5. Before and After Rectifying Process at Sound Graph of Normal Heart Sound

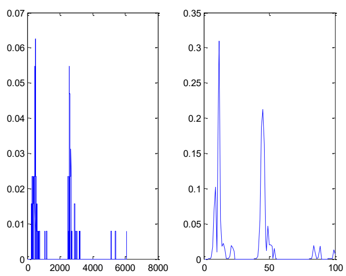

Fig. 6. The Enveloping Process

c. Differentiation

The differentiation proses will be looked for the steep lines from each output enveloping data with calculate gradients position at Fig.7.

d. Thresholding

The thresholding process is to more feature of specifics characteristics from input signal with give threshold number. This research was used threshold number of 0,15 at Fig.8. The output of this process is the feature of signal

4.2. Network Architecture

The artificial neural network is design using backpropagation method. The network layers include layers of input, hidden, and output. With variation of neuron number in hidden layer with two layers of the hidden unit, also usage logsig method as the activation function. The epoch adjust 15000 and error target is 0,001. The results of the neural network can be showed at table I.

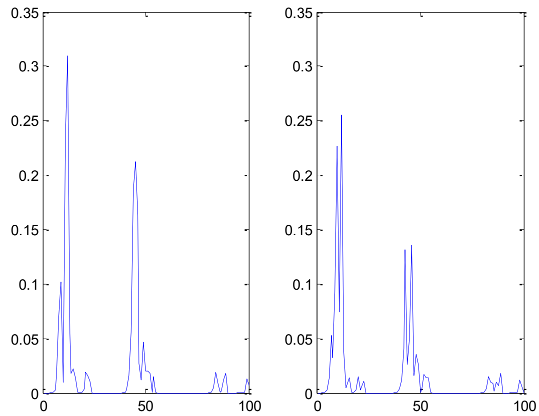

Fig. 7. The Differentiation Process

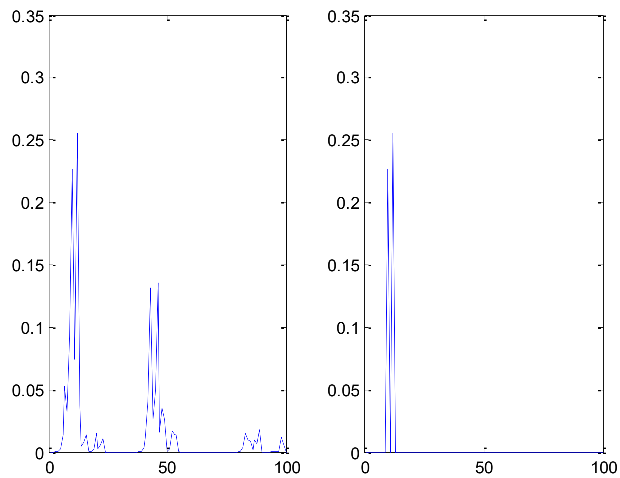

Fig. 8. Graphics of thresholding output

TABLE I. RESULT OF NEURAL NETWORK WITH 2 HIDDEN LAYER

Wavelet Type	Decom-position Level	Number of neuron	Time (s)	Training Accuration (%)	Testing Accuration (%)
Db3	7	100 (layer1)	125	88,04	39,29
		50 (l layer2)			
Db3	7	75 (layer1)	144	89,13	42,86
		75 (layer 2)			
Db3	7	50 (l layer1)	103	89,13	46,43
		100 (layer 2)			
Db6	7	100 (l layer1)	111	86,96	42,86
		50 (layer 2)			
Db6	7	75 (layer1)	116	86,96	46,43
		75 (layer 2)			
Db6	7	50 (layer 1)	115	85,87	57,14
		100 (layer 2)			
Db3	10	100 (layer1)	89	96,74	75
		50 (layer 2)			
Db3	10	75 (layer 1)	96	96,74	82,14
		75 (layer 2)			
Db3	10	50 (layer1)	93	96,74	75
		100(layer 2)			
Db6	10	100(layer 1)	101	93,48	78,57
		50(layer 2)			
Db6	10	75 (layer1)	116	96,74	75
		75 (layer 2)			
Db6	10	50(layer 1)	132	98,91	78,57
		100 (layer 2)			

TABLE II. RESULT OF TESTING ACCURATION

Heart Condition	Number of testing data	Correct data	Accuration (%)
Aorta regurgitation	4	4	100
Tricuspid regurgitation	4	4	100
Mitral stenosis	4	3	75
Mitral regurgitation	6	5	83,3
Normal	10	7	70

From table I, the best network architecture is used at number of neuron in second layer with each layer of 75 neuron. This architect produces highest accuration, the accuration is 82,14 % and need learning time fast enough compare with another ones, time is 96 second. And wavelet type that suitable is wavelet db3 with 10 decomposition level.

From table II, we can know that the network architecture have highest accuration to identify the heart condition with murmur aorta regurgitation and trikuspidregurgitation, of 100 %, then mitral regurgitation with accuration of 83,3 %, mitral stenosis with accuration of 75 % and lowest accuration for normal heart with accuration of 70 %.

V. CONCLUSIONS

The research have been developed instrumentation of digital stethoscope which can identify heart condition's patient. The instrument accuration is 82,14 %. Types of heart condition's patients are aorta regurgitation, tricuspidregurgitation, mitral stenosis, mitral regurgitation, and normal. Highest accurations are identifications of aorta regurgitation and tricuspidregurgitation with accurations of 100 %. However, lowest accuration is normal with accuration 70 %.

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