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Portable heart valve disease screening device using electronic stethoscope

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ABSTRACT

Heart sound analysis has been a popular topic of studies since a few decades ago. Most of the studies are done in PC platform since embedding the complex algorithm into a simple small device such as microcontroller board seems to be very difficult due to limited processing speed and memory. This study classifies normal and abnormal heart sound signal from four categories of Heart Valve Disease. An automated system that consists of segmentation, feature extraction and classification of the heart sound signal is developed in PC and hardware platforms. A multimedia board completed with a single board computer, audio codec and graphic LCD is used to make a portable heart valve disease screening device with electronic stethoscope as the input for the system. Both system recorded 96.3% specificity. However, the portable device has only 77.78% sensitivity and 87.04% accuracy compared to PC platform that have sensitivity and accuracy of more than 90%.

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1. INTRODUCTION

Heart disease is a general term for a variety of different diseases affecting the heart. Heart disease is a type of cardiovascular diseases (CVDs) which is the number one cause of death globally [1]. The same scenario happens in Malaysia. Statistics provided by Malaysia Ministry of Health (MOH) claimed that the first principal cause of death in MoH hospital is cardiovascular disease (including heart disease) with the percentage of 22.62% [2]. Therefore, the study of normal and pathological heart behavior became an active research area. In particular, the study of the shape and motion of the heart is important because they are very much affecting the heart sound signal. Many heart diseases are strongly correlated to these two factors [3].

Advanced imaging techniques such as Electrocardiogram (EKG/ECG), Echocardiograph (ECHO), Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) can provide more direct accurate evidence of heart disease better than heart auscultation. However, it is not suitable for use in rural areas, in homecare and generally in primary healthcare set-ups since it is very expensive, large in size and operational complex [4]. Hence, heart sound auscultation technique has remained as the major tools for early screening of heart disease. However, the technique is very subjective and very hard to acquire. Different auscultator might describe the heart sound differently because the sound especially low murmurs are very hard to be heard even with the assists of electronic stethoscope [5]. Despite the importance of auscultation, trainees are not adequately trained in their training program to master the skill of auscultation [6].

In the last three decades, many research activities were conducted concerning automated and semi-automated heart sound diagnosis. The researches were concentrated at three major tasks which are segmentation of the heart sound, feature extraction and classification of heart sound using artificial intelligence system. Heart auscultation and diagnosis are quite complicated, depending not only on the heart sound but also on other factors such as the acquisition method and patient condition [7].

The application of conventional and advanced digital signal processing techniques to the analysis of heart sounds requires computer-based capabilities, necessitating the use of relatively powerful processors, which are found in desktop or laptop computers. This is because the processing involves complex mathematical algorithm that can only easily be solved using dedicated function, toolbox or library provided by other simulator software such as MATLAB and LabVIEW. The system requires high processing speed of processor and high memory size for data storage and calculation. Hence the need of a robust and reliable analysis of heart sounds is not only justified but highly desirable [8]. Developing a small portable device in screening and diagnosing heart sound signal are going to be very difficult due to the far gap between personal computer or laptop and current processing microcontroller unit.

In this study, a less complex technique is introduced in screening heart sound signal captured from an electronic stethoscope so that it is possible to embed the algorithm in a portable microcontroller unit. A complete multimedia board is used in this study to develop the portable screening device. The board is completed with Single Board Computer (SBC) as the processing unit, audio Encoder and Decoder (CODEC) for amplifying, recording and playing purposes and Liquid Crystal Display (LCD) to show the output of the processing.

The complete screening code which consists of segmentation, feature extraction and classification of the heart sound signals is embedded into the single board computer. An artificial intelligence system is used in this study to classify normal and abnormal heart sound signals as well as classify the abnormal heart sound signals into four common categories of heart sound from Heart Valve Disease. Efficiency of the system in term of specificity, sensitivity and accuracy in both platforms are discussed in this paper.

2. RESEARCH METHODOLOGY

Heart Valve Disease is a condition where one or more valves in a heart is not functioning properly. Although it is uncommon in high-income countries such as the United States, it remains an important cause of morbidity and mortality in low-income and middle-income countries. Through statistic, from the time of initial US Food and Drug Administration approval in late 2011 through 2014, more than 26 000 transcatheter aortic valve replacements for calcific aortic stenosis were performed at 348 centers in 48 states [1].

2.1. Heart Valve Disease and Heart Sound Recordings

Heart valve disease is chosen in this study because the disease caused the heart to have murmurs with different sounds, shapes and frequencies. Stenosis and Regurgitation problems are always affecting the heart valves. There are cases where one or more valves affected by both problems. So there will be multiple types of heart valve disease that make the classification of the heart sound signal is very difficult [5]. That is why the scope is limited with two heart valves which having regurgitation or stenosis problems. The study will be limited to the following classification of heart conditions:

a) Normal heart sounds (N)
b) Aortic Regurgitation (AR)
c) Aortic Stenosis (AS)
d) Mitral Regurgitation (MR)
e) Mitral Stenosis (MS)

54 sets of recording of normal and abnormal heart sound signal from the four categories of heart valve disease are used in this study. These data are manually collected from Hospital Tuanku Fauziah at Perlis, Malaysia. Some data are obtained from a few trusted medical, medical university and sthethoscope company websites such as Texas Heart Institute, University of Washington, eGeneral Medical, Thinklab Stethoscope Community and The Cardiac Exam [9-13]. However, the heart sound signals taken from these websites are observed and selected so that ideal or artificial heart sound and murmur signals are not taken. Only original signals recorded from patients are taken. Table 1 shows the number of heart sound recordings in each category of normal and abnormal heart sound.

2.2. Heart Sound Analysis

In general, the study consists of three main tasks, which are segmentation, feature extraction and classification of heart sound signals. Raw data or the heart sound signal is automatically segmented into two cycles samples since it is believed that each signal carries similar information. This segmentation is done based on a method proposed by Liang, Lukkarinen and Hartimo from Helsinki University of Technology, Finland [14]. A pattern recognition (peak interval) technique are implemented to determine the cycles. The technique includes detecting significant peaks of first and second heart sound (S1 and S2), determining peak interval and interval consistency level as well as detecting missing peaks and removing unwanted peaks (motion artifact). 83.38% of 1089 heart sound samples is successfully segmented into cycles by using this method [15].

Table 1. Heart Sound Recordings

Category	Type of input signal	No of input signals
Normal	Normal	27
Abnormal	Aortic Regurgitation	7
	Aortic Stenosis	8
	Mitral Regurgitation	9
	Mitral Stenosis	3
	Total	54

Feature extraction is done to find differences of each sample (the two cycles sample) of different category. Power spectrum of the sample is obtained to get the frequency features of sample using (1) and (2). Cross-correlation between the power spectrum sample and power spectrum of reference sample (an average of 100 normal heart sound samples) is then determine using (3). It is found that each normal and abnormalities of heart valve disease give different plot pattern [16]. The plot pattern is then downsampled to 50 values using averaging technique before it can be trained and tested by the classifier.

$$DFT, X(k) = \frac{1}{N}\sum_{n=0}^{N-1} x(j)e^{-j\left(\frac{2\pi kn}{N}\right)} \quad (1)$$

$$Power\ Spectrum, P_X = \frac{(X) \times conj(X))}{N} \quad (2)$$

$$Cross\ Correlation, r_{P_r P_y}(k) = \frac{1}{N+1}\sum_{n=0}^{N} P_r(n) \times P_X(n-k), \quad (3)$$
$$= \frac{1}{N+1}\sum_{n=0}^{N} P_X(n) \times P_r(n-k),$$
$$k = 0, \pm 1, \pm 2, ..$$

The classifier used in this study is feed forward Multi-Layer Perceptron (MLP) network. A hierarchical technique of classification was used to classify normal and abnormal heart sound signal first before the detected abnormal signal are classified to their category of AR, AS, MR and MS. The network structure is sketched as in Figure 1. The network used 50 input neurons for 50 cross-correlation values of a sample and 5 output neurons for 5 categories of heart sound signals. Using an output neuron for a category will make the training process easier. This is because the network only has to produce output valued 1 to the corresponding neuron and 0 to the others [17].

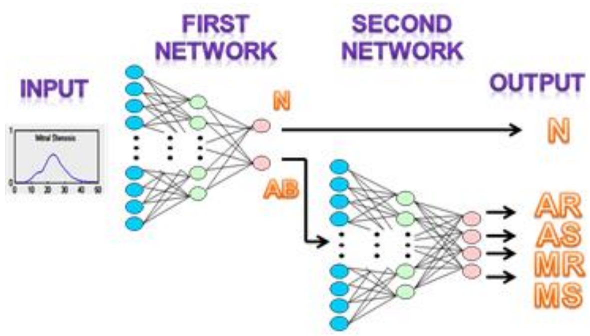

Figure 1. Classification of 5 categories of heart sound signal using hierarchical MLP network

2.3. Portable Screening Device

It is a complex task to design embedded system for heart sound screening system. The design activities involved the resolution of intense conflict and compromise among the desired features. In designing the system, many aspects should be considered such as requirements of designing the products, product's efficiency, safety, costs and competition in current market. Ulrich and Eppinger [17] propose five aspects to produce a good quality of a product design which are product quality, product cost, development cost and time as well as enhanced development capability. Kutz [18] suggests that the development of a biomedical product should starts with goal defined, proper planning, developed user needs, product specifications, concept development and evaluation, system design, detail design, rollout and lastly process overview.

The fully automated heart valve disease screening device is designed using a complete multimedia board with an electronic stethoscope as its input. The captured heart sound signal is first handled by the audio CODEC with that has programmable amplifier features before it can be processed by the single board computer. The processing done are automated segmentation, feature extraction and classification of the heart sound signal. Heart sound waveform (Phonocardiogram) and classification output are displayed on the graphic LCD. The recorded heart sound also can be played back using speaker or headphone. Figure 2 shows the block diagram of the portable system.

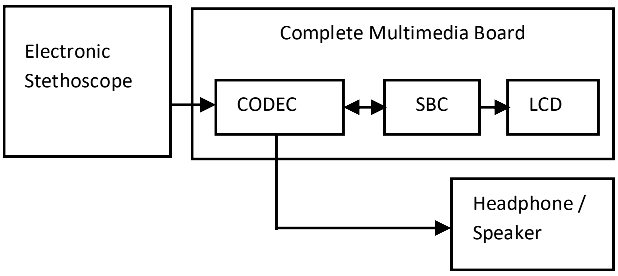

Figure 2. Block diagram of the portable device

2.3.1 Electronic Stethoscope

In this study, a good electronic stethoscope is used from Welch Allyn Inc. The selected model is 5079-405 Welch Allyn Master Elite Plus Electronic Stethoscope, see Figure 3. This electronic stethoscope can be connected to the audio-in jack of the multimedia board as the audio input source. This stethoscope can also be connected to PC, has 200 hours battery life, adjustable ear-piece and a safety cut-off of 95 dB. It also has volume control and two mode settings for heart and lung sounds. Unlike other electronic stethoscopes, Welch Allyn electronic stethoscope uses piezoelectric sensors instead of microphones in the chestpiece of the stethoscope to eliminate the interference of ambient noise. More recently, ambient noise filtering has become available in electronic stethoscopes, with 3M's Littmann 3000 and Thinklabs ds32a offering methods for eliminating ambient noise.

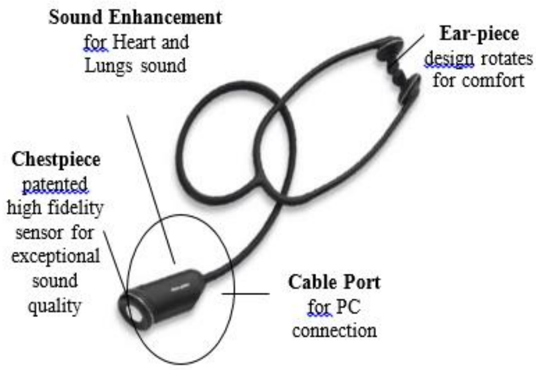

Figure 3. Welch allyn master elite plus electronic stethoscope

2.3.2 Multimedia Board

A complete multimedia board used in this study is called VC21PC1 Portable Computing Cog, Figure 4. It is provided by Virtual Cogs Embedded System Incorporation. It is a complete multimedia platform for the single board computer. It consists of removable Li-ion battery with charger jack, i.MX21 controlled power switch, 16:9 Color TFT LCD with 480x272 pixel resolution, touch screen interface for LCD, mini-SD card interface, two mini-joysticks (digital), two shoulder buttons and six other general-purpose buttons, audio CODEC with 16, 20, 24, or 32 bit 97-dB stereo playback and mono record up to 48ksps, on-board microphone, stereo amplifier and speakers, audio-in jack and audio-out jack.

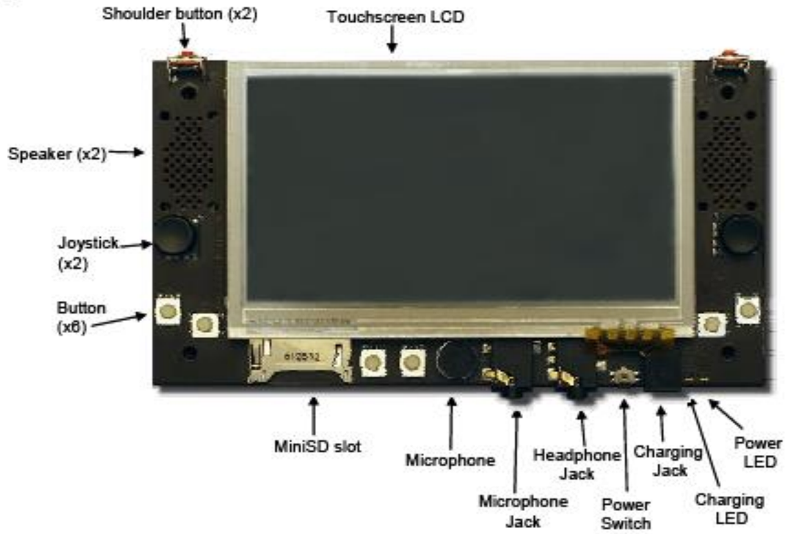

Figure 4. VC21 multimedia computing cogs

The portable board is originally designed for gaming purposes. Hence, it has many buttons including joysticks as well as good audio and graphic features. All these features are perfect for the portable heart valve disease screening device. The audio input from electronic stethoscope can be connected to the audio-in jack which is controlled by the audio CODEC. With this CODEC, heart sound can be easily stored and played back by connecting external speaker or headphone to the audio-out jack. SBC unit is responsible in handling the processing that includes segmentation, feature extraction and classification. Classification output and the heart sound signal itself can be displayed on the onboard graphic LCD.

2.3.3 Single Board Computer (SBC)

Current technologies of semiconductor have enabled such process done digitally using microcontroller, digital signal processor (DSP) or RISC (Reduced Instruction Set Computing) chips instead of using a personal computer, laptop or desktop. There are also mobile application set developed with embedded operating system such as Personal Digital Assistance (PDA). However, in this study we are using a single board computer, which is a complete computer board built on a single circuit board, with microprocessor, memory, input/output (I/O) and other features required of a functional computer. An SBC is usually a simple, portable and low cost designed board compared to a PC system. It can be programmed to the required tasks because the processor's performance is compatible for the designed screening system.

The SBC used in this study is VCMX212, Figure 5. The board is compatible to the multimedia board of VC21. The VCMX212 SBC is chosen because it is a self-contained computer, small size (50 mm x 44 mm, half-size of a business card) and uses minimal power to operate which is very suitable to make a portable device. The VCMX212 SBC uses a Freescale i.MX21 266 MHz ARM9 processor with many internal peripherals. The i.MX21 processor is connected to 64 MB of 133 MHz SDRAM (Synchronous Dynamic Random Access Memory). The board also contains 16MB of NOR FLASH which is used to store bootloader and operating system.

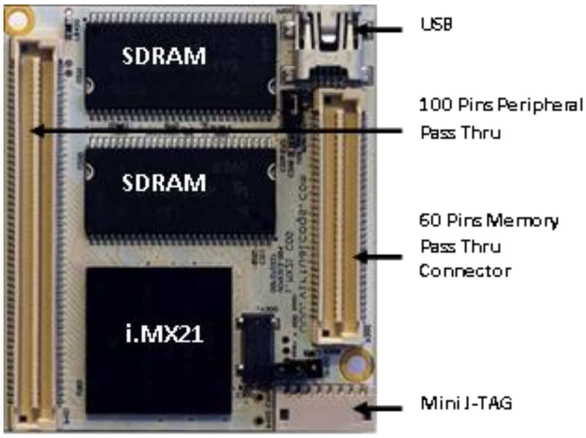

Figure 5. VCMX212 SBC

2.3.4 Encoder and Decoder (CODEC)

CODEC is used in this study to compresses and decompresses a digital audio signal obtained from the electronic stethoscope. A codec encodes a data stream from the heart sound signal for transmission, storage or encryption and decodes it to playback the heart sound signal. This will save the memory usage of the single board computer. The CODEC is also used to obtain an acquired sampling rate for signal processing.

The VC21PC1 uses the TSC2100 as its audio CODEC. This chip also contains a touchscreen processor making ideal for the VC21PC1. The TSC2100 registers (including ADC values) are accessed through an SPI interface. The audio codec sends and receives data to the i.MX21 using the I2S protocol. An internal PLL generates a 44.1 kHz or 48k Hz clock signal from the 12 MHz oscillator on the VC21PC1. Internal dividers can be programmed to provide standard sampling rates of 8 kHz, 11.025 kHz, 12 kHz, 16 kHz, 22.05 kHz, 24 kHz, 32 kHz, 44.1 kHz and 48 kHz. In this study, the minimal rate, 8 kHz, is chose to minimize the number of data calculated during segmenting and extracting the features of the heart sound signal. 8 kHz sampling rate is already follows the Nyquist rule of sampling since the heart sound signal frequency is normally less than 1 kHz. However, calculation of DFT algorithm really took long time even for 1 sec of heart sound signal. So for signal processing done in embedded system, the signal is downsampled to 4 kHz only.

An internal Programmable Gain Amplifier (PGA) provides up to 59.5 dB of gain in steps of 0.5 dB. The gain is adjusted for only 15 dB which is found suitable for thin, fat, hairy and non-hairy subjects. If the heart sound signal is already loud and it is amplified at more than 15dB, the loud signal will be automatically cut-off by the CODEC. An Automatic Gain Control (AGC) block can control the PGA gain and uses a number of programmable settings such as target gain, maximum gain, attack and decay time constants, and noise threshold.

2.3.5 Graphical User Interface (GUI) Design

The embedded screening system is design with three major tasks, which are segmentation, feature extraction and classification of the heart sound signal. The work flow of the embedded system is simple. A heart sound signal firstly needs to be recorded for 8 seconds before the system can segment it to at most 3 two-cycles samples. Each sample is being analyzed and classified to its classes. A graphical user interface (GUI) for the system is designed as in Figure 6. Phonocardiogram window is designed to view the heart sound signal, a black command window to show the ongoing process and results as well as several buttons to control the embedded system. The screening system can simply be completed with two buttons only, ‘Record’ and ‘Analyse’ buttons.

The device can record the heart sound signal from the stethoscope and play it back using headphone or external speaker. This allows user to understand each type of heart sound better. In the recording process, the system require user to record the heart sounds in 10 seconds time before analysis can be done. However, the system needs only 8 seconds of recording signal to be analyzed. The first two seconds is a delay made before recording to give the user time to stabilize the chestpiece position. After recording is done, a red plot of heart sound signal at Phonocardiogram window will be automatically plotted.

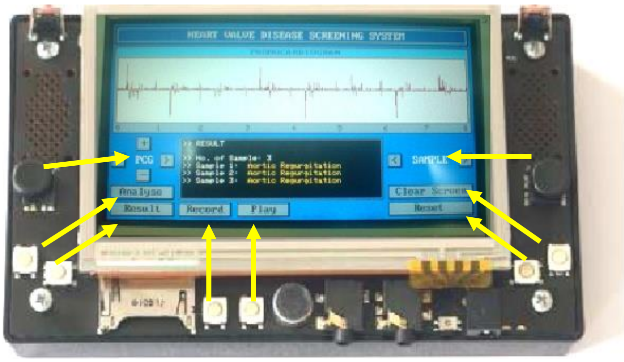

Figure 6. GUI Designed for the portable screening device

The plot of heart sound signal is very important for the system. Cardiologists often use this plot to recognize the murmurs in order to determine the disease of the heart sound. Hence, the plot function of the heart sound signal is designed in the system GUI. The plot can be zoomed in and out based on the user needs using the left joystick. PCG buttons of '+' or '-' button is made so that user can zoom the signal in or out. '<' or '>' buttons are created to move the signal to the left or right by using the right joystick. Figure 7 shows an example of the zoomed plot of heart sound signal.

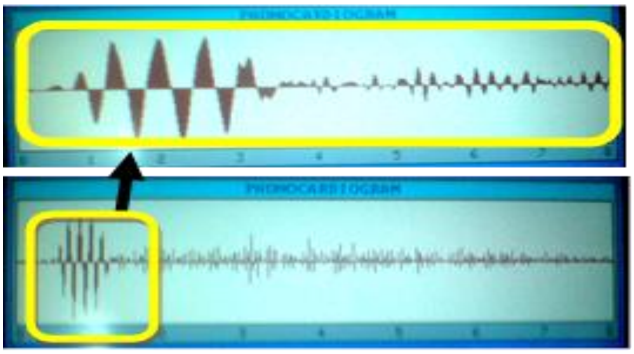

Figure 7. Plot of heart sound signal on phonocardiogram window

Analysis can only be made after the heart sound signal is recorded using the 'Analyse' button. The analysis starts with heart sound segmentation where the heart sound signal is segmented into at most 3 samples based on the cardiac cycle. This process takes around 2 seconds duration. The analysis proceeds with extracting the heart sound features. The process takes around 40 seconds duration for each sample. Finally, the classification process can be done and it will take about 2 seconds duration for each sample. After the analysis is completed, results will automatically be shown at the command window. User can always see the results as long as 'Reset' button is not pressed. If screen is cleared, results can be seen by pressing the 'Result' button.

Once the result of screening test for all segmented samples is obtained, the screening test is completed. User can review the details of the result by controlling the right joystick. Figure 8 shows the Samples windows. This window will replace the Phonocardiogram window until user is exiting the window by pressing the right joystick down. Button '<' and '>' at the right joystick is used to see the details for each sample which are:

1) The segmented heart sound signal (Sample 1, Sample 2 or Sample 3)
2) Power spectrum of the sample
3) Reference spectrum which is used in cross-correlation analysis
4) Cross-correlation plot as an input for the classifier
5) The output of the classifier whether it is Normal (N), Abnormal (AB), AR, AS, MR or MS

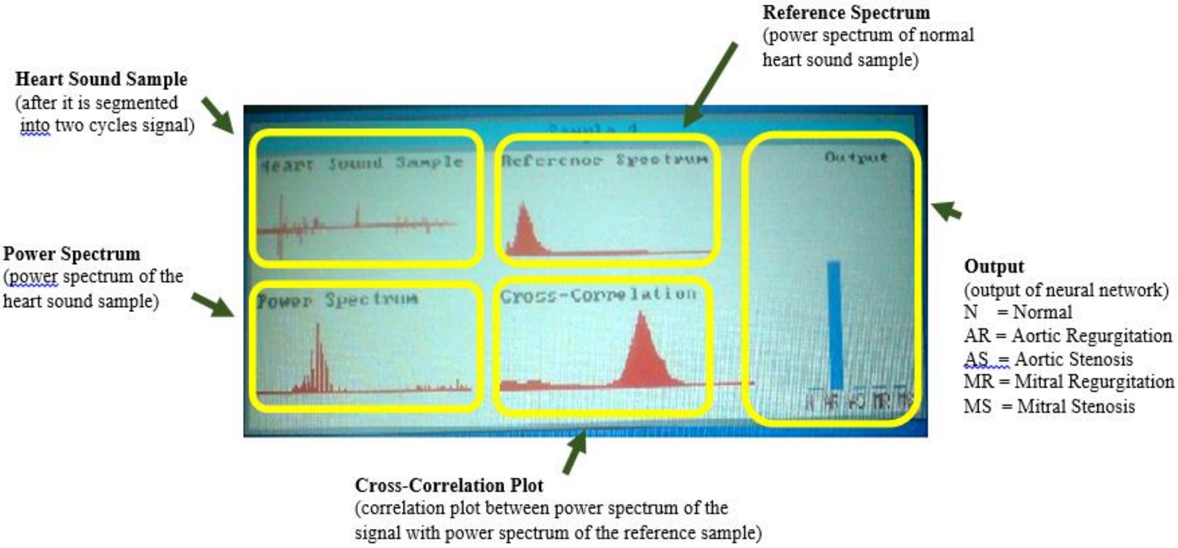

Figure 8. Detail of each segmented sample

3. RESULTS AND ANALYSIS

The output of the system is depending on the number of segmented sample obtained. If the system has segmented 3 samples from a set of recorded heart sound signal, there will be 3 outputs. Hence a decision must be made to produce only one output (Final Output) to describe the category of the tested heart sound signal. The final output is determined using majority rules. If majority of the segmented samples were classified as Normal for example, the final output will be Normal (N).

Fifty-four sets of heart sound signal are used to obtain the screening results of the complete system in both PC platform and hardware platform (VC21PC1 multimedia board). Specificity, sensitivity and accuracy of the screening system are determined to measure the system performance. Specificity of the system refers to the ability of the system to recognize the normal heart sound as normal. Sensitivity of the system refers to the ability of the system to recognize the abnormal heart sound signals as abnormal (AR, AS, MR and MS). Both sensitivity and specificity were calculated based on the final output of the tested heart sound signal. The equation used to calculate sensitivity and specificity of the system are shown in (1) and (2), respectively.

$$Specificity = \frac{True\ Negative\ (TN)}{True\ \ Negative(TN)+False\ \ Positive(FP)} \tag{4}$$

$$Sensitivity = \frac{True\ Positive\ (TP)}{True\ Positive\ (TP)+False\ Negative\ (FN)} \tag{5}$$

True Positive (TP) means that the abnormal tested heart sound signal is correctly classified as abnormal; otherwise it is False Negative (FN). True Negative (TN) means the normal tested heart sound signal is correctly classified as normal; otherwise it is False Positive (FP). Based on this information, screening accuracy is calculated as (6).

$$ScreeningAccuracy = \frac{TP+TN}{TP+TN+FP+FN} \tag{6}$$

3.1. Classification output in PC and Hardware platforms

Comparison is made between results obtained in both platforms. Even though 54 same input signal is given to both platforms, the portable device is set to have a maximum input of 8 seconds only. Hence, the number of segmented sample is different as well, which will significantly influence the final output. Larger number of segmented samples give more accurate output since majority rule is used. Table 2 shows the classification output by both platforms.

For PC platform, the result shows that 26 out of 27 set of normal heart sound signals has been successfully recognized by the system and that’s make the specificity of the system to 96.3%. For the other

27 set of heart sound signals form Abnormal category, the system has recognized 25 set of the heart sound signal as abnormal. Hence sensitivity of the system is 92.59%. Based on these results, the screening accuracy is 94.44% where 51 from 54 input signals are successfully classified to its categories.

Portable Heart Valve Screening Device shows exactly the same specificity as in the PC platform, 96.3%. For abnormal category, only 77.78% sensitivity recorded (21 out of 27 signals are correctly classified by the system). This show 87.04% accuracy, slightly below compared to the PC platform which have 94.44% accuracy. The difference is caused by limited number of segmented samples provided by the portable device. Different sampling frequency (8kHz for PC platform and 4kHz for Portable Screening Device) also affects the accuracy. This is disadvantages of the portable system but it has to be done to reduce computational time. successfully classified to its categories.

Table 2. Classification Result in PC and Hardware Platforms

Category	Input	PC Platform		Portable Device	
		TRUE	FALSE	TRUE	FALSE
Normal	N	26	1	26	1
Abnormal	AR	7	0	6	1
	AS	6	2	7	1
	MR	9	0	6	3
	MS	3	0	2	1
Total		51	3	47	7

3.2. Comparison with Other Existing Systems

There are very limited portable devices developed by researchers in screening or diagnosing various kind of heart disease or heart disorder. Others are focusing on the monitoring of heart sound signals by integrating wireless and Internet of Things (IoT) technology. Recently, Haoran Ren et. al [20] has developed a wireless sensing based of cardiac auscultation monitoring system using Bluetooth 4.0 and Android mobile apps to collect the heart sound signal and store it in cloud storage, but still, signal processing and analysis are done in PC platform.

For comparison, three similar projects (in term of device and heart disease classified) are reviewed and discussed. All of them used different processing techniques with different hardware platforms that includes PDA, DSP processor and small PC [8, [21, 22]. Table 3 shows the comparison of this project (Portable Heart Valve Disease Screening Device) with other existing system in term of heart sound signals used, methodology and results.

Brusco and Nazeran [8] have developed an Intelligent PDA-based Wearable Digital Phonocardiograph which classifies 5 types of heart sound signal. The project is the most similar project with this project where same types of heart sound signals were used. They have used normalized average Shannon energy for segmentation and obtained 79.32%. For feature extraction, they have used wavelet transform in vector of powers formation with two sub-bands for normal and abnormal components in the heart sound signal. They had obtained 47.62% classification accuracy of 5 categories of heart sound signal by using MLP network in their embedded platform of PDA Pocket PC. For the case of classification into 3 categories, the achieved accuracy was 71.43%.

Ari, Sharma and Saha [20] only use a Digital Signal Processing (DSP) processor with an LED to indicate normal and abnormal heart sound outputs. The specificity of their system is very good, 96.67% even with ten difference types of heart sound signals were used from 60 different subjects. However, no percentages of abnormal category’s classification is stated. The algorithm used to extract and classify the heart sound features are rate extraction and threshold crossing percentage.

Intelligent Diagnosis System developed by Cheng, Kai, Hung and Chun [21] had used an embedded board of Nano-ITX which is similar to small PC with great processing performance of 1.2 GHz and 120 GB storage. They have used 60ms sliding window method on 125 samples from 40 subjects to extract the feature of heart sound signal before applying 64-bit FFT to the features to feed the MLP classifier. The accuracy achieved is 72.5% of normal and abnormal classification. The accuracy obtained is not as good as Ari, Sharma and Saha (2006).

Table 3. Comparison of Heart Valve Disease Screening Device with Other Existing Device

	Intelligent PDA-based Wearable Digital Phonocardiograph [8]	Heart Valve Disorder Detection System [21]	Intelligent Diagnosis System [22]	Heart Valve Disease Screening System (current study)
Developer	Brusco and Nazeran	Ari, Sharma and Saha	Cheng, Kai, Hung and Chun	Suboh, Mashor, Hadi, Saad and Mohamed
Year & Place of Development	2005, University of Texas	2006, Indian Institute of Technology	2007, National Taiwan University	Current projects
Heart Sound Used	5 (N, AR, AS, MR & MS)	10 (N, AR, AS, MR, MS, MVP, TR, TS, PR & PS)	-	5 (N, AR, AS, MR & MS)
No. of Heart Sound Classified	5 (N, AR, AS, MR & MS)	2 (normal and abnormal)	2 (normal and abnormal)	5 (N, AR, AS, MR & MS)
Segmentation Method	normalized average Shannon energy	-	-	Time Properties
Feature Extraction Method	Wavelet transform	Rate Extraction	FFT of Sliding Window	Cross-correlation Analysis
Classification Method	ANN: MLP	Threshold Crossing Percentage	ANN: MLP	ANN: Hierarchical MLP
Recording Devices	*Escope* Electronic Stethoscope	Accoustic Stethoscope with Piezo-Microphone	Electronic Stethoscope (SP-S2)	Welch Allyn Master Elite Stethoscope
Embedded System	PDA Pocket PC iPAQ *hp5550 (400MHz, 128MB RAM, 48MB ROM)*	DSP Processor of TMS320C6711 *(150 MHz, 64K bytes internal SRAM)*	Small PC of Nano-ITX *(1.2GHz, 1GB RAM, 120GB storage)*	SBC of VC21PC1 *(266MHz, 64MB RAM, 16MB memory)*
No. of Subjects	42	60	40	54
No. of Samples	263	360	125	162
Specificity	-	96.67%	72.5%	94.44%
Accuracy (Normal and Heart Valve Disease Classification)	47.62 % for 5 classification categories 71.43% for 3 classification categories	-	-	87.04%

4. CONCLUSION

A portable heart valve disease screening device is successfully developed on the PC platform and on a complete multimedia board of VC21PC1. The board is powered by 266MHz, 64MB RAM, 16MB memory of a single board computer (VCMX212). An electronics stethoscope is used as the input device to record the heart sound. The device is small and portable, easy to use and have a wide LCD to shows the heart sound waveform and classification output. Recorded heart sound signal can be clearly played back by connecting it to external speakers or headphone and can be used for auscultation training purposes.

A complete heart sound analysis is done in both PC platform and is hardware platform. Both records exactly the same specificity. 96.3%, which is almost good as Ari, Sharma and Saha works. However, sensitivity and accuracy in PC platform are much higher compared to the hardware platform due to limited recording time and different sampling rate. Even though, accuracy on the hardware platform is still promising, 87.04% compared to other existing projects.

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