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A SUPPORT VECTOR SIGNAL PROCESSING MODEL FOR HEART MURMUR BASED CLASSIFICATION WITH HARDWARE IMPLEMENTATION

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ABSTRACT

A prototype of a simple and non-invasive system for remotely monitoring the heart sounds (improved phonocardiography) that includes heart auscultation monitoring /hearing is discussed. The frequency and component analysis are integrated with classification schemes to identify the normal and pathological heart sound patterns. The monitoring of the heart sound is an area of research and if interpreted effectively can be useful for clinical interpretation along with cardiac diagnosis like ECG, Phonocardiography and other similar techniques. In this research, frequency, spatial, dimensional data reduction analysis/combined with popular classifier schemes to identify normal and pathological heart sound. The objective of the research work is to provide interpretation, which is of great use to the medical experts. In our research work, the audio part happening in the cardiac cycle is extracted. Hardware implementation with linux kernel is also presented.

Keywords: *Mermur Recognition, Vector Signal Processing, Heart Sound, Hardware Implementation.*

1. INTRODUCTION

The psychoacoustics is the science in which the human perception of sounds is quantified. Each of the sound characteristics has a corresponding perceptual variable. The aim is to derive a quantitative model that matches the results of auditory experiments that can be contrived and to supplement heart murmur sounds, their analysis provided to cardiac specialist. The cardiac cycle has two phases,

a) Diastolic Phase, and
b) Systolic Phase

The audible sound is produced due to the opening and closing of the heart values, which is going to pump the blood. So, flow of blood in the heart causes the contraction and expansion of heart muscles. Basically, this work, measure the acoustic feature of the cardiac cycle. In this research, treating murmurs as audio signals and using these audio signals to extract useful features is explored. So that it can be used as indicators of abnormal sounds. The abnormal sound is going to be a direct measure/ representative of the valve problems or sounds made by artificial pace makers. So, once the behavior of the murmur is properly under stood it will be very useful for community to directly mapping with valve problems. The murmurs are going to be very useful measure particularly in identifying gallop sounds. In the Heart sound 1st & 2nd is easily detected by a stethoscope, call as "LUB" (1st Heart sound) & "DUB" (2nd Heart sound). The activities are taking place in the Aortic Value (AV) that opens and closes. The pressure associated with it is shown in Figure 1.

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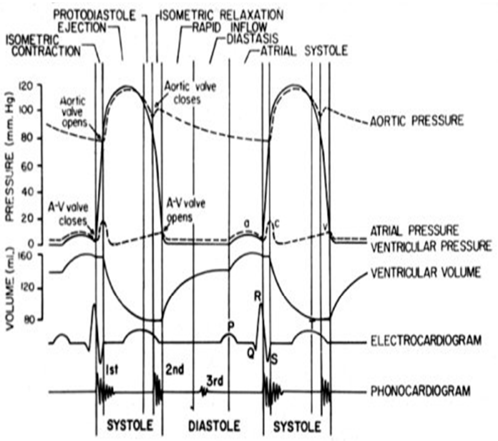

Fig. 1 Aortic Value Activities

1.1 Causes Of Heart Sound

The flapping of the valves leaflets is not enough to generate a heart sound. The causes of the 1st heart sound (during systole) the AV valves are closed and blood tries to flow back to the atrium bulging the AV valves. But, the taut chordae tendinae stop the back bulging and causes the blood to flow forward. This will cause vibration of the valves, blood and the walls of the ventricles which is presented as the 1st heart sound.

1.2 Difference Between 1st And 2nd Heart Sounds

The first sound lasts longer because the AV valves are less taut than the semilunar valves which will enable them to vibrate for longer time. The second heart sound has higher frequency since the semilunar valves are more taut and the increased elastic coefficient of the taut arteries provides the principle vibrations of the second heart sound**.** The third and fourth heart sound can be mapped with electrical heart sound (the ECG). In addition, at the micro scale, there exists murmur, which is not evident in the ECG. Therefore, audio interpretation and analysis is significant in identifying the cardiac cycle better by analyzing these murmurs. To hear the sound,

(i) *Tricuspid valve*: is best heard at the R_t half the lower end of the sternum body.

(ii) *Mitral valve*: is best heard at the Apex of the heart (Lt 5th intercostal space at the mid-clavicular line).

(iii) *Pulmonary valves*: is best heard at the L_t medial 2nd intercostal space.

(iv) *Aortic valve*: is best heard in the medial 2nd R_t inetercostal space.

1.3 Uniquenses In Murmur Detection

Today we have powerful ultrasound system that can give accurate details of cardiac anomalies. Newer technologies are available to do intravascular ultrasound, 3D echo cardiogram and intra cardiac echo. But will any or all of these devices replace the stethoscope? A stethoscope can asses heart function and any obstruction and leakage of its values. It can predict and follow up the effects of treatment of heart failure. Most birth defects involving the heart can be diagnosed fairly well by the use of the stethoscope, besides ECGS, X-rays and Echocardiogram.

Doctors can detect cardiac complications such as papillary muscle rupture and ventricular septal rupture with the stethoscope .It could help accurately evaluate valve functions and the functioning of artificial valves. It could help access lungs and lungs diseases. The ultra sound is of no use in most of these cases. An anaesthetist with a stethoscope is used to know if a patients endotracheal tube is in the wind pipe or in the food pipe and can check if belonging both lungs is proper. An ultrasound device just cannot replace a stethoscope. The most important part of the stethoscope is the medical professional's brain situated between two ear pieces. It gives immense confidence to both patient and the doctor. It will serve the purpose for which it is invented by great clinician with great clinical knowledge.

2. PREVIOUS WORK

Kwak. C and Kwon.O-W [2012] proposed a new algorithm for cardiac disorder classification by heart sound signals that consists of three steps: segmentation, likelihood computation and classification. Kiran Kumari Patil, et al., [2011] proposed the phonocardiography of recording and interpreting of heart sounds using latest digital technology has significantly helped us to understand and interpret the complex heart sounds and in particular valvular diseases. Guremre Guraksin and Huran Uguz [2011] proposed classification of heart sound based on the least squares support vector machine. The heart sound signals in numerical format were separated into sub-bands through discrete wavelet transform is studied in this work. Kiran

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Kumari Patil, et al., [2010] presented the theoretical foundations, psychoacoustic principles and derive the mathematical models for the psychoacoustic features such as loudness, sharpness, intensity, strength, roughness, tonality etc. for a set of heart sounds and murmurs. M.S. Obiadt, [2008] presented the applications of the spectrogram, Wigner distribution and wavelet transform analysis methods to the phonocardiogram (PCG) signals. P.Stein [1981] proposed a physical and physiological basis for the interpretation of cardiac auscultation, evaluations based primarily on the second sound and ejection murmurs. C. Shub [2003] proposed to compare cardiac physical examination with echocardiography for evaluating systolic murmurs. Adrian D.C. Chan, et al., [2008] presented an evaluation of a new biometric based on electrocardiogram (ECG) waveforms. ECG data were collected from 50 subjects during three data-recording sessions on different days using a simple user interface, where subjects held two electrodes on the pads of their thumbs using their thumb and index fingers. Lee, Y.M. [2002] presented a prototype of a simple and noninvasive system to remotely monitor the real-time heart rate of patients or individuals based on phonocardiography, the study of heart sounds has been developed. L. Zhang, et al., [2010] presented on the study of detecting low frequency vibrations from the human chest and correlate them to cardiac conditions using new devices and techniques, custom software, and the SVM classification technique. P. Wang, et al., [2011] presented a combination of Mel-frequency Cepstral coefficient (MFCC) and hidden Markov model (HMM) to efficiently extract the features for pre-processed heart sound cycles for the purpose of classification.

3. BEHAVIOUR OF AORTIC VALVE

Energy level associated will change depending on the position of the probes, where the probes are placed also play a role. The recorded energy level also varies, that gives the requirement to have special processing of the cardiac cycle analysis. The basic four valves that are studied include A.V, P.V, B.V, T.V, the lowest energy, where AV violet is highest energy level.

3.1 Heart murmur caused by Valvular Lesions

The murmurs of the aortic stenosis are:

narrowing of the aorta increases resistance to ejection of blood. As a result severe turbulence of blood at the root of the aorta cause intense vibration resulting in a loud systemic murmur (after 1st heart sound).

3.2 Murmur of the aortic regurgitation

In aortic regurgitation, the aortic valves don't close which is essential during diastole, therefore in aortic regurgitation blood backflow into the ventricles causing diastolic murmurs (after the 2nd heart sound).

3.3 Murmurs of Mitral Stenosis

In mitral stenosis,
Narrowing of the mitral valve increase resistance of blood flow to the ventricles. After 1/3 of diastole when enough blood fills the ventricle, it causes vibration which occurs as diastolic murmur. The murmur is often not heard but could be felt as thrill at the apex of the heart.

3.4 Murmurs of Mitral regurgitation

In Mitral regurgitation, Mitral valves are unable to close which is essential during systole → therefore blood flows back to the atrium causing a systolic murmur.

- Like electronic device FET, MOS, etc.,
- As a result vibration effects will take place, in turn generates systemic murmur at a loud micro scale. It is not audible (usually negligible by stethoscope / ECG). This loud systemic murmur at the micro scale.

3.5 Machinery murmur of Patent Ductus Arteriosis

In PDA blood flows from the aorta to the pulmonary artery resulting in a murmur during systole and diastole. The murmurs during systole are much denser than in diastole because the pressure in aorta is higher during systole than diastole. The fourth heart sound occurs in late diastole and before first heart sound produced by vibrations in expanding ventricles when atria contract that is rarely heard in a normal heart. The results are from the reduced distensibility of one or both ventricles, the stiff ventricles, the force of atrial contraction increases, causing sharp movement of the ventricular wall.

- Heart sound classification and analysis play an important role in the auscultative diagnosis.

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- Human response variables are not linearly proportional to the value of the corresponding stimulus variables.

Table 1: Diagnosing disease from heart murmurs

Heart sound murmurs	Heart valve abnormalities	Clinical importance
S_1	Isovolumetric contraction	Mitral and tricuspid valves closure
S_2	Isovolumetric relaxation	Aortic and pulmonary valves closure
S_3	Early ventricular filling	Normal in children; in adults, associated with ventricular dilation (e.g., ventricular systolic failure)
S_4	Atrial contraction	Associated with stiff, low compliant ventricle (e.g., ventricular hypertrophy)

- Signal Classified: Sys, Tricu, Ejection, Diastolic Gallop when heart beat is high,

3.6 Requirements in analysis of Murmurs

The requirements in analysis of Murmurs are,

(i) Location information
(ii) Radiation
(iii) Timing features(systolic, diastolic, continuous)
(iv) Intensity (1-6 systolic, 1-4 diastolic)
(v) Pitch (high frequency Vs low frequency)
(vi) Quality

3.7 Benign Murmurs

(i) Pulmonary flow (LUSB, soft)
(ii) Peripheral pulmonary branch stenosis (axillae, back)
(iii) Neonatal Still's murmur (LLSB, "vibratory" or "musical")
(iv) Venous hum (continuous, under either clavicle but R more often than L)

Table: 2

Murmur	Age	Timing	Location	Character
Pulmonary Flow	Newborns	early systole	LUSB	Medium to low pitch
PPBS	Newborns	Mid-systole	R or L mid sternal, radiates to back and axillae	Med-high frequency
Still's	Newborns, >50% 2 - 7yrs.	Early-mid systole, short murmur	LUSB	Musical, vibratory, buzzing
Venous Hum	> 50% young children	Continuous, louder in diastole	Infra-clavicular	Blowing, low frequency

3.8 Red flags

(i) Diastolic murmurs (only venous hum is OK)
(ii) Continuous murmurs (PDA should be gone by 48 hours)
(iii) Loud murmurs $\pm$ thrills
(iv) Symptoms, especially cyanosis.

3.9 Pathologic murmur

(i) Caused by abnormal anatomy or communications and the turbulent blood flow through them.
(ii) Typically from problems with valves (pulmonic stenosis, aortic stenosis), narrowings (coarctation) or holes where they shouldn't be (VSD, ASD, PDA)

3.10 FUNCTION OF THE VALVES

(i) Valves prevent the back flow of blood.
(ii) The papillary muscles will not close the valves, but will maintain the closure of the valves.
(iii) The importance of chordea tendinei attached to the papillary muscles is because during ventricular contraction the ventricle size decreases and the papillary muscle must contract to shorten the chordea tendinei to prevent leakage of valves.

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The PCG Signal acquired for different heart murmur is shown in fig. 2

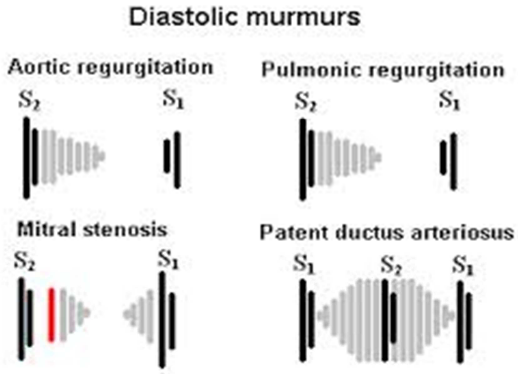

Fig. 2 PCG Signals For Heart Sound

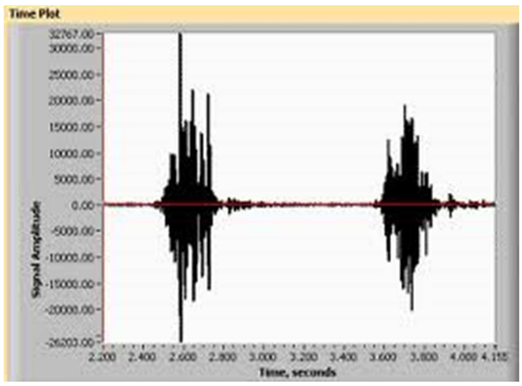

Fig. 3 Signal Magnitude For Time Domain Signals

In Figure 4, 3000 samples with 50 samples per segment are considered for different cases in time domain.

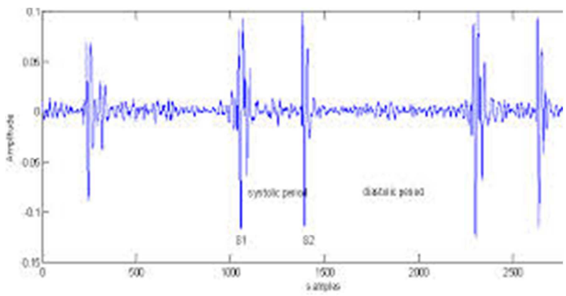

Fig. 4 Samples In Time Domain For Murmur-I

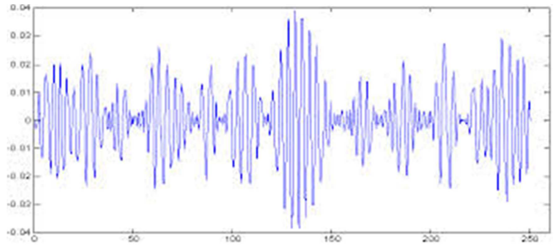

Fig. 5 Samples in time domain murmur -II

4. GALLOP SAMPLE

A short segment impulse like behavior, where segment beep is high (a murmur reflected in gallop) and input signal and murmur signal is acquired represents Gallop from ECG; it is difficult to study the Gallop behaviors of subject. ECG signal can reflect some abnormalities but directly cannot interpret the Gallop behavior (shown in Figure 6).

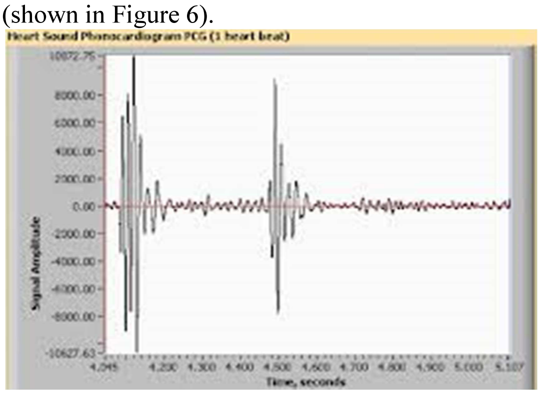

Fig. 6 Gallop Samples

The S_1, soft murmurs is rarely heard in normal instrument and is not reflected in ECG also. ECG does not reflect the systolic behavior in child where as in the time slot based murmur analysis it is reflected. (S1 & S2 is as shown in Figure 7.)

Fig. 7 Reflection Of S_1 And S_2 For Murmur Analysis

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5. HARDWARE IMPLEMENTATION RESULTS

The hardware implementation of unsupervised network that support vector classifiers used in this work as the main objective as an easily integrating with moble phone (e.g. murmurs fatter to mobile phone). To give a clinical analysis and introduce hardware implementation suited to built FL2440 board processor in Linux is chosen . The user space is written in python with four stages,

- Tool chain linking
- Boot loader creation
- Kernel customization
- User space programme with GNU

It uses arm tool chain and boot loader with network capability. Built in compiler already exist in tool chains facility that can be easily interpreted of a compilation part. It has in built in hardware and log file creation The user space consists of a program for removing noise, a program to extract feature from cleaned murmur signal and data reduction higher dimension to lower dimension .

6. RESULTS AND DISCUSSION

The Linux hardware output is generated with GNU core & Linux kernel and python user space. It acquires heart murmur and the heart murmur signal is extracted. Five type of heart murmur are given to test the algorithms namely systolic phase, MT, AC and soft murmur (occur in child).

Fig. 8 Hardware interface with FL2440

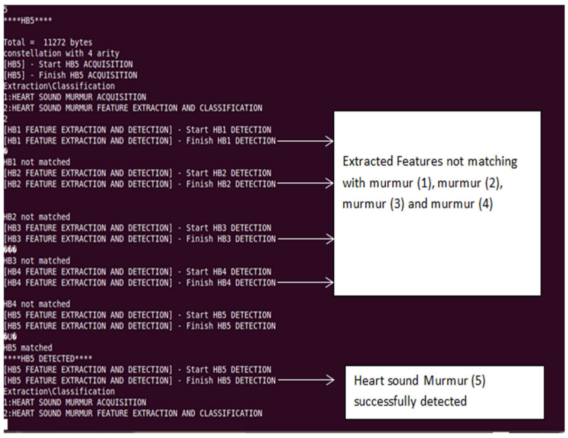

Fig. 9 Hardware interface Output

The SVM classifier performance is plotted for different set of SNR for different observation of samples. Five signals are tested ,

(i) Diastolic rumble signal,
(ii) Systolic aronic stenosis,
(iii) Mitral regurgitation ,
(iv) Ejection murmur, and
(v) Diastolic Ventricular gallop

A practical application of this research work is in the improved detection of foetal murmur/ heart beat (during pregnancy) by observing increased number of samples and usng the proposed algorithm. In this application, SNR is a limitation since mother heartbeat is a strong noise and foetal heart beat is weak signal

6.1 Inference from Result

The performance of the system based on the extracted higher-order statistical feature is verified for SNR level 0, 1 and 5 dB. The results are tabulated in following tables

Classification accuracy at 0 dB SNR

116/(116+133)

Modulation Type	HM1	HM2	HM3	PPV
HM1	116	0	133	46.59
HM2	0	400	0	100
HM3	284	0	267	48.46
Accuracy (%)	29	100	66.75	65.25

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Classification accuracy at 1 dB SNR

Modulation Type	HM1	HM2	HM3	PPV
HM1	213	0	133	61.56
HM2	0	400	0	100.00
HM3	187	0	267	58.81
Accuracy (%)	53.25	100	66.75	73.33

(53.25+100+66.75)/3

Classification accuracy at 5 dB SNR

Modulation Type	HM1	HM2	HM3	PPV
HM1	399	0	133	75.00
HM2	0	400	0	100.00
HM3	1	0	267	99.63
Accuracy (%)	99.75	100	66.75	88.83

Note: HM1 - Diastolic Aortic Regurgitation
HM2 - Diastolic Pulmonic Regurgitation
HM3 – Systolic Aortic Stenosis

7. CONCLUSION

The proposed algorithms are best tested in the present work by applying it to

(i) Nonlinear
(ii) Highly correlated, and
(iii) Low frequency signal processing application with high order statistics.

In this context heart sound murmurs are chosen as input for processing to specifically focus with an application and the metrics are chosen to suit a realtime application. This research works reports,

(i) The signal analysis of heart sounds and murmurs.
(ii) Extraction of an optimal set of nonlinear features.
(iii) Classifying innocent murmurs from murmurs caused by various heart valve pathologies.
(iv) Experimental studies include Diastolic Aortic Regurgitation, Diastolic Pulmonic Regurgitation, Systolic Aortic Stenosis.

REFERENCES:

[1] Kwak. C, Kwon.O-w, "Cardiac disorder classification by heart sound signals using murmur likelihood and hidden Markov model state likelihood" vol 6 issue 4 pp 326-334 IET Journals , 2012.
[2] Kiran Kumari Patil, Dr.B.S. Nagbhushan and Dr. Vijaya Kumar B.P, "Psychoacoustic models For heart sounds",- in Proceedings of Advances in Networks & Communications, communications in computer & Information Science, Vol.132, Part 2, pp. 555-556, 2011.
[3] Guremre Guraksin and Huran Uguz, "Classification of heart sound based on the least squares support vector machine", International Journal of Innovative computing Information and Control, ICIC Internationla Vol.7 number 12 December 2011 ICIC international 2011 ISSN 1349-4198, pp7131-7144.
[4] Kiran Kumari Patil, Dr. B.S. Nagbhushan and Dr. Vijaya Kumar B.P, "An efficient modeling technique for heart sounds and murmurs", published in International Journal of Scientific & Engineering Research, Vol. 2(2), 2010.
[5] M.S. Obiadt, "Phonocardiogram signal analysis: techniques and performance comparison", in journal of medical engineering and technology", Vol.17 (6), pp. 221-232, 2008.
[6] P.Stein, "A physical and physiological basis for the interpretation of cardiac auscultation: evaluations based primarily on the second sound and ejection murmurs", Futura Publishing Company Rabiner, L. and Juang, B (1993), "Fundamentals of speech recognition, Prentice-Hall, 1981.
[7] C. Shub, "Echocardiography or auscultation? How to evaluate systolic murmurs", Can Fam Physician", Vol (49), pp. 163–167, 2003.
[8] Adrian D.C. Chan, Mohyeldin M. Hamdy, Armin Badre, and Vesal Badee, "Wavelet Distance Measure for Person Identification Using Electrocardiograms", IEEE transactions on instrumentation and measurement, vol. 57, no.2, February 2008.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

[9] Lee, Y.M., Moghavvemi, M, "Remote heart rate monitoring system based on phonocardiography", Research and Development, SCOReD, pp. 823-832, 2002.
[10] L.Zhang, J.Kwok and B-L.Lu(Eds) "A Support Vector Machine (SVM) classification approach to Heart Murmur detection ", ISSN 2010 part LNCS 6064, pp 52-59, 2010 Springer-verlag Berlin Heidelberg 2007.
[11] P. Wang, C.S. Lim, S. Chauhan, Foo, J.Y.A., and Anantharaman, V., "Phonocardiographic Signal Analysis Using a Modified Hidden Markov Model. Ann. Biomedical Eng., Vol.35 (3).pp. 367- 364, 2011.