Algorithm to Calculate Heart Efficiency and to Predict the Valve'smuscularity

Tarundeep Singh Kalsi[1], Krupal Shah[2]

[1]Vellore Institute of Technology, School of Biosciences and Technology

[2]Vellore Institute of Technology, School of Biosciences and Technology

Abstract: ***Human heart is the most important organ in the human body, as time passes the valves of the heart starts to gather cholesterol and degrade it in many aspects. Many daily problems like high B.P, mitral valve regurgitation, very high cholesterol leading to cardiac arrest. If the person is aware of the heart situation before hand he or she can actually get treated in the hospital for the condition faced. Hence the idea is to make a simple heart beat analyzer, which can calculate the efficiency of heart and also predict the efficiency in coming years using markov's model, in probability theory, a Markov model is a stochastic model used to model randomly changing systems where it is assumed that future states depend only on the present state and not on the sequence of events that preceded it. Hence the model depends on the present values/data irrespective of past values. The whole system starts with the input from a sensor and ends up with the calculations being done in the simulation software's. This system will help people predict the future of what is the present situation of heart and if same situation goes on what can be the future of such a condition, disease can be predicted.***

Keywords: Markov model, heart efficiency, beat analyzer, calculator, mitral valve.

1. Introduction

Mitral regurgitation is a disorder in which the mitral valve on the left side of the heart does not close properly. Mitral valve regurgitation means leaking from a valve that does not close all the way.It is the most common type of heart valve disorder. Blood that flows between different chambers of your heart must flow through a valve. The valve between the two chambers on the left side of your heart is called the mitral valve. When the mitral valve doesn't close all the way, blood flows backward into the upper heart chamber (atrium) from the lower chamber as it contracts. This cuts down on the amount of blood that flows to the rest of the body. As a result, the heart may try to pump harder. This may lead to congestive heart failure. Mitral regurgitation may begin suddenly. This often occurs after a heart attack. When the regurgitation does not go away, it becomes long-term (chronic). The symptoms of this situation can be many and this include, a heart attack damages the muscles around the mitral valve, the cords that attach the muscle to the valve break, an infection of the valve destroys part of the valve and cases of very high cholesterol in the valve which causes leakage of the blood due to excess blood pressure. Analysis of heart sound is important to generate a report to help the patient know the patterns of his or her heart sounds.

Human heart is muscular in nature and with the due course of time it becomes weak due to many reasons. Hence to predict future of the individual with the present data is the challenge. Hence a system which will work to take present data of heart sounds, calculate the parameters discussed above and then this data will be used to evaluate the future of the condition of heart, precisely calculating the efficiency of the valves. The system made will be user friendly with fewer inputs from the user. Primary heart sounds: First heart sound (S1), this is the LUBB sound created by the heart and this sound is because of the sudden block of the reverse blood flow during the artrioventricular valve(tricuspid and mitral or bicuspid valve) closure at the beginning of systole. Second heart sound (S2), this is the DUBB sound created by the heart and this is because of the sudden block of reverse blood flow during the semilunar valve closure at the end of ventricular systole and beginning of ventricular diastole.

The physiological model of the human heart can be modified into a mechanical model which comprise of mechanical valves, pumps, chambers and pipes to imitate the same human heart model. The analysis of sound is the most important aspect of this research. In many disorders the sound of heart varies, it can be heard by a doctor by using stethoscope. And if the stethoscope can simulate a rough estimate of the condition of the human heart after 25-30 years then it can be next level of intelligent systems which can predict precisely the situation of the human heart. And help the patients analyze and get treated in a stipulated time frame. Hence a software which can perform such predictions can be integrated either in stethoscope or can be burned in the PC and used by the doctors and patients by themselves.

2. Literature Review

When there is feeling associated to impaired breathing in patients with a heart or lung diseases, the amount or the quantity needed to eliminate the metabolically produced CO_2 is said to be ventricular efficiency. In other words we can define it as analytic expressions or the ratio for ventricular stroke work (SW) to ventricular O_2 consumption, this ratio is called as ventricular efficiency, in terms of ventricular contractile properties and arterial after loading properties. This all can be derived of mathematical observations and equations and on the basis, on the recent data from the literature review.

Mathematically, the relationship between ventilation ($\dot{V}E$) and CO_2 output can be determined by the arterial CO_2 pressure and the physiologic dead space or the other word for it is tidal volume ratio. Three methods were compared for expressing this relationship in the research carried out:

The $\dot{V}E$ versus CO2 output slope below the ventilator compensation point, commonly used by cardiologists for estimating the severity of heart failure. The $\dot{V}E$/CO2 output ratio at the anaerobic threshold, commonly used by pulmonologists; The lowest $\dot{V}E$/CO2 output ratio during exercise, the latter parameter not previously reported. The lowest $\dot{V}E$/CO2 output ratio was insignificantly different from the ratio at the anaerobic threshold, less variable than that for the slope relationship, and unaffected by the site and gas exchange measurement systems[21].

The mathematical calculations carried out by fellow researcher out there in world has carried out in this way which states that the ventricular properties were quantified by Ees and V0. Ventricular after load was represented by the effective arterial elastance (Ea), a parameter that is dependent on aortic input impedance parameters. Model analysis indicated that SW is maximum when Ea = Ees, the after load that results in the greatest efficiency is always less than that which provides the maximum SW, the SW and efficiency of a weak heart are more sensitive to changes in after load than in a strong heart, and there is a sigmoidal relation between ventricular efficiency and end-diastolic volume that reaches its maximum at volumes outside the upper limit of the physiological range [18].

Once digitized, this data is processed and analyzed to determine timing relationships between the three signals, frequency (or pitch) of sounds, and dependence or non-dependence of sounds on ECG and respiratory phase. One of the technic used by researcher was the user of the apparatus inputs the place of detection and the maneuver being performed. The user inputs the number of beats and the frames per second to display. Fast Fourier transformed and signal averaged data are displayed, and phase sensitive and non-phase sensitive sounds are extracted. A lesion fitting algorithm suggests diagnoses and possible further maneuvers to perform. The data obtained is compared to a historical patient data [17].

A cardiac rhythm management system includes a heart sound detector providing for detection of the third heart sounds (S3). An implantable sensor such as an accelerometer or a microphone senses an acoustic signal indicative heart sounds including the second heart sounds (S2) and S3. The heart sound detector detects occurrences of S2 and starts S3 detection windows each after a predetermined delay after a detected occurrence of S2. The occurrences of S3 are then detected from the acoustic signal within the S3 detection windows [11].

A cardiac rhythm management system provides for the trending of a third heart sound (S3) index. The S3 index is a ratio, or an estimate of the ratio, of the number of S3 beats to the number of all heart beats, where the S3 beats are each a heartbeat during which an occurrence of S3 is detected. An implantable sensor such as an accelerometer or a microphone senses an acoustic signal indicative heart sounds including S3. An S3 detector detects occurrences of S3 from the acoustic signal. A heart sound processing system trends the S3 index on a periodic basis to allow continuous monitoring of the S3 activity level, which is indicative of conditions related to heart failure [8].

A system receives signals indicative of cardiopulmonary conditions sensed by a plurality of sensors and provides for monitoring and automated differential diagnosis of the cardiopulmonary conditions based on the signals. Cardiogenic pulmonary edema is detected based on one or more signals sensed by implantable sensors. If the cardiogenic pulmonary edema is not detected, obstructive pulmonary disease and restrictive pulmonary disease are each detected based on a forced vital capacity (FVC) parameter and a forced expiratory volume (FEV) parameter measured from a respiratory signal sensed by an implantable or non-implantable sensor [7].

Hidden Markov models: This paper is concerned with algorithms for prediction of discrete sequences over a finite alphabet, using variable order Markov models. The class of such algorithms is large and in principle includes any lossless compression algorithm. We focus on six prominent prediction algorithms, including Context Tree Weighting (CTW), Prediction by Partial Match (PPM) and Probabilistic Suffix Trees (PSTs). We discuss the properties of these algorithms and compare their performance using real life sequences from three domains: proteins, English text and music pieces. The comparison is made with respect to prediction quality as measured by the average log-loss. We also compare classification algorithms based on these predictors with respect to a number of large protein classification tasks. Our results indicate that a \decomposed" CTW (a variant of the CTW algorithm) and PPM outperform all other algorithms in sequence prediction tasks. Somewhat surprisingly, a algorithm, which is a modification of the Lempel-Ziv compression algorithm, significantly differently outperforms all algorithms on the protein classification problems.

Prediction of a web page access:
The problem of predicting a user's behavior on a web-site has gained importance due to the rapid growth of the world-wide-web and the need to personalize and influence a user's browsing experience. Markov models and their variations have been found well suited for addressing this problem. Of the different variations or Markov models it is generally found that higher-models display high predictive accuracies. However higher order models are also extremely complicated due to their large number of states that increases their space and runtime requirements. In this paper we present different techniques for intelligently selecting parts of different order Markov models so that the resulting model has a reduced state complexity and improved prediction accuracy. We have tested our models on various datasets and have found that their performance is consistently superior to that obtained by higher-order Markov models

Problem definition: Main problem faced is the calculation of human heart's efficiency, specially the mitral valve to help detect the mitral valve regurgitation, and also to predict the future efficiency of the heart that means how much efficiency of human heart is left after a period of 25-30 years. Hence building a device with software and hardware integrated which will help detect the same and calculate efficiently without errors.

3. Methodology/ Approach

The whole project is divided in 3 main sections:
1. SENSOR
2. DATA CALCULATOR
3. DATA PREDICTOR

Sensor: The data is to be taken from the human heart, and the best possible way invented back in 1816 by René Laennec at the Necker-Enfants Malades Hospital in Paris. It is the best possible way to capture the heart sound from the chest. The sound gathered from the heart is captured by the capacitive microphone (transducer). The capacitive transducer will convert the heart beats to electric signal and this signal generated can be used as the input for the recording purpose. Now a separate hub is created to capture the signal from the heart, before storing the sample the heart sound is amplified and filtered. Filtering of the heart sound is done to remove the additional noise due to the heart murmurs and many a times due to the signal picking part through the cord from the heart. Hence the diaphragm of the stethoscope is the main part of the sensing system, when the diaphragm is placed in close proximity to the heart it vibrates, then the vibrations travel through the rubber tube which is made hollow. The hollow tubing act as an amplifier to amplify the sound waves and the output is heard at the ear piece. Now the idea is to make an electronic stethoscope in which a microphone is attached to the diaphragm. Input sound waves enter the tube strikes the microphone and gets converted to electric signal. A wire (copper) with a 3.5mm jack is soldered with the microphone to store the sample in software. The software used to store the .au format files was phonocardiograph. The heart samples were displayed using the sensor and converted into different formats to be accessible in major systems. Sensor is made with great care because it is the only part of the system which can gather a lot of noise. Hence filtering process is done in the software's made and murmurs, heart valve sounds are filtered very sharply. And the sound of heart is audible when played. The amplified sound can be used by the physician to judge the situation of the heart. But the patient cannot judge the minute changes in the heart. Hence a digital calculator should be made in which the initial values of the input are fed and the system calibrates and produces output.

Data Calculator: Data is loaded and converted in different formats. The data is used to make software which can calculate the hearts efficiency and produce digital output. The algorithm used to calculate the efficiency is explained in the following steps:
1. Load the sample in the phonocardiograph software and convert the same in .au format which can be readable in MATLAB.
2. Now a master data is prefed in the system, Master data is the signal which is used as a reference and a threshold value is set.
3. Now the data fed is used as the main comparing signal which will be compared with the other input samples.
4. 0Input sample is loaded in MATLAB; fine tuned and filtered using the frequency specific filters to remove the murmurs and sounds of heart valve closing leading to excess noise.
5. The input sample is divided with the master signal to generate a graph with only the left out values.
6. The left values are multiplied with 100 to produce an output efficiency in percentage.
7. The output produced is the percentage, which is actually the efficiency of the heart valve.
8. The output is displayed on the main screen. For the same system GUI software will be made which will actually help the interface and user-system relation much more easy.

Through using GUI's the person can just load the sample and click on specific buttons (according to the will and wish, what is actually to be calculated?). Upon clicking the buttons the output is generated, output generated is both graphical and mathematical. Numerical value can be used to judge the present efficiency of the heart and its valves.

Data Predictor

Markov's model is the best model in probabilistic world which is used in many areas where prediction is required, as in weather forecast.Of the different variations or Markov models it is generally found that higher order Markov models display high predictive accuracies. However higher order models are also extremely complicated due to their large number of states that increases their space and runtime requirements [13].Some parameters are decided, then the states are defined and based on the states the transition matrix is made. The transition matrix is known as transition probability matrix TPM (i,j), The probability of performing action 'j' when the process state is 'i'[15].The state-space of the Markov model depends on the number of previous actions used in predicting thenext action. The simplest Markov model predicts the next action by only looking at the last action performedby the user. In this model, also known as the first-order Markov model, each action that can be performed bya user corresponds to a state in the model. The model takes only the present values to calculate the future efficiency of the heart valve. It actually depicts how much efficiency of the heart is left after a period of say 25-30 years. This can help the patient know the present as well as future status of the heart, its valves and heart walls. The predictor can help patient predict future diseases he or she can encounter. Depending upon the efficiency the chances of mitral valve regurgitation cases can be plotted easily. If the efficiency of the valve to pump all the blood without leak to the other chamber is degraded then the chances of mitral valve getting damaged is maximum. Best part of markov's model is that it only takes present values and does not depend on past values. Hence the input values (present), can be used as the basic medium on which the model will work. The data stored will be transferred to the mathematical markov's model and the model will simulate the same with the use of software's. The markov's model is used in gambling, weather prediction, birth death process etc.

4. Figures/ Calculations

A Sample of some heart beats were collected from a source of 20-30 people and recorded in a sample of few seconds. The sample was then loaded in MATLAB and the same algorithm to calculate the possible efficiency of the heart is allowed to run. The results are shown in the images shown below: The two samples (a and b) are the samples of the same individual and the other graph depict the efficiency. If the peaks are totally overlapping then a value 0 will be generated which means 100 percent efficient. And hence the same algorithm will be used to calculate the efficiency. The numeric value will be multiplied with 100 to calculate the percentage and the same will be displayed on the display.

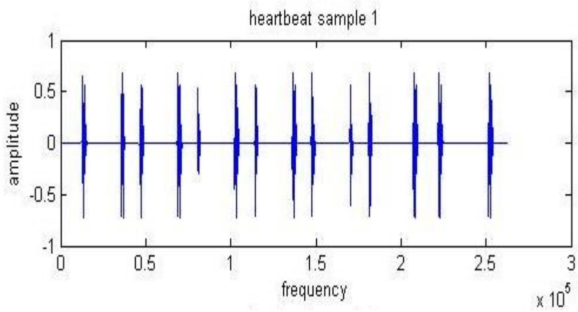

Figure 1: First heart sample of the individual.

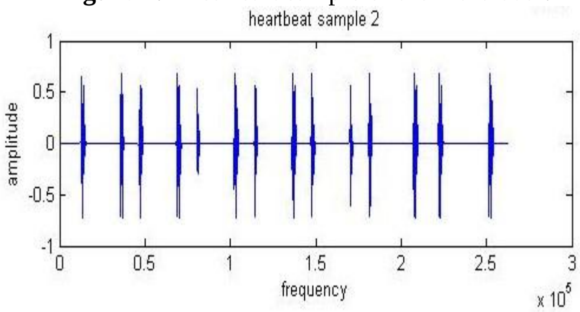

Figure 2: Second heart sample of the individual, same time period as the first one.

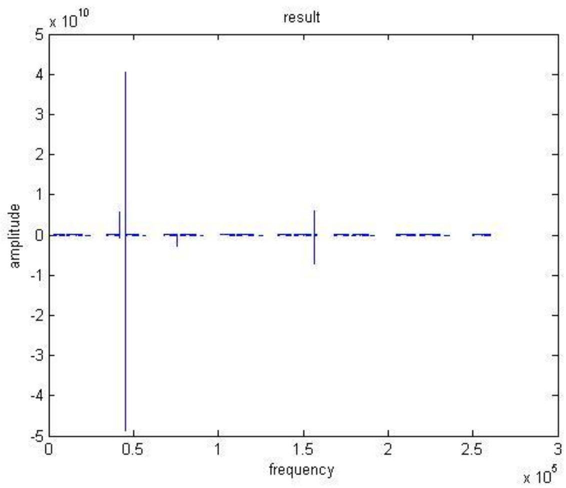

Figure 3: After running the algorithm the results obtained, The same gaps show perfect overlap (100%), Small peaks depict that some part of the peak amplitude was left out, pointing towards the valves of heart.

Markov's model

The Markov's model, uses several states and then actions upon the same states taken, e can take multiple states as an input to predict the data or if sufficient take only 1 state. In our experiment we took 3 states as the basis for calculation: the states taken were the length of the signal, the frequency variation of the signal, and the peak amplitudes of the beats of the heart. Now the transition of one state to another is a probabilistic relation between each state. Suppose the above states are denoted as w1, w2, w3. And let the output state be w0. Now the probability depends upon the transition of states from one level to another. For example if w1 state transit to state w2 then let the probability of such action be a12, similarly from w2 to w3,probability be a23 and so on. Now the probability of one state to transit to the output w0 is 'b'. Now the main idea of the experiment is to predict the future of the given states. A constant is to be used depending upon the values of the states and its attributes. The calculative formulas of Markov's model are shown below:

The task is to compute, given the parameters of the model, the probability of a particular output sequence. This requires summation over all possible state sequences:
The probability of observing a sequence:
Y = y(0), y(1), y (2) …….. y (L-1).
Where L is the length of the signal

$$P(Y) = \sum_{x=0}^{L-1} P(Y|X)P(X)$$

Where the sum runs over all possible hidden-node sequences
X = x (0), x (1), x (2) …….. x (L-1).
Above equation sets are the equations which take into consideration only the state (length), hence taking multiple states and then in order to calculate the probability for next2 years will be calculated as the:

The probability of two the result sample (figure 3), let it be denoted as R:
R = K1 [sample 1/ sample 2]^{25}= Will give the left out efficiency of the heart and K1 is the constant value which will be multiplied to the sample output to predict the future of the valves.

5. Result

The system designed will work to collect data, calculate efficiency and then predict the values of the valve efficiency left after a stipulated time frame. The experimentation of system's data calculator is done and the results obtained are successful in calculating the efficiency of heart.

6. Conclusion

This paper conclude that the efficiency of any part of human organ can be calculated and the future values can be extruded out using model's with multiple states and parameters to predict what is the future of such organs if they keep on going in the same state. System also conclude to help the user govern its hearts well functionality, any small disorder can be a major reason for death in future time frames.

7. Future scope

Such intelligent system are the future of tomorrows technology. Prediction of future and accurate prediction of future are two main points a healthy system which can predict the future accurately is what is needed in health care. A system which can calculate the functionality of an organ is much required the user is pre planned to know when his or her organs can fail in the coming years. Can help the cases of kidney failure, heart valve failures, heart muscles failure and acute chronic cases of organ degradations. The future scope of such an idea do not allow the patient to go to hospital and get checkups he or she can sit at home and complete the whole process of prediction within minutes.

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Author Profile

Tarundeep Singh Kalsi is student of Vellore Institute of technology, Doing engineering in biomedical, He is an innovator, aim to become a successful business man. He had won awards in competitions for innovating new equipments for healthcare, and many other areas. His area of interest includes signal processing, and system designing. He is a quick learner, hard worker and like to imagine, learn new things, and grab knowledge. Aim and vision of life is to make equipments which will enhance healthcare and make life easy.

Krupal Shah, currently pursuing B.Tech biomedical engineering from VIT University is interested in the application of Microsystems technology and signal processing. His research interests lie primarily in the areas of Smart Sensors and signal processing and artificial organs. His parallel area of interest lies in the application of Biomedical Instrumentation and image processing. His strength of a strong academic background, sense of teamwork, integrity and ability to put in sustained quality effort consistently will help him in growing as a better person.