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NIHARIKA JHA
Department of Inter-Disciplinary Science and Technology, I2IT, Pune, India,
niharikaj_embedaug11@isqaureit.ac.in

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Atherosclerosis Detection Using Music

NIHARIKA JHA

Department of Inter-Disciplinary Science and Technology, I2IT, Pune, India
E-mail : niharikaj_embedaug11@isqaureit.ac.in

Abstract - The recent advancements in the field of embedded electronics have given birth to a number of bio-medical consumer devices which include portable blood pressure monitors and blood glucose monitors. Atherosclerosis and cardiovascular disease take a huge toll on our society. Atherosclerosis typically begins in early adolescence, and is found in major arteries, yet is asymptomatic and not detected by most diagnostic methods during life. However it does produce a noticeable change in the waveform generated by an ECG. It is known that ECG interpretation requires a qualified individual, but if the irregularities observed in the ECG signal are used to bring about audible or visual changes, it would enable a common man to diagnose his condition before it gets critical. This project aims at using irregularities in an ECG signal to induce tempo in a polyphonic music piece using the duration of the QRS complex. The amalgamation of a music player and an ECG is yet to be seen in the market. Implementation of this project will also bring forth the feasibility of such a product to see how it will benefit the patient.

Keywords - *Atherosclerosis, Electrocardiogram, ECG reading interpretation ,Power-line interference, audio tempo changing.*

I. INTRODUCTION

Coronary artery disease (CAD) affects more than 16 million people, making it the most common form of heart disease. CAD and its complications, like arrhythmia, angina pectoris, and heart attack (also called myocardial infarction), are the leading causes of death. CAD most often results from a condition known as atherosclerosis, which happens when a waxy substance forms inside the arteries that supply blood to your heart.

Major symptoms :

Atherosclerosis may be present for years without causing symptoms. This slow disease process can begin in childhood. In some people, the condition can cause symptoms by the time they reach their 30s. In others, they do not have symptoms until they reach their 50s or 60s. But, as the blockage gets worse, the slowed blood supply to the heart may begin to cause something called angina pectoris. Patients often say that angina is like a squeezing, suffocating, or burning feeling in their chest. The pain usually happens when the heart has an extra demand for blood, like during exercise or times of emotional stress.

Angina tends to start in the center of the chest but may move to your arm, neck, back, throat, or jaw. Some people say they feel numbness or a loss of sensation in their arms, shoulders, or wrists. An episode usually lasts no more than a few minutes and goes away with rest.

Diagnosis:

A baseline electrocardiogram (ECG or EKG), which records your heart's electrical activity while you sit quietly. An exercise ECG, also known as a stress test, will show how your heart responds to increasing exercise. Both tests are designed to show if your heart is not working properly, most likely due to a lack of oxygen.

An exercise thallium test, also called a nuclear stress test, which uses a radioactive substance that is injected into your bloodstream to show how blood flows through your arteries. Doctors can see if your heart muscle is damaged or dead, or if you have a serious narrowing in an artery. For people who cannot take an exercise test, medicines can be given that make your heart beat as if you were exercising.

Echocardiography, which uses sound waves to produce an image of the heart to see how it is working.

Coronary angiography, which is performed in the cardiac catheterization laboratory. After you are given medicine to relax you, dye is injected into your bloodstream to give doctors an x-ray "movie" of heart action and blood flow through your valves and arteries (called an angiogram). Doctors can see the number of blockages that you have and how serious those blockages are. Doctors often use this test to find out which treatment option may be best for you.

Positron emission tomography (PET) scanning, which uses information about the energy of certain elements in your body to show whether parts of the heart muscle are alive and working. A PET scan can also show if your heart is getting enough blood in order to keep the muscle healthy[1].

Changes brought about in an ECG rhythm:

Normal sinus rhythm

- Rhythm - Regular
- Rate - (60-100 bpm)
- QRS Duration - Normal
- P Wave - Visible before each QRS complex
- P-R Interval - Normal (<5 small Squares. Anything above and this would be 1st degree block)
- Indicates that the electrical signal is generated by the sinus node and travelling in a normal fashion in the heart.

Heart blockages occur when electrical signals that pump blood in and out of the ventricles are blocked.Heart blockages are detected by an EKG exam. There are three types of heart blockage: first, second, and third degree. First degree is less severe and third degree is the most severe. Mobitz type I and II are categorized separately, but they are forms of second degree blockage.

1. First Degree

First degree heart blockage occurs when electrical impulses are slowed as they travel down the atrium to the ventricles. First degree blockages does not exhibit symptoms, and it's more common among young, active people. Young people have more active vagus nerves, and this large heart nerve inhibits electrical activity in heart cells.

- Rhythm - Regular
- Rate - Normal
- QRS Duration - Normal
- P Wave - Ratio 1:1
- P Wave rate - Normal
- P-R Interval - Prolonged (>5 small squares)

2. Second Degree

Second degree blockage is more serious than first degree. This condition is caused when electrical activity is slowed so badly that they do not reach the ends of the ventricles. This inhibits proper pumping of blood. Second degree blockage is further divided into categories.

Mobitz Type I

Mobitz type I is a type of second degree blockage where the electrical activity becomes weaker and weaker until the heart skips a beat. The process is continued consistently, so blood does not get pumped properly. The decreased heart rate causes tissue to lose oxygen from lower blood circulation. The main symptom of mobitz type I is dizziness. The age group at high risk of mobitz type I is the elderly, but congenital heart defects can be passed from the mother to the infant.

- Rhythm - Regularly irregular
- Rate - Normal or Slow
- QRS Duration - Normal
- P Wave - Ratio 1:1 for 2,3 or 4 cycles then 1:0.
- P Wave rate - Normal but faster than QRS rate
- P-R Interval - Progressive lengthening of P-R interval until a QRS complex is dropped

Mobitz Type II

Mobitz type II is a more serious condition where the electrical activity in the heart is irregular. In some contractions, the heart beats regularly. In other contractions, the electrical signals are blocked and the heart skips a beat. This type of condition is remedied using a pacemaker. The age group at high risk of mobitz type II is the elderly, but younger patients with heart disease also suffer from mobitz type II conditions.

- Rhythm - Regular
- Rate - Normal or Slow
- QRS Duration - Prolonged
- P Wave - Ratio 2:1, 3:1
- P Wave rate - Normal but faster than QRS rate
- P-R Interval - Normal or prolonged but constant

3. Third Degree

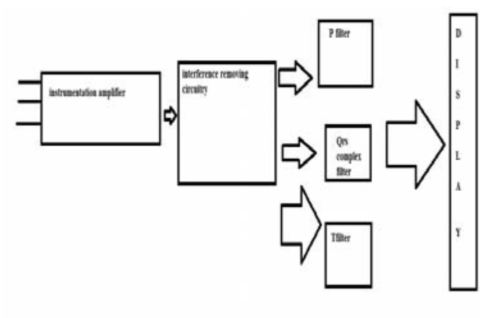
Third degree heart blockage is when whole parts of the ventricles do not receive electrical impulses. This causes irregular heart beats and improper blood regulation. Third degree heart blockage can lead to cardiac arrest if not treated immediately. Some doctors insert temporary pacemakers until a permanent one can be placed.[2].

- Rhythm - Regular
- Rate - Slow
- QRS Duration - Prolonged
- P Wave - Unrelated
- P Wave rate - Normal but faster than QRS rate

- P-R Interval - Variation
- Complete AV block. No atrial impulses pass through the atrioventricular node and the ventricles generate their own rhythm.[3].

As seen above the nature of the ECG waveforms for different kinds of heart blockages are different and hence the parameters such as QRS duration, Pwaveratio,P-R interval can be used for tempo changing to detect bloackages.

II. BLOCK DIAGRAM OF AN ECG.



This is a simplified block diagram of an ECG.

It shows that 3 leads are at least required to properly interpret an ECG signal. One lead attached to the right leg acts as the reference or the ground signal. The 3 signals are amplified by an instrumentation amplifier and sent to the filters. The band pass filters are used for separation of the three characteristic waves and these waves are now sent to the display section.

The recommended system bandwidth is between 0.05 and 150 Hz. Of great importance in ECG diagnosis is the low-frequency response of the system, because shifts in some of the low-frequency regions, e.g., the ST segment, have critical diagnosis value. While the heart rate may only have a 1-Hz fundamental frequency, the phase responses of typical analog high-pass filters are such that the system corner frequency must be much smaller than the 3-dB corner frequency where only the amplitude response is considered. The system gain depends on the total system design. The typical ECG amplitude is ±2 mV, and if A/D conversion is used in a digital system, the enough gain to span the full range of the A/D converter is appropriate.

To first obtain an ECG the patient must be physically connected to the amplifier front end. The patient amplifier interface is formed by a special bio electrode that converts the ionic current flow of the body to the electron flow of the metallic wire. These electrodes typically rely on a chemical paste or gel with a high ionic concentration. This acts as the transducer at the tissue-electrode interface. For short-term applications, silver-coated suction electrodes or "sticky" metallic foil electrodes are used. Long-termrecordings, such as for the monitored patient, require a stable electrode-tissue interface, and specialadhesive tape material surrounds the gel and an Ag+/A g+Cl– electrode.

At any given time, the patient may be connected to a variety of devices, e.g., respirator, blood pressure monitor, temporary pacemaker, etc., some of which will invade the body and provide a low-resistance pathway to the heart. It is essential that the device not act as a current source and inject the patient with enough current to stimulate the heart and cause it to fibrillate. Some bias currents are unavoidable for the system input stage, and recommendations are that these leakage currents be less than 10 µA per device. This applies to the normal setting, but if a fault condition arises whereby the patient comes in contact with the high-voltage side of the alternating current (ac) power lines, then the isolation must be adequate to prevent 10 µA of fault current as well. This mandates that the ECG reference ground not be connected physically to the low side of the ac power line or its third-wire ground. For ECG machines, the solution has typically been to AM modulate a medium frequency carrier signal (≈400 kHz) and use an isolation transformer with subsequent demodulation. Other methods of signal isolation can be used, but the primary reason for the isolation is to keep the patient from being part of the ac circuit in the case of a patient-to-power-line fault. In addition, with many devices connected in a patient monitoring situation, it is possible that ground loop currents will be generated. To obviate this potential hazard, alow-impedance ground buss is often installed in these rooms, and each device chassis will have an external ground wire connected to the buss[3].

III. ECG SIGNAL ACQUISITION:

In clinical practice the standard 12 lead ECG obtained using four limb leads and chest leads in 6 positions. The left and right arm and the left leg(I,II and III respectively) are used as reference for chest leads. The augmented limb leads known as aVR, aVL and aVF are obtained by using the exploring electrode on the limb indicated by the lead name, with reference being Wilsons central terminal. The hypothetical equilateral triangle formed by leads I,II, and III is known as Einthoven's triangle. The center of the triangle represents Wilsons central terminal. The six chest leads V1-V6 are obtained from six standardized positions on the chest.

Some standard important features of the clinical ECG are :

1) Peak to peak value about 2mV.
2) Bandwidth-.5 – 50 Hz
3) Sampling rate- 500Hz[4].

IV. REMOVAL OF ARTIFACTS:

The different kinds of interference waveforms (artifacts) added to the ECG signal during the recording are:

1) EMG related to coughing, breathing, or squirming affecting the ECG.
2) Breath, lung, or bowel sounds contaminating the heart sounds(PCG).
3) Muscle sound (VMG) interference in joint sounds (VAG).
4) Maternal ECG getting added to the fetal ECG of interest.
5) Electrical interference external to the subject and recording system.
6) High-frequency noise in the ECG.
7) Motion artifact in the ECG.
8) Noise due to variation of electrode skin contact impedance.
9) Power-line Interference in ECG signals.
10) Noise generated by electronic devices used in signal processing circuits.

This paper concentrates mainly on removal of power line interference . However the final product will also ensure that the noise generated by the electronic devices used in the entire circuit do not corrupt the ECG signal.

There are mainly three approaches to remove noise and interference,

(1) Frequency-domain filtering (Notch Filter)

(2) Optimal (Wiener) filtering,

(3) Adaptive filtering

Notch Filter :

It is well known or simplest filter to remove the power line interface notch filter compute the Fourier transform of the signal delete undesired component and the inverse Fourier transform. There are two methods for implementation of the notch filter .First one is remove the artifact or set its value to zero. In second method the 50Hz artifact set to be average value of the signal. Later methods not remove the 50Hz component of the signal , but noise removing performance is average and in first one filter removes the 50Hz component of the ECG signal. After closely examining an IIR notch filter and three Type 1 FIR band-stop filters of varying order, it was found the IIR to perform best overall. Although the IIR filter's phase response is non-linear, almost all of the non-linearities occur within the stop-band. This would seem to indicate that it's shifting the phase of frequencies we're not interested in anyway. The IIR's low computation cost is also of importance especially when we are looking at implementing some sort of noise filter for an actual piece of medical equipment. This implies finite computational resources and keeping costs down. The IIR filter achieves both of these goalswhile still delivering a high quality filtered signal.[5]

Wiener Filter :

The notch filter and other pass band, band stop filters are fixed filter, they use only limited resources or we cannot change its performance according to our need. Wiener filter use the statistical characteristics for noise removing process like reference signal or secondary recorded ECG signal.

We can change its parameter to get the optimal results, so then we also called it optimal filter . Wiener filter theory provides for optimal filtering by taking into account the statistical characteristics of the signal and noise processes. The filter parameters are optimized with reference to a performance criterion, the output is guaranteed to be the best achievable result under the conditions imposed and the information provided.

Adaptive Filtering :

Adaptive filters are self-designing filters based on an algorithm which allows the filter to "learn" the initial input statistics and to track them, if they are time varying. These filters estimate the deterministic signal and remove the noise uncorrelated with the deterministic signal , we have considered adaptive impulse correlated filter which requires the signal and a reference input. The least mean square algorithm is used to adjust the weights of the adaptive filter in order to minimize the error and estimate the deterministic component through filter output.

The LMS adaptive filter is widely used to filter the ECG signal, but the existing LMS adaptive filters adapt to the environment showing limitations in the given filter, so its convergence and performance cause distortions and even poor performance, depending on the environment and the patient's condition. A Dynamic Structure Adaptive Filter as proposed byJu-Won Lee and Gun-Ki Lee[6].

V. PEAK DETECTION:

There are many methods that have been implemented for detection of P,QRS,T peaks over the years, two of the most famous ones being 1)derivative based and 2) Pan Tompkins algorithm.

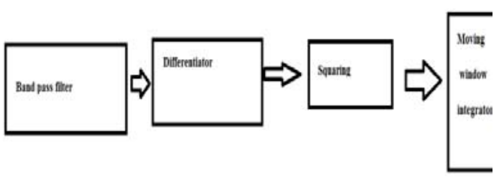
The algorithm developed by Pan and Tompkins identifies QRS complexes based on analysisof the slope, amplitude, and width of the QRS. The various stages of the algorithm are :-

Band pass filter: - The bandpass filter, formed using lowpass and highpass filters, reduces noise in the ECG signal. Noise such as muscle noise, 60 Hz interference, and baseline drift are removed by bandpass filtering. The signal is then passed through a differentiator to provide a large response at the high slopes that distinguish QRS complexes from low-frequency ECG components such as the P and T waves.

Differentiator:- The signal is then passed through a differentiator to provide a large response at the high slopes that distinguish QRS complexes from low-frequency ECG components such as the P and T waves.

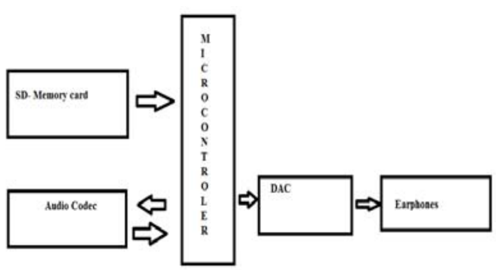
Squaring :-The next operation is the squaring operation, which emphasizes the higher values expected due to QRS complexes and suppresses smaller values related to the P and T waves

Moving-window Integrator:- The squared signal is then passed through a moving-window integrator of window length N = 30 samples (for the sampling frequency of fs = 200 Hz). The expected result is a single smooth peak related to the QRS complex for each ECG cycle. The output of the moving-window integrator may be used to detect QRS complexes, measure RR intervals, and determine the duration of the QRS complex.[4].



VI. BLOCK DIAGRAM OF A MUSIC PLAYER:

A music player consists of a memory unit in this case a micro SD card interfaced to a controller. The controller reads the memory device and sends data to the audio codec unit. The audio codec unit converts an MP3 file to a wav file which can be sent to the earphones through a DAC.



VII. INDUCTION OF TEMPO IN MUSIC

The tempo refers to the pace of a musical excerpt. Given a metrical structure, tempo is defined as the rate of the beats at a given metrical level, for example the quarter note level in the score. It is inversely proportional to the pulse period. For music with almost constant tempo, tempo induction is feasible with around 80% accuracy and a relatively good robustness to distortion. AnssiKlapuri from the Tampere University of Technology submitted one algorithm as a GNU/Linux binary, referred to as Klapuri algorithm.The onset time is defined as the beginning time of abeat or note played. To track a beat, spectrogram analysis to raw signals with 4096window size is applied.

The spectrogram represents the power of different frequencies at different time indices. Let *p(t,f)* being the spectrogram of given signal. The degree of onset *d(t,f)* is given by

$$d(t,f) = p(t,f) - pp + \max(0, p(t+1,f) - p(t,f))$$

Where $pp = \max(p(t-1,f), p(t-1,f\pm1), p(t-2,f))$,

Finally, the degree of onset is a function of time and given by

$$D(t) = \Sigma f\, d(t,f)$$

In this algorithm, possible inter-onset interval is looped over from 9 to 120 in unit of the parameter of *D(t)*.

Finally, normalize the score and obtain the IOI reliability score.

An important aspect of this algorithm lies in the feature list creation block: the differentials ofthe loudness in 36 frequency sub-bands are combined into 4 “accent bands”, measuring the “degree of musical accentuation as a function of time.” The goal in this procedure is to account for subtle energy changes that might occur in narrow frequency sub-bands as well as wide-band energy changes. The pulse induction block implements a bank of comb filters.

Another particularity of this algorithm is the joint determination of three metrical levels (thetatum, the tactus and the measure) through probabilistic modeling of their relationships and temporal evolutions. After computing the tactus beats of the whole test excerpt, the tempo was computedas the median of the IOIs of the excerpt’s latter half.

VIII. CONCLUSION:

The above paper is an intermediate step to realizing the feasibility of changing the tempo of music in accordance with an ECG signal. When achieved, the product will have fixed values of the tempo at which the music should be played for every kind of heart blockage.

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