



A novel approach for non-invasive measurement of mean arterial pressure using pulse transit time

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Received: 15 September 2018 / Revised: 28 October 2018 / Accepted: 27 November 2018 /

Published online: 15 December 2018

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Abstract

Recent days many researches are carried out related to the heart of the human. As a result many remedies are found for the various heart disorders. Electrocardiography (ECG) is the exertion of the electrical response from heart by placing the electrodes over the chest. The Einthoven triangle is an imaginary formation of the three leads in the triangle used in electrocardiography; by that technique of placement of electrode we can analysis the electrocardiogram of the heart. The waveform is also known as PQR waveform which contains the information of arterial repolarization, arterial polarization, ventricular repolarization and ventricular polarization. In general the BP monitor is carried out using oscillometry. In the existing system separate techniques and devices are used to measure electrocardiography and BP. The proposed system is to integrate both electrocardiography and blood pressure measurement by means adopting transit pulse time. It is defined as the systematic time lay off betwixt oscillometric pulses and peaks of ECG especially R peaks of it. The major advantage of the system is to exhibit non-zero crossing and gives more accurate result. The mean arterial pressure estimation is done by using MatLab which is the unique estimation method for measuring pulse transit time interval. Thus the non invasive system designed which reduce the cuff deviations and errors in electrocardiography. It can be applied in detecting the arterial disorders at most efficient manner.

Keywords Blood pressure (BP) · Electrocardiography (ECG) · Mean arterial pressure (MAP) · Pulse transit time (PTT)

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1 Introduction

1.1 Working of heart

The heart is the vital organ that basically serves as a pump in the human body. The heart is also a form of tissue which exigency the blood with oxygen and nutrients. The dissemination of the gore take place in two different passage way: such that the pulmonary system and systematic circuit. The deoxygenated blood assents by right ventricle of the heart. From the lungs to heart, the deoxygenated blood assents through the right ventricle which in turns the oxygenated blood travels to the right artery through pulmonary vein. In the systematic the oxygenated blood flows all over the body from left ventricle to aorta then travels to arteries at last to capillaries. The deoxygenated blood recompenses from veins to superior, inferior venacava and then to right atrium.

Oxygenated bloods are feed to the heart muscle through aortic values by means of two set of arteries. On one side of aorta, the blood is feed from left main coronary artery which is declining and forms left circumflex artery. On the other side the right coronary artery branches to right part. The heart attack or blemish to the flesh of it caused. It is palatable occurs due to the expeditious dispossession of the heart downbeat. On one side of aorta the left main coronary artery branches into the left anterior which is descending artery and left circumflex artery. On the right side of the aorta the right coronary artery branches out on the right side of the aorta. The heart attack or damage to the muscle of the heart is caused by the blockage of any of these arteries [23].

It produces heartbeat through the electrical pacemakers which cause it to contract. This contraction happens in five stages such as the heart is relaxed in first stage early diastole followed by the atrium contracts in other words arterial systole via the ventricles. Next, it begin diminution by not affecting the amount, at final the semi lunar valves are expanded finally it stops contraction and relax [24].

This has been clearly viewed by the Fig. 1 Heart Valve Anatomy Diagram Anatomy of The Heart View of the Valves adopted by human Anatomy Diagram.

1.2 Reasons for heart diseases

The pressure exerted upon the valves of blood vessels by circulating blood is called blood pressure which refers to the arterial pressure. Systolic pressure over diastolic pressure is the way of insinuating human body pressure. It is deliberated in terms of mm/Hg in which the regular blood pressure value is 120/80 mmHg. The pressure at which the heart is contracting is known as systolic blood pressure whereas the normal ranges are 90-140 mmHg and 60-90 mmHg. The mean arterial pressure occurs all the while of the left ventricle shrinkage [15]. Over 50 years old most typical factors for cardiovascular disease is systolic blood pressure [4]. Due to the following factors such as age as in increase rheumatic of arteries, prolonged formation of contagion and maximization incidents of cardiovascular disease [25]. When the heart exerts some pressure in arteries during when it is in rest state that pressure is known as diastolic blood pressure which ranges from 80 to 89 mm/Hg. It is conspicuous term and primitive of antihypertensive therapy.

1.2.1 High blood pressure

The high blood pressure also referred to as hypertension which occurs when the person blood pressure increases than the normal value due to unhealthy conditions. The causes for the high

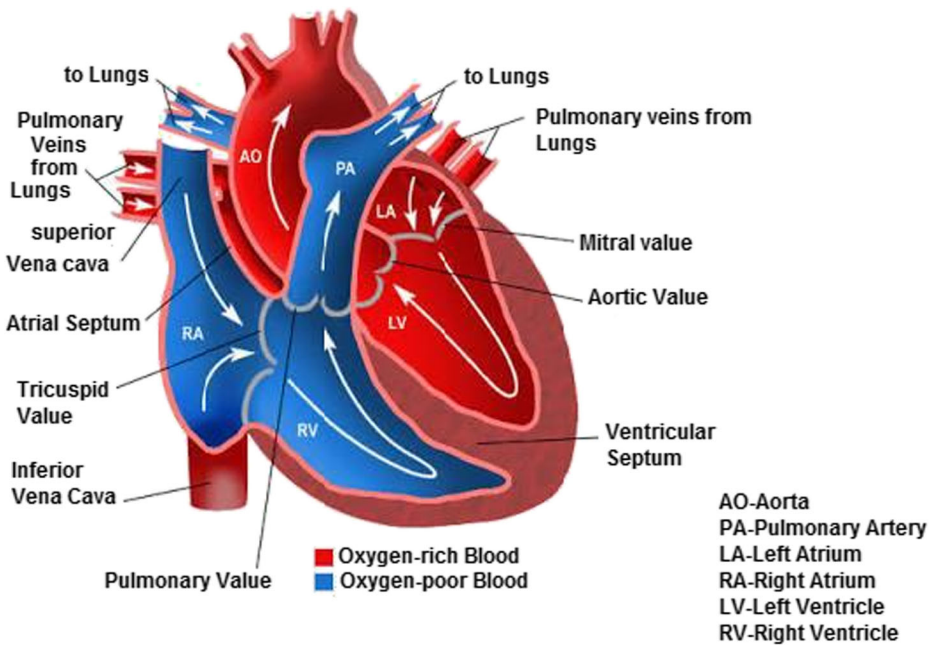


Fig. 1 Anatomy and physiology of heart

blood pressure can due to the increase in resistance of the blood flow due to the narrowing of the arteries which in turn cause heart disease and also damages the internal organ such as brain, eyes, and kidney.etc., [2].

1.2.2 Low blood pressure

It is the pressure of the artery in which the pumping of heart slows down than the normal rate [7]. It causes impotent blood supply to body organs which in turn causes stroke, heart attacks and kidney failure. Its most severe form is shock. One of the methods for diagnosis of hypo and hypertension is Electrocardiography [17].

2 Background

2.1 Electrocardiography (ECG)

It is the visual representation of the heart beat. The recording processes of electrical rhythm heart. It is done by placing the electrodes on the subject's body which is responsible for detecting the tiny electrical changes from the heart muscle occurring at depolarizing of heart beat.

A normal ECG small out as follows: Depolarization of arteria in response to SA node which is known as P wave. Additionally QRS complex is depolarization of ventricles, ST segment where the ventricle repolarization begins [3]. T wave is responsible for ventricular repolarization.

The ECG is traditionally interpreted methodically in order to not miss any important findings.

2.1.1 Mean arterial pressure

It is average arterial pressure occurs during a single cardiac cycle. It is used as the tool to find any cardiovascular risk. It is present all over the body and the pressure greater than 60 mm/Hg is enough for average person. This is the best way to estimate the actual pressure of blood [5]. MAP estimation is also vital in the diagnosis of sepsis, trauma, intracranial bleed and hypertensive emergencies.

2.1.2 High map levels

If the mean arterial pressure goes above heart undergoes stress much it feels much harder if it situation continues the fatty materials will be deposited in the wall of arteries. This is known as “atheroma” [26]. The condition become worse and leads to organ failure if the MAP is elevated from the normal.

2.1.3 Low map levels

Due to low MAP include sepsis, haemorrhage, stroke and trauma and even it may lead to fatal if it is untreated. It is necessary to measure MAP during surgery rather than systolic and diastolic blood pressure since MAP will be low even if the systolic pressure will be normal [6].

2.1.4 Treatment of high and low map

The immediate action or treatment is to be given for the cases with high mean arterial pressure. Primarily the intravenous blood pressure measurements taken and monitored. Similarly in the case of low mean arterial pressure the blood vessels constrict the pressure regulated by the body of healthy person is mean arterial pressure [13]. The mean arterial pressure is regulated by the body in healthy people and is usually unchanged. The regulation of mean arterial pressure is done through bar receptors. They are the pressure sensors present in the blood vessels to detect the abnormalities in the blood pressure. When it senses abnormality in blood pressure, it sends a signal to central nervous system as bar receptor reflexes. These receptors read the stretching of the arterial walls, heart and veins [16].

3 Overview of the existing system and proposed system

The frequent method for measuring blood pressure is oscillometric pulse in which the occluding cuff [10]. It is ascertain the pressure changes. In conventional method the mean arterial pressure is estimated as twice the diastolic blood pressure plus the systolic blood pressure and the result is divided by three. This is given by,

$$MAP = \frac{2DBP + SBP}{3} \quad (1)$$

This is further simplified as,

$$MAP = DBP + 0.33 * PP \quad (2)$$

Where

$$PP = SBP - DBP$$

This is known to be the Thirty-Three percent formula.

As we know that pulse transit time is nothing but the time interval between the R peaks and oscillometric pulses. It is found the maximum slope of these pulses is too close to mean arterial pressure. The advantages are accuracy and acquiring the signal directly from the cuff pressure. Cuff pressure is nothing but the maximum amplitude that is used to estimate has the limitations such that it is not trivial due to body movement, contraction of muscles etc. [8]. Even the amplitude will not show the clear peaks depending on age factors [18]. In order to overcome the above defects a new robust system is developed to estimate the mean arterial pressure (Figs. 2 and 3).

In general ECG is not included in the estimation of BP. In our proposed method ECG is included because of the hovering privy and consistency. There will be lot of noise and artifacts along with the original cardiac pulses in the oscillometric blood pressure estimation [21]. The determining R-peaks for MAP are due to its easy interpretation, high amplitude and structural form. The clinical significance of R-R interval is Tachycardia, Bradycardia, Heart block, Arrhythmia and other cardiovascular diseases.

4 Block diagram of the proposed system

We designed a novel detection technique which helps to acquire the blood pressure of the person. By of acquiring the blood pressure of the person gives the information about the early detection if the heart disease. It is carried out by determining the mean arterial pressure of the blood pressure acquired. The estimating of mean arterial pressure is done by the transit time pulse. Depending on the time interval of the R wave of the ECG waveform the subject can be analyzed whether they

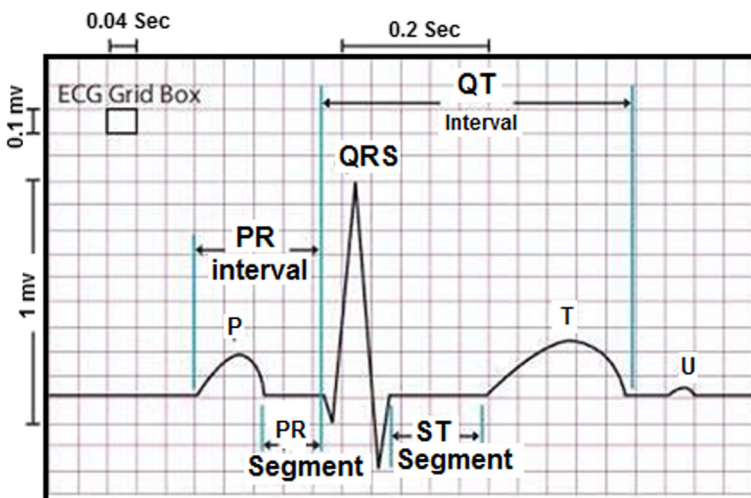


Fig. 2 ECG recording of a healthy heartbeat

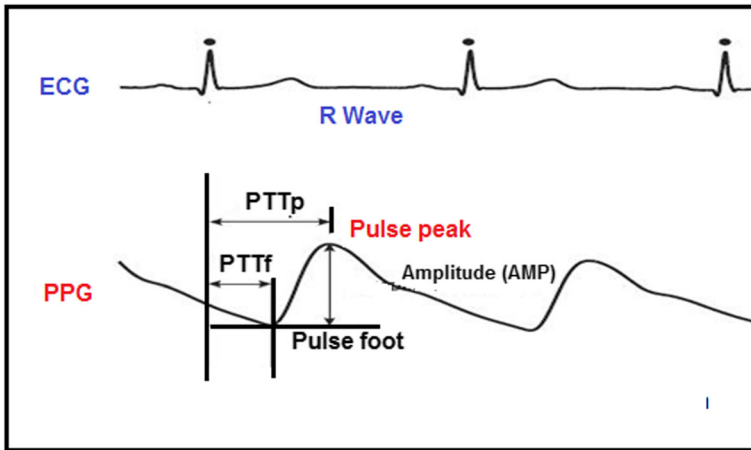


Fig. 3 Pulse transit time estimation

are normal or suffering from any type of abnormality. The hardware part is designed to acquire the real time blood pressure of both the type's i.e. high pressure levels and low pressure levels. The mean arterial pressure varies for both the pressure levels. The process of recording electrical activity of heart is known as electrocardiogram and to measure that we need to place the ECG sensor over the person body. The surface electrodes will be used since the adhesive nature of the sensor with the body gets small amount of the electrical impedance which in turn reduces the noise and artifacts of the obtained signal. The heart beat is another essential component that is to be considered to detect the heart disease. The heart beat is nothing but which gives the complete

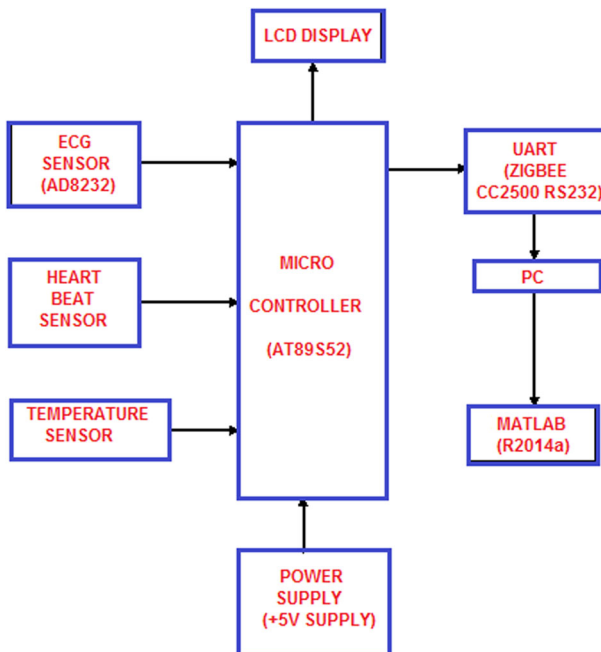


Fig. 4 Proposed system block diagram

information about the ventricle contraction and relaxation. The heart beat varies if the person pressure levels. That heart sound can be determined by using the heart sensor [1].

The inputs are taken from two points: one from ECG sensor through surface electrodes placed on various arms, legs and heart beat sensor on a finger. These input signals are fed into the microcontroller unit and additional input information of temperature sensor is also included. The proposed block diagram has been shown in Fig. 4.

An electronic circuit is programmed to perform various numbers of tasks. It can be in the form of timers or to control a production line [19]. The features are 128bytes of EEPROM. The LCD unit displays the heart rate and also tells us whether the ECG signal is acquired or not. The UART works in the sequential fashion in which it takes bytes of data and transmits the individual bits. At the destination, a second UART re-assembles the bits into complete bytes [20]. The data then interfaced into PC and simulated using MATLAB.

4.1 Methods and materials

4.1.1 Atmel microcontroller (MCU)

Atmel microcontroller has a very good efficient integrated design, proven technology and new innovation technique for today's smart and connected products. It provides high performance, power efficiency and design flexibility. In addition to the above features it also have rich interface support, low power, high speed connectivity and best data bandwidth.

4.1.2 Pic controller

The unit of PIC microcontroller acts as timer. The UART works in a sequential fashion. The P16F877A features two comparators, A/D convertor, and a universal asynchronous receiver transmitter. The registers are function as the random access memory and the special purpose registers are used to incorporate with the hardware section and it can also be used in mapping into data space.

4.1.3 ECG sensor (AD8232)

Output obtained from sensor will in the form analog along noisy input. So in order to remove the noise it wills beating as an op-amp as result it produces a clear result of PR and QT intervals effectively. It is also known as e-health sensor which is used to measure both the electrical and muscular activities of the heartbeat of the subject [9].

4.1.4 Heart beat sensor

These measures the heart beat when the finger is placed on it that gives the digital output. It can be measured as beats per minute [22]. The light modulation technique of blood flow is used. It works on the principle of light modulation by blood flow through finger at each pulse.

4.1.5 Temperature sensor (LM35)

It is an electrical output which is proportional to the acquired temperature, which measures the temperature. The obtained output voltage is high enough for processing so not need separate amplification is required [11, 12].

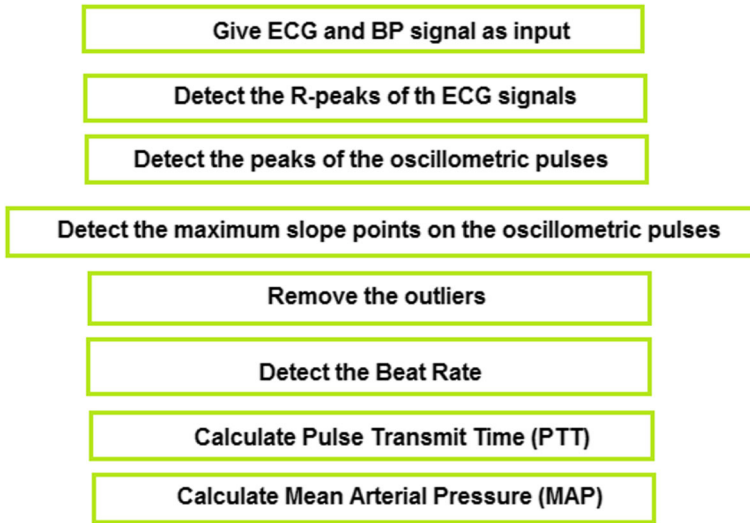


Fig. 5 Flow chart for Map estimation

5 Implemenatation and results

5.1 Steps performed in MATLAB

The acquired ECG signals are sent for the preprocessing section. The preprocessing is carried out in the MATLAB software. The various steps involved in preprocessing section are detecting the R peaks from the acquired signals and oscillometric peaks. The maximum slope points of the oscillometric pulses are detecting using maximum average filter. Thus the artifacts are removed or reduced by means of adopting this in the input signal. The cubic smooth spline function is used to calculate the pulse transit time. At last the mean arterial pressure is derived from the heart rate dependent formula as shown in Fig. 5.

5.2 Map estimation method

- To determine the maximum slope points.
- Estimate the pulse transit time
- Removal of noise

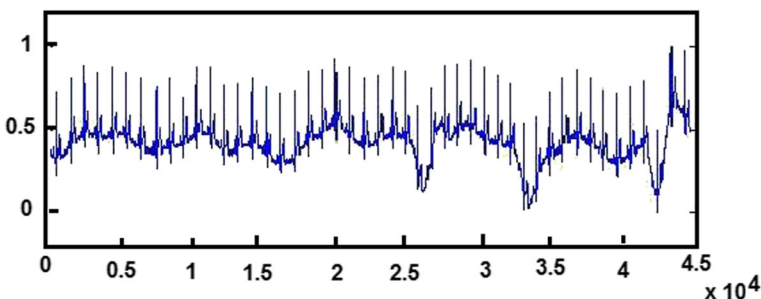


Fig. 6 Acquired raw ECG

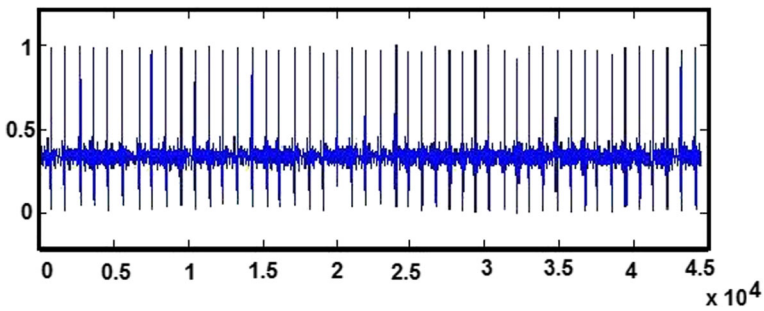


Fig. 7 ECG signal filtered using FFT

It is adopted by outlier technique which removes the samples that are inconsistent. It is based on fitting a quadratic polynomial function to pulse transit time signal.

- Rounding off the pulse transit time
- The method used for rounding off is seven points moving average filter [14]. The artifacts are removed and reduced by means of cubic smoothing spline function.
- Calculate the mean arterial pressure.
- Heart rate dependent formula is used.

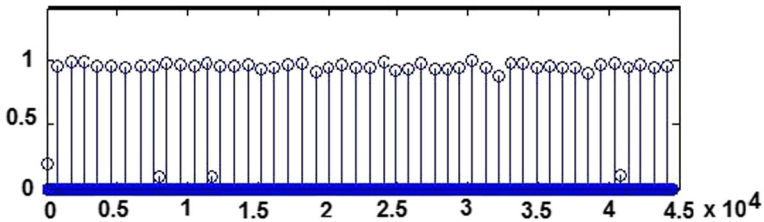


Fig. 8 PTT signal

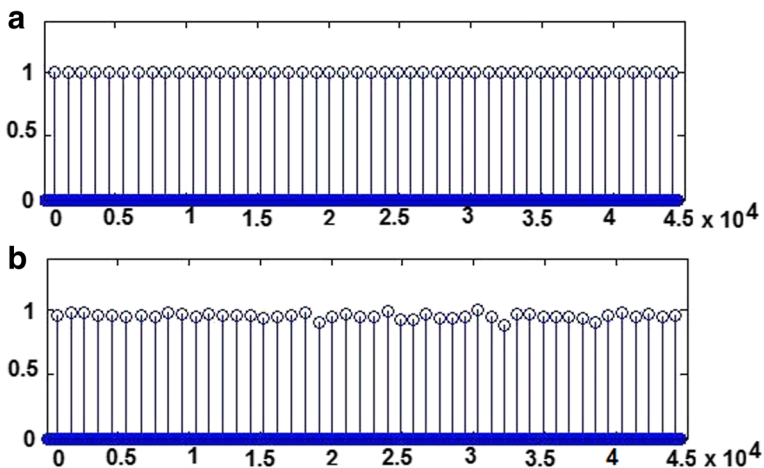


Fig. 9 (a) Detected peaks, (b) Filtered ECG-2nd pass

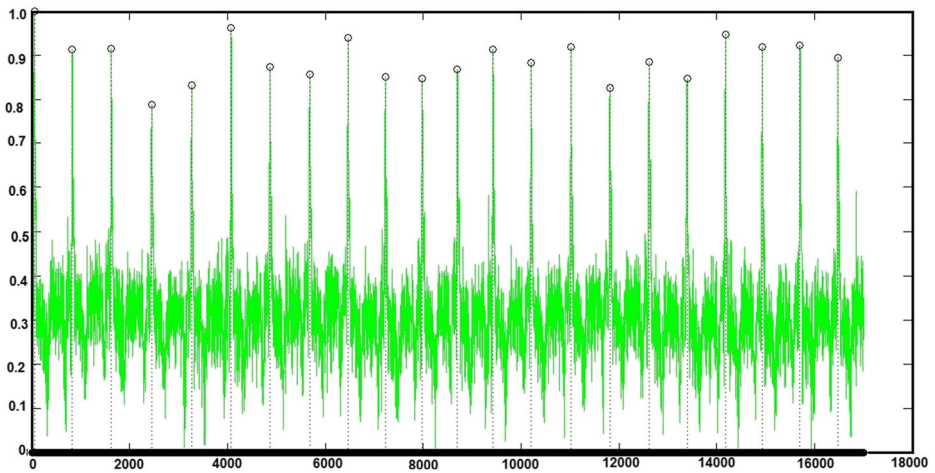


Fig. 10 Comparisons of ECG R-peaks and maximum slope points

5.3 ECG signal processing

5.3.1 Stage 1 ECG preprocessing

The first stage of the preprocessing is acquiring the raw ECG signal from the various subjects by placing the ECG electrodes. It gives the electrical activity of the heart of the person in the form waves which consist of PQRST.

The acquired raw ECG signal contains artifacts and noise along with the original signal. These artifacts may be due to power line interference, subject disturbance and electrode placement in the body. So in order to reduce these artifacts the Fourier transform technique is used. The Fourier transform technique is preferred for bio-signals since it is required for spectrum analysis and filtering operation.

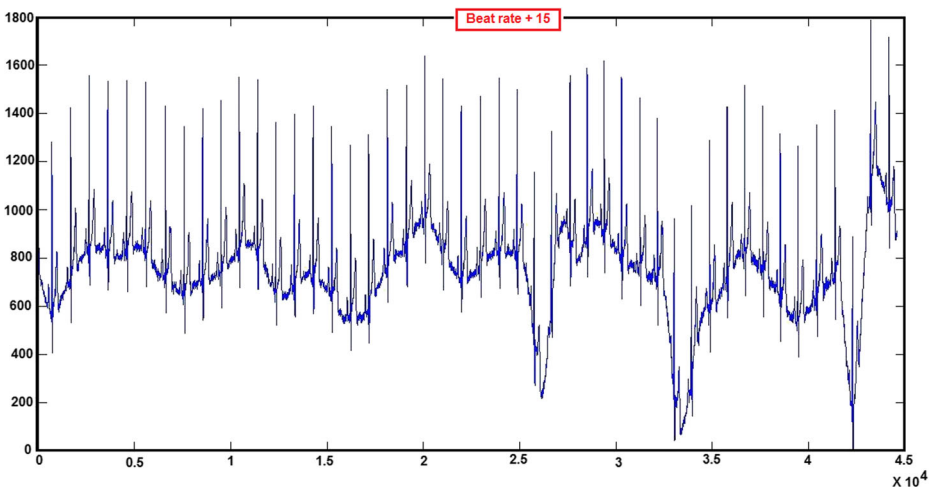


Fig. 11 Beat rate calculation for map estimation

After the removal of noise from acquired signal the pulse transit time is calculated in order to know the exact value of heart rate of the subject. The pulse transit time is calculated and rounded by means of moving average filter and cubic spline function.

After detecting the pulse transit time from the acquired signal, the maximum slope of oscillometric pulses are alone detected to measure the heart rate.

Again the filtering technique is adopted for the detected pulse transit time in order to obtain the 2nd order of the signal.

5.3.2 Stage 2: comparison of ECG R-peaks and maximum slope points

The detected maximum slope of the oscillometric pulses are compared with the original test ECG signal i.e. mainly with the R peaks of the ECG signal. The comparison technique is done by means of cubic spline function.

5.3.3 Stage 3: beat rate calculation for map estimation

Thus at the final stage of processing the heart beat rate is calculated by MAP estimation method. The mean arterial pressure is calculated after detecting the slope of oscillometric pulses from the pulse transit time pulses. Thus the output obtained from this is beat rate of the person (Figs. 6, 7, 8, 9, 10 and 11).

6 Conclusion and future scope

The proposed method developed a novel technique for estimating mean arterial pressure through pulse transit time. Thus the main objective of proposed system is to save the life of person and to detect the disorder at the early stages. The efficiency of the system is high. This method gives the information about the heart beat so that the pressure variation can be noted at the particular level without making delay. The heart beat gives information about the depolarization and repolarization of atria and ventricles. The pulse transit time is measured or computed by means of the duration between ECG R peaks and the maximum slope points. The methods used in the proposed system are maximum amplitude method. This paper improves the accuracy of non-measurement of blood pressure through non-invasive technique in terms of estimating the mean arterial pressure from the envelope of oscillometric pulse. The important significant of this system is that the obtained parameter does not vary with cuff deflation. The time duration for this estimation is as short as 30s for subjects with arterial fibrillation.

Our future work will focus on developing a real-time monitor for MAP estimation rather than using predefined signals. Models may be developed by as similarity these parameters in additional to that excess clinical testing is to be adapted in both healthy persons and also subject suffering from disorders. These recorded results is to be compared with conventional method where the test is been carried out by the experts.

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