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GUI Using MATLAB for PTT and HRV Analysis for Detecting Early Changes in Physiological Variables

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Abstract

Heart Rate Variability (HRV) and Pulse Transit Time (PTT) are important biomarkers individually. They are helpful in detecting and predicting the diseases as these variables are different in healthy and diseased individuals. It will be additional and precise, if we are able to obtain HRV and PTT in a single screen. In this work GUI has been created in MATLAB to display HRV and PTT on a single screen. MATLAB code is written for implementing the algorithm to obtain HRV, PTT and Stiffness index. The simultaneous data of Electrocardiogram (ECG) and Photoplethysmography (PPG) from different age groups were acquired and also taken from the Physionet data base. The GUI was tested for detecting early changes in physiological variables. The GUI measures the changes in the reflection index, augmentation index and stiffness index for different age grouped sets of data. The reflection index and augmentation index decreased in older individuals compared to younger individuals, whereas stiffness index increased with the aging of the arteries. Also, the HRV and PRV showed decreased variations in aged individuals compared to young individuals.

Keywords: *ECG, PPG, PTT, GUI, MATLAB, Arterial Stiffness*

1. Introduction

The cardiac autonomic role can be assessed in many ways, among that HRV(Heart Rate Variability) is one of the methods of assessing. ECG(Electrocardiogram) can be used to analyse the modulation of systematic control of ANS (Autonomic Nervous system system) by analyzing the heart rate[1]. As heart rate is mainly controlled by sympathetic and parasympathetic nervous systems according to the physiological need of the body. In contrast ANS activity can be analysed using Heart rate variability parameters. Various standard Linear and Non-Linear parameters have been suggested by the researches for obtaining ANS functions using HRV after decades of research on HRV[2]. Heart rate variability can be analyzed using mainly through ECG signals. PPG(photoplethysmography) signals were also used by some of the researches as alternate to ECG signal for analyzing HRV, in later case it is called as PRV(Pulse Rate Variability)[3]. Many have compared the results of ECG and PPG signals for HRV statistical and frequency analysis and found almost similar results. Hence, both ECG and PPG signals can be used for HRV analysis. PPG is widely used as it is simple in the design. It gives the blood volume changes parameters. A simple sensor can be connected to the tip of the finger and can be able to give many of the parameters like oxygen saturation, pulsatile waveform relating to the cardiac activity and hence the ANS functionality, arterial stiffness calculations and other important physiological parameters can be obtained noninvasively using PPG signals.

PPG signals estimates the blood flow through the skin using infrared or green light. PPG is the area of interest for many researchers because of its noninvasive, inexpensive, low cost features. PPG is mainly utilized for measuring blood oxygen saturation and heart rate. PPG is gaining its importance in analysis of arterial stiffness and PTT(Pulse Transit Time)[4]. Arterial stiffness defines the ability of the arteries to contract and relax at cardiac cycles. Two proteins collagen and elastin plays vital role, where arterial contraction and relaxation depends on the degradation and formation of these two proteins. If this is disturbed, regular contraction and relaxation of the arteries will be disturbed. These changes in the arteries can be detected using Augumentation index, Reflection index and Arterial stiffness index.

1.1 PTT

Pulse transit time can be defined as the time taken by the arterial pulse wave to move from aortic valve which is ejected from left ventricle to rest of the peripheral site of the human body. Blood pressure has inverse relation to the PTT, as the PTT time increases, blood pressure decreases and as PTT time decreases, blood pressure increases. As the Blood pressure increases shows that PTT has taken very small time to reach the peripheral site. There are various ways for detrining PTT, one of the convenient method of determining PTT is through analysis of ECG and PPG signal. In this method PTT is defined as the time interval between peak of ECG and the peak of PPG signal taken at the ear lobe, fingertip or at toe.

2. Materials and Methods

In this work a GUI(Graphical User Interface) is created for HRV, PRV, PTT, notch detection, reflection index and the stiffness index. In this study ECG and PPG signals are used for the analysis purpose of the above functionalities.

Fig.1:Graphical User Interface created.

Fig.1 Shows the GUI created for the analysis of HRV, PRV, PTT and Arterial stiffness. In this work ECG and PPG signals are taken from the individuals simultaneously and recorded for offline analysis.

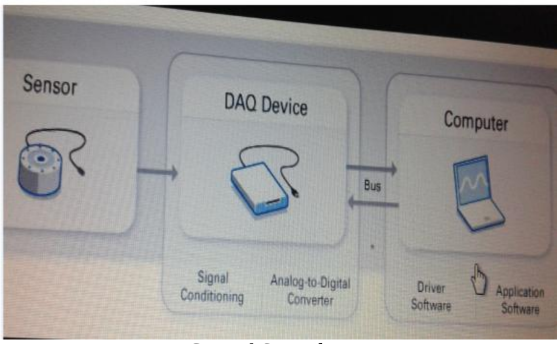

Figure.2: General Setup for Measurement.

Signals are taken from ECG and PPG sensors and the signals are conditioned and converted the analog signal to the digital signal using DAQ device. Through the USB signals have been taken to the system from DAQ device. The signals are stored in (.txt) format and it is loaded for MATLAB where analysis of the HRV and other functionalities are carried on.

Fig3. PPG machine setup

For obtaining PPG signals, reflectance type PPG sensor,TMI systems machine is used. The sampling rate chosen was 250hz and signals are stored to the system via USB cable. Fig.3 shows the PPG setup used for obtaining PPG signals. ECG signals were obtained using Three leads electrodes, and bioamplifiers. The ECG set up is as shown in fig4.From the bio amplifier, the signals are filterted at different frequencies to obtain the noise free ECG signals and it is stored for further extraction and classifications.

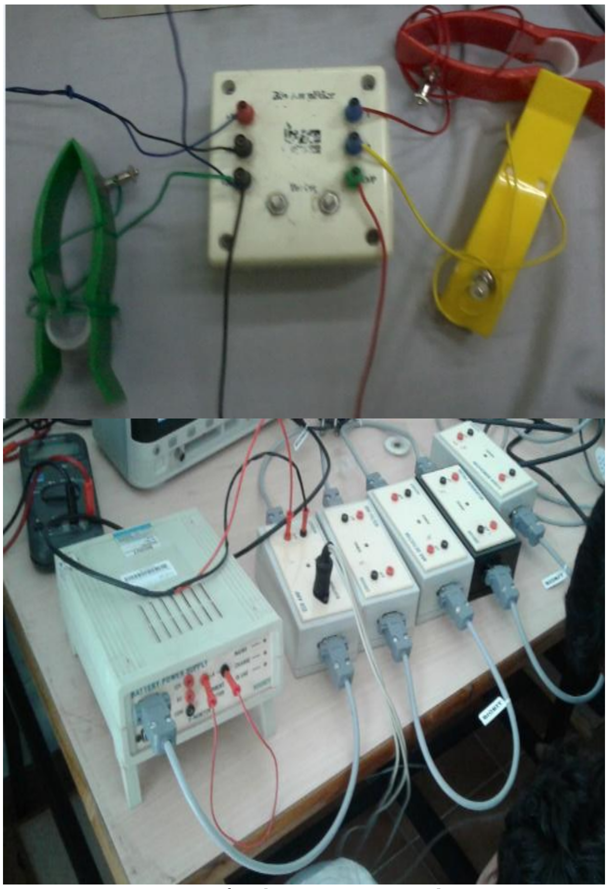
Fig.4 Setup for obtaining ECG Signals.

The obtained ECG signals are loaded in MATLAB with sampling frequency of 1kHz.

3. Results and Discussion

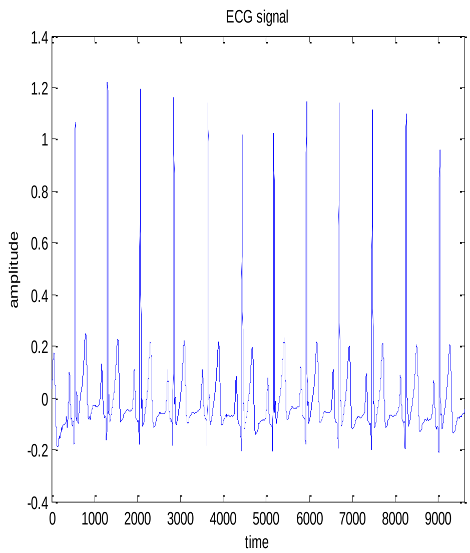

Fig.5 Plot of ECG signals

From the GUI, when ECG signals are selected we are able to see the ECG signals plot which is as shown in fig.5. When PPG signals are selected a plot of PPG signal will be obtained, as shown in fig.6.

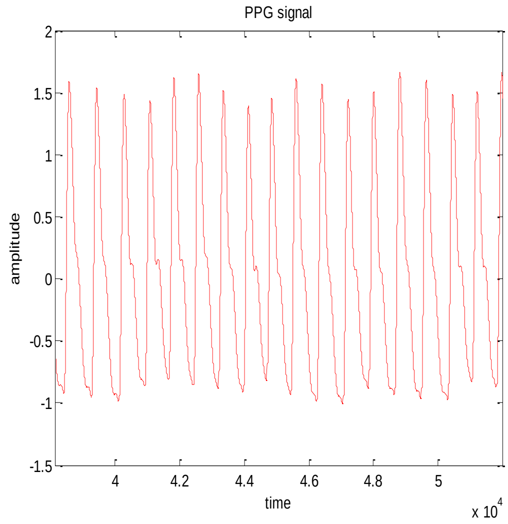

Fig.6 Plot of PPG Signals.

Peak has to be detected for both the ECG and PPG signals for which there is a option in the GUI. The plot of peaks detectd is as shown in fig.7.

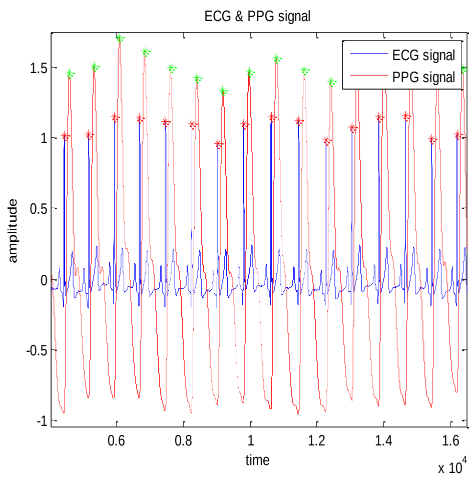

Fig.7 Plot of peaks detected in ECG and PPG signals.

The time differences between the ECG and PPG signals peak gives the PTT, and the contineous measure of PPT generates the plot of PTT as shown in fig.8.

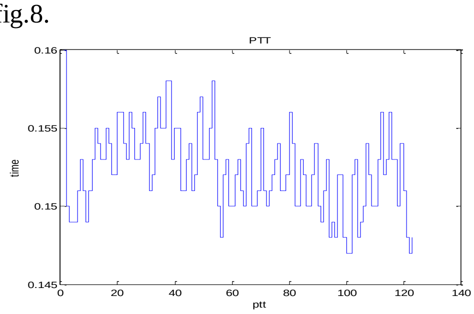

Fig.8 Plot of PTT obtained.

By selecting HRV in the GUI, HRV plot will be obtained as show in fig.9. With the HRV plot obtained, we can further use it for HRV parameters analysis like linear and nonlinear parameters of HRV.

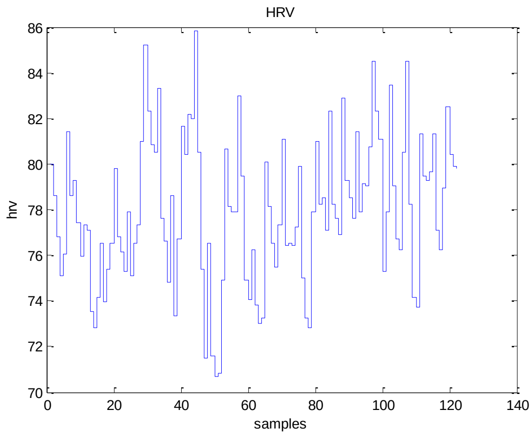

Fig.9 Plot of HRV.

By converting the plot in to frquency domain, low frequency and high frequency values of HRV are obtained. By selecting PRV in the GUI, PRV plots are obtained as shown in fig.10.

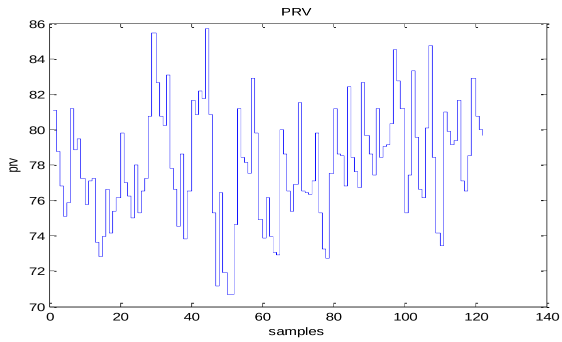

Fig.10 Plot of PRV.

The HRV and PRV plots are compared and there were very minute deviations. Hence, PRV which is obtained from PPG signals can be used as the surrogate for the HRV in the absence of the ECG signals.

Arterial stiffness is a term employed to define the arteries' capacity to expand and contract during the cardiac cycle. The physical properties of the arterial wall largely depend on the two extracellular proteins elastin and collagen. The proportion of elastin and collagen in the arterial wall is regulated by a slow dynamic process of formation and degradation. Disturbances of this balance typically lead to higher collagen content and a diminished proportion of elastin, which reduces arterial elasticity. Estimation of arterial stiffness by using PPG reliably estimates arterial stiffness based on the analysis of age and heart rate normalized reflected wave arrival time. From the literature survey shows that subjects with CVDs (Cardiovascular Diseases) have increased arterial stiffness compared to those without CVDs. Furthermore, arterial stiffness has also been shown to be a useful predictor of all-cause and cardiovascular mortality in subjects with end-stage renal diseases. Arterial stiffness therefore, not only serves as an indicator for CVDs but can also serve as an important tool to continuously monitor and manage CVDs.The measurement of the reflection index and stifness index is as shown in fig.11. With analysis of relflection index and stifness index, augementation index it is possible to determine the arterial stifness of an individual approximately.

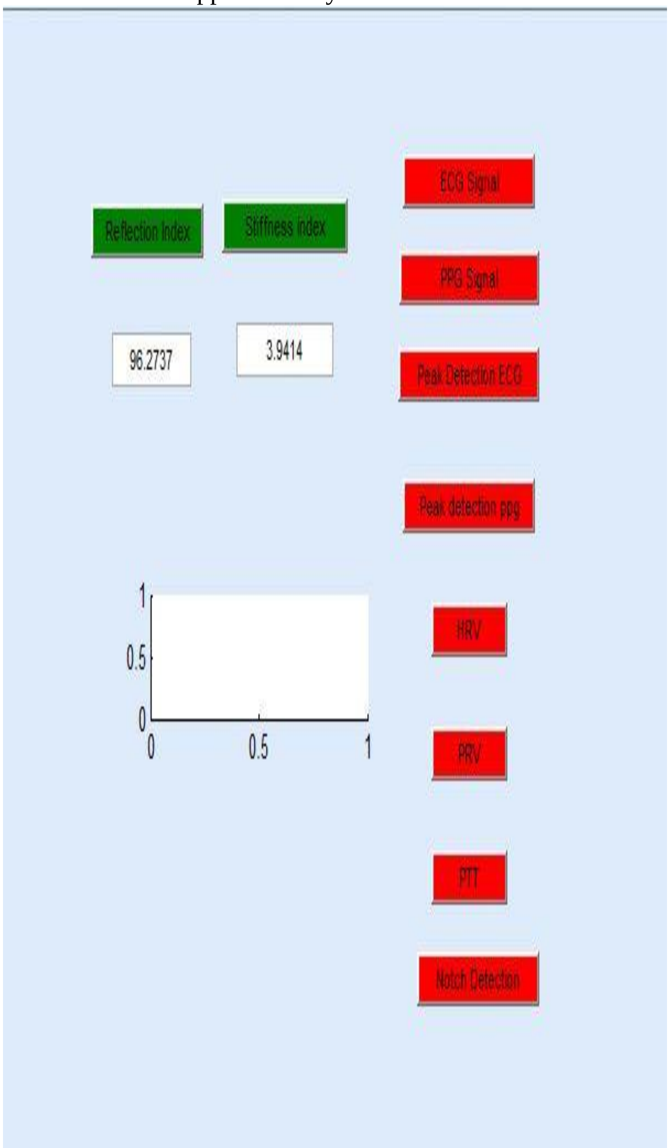

Fig.11 GUI measuring Reflection Index and Stiffness Index

Reflection index(RI) is calculated by using the formula,

$$RI= y/x*100\% \quad (1)$$

Where y is the amplitude of inflection peak (second peak), and, x is the maximum amplitude of the pulse. Reflection index is normalized for percentage calcualtions. It can also be calculated using below eq[2]. In the present work reflection index is calculated using eq.2.

$$RI=\frac{x-y}{x}*100\% \quad (2)$$

The basic concept here is that the second peak is prominent in healthy arteries, as the arteries gets old these second peak of the PPG signals diminishes prominently. Hence the reflection index decreases with thee old arteries.

Augmentation index (AI) is derived by taking the second derivative of the PPG signal.

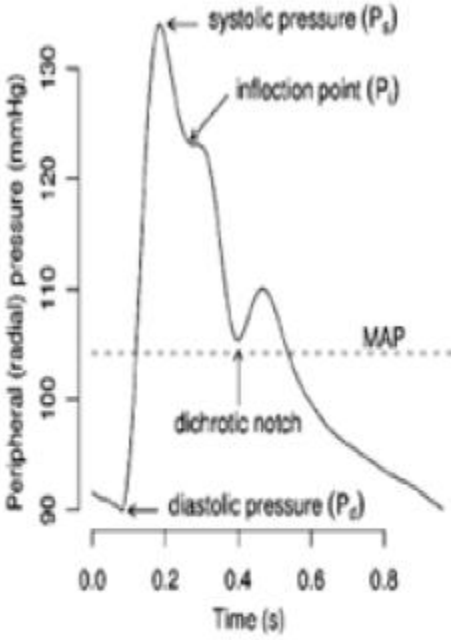

Fig.12 The second derivative of the pulse wave.

Augmentation index (AI) is derived by taking the second derivative of the pulse wave. The second derivative of the pulse wave is as shown in fig12. It can be derived as,

$$AI=\frac{Ps-Pi}{Ps-Pd} \quad (3)$$

Where "Ps" is the peak systolic pressure, "Pi" is the inflection point that indicates the beginning up-stroke of the reflected wave, "Pd" is the minimum diastolic pressure of the PPG signal. Augmentation index increases with the aging of the arteries.

Arterial Stiffness Index (ASI)

Arterial stiffness index(ASI) is defined as the ratio between the height of the individual and the time difference between the systolic peak and diastolic peak.

$$ASI=\frac{h}{\Delta T} \quad (4)$$

In the above equation "h' is subject height and ΔT denotes the time difference between systolic and diastolic peak amplitude.

Five PPG signals were analyzed with the GUI created. Out of which 2 signals are taken from the old individuals aged around 70 years and 3 signals were taken from the young individuals around 25 years.

Table.1 Results of Reflection index, Augmentation index and stiffness index calculated for old and young individuals data.

Subject's Age	Reflection Index	Augmentation Index	Stiffness Index
68	64.15	0.54	12.2
71	63.59	0.52	10.4
23	96.27	0.72	5.4
28	95.78	0.76	5.9
24	89.24	0.84	4.9

In the table.1 it is clearly seen that reflection index and augmentation index is reduced in old individuals data and it is more in young individuals data. Stiffness index is more in older individuals compared to younger individuals.

4. Conclusions

Pulse transit time (PTT) is growing its importance as it can be used to derive many of the physiological signals, also it alone can be used in perdition of diseases. In the present work a GUI is created to obtain the PTT signals which are derived from PPG and ECG signals. The ECG and PPG signals were collected simultaneously from two different age groups and GUI was able to filter the obtained ECG and PPG signals plot the HRV signal, PRV signal and to derive the PTT signals. The GUI can also be used for detecting the arterial stiffness of an individual. The analysis has to be done with larger data to obtain the approximate threshold values of reflection index, augmentation index and stiffness index values.

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