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Heart Rate Variability Analysis Based on the ECG, PPG, and Mobile HRV Measurements

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ABSTRACT

The ECG, PGG, and Mobile Elite HRV measurements are taken into consideration for opportunity to realize a practical, cheap, and easy health condition detection for cardiovascular diagnosis. PPG could be applied for measuring the physiological state of individuals along their ages in daily life to connect healthcare applications with other biosensors. Determination of heart rate variability (HRV), pulse rate variability (PRV) or heart rate fluctuation (HRF) requires accurate and precise measurement of inter beat intervals (IBI) in the ECG (electrocardiogram), PPG (photoplethysmogram), or in Mobile Elite captured signal. In practice, the signals are mathematically collinear which happen when PPG, ECG, and Elite HRV based data is simultaneously sampled and recorded. For both ECG. PPG, and Mobile Elite HRV based IBI can be analyzed by the cumulative sum technique (CUSUM). This technique is for a series of pulsed time signals from any source. Here the results visualization is based on the precise and accurate data on the variance inflation factor (VIF) analysis so that extra or lagging heart beats were cancelled. Then the data is highly correlated with each other based on the correlation coefficient (R2). VIF is very informative factor on the linearity. The statistics of CUSUM-slope (CUMULATIVE SUM OF ABSOLUTE VALUE DIFFERENCES) is as a measure for IBIs captured the average of signals, for which the CUSUM slope is computed. Because we two or even three dependent variables (IBIs) this can provide an elimination of the independent variable (time) for estimating the signal content in the biomedical signal recordings.

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Introduction

ECG is the golden standard signal in the healthy heart, it is used as a reference for the heart rate, heart rate variability, an overall diagnosis. However, precise and accurate PPG sensors typically use ECG signals as a reference for dynamic inter beat interval (IBI) comparison in relation to continuous uses. The ECG, PPG, and Mobile Elite HRV measurements are taken into consideration for opportunity to realize a practical, cheap, and easy health condition detection for cardiovascular diagnosis. PPG could be applied for measuring the physiological state of individuals along their ages in daily life to connect healthcare applications with other biosensors. Determination of heart rate variability (HRV), pulse rate variability (PRV) or heart rate fluctuation (HRF) are easily captured nowadays to determine inter beat intervals (IBI) in the ECG (electrocardiogram), PPG (photoplethysmogram), or in Mobile Elite captured signal. In practice, the signals are mathematically collinear which happen when PPG, ECG, and Elite HRV based data is simultaneously sampled and recorded. For both ECG. PPG, and Mobile Elite HRV based IBI can be analyzed by absolute value differences between IBI based on ECG and PPG, but also the Mobile HRV to calculate the cumulative sum (CUSUM). Then the data is highly correlated with each other based on the correlation coefficient (R2). For this reason the variance inflation factor (VIF) is very informative also on the goodness of fit [1, 2].

Materials and Methods

This study is aimed to propose an accurate system by examining nonlinear dynamics of PPG, ECG, and CorSense Mobile Elite application for HRV determination based on inter beats intervals (IBI). ECG is an electrophysiological phenome measured over body whereas PPG is bio-optical change caused by blood content and volume pulses in small blood vessels and capillaries of the upper skin based on tissue absorption, its scattering, and also light transmission properties as a function of light wavelength. The ECG electrodes were place the subject's chest and the PPG sensor was placed on the tip of the right hand forefingers. CorSense is located on the tip of the left hand forefinger for detect automatically the heart pulse after connecting to Mobile Elite HRV application. This is designed in the rest measurements. CorSense uses sensitive motion detection to power automatically on the device and detect a heart pulse with no buttons. The high resolution ECG data was collected with means of a high impedance ECG amplifier with the sampling rate of 1 kHz simultaneously. The ECG electrodes were the monitoring disposable INTCO sensors. These sensors measure one channel high resolution ECG with three lead electrodes with the amplitude resolution of 16 bit ADC. The PPG data collection was based on the photomicrosensor's emitter and detector (component: Omron ee-sy113) which are on the same side (reflective mode) of the fingertip with the sampling rate 1 kHz also simultaneously. The Elite HRV CorSense PPG sensor is in transmission mode with sampling rate 500 Hz. Before the measurement we used skin warm tap water, and the comfortable skin temperature was received for improving the quality and accuracy of the PPG signals, but it did not cause any effect on the quality or precision of ECG signal. However, the room area, devices and device construction, and personal factors can affect the variability in the measured biomedical signals and can cause artefacts especially in optical signal which can cause errors within the analysis of the signal.

Below is shown R^2 as a function of VIF

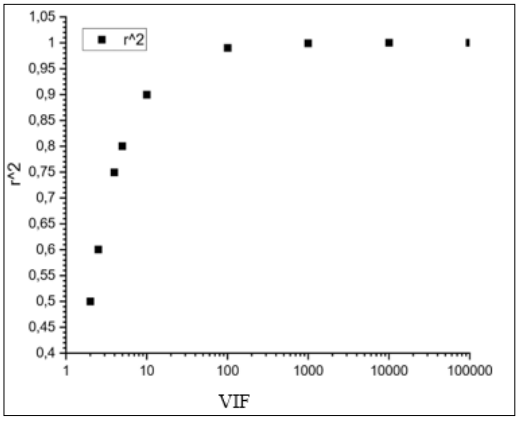
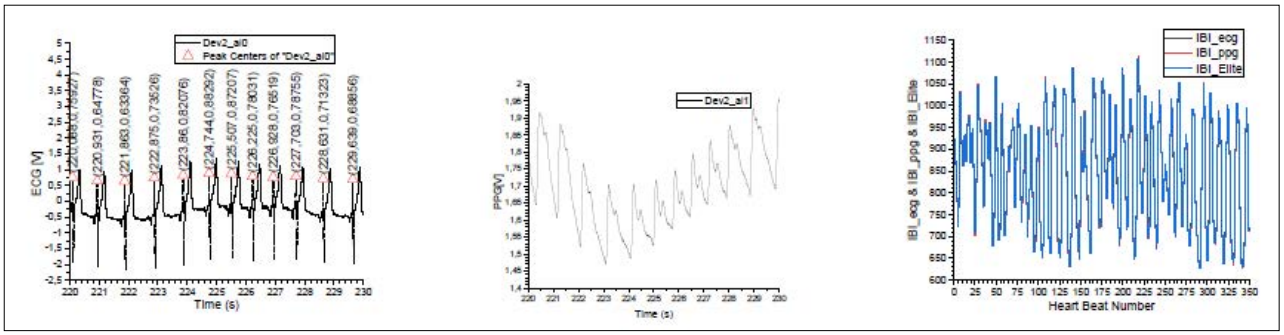


Figure 1: The r^2 as a Function of VIF

Mobile Elite HRV apps may be a preferred method of HRV data collection for young person due to its practicality. However, elderly people needs an accurate device to receive reliable result to get rid many erratic heart beats such as premature heart beats. Accordingly, few studies exist that asses the accuracy of combined ECG, PPG & Elite HRV. Because HRV or PRV are highly correlated with each other based on the goodness of fit (R2), or variance inflation factor (VIF) can be further analyzed. A VIF under 1.5 indicates the total absence of linearity, Figure 1 where log(VIF) vs R^2.

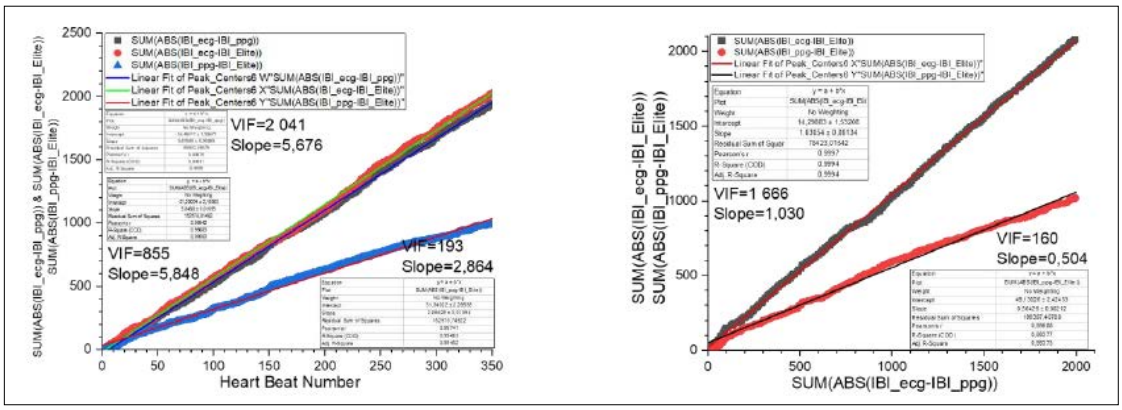
Results and Discussion

Basic results are shown below in the below Figures.



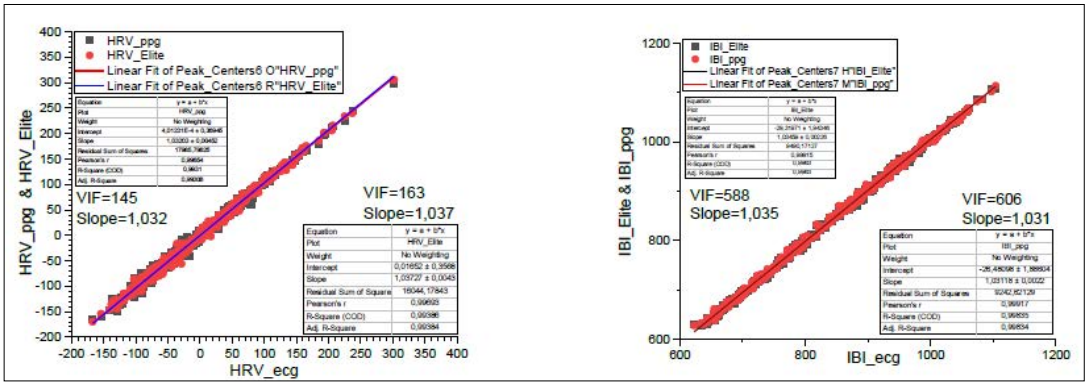
(A) (B) (C)

Figure 2: (A) ECG signal, (B) PPG signal and (C) IBIs for ECG, PPG, and Elite HRV vs Time.



(A) (B)

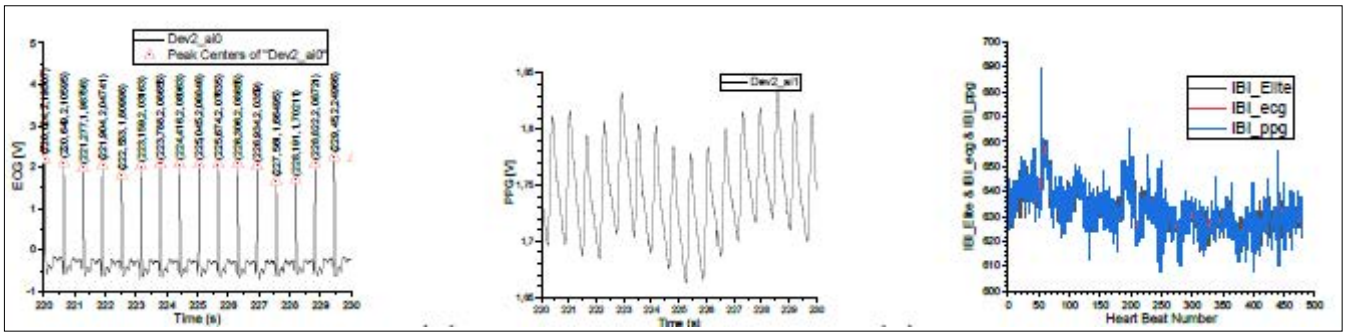
Figure 3: (A) CUSUM of the differences between IBI_ecg minus IBI_ppg, IBI_ecg minus IBI_Elite, and IBI_ppg minus IBI_Elite vs heart beat number (black, red and blue). (B) Similarly, CUSUM of the differences between IBI_ecg minus IBI_Elite (black) and IBI_ppg minus IBI_Elite (red) vs IBI_ecg minus IBI_ppg. (Male 28 y of the Figure 1).



(A) (B)

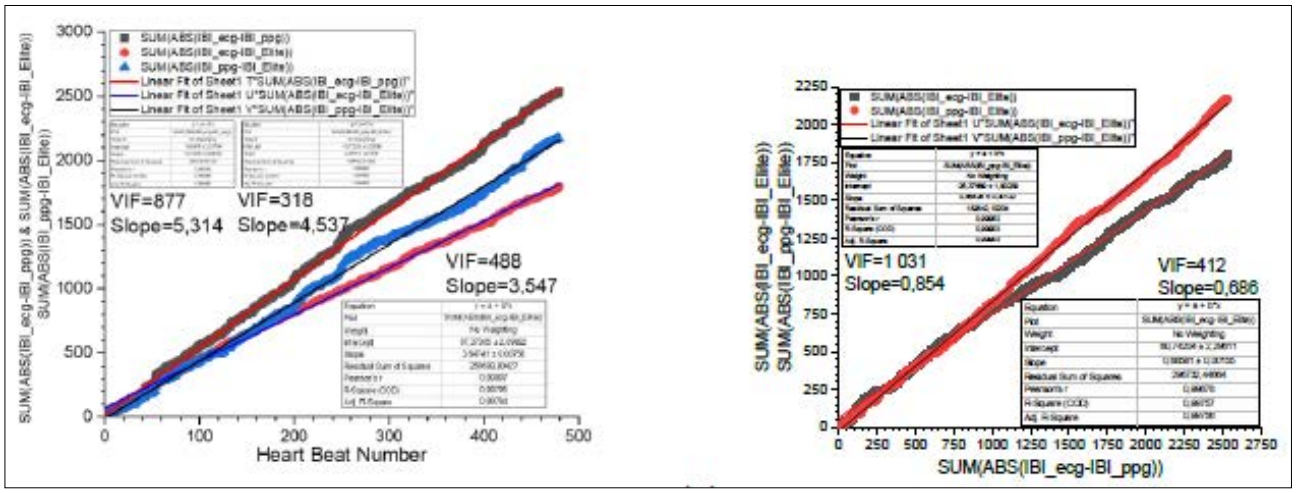
Figure 4: (A) Correlation of the Differences Between IBI_ecg minus IBI_ppg (HRV_ppg, black dots) and IBI_ecg minus IBI_Elite (HRV_Elite, red dots) vs IBI_ecg minus IBI_ppg (HRV_ecg). (B) IBI_Elite and IBI_ppg as a function of IBI_ecg. (Male 28 y of the Figure 1). In the Figure A & B the VIF>100 that means there is good correlation.

Detailed information on the regulatory HRV and variability of HRV parameters will create novel opportunities both for healthy technology intervention and sickness conditions as anemia, ischemia, inflammation, diabetes type II, many heart diseases. The R2 and VIF are statistical measures of the strength of a linear relationship between IBI of ECG vs. IBI of PPG, or IBI of ECG vs. IBI of Elite HRV. In the Figures 5-7 there the data based the ECG, PPG, and Mobile Elite HRV from a heart male patient 68 y, but in the good conditions.



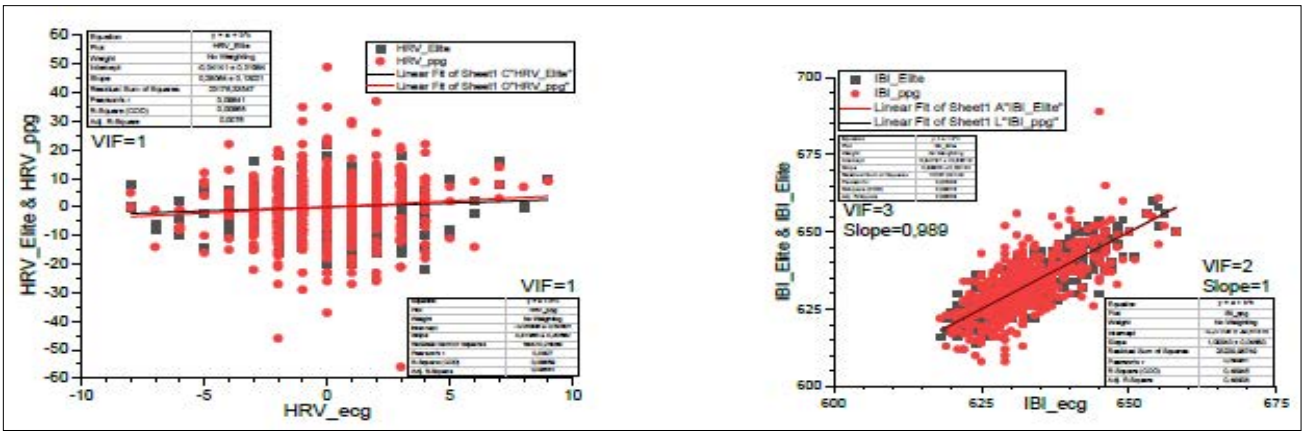
(A) (B) (C)

Figure 5: (A) ECG signal, (B) PPG signal and (C) IBIs for ECG, PPG, and Elite HRV vs Time.



(A) (B)

Figure 6: (A) CUSUM of the Differences Between IBI_ecg minus IBI_ppg (black), IBI_ecg minus IBI_Elite (red), and IBI_ppg minus IBI_Elite (blue) vs heart beat number. (B) Similarly, CUSUM of the differences between IBI_ecg minus IBI_Elite (black) and IBI_ppg minus IBI_Elite (red) vs IBI_ecg minus IBI_ppg. (Male 68 y of the Figure 5).



(A) (B)

Figure 7: (A) Correlation of the differences between IBI_ecg minus IBI_ppg (HRV_ppg, black dots), and IBI_ecg minus IBI_Elite (HRV_Elite, red dots) vs IBI_ecg minus IBI_ppg (HRV_ecg). (B) IBI_Elite and IBI_ppg as a function of IBI_ecg. (Male 68 y of the Figure 5). In the Figure A the VIF=1 that means there is no correlation.

In the Figures 7 there the data much variation based the ECG, PPG, and Mobile Elite HRV from a heart male patient 68 y because of earlier heart vessel operations compared the 28-y male person. However, the heart operated person (68 y) is in the good conditions. The data shown were given by the persons in the mind that it is not used wrongly by their wishes.

References

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