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ADAPTIVE FUZZY RULE BASED PULSEWAVEFORMSEGMENTATION AND ARTIFACT DETECTION

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Abstract

A photoplethysmogram (PPG) is an optically obtained plethysmogram, a volumetric measurement of an organ. A PPG is often obtained by using a pulse oximeter which illuminates the skin and measures changes in light absorption. It is a non-invasive, electro-optical method that provides information about the volume of blood flowing in a test region close to the skin of body. In the proposed method an adaptive fuzzy rule based pulse wave segmentation and artifact detection is used. The existing method had low detection accuracy so to overcomethese problem adaptive fuzzy rule is used. The definition of the fuzzy rule is the single most important and challenging aspect of fuzzy rule its effectiveness is vital to the overall performance. Fuzzy-rule-based modeling has become an active research field in recent years because of its uniquemerits in solving complex nonlinear system identification and control problems. When using a fuzzy model to approximate an unknown system, it is desired that the model include many rules so that it can cover the input–output state space of the system with sufficient patches, yet it is also desired that the model include as few rules as possible because the generalizing ability of the model decreases as the number of rules increases. When we speak here of generalization we are referring to the system's mean performance in terms of approximation accuracy evaluated over some independent test data set. Experimental result show high detection accuracy compared to existing method.

Keywords:

Photoplethysmogram (PPG);
Artifact;
Pattern Recognition;
Medical inference;
Contour Analysis.

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1. Introduction

Respiratory activity is reflected in many cardiovascular signals, such as the heart rate and the arterial pressure, mainly due to intrathoracic pressure changes and autonomic nervous modulation. Photoplethysmography (PPG) is a non-invasive, electro-optical method that provides information about the volume of blood flowing in a test region close to the skin of body.

A. Photoplethysmography

Photoplethysmography is an optical technology. It uses one or more light emitting diodes. It illuminate tissue with different wavelengths. The wavelength is measured by a photodiode. Two modes of operations are transmission mode and reflection mode. Transmission mode where the tissue sample is placed between the source and the detector. Reflection mode where the sensor and detector are placed side-by-side.

B. Photoplethysmogram

Photoplethysmogram can be used to monitor breathing, hypovolemia and other circulatory conditions. Additionally, the shape of the PPG waveform differs from subject to subject, and varies with the location and manner in which the pulse oximeter is attached. A conventional pulse oximeter monitors the perfusion of blood to the dermis and subcutaneous tissue of the skin with each cardiac cycle the heart pumps blood to the periphery. If the pulse oximeter is attached without compressing the skin, a pressure pulse can also be seen from the venous plexus, as a small secondary peak.

C. Previous work

In previous work various algorithms for pulse waveform segmentation and artifact detection in Photoplethysmogramare published. Changes in blood volume in a given region of tissue can be analysed using Photoplethysmogram (PPG) signal and is thus used to determine respiratory rate. Respiratory activity induces respiratory-induced variations in frequency, intensity and amplitude in the PPG signal. The frequency content of each respiratory-induced variation is analysed using fast Fourier transforms and a Smart Fusion method [1] combines the results of the three respiratory-induced variations using a transparent mean calculation. But this method have low detection accuracy.

A novel method based on waveform morphology [4] for detecting artifacts in Photoplethysmography (PPG) signals and thus, improve reliability of PPG. By considering inter-individual and measure condition variability, specific parameters are estimated for each record. Then, to propose a detection method based on Random Distortion Testing (RDT) because it has low performance.

To describe an automated detection algorithm [9] that may be used to identify the percussion peak (P), tidal peak (T), dichrotic notch (N), and dichrotic peak (D) components of the intracranial pressure (ICP) signal. The algorithm uses a moving average filter to remove quantization error, a low pass filter to identify the beat series, and a local search to identify the components of each beat. The disadvantage is highly complex.

Stepwise regression analysis between wave separation analysis [6] and PWA parameters are performed to provide determinants of methodological differences. Against Doppler measurement mean difference and standard deviation of the amplitudes of the decomposed forward and backward pressure waves are comparable for Windkessel and averaged flow models. The results indicate that the Windkessel method provides accurate estimates of wave reflection in subjects with preserved ejection fraction. So the main disadvantage is low performance.

Heart rate variability (HRV) represents one of the most promising such markers. Frequency domain analysis [10] has popularized its use. As many commercial devices now provide automated measurement of HRV, the cardiologist has been provided with a seemingly simple tool for both research and clinical studies. However, the significance and meaning of the many different measures of HRV are more complex and low performance.

A new method for measuring photoplethysmogram (PPG) signals remotely using ambient light and a digital camera that allows for accurate recovery of the waveform morphology. In particular, we show that the peak-to-peak time between the systolic peak and diastolic peak/inflection can be automatically recovered using the second order derivative of the remotely measured waveform by the independent component analysis [7] technique. The main disadvantage of this thechnique is less efficient.

Multi-center pragmatic [5] studies evaluating the time indicator of cardiac perfusion reserve were performed. Related experiments, clinical trials, and surveys were conducted at 5 centers. Results: The results showed that the measurement of D/S ratio is both accurate and precise; the mean values of D/S of all of the 3 species studied (human, rabbit, and rat) were greater than 1. It is highly complex.

To develop a new prediction formula [3] for HRmax through analysis of HRmax measured at VO2peak in a diverse population of 4635 healthy subjects and compare this formula with three commonly used prediction formulas. But in this method the main disadvantage is increased product cost.

Beat-to-beat variation of LVfunction was determined by biplane Simpson's ejection fraction (EF) [8] over 20 beats in 120 patients with chronic AF. The relationship of normalized EF (y) versus the RRp/RRpp ratio (x) were analyzed by the regression equation $y = a + bx$. The relation-slope b describes the steepness of the relationship and is a measure of the sensitivity of LV function to ventricular cycle-length irregularity and it has inaccurate.

An overview of PhysioNet and discusses its benefits to the global community of researchers, clinicians, educators, and students used statistical physics and nonlinear dynamics [2] with examples that include support of exploratory data analysis, development and validation of experimental methods, collaboration among geographically distant investigators, and stimulating rapid progress on specific questions via open research and engineering challenges. It consume more time.

2.System Methodology

Fuzzy-rule-based modeling has become an active research field in recent year becauseof its unique merits in solving complex nonlinear system identification and control problems. Unlike conventional modeling, where a single model is used to describe the global behavior of a system, fuzzy rule-based modeling is essentially a multimodel approach in which individual rules are combined to describe the global behavior of the system.

When using a fuzzy model to approximate an unknown system, it is desired that the model include as many rules as possible so that it can cover the input–output state space of the system with sufficient "patches;" yet it is also desired that the model include as few rules as possible because the generalizing ability of the model decreases as the number of rules increases. When we speak here of generalization we are referring to the system's mean performance in terms of approximation accuracy evaluated over some independent test data set.

The tradeoff between goodness of fit and simplicity is a fundamental principle underlying various general theories of statistical modeling and inductive inference. The definition of the fuzzy rule is the single most important and challenging aspect of fuzzy rule its effectiveness is vital to the overall performance. The method of fuzzy rule is one of the popular solutions for ECG analysis and diagnosis because it uses smooth variables with membership functions for medical inference.

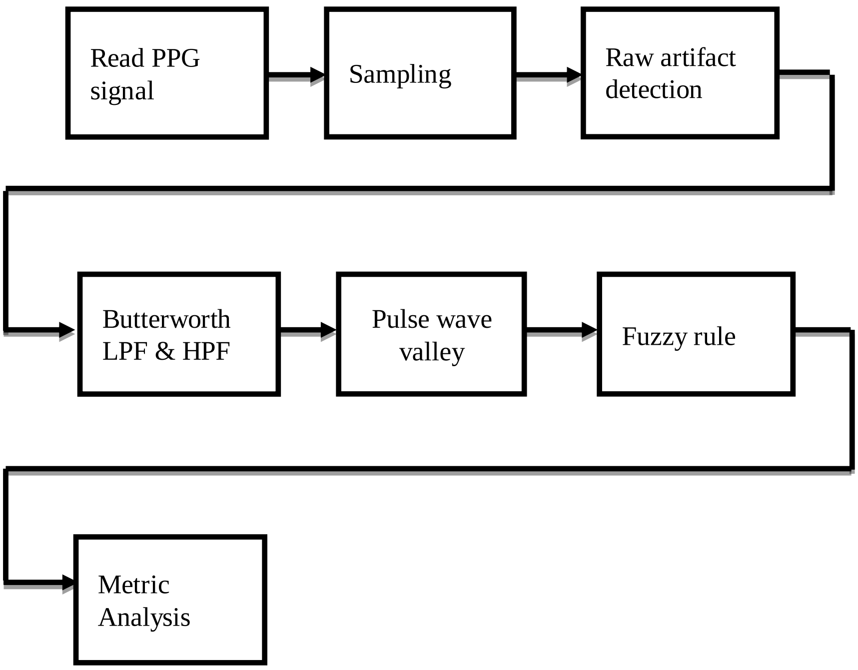

Fig.1. Block diagram of proposed system

A. *Preprocessing*

The first stage with the first decision lists detects clipping values in the raw signal before the proceeding filters alter the signal. The thresholds for top and bottom clipping must be determined only once for each type of recording system because they reflect the signal processing resolutions. These values where derived from the signal channel minimum and maximum. The power spectrum of the PPG consists of frequency components up to 15 Hz with a dominant power range between 6 and 8 Hz. Therefore, the cutoff frequency of the low-pass filter in the second stage was set to 15 Hz in order to remove higher artifact frequencies. To suppress the DC part without removing any information about the autonomic nervous system control of the cardiovascular system, the cutoff frequency of the high-pass filter in the third stage was set to 0.01 Hz.

B. Feature extraction

Then we detect potential valleys and peaks of a pulse wave. Therefore, an adaptive threshold is calculated by applying a moving average filter with a span size of 75 % of the last valid PWD. The value 75 % was chosen after a comparison analysis with 50 % and 100 % based on the development set in order to get a threshold, which better tracks DC changes than 100 % without as much false detection of peak candidates in the presence of strong diastolic peaks as compared to 50 %. Then the absolute maximum is identified as potential pulse wave peak in every part of the signal above this threshold, and the absolute minimum is selected as potential pulse wave valley in every signal part. Thereafter, wrongly detected potential peaks and corresponding valleys belonging to diastolic peaks are discarded by demanding that the vertical distance between them multiplied by a factor must be bigger than the previous valid PWA. The results of these detections are stored synchronously to the filtered PPG ring buffer in the PPG annotation ring buffer.

C. *Artifact detection*

Each time a complete pulse wave is recorded, the fifth stage with the second decision list checks absolute and relative pulse wave characteristics. The remaining checks in the second decision list are intended to prevent pulse wave detection in a pure noise signal or to detect disturbances of the overall pulse waveform. This artifact annotation is also stored synchronously to the filtered PPG ring buffer in the PPG annotation ring buffer. In addition, the sixth stage compares relative changes of the last complete pulse wave (N-1) with the previous pulse wave (N-2). The thresholds for permitted beat-to-beat variation of PWD were set from 33 to 300 % and for PWA from 25 to 400 %, as derived from extreme values reported in literature. This artifact annotation is also stored synchronously to the filtered PPG ring buffer in the PPG annotation ring buffer.

D.Metric analysis

The PWF analysis outputs after each processing loop are the filtered PPG value and its annotations delayed by 4.8 as compared to the corresponding input raw PPG sample value. After the PWF analysis, in a post-processing stage various beat-to-beat metrics like PWA, PWD, and rise time and pulse rate are calculated based on the detected pulse waves. Furthermore, the number of pulse waves during artifacts is estimated in order to determine the true negatives for some performance metrics. For that an average PWD based on the mean duration of the undisturbed pulse wave before and after the artifact is fitted into the artifact area.

E. Algorithm

1. *Butterworth filter*

The Butterworth filter is a type of signal processing filter designed to have as flat a frequency response as possible in the pass band. It is also referred to as a maximally flat magnitude filter. Butterworth had a reputation for solving "impossible" mathematical problems. At the time, filter design required a considerable amount of designer experience due to limitations of the theory then in use. The filter was not in common use for over 30 years after its publication. Butterworth stated that: "An ideal electrical filter should not only completely reject the unwanted frequencies but should also have uniform sensitivity for the wanted frequencies".

2. *Fuzzy rule*

The algorithm is now presented as follows:

Step 1: Convert each training data in the initial training data set into a fuzzy rule and put them into the set of initial rules.

Step 2: If the set of initial rules is empty or all of the fuzzy rules in the set of initial rules have been taken then Stop; else take a fuzzy rule R form the set of initial rules.

Step 3: If the set of definitive rules is empty or all of the fuzzy rules which are in the set of definitive rules that have the same output with fuzzy rule R have attempted to merge with fuzzy rule R then fuzzy rule R becomes one member of the set of definitive rules; else go to Step 4.

Step 4: Take a fuzzy rule R' which has the same output with fuzzy rule R and has not attempted to merge with fuzzy rule R from the set of definitive rules.

If the merge of fuzzy rule R with fuzzy rule R' is allowed then merge them into fuzzy rule R" and replace R' by fuzzy rule R", and go to Step 2 else go to Step 3.

3. Results and Analysis

The Figure 2 shows the input PPG signal which is taken using the photopletyhsmography technique.For the segmentation purpose the PPG signal was partially extracted.It uses one or more light emitting diodes. Two modes of operation exist transmission mode where the tissue sample is placed between the source and the detector (e.g., fingertip) and reflection mode where the sensor and detector are placed side-by-side (e.g., forehead).

The power spectrum of the PPG consists of frequency components up to 15 Hz with a dominant power range between 6 and 8 Hz. Therefore, the cutoff frequency of the low-pass filter in the second stage was set to 15 Hz in order to remove higher artifact frequencies. To suppress the DC part without removing any information about the autonomic nervous system control of the cardiovascular system, the cutoff frequency of the high-pass filter in the third stage was set to 0.01 Hz.

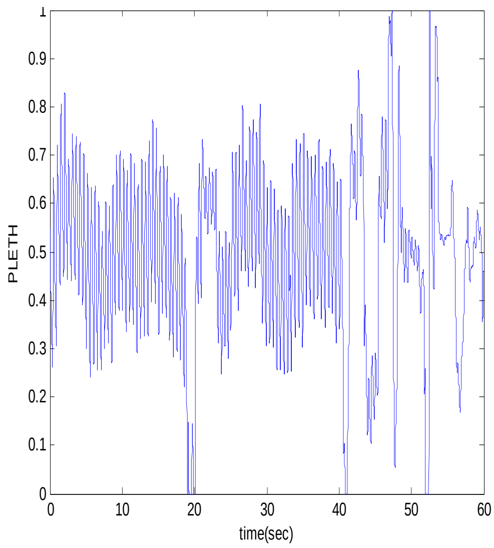

Fig 2: Input PPG Signal

Then the PPG signal undergoes 4thorder low pass Butterworth. Because other filter model is more complicated compared to that of a 4t h order. In this the sampling techniqueis used. This technique mainly used to sample the signal between the magnitude, phase and the normalized frequency. The power spectrum of the PPG consists of frequency components up to 15 Hz with a dominant power range between 6 and 8 Hz. Therefore, the cutoff frequency of the low-pass filter in the second stage was set to 15 Hz in order to remove higher artifact frequencies (e.g., power line interference). The low pass filter mainly used to filter the low power noise.

Then to suppress the DC part without removing any information about the autonomic nervous system control of the cardiovascular system, the cutoff frequency of the high-pass filter in the third stage was set to 0.01 Hz. To apply the low pass filter high interference are affected by the signal. So the high pass filter is used to remove the high interference.

A membership function of a fuzzy set is a generalization of the indicator function in classical sets. In fuzzy logic, it represents the degree of truth as an extension of valuation. The PWRT value is apply to the fuzzy logic and find the threshold value.

A set of membership degrees can be thought of as membership functions mapping predicates into fuzzy sets more formally, into an ordered set of fuzzy pairs, called fuzzy relation with these valuation, many valued logic can be extended to allow for fuzzy premises from which graded conclusion may be drawn. The SD ratio value is apply to fuzzy logic and fine the threshold value.

Thecombination of PWRT and SD ratio value is send to the fuzzy logic and determine the corresponding threshold value. In existing method all parameters have the particular threshold and find the artifact but, in proposed method only the PWRT and the SD ratio values are applied to the fuzzy rule and find the threshold value. Then these threshold value determine the artifact.

Figure 3, shows the artifact detection for existing and proposed method. The red box shows the proposed method and it detect the artifact as early as possible comparing to the existing method which is shown using green box.

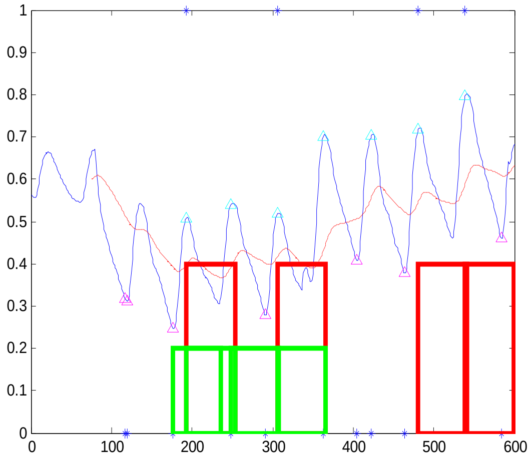

Fig 3 : Artifact detection from the PPG signal

After the artifact detection the metric analysis of pulse wave amplitude is takes place. The different environments, in the manually annotated validation and reference set the observed pulse wave characteristics varied for all cohorts within the threshold values taken from the PWA to diastolic peak factor.

Then to determine the metric analysis of pulse wave ratio. Improve the storage and data transfer of the PPG by compressing the signal to relevant points of interest. Pulse rate and the sampling rate can be reduced from the fix sample rate. The data compression ratio and the space saving are sampled to the threshold values.

To determine the metric analysis of systolic/diastolic ratio, they use the artery that compares the systolic with the diastolic flow and the amount of resistance in the respiratory system.Then to determine the metric analysis of pulse wave duration,the recording of an undisturbed pulse wave or at most two times the maximal permitted pulse wave duration, which is similar to expert interpretation of such pulse waves. In most online setups in which a user views the data on a screen in near real -time, this delay is also negligible as long as the annotations are displayed at the correct position in time.

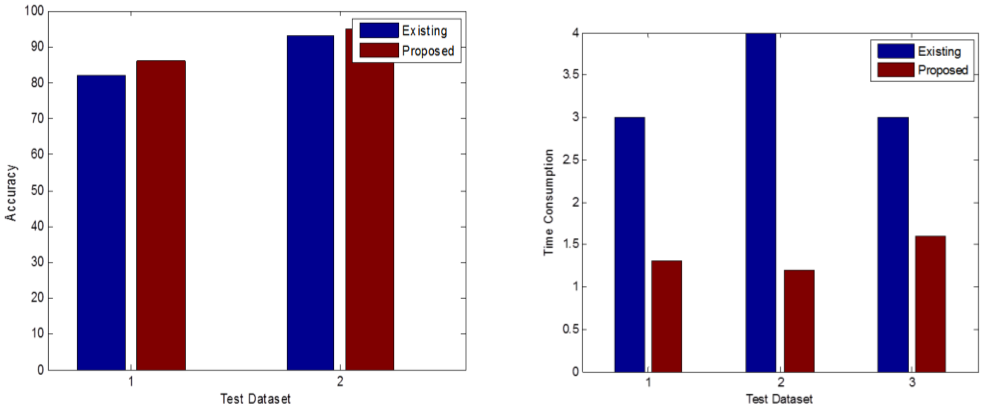

Fig 4 : Comparison chart For Accuracy and Time Consumption

The Comparison chart in Figure 4 shows the detection accuracy is very high and time consumption is low for the proposed system. So the proposed system is more efficient comparing to the existing method.

4. Conclusion

We have presented a new algorithm for segmentation of PPG waveform into pulses and the automatic classification of artifacts. The adaptive fuzzy rule algorithm is iterative and can be easily implemented for real-time applications. It operates in the time-domain only and can be configured with a single parameter m which adjusts the segment size. The adaptive fuzzy rule algorithm computes faster and is less sensitive to noise with larger m, but the pulse peak detection is less precise in temporal space. A comparison with the CSL Reference algorithm shows comparable performance in detecting normal pulses. Since the CSL Reference algorithm was not designed for labeling artifacts a direct comparison for this task cannot be made. Whereas the CSL experts only annotated peaks that were clearly identifiable as such (a clipped pulse peak would not be marked as peak, but a pulse with a clipped base was marked), the third expert was more conservative and marked all artifact zones.

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