A DETAILED OVERVIEW OF DEVELOPMENTS AND FUTURE CHALLENGES IN THE FIELD OF ECG ANALYSIS

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Abstract:
Heart diseases are increasing and Electrocardiogram (ECG) signal plays critical role while analysing problems related to heart. In this paper, current accomplishments in the field of ECG analysis using computer software and their applicability in the real world is presented. The current work in this field covers the problems of noise removal from the raw ECG Signal, detecting rhythm-based analysis and pulsations. Improvements have been made in the identification and beat classification of ECG segments but tests in this area are limited. This paper presents progression in ECG analysis using computer software until the present day and this paper also covers forthcoming challenges with regards to ECG signal anatomy. This paper concludes perceived gaps in existing progressions and future research challenges.

Keywords: ECG analysis, Noise removal, Feature Extraction.

Introduction:

ECG tools are used for capturing the information on heart beats but different types of noise, such as EMG interference, motion artifacts, baseline wander noise, 50 or 60 Hz power line interference can corrupt the electrocardiogram (ECG) signal. For diagnosis, the ECG signal embedded in these noises is very difficult to interpret correctly. Therefore, digital software filters are typically used in biomedical signal processing to minimise and eliminate noise. Noise may be handled by analog filters, but they incorporate nonlinear phase shifts and rely on instruments such as resistance, temperature and design. Digital filters are much more reliable and fault-less with more benefits over analog filters.

A lot of research work is ongoing in ECG analysis domain, many advancements in the field of noise removal techniques has been done already, QRS discovery techniques and heart rate variability (HRV) analysis of ECG Analysis. As researchers are working towards making powerful and precise algorithms, gaps are also emerging between those algorithms and testing methodology. This paper presents upgradations happened in recent times in noise removal techniques and QRS detection techniques, future challenges in the area of ECG analysis are also discussed in this paper.

Objectives:

1) To compare the different noise removal techniques and QRS detection techniques available in the discipline of ECG analysis.
2) To discuss the current accomplishments in the area of ECG analysis using computer software and their applicability in the real world.

Electrocardiogram Explained:

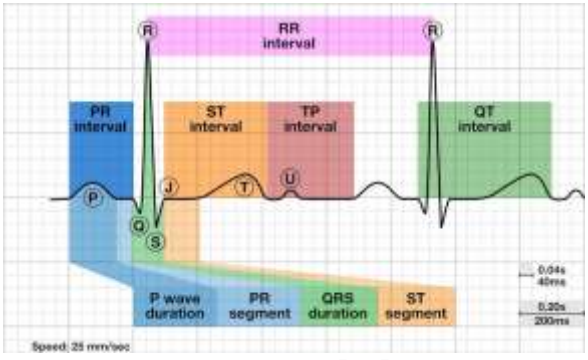

Figure:1 – [26]

The ECG is a linear graphical reporting of the electrical momentum that originate in the heart throughout the cardiac cycle. The electrical impulses are determined on the skin using electrodes. That shows the overall rhythm and heart irregularities.

The heart creates minute, electrical impulses that proliferate within the heart's muscle to cause heart contractions. ECG machine understands these impulses and in turn these impulses are named as - P, Q, R, S and T waves. The foremost wave is P wave that is a short upward wave in the ECG tracing. The QRS complex wave which starts with a downward arc, Q; a bigger upwards arc, R; a peak and S; a downwards wave. The interval in PR wave indicates the transit time from the sinus node to the ventricles of the electrical signal. A moderately inclined waveform is the T wave. The shape, orientation and time intervals between these waveforms represent the activities taking place in the heart and the nervous system. Though today there are enormous advanced types of equipment's available for diagnosis of heart-related problems, still ECG is the first step taken by cardiologists. The figure given below shows the standard ECG signal.

Developments

Comparing Noise removal techniques:

Noise removal in ECG analysis is the first step because an ECG signal becomes contaminated by different forms of noise and artifacts [16] for instance Power line interference, Electrode contact noise, Motion artifacts, Muscle contraction etc. These artifacts or noises are present within the frequency range (0.5 Hz-100Hz) of ECG signal and while recording the ECG Signal these noises are also captured. ECG data makes the valuable information difficult to obtain because of the noise present in it, therefore, noise removal is an important and necessary step.

In this area, innovations cover the use of digital filters, for instance, Infinite Impulse Response (IIR) and Finite Impulse Response (FIR).

In [16] **digital filtering technique** is introduced and this techniques is used to minimise noise associated with the raw ECG signal. The paper discusses **Butterworth IIR filter** and **type1 FIR filters** as well. And both the filters applied were able to reduce the high and low-frequency noise.

In [14] it is suggested that **FIR filters** are preferable as they have linear phase property, but they require higher order filters as well. **IIR filters** needs less filter orders as compared to FIR filters and based on hardware's complexity and cost of computation, IIR filters can be selected. It is also proposed that adaptive digital filtres with improved performance may be considered for noise tracking.

In [13] **Kaiser window FIR filter** was used to eliminate ECG signal's noise. The Kaiser window-based low pass filter was designed to eliminate noise which has high-frequency such as EEG, researchers also designed a high pass filter to eliminate noise which has low-frequency such as baseline wander and researchers also designed a notch filter to eliminate power line frequency noise from ECG signal. In the work, all these filters were also cascaded and the performance was analysed. And with the cascading design devoid of distortion and noises were produced.

In [12] researcher has investigated the improvement of the raw signal by using various **window-based FIR filter** and the performance was measured through **SNR and Correlation coefficient**. Analysis was also performed to study noise effect on the ECG signal. The use of FIR filter with Kaiser Window was suggested which gave excellent results in removing noise from ECG signal.

In [21] an elliptical digital noise reduction filter was developed for ECG Signals, and it was observed that this filter works well when contrasted with chebyshev type I & type II filters and butterworth.

Comparing QRS Detection techniques:

The next step in the process of ECG analysis is the feature extraction so that abnormalities can be detected, and further medication can be given to the patient. And in the area of feature extraction following advancements has been made.

In [10] ability of a **simple neural network** to classify multiple discreet pathologic ECG's into four different classes is investigated. A holistic approach is taken and each signal is viewed as an integrated entity and not as a collection of discrete waves, therefore a sample neural network is

created with several sample vectors that represents signal. This paper explains the pattern recognition as a four-step process:

1) The first step is pre-processing where wide range of ECG signals are collected having different abnormalities.
2) The second step is QRS detection.
3) Third step is feature extraction.
4) The fourth step is signal classification.

This paper also explains the ECG system as a combination of P, QRS and T wave, segments and intervals.

In [3] **artificial neural network** and **wavelet transform** are used as well as new method is recommended for categorization of ECG arrhythmias (abnormal rate of muscle contraction in the heart). Two steps, feature extraction and classification, are included in this process. Using discrete wavelet transformation (DWT), the feature values are extracted for each arrhythmia in the feature extraction step. In the classification process, the features obtained are used as input for ECG arrhythmia's categorization into the artificial neural network. And it is concluded that Artificial neural network is an important tool for decision support systems.

In [4] **MLP, RCE and a novel hybrid neural network** are compared where MLP is **multi-layer perceptron and RCE is restricted Coulomb energy** and it is noted that if numerous beat classes are expanded then analysis of ECG signals can be enhanced, But as the class set increases class separation efficiency decreases. Hence to increase the number of class categories and class separation efficiency, a neural network structure and a wavelet transformation-based feature extraction process is created.

In [2] **pattern recognition** on ECG is done in two parts i.e Feature extraction utilizing discreet wavelet transform and classification using neural networks. Discrete wavelet transform method is used so that the signal can be represented in a multiresolution structure. And neural networks were used for their ability to generalize. As the **proposed method is fast and easy** to implement it is a suitable tool for automatic pattern recognition in ECG time series in clinical practices. The paper shows the importance of the choice of wavelet transform function and an optimal design of network. For ECG recognition task the first task is to **classify the various waves** present in ECG that are P, QRS and T waves and after classification **parameters in these waves are measured**.

In [19] current trends on non linear transformations on ECG pattern recognition, use of **techniques based on neural networks and principal component analysis** on ECG pattern recognition and classification are reviewed. The methods presented do not employ any inference point other than R wave. Usage of digital filtering techniques is also avoided so that ECG components can be saved from any corruption. The methods presented in this paper worked on file to file basis. The paper discusses about the different approaches that are used for pattern recognition on ECG. The approaches are: **Syntactic or structural matching, Statistical classification**, **Template Matching** and **neural network**. The easiest approach is ***Template matching*** in which test samples and templates are compared so that the differences and similarities in terms of curves, points and other services between two entities could be given. ***Statistical classification*** approach is most rigorously studied and used . In this approach data is categorized in groups according to some features. In ***structural matching*** human perception and cognition is used of pattern recognition. The issue of identifying complex patterns of arbitrary orientation, scale and location is solved by the **neural network method.**

Upcoming Challenges:

Despite very sophisticated and quick heartbeat detectors and even recent ECG analysis findings, there is little use of those algorithms in clinical practice. Here we will try to classify problems relating to medicine.

P Wave and T Wave

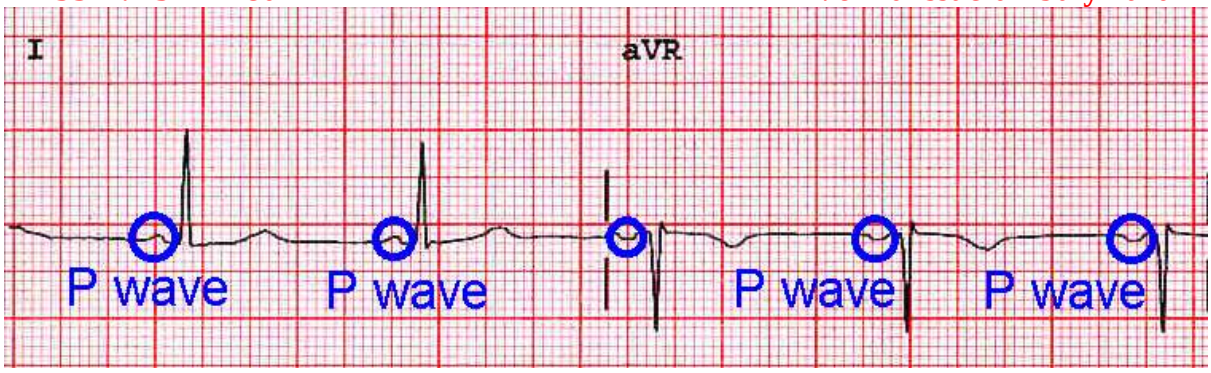

Figure 2- [25]

Analysis of the ECG's P wave is important because certain pathological conditions can significantly alter their shape and length.

Number of techniques has been identified by researchers to detect P and T waves., in the attempts done by researchers both the waves were recognised reliably at same time, but their classification relied heavily on an unverified assumption of the priori model. In addition, the method adopted has a high overhead in computation as well[21].

In [22] A template-based correlation approach on Physionet QT repository was tested. The authors reported that estimation variability was higher while the signal quality was low, thereby showing the lack of robustness of the noisy signalling method.

As a result of signal filtration P wave's attenuation and amplitude becomes small and this creates a problem in its detection and classification. But, since P wave is helpful in detecting many atrial problems it has clinical importance in the ECG diagnosis process. This importance of P wave is not just only because of its frequency of occurrence but also because of its structure.

Most algorithms discussed in the literature independently recognise either P or T waves. There have been enormous attempts by researchers to search a satisfactory global system to detect P and T waves. In addition, after eliminating some segments or beats from the records used, most algorithms showed good results in P and T wave recognition at high rates. Many problems in the detection process arise largely due to the dissimilarity of T and P waves, artifacts accompanying ECG's signals and minimal signal-to-noise ratio (SNR) [23], particularly in presence of arrhythmia [24].

Pathological changes in T wave are critical as well in diagnosis of pathologic states. Distinct patterns of T wave can give a hint towards the complication with beat's origin and re-polarization concern because of branch block. Based on the P wave's visibility and thinness of QRS wave, normal or abnormal T wave's pattern can reveal heart blockage issues and other difficulties can be revealed by inverted T wave.

Multi-Lead Analysis

Experienced cardiologist can diagnose the problems in the heart muscle as well as the section of the heart which is affected by analysing the morphological features of the Electrocardiogram (ECG). An experienced cardiologist can also detect the problem's source. Therefore ECG can be looked upon as a fast and low cost device for the initial examination process. For vast range of pathology identifications Multi lead analysis is a decisive.

Individual Adjustments

In computer assisted ECG analysis there is one more challenge that Electrocardiogram (ECG) is treated as a biometric characteristic that means that each and every individual has a distinct ECG signature. ECG demonstration is similar for most of the population but there are some people for whom there are significant deviations in ECG graph.

Conclusion:

The Electrocardiogram is a quick and low cost device for the initial analysis of potentially fatal cardiac pathology. Complexity of ECG curve confuses computer programmers in discovering the best analytical model to outline the exact cardiac cycle's working and this is the reason behind less

number of software solutions available for analysing ECG, which can be compared to clinical decisions given by doctors. Any novel representation is helpful in characterizing ECG curve for prospective developments of improved software programs for ECG study, which can be used for ECG machines as well as in many devices related to cardiology such as monitors and pacemakers. The new softwares can also be used for understanding the ECG in numerous clinical conditions. Some of the techniques for noise filtering which are available currently are: **digital filtering techniques** which include FIR, IIR filters and Elliptical digital filters. These filters are sometimes used in conjunction with different techniques such as Kaiser window, SNR and correlation coefficient to remove the most of the noise that disturbs the ECG signal.

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