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ECG Viewed using Grayscale Patterns

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***Abstract*—The paper forms a precursor to future research which blends signal processing and image processing for the application of biomedical signals interpretation, especially on ECG signal. The work emphasizes on relating the one dimensional (1D) ECG signal to two-dimensional (2D) grayscale patterns based on vertical amplitude surge. This work investigates on the computation (the interpretation) of 1D ECG in order for it to display in the form of 2D-Grayscale by using moving-average windowing technique using various setting of window sizes.**

Keywords- ECG, Moving Average, Time Series, Grayscale mapping.

I. INTRODUCTION

Heart is an important organ of the human body which should be taken care attentively by consulting the medical doctor in case of any symptoms occurs. Recently, the heart disease has killed so many human lives with difference types of heart diseases have been discovered. Due to these problems, scientists have developed several solutions to easily check and diagnose these serious diseases. by inventing several equipments for checking the heart in which the Electrocardiograph (ECG) machine was invented to diagnose the heart related disease. The function of the ECG machine is to display the heart pulse in a specific waveform.. The ECG waveform contains a lot of useful information related to the functioning of heart where from the ECG waveform, it allows the medical doctor to translate the heart related disease of the patient offline, that after collecting and processing the signal using various available machine learning technique [1].

This paper will look into an initial or preliminary work on how to translate the ECG signal to 2D grayscale pattern based on instantaneous sliding widow time series of data. The paper investigates future research which blends signal processing and image processing for the application of biomedical signal, especially on ECG signal. The work emphasizes on relating the one dimensional ECG signal to two-dimensional grayscale model based on vertical and in amplitude.

The paper is organized as follows, section II looks into standard ECG features, while section III look into the conventional feature extraction used for ECG signals and the new technique used in this paper. Section IV explained on the 2D conversion being used. Section V depicts and explain on the simulation results and finally the section VI concludes the paper and gives the future direction of the work.

II. STANDARD ECG FEATURES

The ECG is the electrical signal which describes contractile activity of the heart, and is recorded commonly with surface electrodes on the limbs or chest. The ECG is perhaps the most commonly well known and used biomedical signal due to its importance. The rhythm of the heart in terms of beats per minutes may be estimated by counting the readily identifiable waves. More important is the fact that the ECG wave shape is altered by various cardiovascular diseases and abnormalities such as myocardial ischemia and infarction, ventricular hypertrophy, and many more.

Due to poor medical knowledge, people are unable to interpret the result of the heart pulse, thus ECG is being adopted for the medical doctor to ease the diagnostics procedure. The medical doctor is able to interpret this signal according to the knowledge and experiences gain overtime. ECG was invented in term of signal waveform which is difficult to explain accurately. The interpretation of this waveform might not be exactly correct which leads to some human errors in interpreting the waveform due to the scale or the vibration of the waveform during the interpretation process.

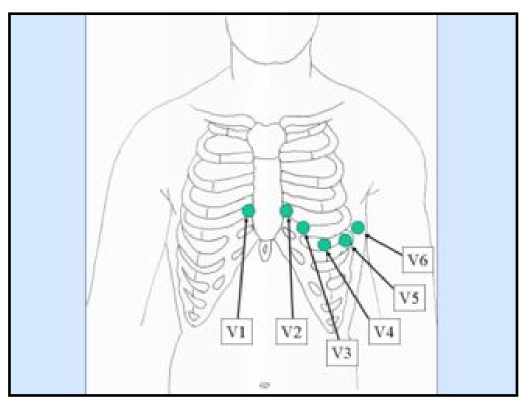


Fig 1. Location of the difference ECG lead sensors [2]

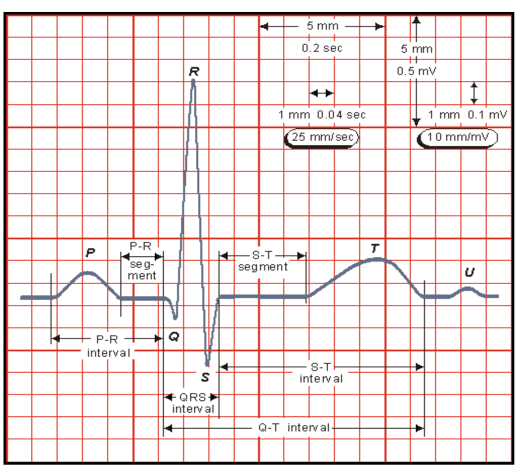
Electrocardiograms (ECG) are signals representing the cyclical contractions and relaxation of thuman heart muscles, by which blood is pumped to the whole body. The heart muscle activity is controlled and synchronized by electrical pulses transmitted via vast network of nerves. The electrical pulses are quite strong enough and can be sensed by electrodes placed on the human skin [2].

ECG is obtained by sampling the electrical current readings sensed by these electrodes, known as *leads*. Lead commonly defines as either the wire that connects an electrode to the electrocardiograph, or to a combination of electrodes in the body along which the electrical signals are measured. It records the electrical signals of the heart from a particular combination of recording electrodes which are placed at specific points on the patient's body [3], which is shown in Figure 1

Figure 2 shows an idealized pattern of one cardiac cycles which the ECGs as the combination of several components such as:

- P wave: the sequential activation (depolarization) of the right and left atria
- QRS complex: right and left ventricular depolarization (normally the ventricles are activated simultaneously)
- ST-T wave: ventricular depolarization
- U wave: origin for this wave is not clear, but probably represents "after depolarization" in the ventricles
- PR interval: time interval from onset of atrial depolarization (P wave) to onset of ventricular depolarization (QRS complex)
- QRS duration: duration of ventricular muscle depolarization
- QT interval: duration of ventricular depolarization and repolarization
- RR interval: duration of ventricular cardiac cycle (an indicator of ventricular rate)
- PP interval: duration of atrial cycle (an indicator of atrial rate)

Fig 2:



Idealized pattern of one cardiac cycle

(Source by Jon Barron, Secret of the Heart Newsletter, 2007)

The ECG tool is able to display only in from of waveform harmonics where the commonly medical staffs are unable to read in detail the signal according to the periodic wave but normally able to have the rough insight on certain harmonic patterns. This may lead to problem for real time diagnostics for the patient who are suffering from heart diseases when comes to appropriate treatments. Since most medical practitioner also look for abnormal signs in the ECG harmonics, there should be a better solutions in conquering this problem. One of the possible remedy to is to transform the ECG waveform to display on 2D-Grayscale screen or some form of patterns. Two dimensional (2D) grayscale will display the effect of the ECG time series signal to in the form of patterns. The next section will looking onto the feature extraction of ECG signals.

III. ECG Feature Extraction

Extraction of various parameters or features is of paramount importance in automatic ECG signal classification. The ECG signals parameters are extracted from the QRS complex and the ST segment in order to model the periodic properties of its various cycle [4]. The following features have been demonstrated which is described next,

A. QRS Feature Extraction

The QRS complex duration is important parameter employed in the analysis and classification of the ECG signal. It is defined as the time taken for depolarization of the ventricles in the heart. Normal depolarization requires normal functioning of right and left bundle branches inside the heart muscle. It varies from 0.04 to 0.09 seconds. In abnormal cases, the QRS interval is 0.1 seconds or more. The PR interval is another useful feature representing time lag from the start of atrial depolarization to the start of ventricular depolarization and allows atrial systole to occur. The normal PR interval is varied 0.12 to 0.20.

To measure the QRS duration, two steps were taken. First, the area under the QRS complex was calculated, and then by assuming this area is a triangular shape, the following equation is used to calculate the QRS duration:

QRS duration = 2 x (area under the QRS complex)/(R-wave amplitude) (1)

The R-wave amplitude and the area under QRS complex are in direct relationship. Therefore, the product of the R-wave amplitude and the area under the QRS complex was selected as a powerful feature for cardiac arrhythmia classification.

B. ST Feature Extraction

Features extracted from the ST segment: Two important features can be extracted from ST segment namely: level and slope of the ST segment. The ST level is determined by the maximum deviation from the isoelectric level of ECG signal. The isoelectric level is determined between the offset of the P and Q-wave respectively. The slope of the ST segment is determined by difference between the amplitude of the starting point to its the ending point.

Most of the feature extraction of ECG signal involves extraction of each component of ECG signal, commonly using Fourier or wavelet Analysis. The next section will explains a method to manipulate ECG signal by vertical surge and only looking into time series properties of the signal (commonly looking into the frequency response in most literature) [5].

C. New Concept of Time Series Averaging

One of the most important parameters in statistical feature extraction process is the expectation vector or mean of a random vector. Two distinct types of mean are used, short and long term time moving averaging with auto covariance.

The moving time average is calculated on an actual 1)
physical realization of a random process. The mean of a time 2)
series with data *x*(n) is defined:

$$E\left[x(n)\right] = M = \frac{1}{N}\sum_{n=0}^{N-1} x_n \qquad (1)$$

Where E is expectation and N is the number of data points which is viewed as discrete sampling process. In this work, a nine (9) set window sizes being adopted to as a moving average window to calculate the sliding window of ECG data/

The theoretical way of calculating average uses the probability density function at some given instant of time. The mean of x(n) is defined as:

$$E\left[x(n)\right] = M = \int x p(x) dx \qquad (2)$$

where p(x) is the probability density function of the data.

Another statistical attribute being used is to compute the auto covariance measure. This important measure of covariance matrix which indicates the dispersion of the distribution. The frequency-domain equivalence is called power spectrum of the original signal and can be applied to the classification of cardiac arrhythmia problem. The operation of convolution in the time domain is similar to that of correlation or more specifically the calculation of cross covariance and hence, the autocorrelation function and the power density spectrum are Fourier transforms of each other.

The classification aspect of ECG signal recognition can be immediately obtained by simply identifying the highest cross correlation between a set of stored templates and unknown ECG signal.

The variance x(n) is defined by:

$$\mathrm{var}\left[x(n)\right] = \sum = E\{[x(n) - M^{2}]\} \qquad (3)$$

The autocovariance of x(n) is defined by:

$$C(m) = \sum = E\{[x(n) - M][x(n+m) - M]\} \qquad (4)$$

The correlation coefficients can be used in place of the autocorrelation to classify the selected ECG beats. By taking the covariance of vector of the various means of ECG signals (normalized), each covariance matrix element represents the strength of correlation between means of ECG signals with varying window sizes.

IV. GRAYSCALE CONVERSION PROCEDURES

The ECGs signal interpretation to grayscale involves three (3) stages which will be describes as follows [6][7],

Step 1: Calculate the Difference ECGs

This step will look check the variation of the signal amplitude for each time instant (epoch) of the signal. The change in amplitude allows us to check some hidden attribute of the signals. After calculating the difference ECGs, the positive value of the difference is calculated by using the absolute sign to the obtained difference ECG. Difference ECGs and absolute difference ECG provide basic information for step two (2).

Step 2: Calculate the Mean of the signal

As describe in equation (1), mean of the signal provides the information on how the signal is fluctuated. This implementation provides us the calculation of the mean for three difference signals namely: Mean of ECGs (MECG), Mean Difference of ECGs (MD), and Mean Absolute Difference of ECGs (MAD). These three means value signal provide a lot of information for ECGs interpretation. The means have been calculated for different window size to obtained more accurate information for ECGs interpretation in this case there are nine (9) different window size. This next step provides a very useful result for performing grayscale conversion.

Step3: Performing the Grayscale conversion

After completing calculating the means of signals, grayscale conversion can be implemented with ease. To perform this task, a 9x9 grouped pixel matrix is set as a display for converting ECG to patterns. From step two, nine window sizes, which in vector form can form a 9x9 covariance matrix which in results allows to establish a 9x9 matrix 2D grayscale mapping.

Figure 3 show the three (3) grayscale conversion steps and Figure 4 show the signal being derived from the procedural step describe above for window size n = 4.

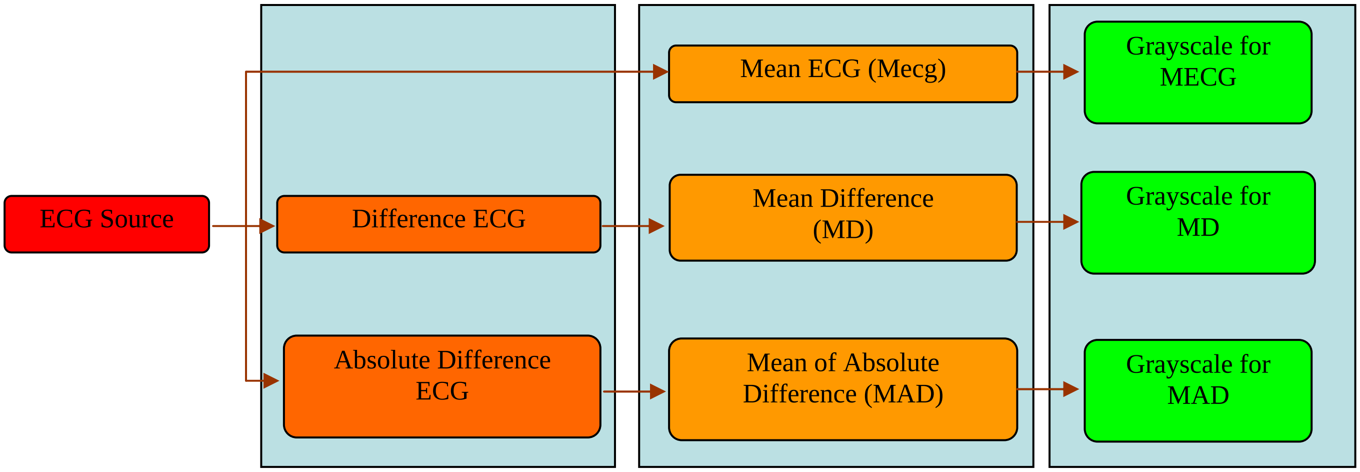


Fig 3. Three Segments of Classification for ECG Signal

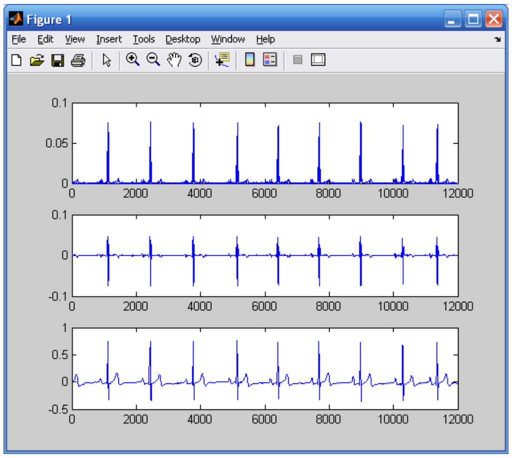


Fig 4. Absolute difference, Difference and ECG signal for Window Size n = 4.

V. Results And Discussion

Simulation results on pattern form ECG showed in Figure 5 which described the mean ECG, mean difference ECG and absolute difference ECG (Figure (a)-(c)) for various window size (nine window sizes). Using the nine window nine moving average windows, three normalized covariance matrix are formed (respectively representing mean ECG, difference in ECG and absolute difference ECG) to form three grayscale patterns as depicted in Figure 5 (d)-(f). There is a similarity on the pattern for row versus column due to the symmetrical properties of auto-covariance matrix computed.

From the grayscale patterns yield (Figure 5 (d)-(f)), which is derived from healthy or normal patience ECG signal, there is a periodic pattern observe as shown by the green line over those figures. This shows continuous and typical QRS segment being observed over various size of moving average windows. Figure 5 (g) shows a patience with *Ventricular Arrhythmia* heart condition and it can be observe there is a irregular or random pattern being observed.

VI. Conclusion And Future Work

The algorithm of translating ECGs to grayscale mapping has been studied in order to view pattern from a one dimensional ECG signal. The objectives of the study are to find better portrayal of ECG from time series to grayscale mapping. The variation of the signals amplitude of each time sample has been observed by calculating (for varying window size) the means value of the ECG signals, the difference of ECGs means of, and absolute difference of ECG. These information are fed in order to calculated in order to perform 2D-Grayscale transformation by using 9x9 grid matrix pixel group manipulation (using covariance matrix).

Future work will look into horizontal displacement for ECG signals and possible adopting RGB colour components in order to display in colour form of matrix patterns.

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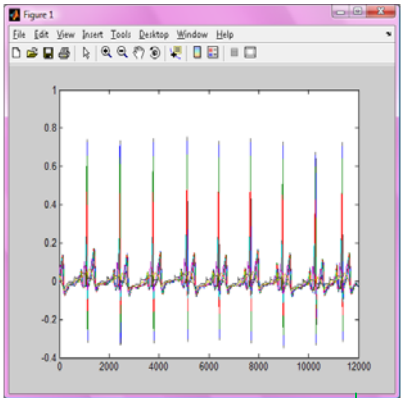
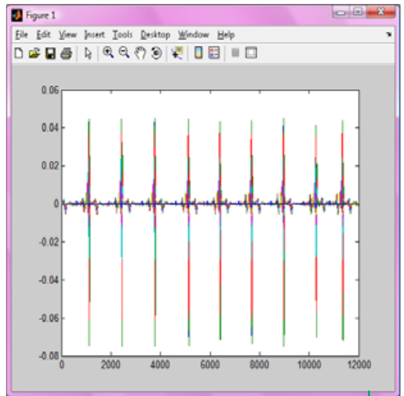
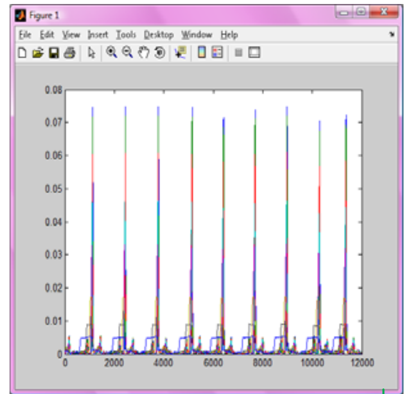


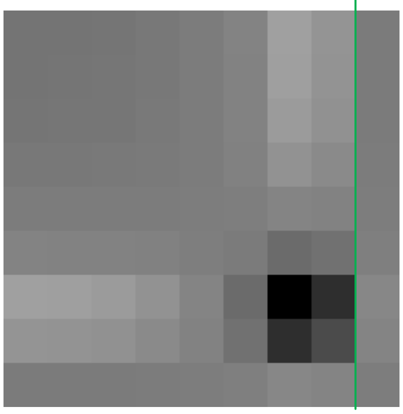
(a) Mean ECG



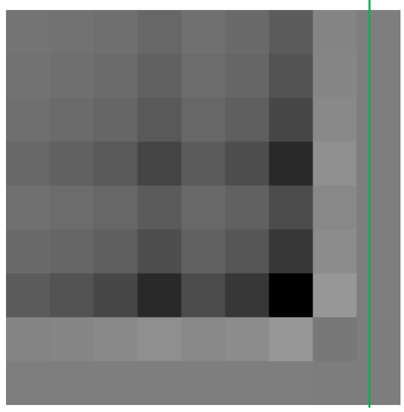
(b) Difference Mean



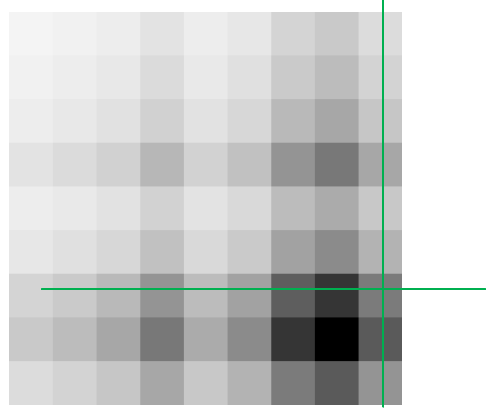
(c) Absolute Difference Mean



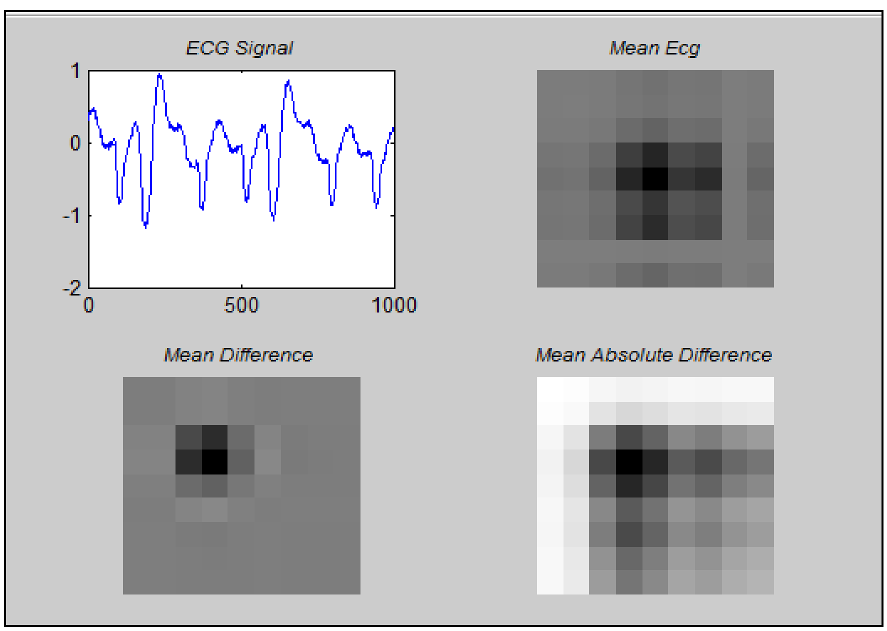
(d) Mean ECG



(e) Difference Mean



(f) Absolute Difference Mean



(g) Malignant Ventricular Arrhythmia ECG signal, Mean ECG, Mean difference and Mean Absolute Difference.

Fig.5 Two (2D) Grayscale Patterns yield from various form one dimensional ECG signals