International Journal of Trend in Research and Development, Volume 3(1), ISSN: 2394-9333
www.ijtrd.com

The Explanation of Matlab Simulations of Published Biomedical Engineering Papers

Virtyt Lesha,
Department of Electronics and Telecommunications, Polytechnic University of Tirana, Shkoder, Albania

Abstract **-** The digital image processing consists in using mathematical operations of any form of signal processing in general where the input is an image of an object such as: a photo, a video capture or a set of parameters related to the image. As a concept, an image can be defined as a two-dimensional function f(x, y), where x and y are plane coordinates and f is the amplitude of the pair of coordinates (x, y) and it is called the intensity of the image at that point.

In this paper we have treated the digitalization of medical images with the objective of using them for further processing. The work in this paper consists, in general, in the explanation of the recognition of some certain useful parameters at the image of generated to detect the early-re-polarization in standard 12-lead electrocardiography.

The work is divided in two processes that constitute in the explanation of developing two algorithms: the detection algorithm of the status of the early-re-polarization at the image that is going to be scanned (ER positive/negative); in case of being ER-positive the next algorithm is applied to classify the type of the ER-positive: notch/discrete type, slurred type and finally the indeterminate type. The algorithms developed are designed to achieve well defined results of accuracy.

The paper treats a theoretical overview of the biomedical image processing. Second at the methodology section, we have described in detail the two algorithms. Then, the results forecasted according the directions are treated and finally we have given suggestions, limitations and the conclusions of our work.

Keywords: *Image, Early-Re-Polarization, Algorithm, Detection, Classify*

I. INTRODUCTION

A. *Overview of the theoretical concepts of digital image processing*

The identification of the image is a process that consists in several sub process attached to each other and that are executed according to a well-defined order [8]. Identifying the image is finding through a certain algorithm to determine which parameters defined in the directives are actually present at the image in question.

To achieve the desired results the signal, at the entrance of the system, needs to pass in the process of conversion from analog signal to digital signal. Below, in figure 1 we have shown the schematic blocks that enables conversion from analog to digital signals.

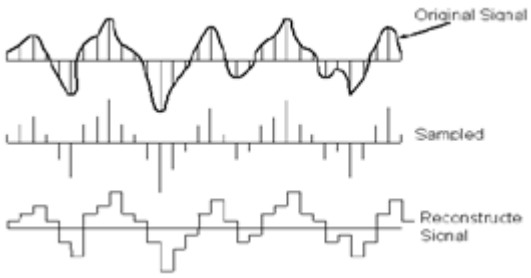

Figure 1: The schematic blocks showing the modules that enable the conversion of analog to digital signal

In figure 2 we have shown the respective charts of the analog, the sampled and quantized signal.

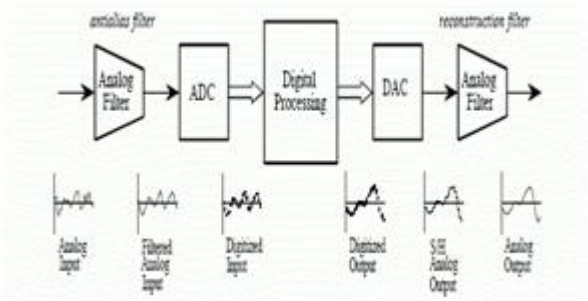

Figure 2: Three graphs showing respectively the original signal (analog), the sampled one and the rebuilt one

An image may be defined as a two-dimensional function f(x, y), where x and y are spatial (plane) coordinates and the amplitude of f any pair of coordinates (x, y) is called the intensity of the image of that point [7]. The term gray level is used often to refer to the intensity of monochrome images. Color images are formed by a combination of individual 2-D images. For example, in the RGB color system, a color system, a color image consists of three (red, green and blue) individual component images [1].

An image array may be continuous with respect to the x- and y-coordinates and also in amplitude. Converting such an image to digital form requires that the coordinates as well as the amplitude be digitized [2]. Digitizing the coordinate values is called sampling; digitizing the amplitude values is called quantization. Thus, when x and y and the amplitude values of f are all finite, discrete quantities we call image a digital image.

In our case the analog signal that is going to be processed is the heartbeat that is converted as a electrical impulse from the corresponding sensors and then it sampled with different techniques to be suitable for the computer.

B. Overview of the theoretical concepts about early re-polarization

Early re-polarization is a term used classically for ST segment elevation without underlying disease. It probably has nothing to do with actual early re-polarization [10]. It is commonly seen in young men. It is important to discern early re-polarization from ST segment elevation from other causes such as ischemia. Characteristics of early re-polarization are [4]:

- an upward concave elevation of the RS-T segment with distinct or "embryonic" J waves
- slurred down-stroke of R waves or distinct J points or both
- RS-T segment elevation commonly encountered in the pre-cordial leads and more distinct in these leads
- rapid QRS transition in the pre-cordial leads with counterclockwise rotation
- persistence of these characteristics for many years
- absence of reciprocal ST depression
- large symmetrical T waves

Before then, it has to overcome "growing pains" of being miss-named and the failure of electro-cardiographers to deal with R wave down-slope phenomena (J waves, notches and slurs) prior to this time. When R wave down-slopes phenomena are present, we have to clarify the J-point definition as well as specify where end of the QRS complex and beginning of the ST segment occurs [6].
Prior to 2009, ECG waveform definitions and measurement were based on inclusion of the R wave down-slope phenomena in the QRS complex per the CSE Measurement Statement but recent studies have not done so [3].

These stable 12 lead ECG measurement issues have to be resolved if appropriate population studies can be performed to demonstrate that R wave down-slope phenomena can be used to predict individuals at risk of sudden cardiac death due to this genetic mutation [3].

Characterization of standard 12 lead ECG abnormalities can be facilitated by considering the portion of the cardiac ventricular action potential which influences them. This is only helpful for action potential phenomena originating with the initial wave of activation. Their temporal timing is influenced mainly by trans-mural dispersion from endocardium to epicardium [6]. This contrasts with late potentials which are due to phase 0 of the action potentials (depolarization) originating from myocardium isolated by fatty tissue (epsilon waves of ARVD) or by fibrosis (cardiomyopathy) experiencing major delays. These can be arrhythmogenic because they compete with the normal pacemakers [5].

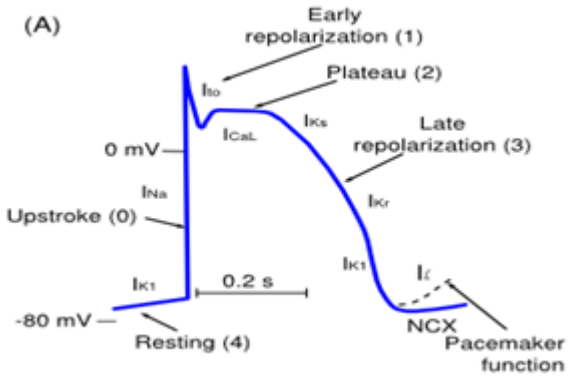

Figure 3 - The Different Phases of Repolarization

Phase 0 depolarization abnormalities that occur with the initial wave of activation include bundle branch blocks, myocardium damage or abnormalities and intraventicular delays. These can be due to electrical disturbances, myocardial hypertrophy, dilatation, damage or infiltrative disease.

Abnormalities of Phase 2 (mid-re-polarization) of the action potential (the plateau) result in ST displacement where amplitude differences in the action potential result in ST elevation caused by transmural ischemia, pericarditis and vagal tone differences or result in ST depression caused by endocardial ischemia, fibrosis or electrolyte abnormalities [4].

Phase 3 (late-re-polarization) abnormalities can result in T wave abnormalities with similar causes as ST depression as well as abnormalities of QT length caused by medications, electrolyte disturbances and specific genetic conditions (LQTS, SQTS). Less understood but recently highlighted are abnormalities of phase 1 (Early Re-polarization). These include abnormal action potentials originating in the right ventricle outflow tract Brugada syndrome and those originating in the left ventricle (J wave syndromes).

The exciting feature of these abnormalities is their specific genetic associations. Similar to the QT syndromes, relatively few genes appear to be involved contrasting with the genetic complexity of more common conditions such as cardiomyopathies, atherosclerosis and diabetes [4].

Introduced in the NEJM in 2009 as *Early Re-polarization*, this new ECG pattern and syndrome is more appropriately named after Michel Haïssaguerre, who first reported it. The ECG pattern consists of J waves, slurs or notches particularly in the inferior leads and the syndrome requires sudden cardiac death (SCD) without cardiac abnormalities, family history and genetic markers.

However, early re-polarization (ER) was already defined for two areas [10]:

1. In cellular physiology, ER is defined as Phase 1 of the action potential.
2. In clinical medicine, ER is defined as a resting ECG pattern of ST elevation in the lateral>Inferior leads sometimes accompanied by J waves or slurs on the R wave down-slope, occurring particularly in athletic, young male African Americans [5].

The main concern with this pattern was distinguishing it from ischemia and pericarditis. Naming of this new syndrome with a name previously assigned to other entities has created considerable confusion particularly in the US where physicians have been taught since the 70's to consider "early re-polarization" a normal variant of ST elevation [9].

In fact, though this new, rare syndrome may be found to be more prevalent now that it has been discovered, nomenclature and ECG measurement disagreements could result in more harm than good. This is particularly the case since many of the widely used automated ECG machines put out a statement of *early re-polarization* based on ST elevation in an otherwise normal ECG.

II. METHODOLOGY

In this section we will provide in detail the two algorithms: the detection of the status of the ECG graph and the classifying the positives cases. The steps of developing the detection algorithm are shown below:

1. We will convert the image in suitable format for Matlab
2. These images will be filtered with Savitzky-Golay smoothing filter with 22-ms window
3. We will apply 3rd order non-linear polynomial regression at this signals and we will generate a trend-line from this regression process
4. We will calculate the peak of the wave.
5. We will calculate QRS onset and QRS offset for each lead (12 leads for a sample) – the algorithm used consists in calculating the smallest angle between the ascending/descending part of QRS complex.
6. We will calculate the median values of QRS onset and QRS offset in lead (the mean of the 12 QRSs)
7. We will use QRS onset in each lead to identify the average value from QRSon-30ms to QRSon-10ms. This average will be subtracted from the signal.
8. We will generate 6 templates: R, (R/S ratios – 2, 1, 05), QS and RSr'
9. We will locate the steepst slope (Dfmax) after the last R or S wave exceeding 50% of the leads maximum absolute amplitude.
10. We will show a trend-line that shows the least-squares method applied at the samples between Dfmax–2 ms and Dfmax+2 ms.
11. We will find the *yield point* that consists in the 1st point that deviates from this line.
12. After the yield point we will find the slurring and the notching of the QSR complex
13. Furthermore to locate the yield point (the distance to the line starting from the steepest line), we will use the following equation:

$$Dist = \frac{|A*t(n)+B*y(n)+C|}{\sqrt{A^2+B^2}} \quad (1)$$

where A is the slope, t is the timeline (in seconds), y is the signal amplitude (in milivolts), B = 1, C is the intercept and n is the sample number. (In our case we will use a threshold of 0.04)

14. If the yield point was >0.1 mV, then the largest slope between the yield point and the largest sample prior to the QRS offset exceeding 0.09 mV will be located.
15. The slope will be searched from the first – order derivative of the signal filtered with 7-point, 14-ms moving average.
16. If a sample point that fulfills the above-mentioned criteria was located, then a line will be fitted through the time (t) and the amplitude (y) value pairs of seven consecutive samples, with the maximum slope as the central sample.

If the ER status is positive then we need to classify these statuses will be classified according the below steps.

A. Notch/Discrete Detection

1. First, a 10th order polynomial function is fitted to the values of *y* from *Dfmax* to *QRSoff +20 ms*
2. If the signal goes below baseline prior to the QRS offset, the polynomial function is fitted starting from the ascending part of the S wave in order to avoid jitter in the fitted signal.
3. All local peaks will be identified from the signal, and their amplitudes from the baseline (*Apeak*) and timing (*TPeak*) will be determined.
4. These parameters will be used in the notch/discrete notch detection.
5. A notch is detected if the yield point amplitude is >0 mV, notch amplitude is >=0.09 mV, and the peak of the notch occurs within the timeframe spanned by the yield point (*TYield*) and QRS offset (*TQRSoff*) + *20 ms*.
6. The QRS morphology must fit either the QR or R template, and the signal cannot go below baseline prior to the examined peak.
7. A discrete notch is detected if the notch amplitude i >=0.09 mV and *TYield _ TPeak _ TQRSoff + 20 ms*.
8. In addition, the signal must fall to or below baseline prior to the examined peak, and the QRS morphology cannot fit the RSr' template.

B. Slurred

1. If none of the local peaks fulfills the notched or discrete criteria, then the signal can be slurred, indeterminate, or negative.
2. A lead is considered slurred if no S wave is present, yield point is >=0.1 mV and terminal slope is >=7.5, which corresponds to an angle of 71° at 25 mm/s or 56° at 50 mm/s paper speeds.

C. Indeterminate

1. If the lead does not meet the criteria for the notched, discrete, or slurred morphologies, it is considered either indeterminate or negative.
2. A lead is categorized as indeterminate if it is not notched or slurred but the amplitude at the global QRS offset still exceeds the 0.1 mV threshold.
3. If none of the criteria are met, the signal is considered negative.

III. RESULTS

The results of this paper consist in achieving the well-defined parameters of automating the detection of ER at the ECG-s.

This is the first study that tried to make possible the automatic detection of ER versus manual evaluation in a large extent on the number of samples. The results of this study show that the accuracy of automatic detection and classification of ER based on the quantification of morphology signal is high when compared with manual evaluation.

The automatic detection of ER properties for 12-lead ECGs presented in this study provides promising results. Since the algorithm has a great sensitivity, it can be used as a tool to increase efficiency in time by 90%. The detection of inferior ERs was not as accurate as in the case of lateral ERs. It consists of a weakness and shows a greater risk in cases of arrhythmia.

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