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Computer Aided System for Diagnosis the Arrhythmia Heart Diseases

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Abstract

A computer aided system is presented for the diagnosis of arrhythmia heart diseases. An analog-to-digital converter (ADC) method is applied with the aid of a digital image scanner. The following stepes were suggested to process the input (scanned) signals: (I) Grid line filter was implemented to cancel the grid lines. (II) Scaling method by using cubic interpolation was used to scale the signal to standard scale. (III) Two thinning methods the top-bottom and mid-point methods were used to choose the portion of the line thickness to be taken as the instantaneous value of the signal. (IV) Baseline correction method was also applied in our work to reconstruct the corrected signals of the ECG. (V) Limiting these features within a series of templates carries out pattern recognition. These templates represent an ideal pattern. 194 templates were implemented in our diagnosis system and 68 cases were tested. A Fast Fourier Transformation (FFT) was applied to the ECG signal. An extracted features are obtained from this transformation representing the power spectrum. The over all accuracy of the classification scheme of the test set is 86.4% .

Introduction

The fluctuations in potential that represent the algebraic sum of the action potentials of myocardial fibers can be recorded from the surface of the human body. The record of these potential fluctuations during the cardiac cycle is called the electrocardiogram (ECG) [1]. The ECG is of particular value in the following clinical conditions: 1) Atrial and Ventricular Hypertrophy. 2) Myocardial Ischemia and Infarction. 3) Arrhythmias [2].

Several research groups are involved in carrying out different types of work in computer aided interpretation of ECG wave since the work done by V. Administration in 1957 [3]. Various directions of work are published with the aim of accurate and reliable interpretation of ECG signals, for research and diagnostic purposes [4-8].

In arrhythmia diseases, the electrocardiogram given nonperiodic signals; therefore; Fast Fourier transformation used in this research to convert the signals from time domain to frequency domain. FFT used in this field due to its ability to analyze the complex signals without being affected by the amplitude of the signal [9]. This process starts from digitizing the signal from graph paper and transform it to digital image using optical scanner.

Cross-Correlation Coefficient (CC) is a parameter used to comparison between two sets of values. The value of CC is ranged from (-1 to 1), where (-1 or 1) indicates a perfect relationship between the values of the adopted signals. A correlation of zero suggests that there is no relationship between the two variables of the data. Cross-Correlation Coefficient used to measure the degree of correlation is given by;

$$CC = \sum_{i=1}^{N} \frac{(x_i - \mu_x)(y_i - \mu_y)}{N \sigma_x \sigma_y} \quad \ldots\ldots(1)$$

where N is the number of points, x_i is the first set of value, y_i is the second set of value, μ_x is the respective mean value of x_i, μ_y is the respective mean value of y_i, σ_x is the standard deviation of x, and σ_y is the standard deviation of y [10].

Statistical analysis, allowed comparison of our findings with previous studies, employing the concepts of; sensitivity which is the ability to recognize wall motion abnormality when it is present.

$$\text{Sensitivity} = T_P/(T_P+T_N) \quad \ldots\ldots(2)$$

Specificity is the ability to exclude wall motion abnormality when it is absent.

$$\text{Specificity} = T_N/(T_N+T_P) \quad \ldots\ldots(3)$$

$$\text{Predictive value of positive test} = T_P/(T_P+F_P) \quad \ldots\ldots(4)$$

$$\text{Predictive value of negative test} = T_N/(T_N+F_N) \quad \ldots\ldots(5)$$

where T_P = True positive, T_N = True negative, F_P = False positive, and F_N = False negative [11].

The objective of this work is to build a computer program for diagnosis the ECG signals. The analysis of the ECG signals passes through the following processes:

I-Enhancing the ECG signals using noise removal and thinning techniques.

II-Extracting the diagnostic feature from the signal using Fast Fourier Transformation (FFT).

III-Generating medical report for diagnosing the patient case by comparing the extracted features with the stored standard features.

Analog to Digital Converter

The Analog to Digital converter is very useful method in the development of advanced programs for cardiac arrhythmia, and other diseases analysis, for which standardized sources of data have been difficult to develop. This method permits paper tracings to be digitized for use by computer, and thus provides a useful method to obtain digital data in the laboratory setting. An optical scanner Jet IICX with resolution of 0.001 inch (100 dots per inch) is used in the present work. It processes single sheets of A4 type papers. The signal assumed to be plotted in Cartesian coordinates, and they are don't overlap each other. The signal in the image form is converted into a series of numbers like those produced by an electronic analog-to-digital converter. A rectangular region on the image which contains the signal lines of interest is selected by the user to specify the locations of the borders of the region on an interactive display of the scanned image. The following steps are necessary for line identification in grid images:

1. An appropriate filter must be applied for free grid line images.
2. The signal line must be of finite thickness.
3. The signal must be normalized to standard scale.
4. Determine number of points describing the signal.

The identification of the signal lines in the image is less complex if no grid lines are presented in the scanner output. A grid lines filter is used to cancel the grid lines from the signal, a threshold with gray value 6 is used as a filter for the grid lines in the image (i.e. each pixel values greater than 6 is removed). Figure (1) shows the scanning image before and after applying the color filter.

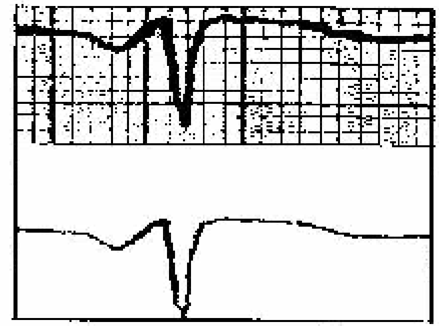

Figure (1) Signal With Grid Lines And After Grid Lines Filter

Typically, the scanned lines are several pixels wide even through it represents a single signal value at every instant. Two methods suggested to overcome this problem. The first technique is termed the midpoint method, in which the midpoint of each line segment is used as the true value of the signal in that segment. This method has the advantage of filtering high-frequency artifacts introduced by the recording instruments. It has the disadvantage of distorting rapidly changing signals. Figure (2) shows the original signal while figure (3) represent the thinning of the original signal by using mid-point method in arrhythmia diagnose system. The second method start by finding the first lit pixel in first time slice in the signal. The original point from top left of the monitor was transformed to first lit pixel by subtracting all the pixels coordinate of the signals from first lit pixel. Figure (4) represent the original signals after thinning by using Top-bottom method in arrhythmia diagnose system.

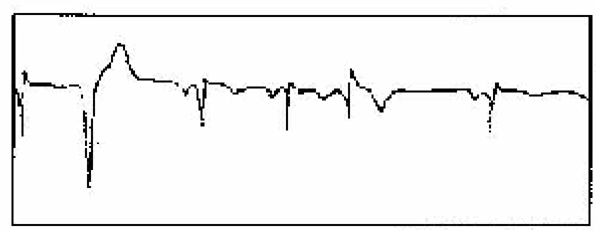

Figure (2) The Oreginal Signal Of The Arrhythmia Diagnose System

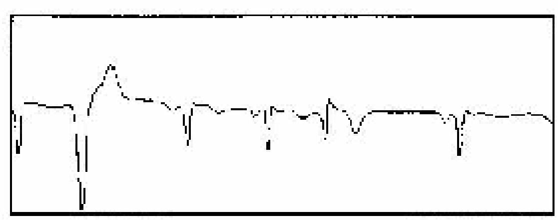

Figure (3) The Oreginal Signal After Thinning By Using Mid-Point Method

Figure (4) The Oreginal Signal After Thinning By Using Top-Bottom Method

Because of output signals are represented in three standardized scale (0.5, 1, and 2 mV/div) according to the type of the ECG device, so, It is suitable to rescale the signal to a standard scale before we start to process the signal. In our present work the 1mv/div is chosen as the standard scale. To achieve this purpose the cubic interpolation method is implemented in our work.To illustrate the interpolation methods Let X and Y be the real coordinates of a point I (X,Y) to be interpolated. Y or P(K,L) is the gray level of a pixel coordinates in the test image where L = int (X) and d = X - L. The following relation defines the mathematical description of cubic interpolation [11,12].

$$G=\frac{\left(Y_1+d\left(-Y_0+Y_2\right)+d^2\left(2Y_0-2Y_1+Y_2-Y_3\right)+d^3\left(-Y_0+Y_1-Y_2+Y_3\right)\right)}{K}$$

where K is the normalization ratio. As shown in figures (5) and (6) a medium smoothness image is a result of the cubic interpolation method.

Figure (5) The Original Image

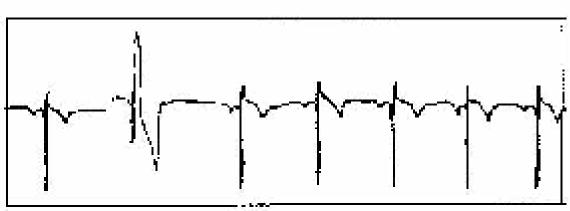

Figure (6) Rescal Image By Using Cubic Interpolation

If the ECG signal is not on straight line then rotation or base line correction must be used. To eliminate this problem without affecting the ECG recorded signal, the following algorithm is applied;

1- Detect the (R) position and amplitude.

2- Determine the number of points in each signal.

3- Chose two points in each signal, the first point at starting signal while the second point at last signal.

4- Find the difference between the amplitudes of these two points $V = V_{end} - V_{start}$

where V is the difference voltage between end and start points, V_{end} the voltage of last point in signal, and V_{start} the voltage of first point in signal.

5- Find the correction ratio to each point in the signal by dividing the interval (T) time of each point relative to the total period (P) in the signal, then multiplied the result by the difference amplitude value (voltage) between end and start point. The correction ratio C_r can be calculated by the following relation $C_r = T*V/P$

6-Add the correction ratio to the original signal to yield the real shape of the signal. Figures (7) describes two ECG signal first before correction and second after correction.

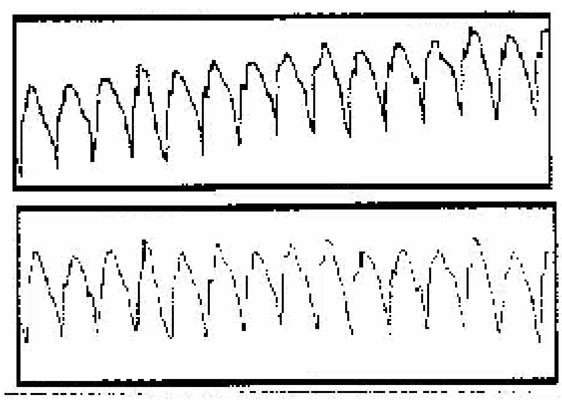

Figure (7) Ecg Signal In Arrhythmia Diagnose System Before And After Correction

Analysis And Results

The ECG signal can be classified into many regions, each region contains many peaks and valleys. The ECG analysis starts by determining the most important and significant peaks (P, Q, R, S, and T) in the signal. Many of segment regions can be derived from these peaks such as QRS width, PR segment, and ST segment which can help in the analysis of the ECG signal. The following steps are followed in analyzing the ECG signals[13-15]:

1- Determine the first derivative for each signal points.
2- Determine the slope for each signal points.
3- Determine the angle between each two neighboring points in the signal.
4- Determine the position of the reflecting points in the signal and choose a threshold value to determine the number of reflecting points

To check the validation of this technique, we test it against standard cases. The test population consists of electrocardiograms from pediatric patients seen at Medicine College of Saddam University and Bin-al-Nafis hospital of heart diseases. Number of cases stored as template cases (standard) was applied for this purpose. In the present research, pattern recognition is carried out by limiting some of statistical properties (features) with in a series of templates (cases). Infect each of templates represent an ideal pattern.

The following can summarize the procedures involved in our classification: we first divide the observed cases into a specific discriminable disease and secondly constructing the classifier to identify the extracted measurements of each case in a vector as to belong to a given decision cases.

The data set are 194 cases were implemented in the arrhythmia diagnosis system are shown in table (1) and 68 cases tested with our system are shown in table (2).The contingency table for classifying the cases in the test set are show in table (3). Statistical analysis is employed the concepts of sensitivity, specificity, predictive value of a positive test and predictive value of a negative test. The over all accuracy of the classification scheme was 86.4%.

From these tables our ECG analysis programs, which analyze each electrocardiogram in accordance with a set of standard diagnostic criteria, are of considerable clinical value, there are several additional and important facts provided by a programs which compares the patient's previous ECG with the current recording. A medical reports can be given here to demonstrate the diagnostic capability. Each report contains some personal information about the patient and include the diagnosis of the patient case. The cross-correlation coefficient is also obtained in the report to estimate the accuracy of the diagnoses. The accuracy of the classification scheme of the system test set was 86.4%. The correlation algorithms have the advantage of being unaffected by some physiological noise accompanying the ECG signal such as baseline drift.

Table (1) The Template Cases In Arrhythmia Diagnose System

Case name	No.of cases
Escape beats in atrial fibrillation	1
Atrial fibrillation, junctional rhythm and coupled ventricular extrasystoles	1
Atrial fabrillation and extrasystoles	1
Atrial fabrillation and coupled ventricular extrasystoles	3
Atrial flutter with 3:1 atrioventricular block	1
Atrial flutter with 1:1 response	1
Atrial flutter with higher ratios of partial atrioventricular block	3
Atrial flutter with irregular atrioventricular	1
Atrial flutter. 2:1 and 4:1 atrioventricuar block producing paired beats	1
Atrial flutter with 4:1 atrioventricular block	1
Atrial flutter with 2:1 atrioventricular block	2
Atrial flutter, morphology of flutter waves	2
Atrial flutter	1
Atrial fabrillation, ultra slow ventricular response	3
Atrial fabrillation, slow ventricular response owing to heavy digitalization	1
Atrial fabrillation	1
Atrial flutter with aberrant conduction	1
Atrial flutter, effect of carotid sinus message	1
Cardiac arrest	3
Post-mortem electrical activity	1
Cardiac message	3
Agonal rhythms	3
Ventricular fabrillation	1
Irregular accelerated idioventricular rhythm	1
Accelerated idioventricular rhythm	2
Ventricular tachycardia and fabrillation following a Ventricular extrasystole	1
Marked junctional bradycardia	1
Control of reciprocating tachycardia by pacing	3
Reciprocating tachycardia	3

Ventricular tachycardia	3
Ventricular tachycardia with independent atrial activity and capture beats	1
Ventricular tachycardia with independent atrial activity	1
Ventricular tachycardia, changing QRS	2
Sinus bradycardia	2
Escape beats in atrial fabrillation	1
Irregular paroxysmal atrial tachycardia	3
Bidirectional tachycardia	1
Paroxysmal supraventricular tachycardia with aberrant conduction	1
Multifocal atrial tachycardia	2
Paroxysmal supraventricular tachycardia in a baby	1
A breif paroxysm of atrial tachycardia	1
Atrial tachycardia with atrioventricular block, digitalis intoxication	1
Paroxysmal atrial tachycardia with complete atrioventricular block	1
Paroxysmal junctional tachycardia with partial retrograde block	1
Paroxysmal atrial tachycardia with type 2 grade 2 atrioventricular block	1
Paroxysmal atrial tachycardia with 4:1 atrioventricular block	1
Paroxysmal atrial tachycardia with 2:1 atrioventricular block	2
Paroxysmal atrial tachycardia with grade 1 block	1
Paroxysmal supraventricular tachycardia	1
Paroxysmal atrial tachycardia	1
Sinus tachycardia	2
Tachycardia arrhythmias in the wolff-parkinson-white syndrome	3
Intermittent wolff-parkinson-white syndrome	2
Wolff-parkinson-white syndrome	1
Atrial parasystole	3
Ventricular parasystole in atrial fabrillation	3
Parasytole	3
Multiple and multifocal ventricular and supraventricular extrasystoles	2
Reciprocal beat following a junctional extrasystole	2
Interpolated junctional extrasystole	1
Coupled junctional extrasystoles	1
Multifocal junctional extrasystoles	2
Junctional extrasystole, post-extrasystolic T wave change	1
Atrioventricular junctional extrasystoles	1
Coupled supraventricular beats	1

Coupling with atrial extrasystoles	1
Blocked atrial extrasystoles mimicking sinoatrial block	1
Blocked atrial extrasystoles	1
Variation in the contour of the QRS complex of atrial extrasystoles	2
Bidirectional ventricular extrasystoles	2
Multifocal ventricular extrasystoles of similar contour	1
Unifocal ventricular extrasystoles with varying contour	1
Multifocal ventricular extrasystoles	1
Unifocal ventricular extrasystoles occuring regularly after every second sinus beat	1
Coupling with unifocal ventricular extrasystoles	1
Normal ECG	6
Ventricular extrasystoles, effect of sinus arrhythmia on compensatory pause	1
Irregular ventricular rhythm in complete heart block	1
Occasional conducted beats in complete heart block	1
Retrograde conduction with atrial capture in complete heart block	2
Stokes-adams attack	1
Partial heart block and extrasystoles	1
Partial heart block and escape beats	3
Grade 2 heart block, type 2 ; 2:1 conduction	2
Grade 2 heart block, 2:1 block	1
Grade 2 heart block, type 2 ; 3:1 conduction	3
Grade 2 heart block, type 2 ; 4:1 conduction	1
Partial heart block, influence of atrial rate	3
Grade 2 heart block, type 2 ; effect of vegal stimulation	1
Effect of respiration on Q waves in lead III	1
Shifting pacemaker in the sinus node	1
Sinus arrhythmia	6
The sick sinus syndrome	3
Carotid sinus hypersensitivity	4
Sino-atrial block with ventricular escape beats	1
Sinus arrest with atrioventricular junctional escape beat	1
Sinus arrest	1
Partial sino-atrial block, wenckebanch periods	1
Sino-atrial block	1

Atrioventricular junctional rhythm	3
Reciprocal beats with partial retrograde block	2
Reciprocal beats	1
Atrioventricular dissociation and capture beats with partial heart block	1
Atrioventricular dissociation with paried capture beats	2
Atrioventricular junctional rhythm with 2:1 retrograde block	1
Escape capture bigeming	2
Wandering pacemaker between the sinus node and atrioventricular junction	1
The sick sinus syndrome	1
Sinus rhythm	1
Sinus rhythm with complete left bundle branch block	1
Sinus rhythm with a single atrial escape ectopic beat	1
Atrial lutter with 1:1 atrioventricular conduction	1
Grade 1 heart block, changing PR interval	3
Grade 2 heart block, type 1; wenckebach periods	1
Grade 2 heart block, type 1; 2:1 conduction	3
Grade 2 heart block, prolonged wenckebach periods	2
Changing grades of partial heart block	3

TABLE (2) THE APPLIED CASES IN ARRHYTHMIA DIAGNOSE SYSTEM

case name	N0.of cases
Atrial flutter with 4:1 atrioventricular block	1
Atrial flutter	2
Atrial fibrelation	1
Atrial flutter with 2:1 atrioventricular block	1
Ventricular fibrillation	1
Ventricular tachycardia	1
Ventricular tachycardia with independent atrial activity	1
Sinus bradycardia	1
Sinus tachycardia	2
Bidirectional tachycardia	2
Paroxysmal supraventricular tachycardia	1
Multifocal junctional extrasystoles	1
Parasystoles	2
Coupled junctional extrasystoles	1
Bidirectional ventricular extrasystoles	2
Atrioventricular junctional extrasystoles	1
Atrial parasystole	2
Stokes-Adams attack	1
Unifocal ventricular extrasystoles with varing contour	1
Grade 2 heart block,:2:1 block	1
Sino-atrial block	1
Atrioventricular junctional rhythm	1
Sinus arrhythmia	1
Atrial fibrillation, ultra slow ventricular response	1
Grade 1 heart block, changing PR interval	1
Coupled supraventricular beats	1
Atrial flutter with 3:1 atrioventricular block 1	1
Atrial flutter with 1:1 response	1
Changing grades of partial heart block	1
Agonal rhythms	2
Multifocal atrial tachycardia	1
Control of recipocating tachycardia by pacing	1
Multifocal venricular extrasystoles	1
Sinus arrest	1
Reciprocal beats with partial retrograde block	2
Accelerated indioventricular rhythm	1
Cardiac arrest	1
Normal ECG	22
Ventricular parasystole in atrial fibrillation	1

TABLE (3) THE SENSITIVITY AND SPECIFICITY OF ARRHYTHMIA DIAGNOSE SYSTEM

Total cases applied	68
Number of true positive (TP)	17
Number of true negative (TN)	44
Number of false positive (FP)	5
Number of false negative (FN)	2
Sensitivity	89.4%
Specificity	89.7%
Accuracy for positive prediction The predictive value of a positive test	77.2%
Accuracy for negative prediction The predictive value of a negative test	95.6%

Conclusion

The Analog to Digital is very useful in the development of advanced programs to detect the ECG signal. In present work we introduced a system used for arrhythmia detection. This system was implement an algorithm based on cross-correlation function and FFT to perform an accurate diagnose of the ECG signal. The accuracy of the classification scheme of the system test set was 86.4%. The correlation algorithms have the advantage of being unaffected by some physiological noise accompanying the ECG signal such as baseline drift. This setting have the following three mean advantages:

a) Many consecutive data points can be acquired rapidly without the random error associated with hand manipulation of a cursor.
b) There is no necessity for immediate electronic capture of the signal as it occurs (low the cost).
c) The investigator can edit the data visually and select for data analysis only those signals, which are most likely to be useful.

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