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Electrocardiogram (ECG) Signal Diagnosis Based on Component Extraction

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Abstract— This work presents a diagnosis system of ECG signal based on its component extraction. The ECG signal was analyzed in time & frequency domain techniques. In time domain techniques, the signal is segmented to extract all the medically important features that were used in the diagnosis. A bottom-up derivative-based algorithm was adopted. This Algorithm subjects the signal derivative to some empirical thresholds. The result of this method is a segment locating waveform that separates and delimits the various segments of the ECG. In frequency domain techniques, the signal is transformed by Fast Fourier Transformation. The signal is transformed sometimes beat by beat. The signal is analyzed in frequency domain by study the power spectrum and find thresholds for normal cases then compare these thresholds with other ECG signals to recognize the abnormal cases. Each disease has its own power spectrum which is different from the normal cases by a threshold in a specify location in the spectrum. Different medical criteria of diseases categories were used in making the diagnostic decision. They were taken from medical books. The system was tried on a large number of ECG signals, some samples of results were given as diagnostic reports.

Keywords- ECG, Time Domain, FFT, Diagnosis.

I. INTRODUCTION

The Electrocardiogram ECG is a graphical representation of the electrical activity of the Heart. The Ecg Signal Contains Diagnostic Information And For This Reason Is Routinely Used In Clinical Practice. Presently, The Work Load Of Ecg analysis has gone to millions of man-year. It is not possible for the expert cardiologists to cope with the increasing demand of interpretation without the aid of computers [1]. The errors due to human factors are completely eliminated in computer aided analysis and interpretation. It is possible to put the experience of many experts together in the computer software. Computerized interpretation increases accuracy, consistency and efficiency and also decreases time and cost of interpretation. Every individual can be put on the regular checking list of computer center and timely advice can be given to those who develop some tendency towards cardiac this order [2].
The ECG used by a capable cardiologist, is a valuable tool in diagnosing certain heart diseases. However, there is considerable disagreement of interpretation of these waveforms among cardiologists, due to the differences in their experience and their understanding of the physiology of the heart. Individual cardiologists make quite different interpretations of identical ECGs at different times. Reliable and consistent interpretations could be made if a reliable computer routine could be devised utilizing the knowledge of an experienced cardiologist [3].

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Several proposed methods of ECG interpretation are under study. A vector cardiography system uses one of several proposed three-orthogonal-lead system [4] . Fourier frequency analysis methods have been investigated. The most popular criteria are the voltage amplitude and time relationships of the several component parts of the ECG waveforms [5]. Most cardiologists use these basic criteria in making their interpretations because they approximate area criteria. The a shape criteria, such as correlation should contain more information than just area, or amplitude and time duration. Different methods that have been developed and used for computer-aided analysis of ECG waves are discussed in this work. This work included three parts:
FIRST: Segmentation of the ECG signal, which is the key point for correct diagnosis, is implemented by utilizing a bottom- up approach based on the first derivative of the signal. This method helps in detecting the most important wave QRS complexes. Then finding location and duration of rested waves (P, T, and U waves).
The main feature of this method is that it does not depend on the base-line of the signal to determine the boundaries of the ECG signal. Instead, it depends on the first derivative to detect and delimit various segments by generating locating waveforms that are unaffected by the drifting base-line and thus improving segmentation performance. The extracted features where used to generate a majority cluster representing the effective peak complex parameters, which is final result of this stage.
SECOND: A Fast Fourier Transformation FFT of ECG signal is founded and sometimes it is applied on the signal beat by beat separately in the cases of finding the heart rate and diagnosing of the sinus arrhythmia. The FFT helps to find the abnormalities in QRS complexes which is appear in the spectrum of the ECG signal because it has high frequently that the other waves (P, T, and U) in the ECG. These waves are distribute in the spectrum so that it is difficult to diagnose diseases effected them.
THIRD: The result of first two parts is a set of measurements that were evaluated in the third part of the work to print out a medical report diagnosing the heart state. The cardiologist evaluation approach is chosen for its ease and reliability. Besides, the criteria developed for interface analyzing and evaluating the final outcome of the whole diagnostic system.

II. COMPONENTS OF THE ECG

A. *Waves and Complexes*

The letters chosen by Einthoven (1860 - 1927) to designate the various components of the ECG are P, Q, R, S, T, and sometimes U [6].

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The atrial muscle is relatively small and electrical change accompanying their contraction is therefore small. Contraction of the atria causes the ECG wave called "P". Since the ventricular mass is large there is a large deflection of the ECG when the ventricles contract and this is called the "QRS." complex. The "T" wave of the ECG is caused by the return of this ventricular mass to the resting electrical state "Repolarization" [7]. The first upright deflection in the QRS complex is an R wave. If it is preceded by a negative deflection, that deflection is a Q wave, any negative deflection that follows the R wave is an S wave. If a second positive wave follows the S wave is called R'. When the ventricular complex consist of a single negative deflection without any positive wave, it is described as QS complex. See fig. 1 for describing labeling of a variety of QRS complexes.

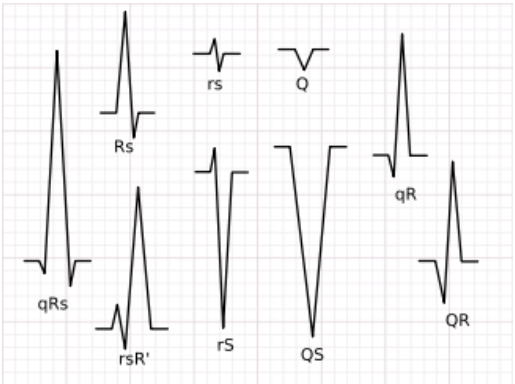

Figure 1: Descriptive labeling of a variety of QRS complexes.

B. Intervals

The waves and complexes are separated by important intervals. The P-R interval is measured from the beginning of the P wave to the beginning of the QRS complex. It measured the time taken by the impulse to travel all the way from the SA node to the ventricular muscle fibers, and this is normally from 0.12 to 0.2 sec. The QRS interval is the width of the ventricular complex and normally measures 0.04 to 0.10 sec, usually 0.06 or 0.07 sec. The Q-T interval is measured from the beginning of the QRS complex to the end of the T wave, it includes the QRS and the T wave and its normal duration varies with the heart's rate the slower the rate the longer the Q-T interval. The R-P interval is measured from the beginning of the QRS complex to the beginning of the ensuing P wave [8]. The R-R interval is the interval between consecutive QRS complexes and, of course, is directly related to the cardiac rate (see fig 2).

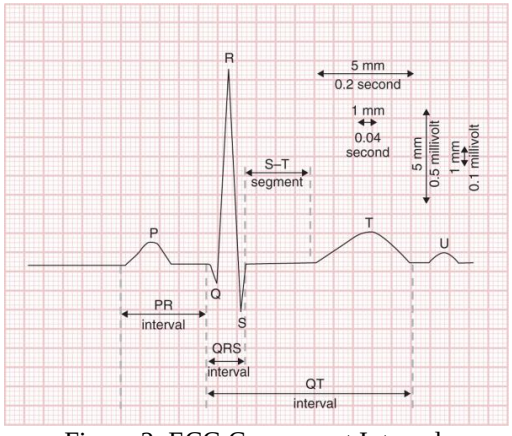

Figure 2: ECG Component Interval.

III. ELECTRICAL AXIS

The orientation of the heart's electrical activity in the frontal plane may be expressed in term of "axis" or "heart position". The axis plays an important role in many diagnosis and therefore it should be obtained. There are many ways of determining the electrical axis but the method described below is the best because it is the simplest and also accurate [6].

This method depends on the hexaxial, fig 3 shows the constitution of the hexaxial reference system. Lead I and aVF divide the clock face into four quadrant.

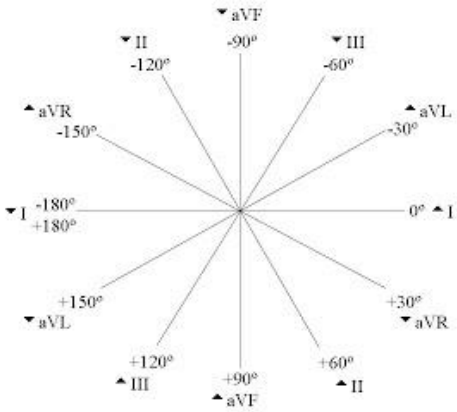

Figure 3 Constitution of the hexaxial reference system,

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These quadrants are labeled normal axis (0° to 90°), left axis (0° to -90°), right axis (90° to 180°), and no-man's land (-90° to -180°). This method involves two simple steps:

(a) placing the axis in the appropriate quadrant by locking at the QRS polarity in lead I and aVF.

(b) finding the lead with the smallest QRS.

If the QRS is upright in both lead I and aVF, the axis is "normal", if it is up in I and down in aVF, the axis is leftward (left axis deviation, LAD). If it is up in aVF and down in I the axis is rightward (right axis deviation, RAD). And if the QRS is negative in both I and aVF, the axis is in no-man's land NML. After placing the axis in its appropriate quadrant find the lead with the "smallest" QRS and place the axis at right angle (perpendicular) to this lead.

IV. NORMAL SHAPES

A. P wave

This is the first wave in the ECG and represents the spread of the electrical impulse through the atria (activation or depolarization of atria).

The P wave is normally upright in lead I and II but is frequently diphasic or inverted in lead III and aVL, and it is always normally inverted in aVR and upright in aVF. In V1 the P wave may be upright, diphasic or inverted. In the other leads, it is normally upright. It shouldn't be taller than about 0.2 mVolt, nor sharply peaked or broadly notched.

B. QRS complex

This is the most important in the ECG, as it represents spread of the impulse through the ventricular muscle (activation or depolarization of ventricles).

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It is normally upright in lead II and in left leads V5 and V6, where as it is always normally inverted in lead aVR and V1. Because some degree of right and left axis deviation is within normal limits, the polarity of the QRS in lead I, III, aVL and aVF varies with the axis.

C. ST-segment

It corresponds to a period of complete depolarization of the heart muscle. The ST-segment takes off from the QRS complex either at the isoelectric baseline or slightly above or below it. When the ST-segment is normally depressed it is never more than 0.02s.

D. T wave

The T wave represents the recovery period of the ventricles, when recruit their spent electrical forces (repolarization). It is normally upright in lead I, II and in V3-V6; and it is always inverted in lead aVR and often in V1.
In the other limb leads it varies with the QRS axis. On the other hand, the T wave may normally be upright in all pericardial leads.

E. U wave

This is a small wave of low voltage, sometimes seen following the T wave. It is normal polarity is the same as that of the T wave (i.e. when the T wave is upright, it is too upright, and vice versa). It is never normally more than 0.1 mV in amplitude.

V. THE RHYTHM OF THE HEART

When analyzing cardiac rhythm remember:
One)Atrial contraction is associated with the P wave of the ECG.
Two)Ventricular contraction is associated with the QRS complex.
Three)Atrial contraction normally precedes ventricular contraction, and there is normally one atrial contraction per ventricular contraction(i.e. there should be as many P waves as there are QRS complexes (see fig 4).

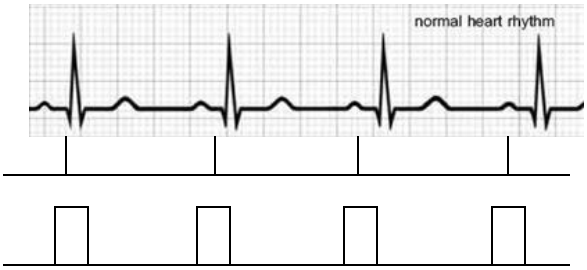

Figure 4; The The Rhythm of the Heart

A. Sinus Rhythm

When depolarization begins in the SA node, the heart is said to be in sinus rhythm. Depolarization can, however, begin in other places, and then the rhythm is named after the part of the heart where the depolarization sequence originates.

B. Ventricular Rhythm (Ventricular Escape)

It is most commonly occurs when conduction between the atria and ventricles is interrupted and complete heart block is the classical ventricular escape rhythm.

VI. ARTIO-VENTRICULAR BLOCK

The time taken by the spread of depolarization from the SA node to the ventricular muscle is shown by the PR interval, and is not normally greater than 0.2 seconds. Interference with the conduction process causes the ECG phenomenon called “heart block”, shows the shapes of the P waves, (see fig. 5).

A. First Degree Heart Block

If each wave of depolarization that originates in the SA node is conducted to the ventricles but there is delay somewhere along the conduction pathway, then the PR interval is prolonged and this is called “first degree heart block”. First degree heart block is not itself important, but it may be a sign of some diseases.

B. Second Degree Heart Block

Sometimes excitation completely fails to pass through the AV anode or the bundle of His. When this occurs intermittently second degree heart block is said to exist. There are three variation of this :
a) Most beats are conducted with a constant PR interval, but occasionally there is an atrial contraction without a subsequent ventricular contraction. This is called the “Morbitz type 2 phenomenon”.
b) There may be progressive lengthening of the PR interval and then failure of conduction of an atrial beat, followed by a conducted beat with a short PR interval and then a repetition of this cycle. this is the “Wenkebach phenomenon”.
c) There may be alternate conducted and non-conducted atrial beats (or one conducted and then two non-conducted beats), giving twice (or three times) as many P waves as QRS complexes. This is called “ 2 to 1” (or “3 to 1”) conduction.

C. Third Degree Heart Block (Complete Heart Block)

It is said to occur when atrial contraction is normal but no beats are conducted to the ventricles. When this occurs the ventricles are excited by a slow ‘escape mechanism’, with a depolarizing focus within the ventricular muscle.
Complete heart block may occur as an acute phenomenon in patients with heart attacks (when it is usually transient) or it may be a chronic state, usually due to fibrosis around the bundle of His.

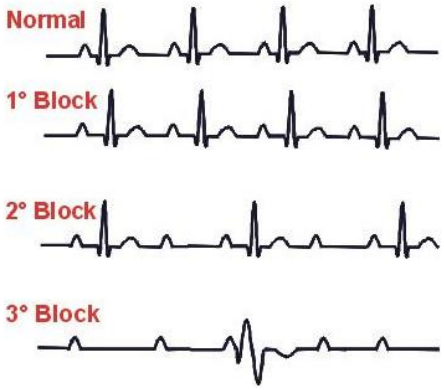

Figure 5; Artio-Ventricular Block

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VII. HEMIBLOCK (HB)

"Hemiblock" implies block of one of the two main divisions of the left bundle branch. If there is left axis deviation (usually -60º) and small Q wave in lead I, small R wave in lead III, and normal QRS duration, then block of the anterior division occur, this is called "anterior hemiblock". If there is right axis deviation (usually +120º) and small R wave in lead I, small Q wave in lead III, and normal QRS duration, and no evidence for right ventricular hypertrophy, then block of the posterior division occur, this is called "posterior hemiblock". A final negative criteria is necessary for the diagnosis of posterior hemiblock, namely, that there must be no evidence of Right Ventricular Hypertrophy this is because both PHB and Right Ventricular Hypertrophy can produce identical patterns in the limb leads.

VIII. CHAMBER HYPERTROPHY

When the walls of one of the cardiac chambers hypertrophy, a greater mass of muscle results and it takes longer to activate it. Consequently, two things are likely to happen to the wave or complex representing that chamber: its amplitude and its duration both increase.

A. Left Ventricular hypertrophy (LVH)

Since the left ventricle LV is normally the dominant chamber, Left Ventricular Hypertrophy (LVH) is many ways merely reflects as exaggeration of the normal. Thus, the normally deep S waves in V1 and V2 become even deeper, and the normally tall R waves in V5 and V6 become taller.

B. Right Ventricular Hypertrophy (RVH)

As right ventricular hypertrophy (RVH) develops, the R wave in right sided leads V1, V2 and the S waves in left sided leads V5, V6 increase in size. At the same time, the frontal plane axis shifts rightward and eventually produces frank right axis deviation.

IX. BUNDLE BRANCH BLOCK (BBB)

If the depolarization wave reaches any part of the ventricles normally, then the PR interval will be normal. However, if there is abnormal conduction through either the right or left bundle branches there will be a delay in the depolarization of part of the ventricular muscle. This is shown on the ECG as a widening of the QRS complex. In the normal heart the time taken for the depolarization wave to spread from the inter-ventricular septum to the furthest part of the ventricles is not more than 0.12 seconds. If the QRS duration is greater than 0.12 seconds then conduction within the ventricles must have occurred by an abnormal and therefore slow pathway, (see fig 6).

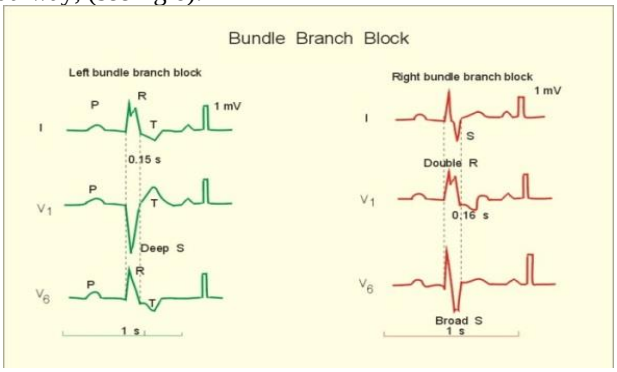

Figure 6; Bundle Branch Block (BBB)

A. Right Bundle Branch Block (RBBB)

No conduction occurs down the right bundle branch, but the septum is depolarized from the left side as usual, causing an R wave in a right ventricular lead V1 and a small Q in a left ventricular lead V6. Excitation then spreads to the left ventricle causing an S in V1 and an R in V6. It takes longer for excitation to reach the right ventricle because of the failure of the normal conducting pathway, and the right ventricle therefore depolarizes after the left. So there is a second R wave R' in V1, and a wide and deep S in V6.

B. Left Bundle Branch Block (LBBB)

If conduction down the left bundle branch fails, the septum has to be depolarized from right to left, causing a small Q in V1, and an R in V6. The right ventricle is depolarized before the left, so despite the smaller muscle mass there is an R in V1 and an S (often appearing only as a notch) in V6. Later depolarization of the left ventricle causes an S in V1 and another R in V6.

X. MYOCARDIAL ISCHEMIA AND INFARCTION

It is also called the abnormalities of the ST segment. The ST segment lies between the QRS complex and the T wave. It should be "isoelectric"-that is, at the same level as the part between the T and the next P, but it may be elevated, or depressed. Elevated of the ST segment is an indication of acute myocardial injury, usually due either to a recent infarction or to pericarditis. Again the leads in which it occurs indicate the part of the heart that is damaged- anterior damage shows in the V leads, and inferior in III and VF. Pericarditis is not usually a localized affair, and therefore it causes ST elevation in most leads. Depression of the ST segment, association with an upright T wave, is usually a sign of ischemia as opposed to infarction. When the ECG at rest is normal, ST segment depression may appear on effort, particularly when effort induces angina.

XI. VENTRICULAR FIBRILLATION-FLUTTER

Ventricular fibrillation is occur when the ventricular muscle fibers contract independently no QRS complex can be identified and the ECG is totally disorganized. As the patient will usually have lost consciousness by the time, realizing that it is not just due to a loose connection, the diagnosis is easy.

Ventricular flutter is the term given by some authorities to a rapid ventricular tachycardia giving a modified pattern in the ECG -a regular zigzag, without clearly formed QRS complexes. Nothing is gained in separating it from ventricular tachycardia .

XII. IMITATIVE ARTIFACTS

In normal and abnormal ECG artifact may occur. It means that there is an error in recording ECG, this error may occur as a result of one of the following reasons:

1. Dirty skin of patient body and dirty electrodes.
2. Little amount of electrode cream.
3. Suddenly movement of patient.
4. An error in an electrocardiograph.

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XIII. WAVEFORM DETECTION AND PARAMETER EXTRACTION

The first step in the ECG waves is the detection of QRS complex, since it is the most important wave. Digital techniques for QRS detection have centered on derivative of the ECG signal [6], [6]. Numerous methods for numerical approximation of the derivative are in use [4]. The choice of which one to use, is based on accuracy and computing time. The six point difference algorithm is mostly favored because of its decreased sensitivity to high frequency noise [2]. Its transfer function is:

$H(z)=0.365\ (1 + 0.35\ z^{-1} + 0.022\ z^{-2} - 0.022\ z^{-3} - 0.35\ z^{-4} - z^{-5})$ ….. (1)

The first derivative DF1 method is preferred since it has the ability to recognize different forms of normal and abnormal QRS complexes.

XIV. QRS COMPLEX DETECTION

The QRS detection is achieved first by finding the maximum absolute value of the derivative of the ECG signal, and then setting a threshold at 60% of the maximum value [3]. If the absolute value of the derivative at any point in the data record exceed this threshold a window is established to point to these places, representing QRS complexes. A search is then performed through the derivative and the signal magnitude to determine the onset and offset of the QRS complex, the "QRS period", depending on these places. After the determining the QRS onset and offset general peak complex extractor performed on each complex to detect peak complexes.

A QRS complex can have from one up to five peak of different signs. the naming of these peaks is performed in a table lookup manner. The entries are shown in table 1 where p^+ stands for positive peak, and p^- stands for negative peak.

Table 1: QRS morphology recognition

peak complex morphology	*QRS morphology*
p^+	R
p^-	QS
p^-p^+	QR
p^+p^-	RS
p^-p^-	QS
p^+p^+	RR'
$p^-p^+p^-$	QRS
$p^+p^-p^+$	RSR'
$p^-p^+p^+$	QRR'
$p^+p^+p^-$	RR'S
$p^-p^+p^-p^+$	QRSR'
$p^+p^-p^+p^-$	RSR'S'
$p^-p^+p^-p^+p^-$	QRSR'S'
$p^+p^-p^+p^-p^+$	RSR'S'R'

XV. P, T, AND U WAVES DETECTION

After determining the onset and offset of QRS complexes, a search is performed in the period between these complexes to detect peak complexes, and classifying them into P, T, and U wave complexes. Table 2 is determine peak number and its classification.

Table 2: The detection of P,T, and U waves

peak no.	*waves morphology*
1	T or P
2	TP, TE, PP, or TT'
3	NP, TPP', TT'P, TUP, NT, TT'E, or TEE
4	NTNP, TEEP, TEPP', TT'EP, NTEE, TT'EE, or TEEE

XVI. PARAMETER EXTRACTION

With P, QRS, T, and U waves detected (their peak values, places, and periods with respect to the start of the record) various parameters such as the heart rate , PR segment , P duration, QRS width, and T duration are calculated. The extracted features are used to generate a majority cluster representing the effective peak complex parameters. By applying this method a large number of false detection are eliminated.

XVII. FAST FOURIER TRANSFORMATION

Digital Spectral analysis the decomposition of a signal into its frequency components using a computer or special purpose hardware is a valuable technique in many branches of engineering, applied science, and data processing. An FFT algorithm is the natural choice for this work because of its speed. The basic assumption behind FFT analysis is that a frequency domain description is likely to reveal important information which is not apparent in the time domain signal. Note that spectral analysis, unlike digital filtering, is primarily investigative. It is not necessarily concerned with modifying the signal. Nevertheless the information it yeilds often leads to important insights or decisions.

In many cases digital spectral analysis is concerned with naturally according signal. Examples arise in the analysis of speech, biomedical signals such as the ECG signal, meterological data, stock market indicators, and so on. Some of these applications involve searching for a wanted signal in the presence of unwanted distribuances or noise, on the bases of their different spectral distributions[5].

For a sequence of N values, where N is a power of 2, the FFT is:

$$F(u) = \frac{1}{N}\sum_{x=1}^{N-1} f(x) w_N^{ux} \qquad \text{……(2)}$$

(1)

$$w_N^{ux} = e^{-j2\pi ux/N} \qquad \text{…….(3)}$$

A widely used allternative is to express each component in terms of amplitude and phase. Thus if the kth coefficent has real part $\Re(ak)$ and imaaginary part $g(ak)$, its magnitude equals the root of the sum of the squares:

$$|a_k| = \{\Re(a_k)^2 + g(a_k)^2\}^{1/2} \quad \text{….(4)}$$

And its phase angle is:

$$\phi_k = \arctan\{\frac{g(a_k)}{\Re(a_k)}\} \qquad \text{…..(5)}$$

Quite often we are more interested in magnitudes than phases, so the phase information may be omitted [5].

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XVIII. A METHOD OF DIAGNOSING DISEASES IN FREQUENCY DOMAIN

This method use large amount of data sequence. To decrease this data, Hamming window is used. In general, we are left with a trade_off of making N large enough so that smearing is minimized, yet small enough to allow reasonable implementation. Much work has been done on adjusting w(n) to satisfy certain main lobe and side lobe requirements. Some of the most commonly used windows are the rectangular, Bartlet, Hanning, Hamming, Blackman, and Kaiser windows. These are defined mathematically as follows:[3]

$$w_{Ham}(n) = \begin{cases} 0.54 - 0.46\cos[2\pi n/(N-1)] & , \quad 0 \le n \le N-1 \\ 0 & , \quad \text{elsewhere} \end{cases} \quad \ldots(6)$$

The sequence of 1024 points passed through a Hamming window to minimize the effects of segmentation on the spectra. Fast Fourier transformation was applied to the sequence. From the resulting complex coefficients, an estimation of the amplitude spectrum was made by approximating the modules by the sum of the absolute values of the real and imaginary parts of the complex coefficients. After calculating the amplitude spectrum, the maximum peak in the range 0.5-9 Hz is searched. Afterward, all components whose value is less than 5% of this maximum are equated to zero. Thus, insignificant components away from the origin of the frequencies are not allowed to influence decisively the estimation of some of the descriptors subsequently produce.

The system satisfactory fulfills the requirement for which it has been designed: to prevent the great majority of artifacts imitating fast ventricular arrhythmias from being considered as arrythmetic episodes.

XIX. RESULTS AND DISCUSSION

Several algorithms have been implemented for the production of the ECG diagnosis system. These algorithms process ECG signal in many techniques. Each of them have many steps as follows:

Extracting diagnostic features from the signal. Applying the Fast Fourier Transformation algorithm to covert signal to frequency domain, sometimes we need to find FFT for the signal beat by beat. Also, analyzing the spectrum of the resultant signal.

Application of clinical criteria to the extracted features and generating a medical report.

A. *Extracting Diagnostic Features*

A derivative based algorithm for the detection of peak complexes was implemented to find peak's values, places and duration with respect to the start of the data record. A 264 ECG signal containing about 1300 QRS complexes was used as a testing set. It is noted that the used set of records contain a high percentage of pathological ECGs, and there are some QRS complexes which are hardly recognized even visually.

B. *Applying the FFT Algorithm*

The FFT is used to generate the frequency domain of ECG signal. In the cases of sinus arrhythmia, the signal is processed from lead I beat by beat. The heart rate is the maximum absolute value of the power spectral of beats. the FFT is applied on an 1300 QRS complexes separately and 246 ECG signal.

The frequency of the ECG signal lies between (0.6-50) Hz in normal cases, but in bundle branch block the minimum BSA (50) Hz will increase. This increasing is seemed also will increase when there is some heart disease. Three cases of bundle branch block were checked. Also four ECG signals of ventricular hypertrophy is examined. The frequencies in LVH decrease, while it increase in RVH. Three cases of fibrillation-flutter and imitative artifact is used.

C. *Clinical Reports*

Medical reports of 20 cases are given hereafter demonstrate the diagnostic capability achieved. Some report contains at its beginning some individual information about the patient that could be demanded by some of the diagnosis criteria or by the cardiologists.

The report indicates the patient heart state. The diagnosis was made using various medical criteria that are available in medical books as well as basing on knowledge gained by consulting expert cardiologists.

The report contains time domain diagnoses then frequency domain. The implemented diagnosis criteria are: sinus arrhythmia, heart nerves conduction blocks, infarction, and ventricular hypertrophy.

The following are diagnosis report of two parts. The first part is a real-time diagnosis, while a second part is a frequency domain diagnosis.

Application of clinical criteria to the extracted features and generating a medical report.

D. *Application Sample Reports:*

Patient Name: a
Patient Age: 45 years old
Patient Sex: Female
Patient (Fat or Thin): Fat
Rate: 120.776 beats/min, Sinus Tachycardia, 7.98% max variation.
Electrical axis: Normal axis, 30 degree.
Clues: PR[II] > 0.36 sec., PR[V3] > 0.36 sec., This heart block is benign and may considered as a normal case..
Second Degree Heart Block is probably present.
Clues: There is a P wave without QRS complex in V1., This heart block is benign and may considered as a normal case.
Second Degree 2 to 1 Heart Block is present.
Clues: Two P waves with one QRS complex followed it - sometimes it is 3:1, 4:1, 5:1, ... in I., Two P waves with one QRS complex followed it - sometimes it is 3:1, 4:1, 5:1, ... in II., Two P waves with one QRS complex followed it - sometimes it is 3:1, 4:1, 5:1, ... in V1.
M. Ischemia is present.
Clues: Inverted T waves, dominant ST depression.
A Bundle Branch Block is present, a frequency domain diagnose
Minimum stop band frequency > 50 Hz
Patient Name: b
Patient Age: 63 years old
Patient Sex: Female
Patient (Fat or Thin): Thin
Rate: 94.488 beats/min, Normal Sinus rhythm, 4.02% max variation.

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Electrical axis: Left axis deviation, -60 degree.
Diagnosis: *First Degree Heart Block is probably present.*
Clues: PR[II] > 0.36 sec., This heart block is benign and may considered as a normal case..
Second Degree Heart Block is present.
Clues: There is a P wave without QRS complex in I., There is a P wave without QRS complex in II., This heart block is benign and may considered as a normal case.
Second Degree 2 to 1 Heart Block is present.
Clues: Two P waves with one QRS complex followed it - sometimes it is 3:1, 4:1, 5:1, ... in I., Two P waves with one QRS complex followed it - sometimes it is 3:1, 4:1, 5:1, ... in II., Two P waves with one QRS complex followed it - sometimes it is 3:1, 4:1, 5:1, ... in V1.
Anterior Hemiblock is probably present.
Clues: LAD < -60 degree, r in III.
Inferior M.I. is present.
Clues: q wave in II, III, and aVF(Q > 0.25R).
Anterolateral M.I. is present.
Clues: Q wave in V4, V5, and V6 (Q > 0.15R).
Inferolateral M.I. is present.
Clues: Inferior M.I. + Q in V5 & V6 > 0.15R.
M. Injury is present.
Clues: ST elevation is dominant.
M. Ischemia is probably present.
Clues: Inverted T waves.
There is a *sinus arrhythmia* seemed in the frequency domain.

Patient Name: c
Patient Age: 55 years old
Patient Sex: Female
Patient (Fat or Thin): Thin
Rate: 79.911 beats/min, Normal Sinus rhythm, 5.00% max variation.
Electrical axis: Normal axis, 60 degree.
Diagnosis: *First Degree Heart Block is present.*
Clues: PR[II] > 0.36 sec., PR[V3] > 0.36 sec., This heart block is benign and may considered as a normal case..
Second Degree Heart Block is present.
Clues: There is a P wave without QRS complex in I., There is a P wave without QRS complex in II., There is a P wave without QRS complex in V1. This heart block is benign and may considered as a normal case. *Second Degree 2 to 1 Heart Block is present.*
Clues: Two P waves with one QRS complex followed it - sometimes it is 3:1, 4:1, 5:1, ... in I., Two P waves with one QRS complex followed it - sometimes it is 3:1, 4:1, 5:1, ... in II., Two P waves with one QRS complex followed it - sometimes it is 3:1, 4:1, 5:1, ... in V1.
Left Ventricular Hypertrophy is probably present.
Clues: R[V5]+S[V1] > 3.5mV.
M. Injury is present.
Clues: ST elevation is dominant.
M. Ischemia is probably present.
Clues: Tall T waves.
A Bundle Branch Block is present, a frequency domain diagnose
Minimum stopband frequency > 50 Hz
The heart rate in the frequency domain is 125.000000
There is a *sinus arrhythmia* seemed in the frequency domain.
A Left Ventricular Hypertrophy is present. It diagnosed in frequency domain
This is a cause of increasing in power spectrum

Patient Name: d
Patient Age: 55 years old
Patient Sex: Female
Patient (Fat or Thin): Thin
Rate: 86.538 beats/min, Normal Sinus rhythm, 1.09% max variation.
Electrical axis: No-man's land axis, -150 degree.
Diagnosis: *Normal.*

Patient Name: e
Patient Age: 45 years old
Patient Sex: Female
Patient (Fat or Thin): Fat
Rate: 72.874 beats/min, Sinus arrhythmia, 116.74% max variation ectopic beats are present.
Electrical axis: Right axis deviation, 150 degree.
Diagnosis: *First Degree Heart Block is present.*
Clues: PR[II] > 0.36 sec., PR[V3] > 0.36 sec., This heart block is benign and may considered as a normal case..
Second Degree Heart Block is present.
Clues: There is a P wave without QRS complex in I., There is a P wave without QRS complex in II., This heart block is benign and may considered as a normal case.
Left Ventricular Hypertrophy is probably present.
Clues: R[V5]+S[V1] > 3.5mV.
M. Ischemia is present.
Clues: dominant ST depression.
Right Ventricular Hypertrophy is probably present.
Clues: Right axis dev. > 110 degree.
A complete Heart Block is present (rate variation > 100%)
A Bundle Branch Block is present, a frequency domain diagnose
Minimum stopband frequency > 50 Hz
A Right Ventricular Hypertrophy. It diagnosed in frequency domain
This is cause a decreasing in the power spectrum

Patient Name: f
Patient Age: 45 years old
Patient Sex: Female
Patient (Fat or Thin): Thin
Rate: 65.111 beats/min, Normal Sinus rhythm, 2.80% max variation.
Electrical axis: Normal axis, 30 degree.
Diagnosis: *First Degree Heart Block is present.*
Clues: PR[II] > 0.36 sec., PR[V3] > 0.36 sec., This heart block is benign and may considered as a normal case..
Second Degree Heart Block is present.
Clues: There is a P wave without QRS complex in I., There is a P wave without QRS complex in II., This heart block is benign and may considered as a normal case.
Normal.

XX. CONCLUSIONS

Development of a practical ECG diagnosing software system suffer of some problems. First problem is occur when there is large number of patterns, each of them need either segmentation -when extracting features- or large storage -when applying the FFT. The second problem is the similarity in signal morphologies which belonging to the same disease category. The software must be able to deal with such signal variation.

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Otherwise wrong results are quite sure. And the third problem is the un-appearance the small waves in the spectrum of ECG signal which is lead to inability to diagnose the disease related to those small waves. In this thesis, a computer-based system for signal processing with a standard 12 lead perform a pattern recognition to extract features in which a number of signal features are measured and analyzed by subjecting them to medical criteria defining different heart diseases. The technique is medical-knowledge oriented, which mimics that of the cardiologist. The design of the software programs was based on a data-base consisting of 264 ECG signals, which contains about 1300 heart beats -QRS complexes- of different patterns and morphologies, digitized and stored on magnetic storage (hard disk). Finally, it is believed that the diagnostic system developed in this limited framework, opens the way to more sophisticated ECG computer analysis.

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