

A RULE-BASED EXPERT SYSTEM FOR AUTOMATED ECG DIAGNOSIS

Muzhir Shaban Al-Ani and Atiaf Ayal Rawi
University of Al-Anbar, Collage of Computer, Anbar, Iraq

ABSTRACT

This paper presents the development of a rule-based expert system that emulates the ECG interpretation skills of an expert cardiologist for introducing way of automating the diagnosis of cardiac disorders. The knowledge of an expert is confined to him and is not freely available for decision-making. An expert system is developed to overcome this problem. In this rule-based expert system, patient's heart rate and the wave characteristics of the ECG are considered. With these 'facts', rules are framed and a rule base is developed in consultation with experts. An inference engine in the expert system uses these inputs and the rule base to identify any abnormality in the patient's heart. An expert system designed on the basis of information derived from the analysis of (ECG) using Microsoft Visual studio.Net. For this paper the shape of ECG is used to diagnose ECG beat in four types such as Normal beats (N), Sinus Bradycardia beat, Sinus Tachycardia beat and Sinus Arrhythmia beat. The ECG image from ECG simulator is processed by some image processing techniques such as red grid removing, noise rejection, and image thinning firstly, then, combining detection component of ECG signal(P,QRS,T) based on Time-series ECG are obtained. In addition, other features of the signal are obtained to be used as final features for diagnosis.

KEYWORDS: component; ECG Simulator; ECG diagnosis; Heart Arrhythmia; Expert System; if-then-else rules; rule-based system.

I. INTRODUCTION

Heart disease has become the most common disease that affects humans worldwide. Each year millions of people die from heart attacks and an equal number undergo coronary artery bypass surgery or balloon angioplasty for advanced heart disease [1]. Early detection and timely treatment can prevent such events. This would improve the quality of life and slow the progression of heart failure. The first step in the diagnosis is to record the ECG of the patient. An ECG record is a non-invasive diagnostic tool used for the assessment of a patient's heart condition. The features of the ECG, when recognized by simple observations, and combined with heart rate, can lead to a fairly accurate and fast diagnosis [2].

Electrocardiogram (ECG) is a nearly periodic signal that reflects the activity of the heart. A lot of information on the normal and pathological physiology of heart can be Obtained from ECG. However, the ECG signals being non-stationary in nature, it is very difficult to visually analyse them. Thus the need is there for computer based methods for ECG signal Analysis [3] [4]. Bioelectrical signals represent human different organs electrical activities and Electrocardiogram or ECG is one of the important signals among bioelectrical ones that represent heart electrical activity. Deviation and distortion in any parts of ECG that is called Arrhythmia can illustrate a specific heart disease [5].The investigation of the ECG has been extensively used for diagnosing many cardiac diseases. The ECG is a realistic record of the direction and magnitude of the electrical commotion that is generated by depolarization and re-polarization of the atria and ventricles. One cardiac cycle in an ECG signal consists of the P-QRS-T waves. Figure 1 shows ECG signal. The majority of the clinically useful information in the ECG is originated in the intervals and amplitudes defined by its features (characteristic wave peaks and time durations). The improvement of precise and rapid methods for automatic ECG feature extraction is of chief importance, particularly for the examination

of long recordings[6].The ECG feature extraction system provides fundamental features (amplitudes and intervals) to be used in subsequent automatic analysis. In recent times, a number of techniques have been proposed to detect these features[7] [8] [9]. ECG is essentially responsible for patient monitoring and diagnosis. The extracted feature from the ECG signal plays a vital in diagnosing the cardiac disease. The development of accurate and quick methods for automatic ECG feature extraction is of major importance. Therefore it is necessary that the feature extraction system performs accurately. The purpose of feature extraction is to find as few properties as possible within ECG signal that would allow successful abnormality detection and efficient prognosis [10].

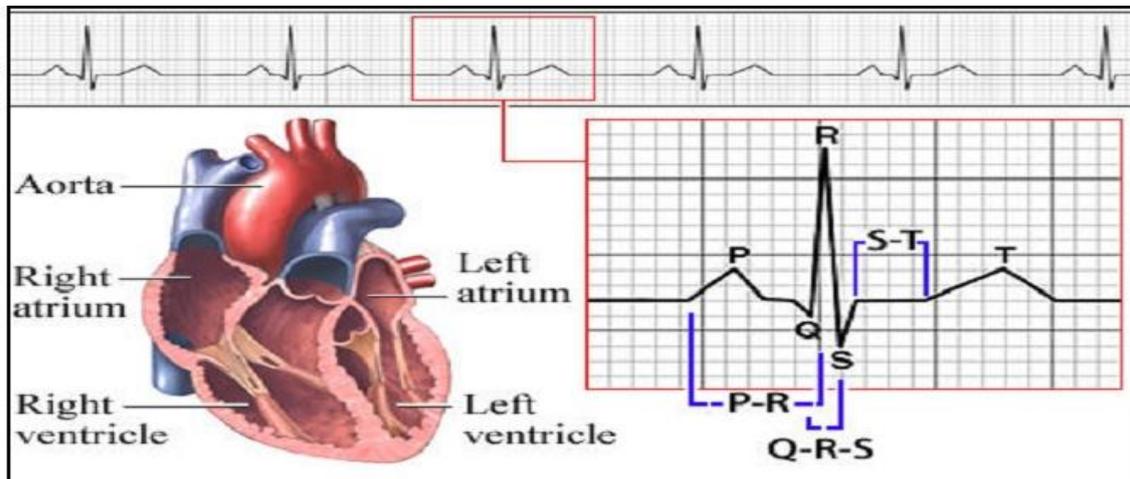


Figure.1. Diagram of the Human Heart and An Example of Normal ECG Trace [11]

II. LITERATURE REVIEW

There are many paper previous works for ECG printout published in this field and some of them are mentioned below:

S. Z. Mahmoodabadi et al, their paper they proposed a fast expert system for electrocardiogram (ECG) arrhythmia detection has been designed in this study. Selecting proper wavelet details, the ECG signals are denoised and beat locations are detected. Beat locations are later used to locate the peaks of the individual waves present in each cardiac cycle. Onsets and offsets of the P and T waves are also detected. These are considered as ECG features which are later used for arrhythmia detection utilizing a novel fuzzy classifier. Fourteen types of arrhythmias and abnormalities can be detected implementing the proposed procedure. They have evaluated the algorithm on the MIT-BIH arrhythmia database. Application of the wavelet filter with the scaling function which closely resembles the shape of the ECG signal has been shown to provide precise results in this study [2].

Mazhar B. Tayel1 and Mohamed E.El-Bouridy in their paper they proposed an intelligent diagnosis system using artificial neural network. Features are extracted from wavelet decomposition of the ECG images intensity. An introduced artificial neural network used as a classifier based on feed forward back propagation with momentum. The classification accuracy of the introduced classifier up to 92% [12].

A. R. Sahab et al. proposed an ECG classifier system based on discrete wavelet (DW) transformation and multilayer Perceptron neural network. Designed Classifier is taught and tested and in its best performance accuracy of 98% percentage [5].

Dusit, et al., their paper they proposed model to classify ECG beats. At first the shape of ECG is used to classify ECG beat in four types. To extract the shape of ECG, DWT transform with level 3 of D1 is used after digital filter was applied to remove noise from ECG signal. After that PCA and SVM are adapted to create model of classifier for using with paper based ECG printout. The performance of this classifier is 99.6367% with LIBSVM [13].

T. M. Nazmy et al. Described an Intelligent Diagnosis System using Hybrid approach of Adaptive Neuro-Fuzzy Inference System (ANFIS) model for classification of (ECG) signals, and comparison this Technique with Feed-Forward Neural Network (FFNN), and Fuzzy

Inference Systems (FIS). Feature extraction using (ICA) and power spectrum, together with the RR interval then serve as input feature vector, this feature were used as input of FFNN, FIS, and ANFIS classifiers The results indicate a high level of efficient, the proposed method outperforms the other methods with an impressive accuracy of 97.1%, As for other methods FFNN, FIS results were respectively 94.3%, 95.7% [14].

Ahmad Khoureich in his paper presented an electrocardiogram (ECG) beat classification method based on waveform similarity and RR interval. The method shows classification rate of 97.52% [15].

III. GENERAL ECG ANALYSIS DESIGN AND ARCHITECTURE

In the previous ECG analysis research, numerous research and algorithm have been developed for the work of analysing and Diagnosing the ECG signal. The ECG analysis techniques are reviewed in and evaluate proposed methods of the Diagnostic methods [11]. The ECG analysis techniques have been identified and it required several stages which are shown in the Figure 2.

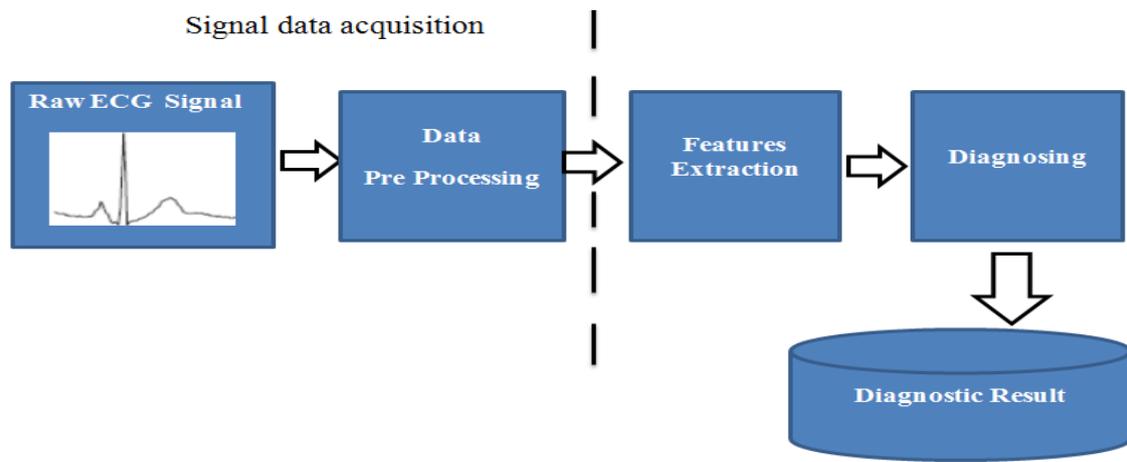


Figure 2. General Diagram of Electrocardiogram Analysis

IV. SELECTED NORMAL AND ARRHYTHMIA ECG SIGNALS CHARACTERISTICS

Figure 1 shows a single period of normal ECG signal. Each normal ECG has 4 main sections include; P wave, QRS complex, T wave and U wave. It is necessary to mention that U wave is existed in 50 to 75 percentages of signals. Distortions, changes or deformations of any main section of ECG signal represent an arrhythmia [5] [16] [17].

A. Normal ECG Signal Characteristics

A normal ECG signal is illustrated in Figure 3.a. The P wave that is the first part of normal ECG signal has the height of 2 until 3 mm, PR length of 0.12 s. Complex QRS has the height of 5 until 30 mm, time span PR length between 0.06 until 0.12 s and T wave is positive with height of approximately between 0.5 to 10 mm and Rate: Normal (60–100 bpm), Rhythm: Regular [5], [17] and [18].

B. Sinus Bradycardia ECG Signal Characteristics

Sinus Bradycardia ECG signal is illustrated in Figure 3.b. Results from slowing of the SA node. The P wave that is normal ECG signal has the height of 2 until 3 mm Normal (upright and uniform), PR length of 0.12 s. Complex QRS has the height of 5 until 30 mm, and T wave is positive with height of approximately between 0.5 to 10 mm but Rate: Slow (<60 bpm) and Rhythm: Regular [17], [18] and [19].

C. Sinus Tachycardia ECG Signal Characteristics

Sinus Tachycardia ECG Signal is illustrated in Figure 3.c. Results from increased SA node discharge. The P wave that is normal ECG signal has the height of 2 until 3 mm Normal (upright and uniform),

PR length of 0.12 s. Complex QRS has the height of 5 until 30 mm, and T wave is positive with height of approximately between 0.5 to 10 mm but Rate: Fast (>100 bpm) and Rhythm: Regular [17] [18] [19].

D. Sinus Arrhythmia ECG Signal Characteristics

Sinus Arrhythmia is illustrated in Figure (3.8) The SA node discharges irregularly. The R-R interval is irregular. P Waves: Normal (upright and uniform); PR Interval: Normal (0.12–0.20 sec). QRS: Normal (0.06–0.10 sec). Rate: Usually normal (60–100 bpm); frequently increases with inspiration and decreases with expiration. Rhythm: Irregular; varies with respiration [17][18][19].

As it can be inferred from Fig.3 a, b, c, d, e and their descriptions, these signals have different maximums and minimums and direction (up, down), and kind wave (P, QRS, T) so that utilizing these differences and some other characteristics vector can be extracted.



Figure(3.a). Normal ECG signal



Figure (3.b). Sinus Bradycardia ECG Signal



Figure (3.c). Sinus Tachycardia ECG Signal



Figure (3.d). Sinus Arrhythmia

Figure. 3. Selected Normal and Arrhythmia ECG Signals

V. THE PROPOSED SYSTEM

The block diagram of the proposed approach for ECG beat diagnosis is depicted in Figure 5. This approach is divided into four steps: (1) preprocessing (2) Detection of wave components (3) Feature Extraction (4) Diagnosis by Expert system.

VI. ECG BEAT DETECTION FROM ECG PRINTOUT

This section is dedicated for ECG beat retrieval method from ECG simulator.

A. Pre-processing

1. ECG Select area of interest

An interesting ECG beat (selected lead) is then selected from the image by two labels vertical and horizontal for image and signal processing .This concept is illustrated in figure (7.a).

2. ECG simulator Invert

The image is inverted explains phase *ECG Simulator (Invert)* image colors reverse which is ECG signal ,grid ,background which are white, red and black, it invert to black, Celestial and white.Lead rate for data recorded with speed of 25 mm/sec and calibration voltage 10mm/mv. This concept is illustrated in figure (7.b).

3. ECG image binarization

The selected segment of ECG image is loaded as color image because the color of ECG signal from the original paper is Light black and the color of paper grid is red the color of paper background is light white.

Threshold selection is the process taking the color of each pixel image and return of only Brightness value and compared with scroll value that the carrying value of 0-100 if the biggest draw and white if not Draw Black used for create binary image. But noise will appear in sometimes as shown figure 2. Then it needs to eliminate noise after binarizing the image. This concept is illustrated in figure (7.c).

4. ECG Image thinning

Since the line of ECG trace of original scanned image from ECG printout has a thickness which is a redundant of data in time series domain. Then thinning process with Parallel skeletonization algorithm 1 is used to eliminate this redundant of data a binary digitized drawing can be defined as a matrix Q, where each element, q [i, j], is either 0 (dark point) or 1 (white point) and these points are pixels. The 8-neighbors of a pixel p are identified by the eight directions shown in Figure 4. The four pixels, p [0], p [2], p [4] and p[6] {i.e. north(p), east(p), south(p), and west(p)}, are called the direct neighbors. The four pixels, p[1], p [3], p [5], and p [7] {i.e., north-east (p), south-east (p), south-west (p), and north-west (p)}.

P3 (i-1,j+1)	P2 (i-1,j)	P9 (i-1,j-1)
P4 (i,j+1)	P1 (i , j)	P8 (i,j-1)
P5 (i+1,j+1)	P6 (i+1,j)	P7 (i+1,j-1)

Figure 4. Pixel P and its neighbors

Neighbor number of p, NN (p); is the number of nonzero neighbors of the tested pixel p:

$$NN (p) = \sum_{k=0}^7 p[k] \tag{1}$$

The result of noise rejection and thinning process is shown in figure (7.d.e).

B. Baseline Detection

The baseline voltage of the electrocardiogram is known as the isoelectric line. Typically the isoelectric line is measured as the portion of the tracing following the T wave and preceding the next P wave. Therefore the iso-electric level detection is required because ECG amplitude at different locations in the beat is measured relative to the iso-electric level. We discovered baseline depending on the horizontal line that contains more than the number of black points in ECG image. Thus been determined RET is a sequence of that line RET Index is the number of black dots in that line by (function Image from points) that receive a picture and receive an array of points then we draw the baseline in black color and wave in color red by function its name Draw baseline . This concept is illustrated in figure (7.f).

C. Baseline Adjustment and wave connection (waving)

Modify the baseline and connecting wave carry out by function we called and waving .waving idea follows receive a picture and receive Block Count and baseline value, a process that Baseline Adjustment so divided image into blocks and each block compare it with the baseline and decide shift up or shift down or keep it on baseline proceed of divided image into blocks execute by following equation:

$$\text{Block Width} = \text{Active Image Width} / \text{Block Count} - 1 \quad \dots\dots\dots (2)$$

We know matrix contain points that away from the baseline in all X and Y registered in this matrix and work arrays of numbers blocks and then calculate point above and below the baseline for all Block by the following equations simple are calculation and if the number of points above of baseline greater than the existing on-baseline shift for up in one and if the number of points below of the baseline higher than the baseline shift for the top one. And Add new points later and create the new image of the points after the adjustment and create Graphics on the image to draw the base line in colour black after the adjustment and connect between previous and current point in red line. This concept is illustrated in figure (7.g).

D. Feature Extraction

The final before stage for ECG signal analysis is to extract efficient features from the signals. The features, which represent the diagnosis information contained in the signals, are used as inputs to the diagnose used in the diagnosis stage. The goal of the feature extraction stage is to find the smallest set of features that enables acceptable diagnosis rates to be achieved. Includes detecting stage applied by function rectangles and this function receives an image and receive the value of the baseline after waving stage and give us a list of rectangles depending on Baseline string from and containing two colour either Black is the colour baseline and red is wave colour after the waving and give the direction of each wave either top or bottom. In the detecting stage start of the accounts is bring a list of rectangles of the image and the value of the baseline and first for each rectangle is calculated following Space, height, and width and left and direction and the type of wave(P,Q,R,S,T). The detecting of the type of wave as follows begin calculates maximum peak height (R) *0.6. The top of it is R. Any detecting of all R wave Then calculate the pre-R is a Q-Wave based on space and on the basis of the time series for waveform and based on direction .In the same way, is to detect the other waves on the same basis. This concept is illustrated in figure (7.h).In drawing stage from the destination image create Graphics for draw each rectangle in the image after detecting stage to draw rectangle in blue colour and then rectangles image. This concept is illustrated in figure (7.i) Before diagnosis stage we calculate Measurement Result by calculate range for each one in them (QRS, QT, QTCB, PR, P, RR, PP) and calculate ECG Regularity (Rhythm) or Irregular and basis this calculate Heart rate (HR) by help human expert (doctor).

If Regular rhythms can be quickly determined by counting the number of large graph boxes between two R waves. That number is divided into 300 to calculate bpm.

$$\text{HR} = 300 / \text{Number of large graph boxes between two R waves} \quad \dots\dots\dots (3)$$

If Regular rhythms can be quickly determined by using 6-sec ECG rhythm strip to calculate heart rate.

$$\text{Formula: } 6\text{-sec (calculate number of R} * 10 \text{ bpm) } \dots\dots\dots (4)$$

This concept is illustrated in figure (7.j).

E. Diagnosis Using Expert System

Expert system technology is considered as one of the useful and interesting applications of Artificial intelligence that could be defined as a program that attempts to mimic human expertise by applying inference methods to a specific body of knowledge (domain) [20]. This technology would fulfil any function through human expertise, or it could be assistance to human decision maker [21]. Expert Systems can be defined as a computer programs which are designed to manipulate information in a high level way, and so to emulate or assist human experts who employ expertise and knowledge[23].Expert (knowledge-based) systems represent a programming approach and

methodology, which considered as an important sub-area of Artificial Intelligence (AI)[24]. Expert system has been successfully applied to diverse range of domains, including interpretation of data, diagnosis of faults or diseases, design, control, and planning [22][27].

The proposed architecture of the expert system for the medical diagnosis support in Cardiology is presented in Figure 5. The framework of the rule based expert system [25] consists of:

- 1) **Facts** – input obtained from the user's response through the graphical user interface based on observations from ECG.
- 2) **A rule-base** – a set of rules developed in consultation with experts based on heart rate and ECG wave characteristics.
- 3) **An inference module** – that matches the input (facts) with a rule in the rule-base to identify the abnormality.
- 4) **A database** – that stores the patient's personal details inputs, diagnosed results. Expert cardiologists were consulted and rules were framed with patient's heart rate and ECG wave characteristics as inputs [26].

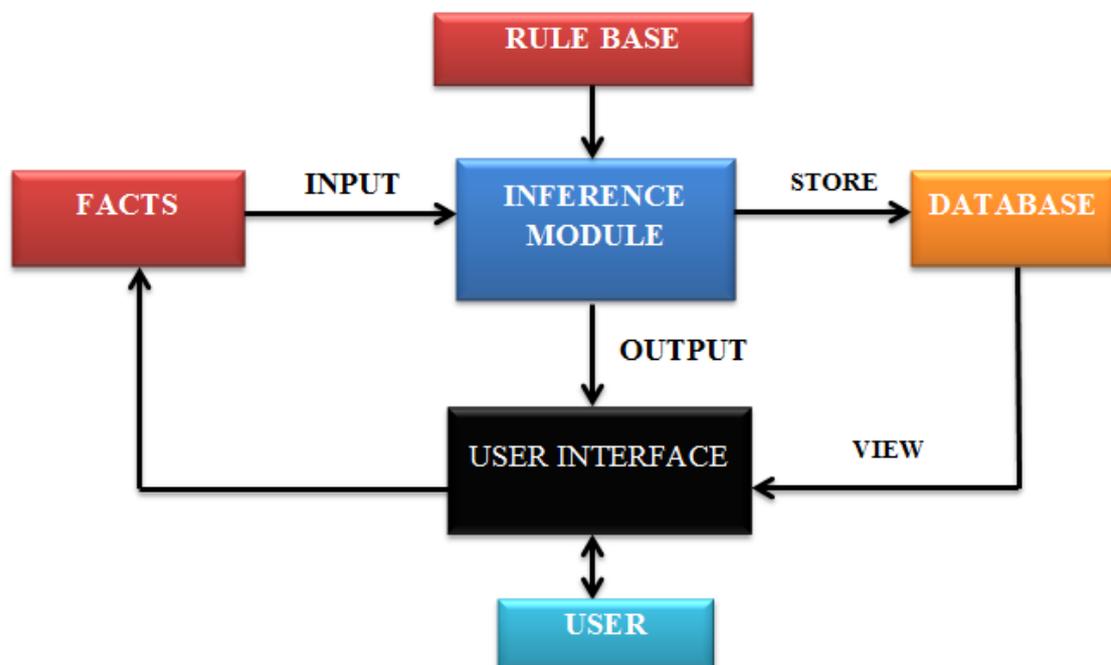


Figure 5. Architecture of the rule based expert system

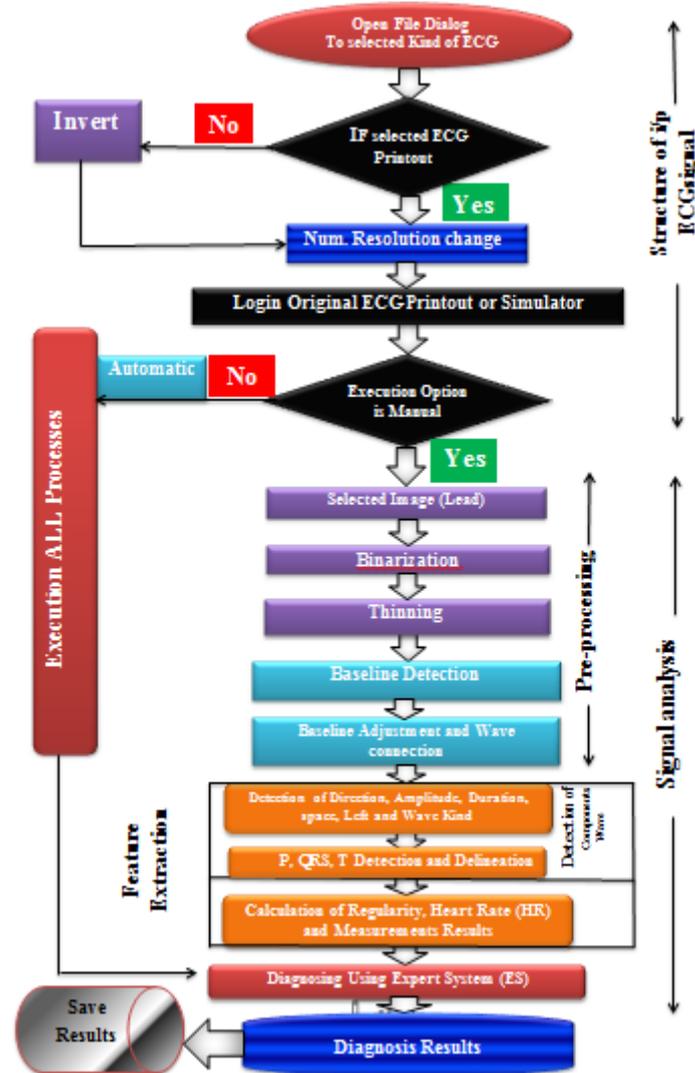


Figure 6. The proposed ECG signal recognition approach

An ECG Automatic Diagnosing based Expert System is presented as a diagnostic tool to aid physicians in the diagnosis of heart diseases. ECGADES using a strategy of expert approach of System, we compose this expert approached, and it will be achieve good reasoning in quality and quantity.

The objective of ECG system is to diagnose four types of ECG signals, the feature extraction were applied as the input to ECGAD Expert System. This concept is illustrated in figure (7.j).

VII. RESULTS & ANALYSIS

The Cardiac Signal Analysis software has been implemented in Microsoft Visual Studio 2010 Ultimate) software. The software has been tested with ECG Software; Arrhythmia data base. The ECG Signal shown in Figure. 7, (Record ECG signal A, is having sinus Normal rhythm Heart;) from ECG Software Arrhythmia data base is taken for validation and applied to the software. The analysis has been carried out for lead cases on the data available from ECG Software arrhythmia database and it has been working satisfactorily. The approach has been found to be successful in four types of cardiac disorders and tested for leads of ECG Software (Record ECG signal A, is having sinus normal rhythm;)(Record ECG signal B, is having sinus bradycardia;)(Record ECG signal C sinus Tachycardia;)(Record ECG signal D, is having sinus Arrhythmia ;) are matched with three cardiac disorders. The results based on algorithm with the steps shown in Figure.6 are as shown in following figures in Figure.7 from a to j. and Figure(.8.a) As shown ECG signal is having sinus Tachycardia

Heart and b. as shown ECG signal is having sinus bradycardia Heart and c. The ECG signal is having sinus Arrhythmia Heart as shown the Record ECG signal is having sinus Normal rhythm Heart) is shown in Table 1.



Figure.(7.a).ECG(Select area of interest ECG simulator)



Figure.(7. b) ECG Simulator Invert



Figure. (7. c). ECG (Binary image of ECG and noise)



Figure. (7. d). ECG (Noise rejection)



Figure (7. e).ECG(Thinning)



Figure.(7.f).ECG (Baseline Detection)



Figure (7.g).ECG (Baseline Adjustment and wave connection)



Figure.(7.h).ECG(Detecting Stage)



Figure.(7. i).ECG(Drawing Stage)



Figure.(7.j) Normal ECG Simulator (Diagnosis Stage)

Figure. (7.a-j) Were Stages of Diagnosis for (ECG Software decision: The ECG signal is having Sinus Normal Rhythm ;)



Figure.(8.a). Sinus Tachycardia (ECG Simulator) diagnosis

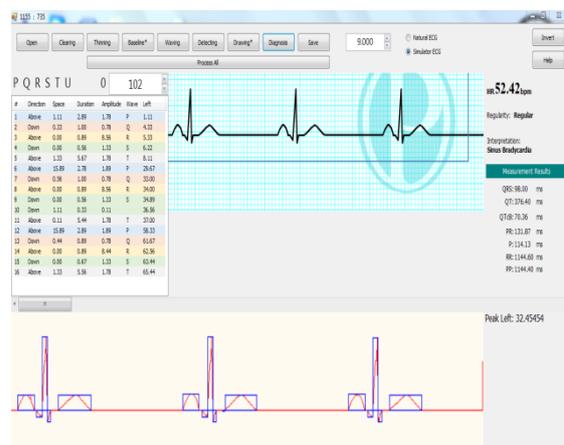


Figure (8. b). Sinus Bradycardia (ECG Simulator) diagnosis



Figure.(8.c). Sinus Arrhythmia (ECG Simulator) diagnosis

Figure. (8. a-c). Were Types of the selected Diseases for Diagnosis

Table 1. Parameters Measured in Analysis Phase and Final Diagnosis for (Sinus Normal Rhythm ECG Simulator ;) and show Testing results of the ECG ADES.

HR	83.46 bpm					
Regularity	Regular					
Interpretation	Normal					
Measurement Results	Expert cardiologist decision: The ECG signal is having Sinus Normal Rhythm Regular 60-100bpm					
QRS: 102.40ms						
QT: 379.52ms						
QTcB: 89.52 ms						
PR: 125.60 ms						
P: 107.68ms						
RR: 718.90 ms						
PP: 716.60ms						
#	Left	Amplitude	Duration	Space	Direction	Wave
1.	0.56	1.56	2.56	0.56	Above	P
2.	3.11	1.00	1.22	0.00	Down	Q
3.	4.33	8.56	1.11	0.00	Above	R
4.	5.44	1.56	0.78	0.00	Down	S
5.	7.67	1.78	5.44	1.44	Above	T
6.	18.44	1.56	2.78	5.33	Above	P
7.	21.78	0.89	0.56	0.56	Down	Q
8.	22.33	8.56	1.11	0.00	Above	R
9.	23.44	1.44	0.67	0.00	Down	S
10.	25.67	1.78	5.44	1.56	Above	T
11.	36.44	1.67	2.67	5.33	Above	P
12.	39.67	0.89	0.67	0.56	Down	Q
13.	40.33	8.67	1.00	0.00	Above	R
14.	41.33	1.56	0.78	0.00	Down	S
15.	43.56	1.78	5.44	1.44	Above	T
16.	54.44	1.67	2.67	5.44	Above	P
17.	57.67	0.89	0.56	0.56	Down	Q
18.	58.22	8.56	1.11	0.00	Above	R
19.	59.33	1.56	0.78	0.00	Down	S

20.	61.56	1.78	5.44	1.44	Above	T
21.	72.22	1.67	2.78	5.22	Above	P
22.	75.56	1.00	0.67	0.56	Down	Q
23.	76.22	8.44	1.11	0.00	Above	R
24.	77.33	1.56	0.67	0.00	Down	S
25.	79.56	1.78	5.44	1.56	Above	T

VIII. CONCLUSION

The paper presents a system expert general structure that provide support for medical diagnosis based on the EKG information retrieved from the human subject. Its content refers only to interface between external medium (human expert, knowledge engineer or any medical user) and expert system. The interface contains the main special characteristics for the knowledge introducing or extracting in a facile and attractive conversational mode. The expert system enter can be a specific external database too. We propose a method that uses expert system approach named (ECG Automatic Diagnosing Expert System (ECG-ADES) for diagnosis of Electrocardiogram (ECG) simulator signals. The ECG expert system is computationally fast and diagnosis achieved is a good. (ECG-ADES) model demonstrated high diagnosis accuracies and combines the benefits of Expert System, we have using component detection of ECG simulator Signal, to extract important feature, and HR, Rhythm, Measurement results calculate together with the RR interval, then serve as input feature extraction, this feature were used as input of ECG Expert system. Four types of ECG simulator beats were selected from the ECG Software; arrhythmia database for experiments. The results indicate a high level of efficient; the proposed method performs with an impressive accuracy. In conclusion, our system has many advantages including efficiency, accuracy, and simplicity. We believe that it is very suitable to arrhythmic detection in clinical practice.

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REFERENCES

- [1]. I. S. Ahuja, R. S. Bhatia, G. K. Ahuja, (2007)“Understanding ECG,” Peepee Publishers and Distributors (P) Ltd, FirstEdition, New Delhi.
- [2]. V.Mahesh, A.Kandaswamy, and R.Venkatesan, (2009)“A Rule-based ExpertSystemfor ECG Analysis,” International Journal of Engineering and Technology V ol. 1, No.3, August, India.
- [3]. S. Priyadarshini., (2010) “ECG Signal Analysis Enhancement and R_ Peak Detection”, Rourkela, INDIA.
- [4]. A.Ghaffari, H.Golabayani, M.Ghasem.i, (2008)“A new mathematical based QRS detector Using continuous wavelet transform”, Computers and Electrical Engineering.
- [5]. A. R. Sahab and Y. Mehrzad Gilmalek., (2011)“An Automatic Diagnostic Machine for ECG Arrhythmias classification Based on Wavelet Transformation and Neural Networks”, University Lahijan Branch.
- [6]. S. Z. Mahmoodabadi, A. Ahmadian and M. D. Abolhasani., (2005) “ECG Feature Extraction using Daubechies Wavelets,” Proceedings of the fifth IASTED International conference on Visualization, Imaging and Image Processing, pp. 343-348.
- [7]. Juan Pablo Martinez, Rute Almeida, Salvador Olmos, Ana Paula Rocha, and Pablo Laguna., (2004) “A Wavelet-Based ECG Delineator: Evaluation on Standard Databases,” IEEE Transactions on Biomedical Engineering Vol. 51, No. 4, pp. 570-581.
- [8]. Krishna Prasad and J. S. Sahambi., (2003) “Classification of ECG Arrhythmias using Multi-Resolution Analysis and Neural Networks,” IEEE Transactions on Biomedical Engineering, vol. 1, pp. 227-231.
- [9]. Cuiwei Li, Chongxun Zheng, and Changfeng Tai., (1995). “Detection of ECG Characteristic Points using Wavelet Transforms,” IEEE Transactions on Biomedical Engineering, Vol. 42, No. 1, pp. 21-28.

- [10]. S.Karpagachelvi, Dr.M.Arthanari, Prof. & Head, M.Sivakumar., (2010)."ECG Feature Extraction Techniques – A Survey Approach", Doctoral Research Scholar, Dept. of Computer Science and Engineering".
- [11]. N. H. Kamarudin., ,(2010) "Feature Extraction And Classification Of Electrocardiogram Signal To Detect Arrhythmia And Ischemia Disease", University Of Malaya.
- [12]. Mazhar B. Tayel1, Mohamed E.El-Bouridy2, (2006) "ECG Images Classification Using Feature Extraction Based On Wavelet Transformation And Neural Network ", Electrical Engineering Department Faculty of Engineering, Alexandria University Alexandria, Egypt.
- [13]. D. Thanapatay1, C. Suwansaroj and C. Thanawattano., (2010) " ECG beat classification method for ECG printout with Principle Components Analysis and Support Vector Machines", D. Thanapatay1, C. Suwansaroj. Department of Electrical Engineering Kasetsart University, Bangkok, Thailand. And C. Thanawattano National Electronics and Computer Technology Center Pathumthani, Thailand (NECTEC).
- [14]. T. M. Nazmy, B. AL-Bokhity and H. EL-Messily. , (2010) " Classification of Cardiac Arrhythmia based on Hybrid System ", T. M. Nazmy Prof. Faculty of computer B. AL-Bokhity and H. EL-Messiry Faculty of computer, and information sciences, Ain Shams University,Cairo,Egypt.
- [15]. Ahmad Khoureich Ka., (2011) " ECG beats classification using waveform similarity and RR interval".
- [16]. P. Welling, Z. Cheng, M. Smelling and G. S. Moschytz.; (1998). "Electromyogram data compression using single-tree and modified zero-tree wavelet encoding"; Proc. Of the 20th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, Vol. 20, No. 3, pp. 1303-1306.
- [17]. Porterfield, Linda M., (1997) "ECG Interpretation Made Incredibly Easy" Ones Edition, Spring House Co, Pennsylvania.
- [18]. Goldberger, Ary L. (1999) "Clinical Electrocardiography A Simplified Approach", 6th edition, Mosby co, St. Louis.
- [19]. A. Jones , (2005)"ECG Notes".
- [20]. Darlington K., (2000) "The Essence of Expert Systems", Prentice-Hall.
- [21]. Stephan J.J., "Certainty Factor Based Expert System for Diagnosing Recurrent Abdominal Pain", MSc. Thesis, Baghdad University, Department of Computer Science.
- [22]. Turban E. Aronson J.E., (1998). "Decision Support Systems and Intelligent Systems", Prentice-Hall.
- [23]. Hart A., (1988). "Expert Systems an Introduction for Managers", Billing and Son Ltd.
- [24]. Waterman D.A(1986).. "A Guide to Expert Systems", Addison Wesley Publishing Company.
- [25]. S. M. Patil, S. D. Bhagwat, (1995) "ECG Analysis – An Expert System Approach," Proceedings of first regional Conference of IEEE – EMBS, pp. 2/48-2/49.
- [26]. S. S. N Alhady, P. A. Venkatachalam, M. Sulaiman, (2000) "Noiseless ECG monitoring system integrated expert system," First International Conference on Advances in Medical Signal and Information Processing, pp.79-87.
- [27]. Muzhir S. AL-Ani, Atiaf A. Rawi , (2013) "ECG Beat Diagnosis Approach for ECG Printout Based on Expert System," College of Computer - Anbar University – Anbar – Iraq.

AUTHORS PROFILE

¹**Muzhir Shaban Al-Ani** has received Ph. D. in Computer & Communication Engineering Technology, ETSII, Valladolid University, Spain, 1994. Assistant of Dean at Al-Anbar Technical Institute (1985). Head of Electrical Department at Al-Anbar Technical Institute, Iraq (1985-1988), Head of Computer and Software Engineering Department at Al-Mustansyria University, Iraq (1997-2001), Dean of Computer Science (CS) & Information System (IS) faculty at University of Technology, Iraq (2001-2003). He joined in 15 September 2003 Electrical and Computer Engineering Department, College of Engineering, Applied Science University, Amman, Jordan, as Associated Professor. He joined in 15 September 2005 Management Information System Department, Amman Arab University, Amman, Jordan, as Associated Professor, then he joined computer science department in 15 September 2008 at the same university. He joined in August 2009 Computer Science Department, Anbar University, Anbar, Iraq, as Professor.



²**Atiaf Ayal Rawi** Received the B.S. in Computer Science from Al _Anbar University, College of Computer, Department of Computer Science 2010, and the M.S. in Computer Science from Al _Anbar University, in 2011 respectively. Her research interests include signal processing, image processing and Expert systems for biomedical signal engineering.