Development Of Methodology for Precise Diagnosis of Ecg By Artificial Intelligent

Conference Paper · February 2019

DOI: 10.1109/ICECCT.2019.8869413

Rachit Patel
Loyola Marymount University

Development Of Methodology for Precise Diagnosis of Ecg By Artificial Intelligent

Rachit N. Patel
Department of Computer Engineering
LDRP Institute of technology
and Research
Gandhinagar-382016, Gujarat, India
rachit.nc@gmail.com

Mehul P. Barot
Department of Computer Engineering
LDRP Institute of technology
and Research
Gandhinagar-382016, Gujarat, India
m.p.barot@gmail.com

***Abstract*— Implementation of Artificial Intelligence in medical diagnosis is a subject of intense study in nowadays. One of the current interests of developing an Artificial Intelligent is to develop an AI system for diagnosis of heart disease from Electrocardiogram (ECG). Few AI programs have also been developed for ECG diagnosis system, but most of them are based on pattern comparison algorithm which can never achieve the sufficient precision and accuracy for diagnosis task. To eliminate these deficiencies, this paper proposes a new methodology that makes AI system more capable for ECG diagnosis. The proposed methodology and design for AI diagnosis system is based on the statistical analysis of ECG and implementation of standard ECG Interpretation Principles for diagnosis of cardiac arrhythmias. This method is completely knowledge based and it applies the same methods and rules of cardiology which are implemented by a medical expert (cardiologist) to make a report of patient's ECG. The proposed methodology also provides an ability of self learning to AI system in order to utilize the experiences in further diagnosis service.**

Keywords*— Electrocardiogram (ECG), Electrocardiograph, Sinus rhythm, Cardiology, Cardiac anatomy, Cardiac Arrhythmias, Rhythm-Strip, ECG-Complex, Ventricular Systole, Ventricular Diastole.

I. Introduction

A. Background of AI in medical science

The Artificial Intelligent can be defined as "A computer program that can think, proceed and reason like humankind". The aim of implementation of Artificial Intelligence in medical science is to provide such services those are being provided by medical experts. Services in medical science are divided into two aspects. One is diagnosis service and the other is medical treatment. The medical treatment is provided by experts or doctors exclusively. But the medical diagnosis is totally based upon knowledge, classified theories, experience and medical history. A doctor identifies the basic symptoms of disease, and then prescribes the medicines and treatments as per medical theory and classified data.

B. AI in ECG Diagnosis System

The ECG diagnosis service in current system is mainly provided by the Cardiologist. The *Electrocardiogram* (ECG) is produced by the machine called *Electrocardiograph* that reads the electric pulses of heart. The Cardiologist examines the ECG by applying the standard ECG interpretation principles and makes a report of heart's performance, cardiac arrhythmias and also prescribes medicines and treatments within the report. By assuming these basic ECG interpretation principles as a finite set of conditional statements for all the possible configurations of ECG, a library have been developed which provides the essential knowledge to the proposed Artificial Intelligent for the implementation of ECG interpretation principles in diagnosis task. By providing such a library, a smart AI system can be developed and trained to perform diagnosis task as proficiently as a human expert does.

II. Problem Definition

AI software for ECG diagnosis system generally uses different images of ECG of unique cardiac arrhythmias and compares them with the ECG of a patient in order to find some similarities for any possible cardiac disease. The AI program uses the pattern comparison algorithm and that costs accuracy, precision and efficiency of diagnosis task. Moreover, this type of AI is able to diagnosis only those diseases whose ECG images are available to it. These aspects limit the scope for ECG diagnosis task and make AI system less relevant to general purpose usage. Hence, it is necessary to develop a smart ECG diagnosis methodology for AI which guarantees the accuracy and precision in ECG diagnosis task and also proficiently applicable for AI at medical diagnosis service.

III. Medical Overview

A. Electrocardiogram

The heart's electrical activity produces currents that radiate through the surrounding tissue to the skin. When electrodes of *Electrocardiograph* are attached to the skin, they sense those electrical currents and transform them into electric waveforms called *Electrocardiogram* (ECG) that represent the heart's depolarization-repolarization cycle. An ECG shows the precise sequence of electrical events occurring in the cardiac cells throughout the functions of heart. A series of ECGs can be used as a baseline comparison to assess cardiac function.

B. LEADs

An ECG records information about electric waveforms produced by heart from different views or perspectives. Those perspectives are called LEADs**.** In the other words, LEADs are different arrangements of electrodes that represent the different electric waves for different views of heart. The standard ECG can have 12 different LEADs show the 12 different views and also known as a 12 LEAD ECG. These 12 different views of 12 different LEADs are obtained by placing electrodes on the patient's *Limbs* and *Chest*. The six limb leads — Lead - I, II, III, augmented vector right (aV_R), augmented vector left (aV_L), and augmented vector foot (aV_F) — provide the information about the heart's frontal (vertical) plane.. And the six Chest or Precordial leads—V1, V2, V3, V4, V5, and V6—provide the information about the heart's horizontal plane.

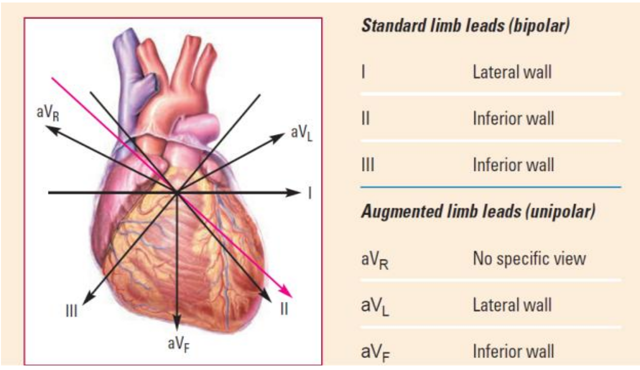

Figure 1: Limb leads [1]

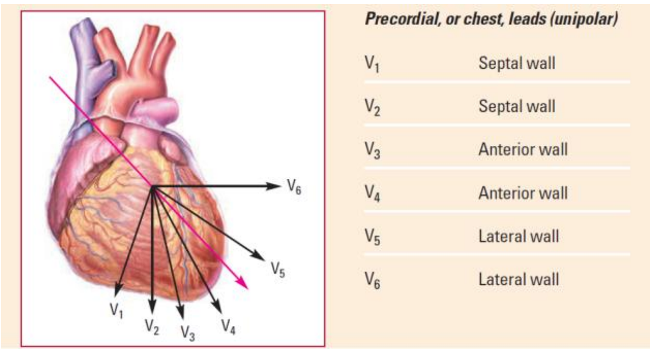

Figure 2: Precordial leads [1]

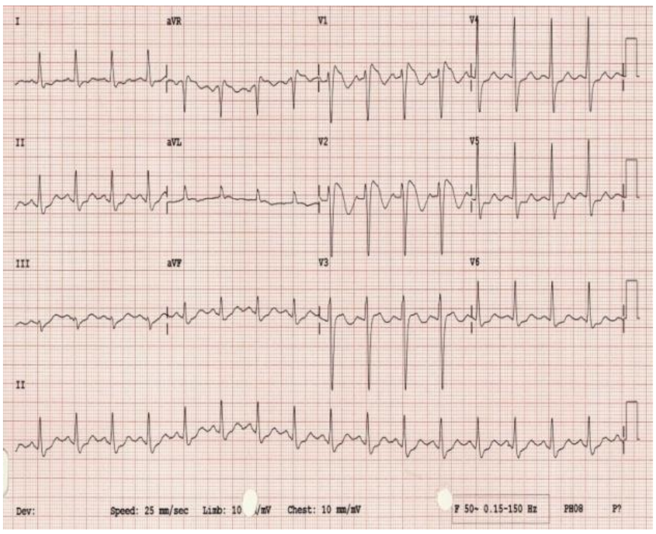

Figure 3: 12 LEADs ECG [5]

C. Rhythm Strip

The interpretation of ECG mainly concerns with the interpretation of a "Rhythm strip" which is produces by heart's electrical impulses throughout the observation time period. The Limb lead LEAD-II is used as the rhythm Strip for routine check-up and illustrated separately at the beneath of the 12 leads in ECG report. The observation time of Rhythm strip is taken most among all the leads.

D. Cardiac Cycle

Heart performs the ventricular diastole (relaxation or repolarization) and ventricular systole (contraction or depolarization) during every heart beat. During ventricular diastole, ventricles stay relaxes and let the blood in. And during ventricular systole, the ventricles contract and forced the blood to move into *Artery* and *Lungs*. The one pair of Ventricular systole and Ventricular diastole creates one Cardiac Cycle.

E. ECG Complex

The ECG Complex represents the electrical events occurring in one cardiac cycle. An ECG complex consists of five waveforms labeled with the letters P, Q, R, S, and T. The middle three letters —Q, R, and S—are referred to as a unit, the QRS complex. ECG tracings represent the conduction of electrical impulses from the atria to the ventricles.

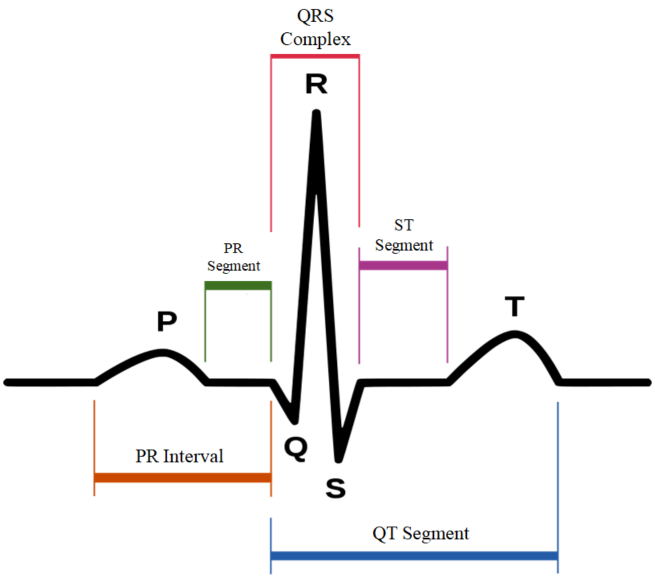

Figure 4: ECG Complex [6]

Components of ECG Complex

- *P-Wave:* The P wave is the first component of a normal ECG waveform. It represents the electric impulse of atrial depolarization from the atria.
- *PR-Interval:* The PR interval tracks the atrial impulse from atria through the AV node, Bundle of His, and right and left bundles of branches. Its location in ECG

complex is from the beginning of the P wave to the beginning of the QRS complex.

- *QRS Complex:* The QRS complex follows the P wave and represents depolarization of the ventricles. Immediately after the ventricles depolarize, as represented by the QRS complex, they contract.
- *ST-Segment:* The ST segment represents the end of ventricular contraction or depolarization and the beginning of ventricular recovery or repolarization.
- *T-Wave:* The T wave represents ventricular recovery or repolarization and it is located after S-wave.
- *QT-Interval:* The QT interval measures ventricular depolarization and repolarization. The length of the QT interval varies according to heart rate.
- *U-Wave:* The U wave represents the recovery period of the Purkinje or ventricular conduction fibbers. It isn't present on every rhythm strip.

F. Summery of Medical Overview

An ECG represents 12 leads and every lead shows different view of heart. Lead II is Rhythm strip which is sequence of numerous ECG complexes. Every ECG Complex represents one cardiac cycle and components of ECG complex are stand for electrical events during one cardiac cycle.

IV. Proposed ECG Diagnosis System

The computer based AI takes an image of an ECG of the patient and performs standard ECG interpretation algorithm. The diagnosis of ECG is based upon rhythm strip because of rhythm strip is used for routine checkup. The waves of all the ECG complexes of a rhythm strip have certain attributes like: Amplitude, Shape, Duration, deflection and position. A cardiologist scrutinizes the configuration of the waves of all ECG complexes of a rhythm strip separately. The main task of diagnosis is to compare the values of all attributes of these waves with their normal criteria. If any wave exceeds its own normal criteria of configuration, then the appropriate disease will be diagnosed. The abnormal conditions in the configuration of any wave of ECG complex can be:

- The value of amplitude is higher or lower than normal criterion of amplitude (the amplitude is in mV).
- The duration is longer or shorter than normal criterion of duration (the duration is in ms).
- The shape of a wave is different from its normal shape.
- The deflection of a wave is totally inverted from its normal direction of deflection.
- The position of a wave with respect to other waves in the ECG complex is deviated from its normal position.The occurrence of similar type of waves is not regular in entire rhythm strip during observation time period.

The ECG interpretation principles are considered as a finite set of conditional statements (or criteria) of all possible configurations of ECG. By using these interpretation principles, a library of conditional statements has been developed which is exclusively used by AI software or Application as a medical literature.

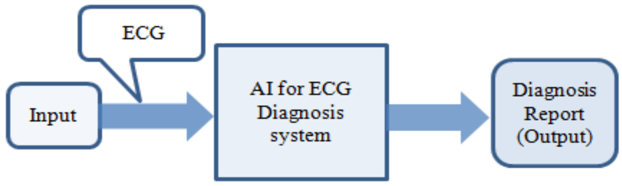

Figure 5: Basic Structure of ECG Diagnosis System

V. Design

The Proposed design of AI diagnosis system supports portable AI software which is created in Python 2.7 with open source image processing library OpenCV and PyQt4 GUI frame work.

The task of ECG diagnosis by Artificial Intelligent is mainly divided into three Layers.

1. Image Analysis
2. Diagnosis Layer1: Determination of Sinus Rhythm
3. Diagnosis Layer2: Recognizing Arrhythmias

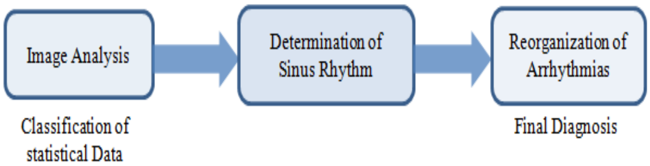

Figure 6: Basic diagram
AI Diagnosis System for ECG

A. Image Analysis

The Electrocardiograph reads the analog signals of electrical activities of heart and converts it into statistical data with respect to observation time period. The Electrograph then plots these statistical data in the form of a graph on the graph paper whose dimensions are globally accepted, and this graphical representation is considered as an ECG. By Image Analysis, AI software reads the .jpeg or .png image of ECG and performs *Heuristic Search* algorithm to fetch the statistical data from electrical events illustrated by rhythm strip on ECG.

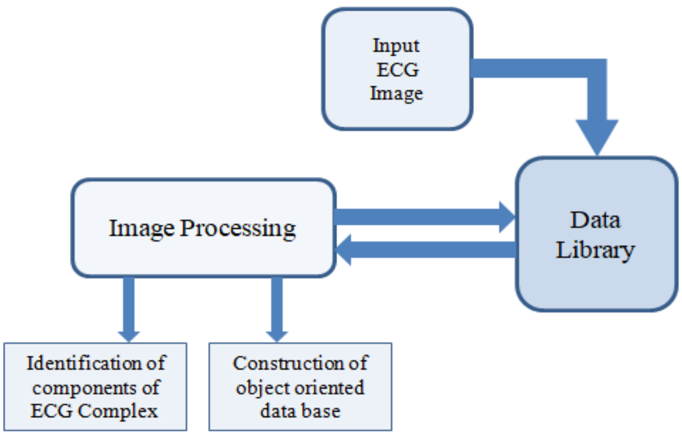

Figure 7: Image Analysis

Tasks performed by AI during Image Analysis:

1. Identification of all the waves in rhythm strip
2. Construction of object oriented database

Figure 8: cropped Rhythm Strip from an ECG

Figure 9: Gray-Scale image of Rhythm Strip

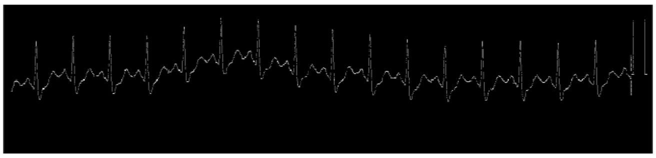

Figure 10: Grid Filtered image of Rhythm Strip

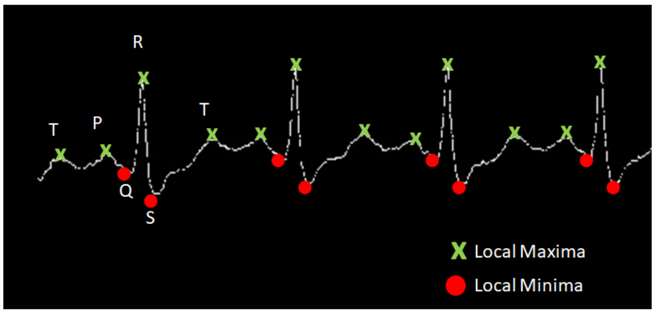

Figure 11: Virtual Image of Identification

After the identification of electric waves, the entire rhythm strip is fragmented into sequential ECG complexes. In object oriented data base of ECG, the object of rhythm strip is made by all the objects of its ECG complexes. Every object of ECG complex has its own objects of electric waves. Hence, all the objects of data base have a relevant inheritance.

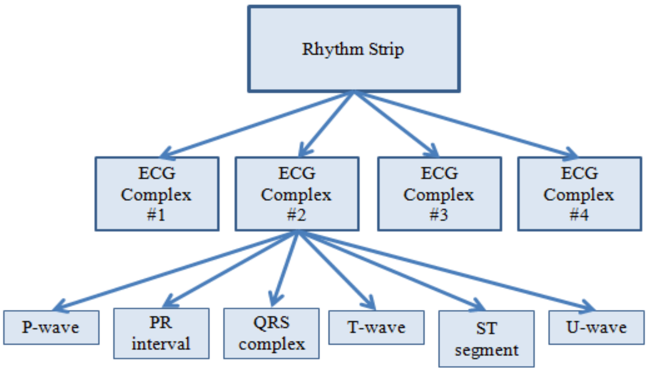

Figure 12: Data Structure

B. Determination of Sinus Rhythm (Diagnosis Layer-1)

Determination of Sinus Rhythm is the first step in the diagnosis of cardiac arrhythmias from ECG. In this first layer of diagnosis task, AI examines the rhythms of all the electric waves and their configuration. If the configuration of all the waves lay in their normal criteria, then AI defines the status of diagnosis layer-1 by “Normal Sinus Rhythm”, otherwise states a “Sinus arrhythmias”.

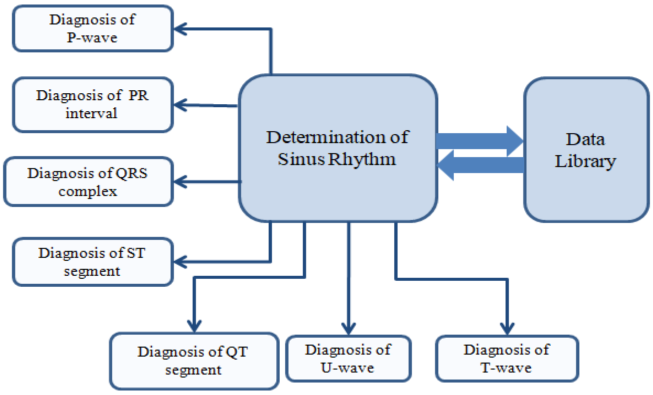

Figure 13: Diagnosis Layer-1

The AI uses the *8 step method* for interpreting Sinus Rhythm which is currently used by practitioners of cardiology. Main advantage of Diagnosis Layer-1 is that it predicts the criteria of possible cardiac arrhythmias and diminishes the number of diagnosis operation in final diagnosis layer.

Tasks of Diagnosis Layer-1:

1. Calculation of rate of Heart beat
2. Determination of Sinus Rhythm

C. Recognizing Arrhythmias (Final Diagnosis Layer)

The Data Library comprises all the definitions of Cardiac Arrhythmia. Both the diagnosis layers share this library in order to fetch the statistical data, definitions of cardiac arrhythmias in the form of user defined functions and the dictionary of the name of all possible Cardiac Arrhythmias. AI performs the final diagnosis task only on those ECG complexes which are suspected by Diagnosis Layer-1. This reduces the time and space complexity of software and uses an optimize solution for diagnosis task.

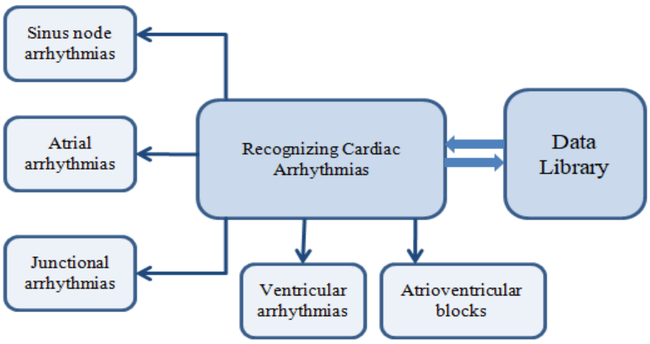

Figure 14: Diagnosis Layer-3

The five major types of Cardiac Arrhythmias are diagnosed during execution of Diagnosis layer-3.

1. Sinus node arrhythmias
2. Atrial arrhythmias
3. Junctional arrhythmias
4. Ventricular arrhythmias
5. Atrioventricular blocks

The Final Diagnosed report is produced after the Final layer of ECG diagnosis. The report contains the performance of heart's functionality, Cardiac arrhythmias or abnormality in heart's behavior and recommendation of medicines and treatments.

VI. Discussions

The proposed methodology of ECG Diagnosis by an AI system is developed in order to provide the same strength of human expert to an AI system for performing diagnosis tasks. In the current diagnosis facility, the determination of Sinus Rhythm is being performed by *Electrocardiograph* and rest of diagnosis of ECG is performed by a cardiologist. These both abilities are integrated into the proposed methodology of AI system. The proposed methodology also requires some additional information like patient's age, gender and weight.

Another aspect of this approach is Self Learning facility which requires a Medical Expert who can observe the performance of the AI system and manually command the AI to accept some exception as additional information. The Self-Learning facility of AI will make it more relevant to perform the knowledge based task than the other AI programs. The authors are pursuing a legal affiliation with a Medical Centre for further development and final implementation.

VII. Conclusion

The study concludes that the Artificial Intelligent can be developed that applies standard ECG interpretation principles for ECG diagnosis. The AI works on proposed methodology can guarantees precision and accuracy that other available AI programs can never. Due this advantage, the proposed method can be used in further research programs of AI for Cardiology and also be implemented in general purpose usage.

Acknowledgment

The authors would like to thank Dr. Hiren B. Patel (head of department of computer Engineering, LDRP-ITR) and Dr. Gargi J. Rajpara (Principal of LDRP-ITR). Authors are also grateful to Mr. Narendra C. patel (Institute for Plasma Research, Gandhinagar-382428) for sharing his precious ideas.

References

[1] Lippincott, ECG Interpreation made Incredibly Easy (Wolters Kluwer), 5th ed, Lippincott Williams and Wilkins, october-2010

[2] Vishal Desai, Dinesh Dave, "Is artificial intelligence better than manual methods in diagnosis of electrocardiograms (ECGs) or not?" International Journal of Advances in Medicine, September-October 2017, Vol 4, Issue 5, pp. 1463–1465

[3] Jaakko Malmivuo, and Robert Plonsey, " Bioelectromagnetism. 19. The Basis of ECG Diagnosis", New York OxfordOXFORD UNIVERSITY PRESS, 1995

[4] Online Arrhythmias Guide Line www.practicalclinicalskills.com/arrhythmia-guide?gclid=CM-V8fzfk7gCFfBDMgodDxwAfA

[5] The online ECG Library - https://litfl.com/brugada-syndrome-ecg-library

[6] Electrocardiography https://en.wikipedia.org/wiki/Electrocardiography