International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-8 Issue-5, June 2019

Hidden Markov Model for The Heart Rate Variability Detection

Pooja Bhor, Gurjot Singh Sodhi Dilbag Singh

***Abstract:** The signal processing is the approach which is applied to process digital signal data. The Electrocardiogram signals are applied to process the heart rate values. The heart rate variability detect has the three phases which are pre-processing, feature extraction and classification. In the previous approach, SVM classifier is applied for the heart rate variability detection. In this research work, Hidden Markov Model classifier is applied for the heart rate variability detection. The performance of proposed model is analyzed in terms of accuracy and execution time. The proposed algorithm improve result upto 8% as compared to existing approach in terms of accuracy.*

***Keywords:** SVM, HMM, Heart Rate variability*

I. INTRODUCTION

Any irregularity in the rate of heartbeat is called arrhythmia. The heart begins to beat either too fast or too slow or in irregular manner at the time of arrhythmia [1]. Some of the arrhythmias can be life-threatening even when few seem to be harmless. Sufficient amount of blood might not be able to be pumped by the heart at the time of arrhythmia. Several other organs like brain and heart can also be damaged due to this kind of lack in blood flow. Life-threatening and non-life-threatening are the two categories of cardiac arrhythmias at critical levels. A cardiac arrest followed by sudden death can be the result of a life-threatening arrhythmia. An emergency treatment is needed for patients of this condition. However, a heart failure can be the result of a non-life-threatening arrhythmia. Any future deterioration of heart function in such cases can be avoided through a timely therapy [2]. In any patient's life, arrhythmia is expected to occur only once in a while. The cardiovascular mortality and autonomous nervous system have been found to be closely related to each other through recent researches. The quantitative approaches to calculate autonomic activity have been designed due to the association between a propensity for lethal arrhythmias and the symptoms of either reduced vagal activity or increased sympathetic. One among such approaches is the Heart rate variability (HRV). It has been growing its popularity due to its easy derivation of measurements [3]. The research and clinical studies have also become easy for the cardiologists since several commercial devices are not using this automated HRV measurement.

Manuscript published on 30 June 2019.
***** Correspondence Author (s)
Pooja Bhor, Apex Institute of Technology, Chandigarh University, Gharuan, India
Gurjot Singh Sodhi, Apex Institute of Technology, Chandigarh University, Gharuan, India
Dilbag Singh Apex Institute of Technology, Chandigarh University, Gharuan, India

However, several measures of HRV have come be known as more complex than they were assumed. This has resulted is providing few incorrect conclusions within different applications. A muscle that pumps blood all across the human body by contracting in a rhythmical way is known as heart. There is a natural pacemaker which initiates the contraction at the arterial sine node and then propagates through all other parts of the muscle. A pattern is followed by this electrical signal propagation. Thus, electrical currents are released on the body surface which results in causing variations in the electrical potential of the surface of skin. Electrodes and appropriate devices are required to measure or capture these signals [4]. An instrumentation amplifier which has optic isolation is used to improve the difference of electrical potential among the points marked by electrodes on the skin. In the next stage, the signal is submitted first to a high-pass filter and then to the low-pass filter. Finally, the analog to digital converter is served with the output generated from previous step. ECG or electrocardiogram is the graphical registration of this acquisition process.Several methods and algorithms have been designed by researchers based on the evolution of processing power of computers over the years. The computational cost is not one of the major concerns of researchers today since faster processing computers have been designed. Thus, achieving higher level of heartbeat segmentation accuracy is the major concern here. Sensitivity and positive predictivity are the two measures used to evaluate the accuracy of heartbeat segmentation. A standard database is applied for a fair comparison of techniques that focus on heartbeat segmentation. Several methods have been applied for heartbeat segmentation:

a. Intensity Based Approach: This approach is also called the Threshold based approach and is the easiest one to be performed among other image segmentation methods [5]. On the basis of discontinuity of pixel values, the thresholding based techniques categorize the image into two parts. Either local or global thresholding can be performed. Histogram, clustering and local adaptive segmentation are the other criteria on which other techniques of thresholding are based.

b. Discontinuity Based Approach: The pixels near edges and boundaries of image have variations in the intensity values, which is a base for this approach. The next step is followed up by performing edge detection approach. Gray histogram technique and gradient based method are the two methods applied to perform edge detection segmentation.

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c. Similarity Based Approach: Otherwise known as region based segmentation, this approach uses the similarity criteria to divide the image into different parts. For removing noise, the similarity based approach is considered to be simple as compared to edge detection methods. As per the region based similarities, the watershed transformations are performed [6]. When there are similar pixels values throughout the image, histogram based segmentation performs in a better way. Region growing and region split and merge are two different kinds of region-based methods.

d. Theory Based Approach: Different algorithms which include derivatives from various fields collectively perform this segmentation approach.

- Clustering Techniques: In the presence of prior knowledge of classes, clustering is performed. Based on some previously stated criteria the homogeneous pixels are grouped in similar classes. For grouping the pixels the intra class similarity is minimized and inter-class similarity is maximized most importantly. The quality of clustering is also determined through this property [7]. Fuzzy clustering and hard clustering are few among different clustering techniques used commonly today.
- Artificial Neural Network-based segmentation: Each pixel is represented as a neuron in this approach. For identifying the connection and weights among various nodes, training set is provided by the network of neurons.

e. Graph Based Approach: Another effective image segmentation method is the graph based approach. Here, an image is given as a weighted undirected graph. The nodes of graph are assigned with pixel values [7]. Further, based on particular criteria, the graph is divided. Several algorithms are included in this method among which few are tree-based segmentation, minimum cut, random walker and so on.

The remaining portion of this paper contains the "Literature Review" section that has the table of comparison. The part having "Problem Formulation". The part Research Methodology explores the evaluation of data preprocessing, feature extraction and classification. The next part contains result and discussion. The concluding portion is examined in the section "Conclusion".

II. LITERATURE SURVEY

Qiu, et al. (2018) proposed a method to identify and classify arrhythmia with abnormal cardiac electrical activity. The five different types of arrhythmia commonly found were aimed to be classified by the proposed technique [8]. For removing the baseline drift and high frequency noise that existed in ECG signal, the wavelet transform and 8-point average filter were applied in the initial step of proposed algorithm. The R-wave was centered in the second step where the front view of R-wave intercepted by 100 sampling points, R-wave was followed by 150 sampling points and to represent a heartbeat, 250 sampling points were present in total. For achieving a total of 66-dimensional features, the convolutional neural network was combined with the db6 wavelet coefficient in the third step. The normalization of features and giving them as input to the libsvm classifier was the fourth step. A two-fold cross validation method was used to assess the performance of proposed model. Around 98% of accuracy was achieved by the experimental results achieved for classification. Paulo et al.s (2018) proposed a novel method using RR intervals, amplitude and Hjorth parameters to classify the heartbeats automatically for performing the electrocardiogram (ECG) feature extraction [9]. There are several applications in which Hjorth parameters have been applied. However, the most prominent application is ECG. Aiming to avoid mixing the information from adjacent beats and improving the classification performance, a novel approach was proposed for heartbeat segmentation. The arrhythmia dataset was collected from Massachusetts Institute of Technology to evaluate the performance of proposed approach. It was seen that against other comparative approaches, the performance of proposed approach was around 90% accurate. Thus, it was seen through the experimental outcomes that to resolve the problem of automatic heartbeat classification, this technique provided very good results. This technique could also be implemented in hardware devices that include limited resources since it included less computational cost.

Wu, and others (2018) proposed an end-to-end model to be applied on ECG data for providing generic and personalized ECG arrhythmic heartbeat detection [10]. In order to address the challenging issue caused due to the inter-patient differences in ECG signal patterns, a deep learning based model was designed. From the MIT-BIH Arrhythmia Database, a generic performance level was achieved for ECG heartbeat arrhythmia detection. In the next step, an active learning process was applied for performing patient-adaptive heartbeat classification tasks on both wearable and non-wearable ECG datasets. It was seen that a query of less than 5% of data was achieved from each new patient by applying the personalization model. Thus, the precision of disease detection was improved here. Further, in both normal and VEB beat predictions, 100% accuracy was achieved. Teijeiro, et al. (2018) proposed that by applying an appropriate set of abstract features achieved from the interpretation of physiological processes, the automatic beat classification on ECG signals could be improved [11]. Due to the abductive interpretation of ECG signal, a set of quanlitative morphological and rhythm features were achieved. Further, for reducing the effect of possible errors in interpretation, a QRS clustering algorithm was applied. Towards the end, a tag was assigned to each cluster by a rule-based classifier. Among all the previously generated automatic approaches, the proposed approach proved to provide better results as per the test results achieved by applying proposed technique on MIT-BIH Arrhythmia Database records. Even the most assisted approaches which needed the intervention of an expert within the process were improved here. The reasoning paradigm was changed to overcome the most commonly known problems of ECG classification which were related to variability of signal patterns among various subjects and even within the same subject.

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Sabeeha (2017) proposed a novel classifier for recognizing the HCM patients which was called the cardiovascular-patient classifier [12]. In case if the majority of patients' heartbeats were identified as property of HCM, they were categorized as having HCM. Therefore, identifying the individual heartbeats segmented from 12-lead ECG signals as HCM beats were recognized by the underlying task of classifier. The commonly applied and newly designed morphological and temporal features were extracted from ECG signals for heartbeat classification. Further, other features were extracted using wavelet decomposition. For checking whether HCM was obstructive or not, these extracted features were utilized. A SVM classifier was trained and tested for assessing the classification performance. The least information features were removed gradually by conducting feature selection experiments. It was seen that the usage of complete set of features provided very efficient performance measures by including highly informative features. Elhaj and others (2017) proposed an integration of Bayesian and Extreme Learning Machine (B-ELM) technique to generate a hybrid classification approach using which the arrhythmia detection could be conducted [13]. The good classification result was outperformed by the proposed approach which was based on B-ELM using significant features. It was also seen that the computational time of training process was high and the occurrence of over-fitting classification was achieved by applying hybrid Bayesian and ELM methodologies. By applying classifiers like SVM and NN methods, high accuracy is achieved by B-ELM. The computation time was reduced to 2.5 s and accuracy was increased to around 98% as per the results achieved after performing evaluation.

Table 1: Table of Comparison

sRef no	Author	Year	Work Done	Pros and Cons
[8]	Qiu	2018	A method was proposed to identify and classify arrhythmia with abnormal cardiac electrical activity. The five different types of arrhythmia commonly found were aimed to be classified by the proposed technique	Around 98% of accuracy was achieved by the experimental results achieved for classification.
[9]	Paulo	2018	A novel method was proposed using RR intervals, amplitude and Hjorth parameters to classify the heartbeats automatically for performing the electrocardiogram (ECG) feature extraction.	This technique could also be implemented in hardware devices that include limited resources since it included less computational cost.
[10]	Wu	2018	An end-to-end model was proposed to be applied on ECG data for providing generic and personalized ECG arrhythmic heartbeat detection.	The precision of disease detection was improved here. Further, in both normal and VEB beat predictions, 100% accuracy was achieved. This research did not focus on sitting and walking cases existing in the databases.
[11]	Teijeiro	2018	By applying an appropriate set of abstract features achieved from the interpretation of physiological processes, the automatic beat classification on ECG signals could be improved.	The reasoning paradigm was changed to overcome the most commonly known problems of ECG classification which were related to variability of signal patterns among various subjects and even within the same subject. However, a better result could be expected if every class label for each QRS observation is considered as a conjecture, enabling to correct it on the basis of posterior evidence, at the expense of a greater complexity of reasoning.
[12]	Sabeeha	2017	A novel classifier was proposed for recognizing the HCM patients which was called the cardiovascular-patient classifier.	It was seen that the usage of complete set of features provided very efficient performance measures by including highly informative features. However, all ECG related diseases could not be detected by this research.

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[13]	Elhaj	2017	An integration of Bayesian and Extreme Learning Machine (B-ELM) technique was proposed to generate a hybrid classification approach using which the arrhythmia detection could be conducted.	The computation time was reduced to 2.5 s and accuracy was increased to around 98% as per the results achieved after performing evaluations.

III. PROBLEM FORMULATION

A myocardial infraction is the other name of heart attack that takes place in case occurrence of blood flow blockage to coronary artery. In case if this situation remains for some period of time can leads to heart attack due to death of tissue by insufficient blood. Heart disease occurs when a plaque substance builds up in arteries and this can be develop in anyone including children. This result in reducing blood flow in heart due to the size of arteries that reduces with time. The risk rate of having heart disease increases by smoking, eating an unhealthy diet and not getting enough exercise. The heart attack pain has been mislead as gastric like or physical problem diseases pain as if it has been detected the exact reason of pain then it can be resolved by proper medication. The heartbeat is the one parameter that helps in detecting heart conditions which consist of 4 heart sounds in which only first two are audible and rest can't be hear.The ECG signals need to be analyzed and features needs to be extracted. In the last phase, the approach of SVM classifier will be applied which will classify extracted features. In the base paper, the SVM classifier is applied for the generation of final results. To improve accuracy, the classification algorithm will be replaced with some other algorithm for the heart variability detection.

IV. RESEARCH METHODOLOGY

This research work is related heart rate variability detection. The heart rate variability has the various steps which are explained below:-

1. Data –Preprocessing: - In the pre-processing phase, the ECG signal is taken as input for the heart rate variability. When the signal has the noise, bi-lateral filter is applied to denoise the signal

2. Feature Extraction: - In order to achieve an accurate heartbeat classification of arrhythmia through ECG signals, the key step to be performed is feature extraction. A feature is considered in the form of any information that is extracted from the heartbeat applied for discriminating its type. There are different forms of extracting the features. Either in frequency or time domain, features can be extracted directly from ECG signal's morphology. There is a certain difference among the feature extraction and feature selection processes. The stage which provides the description of a heartbeat is called feature extraction. With the aim of improving classification stage, a subset with the most representative features is selected through feature selection.A statistical method that reduces the dimensions of data is called PCA. A set of variables that are irrelevant to each other but each one is the linear combination of original variables is chosen here. By ensuring that the maximum proportion of variance of original data set is held by the first principal component and the maximum proportion of remaining variance is held by the subsequent orthogonal components, the principal components are derived from original data.

3. Classification: - The classification is the last phase for the heart rate variability detection. To detect the heart rate variability, the technique of HMM classifier is applied in this research work. The HMM classifier will calculate the morkov value of each class. The classes which has the value above the Markov value will be classified into one class and another into the second class

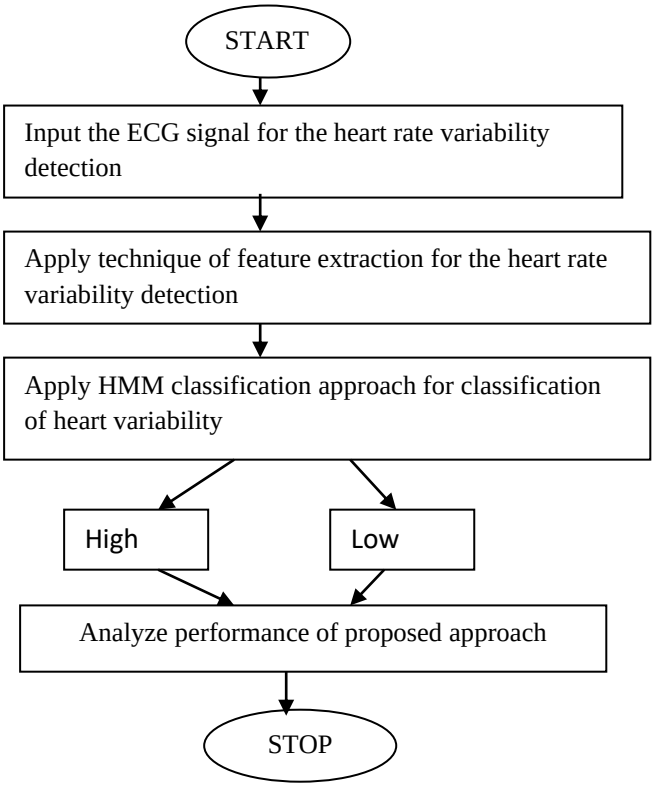

Fig1: Proposed Flowchart

V. RESULT AND DISCUSSION

This research work is related to heart rate variability detection. The HMM classification approach is applied for the heart rate variability rate detection. The performance is analyzed in terms of accuracy.

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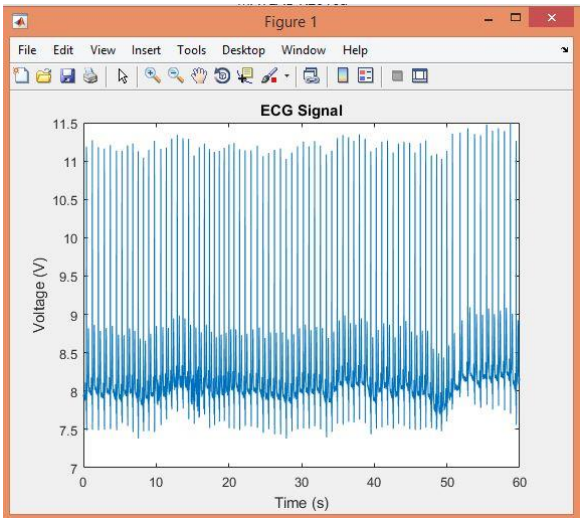

Fig 2: Input Signal

As shown in figure 2, the ECG signal is taken as input for the heart rate variability. The x axis define the time and y axis defines the voltage

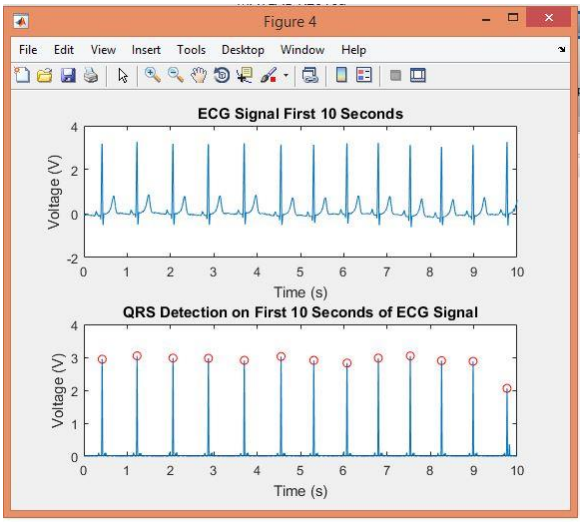

Fig 3: Heart Rate variability

As shown in figure 3, the heart rate variability is shown in this figure. The pack signal values are marked with the red color dots

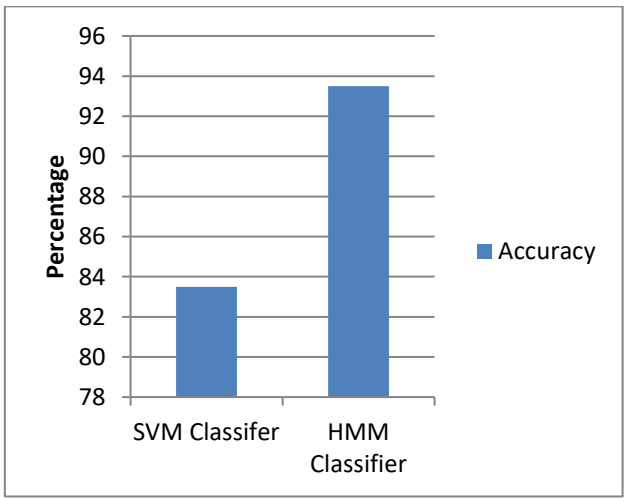

Fig 4: Accuracy Analysis

As shown in figure 4, the accuracy of the HMM classifier is compared with the SVM classifier. The HMM classifier is increased above 90 percent for the heart rate variability detection.

Table 2: Accuracy Analysis

Parameter	SVM Classification [14]	HMM Classification
Accuracy	78.57%	92.86 %

Following are the various validations points for the heart variability detection:-

1. In the previous research work, HMM classifier is applied directly for the heart variability detection, in the proposed method feature extraction will applied on the HMM classifier for the heart variability detection
2. The techniques which are proposed in the previous research work has the high execution time for the heart rate variability detection. The technique which is proposed in this research work has the low execution time for the heart rate variability detection.

VI. CONCLUSION

Any irregularity in the rate of heartbeat is called arrhythmia. The heart begins to beat either too fast or too slow or in irregular manner at the time of arrhythmia. Some of the arrhythmias can be life-threatening even when few seem to be harmless. Sufficient amount of blood might not be able to be pumped by the heart at the time of arrhythmia. Several other organs like brain and heart can also be damaged due to this kind of lack in blood flow. The heart variability can be detected which the approach of feature extraction and classification. The features of the ECG signal will be extracted which later be classified using HMM classifier for the detection of heart variability. The performance of proposed HMM classifier is compared with SVM classifier for the performance analysis. The HMM classifier give high performance in terms of accuracy as compared to SVM classifier. In future, hybrid classification model can be designed for the heart variability detection which increase accuracy of the system

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AUTHORS PROFILE

Pooja Bhoris pursuingMaster of Engineering in computer science Engineering (Big Data Analytics), form Chandigarh University,Gharuan, Mohali, Punjab India. She has done bachelors of Technology in Electronics and Communication Engineering from Punjab Technical University,Kapurthala,Punjab (2016).Her research interest in data analysis.

Gurjot Singh Sodhi obtained M.Tech degree in Computer Engineering from Punjabi University, Patiala, Punjab, India and currently pursuing his Ph.D from Punjabi University, Patiala, Punjab, India. Presently he is Assistant Professor of Computer Engineering, Department of Apex Institute of Technology, Chandigarh University, Punjab, India. His current research interests in the areas of: Software quality, software architecture, XML, SOA and Data Sciences. Apart from that he published various papers in the area of cloud Computing and Security.

Dilbag Singh received his PhD degree from Department of Computer Science and Engineering. Thapar Institute of Engineering and Technology,Patiala.He has done his Master in Technology (Computer Science and Engineering) from Guru Nanak Dev University, Amritsar, Punjab,India (2012).Currently,he is working as an assistant professor at Chandigarh University,Gharuan,Mohali,Punjab,India.He has published more than 27research papers in well-known reputed SCI indexed journals and international conferences. His research interest includes Wireless sensor networks,Digitalimage processing and Meta-heuristic techniques.

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