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Heart Rate Variability Classification and Feature Extraction Using Support Vector Machine and PCA: An Overview

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ABSTRACT
In today's era Heart Rate Variability becomes an important characteristic to determine the condition of heart. That's why the calculation of HRV and classification to generate rules is necessary. Human Heart Generates the electrical signal. ECG is used to detect the heart beat. ECG signal contains lots of noise. To classify the signals first to decompose the signals using wavelet transform. Many Mother wavelet are used to denoise the signals. Support Vector Machine is used to classify the denoise signal and recognize pattern for better classification of ECG signal. Various methods have been done using different classification tools like Neural Network, Support Vector Machine, and Wavelet transform. Among them Support Vector Machine is very successful in many research areas such as pattern recognition, bioinformatics, etc. This paper gives Brief Survey on Support Vector Machine and Combination of Wavelet Transform & PCA for better Feature Extraction of ECG signals
***Keyword* -** Classification, ECG, HRV, Kernel SVM, PCA, SVM, Wavelet Transform

I. INTRODUCTION

Heart Rate Variability is used to measure the variations in heart signals and more specifically variations per unit time of the number of heartbeats.ECG is one of the methods to detect the heart beats. The Electrocardiogram is the electrical activity of heart and generates electrical signals which are called as PQRST waves. The most important wave is the QRS complex. Heart beat depends on the time interval between two QRS complex waves which is called as R-R interval [1] [2]. Normally Healthy persons present large values of HRV. Prediction of HRV analysis is one of the major research topics from last two decades. Several methods for heart rate variability were proposed among them, Spectral Methods based on FFT, non-linear approach, including markov chain model are widely used[2][4][5].

Neural Network and Machine Learning methods are one of the powerful methods to classify and predict the Heart rate variability patterns. Various studies have been done using different classification methods like Support Vector Machine, Neural Network, and Wavelet Transform PCA etc. In this paper we use Support Vector Machine for Classification of HRV data. Support Vector Machine is very popular in many applications such as Pattern Recognition and Data Mining. Support Vector Machine is successful because of finding the hyper plane with widest margin that divides the sample into two classes and to kernel methods for non-linear classifications. This Paper Presents an Survey of Support Vector Machine and Principle Component Analysis (PCA) which is used to reduce the dimension of features in Heartbeat classification.

Section II presents the Brief Survey of Support Vector Machine Including Linear and Non-Linear SVM. Section III presents the survey of PCA and Wavelet Transform for feature extraction of HRV and Finally Conclusion is given in Section IV.

II. Literature Survey of SVM

- **2.1 Classification:**

Classification Rule Mining aims to discover a small set of rules in a database to form an accurate classifier [6]. Classification has many methods such as Decision tree, neural network, etc; mainly there are two steps to implement classification functions first in build classification model to describing a predetermined set of classes or concepts. Second step, Classification. There are many methods used in classification i.e. Bayes Network, Decision tree, SVM etc. To analyze the complex data or complex system such as Heart Rate Variability Support Vector Machine and Neural Network this two methods are widely used.

- **2.2 Support Vector Machine**

Support Vector Machine is based on statistical learning theory. It is supervised learning methods that analyzes data and recognize patterns. Support Vector Machine has used in number of fields such as image segmentation, object recognition and most recently in many biomedical application such as ECG signal Classification. There are many relevant study are involved [2].

Support Vector Machine mainly consist of two types of classification linear and non-linear classification [2][7].

- **2.3 Linear SVM**

Support Vector Machine is an data mining algorithms is used to finding the hyper plane in high dimensional space that separates training sample of each class which maximizing the minimum distance between that hyper plane and the training samples. SVM Identifies those samples that are closest to hyper plane [7][8] .However classification rate is not very high when samples are close to hyper plane. The training data samples along with the hyper plane near the class boundary are called support vector and the margin is the distance between support vector and class boundary hyper planes.

If the training patterns are linearly separable, there exists a linear function of the form [2]

$$\mathbf{f(x) = w\ x + b}$$

Where w is the vector and b is the scalar which represents the hyperplane **f(x) = wx+b=0** separating the two classes.

While there exist many hyper planes separating the two classes the SVM classifier finds the hyper plane that maximizes the separating margins between the two classes. This hyper plane can be found by minimizing the cost function.

$$\mathbf{J(w) = 1/2w^T\ w = 1/2||w||^2}$$

Subject to the separabilty constraints

$$\mathbf{y(w^T\ x + b) \square 1, \quad i=1.......\mathit{l}}$$

If the training data is not completely separable by a hyper plane, a set of slack variables € i≥0,i=1,.........l is introduced that represents the amount by which the linearity constraint is violated[2][7].

$$\mathbf{y(w^T\ x + b)\ \square\ 1-\ \square i\ ,\ \square i\ \square\ 0, i=1.....l.}$$

In this case the cost function is modified to take into account the extent of the constraint violations. To reduce the support vectors, we have to minimize the following equation.

$$\mathbf{J(w,\ \square) = ½||w||^2 + C\sum_{i=1}^{l} €}$$

Where C is the value determine between minimizing training errors and minimizing the model complexity term $||w||^2$

The purpose of using model complexity to constrain the optimization empirical risk is to avoid over fitting, situation in which the decision boundary corresponds to the training data. And thereby fails to perform well on data outside the training set [2][7].

The problem with the constraints can be solved by using following equation it can be shown that vector w is formed by linear combination of the training vectors.

$$\mathbf{f(x) = sgn(}\sum_{i=1}^{l} yi\alpha i(x.xi) + b\mathbf{)}$$

where αi is the Lagrange multipliers[7].

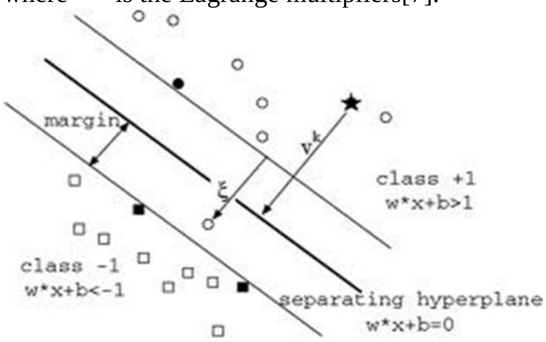

Fig 1.1 Structure of Support Vector Machine

2.4 Non-Linear SVM

The Linear Support Vector Machine can be extended to create nonlinear Support Vector Machine for the classification of linearly inseparable data. Such SVMs are capable of finding nonlinear decision boundaries (i.e., nonlinear hyper surfaces) in Input space.

There are two main steps. In the first step, we transform the original input data into a higher dimensional space using nonlinear mapping.Several common nonlinear mappings can be used in this step, as we will describe further below. Once the data have been transformed into the new higher space, the second step searches for a linear separating hyper plane in the new space. We again end up with a quadratic optimization problem that can be solved using the linear SVM formulation. The maximal marginal hyper plane found in the new space corresponds to a nonlinear separating hyper surface in the original space.

2.5 SVM Kernel Functions

The accuracy of an SVM model is largely dependent on the selection of the kernel method applied, by replacing the inner product (x.xi) with kernel function K(x.xi)the input data are mapped to higher dimensional space that separating hyper plane is constructed to maximize the margin[2][7].

There are number of kernel functions results in different performance level. These include linear, polynomial, radial basis functions[2]

$\Phi = \{x * xi\}$ Linear Kernel

$(yxxi + coeff)^d$	Polynomial
$Exp(-y\|x-xi\|^2)$	RBF

III. SURVEY OF PCA AND WAVELET TRANSFORM FOR FEATURE EXTRACTION

3.1 Principle Component Analysis

Principal Component Analysis (PCA) was generally utilized to reduce the dimension of features in heartbeat classification. The combination of Wavelet and PCA achieved good results in ECG feature extraction [3]. As is well-known, the relations among the principal components are assumed to be linear while performing PCA.

When performing PCA nonlinearity of the ECG signals are also taken into account. By using PCA, a more complete nonlinear representation of the principal components in ECG signals could be obtained [3].

In order to compress the extracted feature space we use PCA, which perform an orthogonal in the wavelet domain data. It makes use of Eigen value decomposition of the covariance matrix and projects the data on eigen basis defined by the respective Eigen vectors. Only few of the Eigen values will be significantly higher and rest are considerably very small and do not contribute to the data variations. Therefore these directions of higher variances are only retained by taking the inner product of the data with the Eigen vectors for those Eigen values. The steps of PCA are given below [9].

3.2 DWT for Feature Extraction

Fourier Transform is used to provide only frequency domain information and poor time resolution for any signal [9]. To provide good. Signals having same frequency at different times have same Fourier magnitude due to high frequency resolution and low time resolution. To overcome this issue Wavelet transform provides multi resolution analysis. To decompose the ECG signal into time frequency several mother wavelet used such as Haar, DB, Coieflet, Symlet, Mexican Hat and many other .

Researches uses many mother wavelet for better results among them DB series i,e Db2 to Db45 which has similar shape as ECG signal. The decomposition is done up to many levels such as level 1 to level 4 for smoothness of signals [9].

PCA and Wavelet transform provides better features extraction and also give more relevant features for better discrimination in ECG signal analysis. Many Researches also works on non-linear features of principle components using Kernel PCA. By using KPCA, a more complete nonlinear representation of the principal components in ECG signals could be obtained. For non-linear feature extraction Polynomial Kernel from support Vector Machine is used which shows good heart beat classification[3][9].

IV. CONCLUSION

In this paper, we present a brief survey of Support vector machine for classification heart rate variability also provides a survey of Principle Component Analysis and Wavelet Transform for ECG data analysis. It shows that combination of both PCA and Wavelet transform gives better results for ECG signal analysis.

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