Diagnosis of Acute Myocardial Infarction using Random Forest classifier through SPECT

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Abstract: Acute Myocardial Infarction (MI) is a severe heart disease which is caused by abruptly reduced blood supply in coronary arteries due to prolonged ischemia condition. It is a type of irreversible necrosis of cardiac muscles, so need to predict this Acute MI in early stages of cardiac ischemia. This paper presents a new computer- aided diagnosis system (CAD) for the early prediction of Acute Myocardial infarction(MI) based on the machine learning algorithms using Myocardial perfusion single photon emission computed tomography(SPECT) images. Myocardial perfusion SPECT image database containing processed SPECT images collected from the 267 patients at cardiac rest study and cardiac stress study to examine the heart blood supply. This processed data are trained using random forest learning algorithm and a result of this proposed model is compared with other six machine learning algorithms. Eight Performance metrics of machine learning are used to evaluate the output of this proposed model. This CAD system helps to evaluate the presence of MI in the cardiac SPECT images, reduce the diagnosis cost due to automation learning and save the life of the cardiac patients.

Index Terms*: *Acute Myocardial Infarction, Myocardial perfusion SPECT, Machine learning, Medical image analysis, Random Forest Algorithm

I. INTRODUCTION

Heart related diseases, i.e cardiovascular diseases are considered as one of the primary cause of mortality in India along affecting rural and urban people of the country. Cardiovascular disease are the medical conditions which affects the function and structure of human heart such as myocardial infarction, ischemia heart disease, diseases with coronary arteries, heart muscle diseases, heart failure. Though there are many causes of deaths in India, and heart disease has considered as the top killer that has affecting major population in rural and urban areas in India [1].Around 25% of total mortality are caused by this disease in India. Mainly, the aged people are affected due to this abnormality. Primarily, people in the rural places are gets affected by this disorder due to lack of awareness about risk factors of heart disease and lack of medical services, so more number of deaths are occurring due to improper medical care.

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According to WHO survey, it is likely that the occurrence of heart disease is anticipated to increase with 2.3 crore mortality rates. So there is a need to create a diagnosis system which predicts the occurrence of myocardial infarction at an early stage to save the cardiovascular patients.

A. Myocardial Perfusion SPECT Imaging

Myocardial perfusion SPECT imaging is also called as rest-stress test, type of non-invasive test method to show how well the flow of blood occurring through (called perfusion) patient's heart muscle. This test is used to find the regions of heart muscle's which are not getting adequate amount of blood flow. As nuclear cardiology techniques are used for this rest- stress study, this test is called a nuclear rest-stress study. This method is used to examine the size of heart's chambers, determine how well the heart valves are pumping the blood, prognosis the severity of blockages that might be present because of coronary artery illness and to check whether the heart has any damaged muscle or dead muscle. These can lead to diagnosis of coronary arteries and prediction of myocardial perfusion at an early stage. So patients can able to change their lifecycle, take medication to recover from the acute MI.As a result, this diagnosis method is a best tool for myocardial perfusion.

B.Cardiac SPECT Image Analysis

During cardiac SPECT analysis patient will be injected with tiny amount of radioactive tracer for stress study and rest study. Special gamma camera is used to detect the gamma rays emission from these radioactive tracers and make the images of patient heart from different angles. In this method two analysis are there as, first analysis is taken 10 to 15 minutes after injection of radioactive substance in the vein of human arm as stress study will be conducted –called maximal stress study to collect stress images . Second analysis is the rest study, will be conducted within 2-5 hours after radioactive injection-called rest images. From this study two sets of 3-Dimensional images are collected. These images represent the Left ventricular cardiac muscle perfusion that is equivalent to the circulation of radioactive traces within the myocardium. There is a need to apply many image transformation techniques to convert 3D images to 2D images for further image analysis task. Then cardiologist evaluates stress studies and rest studies to detect the irregularities in the Left ventricle perfusion. During image analysis three sets of 2-D SPECT images are used, which consist of sequence intensity slices (around 15 to 30 slices).

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Slices that exhibit left ventricular to its long axis are named as “short axis cardiac SPECT”, parallel to its long axis are named as “vertical long axis cardiac SPECT” and “horizontal long axis cardiac SPECT” shown in Fig 1

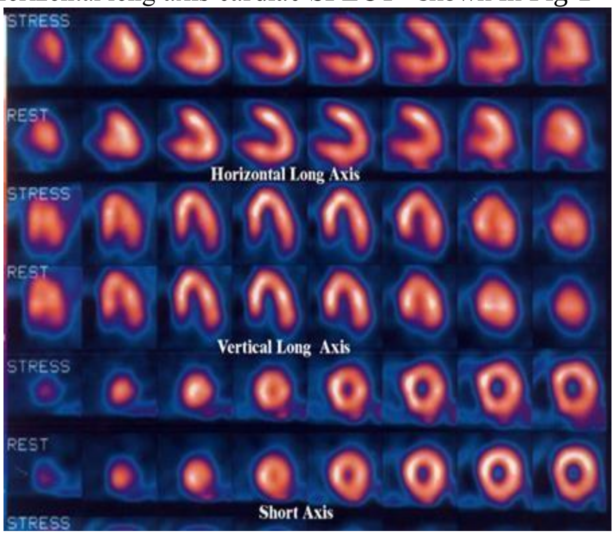

Fig 1.Displays Short axis, Vertical Long Axis, Horizontal Long Axis of Left ventricular cardiac muscles with corresponding coronary arteries with stress study and rest study of Myocardial Perfusion

From the above image slices, cardiologists assess whether the coronary arteries having normal perfusion or abnormal perfusion (Fig .2) by comparing the region in the stress study images and rest study images, results are evaluated with cardiac SPECT image of a healthy human heart. Based on this diagnosis final conclusion is made.

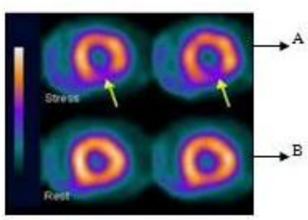

Fig.2 Cardiac SPECT perfusion images (A) indicates abnormal perfusion B) normal perfusion

Cardiac SPECT images provides good sensitivity results, cost of SPECT is low when compared to other imaging methods as PET. Though radiation risk with this method but not very high

A. Related Work

For reconstruction of the SPECT images, need to use image reconstruction algorithm. Two types of reconstruction algorithms [2] are used to estimate an accurate 3-D radioactivity circulation from the SPECT images which are collected from gamma camera. First reconstruction algorithm is called iterative reconstruction method which starts with uniform activity distribution as an initial estimation of the images. Then the mathematical model called forward projection (set of projection data) is applied on the initial estimate. As a next step, resulting projections are evaluated with the recorded projection and the variations between the two are used to update the estimated image. This is repeated till the variation between the calculated and the measured data are smaller than a specific preselected value. Algebraic reconstruction algorithm and maximum like-hood expectation maximization algorithm are part of iterative reconstruction methods. Second reconstruction algorithm called Filtered Back projection algorithm and it is a type of analytical model widely used in SPECT images due to its speed, computational accuracy and simplicity. It is a 2-step process as filtering of images and back projection of filtered image data. Cardiac SPECT images are difficult to interpret due to its high noisy level and poor contrast. Quality of the SPECT images is enhanced using Fourier Filtering the projection image set [3] before image reconstruction. In this method, 2-Dimensional circularly Gaussian model is applied as the spatial frequency filter. This filter is capable to enhance the contrast and reduce noises in the projection image set in a straight forward projection. This technique is used to improve the quality of the images.Patient movement during acquisition of SPECT imaging will be a reason for imaging artifacts during SPECT diagnostic and degrade the image quality and reduce the accuracy of results. This artifact can be reduced by neural network approach [4] using Polaris stereo-Infrared real time monitoring system. Cardiac SPECT images are considered as the key element to find the occurrence of ischemia heart disease [5].Support vector machine can be used for diagnosis of heart disease with 92.3% accuracy, 73.3% specificity, and 98% sensitivity. For Alzheimer’s disease, early diagnosis has great impact and delay the progress of the disease. This can be achieved using novel CAD [6] (Computer-Aided Designing) for Brain SPECT images. As a relevance analysis, Fisher discriminant ratio is used for feature selection and non-negative matrix factorization (NMF) algorithm is used for feature extraction for relevant component of each subset of image in order to minimize the curse of dimensionality. Reduced number of features from NMF is used in SVM algorithm for classification task. The novel approach (NMF+SVM) produced 94% accuracy with 90% sensitivity and specificity.

A. Motivation and Justification of Proposed Work

Myocardial Infarction creates a major issue in epidemic proportion as brings the economic burden of the country, particularly in developing countries like India. In India cardiac death rate is increased by 34% as an instance from 155 to 209 deaths per one lakh population in the same time period. So anticipating its risk factors, tracking disease severity are essential for designing effective CAD model to predict Acute MI at early stages of human life. This CAD system is helpful for reducing the mortality rate of cardiac patients. Cardiac patients are able to get rid from Acute MI by taking the medication based on the cardiologist prescription for improving blood flow in coronary arteries, changing their lifecycle by taking healthy food, routine exercise can useful to diminish the symptoms of heart attack also slow down the disease progression, leads to live normal life as non- cardiac patients.

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Organization of This Paper

Further topics of this paper are arranged like Section.2.describe the system architecture of proposed model and discuss the concepts of Random forest machine learning algorithm, Sec.3.contains experimental setup and result of the proposed model, Section.4.consists of details about performance evaluation metrics, Sec.5.contains conclusion and future work.

II. OUTLINE OF THIS PROPOSED WORK

In this paper, we establish a novel computer-aided diagnosis system for early prediction of acute myocardial infarction using random forest machine learning model on cardiac SPECT images (Fig.3). The output of the proposed model is compared with other machine learning models as naïve bayes algorithm, logistic regression, multilayer perceptron, J48, REP tree and SVM.

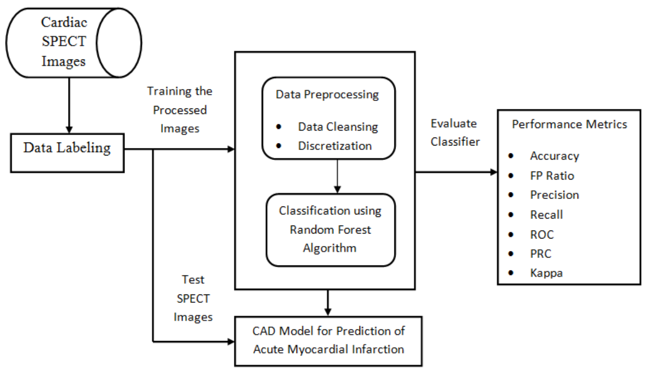

Fig.3.Proposed System Architecture

Observed the mean and standard deviation of the input features for understand the dispersion of the data values with respect to output class. Assessing the Performance of these seven classifiers are using performance evaluation metrics as classifier accuracy rate, False Positive Ratio, Precision measure, Recall measure, Receiver operating curve (ROC), precision-recall curve (PRC), Kappa value.

A. Random Forest Classifier

Random forest algorithm is a type of supervised learning as perform classification on training sample based on the class attribute. It is a flexible and easy to understand machine learning method that produces optimal result for training sample without hyper- parameter optimization. This algorithm can be used for regression and classification task. As the name implies "forest", it is a type of ensemble of decision trees which uses bagging method for training the input samples. To increase the result of training model, this algorithm creates combination of learning models called as bagging. Basically, this model capable to build many decision trees and merge them together to yield optimal accuracy and good prediction (Fig.4).This model uses random sampling of training features when building decision tree and uses random subset of all input features when splitting the nodes in each decision tree.

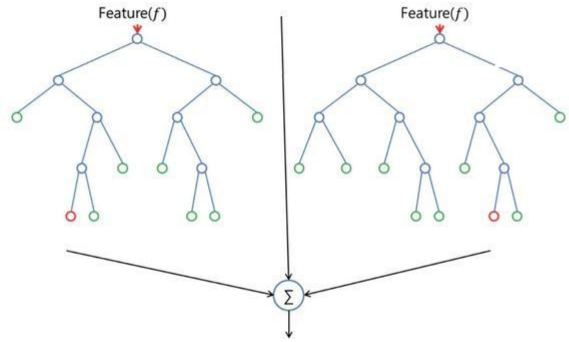

Fig.4.Model of Random Forest Algorithm

For create random sampling of input features, uses bootstrapping (samples are drawn with replacement strategy) as same sample will be used many times in a single tree. This algorithm uses Gini-index as an attribute selection measure for selecting the best attribute from collection of input attribute when creating the decision tree. Special feature of Random Forest is this algorithm run resourcefully on large data sample, capable to handle thousand numbers of input features without deleting the features, produce estimates of which variables are essential in the training phase. This algorithm will accept data sample with missing values, estimates missing values and retain optimal accuracy when applying large dataset with more missing values.

III. EXPERIMENTAL SETUP AND RESULTS

A. Experimental Setup

During SPECT examination, images will be collected from patient for the stress study and the rest study This database contains 267 SPECT heart images collected from UCI machine learning repository.SPECT Images are processed to obtain the relevant features, this dataset totally contains 22 features as 11 features from rest study and 11 features from stress study and one class attribute with two class labels (Normal, Abnormal).80% of the data sample are used for training the machine learning model and 20% of the data samples are used for testing purpose. Applied 5-fold cross validation to optimize and tuning the output of model. Obtained the descriptive statistical measures are mean and standard deviation for the input dataset to understand the regularity of the individual values /ranges of values for every feature (Fig.5). This statistical measure are used for standardize the dataset for optimal performance, helpful for interpret the various prediction outcomes for the developed model.

Feature	Mean	Standard Deviation
F1R	0.44	0.49
F1S	0.24	0.43
F2R	0.39	0.48
F2S	0.28	0.45
F3R	0.40	0.49
F3S	0.23	0.45
F4R	0.28	0.45

F4S	0.42	0.49
F5R	0.31	0.46
F5S	0.37	0.48
F6R	0.24	0.43
F6S	0.29	0.45
F7R	0.49	0.50
F7S	0.30	0.46
F8R	0.17	0.38
F8S	0.31	0.46
F9R	0.14	0.35
F9S	0.13	0.33
F10R	0.24	0.43
F10S	0.32	0.46
F11R	0.36	0.48
F11S	0.41	0.49
CLASS	0.79	0.40

Fig.5.Mean and standard deviation values of input features

A. Experimental Result

We have analyzed that Input dataset which does not contain any missing values. Feed the input features to the classifier to accurately predict the Myocardial Infarction at early stages. Machine learning algorithms such as Naivebayes,Logistic Regression, Multilayer perceptron,J48,Random Forest, Random Tree, Support Vector Machine are applied on this dataset and output of the classifiers are evaluated using performance measures as Accuracy, True Positive Rate, False Positive Rate,Precision,Recall,ROC(Receiver operator curve) Curve,PRC(Precision-recall) curve Area, Kappa value.

IV. PERFORMANCE EVALUATION

A. Metrics

This output of this work is evaluated and compared using performance measure and output are analyzed and presented in Table.1

Table.1.Performance evaluation chart

Classifier	Performance Measures						
	Accuracy	TP Rate	FP Rate	Recall	ROC Curve	PRC Curve	Cohen's Kappa
Naive Bayes	84	0.84	0.28	0.85	0.86	0.88	0.53
Logistic Regression	88	0.88	0.30	0.87	0.9	0.91	0.6
Multilayer Perceptron	92	0.92	0.19	0.91	0.93	0.94	0.75
J48	88	0.88	0.35	0.87	0.86	0.88	0.58
Random Forest	94	0.94	0.13	0.93	0.98	0.97	0.81
REP Tree	86	0.86	0.37	0.85	0.84	0.85	0.54
SVM	82	0.82	0.36	0.81	0.84	0.86	0.79

- The accuracy of the classifier is calculated by taking difference between total number of correct prediction and total number of predictions. This can be defined as:
- Classifier Accuracy=Total number of Correct Predictions/Total number of predictions
- The TP Rate also called precision is calculated by, TP=TP/ (TP+FP)
- The FP rate is measured in terms of FP=FP/ (FP+TP)
- The Recall is calculated by Recall =TP/TP+FN
- ROC is a curve based on probability values of training samples; it tells how much the machine model is capable to differentiate the positive classes and negative classes. Actually, this curve is plotted with TP rate and FP rate where FP rate is on x-axis and TP rate is on y-axis. Area under ROC curve is called AOC (Area under the ROC

  Curve) represents the degree of separability of classifier on training sample.
- PRC Curve is the Precision-Recall curve which presents the trade-off between TP rate and the positive predictive value for a predictive classifier using various dissimilar probability threshold values.
- Cohen's Kappa measure gives the difference between observed output value and expected output value, measured by kappa=observed output –expected output/1-expected output.

Note: TP-True Positive Ratio; FP-False Positive Ratio; FN-False Negative Ratio

A. Analysis of Experimental Result

Random forest algorithm performs well compared with other machine learning algorithms in terms of classifier accuracy, precision, FP Rate, recall value, Kappa value. Particularly, kappa and ROC curve are best measures for estimating the performance of classifier, though for imbalance dataset. If, kappa value >0.75,indicates a good classifier as random forest algorithm has achieved 0.81.Hence, we conclude that random forest model is most suitable classifier to build a computer-aided diagnosis system to accept process and work with cardiac SPECT images for early prediction of Acute MI disease.

V. CONCLUSION AND FUTURE WORK

In this paper we have built computer –aided diagnosis model which predicts the early chances of Acute MI disease with accuracy 94%, kappa value with 0.81.

This model will give best predictive analysis on SPECT Data. This CAD model is used to predict the chances of Myocardial infarction for the new test samples to validate the robustness and validity of the proposed model. Further, the performance of this model can be improved using optimized random forest models using parameter tuning.

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