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Neural Network Based Abnormality Classification of Echocardiographic Images

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ABSTRACT
Heart Diseases are nowadays most common in all age groups leading to severe problems and abnormalities, even fatigue in many cases irrespective of gender and age. Proper and early diagnosis can prevent hazardous consequences of heart abnormalities. Currently due to the Pandemic, it is the need of the hour to come up with techniques that could assess Doctors in diagnosis which, results in appropriate treatment of heart diseases. Paper deals with the classification of echocardiographic images using neural networks. The Gray Level Co-occurrence Matrix (GLCM) texture feature extraction and shape feature extraction being used to train the Neural Network for classification. Finally, classification of echo images based on extracted features is achieved. These features are used further to detect abnormality: if an abnormality exists whether it is mild, moderate or severe could be further classified. Classification Techniques are analyzed in image quality metrics, visual quality assessment and clinical validation. The algorithm's accuracy is tested using Regression analysis and the regression plot showed good correlation. Best training performance is achieved in the research. The neural network is trained and tested successfully on a set of echocardiographic images. Accuracies greater than 96% are accomplished. The results further facilitate for classification of heart abnormalities with the effect of categorization as to whether the problem is mild, or moderate, or severe using the Support Vector Machine Classifier.

Keywords - Neural network, classification, feature extraction, machine learning, GLCM features.

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I. INTRODUCTION

The classification problem is dependent on allocating a category to test data based on information obtained from training data. The classification model is obtained by using a classifier algorithm based on the classifier model from labelled data, class label is assigned to test data [1].

Overall, machine learning procedures are effectively used in echo image classification [2]. An essential requirement is for this type of classification [3]: huge databases are required to analyze different patients with different pathological issues related to the heart. The algorithms are based on the extracting features [4] and employing these features for classification. The acquired datasets are generally divided into training and testing data typically, 70-80 % of the total available dataset is used for training and 20-30-% for testing. The model so developed needs to be tested and validated on different datasets. Cross-validation being done for the optimal values of required parameters. A neural network (NN) comprises of a large number of neurons. Neurons which are processing elements, are a function of the inputs received and activation or activity level. The values of the connection weights, give the information of every neural network. A learning rule frequently implied is varying the values of the weights, as a function of experience and the data stored in the network is modified.

The activation is sent by the neuron to other neurons as a signal. This signal is either sent only one at a time or can also be broadcasted to other neurons. This study uses a machine-learning algorithm employing a neural network [6],[11]. The network is trained to identify echocardiographic images' texture and shape features. The region of interest or contour can be traced quickly based on preliminary knowledge. The multiplicative noise is the main reason that corrupt the images when they are captured and transmitted.

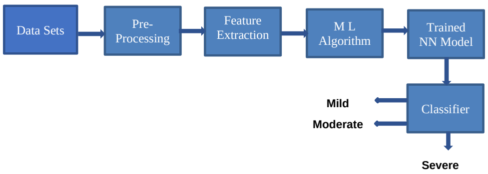


Figure 1: Fundamental steps in the machine learning algorithm.

NN consist of processing elements which are interconnected using unidirectional signals referred to as connections. It is thus a structure comprising of distributed parallel processing elements [12]. These elements have one output connection branching into many collateral connections. The output is dependent on the current value of the input as well as upon values stored in the neuron's memory. This output signal can be of any mathematical type [16]. It also implies that it is more accurate and more efficient. Since analysis and prediction are essential tasks used in many fields of practical applications. It's been observed that the use of NN for classification applications has become a buzz in the fields of signal/ image processing. In many application areas, the task of getting the best prediction has grabbed the researcher's interest.
Classification requires obtaining an NN-based model which can classify input images into categories using energy and average values (DWT and Debauchee's techniques for normal and abnormal images) and apply them to the neural network and then classify abnormality using features extracted and output of classification obtained using MATLAB.

ML is a subset of AI but one step ahead of AI. Another step ahead of machine learning is deep learning. Such is the hierarchy of the fields and serves as a basis for AI functions. Machine learning involves training the machine to learn, store and analyze data. Computers used in ML as Machines improve with experience and give better prediction results. A general classification of ML can be put into three broad types as follows.

- Supervised learning: It is a predictive method of ML. The machine makes a prediction of a class of unknown objects predicted on information related to pre-existing class of similar entity. In other words, this category of ML uses labeled or known data. Nowadays this is the type of ML which is popular.
- Unsupervised learning: It is descriptive learning. The Machine finds patterns in unknown objects by similar grouping objects together. In other words, unsupervised learning uses unlabelled data. One primary type of unsupervised learning is Clustering.
- Reinforcement learning: A machine learns to act independently to achieve desired goals.

The significant aspect of supervised learning is it learns based on past information. In supervised learning, inputs are given with desired outputs and the algorithm help enable the machine for classification or prediction of objects, problems, or situations [15]. This prediction is based on labeled data given to the computer. Classification and regression are types of supervised learning. Since echocardiographic images are poor in quality. A Neural network is an appropriate method for processing [9].

The main contributions of the present work are as follows

(1) After preprocessing the image to remove noise and improve quality, it is segmented using the KNN algorithm.
(2) ROI is highlighted using MATLAB as the area marked for classification using GLCM features.
(3) Once an abnormality is identified based on features extracted, the image is classified using a classifier into mild or moderate, or severe.

Plain summary of the article: The following paper is organized as follows: Section 2 gives the specific literature review and the features and challenges faced by earlier same approaches. Preprocessing, Proposed Methodology and Materials are discussed in Section 3. Results and Discussions are highlighted in Section 4. Section 5. Concludes.

II. RELATED WORK

In [4] authors proposed GLCM based texture analysis process. The authors mention that choosing GLCM aims to achieve good recognition. And this was possible using the values of contrast, correlation, homogeneity and energy. Haralick proposed a computational texture feature. The image's texture is characterized by significant components such as the co-occurrence Matrix feature [5]. In addition to the co-occurrence matrix, it is required to define a few internal factors for the medical images, which are the Contrast, Homogeneity (H), entropy & Local Homogeneity (LH) [7]. O. R. Indriani et al. in [13] highlight these parameters of GLCM and HSV calculations could classify tomatoes based on maturity level using K-Nearest Neighbor (KNN). S. Jain in [17] proposed brain tumor classification in MRI images using an Artificial Neural Network (ANN). The algorithm classified MRI of different patients with a different kind of brain tumor. The authors implemented the detection of the tumors using GLCM texture features. Based on an extensive literature survey, this article is based on KNN segmented images used to classify abnormalities in echo images using Multirate SVM classifier.

This section highlights a review of the latest state-of-the-art methods. The Rajesh et al. developed method [14] to classify tumors using extracted features. Authors used rough set theory (RST) for feature extraction and particle swarm optimization neural network (PSONN) algorithms to classify brain images in MRI modality in terms of normal or abnormal. The dataset comprises of a total of 90 images, 60 images of which were used for testing and 30 for training and the algorithm resulted in an accuracy of 85% in comparison to other RST algorithms (RST-FFNN (Feed-forward neural Network) and RST-FSVM). Chaudhary *et al.* proposed DWT for feature extraction and K-Means for segmentation [8]. Then classification of tumors into malignant and benign tumor using SVM classifier. The data set of 6 images used for implementing their algorithm and they achieved an accuracy of 89.6%. The authors in [18] Vijh et al. proposed adaptive PSO with OTSU to find the optimal threshold value. Denoising and enhancement were achieved using Anisotropic diffusion filtering, the images were again brain MRI. The features extracted for performing classification based on the convolutional neural network. They used a dataset comprising of 40 non-tumor images which were in MRI modality and 61 tumor images and achieved an accuracy of 89.6%. In [2] M. A. Ansari et al. proposed denoising using median filter and Morphological Operation for Image Segmentation. Then feature extraction using DWT and GLCM and classification using SVM for categorizing brain tumors as benign and malignant. Their dataset comprises of a set of 5 MRI images for implementing their algorithm (the images file format tested were JPEG/JPG format) and they resulted in an accuracy of 89.91%. In [10] Gokulalakshmi et al. developed a classification algorithm using machine learning-based SVM classifier and K-means clustering. Again, GLCM and DWT used for extracting features. The dataset includes DICOM images comprising of 750 samples of 30 images, achieved an accuracy of 89.1%.

2.1 COMPARISON WITH STATE-OF-THE-ART CLASSIFIERS

TABLE 1: PERFORMANCE MEASURE COMPARISON WITH STATE-OF-THE-ART METHODS

Performance Metrics	RST+PSONN (Rajesh et al. 2019)	K-Means+DWT SVM (Chaudhary et al .2020)	Adaptive PSO+ OTSU(Viih et al .2020)	GLCM+SVM (Ansari et al. 2020)	K-Means DWT+ GLCM, SVM (GokulaLakshmi et al. 2020)	KNN+ GLCM SVM Proposed
Accuracy	0.82583	0.86167	0.88583	0.88	0.881	0.92667
Sensitivity	0.865	0.845	0.8525	0.87	0.87	0.8975
Specificity	0.52125	0.9225	0.9225	0.92	0.9225	0.94125
Precision	0.46276	0.81927	0.82133	0.83	0.819	0.87585

The proposed methodology is compared with other conventional classifiers. The above table clearly shows that the proposed method efficiently determines abnormalities. Accuracy is much more than other methods. Other parameters in the performance metric are also better than previous methods.

III. MATERIALS AND METHODS

Data sets utilized in research comprises of a set of echocardiographic images containing different views such as A2C, A3C, A4C, A5C, Parasternal views etc. This section discusses various processing carried out in the proposed method, starting with preprocessing, training of the neural network, feature extraction and classification as subsections below.

3.1 PREPROCESSING

Noise is inherent in all echocardiographic images. Denoising is an essential step of processing echocardiographic images. The denoising filter is fractional order integral filter and enhancement achieved through fractional order differential filter. These filters resulted in efficient noise removal and quality improvement through denoising and enhancement. These filter designs and implementation are discussed in different papers.

3.2 NEURAL NETWORK APPROACH

The main reasons for the extensive usage of NN in various applications are their powerful aspects and ease of use. A simple approach is a two-step procedure: Starting with extracting the features from samples in the database. Then the next step is to make the NN learn the relationship between pixels in an image and its class among other regions. After learning this relationship, present the network with test input which can be classified based on GLCM values compared with output M1 (discussed below). NNs serve for modeling global aspects of input data. Structure features are used in the proposed system.

3.3 EXTRACTION OF FEATURES

Texture provides information based on the intensities of pixels. Intensity variations are visually reflected in gray tones. GLCM is a statistical texture-based feature extraction characterized by energy and entropy. This classification is to classify the images in terms of GLCM parameters. Textures are complex visual patterns or sub-patterns described in terms of contrast, correlation, energy, homogeneity, etc. In grayscale images, every pixel has contrast, brightness and intensity (i.e., for an 8-bit pixel depth number of gray levels are 0-255). The first threshold is fixed, for calculated number of zeroes and ones because input grayscale images need to be converted into pure black and white image. GLCM-based texture features are extracted. Table 2 gives comparative analysis of image quality metrics. The feature extraction gives GLCM texture values for Contrast, Correlation, Energy and Homogeneity for every image: it calculates a maximum and a minimum value of these parameters as shown in Table 3. In addition to texture features, shape feature values are also obtained such as Area, Maximum length, Minimum length, Perimeter, Eccentricity, Extent, Diameter in the command window as shown in Table 4 for every input image. The results for processing and analysis of echocardiographic images are shown in Fig 2. They are self-explanatory with fig (a) being the original input echo image and fig (b) is the segmented image after first segmentation fig (c) gives the final segmented image fig (d) plot showing MSE performance fig (e) shows the PSNR performance plot fig (f) gives the plot for neural network training state with number of epochs required fig (g) gives plot for training performance fig (h) is the gradient plot and fig (i) gives the regression plot for any given image. For every iteration the trained value M1 is compared with GLCM values. Suppose M1 is close to Contrast then Neural Network Classify as contrast is high, if M1 value is close to correlation NN classify as correlation is high and so on. Once the iterations are completed training achieved is displayed.

3.4 PROPOSED METHODOLOGY

Firstly, extract and highlight abnormality area and mark the contour with color. NN is good for all medical images and so for echocardiographic images. It is applied twice with two different threshold values. Segmentation is first applied from extracted features as discussed in KNN segmentation. Then contour is identified from the feature extracted area and marked with different color. Thus, segmentation and feature extraction are to be done twice. The first extraction of echo image with different boundary and threshold, extract the abnormality area and mark boundaries, segment and apply Region of interest (ROI) algorithm and extract region which is desired as output. This is the area which is concentrated in whole image. Identify the location of problem and separate it using ROI. Based on shape and texture feature values, total area is calculated. Highlight the required area and combine all together using concatenation function (cat). Extracted areas are then passed through M1 the final output. GLCM extracted texture values and shape feature values are obtained as shown in tables 3 and 4 respectively. The objective of the proposed methodology is classification of images in terms of abnormality if present. This is achieved by maximizing accuracy, which is evaluated as per Equation 1. GLCM is a texture feature extraction method obtained by considering the spatial relationship between pixels. Contrast, entropy, homogeneity and correlation as GLCM features used for the detection of an abnormality. If an abnormality is detected it is classified as mild, moderate, or severe using extracted features. The classifier is the SVM classifier. The novelty of the proposed methodology lies in segmentation carried out using the KNN algorithm and classification using SVM. The Multirate SVM is an efficient classifier that classifies input images into mild or moderate or severe using extracted features. This classifier is NN based classifier having an activation function that receives two inputs, one from the training set other from the output of ANN here: it compares both the inputs and gives the result of the comparison as output. When there is a match in features with the training set, output is image abnormal else normal. The classifier also classifies the abnormality based on membership function.

3.5 PERFORMANCE METRIC

The performance measures used in the analysis of classification are as follows

Accuracy = $(TP+TN)/(TP+FP+TN+FN)$ (1)

Where TP, TN, FP and FN specify the true positive, true negative, false positive and false negative elements respectively.

Sensitivity = $TP/(TP+FN)$ (2)

Specificity = TN/FP (3)

Precision = $TP/(TP+FP)$ (4)

F1score = $(Sensitivity X Precision)/(Sensitivity+Precision)$ (5)

IV. RESULTS AND DISCUSSIONS

The experimental setup for the model proposed using echocardiographic images for classification is implemented using MATLAB 2017a for analysis. In this paper standard clinical database from Medical Information Mart for Intensive Care III (MIMIC-III) is used. It is an extensive, freely available database that comprises data approximately around 40,000 patients. The analysis is followed by the metric of performance evaluation, which includes parameters like sensitivity, specificity, accuracy and precision for classification. In the classifier approach, concerning to the neural network-based method it is found that the number of input layers was kept at 108 and hidden layers at 39 at the output.

TABLE 2. COMPARATIVE ANALYSIS OF IMAGE QUALITY METRICS

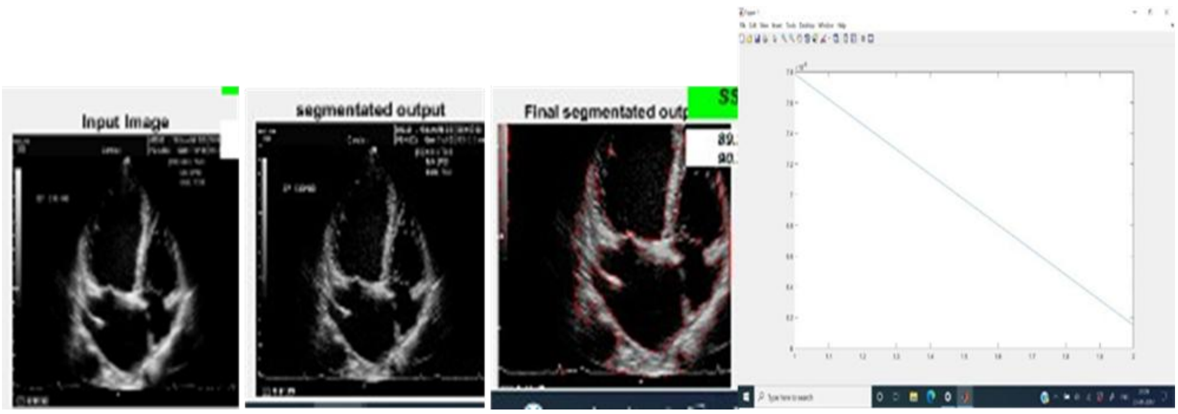
S. No.	SNR	PSNR	OBJFCN	MSE	AD	SC	NK	MD	LMSE	NAE
Image 1	73.95+27.28	85.14dB+13.64	18.202	-0.0513	-0.0513	1.055	0.964	40.22	0.2400.091	
Image 2	79.49+27.87	99.54dB	17.11	-0.0271	-0.0271	1.029	0.983	9.059	0.087	0.077
Image 3	61.265+27.28	78.79dB+13.64	27.76	-0.022	-0.022	1.092	0.943	66.55	0.252	0.160
Image 4	75.78+27.29	86.05dB+13.64	15.697	-0.041	-0.041	1.028	0.984	44.44	0.076	0.060
Image 5	74.34+27.28	85.33dB+13.64	13.174	-0.049	-0.049	1.012	0.993	31.89	0.080	0.037

TABLE 3. GLCM TEXTURE VALUES

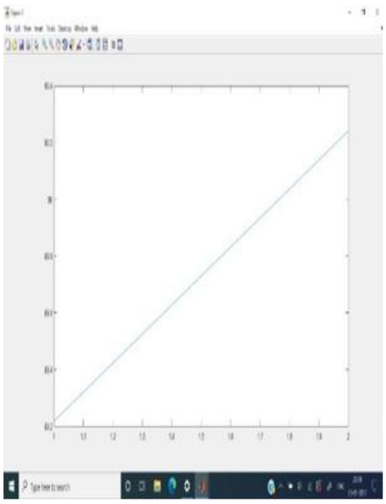
Sl. No.	Contrast		Correlation		Energy		Homogeneity	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
Image 1	6.523	7.135	0.559	0.595	0.442	0.454	0.808	0.813
Image 2	1.217	1.233	0.663	0.668	0.6023	0.6024	0.8875	0.8879
Image 3	9.432	9.454	0.464	0.465	0.404	0.405	0.7775	0.7784
Image 4	2.445	3.173	0.775	0.827	0.554	0.596	0.904	0.920
Image 5	2.797	2.924	0.793	0.802	0.655	0.656	0.947	0.950

TABLE 4. SHAPE FEATURE VALUES

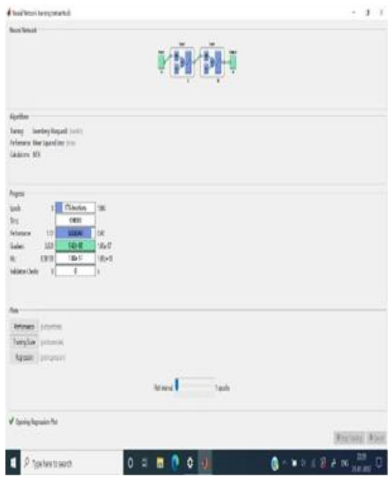
Sl. No.	Area	Max. Length	Min. Length	Perimeter ECC	Extent	Diameter	
Image1	6x1 Double 6x1 Double	6x1 Double	6x1 Double	6x1 Double	6x1 Double	6x1	Double
Image2	12x1 Double 12x1 Double	12x1 Double	12x1 Double	12x1 Double	12x1 Double	12x1	Double
Image3	6x1 Double 6x1 Double	6x1 Double	6x1 Double	6x1 Double	6x1 Double	6x1	Double
Image4	14x1 Double 14x1 Double	14x1 Double	14x1 Double	14x1 Double	14x1 Double	14x1	Double
Image5	6x1 Double 6x1 Double	6x1 Double	6x1 Double	6x1 Double	6x1 Double	6x1	Double



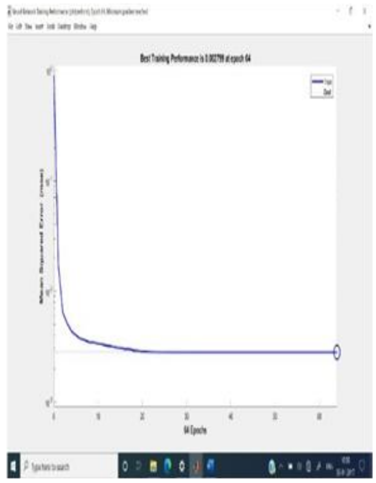
(a) (b) (c) (d)



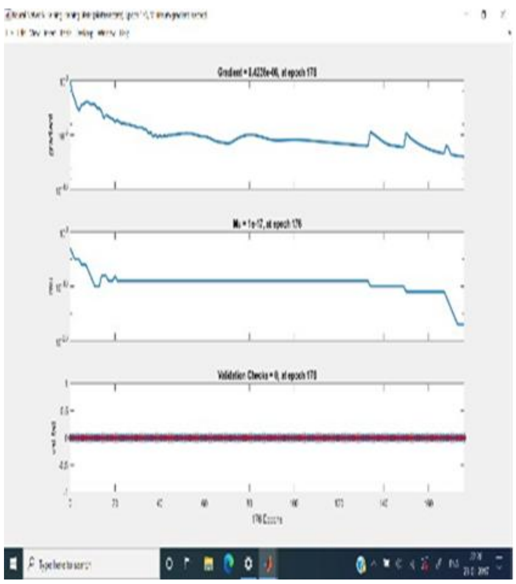
(d)



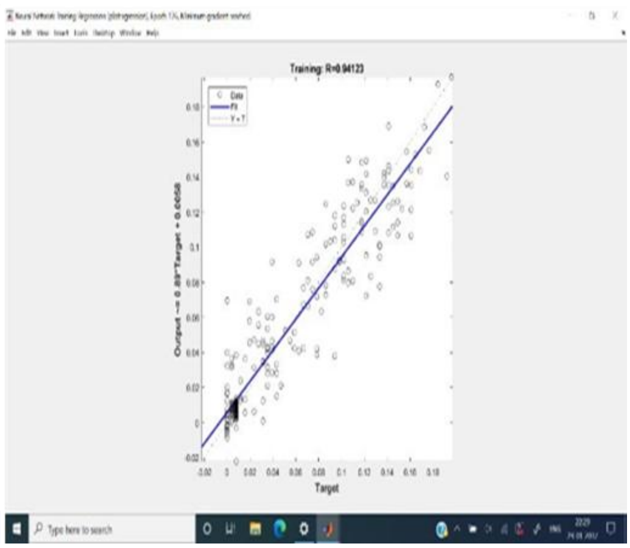
(e)



(f)



(g)



(h)

Figure 2: Original Echo Image and results of segmentation and processing: (a) Image; (b) Segmented Image; (c) Final segmented Image;(d) MSE plot; (e) PSNR plot; (f) Neural network training state plot; (g) Training performance plot; (h) Training state gradient plot; (i) Regression plot.

V. CONCLUSION AND FUTURE WORK

Neural network-based classification of images using GLCM-based texture and shape features resulted in good classification accuracy and the results of qualitative and quantitative analysis is good enough. The research objectives are accomplished starting from denoising and enhancement as preprocessing carried out using fractional order calculus, then segmentation and feature extraction using KNN algorithm, machine-learning-based model for classification with satisfactory results. This could be a boon for medical practitioners, assessing them in diagnostic decisions with high accuracy and efficiency. As a result, this would speed up the process and help in the early initiation of treatment and save lives. Further, the requirement of classification is to obtain an NN-based model which can classify input image into mild, moderate and severe abnormalities based on features extracted using energy and average values obtained using GLCM techniques (for normal and abnormal images) and applied to a neural network and then classify images using classifier and output of classification is validated by doctors.

In the future, there is a scope to explore many such applications of ML and NN for video applications or for 3D Images. These could also be considered an open challenge as well as future research directions. Artificial Intelligence (AI) has become a buzz in medicine. It broadly comprises of a system that makes it possible for the computer to mimic human thinking. AI uses algorithms or instructions capable of recognizing and segmenting heart structures automatically. In the near future, automated diagnosis of diseases using AI is expected.

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