An Efficient Techniques used for Diagnosis of Mitral Valve Regurgitation Severity

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Abstract*: Mitral valve diseases are more common nowadays and might not show up any symptoms. The earlier diagnosis of mitral valve abnormalities such as mitral valve stenosis, mitral valve prolapses and mitral valve regurgitation is most important in order to avoid complex situation. Many existing methodologies such as heart sound investigation model, 3-layered artificial neural network (ANN) of phonocardiogram recordings, 3-layer artificial neural network (ANN) of phonocardiogram recording, echocardiography techniques and so on are there for Mitral Valve diagnosis, but still most of the methods suffer from inefficient image segmentation and misclassification problems. In order to address this issue, this paper proposes two techniques namely 1) Deep Learning based Convolutional Neural Network (CNN) model for Mitral Valve classification model meant for diagnosis and edge detection-based segmentation model to enhance the classifier accuracy. 2) Watershed Segmentation for Mitral Valve identification and image segmentation and Xception model with Random Forest (RF) classifier for training and classification. The proposed models are evaluated in terms of three parameters namely accuracy, sensitivity and specificity, which proved that the proposed models are efficient and appropriate for Mitral Valve diagnosis.

Keywords*: Deep Learning based Convolutional Neural Network (CNN) model, Edge detection-based segmentation model, Watershed Segmentation, Xception model with Random Forest (RF) classifier.

I. INTRODUCTION

Among all valves mitral valve plays an important role in regulating blood flow from the upper left chamber (left atrium) into the lower left chamber (left ventricle), the heart's main pumping chamber. Mitral valve has leaf like flaps which closes tightly between each beat preventing the flow of blood in opposite direction. In recent years many people suffer from mitral valve related diseases leading to valve replacement and valve replacement [1]. Only specially trained doctors can predict the severity of the mitral valve disease, by listening to the signals produced by the heartbeat from Echocardiograms (ECG) [2]. But this prediction might not be always accurate leading to fatal death of patients. Hence an automated and computer aided tool is required for detecting the heart signals and reporting the severity of the mitral valve disease based on the variation in the heart sound [3].

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Medical imaging plays a vital role in the diagnosis of mitral valve. Medical image processing generally involves boundary detection, image segmentation, feature extraction and image classification [4]. Our proposed methodology focuses only on two processes namely image segmentation and image classification. Image segmentation aims at diving image into different segments and every segment are represented as pixels. Each segment will have both the background and foreground details with various color indications and shapes like circle, polygon and ellipse. These segments are applied to the classifier which classifies the image based on the different heart and signals and assists the doctors by separating the images into different severity levels of the mitral valve disease.

In general, the segmentation and classification of mitral valve disease from the computed tomography (CT) images are very difficult because of the distinctions in presence and prominence across subjects. To overcome difficulties in mitral valve image segmentation and classification, this paper proposes two techniques namely 1) Deep Learning based Convolutional Neural Network (CNN) model for Mitral Valve classification model meant for diagnosis and edge detection-based segmentation model to enhance the classifier accuracy. 2) Watershed Segmentation for Mitral Valve identification and image segmentation and Xception model with Random Forest (RF) classifier for training and classification.

II. REVIEW CRITERIA

DeGroff et al [5] has proposed an accurate diagnostic tool using Artificial Neural Network, which makes an exact different between normal heart murmurs and heart murmuring sound with even slight variations. Nygaard et al. [6] analyzes the severity level of MV by estimating the parameters of transvalvular pressure via the investigation of the spectrum of cardiac systolic murmur. Hebden and Torry [7] projected a method for distinguishing the systolic murmurs arising from aortic stenosis and MV regurgitation by the computation of frequency contents. Bijvoet et al [8] has discussed about the literature survey on optimal strategies for predicting severe mitral valve regurgitation on patients after surgery as well as global longitudinal left ventricular dysfunction. Bruscoand Nazeran [9] discussed an intelligent PDA dependent wearable digital phonocardiograph that could not save the heart sounds; however, diverse signal processing and statistical approaches are employed to segment the signals into a set of four parts, namely, S1, systole, S2 and diastole.

It then invokes the multilayer perceptron (MLP) for classifying the input under 5 divisions, namely, "normal, aortic regurgitation, aortic stenosis, mitral regurgitation and mitral stenosis". Herold et al. [10] introduced a heart sound analysis model for diagnosing aortic valve stenosis by the utilization of wavelet filtering and envelope computation. It then computes the interrelation on the basis of these envelopes. Additionally, Voss et al. [11] provided an analysis model offering the physician for discovering aortic valve stenosis at the infant stage. It utilizes wavelet and Fourier transform for filtering suitable parameters of the heart sound signals, and linear discriminant function for detecting the aortic valve stenosis from the parameters.

Higuchi et al. [12] introduced a 3-layer artificial neural network (ANN) of phonocardiogram recording for diagnosing the condition of heart for the patients with murmurs. It permits to identify the heart sounds under a group of categories. Ahlstrom et al. [13] devised a model for classifying the systolic heart murmur. It includes distinct tasks and neural network (NN) model is applied to classify the murmurs. A decision tree (DT) classifier is employed for identifying diverse aortic stenosis from mitral regurgitation utilizing the heart sound Pavlopoulos et al. [14]. Chauhan et al. [15] employed an automatic classification tool for heart sound using a probabilistic method of Mel-frequency cepstral coefficients (MFCC) and Hidden Markov Models (HMM). Numerous studies have explored the automatic detection of MV diseases by the use of distinct and pricey signals namely Doppler Heart Sound (DHS), Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) [15-18]. Turcoglu et al. [16] devised a new classification technique which extracts the features from DHS by the utilization of wavelet and short time Fourier transforms. Back-propagation NN is used to classify the images. Uguz et al. [17] introduced a Hidden Markov Model and Support Vector Machines for designing an automatic identification tool.

Even though there are many existing methodologies like semi-automatic method for tracking the mitral valve leaflet, jet in sequences of 2D+t Doppler echocardiography for Mitral regurgitation, automatic algorithm using Robust Nonnegative Matrix Factorization (RNMF) method and so for diagnosing mitral valve disease in advance and helps the doctors for both pre and post-surgical decision making, these existing methodologies do suffer from segmentation and classification inaccuracies leading to lack of assessment of mitral valve diseases, which then involves manual assessment of mitral valve disease, a very time consuming and inefficient task. Our proposed methodology, overcomes the above mentioned drawbacks by efficient segmentation of mitral valve leaflet, which leads to accurate classification of mitral leaflet. This classification helps the doctors in diagnosing the mitral valve diseases automatically without any manual intervention, making the system robust and efficient.

The remainder of the section is organized as follows: Section 3 discusses about the downside in existing works. Section 4 converses our proposed methodology with advantages and future enhancements. Section 5 discusses about experimental results of our proposed methodology. Section 6 concludes the paper.

A. Downside in existing works

Martin et al [19] has proposed a semi-automatic method for tracking the mitral valve leaflet in Transesophageal echocardiography. This method is a two-step pre-operative process, which segments the moving mitral valve in several cardiac cycles. But this method undergoes parameter tuning issues, in which the pre-operative collected segmented leaflet samples are taken for intra-operative mitral valve segmentation for obtaining more refined samples. Eva Costa et al [20] have proposed jet in sequences of 2D+t Doppler echocardiography for Mitral regurgitation. Most of the Rheumatic Heart disease and Rheumatic fever can be detected only after symptoms which has crossed the worst stage of heart disease. The proposed jet 2D+t Doppler echocardiography makes the diagnosis at earlier stage which reduces the screening cost and saves from fatal conditions of the patients. But the proposed method cannot detect cardiac cycle phase when the inclusion of characteristics other than color for jet detection is done. Dukler, Yoni et al [21] has proposed an automatic algorithm using Robust Nonnegative Matrix Factorization (RNMF) method, which does the mitral valve diagnosis in an improved manner. This framework separates the mitral valve alone from overall heart using motion complexity. This non-linear separation of mitral valve helps in improved mitral valve diagnosis than other techniques. But this algorithm fails to use the temporal information of the video sequence. A.M.Pouch et al [22] has proposed a fully automatic algorithm for segmenting the mitral valve in as a 3D Transesophageal image, which automatically generates 3D geometric model of mitral leaflet. This methodology is an accurate 3D image segmentation method, which helps in analyzing the patient specific leaflet geometry at both systole and diastole phases.

Daniel DeMenthon et al [23] have proposed a unique patient-specific mitral valve surgical planning method, envisioned for preoperative surgical planning by heart surgeons. But this method suffers from limitations in segmenting and modeling the image, when blood pressure forces are involved. P. Abdul Khayum et al [24] has proposed multi objective firefly optimization method, which efficiently identifies the mitral valve regurgitation and does the segmentation of mitral image using SVM. Though this method is efficient when compared to other existing optimization methods and segmentation, classifier accuracy still has to be optimized. Pierre-Frederic Villard et al [25] has proposed a semi-automatic method named Fast finite element method (FEM), for computerized diagnosis of Computed Tomography images of mitral valve leaflet using Simulation Open Framework Architecture (SOFA). The mitral valve model can help the surgeon understand valve actions and forestall the result of a process. But this method have drawbacks like neglected residual stress between multi-layered mitral valve and this model assumes that the leaflet thickness and chordae diameters are uniform, but actually it might be non-uniform leading to bad impacted to the results of the simulation.

Kan Seito et al [26] has examined how far the mitral valve tethering affects the patient with Functional Mitral Valve Regurgitation using three-dimensional Transesophageal echocardiography. But this assessment fails when the patient has isolated inferior wall-motion abnormality leading to underestimated total leaflet area.

III. PROPOSED SYSTEM

In order to address this issue of inefficient image segmentation and reduced classifier accuracy, this paper proposes two techniques namely 1) Deep Learning based Convolutional Neural Network (CNN) model for Mitral Valve classification model meant for diagnosis and edge detection based segmentation model to enhance the classifier accuracy. 2) Watershed Segmentation for Mitral Valve identification and image segmentation and Xception model with Random Forest (RF) classifier for training and classification.

A. CNN-MV model

The working procedure involved in the CNN-MV model is shown in Figure-1. It consists of a set of sub-processes, namely, preprocessing, segmentation and classification. Our proposed work mainly focuses on segmentation and classification. The pre-processing task eliminates the unwanted portions of the image including noise, blurring and so on. Edge detection method is employed for segmenting images.

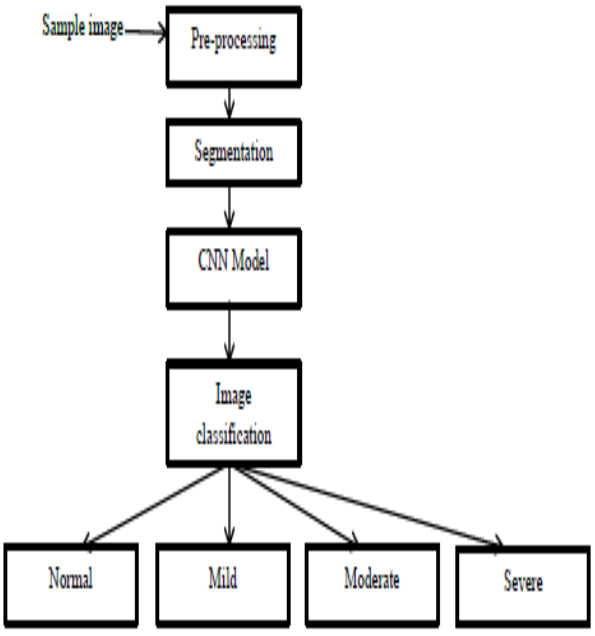

Fig. 1.Overall Process of CNN-MV model

The actual images are converted into edge images by modifying the gray scale values in the image. The edges generally appear on the boundaries among two portions. The major characteristic is the extraction of features from the image. The characteristics are utilized to detect the edges in the applied medical MR images. To classify the mitral valve disease based on severity levels like normal, mild, moderate and severe, feedfoward Convolutional Neural Network (CNN) is applied to the segmented images.

CNN model shown in Figure-2 contains a set of convolutional and pooling (or subsampling) layers that is collectively clustered into modules. The input image is provided straightly to the network and it follows various stages of convolution as well as pooling. Next, representation from this function is provided to one or many fully connected layers. At the end, the final fully connected layer provides the class label to the input image. From that we can be ale to classify the severity of the mitral valve disease.

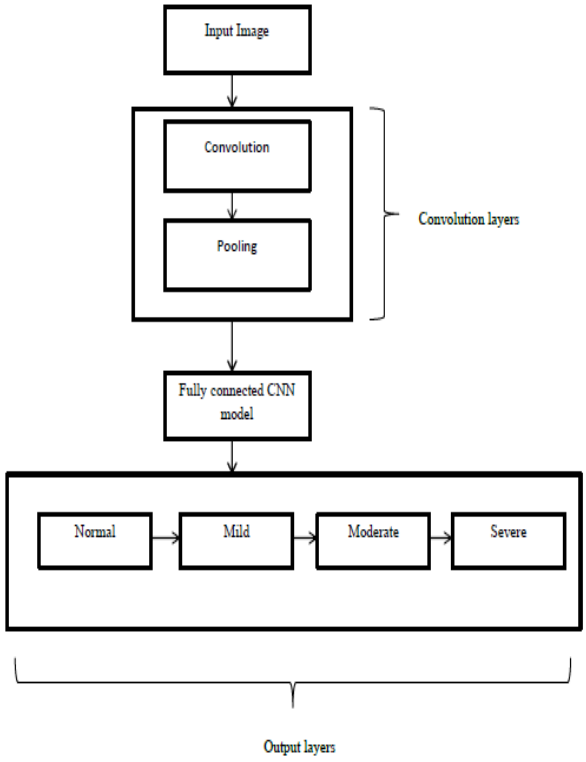

Fig. 2.CNN model for MV classification

B. WS-X model

Figure-3 shows the entire working process of the presented WS-X model. The presented model comprises of two main levels called as segmentation and classification. A watershed algorithm with channel separation is applied for the segmentation of MV images. The Xception model with random forest (RF) classifier is employed for training and classification purposes. The Xception model performs the training process and the model is created. After the model creation process gets completed, testing process will be initiated. The test images are provided by passing it to various stages namely preprocessing, segmentation and then it will be classified into four different classes, namely, normal, mild, moderate and severe.

The advantages of the proposed system are:

- No manual parameter tuning required for diagnosing the severity of mitral valve disease.
- Irrespective of motion and color changes in the segmented mitral valve leaflet, classifier makes

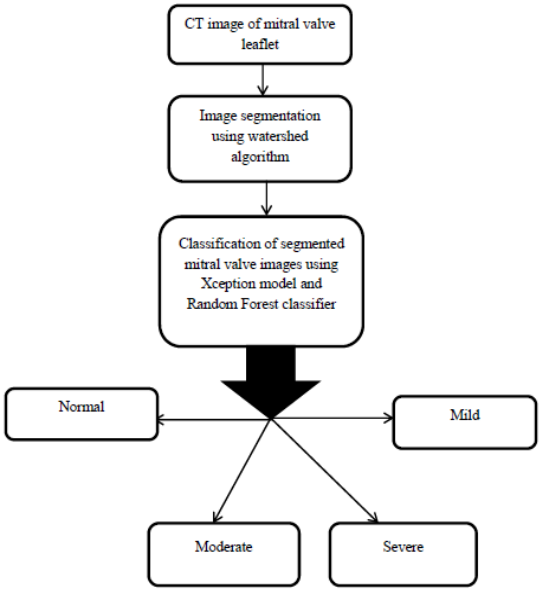

Fig. 3. Overall Process of Watershed algorithm with Xception and Random Forest Method

accurate classification of severity of mitral valve diseases.

- Increased classifier accuracy when compared to that of existing methodologies discussed in section 3.
- No need of temporal information for mitral valve segmentation and classification.
- Due to accurate segmentation, residual errors between the layers of the mitral valve can be excluded.
- No need to estimate total leaflet area for diagnosis based on proposed segmentation and classification.

IV. DISCUSSION

In order to diagnose the severity of the mitral disease without manual intervention, this paper proposes two methodologies namely 1) CNN-MV model and 2) WS-X model. Both models focus on image segmentation and classification. CNN-MV model uses edge detection for image segmentation and the segmented images are fed to the Feedfoward CNN classifier for classifying images based on the severity. In WS-X model, a watershed algorithm with channel separation is applied for the segmentation of MV images. The Xception model with random forest (RF) classifier is employed for training and classification purposes. The performance measures of accuracy, specificity and sensitivity should be measured for normal, mild, moderate and severe mitral valve disease levels. The obtained simulation result indicated that the presented CNN-MV model shows superior results with the maximum accuracy of 71.32 and acts as an appropriate tool for MV diagnosis. The experimental results exhibited that the WS-X model shows up an accuracy of 74.56 % which outperforms our proposed CNN model, proving it as the best Mitral valve severity diagnosis tool.

Table- II: Comparative analysis on Techniques Used for Diagnosis of Mitral Valve Regurgitation Severity

S.No	References	Method	Drawbacks
1	Martin et al [19]	Semi-automatic method for tracking the mitral valve leaflet	Parameter tuning issues
2	Eva Costa et al [20]	Jet in sequences of 2D+t Doppler echocardiography for Mitral regurgitation	Cannot detect cardiac cycle phase when the inclusion of characteristics other than color for jet detection
3	Dukler, Yoni et al [21]	Robust Nonnegative Matrix Factorization (RNMF)	Lack of temporal information of the video sequence
4	A.M. Pouch et al [22]	Real-time 3D Transesophageal echocardiography (3D TEE)	Registration errors, leaflet labeling inaccuracies, less efficient
5	Daniel DeMenthon et al [23]	Patient-specific mitral valve surgical planning method	Reduced classifier accuracy.
6	P. Abdul Khayum et al [24]	Multi objective firefly optimization method	Classifier accuracy still has to be optimized.
7	Pierre-Frederic Villard et al [25]	Fast finite element method (FEM)	Neglected residual stress.
8	Kan Seito et al [26]	Three-dimensional Transesophageal echocardiography	Underestimated total leaflet area

V. CONCLUSION

The proposed system CNN-MV and WS-X model focusses mainly on image segmentation and classification for the effective diagnosis of mitral valve severities. CNN model did the image segmentation using edge detection method and classification using Feedfoward CNN model, which shows up clear classification of mitral valve image based on the severity. The classification accuracy simulation resulted in 71.32 %, which outperforms all other existing segmentation and classification methodologies.

WS-X model does segmentation using watershed algorithm and classification by applying to Xception model with random forest (RF).

The accuracy of the WS-X model was found to be 74.56%, which proves to be the best Mitral valve severity diagnosis tool than our proposed CNN model and other existing methodologies.

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