

Coslets for Classification of Covid-19 X-Ray Images

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Abstract—COVID-19 (Corona virus) endures to have disastrous effects on the lives of human beings. Corona virus was first reported in the year 2019 and later widely spread throughout the world. The machine learning approaches are extensively used to analyze the characteristics of Covid-19 pneumonia in chest X-ray images. In this paper, a sequential approach is implemented to study and classify the Covid-19 pneumonia case, non-Covid-19 case and Normal cases. Discrete Cosine Transformation (DCT) and wavelet decomposition methods are employed to extract the coslets features from the chest X-ray images. The discriminative properties are retained by employing Singular Value Decomposition (SVD) method. Finally, Probabilistic Neural Network (PNN) and Generalized Regression Neural Network (GRNN) is applied to classify the given chest X-ray images into three classes such as Covid-19 pneumonia case, non-Covid-19 case and Normal case. The performance of the proposed method is evaluated in terms of accuracy, sensitivity and specificity. The result shows that method is promising and encouraging.

Index Terms— COVID-19, X-ray, Discrete Cosine Transform (DCT), coslets features, PNN, GRNN.

I. INTRODUCTION

Corona virus is a newly emerged respiratory disease and it became an identical pandemic in the year 2019 December, hence the name is Covid-19. As the Covid-19 pandemic evolves, an everyday life of the human being has disrupted in the globe. Most Covid-19 infected patients have mild to moderate symptoms such as fever, headache, cough, cold, breathing problems, anxiety and pneumonia. Due to elevated infections on humans, the WHO declared as global public health emergency on 30th January 2020 [1]. Hence, there is need of better understanding the morphology and epidemiology of Corona virus.

Clinical testing methods are needs to be enhanced to detect the actual Covid-19 cases and non-Covid-19 cases, so that the effectiveness of the medical treatment of Covid-19 can be improved and avoid the spreading. The clinical radiography testing approaches analyse the radiography images like MRI, CT and X-ray images [2, 3]. The major challenges in radiography images are to classify the features of Covid-19 virus pneumonia and features of other viral pneumonia. Hence, most of the technical researchers are interested to introduce the machine learning models for analysing the radiography images to study the characteristics of Covid-19 pneumonia. The rest of the paper is organized as follows, the literature survey is explained in section 2, proposed methodology based on coslets features is discussed in section 3, PNN and GRNN classification algorithms are described in section 4, the experimental analysis is done in section 5 and finally, section 6 explains the conclusion and future work.

II. LITERATURE SURVEY

The significance of machine learning algorithms for Covid-19 is discussed by Kushwaha et al. [4]. The implication of artificial intelligence and data mining techniques to combat against Covid-19 is explained by Alimadadi et al. [5]. Neural network based classifiers were implemented by Wang et al. [6] for screening the large scale Covid-19 patients using discrete respiratory patterns. Deep learning techniques were developed by Gozes et al. [7] to detect and monitor the Covid-19 pneumonia in CT images. Apostolopoulos et al. [8] used convolutional neural network model to automatic detection of Covid-19. Narin et al. [9] proposed five pre-trained convolutional neural network models such as ResNet50, ResNet101, ResNet152, InceptionV3 and Inception-ResNetV2 to detect the Covid-19 pneumonia using chest X-ray images. Aradhya et al. [10] introduced the one shot cluster based method for identifying the Covid-19 pneumonia in chest X-ray images. Barstugan et al. [11] applied Local Directional Pattern (LDP), Grey Level Co-occurrence Matrix (GLCM), Grey-Level Size Zone Matrix (GLSZM), Grey Level Run Length Matrix (GLRLM), and Discrete Wavelet Transform (DWT) algorithms to extract the features from the CT images. The Support Vector Machine (SVM) is employed to classify the Covid-19 pneumonia and non-Covid-19 pneumonia. Xu et al. [12] categorized Covid-19 CT images into three classes such as COVID-19, Influenza-A viral pneumonia, and healthy cases. 3D-dimensional deep learning model is used to classify the given CT images. Shan et al. [13] implemented a deep learning based model for segmenting the infected regions and the entire lung from the chest CT images. Basavaraju et al. [14, 15] discussed the importance of key features for gray scale images by applying double line structure model. Hanumantharaju et al. [16] developed an image enhancement algorithm using multiscale retinex and parameter adjustment concept to intensify the details of chest X-ray or CT images. Zoabi et al. [17] proposed a machine learning algorithms and eight binary features to predict the result of covid-19 based on the given symptoms.

III. PROPOSED METHODOLOGY

The proposed method is a sequential algorithm consisting step by step process like feature extraction, feature selection and classification. Initially, Discrete Cosine Transformation (DCT) and wavelet decomposition methods are used to extract the coslets features from the chest X-ray images. Singular value decomposition method is employed to select the minimum number of features and finally, Probabilistic Neural Network (PNN) and Generalized Regression Neural Network (GRNN) is used to classify into three classes such as Covid-19 pneumonia case, non-Covid-19 case and Normal cases. The Figure 1 shows the training and testing architecture of the proposed method.

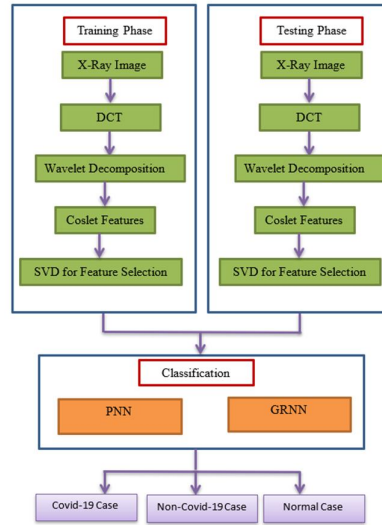


Figure 1. Training and testing architecture of proposed method

A. Coslets Feature Extractions

The characteristics of Covid-19 pneumonia are studied to identify the semantic distance between Covid-19 cases, non-Covid-19 cases and normal cases. In this order, discrete cosine transform and one dimensional wavelet decomposition is employed to extract the coslets features from chest X-ray images.

B. 2D-Discrete Cosine Transform

The two dimensional discrete Cosine Transform (2D-DCT) converts the image from spatial domain to frequency domain and it helps to separate the gross features, which are essential to view the image from fine detail. 2D-DCT represents the finite sequence of data elements into sum of cosine functions. Here, 2D-DCT translates the each pixel of chest X-ray image into its equivalent frequency value. The cosine transform helps to concentrate the energy present in the first few coefficients of the transformed elements. Hence, the feature matrix of 2D-DCT shows that most of the energy in the first few elements of coefficient values. Hence, 2D-DWT extracts the DCT coefficients and frequency coefficients from the chest X-ray images using equation 1. The zig-zag order rearranges the DCT coefficients in terms of linear order and frequency coefficients are arranged by an increasing order. The DCT coefficients of Covid-19 (Fig 2a) are having low frequency coefficients as compared to non-Covid-19 (Fig2b) and normal case (Fig 2c). The Figure 2 shows the 2D-DCT coefficients of Covid-19 case, non-Covid-19 case and normal case respectively.

$$C(u, v) = \frac{2}{\sqrt{mn}} \alpha(u) \alpha(v) \sum_{x=1}^m \sum_{y=1}^n f(x, y) \cos \left[\frac{(2x+1)u\pi}{2m} \right] \cos \left[\frac{(2y+1)v\pi}{2n} \right] \quad (1)$$

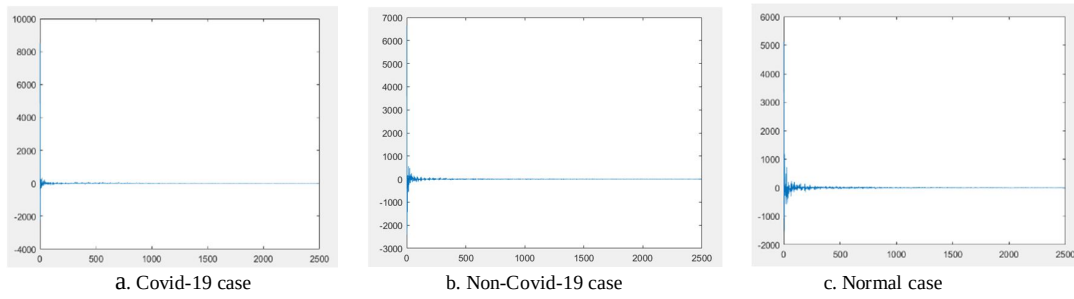


Figure 2. DCT coefficients of chest X-ray images.

C. Haar Wavelet Decomposition

One dimensional wavelet transform decomposes a function into collection of wavelets. A wavelet is a wave-like oscillation with respect to time. A wavelet consist two parameters such as scale and location. Where, scale represents the wavelet is stretched or squished and location depicts the wavelet position in time. The product of scale and location gives the wavelet coefficient values. Here, the Haar wavelet is applied to study the spatial frequencies appeared in the chest X-ray images and to get the corresponding locations of respective frequencies. Hence, Haar wavelet is implemented to extract the local spectral information and temporal information from the resultant of 2D-DWT coefficients. Figure 3 represents the Haar wavelet decomposition of 2D-DWT coefficients.

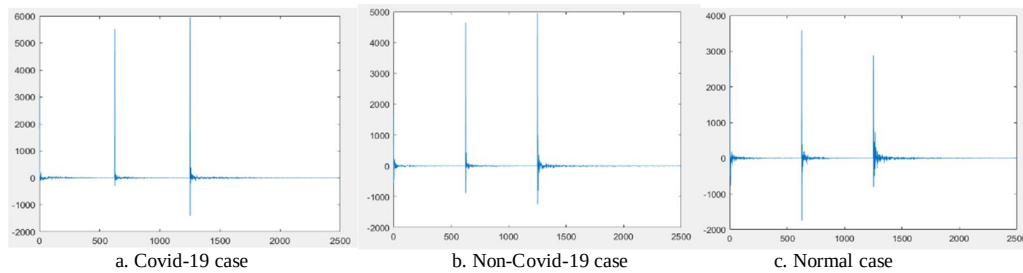


Figure 3. Wavelet decomposed representation of 2D-DCT coefficients

D. Feature selection using SVD

Singular Value Decomposition (SVD) is the spectral decomposition of the squared matrix. This technique widely used to decompose a coslet feature matrix into several constituent matrices, which represents the useful properties of coslet feature matrix. The SVD computes the Eigen values and Eigen vectors to select the interesting features. Hence SVD is applied to select the minimum key features from the coslet features. SVD results with unitary matrices with singular vectors and diagonal matrix with singular values.

IV. CLASSIFICATION BASED ON PNN AND GRNN

2D-DWT and Haar wavelet decomposition consider the low frequency components as coslet features from the chest X-ray image. Later, SVD select the orthogonal features to reduce complexity of classification process. In this regard, the classification process is performed by employing neural network classifiers such as probabilistic neural network and generalized neural network.

A. Probabilistic Neural Network (PNN)

Probabilistic Neural Network (PNN) is a four layer supervised feed-forward neural network to estimate the Probability Distribution Function (PDF) using Parzen window and non-parametric function. PNN evaluate the non-linear decision boundaries by adding the sample data vectors to existing weights. The proposed method trained the PNN with selected coslet features of chest X-ray image. Every node of the PNN hidden layer is considered as weights of the example vector. Hence the activation of hidden node (h_i) is represented in equation 2 i.e. product of coslet feature (CFV) vector and example vector (EV). PNN classifier maps all input feature vector to a number of classifications and inclines to create an optimum classifier convergent. Finally, the trained PNN is tested using other trained samples of chest X-ray images. Output activations of class are performed using equation 3, where N is the example vector of class S , h_i is the hidden node and Φ is the smoothing value.

$$h_i = \text{CFV} * \text{EV} \quad (2)$$

$$S_j = \frac{\sum_{i=1}^n e^{-\frac{h_i^2}{2\sigma^2}}}{N} \quad (3)$$

B. Generalized Regression Neural Networks (GRNN)

GRNN is a variation of Radial Basis Functions (RBF) network. GRNN used for identifying and controlling the nonlinear systems based on one pass learning. The main advantage of GRNN is one pass learning i.e. the network is able to learn and converge with minimum training chest X-ray samples. The regression technique helps to produce the probable value for a dependent variable. The Gaussian function is used in hidden layer and the weight vectors are computed using equation 4. Finally, GRNN estimates the function approximation to predict the output for Feature Vector (FV) of chest X-ray data.

$$\text{FV}(I) = \frac{\sum_{i=1}^n T_i W_i}{\sum_{i=1}^n W_i}, \quad \text{with} \\ W_i = e^{-\frac{\|I - I_i\|^2}{2h^2}} \quad (4)$$

V. EXPERIMENTAL RESULTS

The performance of the proposed method is experimented on 24,614 chest X-ray images, which categorized into 614 samples are Covid-19 pneumonia cases, 12000 samples are non-Covid-19 cases and another 12000 samples are normal cases. It is quite difficult to distinguish the characteristics of Covid-19 pneumonia and non Covid-19 pneumonia like other viral infections. Coslet features identify distance between Covid-19 and non-Covid-19 pneumonia. PNN and GRNN effectively used as neural network classifiers to classify three different cases. 80 percent of chest X-ray data has considered for training the classifiers and remaining 20 percent is taken for testing the classifiers. The performance of the proposed model is evaluated using performance measures like accuracy (equation 5), sensitivity (equation 6) and specificity (equation 7). All these performance uses certain parameters like True Positive (TP): Covid-19 affected people correctly classified as infected. True Negative (TN): Healthy people correctly classified as healthy. False Positive (FP): Healthy people incorrectly classified as infected and False Negative (FN): Infected people incorrectly classified as healthy.

$$\text{Accuracy} = \frac{TP + TN}{TP + FP + TN + FN} \quad (5)$$

$$\text{Sensitivity} = \frac{TP}{TP + FN} \quad (6)$$

$$\text{Specificity} = \frac{TN}{TN + FP} \quad (7)$$

A. Classification based on PNN

The proposed method trained the probabilistic neural network with coslet features of 80% chest X-ray images and remaining 20% is used for testing trained network. The table 1 presents the confusion matrix of PNN network and table 2 represents the analysis of accuracy, sensitivity and specificity on chest X-ray images.

TABLE I. CONFUSION MATRIX OF PNN

Cases/Class	Covid-19	Non-Covid-19	Normal
Class1	80	2	8
Class2	33	2160	262
Class 3	10	238	2130

TABLE II. ANALYSIS OF PNN ON CHEST X-RAY IMAGES

Accuracy			Sensitivity			Specificity		
Class1	Class2	Class3	Class1	Class2	Class3	Class1	Class2	Class3
98.92	89.11	89.46	88.89	87.94	89.57	99.11	90.28	89.35
92.49			88.80			92.91		

B. Classification based on GRNN

The proposed method trained the generalized regression neural network with coslet features of 80% chest X-ray images and remaining 20% is used for testing trained GRNN network. The table 3 presents the confusion matrix of GRNN network and table 4 represents the analysis of accuracy, sensitivity and specificity on chest X-ray images.

TABLE III. CONFUSION MATRIX OF GRNN

Cases/Class	Covid-19	Non-Covid-19	Normal
Class1	80	2	8
Class2	33	2158	263
Class 3	10	240	2129

TABLE IV. ANALYSIS OF GRNN ON CHEST X-RAY IMAGES

Accuracy			Sensitivity			Specificity		
Class1	Class2	Class3	Class1	Class2	Class3	Class1	Class2	Class3
98.92	89.07	89.42	88.89	87.93	89.50	99.11	90.20	89.34
92.47			88.77			92.88		

VI. CONCLUSION

Corona virus is fast spreading respiratory disease and it declared as pandemic in the year 2019. This research work incorporated the step by step machine learning concepts to categorize the chest X-ray images into affected, non- affected and normal cases. Discrete Cosine Transformation (DCT) helps to denote the finite sequence of elements into sum of cosine functions and wavelet decomposition methods are used to extract the coslets features. Singular value decomposition method is applied to identify the discriminative properties to represent the Covid-19 pneumonia. Finally, Probabilistic Neural Network (PNN) and Generalized Regression Neural Network (GRNN) is used to categorize the chest X-ray images into Covid-19 pneumonia case, non-Covid-19 case and Normal cases. In the future work, the probabilistic models will be studied to fast and effective classification of chest X-ray images.

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