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Neural Network and Cuckoo Optimization Algorithm for Remote Sensing Image Classification

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***Abstract:** Since Remote sensing images are used for a variety of applications, classification of such images is essential for extracting information. However, due to the lack of sufficient training examples, classification of remote sensing images is more complex. Also, in traditional method of classification, the statistical procedure uses only the gray value of the digital images to extract information. Neural network (NN) has a better impact in this domain. The proposed work uses an integrated NN and cuckoo Optimisation Algorithm (COA) for classification. The NN picks, organise and constructs the data to be trained into a network. The network is then trained and tested. The COA is combined with NN to aid the task of classification and to calculate the cost function. The optimization algorithm provides an appropriate feature suitable for the neural network classifier to produce final output. This hybridized technique presents the effective advantages of the neural network and further investigate the classification of the multispectral remote sensible images. The performance and error rate of the system is better when compared with other classical methods. The observed results illustrate the effectiveness of the COA to optimize the cost function. As training parameters in Neural network is found to be NP hard, utilization of COA involve its responsibility in optimizing the learning rate of NN.*

***Keywords:** Neural Network, Cuckoo Optimisation Algorithm, classification, cost function.*

I. INTRODUCTION

Remote sensing is a process of obtaining data about an object from a distance without any physical contact with the object. The primary goal of remote sensing is to study about the surface of the earth using remote sensors. The major advantage of remote sensing is that, it can be used to view larger areas of earth surface which are never visited by humans. Images captured by remote sensors carry a lot of information. But the accuracy of such images is usually distressing and they possess less difference over different areas of land.

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Different features on the earth's surface have a different spectral reflectance and remittance properties Hence these images can be recognised only through classification. Studies have shown that application of neural networks in remote sensing images provides better results. NN requires only a little number of samples for training. NN works more precisely than other methods, even with complicated feature space [1]. The model of NN resembles a brain. As the brain studies from the environment, NN studies from training samples.

It uses synaptic weights (strength that connects neurons) to store the gathered knowledge. Each neuron takes an input, processes it and passes the output of processing to the next neuron. However, speed of NNs is much faster than human brain.

But the efforts to create artificial brains are still a way behind. NN is primarily applied in remote sensing images for better classification. It classifies images by grouping pixels into classes. If a pixel satisfies certain conditions then it is assigned to the class that possess the same characteristics.

Optimisation is an action of improving the performance of a system either by adjusting inputs or the features of the system. The optimisation algorithm, COA proposed in this work is prompted by the lifestyle of the bird Cuckoo. As a brood parasite, Cuckoo possesses reproduction in a different fashion. They watch the nests of a variety of birds and imitate the shape and colour of the host's egg. Cuckoo lays eggs on some other birds' nest by replacing one of the host's egg. If the host recognises the cuckoo's egg, it pushes the egg down. If unrecognised, the egg hatches and the cuckoo grows into mature. The steps carried out in COA algorithm are demonstrated in fig 1. If the hatching of the eggs is at high rate, then the current environment is considered suitable. Otherwise, the eggs are let to grow. The nests' with best survival rates are determined. Depending on the determination, cuckoo societies are formed. Since the current environment is considered unfit for them to reproduce, they migrate to suitable environments. Then egg laying radius is determined for each cuckoo. The entire process repeats until suitable high profit environment is reached [2].

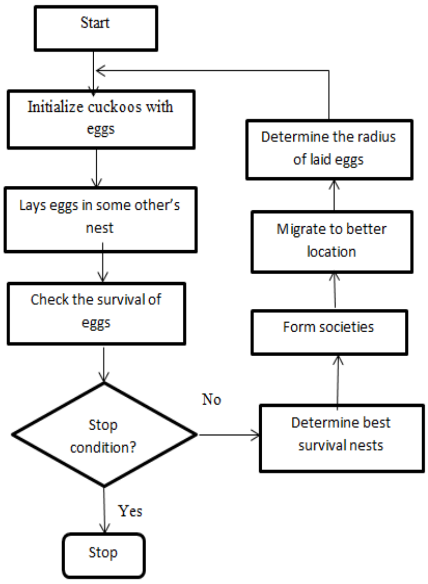

Fig1. Flow diagram of COA

An idea of extending a technique using an optimisation algorithm seems to provide better outcomes [6]. Hence NN technique is integrated with COA to provide better classification results with efficient cost estimation. The cost plot is generated by specifying the cost for all iterations.

The system requires a minimum number of iterations to determine the optimal domain. The performance and error rate of the training is generated for different iterations. Existing systems does not enable to compute the cost of classification. In order to enable that, the proposed work is intended to compute the cost of classification. It is designed to compute the cost of each iteration of the training phase. The best performance value along with the corresponding epoch can also be viewed.

II. RELATED WORK

A variety of works have been done in classification of remote sensing images. However the techniques use has poor ability to classify images. Land cover datasets were produced over large areas.in [3] by computing the patch-based samples from multidimensional top of atmosphere reflectance data. Neural network called Progressively Expanded Neural Network (PEN Net) is used in [4] which explicate hyper spectral pixels of nonlinear feature spaces and ascertain the groups. A classification structure is built, that checks the abstraction and strength of the network. A combination of deep convolutional neural network (DCNN) and grading transfer is proposed in [5]. In this initially, fine tuning was carried out by applying an already trained dataset to a small dataset. By this, the first level classification features of images can be obtained. The system then clusters similar images of the target dataset and extracts the second level classification characteristics. Both classification characteristics are then encoded and combined. The domain blocks are classified based on average of pixel intensities. Convolutional Neural Networks are used in [7] for segmenting remote sensing images combined with inter band and intra band fusion. In this paper separates bands of the image and assigns committee of boosted CNN to each band, from which confidence maps are derived. Each map is integrated using inter-fusion into fused map. An efficient algorithm for data clustering is proposed in [8]. It uses COAC and Fuzzy COA to produce random solution and to generate cost function. A deep convolutional neural network is used in [9] for image recognition. But the system is not well optimised and it possesses limited effectiveness. A fuzzy based cuckoo algorithm is used in [10] which combines cuckoo algorithm with k-means algorithm. However the computation of this methodology requires more time.

III. PROPOSED WORK

Classification of remotely sensed images makes a great sense in today's world. Most classification algorithms provide poor performance owing to the fact that remote sensing images possess limited samples. As NN can be trained using minimum number of samples, it can be used effectively in this case. The system proposes an integrated technique of NN and COA. The integration aids in better classification and estimation of cost function. The detailed description of both algorithms is discussed below.

Classification using Neural Network

NN is composed of a set of neurons where the response of one neuron is fed into the other as input. These set of neurons form a network. The network is initially trained for a set of images. It is trained repeatedly until the error function reaches a minimum value. During training, initial weights are assigned as random values. Each time if the error function is found to be high, the weights are adjusted based on the error. The network is said to have completed training, once the error function reaches a certain minimum value. Once the network is trained, it is used to generate output for similar images. In the proposed work, the network is trained using a dataset called the Indian pines dataset. Images in the dataset are represented in the form of matrix. Once the dataset is loaded, pre-processing steps takes place. Pre-processing involves resizing the images to remove positive as well as negative outliers. The classification data is then loaded and the number of classes is determined. The inputs are organised into a network and then the network is trained. During training, the weights are assigned as random values .At the end of training, the network is tested with the target result for error. Error is considered as a main concept which shows how a network works during the training phase. If error is found to be more, then back propagation takes place in order to adjust the weights. The network updates the weight based on the category of error that the previous weight results. The error gets reduced at each step. Training continues until error reaches a minimum level, which means that until the network gains the ability to make predictions closer to the real value. When the training phase gets completed, classification of images can be carried out.

COA optimisation

The optimisation algorithm used with the NN aids in classification and it calculates the cost function for each class. The COA involves a number of iterations which the user can specify. It computes the cost of classification with a cost function. In this work, rastrigin is specified as the cost function. The Rastrigin function is a non-convex function used as a performance test problem for optimization algorithm It is defined as,

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$$f(x) = An + \sum_{i=1}^{n} [x_i^2 - A\cos(2\pi x_i)]$$

Where A=10 and n-dimensions and $x_i \in [-5.12, 5.12]$

It calculates the cost function during the training phase so that better classification is learned by the network with better knowledge.

Integrating both the algorithms generates a NN train tool. The performance of the system is calculated for different iterations using the train tool. This tool box is an inbuilt function which contains several functions on it. The error rate, training confusion and receiver operating characteristics is generated using the train tool and are plotted. Cost minimisation plot of the COA algorithm is also obtained.

IV. RESULTS AND DISCUSSIONS

The simulation results obtained from the proposed NN& COA integrated algorithms are displayed below along with their brief descriptions.
The COA cost function is specified as rastrigin and applied for several iterations.

The algorithm computes the cost by considering the lower band parameter as -5 and higher band parameter as 5. Fig2 shows the cost estimation plot for 2 iterations with the current cost value for iteration 2.

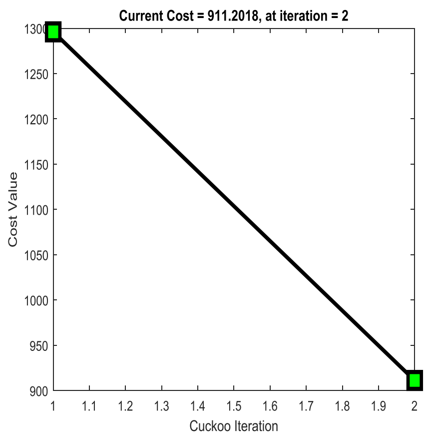

Fig2. COA cost in 2 iterations

The cost calculation plot of COA after 75 iterations is shown in fig3 with number of iterations plotted over the x label and the corresponding cost along the vertical direction. The initial profit value is considered as a negative number. Goal point is specified as the difference between the higher and lower band parameters.

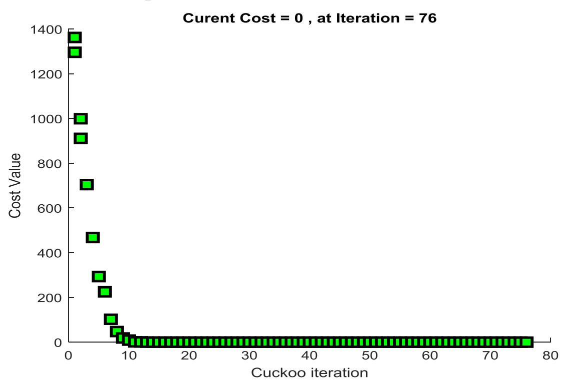

Fig3. COA cost in 75 iterations

Fig4 represents the NN training tool. It is an inbuilt toolbox which is called using nntraintool to make the training GUI visible. The train tool provides the easier way to use neural networks in matlab. It contains a set of structures and functions that handles neural network.

Fig4. Neural Network train tool

Hence it is not necessary to specify codes for all functions that we use. This tool includes the values for performance, gradients and validation checks for varying iterations**.**

The proposed work tends to train NN classifier using the Indian pines dataset. The following figure is a sample figure taken from the dataset for the purpose of training the classifier.

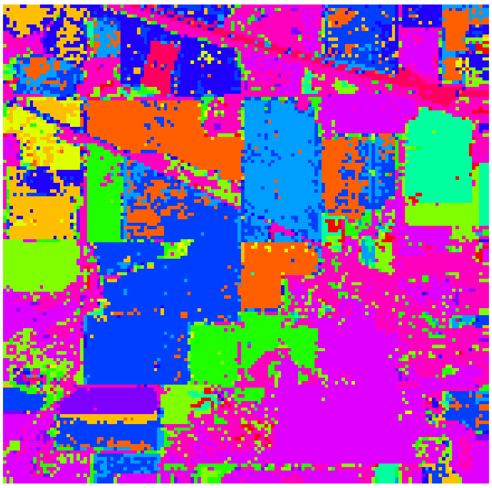

Fig5. Training image

The performance of the system is generated by taking into account training, validation and testing values for different iterations using the training tool. The best performance value is evaluated and the corresponding iteration is also specified. Generally, the error reduces after more epochs of training, but might start to increase on the validation data set as the network starts overfitting the training data. In the default setup, the training stops after six consecutive increases in validation error, and the best performance is taken from the epoch with the lowest validation error.

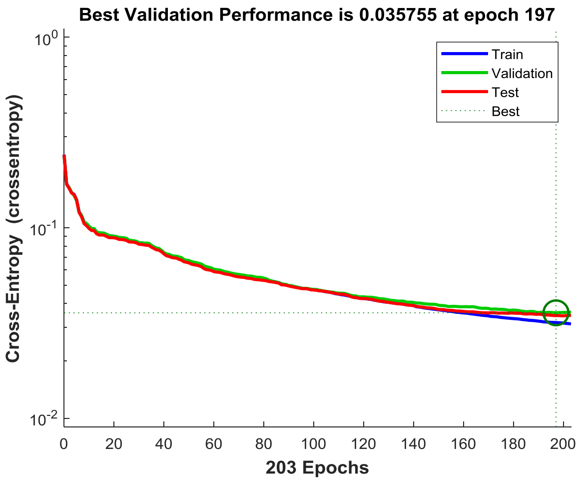

Fig6. NN training performance

Fig7 shows the gradient coefficient variation with respect to the number of epochs. The value of gradient coefficient at epoch number 203 is 0.0080774. The training and testing of networks will be better when the value of gradient coefficient is minimum. It is clearly noticed from the picture that the gradient value decreases with the increasing number of epochs

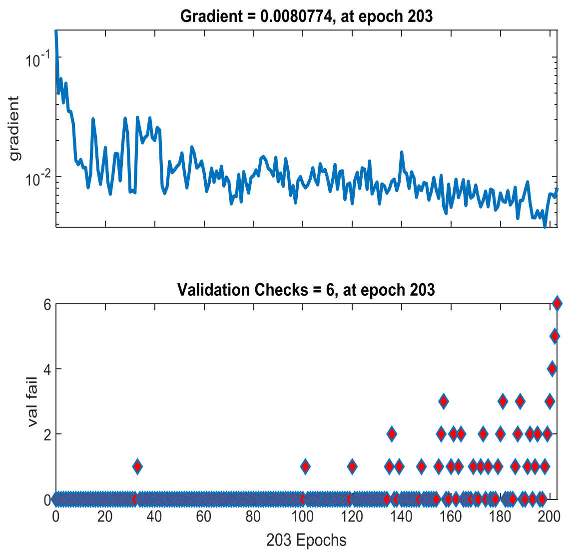

Fig7. NN training state

The error histogram of NN with respect to training, validation and testing steps is presented in fig8. Error can be computed by finding the difference between the target output and the output achieved. The error function is computed as a sum of the difference between the target and output. It is shown that the errors are distributed within a reasonably good range around zero.

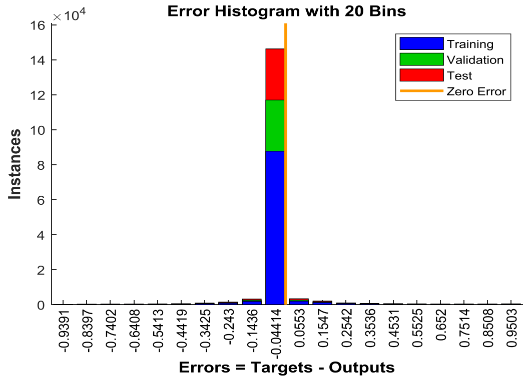

Fig8. Error histogram.

Fig9 shows the ways in which the NN is confused when it being trained. On the confusion matrix plot, the predicted class is plotted on rows and the true class along columns. The cells along the diagonal represent the correctly classified observations. The cells other than the diagonal represent the observations that are wrongly classified. Each cell includes the number of observations and the percentage of the total number of observations. The right most columns of the plot shows the percentages of all the examples predicted to belong to each class that are correctly and incorrectly classified. These metrics are often called the precision (or positive predictive value) and false discovery rate, respectively. The bottom row of the plot shows the percentage of all the examples belonging to each class that are correctly and incorrectly classified. These metrics are often called the recall (or true positive rate) and false negative rate, respectively. The cell in the bottom right of the plot shows the overall accuracy.

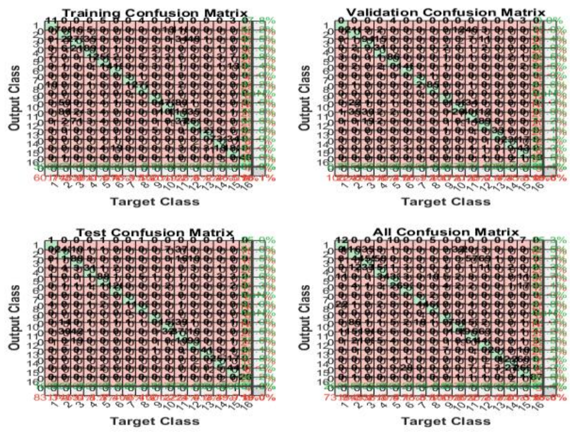

Fig9. NN training confusion

Fig10 shows the training receiver operating characteristics. The receiver operating characteristics is evaluated for training, validation test and all against false and true positive rates. It is used to evaluate the performance of the classifier. ROC analysis provides tools to select possibly optimal models and to discard suboptimal ones independently from (and prior to specifying) the cost context or the class distribution.

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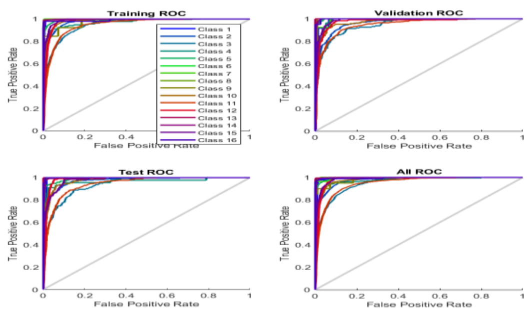

Fig10. Training receiver operating characteristics

V. CONCLUSION

Classification of remote sensing images gains a lot of attention in today's world. Hence an idea of integrating **NN** with COA has been explored and implemented in this paper. NN classifiers are used to train remote sensing images from the Indian Pines dataset. COA algorithm evaluated the cost of individual iterations and is plotted. The performance of the system has been experimented using the Indian Pines dataset. It is found to be better than other classical methods. The error distribution has also been found to be at reasonable range. The confusion matrix and ROC has been found. The cost has been estimated effectively. It also illustrates the effectiveness of the optimization algorithm in producing better classified relevant information. Lower computational time is taken by the hybrid technique to produce effective cost function when compared to the other approaches. The stochastically obtained information produces an optimal result due to the integration of the COA. COA produces a superior generalization capability by resolving the unclassified image regions with better performance than that of the conventional approaches.

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