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The Hybridization of Neural Network and Particle Swarm Optimization for Natural Terrain Feature Extraction

Sakshi Dhingra, Dharminder Kumar

Abstract: The optimization of various soft computing and metaheuristic techniques can be ameliorated in a global area network, Swarm intelligence. In this research, a hybrid algorithm of neural network and particle swarm optimization has been presented for remote sensing applications. The terrain features of the land in a remote sensing image have been classified using these algorithms. Remote sensing basically deals with the processing and interpretation of satellite images without any physical contact to that particular region. In addition, the geo-spatial characteristics of the data also recorded during image classification. The hybrid concept used in this research, the implementation of algorithm in this paper based on the neurons network to find the best solution, which is further resolved using the Particle Swarm Optimization approach, an optimization technique. The proposed algorithm easily classifies the terrain features with higher efficiency and kappa coefficient value. The results show that 94.36% accuracy attained from the proposed technique. The overall accuracy improved by 5.24 % and 14.93% and kappa coefficient enhancement of 6.97 % and 18.99 % in comparison to existing studies.

Keywords: Remote Sensing, Satellite Images, Particle Swarm Optimization, kappa coefficient

I. INTRODUCTION

The amazing benefits of the Artificial intelligence approaches came into sight due to its high efficiency and incredible advantages of natural behaviour of the birds to solve complex problems [1]. Swarm intelligence has been accepted as a most reliable method. Due to its novel architecture and highly efficient behaviour, algorithm is feasible for various applications such as detection of optimal routes, data analysis, route scheduling, image classification, etc. In this paper, we are applying the hybridization of NN for remote sensing and for the classification of land images to detect the terrain features. Remote sensing is an efficient technology which observes, sense, and determines the geo-spatial characteristics of the object [2]. The characteristics have been displayed over a 2D spatial grid. Specifically, image classification using NN recognizes the terrain features of the classified images.

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* Correspondence Author
Sakshi Dhingra*, Guru Jambheshwar University of Science and Technology, Haryana, INDIA. Email: sakshi24.dhingra@gmail.com
Prof. Dharminder Kumar, Professor, Department of Computer Science and Engineering, Guru Jambheshwar University of Science and Technology, Hissar, Haryana, India.

The multispectral images consists of various pixels which are categorized into terrain features of all regions like water, urban, rocks, and vegetation. Currently, there are many soft computing techniques proposed in literature such as Particle Swarm Optimization (PSO), Biogeography Based Optimization (BBO), Artificial Bee Colony Optimization (ABC), Membrane computing, and Genetic Algorithm.

Out of these, PSO algorithm are being used for optimization and Neural Network for image classification.

A novel approach has been introduced in this research by hybridization of NN and PSO for image classification by sensing and observing to attain higher efficiency and optimization value. Neural Network based on the neural structure of the brain. The elements operate in parallel. Neural network classify the data and PSO optimized it. PSO based on the intelligent sharing behaviour of the birds. It is a population based approach that finds the optimal solutions by noticing the behaviour of the flying particles. The nature of NN and PSO is dominating, so hybridization of these two techniques proposes a new algorithm. The proposed hybrid technique applied for image classification. The main objective of this research is to classify the terrain features of the land and compare the proposed methodology with other soft computing approaches.

This paper is organized as follows: Section 2 elaborates the related work. Section 3 discusses the classification and optimization approaches. Section 4 describes the proposed methodology. Results and discussion defined in section 5 which is finally concluded at the end in section 6.

II. RELATED WORK

This section describes the discussion on past studies related to image classification to detect the terrain features. Researchers use the different classification and optimization techniques to detect the terrain features from the remote images. The ant colony optimization (ACO) optimization technique has been used to classify the data using the large data sets. Scholars use the statistical methods to sense the data. But these methods have to follow the rule ordered to classify the image which is a difficult problem [3]. In a survey, ACO optimization technique has been discussed to evaluate the results regarding the image classification. But the main problem is the changing nature of the scout bees as when the threshold occur then scout bees become onlooker bees and does not perform their task. This reduces the performance of the work [4]. The classification problem becomes a prime concern nowadays due to various factors. A more robust technique focussed in literature where resolution of an image has been considered.

The remote sensing images taken as input to test the hypothesis of the proposed approach. The Markovian model considered to classify the images. The results has been concluded using the probability density function of the proposed technique [5]. But, still accuracy obtained from the developed approach lacks due to large error rate.

So, hybridization of classification and optimization approach was proposed in the past studies to improve the accuracy and error rate. The results improved the accuracy and terrain features successfully detected from the images [6]. The improved results enforced the researchers to use the machine learning techniques to attain the required results. So, machine learning algorithms were used to enhance the results [7]. In addition, Support Vector machine (SVM) and K-means clustering approach successfully classify the images. SVM is a classifier technique which worked on supervised and unsupervised learning. The training technique train the data which enhances the result but it depends upon the applicability of the data [8]. Therefore, researchers use the SLIC super pixels to ameliorate the detection rate. The fast segmentation technique proposed in the past to test the high resolution images. The proposed technique applied on the images of multispectral nature with high resolution. The segmentation results successfully classify the data in a prescribed range [9]. Wang et. al. proposed a novel method based on convolutional neural network approach to sense the remote images. The craters impact detected through the CraterIDnet to identify the remote images of any size and colour [10]. The recognition of such high resolution images limits the quality and thus introduces the interclass variance to make use of various features. The prediction of mappings from class activating use mask filters to predict the objects from the image. The challenging data set has been used to evaluate the results [11]. But, extraction of terrain features still a challenging task. So, various techniques have been analyzed in a recent survey on satellite remote sensing images. The various techniques discussed and applied on the remote images to check the effectiveness of different approaches. The validity of the classifier and optimization approaches has been evaluated to attain the required outcomes [12].But the main drawback is that all the images to sense the required features was not covered. So, the present survey does not seems to be fruitful for the other researchers.

In [13] a new size reduction approach named as locality adaptive Discriminant analysis (LADA) has been presented for HIS classification. The technique helps to find the close relationship between the spectral as well as spatial data points in the HIS image. In [14], have used multi-level threshold based scheme to distinguish between things and backgrounds. The approach is able to segregate the grey level images into multiple homogeneous regions. Also, to enhance the robustness and minimize the computation time Differential Evolution (DE) in combination with Support Vector Machine (SVM) has been employed.

1.1 Problem Formulation

Classification of remote sensing images is a difficult task for the scholars. Therefore, various techniques proposed in literature to better classify the images. In addition, researchers attempted to propose the robust technique to attain the better accuracy by reducing the error rate. But, many conventional techniques was developed using SVM, which is a binary classifier andprocess the task with large computation time which reduces the performance of the system. So, it is not possible to attain the required accuracy within such a large time gap. In addition, error occurrence increases with more detailed features which ultimately reduces the accuracy. Consequently, there is very less work proposed in the previous studies to classify the terrain features. Moreover, some papers miss the optimization approach which reduces the efficacy to classify the image. However, researchers use the optimization approach such as Artificial Bee Colony still inefficient in identifying the classes [1]. This is because of the nature of the scout bees as when maximum iteration has been reached then scout bees does not perform their operation. So, this problem has been avoided by hybridization of classification and optimization approach.

III. CLASSIFICATION AND OPTIMIZATION TECHNIQUES

The classification and optimization techniques has been discussed in this section to classify the terrain features. The neural network and PSO technique used to classify and optimize the results.

1.2 Neural Network

Neural Network is the latest metaheuristic classification approach inspired from the neuroscience. The processing of information and its computation involves pattern recognition and controlling processes.

Fig. 1 show the network of neural layer for processing information.The NN is based on three layers named as input layer, hidden layer and output layer. NN are successful in doing a variety of functions. The intelligent capability of the network helps to learn various functions intelligently through a training process. The human brain structure provides solutions to solve complex problems. The brain structure consists of group of nodes connected through various layers. Each node in the brain communicate through different layers. The communication process use in this paper is to classify the image. A novel NN algorithm has been implemented in this paper to detect the terrain features in remote sensing images.

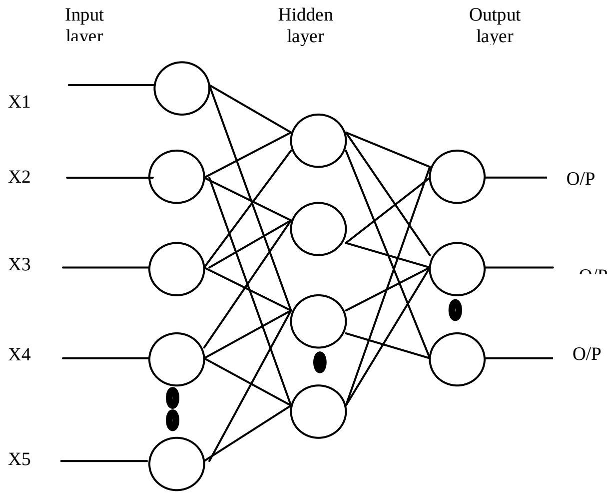

Figure.1 Neural Network

1.3 Particle Swarm Optimization (PSO)

PSO is a meta-heuristic approach that finds the optimal solution for complex problems, the flying bird's flies on a particular velocity, which is adjustable according to the bird's efficiency.

The search space corresponds to the entire universe, in which historical performance of the birds and its neighbours noticed. The intelligent behaviour of the birds captured in this paper has been related to find the optimal solution to optimize the classified terrain features in the image.

In PSO, each bird flying in the flock referred as a particle. The social behaviour of the birds in the population to evolve and reach on their destination. The flying birds communicate with each other for the identification of best location. Similarly, each bird flying at a particular velocity based on current location or we can say, current position. Then, search space has been investigated by the birds based o newly located position of the birds. This process repeats until the birds in the flock attained the desired destination.

The developed algorithm works in a similar manner and it is based on the iterations to acquire the best solutions. Random particles, N has been initialized in the process to attain viable solutions. The nth particle is represented by the position of the birds in the S-dimensional space, where S represents number of variables. The process basically monitors three values such as current position (Y_n), position attained in the previous cycle (P_n) and flying velocity (F_n)). These values represented as follows:

$$\textit{Current position of the bird}: Yn = (Yn1, Yn2, \dots\dots\ Yns) \qquad (1$$

$$\textit{Previous position of the bird}: Pn = (Pn1, Pn2, \dots\dots\dots..Pns) \qquad (2)$$

$$\textit{Flying velocity}: Fn = (\ Fn1, Fn2, \dots\dots\ Fns) \qquad (3)$$

For each iteration the best particle position is calculated based on the particle's best fitness value. In the same manner, particle position updated based on the flying velocityFn of the particle to catch the best position, given as follows:

$$Fj(t+1) = \omega F_{n(t)} + b_1 m_1 \left(Y_{n(t)} - P_{n(t)}\right) + b_2 m_2 (Y_h - Pnt \qquad (4)$$

The updated position of the particle based on the new velocity (F_n) of the particle to catch best position (h), it becomes:

$$F(t+1) = \omega F_{n(t)} + b_1 m_1 \left(Y_{n(t)} - P_{n(t)}\right) + \ b_2 m_2 (Y_h - Pnt \qquad (5)$$

Hence, particle new velocity of the updated position becomes:

$$Y_{n(t+1)} = Yn(t) + F_{n(t+1)}; F_{max} \geq F_n \geq -F_{max} \quad (6)$$

Where, b_1 and b_2 are the learning factors, it usually become ($b_1 = b_2 = 2$); $m_1$and m_2 are random functions in the range of [0 to 1]. F_{max} depicts the upper limit for the maximum change in velocity and inertia weight represented by u, an improvement on the current velocity based on past histories. However, u plays an important role in balancing the global and local search and it decreases with time from 1.3 to 0.6. The large weight attach to the global search while local search favoured with low value.

IV. RESEARCH METHODOLOGY

1.4 Hybridization of Neural Network (NN) and Particle Swarm Optimization (PSO)

NN is a classification approach and PSO is a metaheuristic optimization technique which works on the social behaviour of the birds. The learning, guiding, and adaption behaviour of the species adopted in this paper to calculate the fitness value of the function.

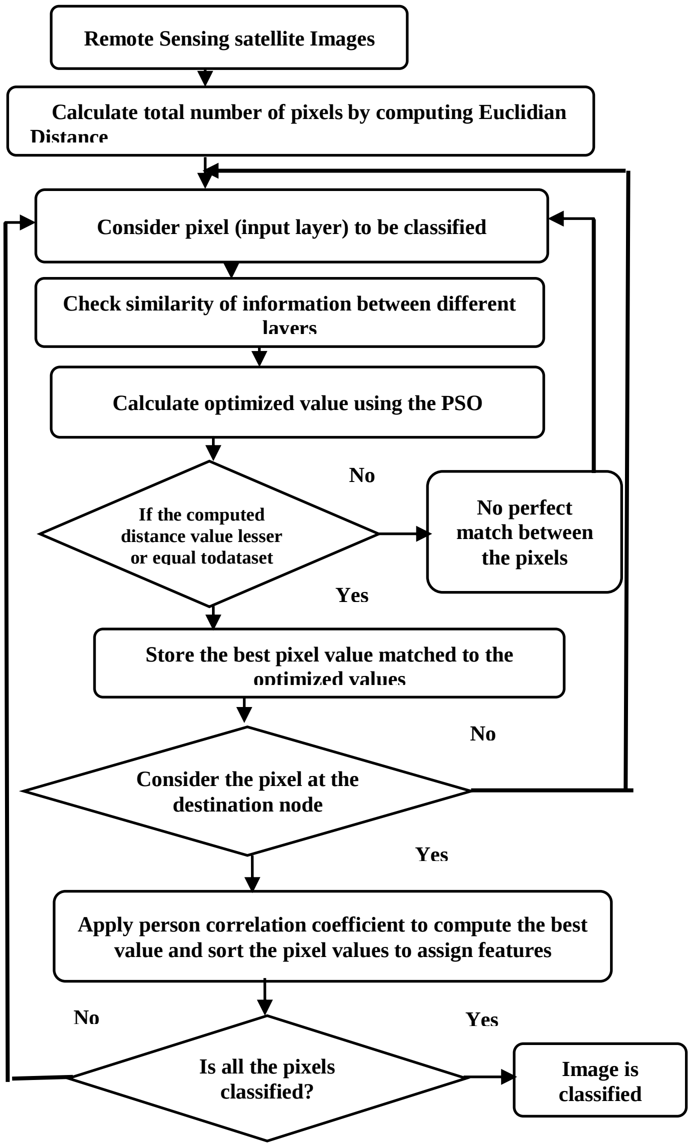

Figure2: Flowchart of the proposed technique

In Neural Network (NN), basic functioning of the brain to response an output is considered. In other words, mechanism of brain based on three layers. The nodes in a neural network having values of 0.0 to 1.0, where 0 represents inactive nodes and 1 represents active nodes. The signal values transfer from input nodes to output nodes through middle layer.

In PSO, birds fly in a free space to search for the food at the best position with an initial speed vector. The best position or we can say experience can be stored in the memory, as each particle unified with memory.

The distance between the particles is maintained and this process continues until best position attained by the particles. The behaviour of birds has been copied in this article, which is related with the particles to optimize the problems.Fig. 2 depicts the flowchart of the proposed technique.

The input taken as the remote sensing satellite images and obtained output is classified image. The dataset has been considered to validate the results. The classification steps of proposed technique are explained below:

Step 1: The images are classified in training data set, terrain features, and satellite images, training dataset of pixels taken as input. The data set pixels taken as input layer and features classifies as output layer.

Step 2: Multispectral image has been considered and total pixels calculated by depicting the distance between nodes and output.

Step 3: Once, distance is obtained the search strategy of PSO used to find the similar nodes.

Step 4: The best solution attained by calculating the Pearson correlation coefficient between the Neural Network neurons and nodes.

Step 5: The nodes transmit information having maximum value of correlation is the best node for the Neural Network.

Step 6: Compute the class based on the best solution given by the nodes.

The main aim of hybridization of NN and PSO is the best solution attained by the neurons mechanism is replaced by the PSO bird best position. When the neural network provides the best solution then PSO technique used for search process. So, neural network provides the best solution at the best position in the search space. In this way, best method created using the hybridization of both techniques. So, efficient and effective solution attained to solve the complex problems.

Dataset: The proposed technique applied on the terrain images for classification. To attain this, we consider here multi-sensor, multi-spectral and multi-resolution images of PAVIA dataset which is a free dataset with the following download link http://www.ehu.eus/ccwintco/index.php/Hyperspectral_Remote_Sensing_Scenes . It is a hyper-structural image set out of which the data is being extracted by completing a loop for each image in the hyper structural image set. . In the proposed section, we have used satellite image having multispectral gathered by AVIRIS sensor over the Indian Pines test site in North-western Indiana. The proposed technique applied to this region as scene contain 2/3rd agriculture, and 1/3rd forest or other natural perennial vegetation. This scene contains two major dual lane highways, a rail line, as well as some low density housing, other built structures and smaller roads.

Table1. Dataset Explanation

Dataset	PAVIA
Dimensions	Indian Pines
Total Number of classes	03

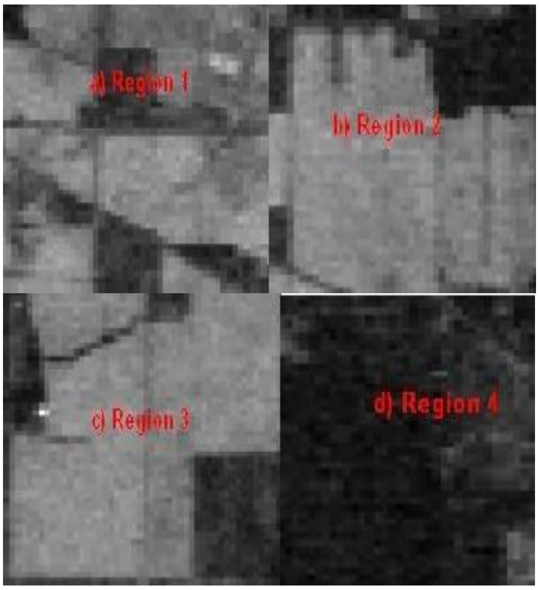

Figure3. Data set of PAVIA

Algorithm 1: ANN Algorithm

$\boldsymbol{Input}$: $\boldsymbol{Multispectral\ images\ as\ a\ Training\ Data\ set\ (T), Target\ (G)\ and\ Neurons\ (N)}$

$\boldsymbol{Output}$: $\boldsymbol{Classified\ Images}$

$\boldsymbol{Initialize\ ANN\ with\ parameters}$ $\boldsymbol{-\ Epochs\ (E)}$

$\boldsymbol{-\ Neurons\ (N)}$

$\boldsymbol{-\ Performance\ parameters: MSE, Gradient, Mutation\ and\ Validation\ Point\ /\ Classified\ Parameter}$

$\boldsymbol{-\ Training\ Techniques: Levenberg\ Marquardt\ (Trainlm)}$

$\boldsymbol{-\ Data\ Division: Random}$

$\boldsymbol{For\ each\ set\ of\ T}$

$\boldsymbol{Group\ =\ Categories\ of\ Training\ data}$

$\boldsymbol{End}$

$\boldsymbol{Initialized\ the\ ANN\ using\ Training\ data\ and\ Group}$

$\boldsymbol{Net\ =\ Newff\ (T, G, N)}$

$\boldsymbol{Set\ the\ training\ parameters\ according\ to\ the\ requirements\ and\ train\ the\ system}$

$\boldsymbol{Net\ =\ Train\ (Net, Training\ data\ , Group)}$

$\boldsymbol{Classify\ =\ simulate\ (Net, Single\ node\ properties)}$

$\boldsymbol{If\ Classify\ =\ True}$

$\boldsymbol{Best\ Node\ =\ Simulated\ Node}$

$\boldsymbol{Else}$

$\boldsymbol{Distorted\ Node\ =\ Simulated\ Node}$

Consider training data set pixels as input and feature classes considered at the output layer.

- Step 1: Compute the distance

Consider the satellite images and compute the total pixels by calculating distance between nodes input and output layer.

$$Distance(m, o) = d(m, o) = \sqrt{(m_1 - o_1)^2 + ((m_2 - o_2)^2 + \cdots . +(m_u - o_u)^2} = \sqrt{\sum_{i=1}^{u}(m_i - o_i)^2} \quad (7)$$

d depicts the distance between m and o; m_i indicates the i[th] pixel value of the input layer and o_i indicates the i[th] pixel value of the output layer of Neural Network.

- Step 2: Similar information computation

The similar information detected through the PSO. The similarity criteria determined by finding the best similarity mean between the intensities of the pixel as calculated aforementioned.

1.5 Particle Swarm Optimization

PSO has been initialized through a random particles and then optimal solution searched by updating the best particle location. Each particle goes through the search space, the position adjusted based on the best position of the swarm and its own position. The performance of different particles can be measured through fitness function depends upon the optimization problem. The mean of similarly difference can be measured through pixel intensities, such as:

$$F(y) = mean(\sqrt{(y-x)^2} \quad (8)$$

Each particle goes through the search space and following information maintained by the particle.

$y_n = Current\ particle\ position$

$B_n = Best\ particle\ position$

$F_n = Velocity\ of\ current\ particle$

The linear sum of velocities of position of particles updates the velocity and position. Thus new velocity is given as follows:-

$$F_n(t+1) = \omega F_{n(t)} + b_1 m_1 \left(Y_{n(t)} - P_{n(t)}\right) + b_2 m_2 \left(Y_h - P_{n(t)}\right) \quad (9)$$

As per given equation using the new velocity F_n, the updated position becomes,

$$Y_{n(t+1)} = Y_{n(t)} + F_{n(t+1)} \quad (10)$$

In Eqn. 9, ω depicts the inertia weight, $b_1 b_2$ are the acceleration constant, $m_1 m_2$ are random numbers lies in the range of 0 to 1. F_n specified in the predefined range {V_{max}, V_{min}].The optimized value of the mean has been considered, minimum distance attained similar to the different layers.The information less than mean value has been considered, and the worst information has been discarded.The similar information has been stored.

- Step 3: Computation of best Information

Compute the best information from the layers travelling through different nodes. The best information attained by computing PCC between layers and similar information calculated. The PCC calculated as given below:

$$r = \frac{\sum_{n=1}^{a}(X_n - \bar{X})(Y_n - \bar{Y})}{\sum_{n=1}^{a}(X_n - \bar{X})^2 \sqrt{\sum_{n=1}^{a}(Y_n - \bar{Y})^2}} \quad (11)$$

- Step 4: Correlation

The nodes having correlation value is maximum is the best attained information for the Neural Network.

- Step 5: Pixel classification

Compute the class in which best information based on the expert data. The attained pixel value belongs to the same class in which best solution attained. Hence terrain feature based pixel is classified.

V. RESULTS AND DISCUSSION

This section discusses the results of the proposed technique on PAVAIA dataset for 16classes divided into 4 regions.

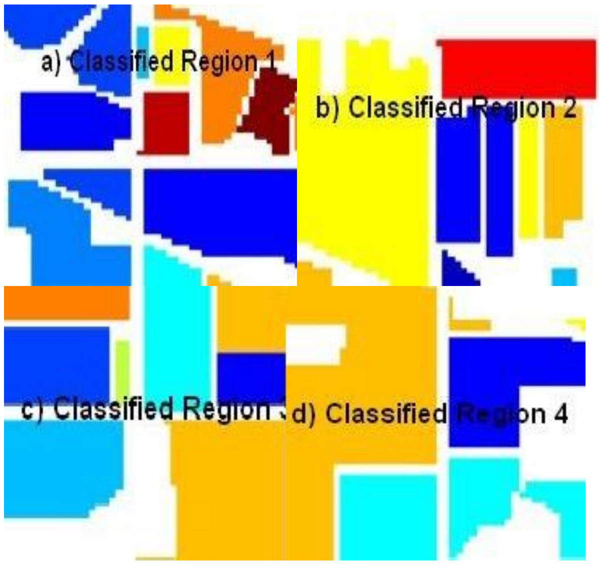

Figure 4.Classified Regions

Accuracy:

The efficiency of the proposed work is determined by measuring the accuracy in the classification process of the image. The main aim is how pixels correctly classified in the given region to feature the classes. The testing of pixels practically not possible. So, reference pixels have been considered for experimentation. The actual features detected from the classified images. The results has been validated by considering the following pixel values in Table 2.

Table 2. Pixel Values

S.No.	Associated Class Label	Available Data Count
1	Alfalfa	46
2	Corn-notill	1428
3	Corn-mintill	830

- Kappa Coefficient

It is a discrete technique used to interpret the error matrix results. The statistics of Kappa defines the diagonal observation of the values of rows and columns. This gives a more robust accuracy than the overall accuracymeasurement. Following kappa coefficient applied to the error matrix.

$$K = \frac{N\sum_{n=1}^{r} x_{nn} - \sum_{n=1}^{r}(X_{n+} \cdots X_{+n})}{N^2 - \sum_{n=1}^{r}(X_{n+} \cdots X_{+n})} \quad (12)$$

- Producer's Accuracy (P_A)

The land classification correctly determined in columns in this function. Simply, determines the analyst classify the data correctly through the columns. This is calculated as:

$$P_A = \frac{N\,(major\ diagonal)}{M(total\ columns)} \quad (13)$$

N= Classified pixels in rows and columns

M= Training set pixels used for each category

- User's Accuracy (U_A)

The land classification correctly determined in rows in this function.

Simply, determines the analyst classify the data correctly through the rows. This is calculated as:

$$U_A = \frac{N(major\ diagonal)}{M(total\ rows)} \qquad (14)$$

- Overall Accuracy (O_A)

It is the ratio of total number of correct observations divided by total number of classifications. This is calculated as:

$$O_A = \frac{Sum\ of\ diagonal\ values}{Total\ count\ of\ classifications} \qquad (15)$$

Table 3.Accuracy Computation

Accuracy	Alfalfa	Corn-nontill	Corn-mintill
Producer's	94	93	96
User's	94.3	94.1	95.123
Overall	94.15	93.5	95.22

The proposed technique applied to attain the required accuracy as depicted in Table 3. The accuracy of the Alfalfa, Corn-nontill, and Corn-mintill has been computed. It is clearly seen that classified features for Alfalfa is 94 % and 94.3 % for the producers, and user respectively. The overall accuracy of the classified images is 94.15% for Alfalfa, 93.5 % for Corn-nontill, and 95.22% for Corn- mintill features.

Table 4.Comparison of Proposed and Existing work [13][14]

Parameters	Proposed	Existing [13]	Existing[14]
Kappa Coefficient	0.921	0.861	0.774
Accuracy	94.36	89.66	82.1

\The obtained results further compared with the existing techniques [13] [14], to validate the proposed approach. The overall attained accuracy of the proposed technique is 94.36%, while that of existing research it is 89.66% and 82.1% as given in Table 4. This proves that obtained value better than the existing technique. Thus, overall accuracy improved by 5.24% and 14.93% in contrary to past technique presented in [13] and [14] respectively. Thus, kappa coefficient of the proposed approach has been improved by 1%.

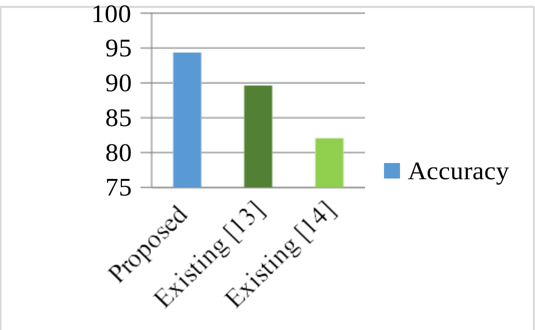

Figure 5.Comparison of Accuracy of proposed and existing work

Fig. 5 represents the comparison of the proposed work with the existing approach [13][14], in computing the accuracy. The given graph shows that proposed results outperformed in contrary to existing approach. The overall accuracy has been improved by 5.24% and 14.93% in contrary to existing work[13][14].

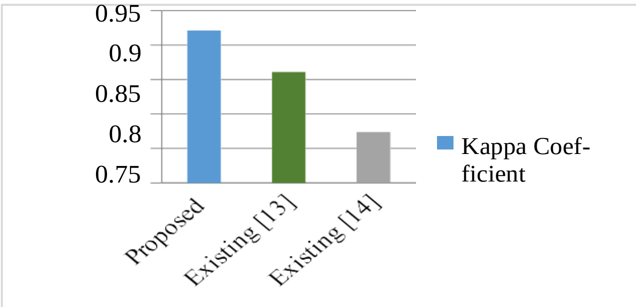

Figure 6.Comparison of Kappa Coefficient of proposed and existing work

Fig.6 depicts the comparison of Kappa Coefficient. The comparison has been shown to depict the effectiveness of the work being proposed. 6.97% and 18.99% enhancement has been seen in Kappa Coefficient in the proposed work while comparison has been drawn with the existing work [13] [14] respectively.

VI. CONCLUSION

In this research, an attempt has been made to propose the hybrid technique of neural network and particle swarm optimization to classify the image based on terrain features. The proposed technique applied provides amazing results such as high accuracy as compared to other techniques. The classification approach of neural network find the best and optimal solution to detect the features form the images. The optimal results further optimized using the optimization technique. The PSO technique attains the best location which encompasses that best solution attained with higher accuracy. Overwhelmingly, the kappa coefficient and accuracy has been used to evaluate the proposed technique. The results have been contrasted with the existing approach and proposed work has proven outperformed results. The improvement in accuracy and Kappa coefficient has been noticed such that 5.24% and 14.93% enhancement in accuracy and 6.97% and 18.99% amelioration in Kappa Coefficient against [13]and [14] respectively.

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AUTHORS PROFILE

Sakshi Dhingra is an Assistant Professor in Department of Computer Science and Engineering in Guru Jambheshwar University of Science and Technology, Hissar, Haryana, India. She graduated from Punjab Technical University Jalandhar in 2010 and received Master's Degree (Gold Medallist) in Computer Science and Engineering from Guru Jambheshwar University of Science and Technology in 2012. She has presented many papers in International Journals/Conferences. She has supervised many students at M.Tech and MCA level. Her areas of interest are Image Processing, Soft Computing, Remote Sensing.

Prof. Dharminder Kumar is currently working as Professor in Computer Science and Engineering Department of Guru Jambheshwar University of Science and Technology, Hissar, Haryana, India. He is coordinator of Technical Education Quality Improvement Programme (TEQIP) of World Bank. He also worked as Dean of Faculty of Engineering and Technology, Head of Department (HOD) of Computer Science and Engineering and founder Dean of Colleges. He has supervised many students at PhD and M.Tech. Level. His area of interest includes Data Mining and Computer and communication Networks.