Indian Journal of Science and Technology, Vol 9(45), DOI: 10.17485/ijst/2016/v9i45/105304, December 2016
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

A Survey of Various Algorithms Used on Multispectral Satellite Image Classification of Alwar Image Dataset

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Abstract

Objectives: The aim of the survey was to study and compare the efficacy of using bio inspired algorithms for the purpose of classification of a satellite dataset. The final objectives involved identification of a suitable technique to most effectively classify a satellite image using various strategies. **Methods/Statistical Analysis**: Bio Inspired Algorithms (BIA) are increasingly being used in classification tasks as they are extremely efficient and can generate solutions for complex associations from simple initial settings. The paper presents a survey and review of the use of the BIAs in the domain of satellite image classification to segregate similar pixels with common values for different bands of data and classifying them into various classes. This study concentrates on a multispectral satellite data of size 472 X 576 (257712 pixels) of the Alwar region, Rajasthan having 7 bands of attribute information. The data is classified into classes of major land-use types. **Findings:** The study has taken into account various strategies used by different researchers to produce the best classification accuracies for classifying a satellite image dataset. This includes the process of feature selection and feature reduction wherein a combination of classifiers are used as ensemblers or in a hybrid model to achieve better classification. The different classification approaches like per pixel, sub pixel, object based and knowledge based classification has been studied and categorized based on their usage. The parameters used to determine the efficacy comparisons for these classifications are namely kappa coefficient, producers, users and overall accuracy. The various classification strategies have been compared based on their kappa coefficient performance. Cuckoo search algorithm and artificial bee colony, two of the recent bio inspired algorithms has shown an impressive classification accuracy and comparable performances are given by the variants of ant colony optimization algorithm in different hybrid models with PSO and BBO. The performances of per pixel and object based classification methodology are similar and the higher accuracies are determined by the use of better classification algorithm. **Application/Improvements:** In addition certain application usage of the bio inspired classification algorithm in the domain of remote sensing has also been studied. To substantiate the efficient performances of these bio inspired algorithms in the satellite image classification; the effect of these on different sets of satellite images has also been studied and found to be good.

Keywords: Ant Colony Optimization (ACO), Biogeography Based Optimization (BBO), Bio Inspired Algorithms, Classification Accuracy, Particle Swarm Optimization (PSO), Satellite Image Classification

1. Introduction

The ability to analyze and infer information from remote sensing satellite data has emerged as a very important task as it provides the facility to monitor the earth's surface and its changes remotely using the data transmitted by the satellite[1]. Initially, this task was being carried out manually and there has been considerable effort being undertaken to automate this functionality. Thus the computerized methodology of land-cover classifications was undertaken by many and then the efforts to improve the accuracies of classification has emerged as a primary research topic

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in the field of remote sensing[2]. There are multiple uses of remote sensing image classification which includes multi disciplinary applications, like cartography, land use planning, land parcel management, change detection, disaster management and image interpretation.

1.1 Satellite Image Classification

Is the task of classifying various information classes in a satellite image dataset based on categorization of pixels of a satellite image dataset into one of several land classes. Classification techniques can be divided into two types: supervised and unsupervised. In supervised classification[3], the training dataset is formed from the spectral features of some known areas from a satellite dataset. The test data set is then classified into the different classes on the basis of their closeness to the spectral features of the training dataset. In unsupervised classification, the groups of pixels are automatically clustered into separate clusters from the image based on the spectral features and then each cluster is identified as a separate land cover type by the analyst.

Classifying remotely sensed data is a challenging task because of various issues like the complex landscape, types of satellite data, and the classification methodology being used. All these factors will have an effect on the results of satellite image classification. Image classification task will also depend on the various tasks in the process such as training data, data preparation, feature selection, classifier used, post processing tasks, and accuracy assessment. Large amount of work is being done in the area of developing advanced classification approaches and techniques for accomplishing this task.

Bio Inspired Algorithms (BIA)[4] is increasingly being used in classification tasks in different domains. They are extremely efficient and can generate solutions for complex associations from simple initial settings. Rules are generated from the search space based on the context or knowledge of the search space. Researchers have been trying to mimic nature in many areas of research. Bio inspired computing has emerged as a novel technique in wide range of applications, like network analysis, cyber security, bio technology research, control systems, data mining, robotic systems, industrial engineering and many others. This paper presents a survey of the use of the bio inspired algorithms in the domain of satellite image classification with special emphasis on a particular satellite image dataset of ALWAR region so as to compare the algorithms on a common dataset. We also discuss the use various BIAs on some other datasets to illustrate their efficacy in the task of satellite image classification and also to propagate further research in this direction.

The foci of this paper are about providing a summary of the use of few bio inspired classification methods and techniques on a satellite image classification task and to study the reasons affecting the success or failure of use of a particular method of image classification. The organization of the paper is as follows: Section 2 provides a brief overview of various issues involved in satellite image classification. The detailed description of a satellite image dataset of ALWAR region is in Section 3. Section 4 provides an overview of various bio inspired algorithms used in the domain of satellite image classification. Section 5 gives the implementation strategies and performance of various bio inspired algorithms on the common dataset i.e ALWAR image dataset and gives a comparison between them. Section 6 gives out the use of various bio inspired algorithms for the task of image classification on other satellite imagery data sets. The conclusion is drawn in Section 7.

2. Issues in Satellite Image Classification

2.1 Dataset

The satellite image datasets that are generally used for satellite image classification are of two types: *Multispectral and hyper spectral*. Remote sensing data are available as multispectral and hyperspectral data in which each pixel has values corresponding to different bands of the electromagnetic spectrum.

- Multispectral[5] remote sensing technologies has data from up to eight bands of spectral sensors ranging from the visible and near-infrared region of the electromagnetic spectrum.
- Hyperspectral sensors have several bands of spectral data from sensors ranging from the visible, near-infrared, mid-infrared, and short-wave infrared portions of the electromagnetic spectrum. The number of bands typically range up to 200 or more, having a almost continuous spectral signature.

Classification techniques are used to segregate similar pixels having similar values into classes. The scale of data will determine the level (local, regional or global scale) at which classification is performed and will also determine the final land cover / land use data that is to be identified. Another important factor that will influence the satellite image classification results are the atmospheric conditions such as fog, clouds, ambient light conditions and shadows etc prevailing during the capture of the satellite data. Different kinds of radar data, vegetation indices, DEM data can be used as additional attributes to improve the classification accuracy.

Major issues in dealing with remote sensing data are related to the large dimensionality of the hyperspectral data, data with inherent error conditions like cloudy conditions, fog, shadows and also the availability and quality of the accurate training data. Training data are generated by experts using the satellite image with high spatial resolution and ground as well as aerial survey. Generation of training data is a time consuming and complex task especially in heterogeneous locales or remote, inaccessible areas where data collection would be logistically difficult and expensive. There is also the problem of creating sufficient training data. The training data selected may not always represent the true probabilistic distribution of the test data set to include the class features. There are also problems of mixed pixels (when a pixel contains two or more type of land cover class, e.g. forest and road) in a coarse scale satellite data. Very few data with suitable dataset is available free online for the purpose of study and research like the LANDSAT imagery data and the UCI imagery data set.

2.2 Feature Selection and Feature Reduction

Selecting suitable attributes are an significant step in increasing the efficiency and performance of a satellite image classification system. Different attributes that can be used in an image classifier includes different spectral signatures, vegetation indices, contextual information, multitemporal images, Multisensor data and ancillary data. Hence correct selection of these additional information or attributes so as to design an efficient classifier system is an important step in satellite image classification. Another diametrically opposite issue in case of hyperspectral satellite image data is the existence of a large number of attributes in the data affecting the performance of the classifier and the computational requirements of the system resulting in slower performance. Thus it is imperative to select only the requisite features for identifying the requisite land-cover classes. Many approaches have been suggested in different research works to reduce the data redundancy or to select features for specific land cover classes.

2.3 Accuracy Assessment

Accuracy assessment is an essential process and different methods have been used by many researchers ranging from qualitative analysis or quantitative analysis. The aim is to determine how effectively pixels have been grouped as per their respective class. Classification error will be determined by the difference between classified image result and the reference data which is as per actual. We present few of the error matrices for assessing the accuracy of the classification:

Kappa Coefficient. The Kappa Coefficient is a discrete multivariate technique to interpret the results of a contingency matrix.

$$\widehat{k} = \frac{N\sum_{i=1}^{r} x_{ii} - \sum_{i=1}^{r}(x_{+}.x_{+i})}{N^{2} - \sum_{i=1}^{r}(x_{+}.x_{+i})}$$

Where,

r = rows of the matrix

x_{ii} = records in row i and column i (major diagonal)

x_{i+} = records in row i (shown to the right of the matrix)

x_{+i} = records in column i (shown at the bottom of the matrix)

N = total records in matrix.

Producer's Accuracy. Producer's Accuracy is a measure of how much of the land in each category was classified correctly.

p = (Number of pixels classified correctly in each feature (on major diagonal))/(Total Number of training set pixels available for that feature

User's Accuracy. User's Accuracy is a measure of how well the classification performed in the field by category (rows).

p = (Number of pixels classified correctly in each feature (on major diagonal))/(Total Number of pixels available for that feature (on row total

Overall Accuracy. Overall Accuracy is the number of correct observations divided by the total number of features classified.

ıssifications (sum of all values on major diagc
l Number of classifications

Classification Approaches. There have been different approaches to satellite image classification such as the following :

- Per-pixel based approach,
- Sub pixel classification (for the issue of mixed pixels)
- Object based classification [6].
- Knowledge based approach.

Per-pixel classification is most commonly used in practice in which only the spectral signature values of each pixel are considered and the other spatial and texture information of pixels are not used. Each pixel is separately classified into a certain class; however the results of this type of classification may not be very accurate due to the result of high spatial frequency existing in the landscape under study. The accuracy is negatively influenced by the presence of mixed pixels in the satellite image dataset.

Subpixel classification approaches cater to the problems of mixed pixel in a satellite image dataset however they are tedious and computationally intensive.

Object based classification approaches deal with classifying the satellite dataset based on an entity which is a meaningful image-object, i.e. a homogeneous area in which every pixel has similar property [7]. The object based classification consists of two steps namely[8]: image segmentation and image classification. Image clustering or segmentation clusters similar pixels into certain objects and then these objects are used to perform the task of classification. The size of an specific object generally affects the results of classification[9,10]. However, object based classifications have issues with regard to the spectral and spatial properties of the image data, the size and shape of the objects, the definition of object boundaries, and the landcover classes chosen[11].

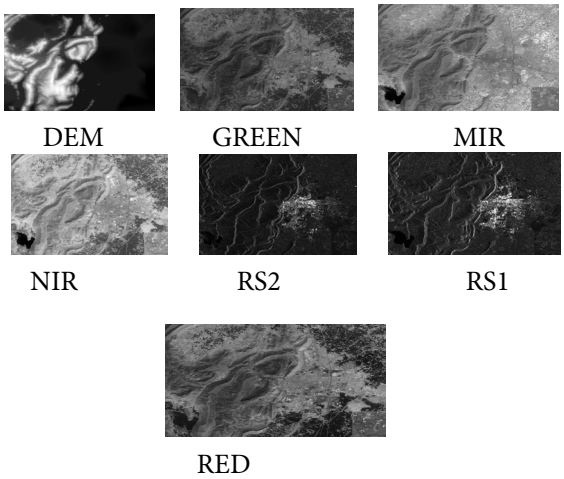

Figure 1. Satellite image dataset in various bands.

Knowledge-based classification methods are employed in case of multisource data having a mixture of spectral features, texture, contextual information and ancillary data. Ancillary data, such as DEM, soil information, infrastructure and population density, connectivity network, water logging and precipitation are used as attributes for the process of classification. For example, elevation, slope, and aspect ratio are used for mountainous regions.

Selection of a suitable classifier requires consideration of many factors, such as classification accuracy, algorithm performance, spatial resolution of the remotely sensed data, use of ancillary data, the available software, analyst's experience and computational resources[12].

3. Dataset For Image Classification (Alwar Satellite Image Dataset)

Remote sensing data is available as multispectral and hyperspectral data wherein each pixel of the satellite image dataset corresponds to values of different bands of electromagnetic spectrum. Multispectral satellite data of size 472 X 576 (257712 pixels) of the Alwar region Rajasthan was sourced from Digital Terrain Research Lab (DTRL), a DRDO lab [13]. This data has been cited and used by many researchers for the purpose of image classification. This is an Indian Remote Sensing satellite's (IRS-P6) optical band image dataset with data for Green (G), Red (R), Near-Infrared (N), Middle-Infrared (M), radarsat-1(RS1), radarsat-2(RS2) and digital elevation model (DEM) as attributes. Major land-use types classes used for classification are vegetation, urban, water, rocky and barren. The training dataset is a small part of the dataset and the composition of the training data set is shown as per **Table 1.** and displayed in various bands in the **Figure 1**.

Table 1. Composition of Training Set

Land cover Type	No of Pixels
Barren	191
Rocky	288
Urban	417
Vegetation	329
Waterbody	206
Total	**1431**

3.1 Bio Inspired Algorithms for Image Classification

The source of bio-inspired computing is the behavior of social insects: a population of simple agents interacting and communicating indirectly through their environment for solving a given task, such as the foraging, the task division and prey capture. In the succeeding paragraphs, we have described some of the bio inspired algorithms employed for the task of satellite image classification.

3.2 Particle Swarm Optimisation (PSO)

PSO[14] is a stochastic, population based global optimization technique proposed by[14] that is based on the behavior of birds swarms searching for food. It has been used in for many optimization problems because of its successful search strategy, simplicity in implementation, high efficiency and good results. Each bird of the population identifies with a particular solution in the high-dimensional space with multiple vectors which are position, the best global position and velocity vector. The bird adjusts their individual positions in the search space based on the best personal position (pbest) and on the best global (gbest) during the search process. In each iteration, the position and velocity of the birds are updated as follows:

$$X_{k+1}^{i} = X_{k}^{i} + V_{k+1}^{i}$$

$$V_{k+1}^{i} = V_{k}^{i} + c_1 r_1 (p_k^i - X_k^i) + c_2 r_2 (p_k^g - X_k^i)$$

where

x^i_k represents the position of the particle.
v^i_k represents the velocity of the particle.
p^i_k represents the Best remembered position.
c_1, c_2 represents other parameters,
r_1, r_2 are random numbers between 0 and 1

In PSO, the global best is always used to improve the individual position to maintain the diversity of the swarm. PSO can effectively deal with continuous functions and also displays considerable stability and convergence in a multidimensional complex space. PSO has been used in a hybridized version with the ACO to deal with dataset having nominal attributes as well as continuous attributes and this approach has been used in the task of satellite image classification[15]. In this the authors have used the PSO/ACO2 algorithm to generate rules from the training set and used these rules set to classify the test dataset. The authors further hybridized this with the BBO algorithm to classify a specific cluster using BBO and the rest of the clusters using the hybrid PSO/ACO2. This new hybrid algorithm was able to increase the classification accuracy of satellite image classification. PSO has also been used in conjunction with MLPNN[16] for satellite image classification wherein PSO is used for training and adjusting the weights of the neural network and the MLPNN does the classification of the satellite image. PSO-Miner, a PSO based rule induction algorithm has been used for the task of classifying a Landsat TM satellite image and the results were compared with classification results obtained using a Decision Tree algorithm. The results of PSO-Miner showed a considerable increase as compared to the other classification algorithm.

3.3 Ant Colony Optimisation (ACO)

ACO is based on the movement of ants in search of food and this behavior is the inspiration behind the implementation of this algorithm. A phenomenon known as stigmergy which is the indirect communication between self-organizing systems based on individuals modifying their local environment to suit the changed circumstances. Ants have a rare methodology to find the shortest paths between their nest and the food source incorporating their collaborative behavior of following the pheromones on ground. The stronger the pheromone on a path, higher is its probability of being selected. Ants deposit pheromones on the path they take during their movement to the food source, leading to paths with high pheromone concentration. ACO has been used for solving complex, combinatorial optimization problems. The ACO Meta heuristic is structured into three main functions of construction of different solutions, pheromone updation in each iteration to include pheromone evaporation and applying additional pheromone reinforcement to the best generated solution.

Ant-Miner (based on ACO) has been used for the task of satellite image classification wherein Ant-Miner generates rules set for classifying a Quick bird multispectral satellite image using a sample training dataset from the satellite image under consideration. C Ant-Miner, an extension of Ant-Miner has the capability to deal with continuous as well as nominal attributes and was used in the task of satellite image classification of Alwar image dataset. Classification rules were set in the form of IF < Term1 AND Term2 AND …> THEN <Class> is generated using the Myra tool on the training dataset and the

extracted rules set were applied on the test dataset to classify the pixels into respective land cover classes (water, vegetation, barren, rocky and urban). Combination of Ant-Miner/BBO algorithms has also been used for classifying the satellite image dataset. The authors initially clustered the dataset using the Rosetta tool (based on Rough set theory). Clusters so generated are then classified using Ant-Miner and BBO depending on the efficacy of the algorithm for the specific type of clusters (having a particular class). ACO has also been used for clustering the dataset and then the clusters have been classified using BBO algorithm. The authors have created clusters of the dataset using the SOM algorithm and then classified the clusters using an ACO algorithm. ACO has also been used in combination with PSO for classification of the satellite image dataset.

3.4 Artificial Bee Colony Algorithm (ABC)

This algorithm is based on the simulating the foraging behaviour of honeybee swarms. Artificial Bee Colony is based on the behaviour of three groups of bees namely employee bees, onlooker bees and scout bees. A bee about to make a decision for choosing a food source is called the onlooker bee and the one following it is named as the employed bee. Scout bee carries out a random search discovering new sources of food. The food source is representing the possible solution to an optimisation problem and the quality is determined by the amount of nectar corresponding to the food source. A designated population of bees' moves randomly in a two-dimensional search space interacting with each other to find target nectar and finally the solution is decided by the intensity of bee interactions.

ABC algorithm has been used for classification of satellite image classification. In this bees were represented by the pixels of the satellite image and the food sources are the land cover classes' water, vegetation, rocky, urban and barren. Neighbourhood solutions are the neighbouring pixels provided by the training data and the employed bees are simulated from the training set with pixels having pure values of the solution. The function values (nectar quality) are calculated based on the Euclidean distance measure. This technique was further compared with traditional classifier performance like Minimum Distance classifier (MDC), Maximum Likelihood Classifier (MLC), BBO, Membrane Computing (MC) and Fuzzy classifier. ABC has also been implemented in a hybrid form in conjunction with BBO for satellite image classification. In this the authors have used ABC to generate habitats which are further classified by the BBO algorithm. This simplifies and enhances the quality of BBO algorithm classification.

3.5 Artificial Immune System Algorithm

This algorithm was proposed by[17]. Artificial Immune algorithm is a population based algorithm inspired by the human immune system and has the following operations: immune recognition, reinforcement learning, feature extraction, immune memory, diversity and robustness. The main search power in AIS relies on the mutation operator which decides the efficiency of the technique. Following steps describe AIS operations:

- Initialization of antibodies. Antigens represent the value of the objective function f(x) to be optimized.
- Cloning. This is the fitness factor and based on it the antibodies are cloned. The number of clones generated from the n selected antibodies are given by:

$N_c = \Sigma$ round $(\beta * j/i)$ $\quad i = 1, 2 \ldots\ldots n,$
Where N_c is the total number of clones
β is a multiplier factor
j is the total number of the antibodies.

- Hyper mutation. The generated clones undergo hyper mutation process in which the clones get mutated based on their fitness value. The clones are then compared with the original antibodies and the best N antibodies are selected for the next iteration.

Artificial Immune Network (AIN) has been used for the task of satellite image classification wherein the immune network is trained using the training data and then classifies the test satellite image dataset.

3.6 Biogeography Based Optimisation

Biogeography-Based Optimization (BBO) is a global optimization algorithm developed by Dan Simon in 2008[18]. This algorithm is based on the study the immigration and emigration pattern of species between various locations. Each candidate solution is characterized with a suitability index variable (SIV) and the fitness of these solutions

is called the habitat suitability index (HIS). High fitness candidates share their features with low fitness candidates by the process of immigration. This process of immigration and emigration is to improve the candidate fitness values and thus will help in finding an optimum solution to the optimization problem. The main operators in the BBO algorithm are migration and mutation. Information is shared between habitats during the process of migration and the process of mutation is used to increase the diversity of the candidate solutions

BBO has been used extensively for the task of satellite image classification. In majority of the models, initial clusters are generated using a clustering algorithm and the generated clusters are then classified by the BBO algorithm. Combination of Rough Set Theory, Fuzzy C Means, ACO, FPAB and ABC for clustering the satellite image dataset and BBO for classification of the clusters has been proposed. BBO has also been used in hybrid combinations with various algorithms like PSO/ACO2 and Ant-Miner. BBO has also been employed in the task of obstacle detection and path planning in conjunction with ACO and BCO.

3.7 Cuckoo Search Algorithm

Cuckoo Search algorithm proposed by Yang and Deb [19] is based on the reproduction strategy of cuckoos[20]. Each cuckoo or individual from the population will lay an egg and place the egg in any randomly chosen nest. The best nest with high quality or fitness value will be chosen for the next generation. CS has two important characteristics namely intensification and diversification [21]. Intensification is the problem searching for the current best solution initially and later on for the global solution. Diversification relates to exploration strategy of cuckoos wherein they search the complete search space efficiently.

Cuckoo search algorithm has been used very effectively for the task of satellite image classification. The test dataset is compared with the training dataset to generate quality solutions showing similarity to the test dataset and the quality solutions are then ranked based on their correlation to the test pixel. The test dataset receives the class of the best quality solution.

3.8 Genetic Algorithm

GA is an evolutionary stochastic optimization algorithm proposed by Holland in 1975[22]. A Genetic Algorithm has an initial population of chromosomes which are then replaced by the new population of members (possibly modified copies of the parents) in the next iteration. The operators of mutation and crossover decide the characteristics of the population in subsequent iterations. Algorithm begins by initializing a population of solutions (chromosomes) and evaluation of fitness function for each chromosome. The best chromosomes are selected in a population and reproduce undergoing cross over and mutation to give birth to a new set of offspring's. GA operators are selection, crossover, and mutation. GA is efficient in a large complex and poorly known search space. GA is often able to search through a huge search space in a reasonable amount of time and come up with a good, if not optimal, solution however GAs are not directly suitable for solving constraint optimization problems.

GA has been used for the task of satellite image classification. The authors initially perform feature/attribute selection on a multispectral dataset using different feature selection techniques and then generate classification rules using GA on the reduced dataset. The classifier is then compared with a decision rules classification wherein the GA classifier generates better classification accuracy. However this GA based approach is time consuming in case of dataset with large training instances.

3.9 Multi Layer Perceptron Neural Network

Multilayer perceptron neural network (MLPNN) is a popular neural network based algorithm used in a host of applications[23]. Multilayer perceptron (MLP) are a class of feed forward neural networks trained with the standard back-propagation algorithm which has been widely used in supervised image classification of remotely sensed data. The training data is fed as an input vector through a neural network and the errors of the output layers are calculated to adjust the weights of the network to achieve minimum error. The outside samples make up the validation set. MLP architecture consists of one input layer of nodes (a fan-out layer) and one or more hidden layers along with one output layer. The output of the nodes in one layer forms the input of the nodes in the next layer. The nodes are completely connected between two successive layers. Like perceptron, the learning algorithm of MLP is also based on error-correction. However, due to multilayer architecture, the error of hidden nodes can be estimated indirectly only. The back-propagation learning algorithm[24] computes the local gradient for a node in the layer l. The performance of a multilayer perceptron net-

work is highly dependent on the topology of the hidden layers. Too few neurons can lead to over generalisation and too many can lead to an over fitting in predictions. ANNs are commended for their non- parametric nature, adaptability to different data structures, robust generalisation and classification capabilities, and ability to handle non-linear relationships between input and output features.

MLPNN has been used for the satellite image classification. The authors have used a three layer MLPNN for the classification task and combined it with PSO for the training of the weights of the neural network. They have classified a multispectral Quick bird satellite image dataset and compared the performance with Ant-Miner based classification algorithm.

4. Performance Comparison Of Various Bio Inspired Algorithms For Classification of Satellite Image Dataset

The various bio-inspired algorithms described in the previous section are compared based on the strategy, classification approach, accuracy of classification and presented in a concise way in this section. **Table 2.** displays the different strategies used for classification of satellite image using bio inspired algorithms and also gives the accuracy achieved using each of these strategies. This also compares the performances of each of these algorithms whether they are used alone or in combination as a hybrid alongwith other bio inspired algorithm. **Table 3.** describes the application level usage of satellite image classification and the bio inspired algorithms used to achieve the final result as desired by a specific application domain. All the data and results discussed till now have been based on the usage of various bio inspired algorithms and its resultant effectiveness in classifying a specific satellite image data set i.e ALWAR satellite image dataset. However to show that bio inspired algorithms have been equally effective on other satellite image datasets, we have included the study of performances of the bio inspired algorithms described above on some other satellite image dataset as we could search from our survey efforts. These dataset as well the effectiveness of the bio inspired algorithm used and the type of classification with its resultant accuracy is described in **Table 4**.

Table 2. Usage of Bio Inspired Algorithms for Image Classification on the ALWAR Satellite Image Dataset

Algorithms Used	Strategy	Classification Approach	Accuracy (kappa coefficient)
Cuckoo search algorithm	Each test pixel data is compared with the training dataset to identify quality solutions which shows similarity to the test pixel. These quality solutions are then ranked based on their correlation to the test pixel. The class of the best solution is then given to the test pixel.	Per-Pixel Classification	0.946
ACO2/PSO [25]	Rule sets generated using ACO2/PSO is applied on each pixel of the test image to classify the pixel.	Per-Pixel Classification	0.975
Rough Set + BBO	Rough sets are used to generate unsupervised clusters (20 clusters). Clusters are classified using BBO. Clusters not classified in the first iteration are again clustered using Rough sets and re-classified using BBO. Process continued till all the clusters are classified.	Object Based classification	0.671
ACO2/PSO + BBO	Water pixels classified using BBO. Rests of the clusters were classified using ACO2/PSO.	Per-Pixel & Object based Classification	0.981
Fuzzy + BBO	Fuzzy C Means clustering is used to generate clusters. Clusters are classified using BBO.	Object Based classification	0.692
ACO/SOM	SOM is used for clustering and ACO is used for classifying clusters.	Object Based classification	0.707
ACO/BBO	ACO is used for clustering and BBO is used for classifying the clusters.	Object Based classification	0.763

FPAB + BBO [26]	Flower Pollination by Artificial Bees (FPAB) algorithm is used generate clusters. Clusters are classified using BBO.	Object Based classification	0.679
Ant Miner + BBO	Rough sets are used to generate unsupervised clusters. Some of the specific clusters are classified using BBO. Rests of the clusters are classified using Ant miner.	Object Based classification	0.97
ABC + BBO [27]	Artificial bee colony (ABC) is used to generate clusters. Clusters are classified using BBO.	Object Based classification	0.917
ABC [28]	Per pixel classification is done using ABC algorithm.	Per-Pixel Classification	0.917

Table 3. Application based Usage of Bio Inspired Algorithms on ALWAR Satellite Image Dataset

Algorithms Used	Application	Strategy
BBO & ACO [29]	Country Path Finding using Hybrid approach of BBO and ACO.	BBO is used for obstacle detection (Binary classification). ACO is used for path planning for avoiding the obstacles.
BBO & BCO [30]	Country Path Finding using Hybrid approach of BBO and Bee Colony Optimization (BCO).	BBO is used for obstacle detection (Binary classification). BCO is used for path planning for avoiding the obstacles.

Table 4. Usage of Bio Inspired Algorithms of Image Classification of other Satellite Image Datasets

Algorithms	Strategy	Classification Approach	Accuracy	
			Accuracy	Kappa coefficient
Ant-Miner	Ant Miner was used to generate rules for classifying the images.	Per-Pixel Classification	90.44%	-
MLPNN/PSO	Three layer MLPNN is used for classification. PSO is used for training and adjusting the weights of the neural network.	Per-Pixel Classification	93.68%	-
PSO-Miner [31]	Classification rule is generated using PSO-Miner	Per-Pixel Classification	84.6%.	0.821.
GA [32]	Feature selection: hypothesis testing. normalization score model. information gain method. Genetic search process extracts 15 land-cover classification rules for classification.	Per-Pixel Classification	Dataset 1 - 98.7%. Dataset 2 - 73.3%.	-
AIN [33]	Artificial immune network is used to classify the satellite image dataset.	Per-Pixel Classification	Dataset 1 - 89.88%. Dataset 2 - 92.29%.	0.8625 0.9058

5. Conclusion

Satellite image classification is a very exciting area of research in the academic world because of the availability of large amount of remotely sensed data as well as its requirement in multiple applications. Efforts are on to incorporate different types of data, indices, attributes and use of different methods to achieve better results. Improvement of results could be in terms of achieving better classification accuracy or improving the details of classification or reducing the classification complexity or the time taken in classification. Bio Inspired algorithms have proven to be an effective and efficient classification technique and has thus been successfully employed

for the task of satellite image classification. We have discussed the use of bio inspired satellite image classification methods with specific reference to its usage in terms of the classification methodology or approach and the results generated. Many factors, such as quality of the remotely sensed data, the source of data, a classifier system, and the selection of suitable classification software have to be taken into account for this task. Classification techniques differ in their approaches and have their own merits/demerits. However it can be demonstrated that a certain approach of classification will generally enable us with good results from all satellite datasets. Multispectral satellite data of the Alwar region has been sourced from Digital Terrain Research Lab (DTRL), a DRDO lab. This data has been cited and used by many researchers for the purpose of image classification. We have tabulated the results of certain bio inspired algorithms on this common dataset. We have also discussed different types of use of bio inspired algorithms on various other satellite image datasets.

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