Moth Flame Optimization for land cover feature extraction in remote sensing images

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***Abstract*—Nature inspired meta heuristics are inspired from the phenomenon which occur in nature. Wide range bio-inspired algorithms provide good results when applied to various kind of applications. In our research we focus on a new nature-inspired algorithm called Moth Flame Optimization(MFO) and adopt it for efficient land cover feature extraction. MFO is based upon the navigation technique of Moths to move in straight line called transverse orientation. Remote sensing is an area which provides enormous benefits for the mankind and a lot of classification techniques have been applied to produce good results. The results are compared to the existing algorithms for the satellite data of Alwar region. We therefore present a model to adopt the MFO algorithm for Image Classification.**

***Keywords*—IEEEtran, journal, LaTeX, paper, template.**

I. Introduction

Engineering has a wide range of complex problems which cant be solved by deterministic techniques like mathematical optimization efficiently. One such field is satellite remote sensing. Remote sensing [3] is instrumental in taking important decisions regarding environment. Extracting features from the images is a problem which is addressed by various optimization algorithms. Artificial Intelligence is a part of machine learning [30], these may replicate the model of human intelligence or the natural phenomenon. Optimization algorithms aim at providing the best possible solution for a problem. Metaheuristic algorithms are developed to provide sufficiently good results for optimization problems while not increasing the computation or size. Bio Inspired algorithms are form of meta heuristics which model their behavior upon the phenomenon occurring in nature. Nature is seen a inspiration to solve numerous complex and hard problems where search space is not known. Nature provides a wide range of phenomena which exhibit optimized behavior to solve problems. Bio-inspired algorithms may be further categorized into following categories: Evolution: These methods are based on the process of biological evolution in nature which forms the basis of all living things. It considers the strategies used by living things to interact with each other. Family of algorithms considered under evolution are genetic algorithm (GA), genetic programming (GP), Differential Evolution, evolutionary strategy (ES). Swarm Based: These are based upon the collective social behavior of the organisms [29]. Popular algorithms in this category are Particle swarm optimization (PSO), Ant Colony Optimization (ACO) [9], Artificial Bee Colony Algorithm (ABC) [31], Firefly algorithm [32], etc. Ecology: These take inspiration from the nature ecosystem to solve difficult problems. These consider the interaction of the organisms in ecosystem with the biotic and abiotic components. Popular algorithms in this category are Biogeography-Based Optimization (BBO).

No single bio inspired algorithm is suitable for optimizing all the problems which results in development of new techniques which could provide better solutions. One such recent algorithm is Moth Flame Optimization. This Algorithm simulates the navigation mechanisms used by moth which travel in straight line by maintaining a fixed angle with moon. This is called transverse orientation. As the distance of earth from the moon is quite large, moths are able to navigate in straight line by maintaining a fixed angle but if they approach any artificial light they get caught in a deadly spiral around that source. As light source is extremely close to the moths as compared to moon by maintaining a fixed angle with the source the moth forms a spiral around that source. As the moths ultimately converge to the light source it is used as optimization algorithm. Moths represent search agents and flames best available solutions respectively. Moths find the best flames and fix their exploration around the flames and converge in a spiral motion similar to moths to the flames. Numbers of flames are reduced with corresponding iterations to provide better exploitation. As the moths converge to the flames they optimize the solutions. In our research we have modelled MFO for image classification. We have classified and extracted features from the satellite image of Alwar region and then compared our algorithms with other similar bio-inspired algorithms. The organization of the paper is as follows: Section 2 presents the brief review of nature inspired algorithms used for classification and popular techniques used for remote sensing feature extraction. Section 3 brief review of MFO. Section 4 describes the proposed image classification algorithm based upon MFO. Section 5 presents the implementation results of the proposed framework. Section 6 describes the future work to be done and conclusion of the paper. Section 7 mentions the references.

A. Subsection Heading Here

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II. Related Work

In our research we create a model to extract land cover features from satellite remote sensing data based upon a new nature-inspired algorithm Moth Flame Optimization [1]. In MFO natural phenomenon of moths maintaining a fixed angle with moon i.e. transverse orientation; which they use to travel in straight line was modelled to solve optimization problems. Moths confuse artificial sources of light with moon and get caught up in deadly spirals, this phenomenon is useful for optimization problems as this spiral behavior is modelled for exploration and exploitation. Satellites capture images from a long distance. Remote sensing uses technologies to analyze the important characteristics of those images. Feature extraction from remote sensing image [2], provides the various techniques that are used for extracting important features from the images. The research studies the various form of the feature that are extracted from the image and what sort of processing is them applied to them. It provides us with the comparison of different form of feature extraction methods which are popular. Its important to understand what different fields of Remote Sensing are, an introduction to remote sensing [3] describes the history of remote sensing methods used. Image classification forms basis of remote sensing land cover feature extraction [4]. A Survey on Image Classification Approaches and Techniques [5] and [6] provides various different classification processes used and process that needs to be followed for designing a suitable image classification model, it also talks about the remote sensing images and what process needs to be followed for feature extraction from image. Artificial intelligence is a very good tool for solving optimization problems. These algorithms are also used for the purpose of classification, clustering and other relevant data mining tasks. In remote sensing Artificial intelligence techniques have been applied for land cover feature extraction, analysis of geography and similar tasks. Use of AI in Remote sensing [7] provides the insights of current researches in the field of remote sensing which involves artificial intelligence. Nature-based based classifiers are very popular as they outperform other evolutionary classifiers [8]. Nature inspired algorithms explore the branch of AI where the heuristics are used based upon some natural phenomenon. Ant Colony Optimization [9] is one of the oldest and most popular bio-inspired algorithms available. It models the phenomenon of food finding employed by ants to find optimized solution. Numerous number of nature-inspired techniques producing good results for remote sensing exists. A Hybrid of ACO2/PSO and BBO [10] produces extremely good results for land cover Feature Extraction. It employs the technique of first using the strengths of modified BBO then refining the result by the means of ACO2/PSO to produce fairly accurate results. Similarly, a combination of geo-sciences and biogeography [11] uses surface entropy to calculate habitat suitability index of the species; this forms the basis of the features used. Application of PSO to the existing clustering algorithms [12] has been used for remote satellite data classification, algorithm is applied to the Alwar dataset. Oldest and most popular bio-inspired algorithm that exists is ACO, it has been used for extracting features from images [13]. Ant Miner [14] is a popular variation of ACO which is used for data mining tasks. Ant Miner is used for classification rules generation. Other variations of Ant Miner, Ant-Miner+ [15] produces much better results as compared to the existing techniques. When compared with Decision trees and rules based classification these produce much efficient results. ACO/PSO [16] makes use of self-organizing nature of Swarm intelligence to boost the feature extraction in remote sensing data. A hybrid of ACO/PSO and cAnt Miner [17] for land cover feature extraction is used for exploring the possibilities of nature inspired algorithms in the field of remote sensing land cover feature extraction. The results obtained show that the nature inspired algorithms are well suited for finding features from satellite data. As ACO/PSO gives a better prediction and with a less number of rules its better than traditional classifiers. ACO/PSO hybrid has found wide range of applications in different fields of studies which further proves the relevance of the nature inspired algorithms for the purpose of data mining. ACO/PSO provides good results when it is used for hierarchical classification [18] and is applied to biology dataset J Hand in his book [19] describes the methods used for creation and evaluation of classification rules. The author mentions different methods by which classification rules could be build and then maps the methods to the problems. He has reviewed different approaches in terms of classification and helps to find out which method is relevant to which study. D. Simon formulated the basic Biogeography Optimization [20] and [21] under which the population of species on the earth is considered and their migration strategy is used for the optimization of results.He also presented a combination of evolutionary strategy with BBO [22] to improve the results of BBO. Since then many variations of BBO have been used for optimization problems. A hybrid of ACO and BBO has even found application in defense [23] for strategizing the positions of the army troops. Urban images have been classified using bio inspired techniques [24]. Land use information is useful for making some specific decisions in urban planning. Comparison of land cover classification in China [25] presents the methods used in real life problem in China. Nature inspired techniques applied to mixed pixels have been useful for resolution and pixels assignment in image classification [26]. Swarm intelligence when used for mixed pixels gives accurate results. In order to classify images for purpose of detection, planning and other decisions certain toolsets make use of expert opinion [27]. Classification done by the means of ERDAS lets us know the pixel color coding. BBO and plate tectonics based methods have also been used for extraction of water pixels from satellite image [28].

III. Brief Review of Moth Flame Optimization

Moth flame models the natural phenomenon of movement of moths around artificial lights. In nature moths travel in straight line by maintaining a fixed angle with the moon.

This phenomenon is called transverse orientation. As these moths approach any artificial light they get caught in a deadly spiral around the light source as they form a fixed angle with this source just like moon. As the distance of the moon is much larger than the light source the moths form a spiral motion around the light source which results in the ultimate convergence of the moth to the light source. Following are the basic features of MFO

- Candidate solutions are represented by Moths which are generated randomly for according to distribution of population.
- Best Solutions are represented by flames.
- Search space is represented by the moths spiral movement around the flames. Moths align themselves according to their best flames.
- Better exploration as flame gets updated and moths adjust their paths.
- Number of Moths and Flames decreases in every iteration hence only best solutions are preferred.

IV. MFO BASED CLASSIFIER FOR LAND COVER FEATURE EXTRACTION

In this section we describe the model we have used for land cover feature extraction by using MFO. The step by step process used for the process is described below.

A. *Process Flow for MFO based land cover feature extractor*

Following section describes the step by step process we take for the classification. Given below is the process

- Retrieve the training multi spectral images.
- Generate the training data by classifying the pixels using ERDAS software
- Apply K means clustering algorithm to generate a rough number of initial clusters.
- Generate the most representative points of the clusters.
- Flames define the best solutions in the search space. Initialize moths to the random numbers and flames to the most representative points we obtained after initial clustering.
- Generate the rule set from the movement of the moths according to the spiral movement of the flames.
- Adjust the position of the moths according to the fitness to the flames.
- After rule set generation retrieve the test image.
- Classify the pixels to the features according to the rules and calculate kappa coefficient.

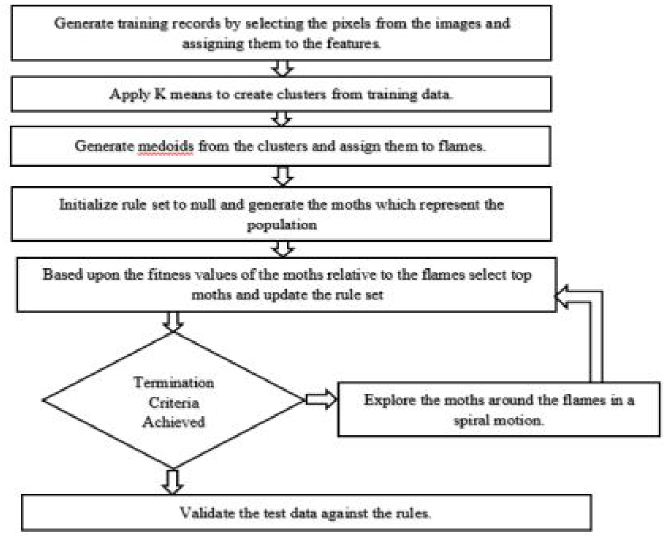


Figure 1: Flow Chart.

B. *MFO based land cover feature extraction*

As per the MFO algorithm the moths represent the candidate solution. Moths may fly in any direction based upon the dimensions of the solution space. It may be 1D, 2D, 3D etc. Our dataset for land cover is a 7 band image therefore the number of dimensions for the following moths will be 7 dimension. The representation of the moths will be a matrix of the following format. Let the matrix representing the populations of the moths be M. M1, M2 . Mn represents the populations of the moths. Moths are represented in the following format.With each dimension of the moths representing one band of the image. The subsequent values of the moths represent the band images DN values of RED, GREEN, NIR, MIR, RS1, RS2, DEM. For every moth there will be an associated value of the fitness. The fitness value is an matrix of the following format.

$$OM = \begin{bmatrix} F_1 & Dist_1 \\ F_2 & Dist_2 \\ .. & .. \\ .. & .. \\ F_n & Dist_n \end{bmatrix} \tag{1}$$

This matrix is therefore useful for the alignment of the moths to the closest flames and also serves as the rejection criteria. Fi represents the flame which is closest to ith moth. The flames are found by the fitness function. Disti represents the distance of the moth to the closest flame. Flames represent the best solutions as per MFO therefore the flames are represented by the medoids of the clusters generated initially. Each flame is a 7 dimension variable where every dimension represents a corresponding DN values of the 7 different spectrum bands of RED, GREEN, NIR, MIR, RS1, RS2, DEM. Flames are represented as per equation 3.

$$F = \begin{bmatrix} F_{1,1} & F_{1,2}.. & .. & .. & F_{1,n} \\ F_{2,1} & F_{2,2}. & .. & .. & F_{2,n} \\ .. & .. & .. & .. & F_{3,n} \\ .. & .. & .. & .. & .. \\ F_{1,n} & .. & .. & .. & F_{n,n} \end{bmatrix} \tag{2}$$

(a) Input training data. Data is in the form of 7 band images.
(b) Form Initial clusters of data by using K means algorithm. The process of K means is described below. Choose initial points as clusters For all points in cluster assign it to the closest centroid.Recalculate the centroids and adjust the cluster until cluster stop changing.
(c) Find medoids of the clusters and initialize the flames with the medoids of the clusters. For calculating the medoids we find the points in cluster which have least sum of distances to all other points.
(d) Generate the initial population of the moths as follows.For each band find the minimum and maximum DN values.Uniformly generate random moths in the range of the moths.
(e) Initialize the rule set to empty and then generate the rules set as follows: Find fitness values of all the moths and select the best moths according to their corresponding fitness values. Initialize t=1 and loop till t¿-1 For top moths arrange their next position according to the spiral function Generate the fitness values of all the moths according to new position and then for top n values update the rule set Rule set consists of the moth position closest flame and the distance to the closest flame.
(f) Input the test data and convert it to 7 band image format.
(g) For each pixel validate against the rules. Rules are validated by taking the top distances to the moths in the rule set and then the mean of all the distances for every feature is taken. Whichever feature has the lowest mean is assigned to the pixel.

The above data first accepts the training data in the form of 7 band DN values for RED, GREEN, NIR, MIR, RS1, RS2, DEM. Initial clustering is done by the means of Kmeans and flames are initialized to the medoids (most representative points of the clusters) of the clusters formed. Fitness function returns the values of the distance of the moths to the closest flames. The value of the fitness function is calculated by the minimum of the Minkowskis distance to the flames.

$$\text{Dist}(\text{M}_i, F_i) = \sqrt[p]{\sum_1^7 (M_i - F_i)^p} \tag{3}$$

$$\text{Fitness(M)}=\sum_{(i=1)^n Min(Dist(M,F_i))} \tag{4}$$

Fitness values is calculated by taking the minimum of the distances to all the flames. It returns the best flame and also the distance to it.Spiral function is used to generate the next position of the moth around the flames. The spiral function is responsible for the exploration of the moths around the flames in a spiral motion. The spiral function is represented by the following equation.

$$\text{S}(\text{M}_i, F_j) = D_i.e^{bt}.\cos(2\pi t) + F_i \tag{5}$$

Where Di indicates the distance of the ith moth for the jth flame, b is a constant for defining the shape of the logarithmic spiral, and t is a random number in [1, 1] t is changed in the subsequent iterations. Flame in the above equation is generated by the fitness function and then the distance of the moth to the closest flame is used for the purpose of the spiral equation.

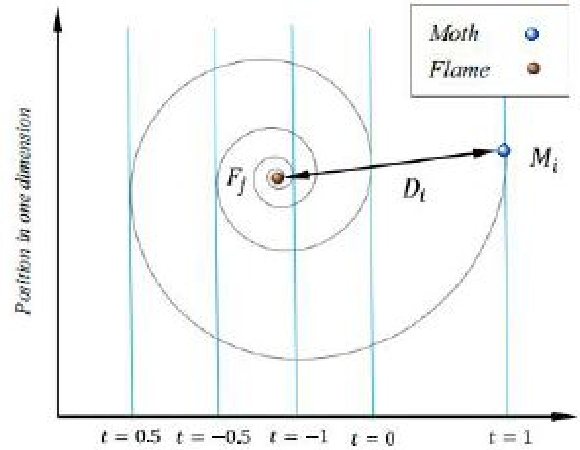


Figure 2: Logarithmic spiral around the flame

V. Implementation and Results

A. Dataset Used

We have taken a multi-spectral, multi resolution and multi-sensor image of size 472 546 pixels of Alwar area in Rajasthan, India. The satellite image for 7 different bands is taken. These bands are red, green, near infra-red, middle infra-red, radarsat-1, radarsat-2, and digital elevation model. The ground resolution of these images is 23.5 m and is taken from LISS-III sensor. The 7-band satellite image of Alwar area in Rajasthan is given in the figure 10.

The proposed algorithm is run on the test data from the Alwar region (taken by LISS-III sensor used by DRTL remote sensing lab, DRDO New Delhi. India) which is IRS-P6 satellite optical seven band image having resolution 23.5m. With the help of following parameters the error matrix is generated from the ground truth and kappa coefficient which represents the actual correspondence of the classifiers results with that of the expert. Kappa coefficient removes the possibility of the by chance matching and reflects the true measure of classifiers accuracy. For the purpose of the rule set generation following settings were taken.

1.Value of t is in between 1 to -1 2.Number of moths= 200 3.Number of flames= 150 4.P in Minkowskis distance=2 5.Value decremented is 10 for best moths in every iteration 6.30 top results are taken

Kappa Coefficient obtained is 0.9635. The proposed method gives best accuracy for water pixels when we calculate the error matrix, producers and users accuracy for the result following results are obtained. Error matrix is mapping of classification of pixels between the original pixels and predicted pixels. Producers accuracy indicates the quality of the classification of training set pixels and Users accuracy indicates the probability that prediction represent reality.

Our algorithm gives very good accuracy for the water, vegetation and Rocky features. Users is calculated by taking the correctly classified features divided by the sum of the corresponding rows. For our classifier table 3 shows the user accuracy.

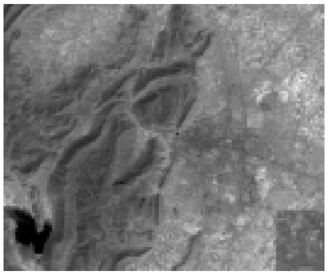


Figure 3: Green

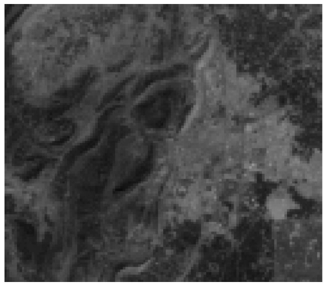


Figure 4: MIR

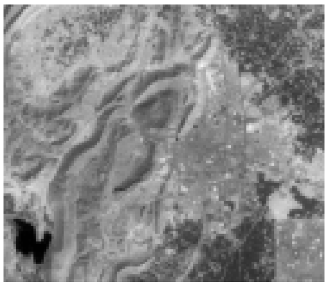


Figure 5: NIR

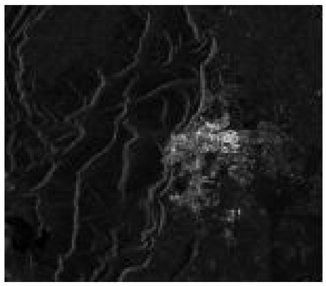


Figure 6: radarsat-1

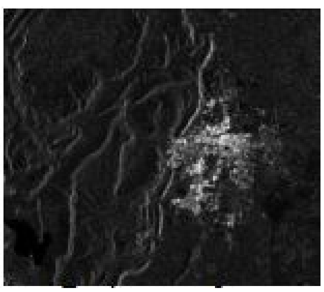


Figure 7: Radarsat-2

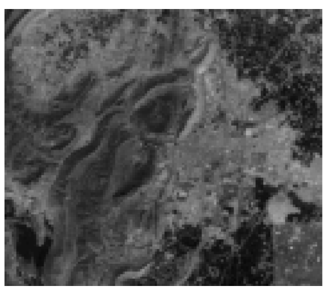


Figure 8: Red

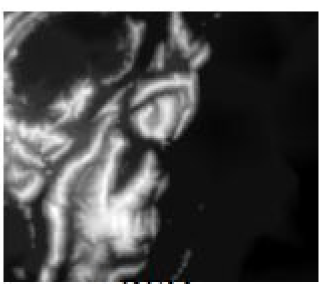


Figure 9: DEM

Figure 10: 7-Band Satellite Image of Alwar Area in Rajasthan, India (Courtesy of Defense Terrain & Research Lab (DTRL), Defense and Research Development Organization (DRDO), India

Table I: Error Matrix

	Barren	Rocky	Urban	Vegetation	Water
Barren	184	0	7	0	0
Rocky	8	280	0	0	0
Urban	25	0	392	0	0
Vegetation	0	0	0	329	0
Water	0	0	1	0	205

Table II: Producer's Accuracy

Feature	Accuracy calculation	Producer's Accuracy
Vegetation	329/329	1
Urban	392/400	0.98
Rocky	280/280	1
Water	205/205	1
Barren	184/217	0.847

B. *Classified Alwar Image*

Some portion of Alwar remote sensing image was taken as test set. The pixels were manually assigned features as BARREN, ROCKY, URBAN, VEGETATION and WATER. We formed the rules set based upon the MFO based image classification as presented earlier in the section 4. Finally, we have classified complete Alwar image bases upon the rules we have obtained. The classified image is assigned colors according to the features added.

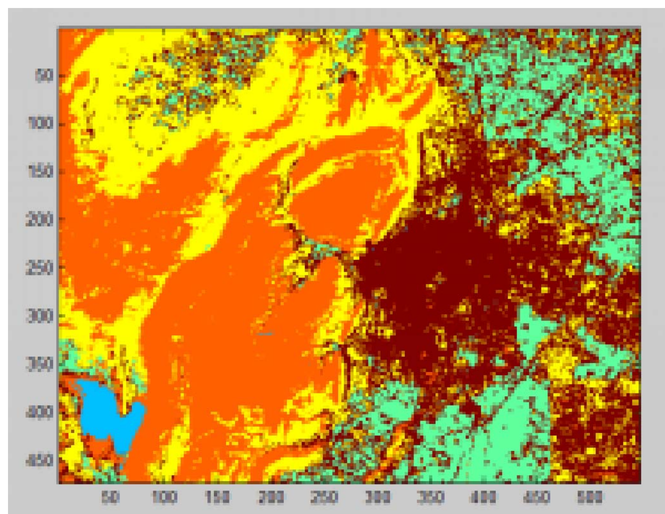


Figure 11: Classified image of Alwar satellite data

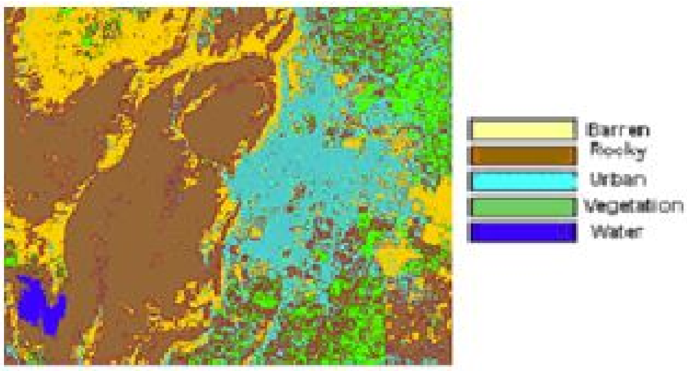
Following image has coded the pixels in following manner. BARREN region corresponds to yellow color, ROCKY region corresponds to orange color, URBAN region corresponds to brown color, VEGETATION region corresponds to green color and WATER region corresponds to blue color. From the domain knowledge about the image it could be inferred that the water and rocky regions denoted by the classifier is fairly accurate and provide us good results for classification.

C. *Comparison with other Classifiers*

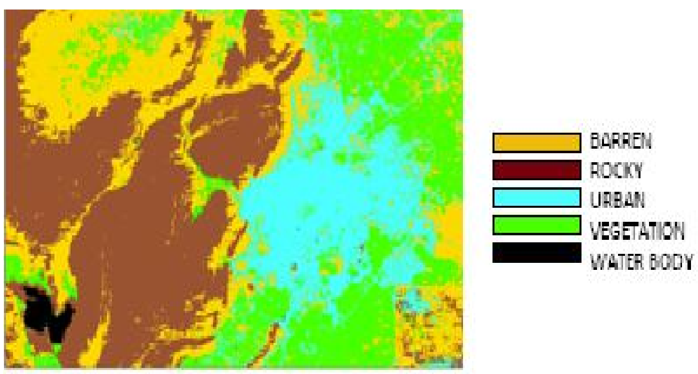
Various nature-inspired classification techniques have already been applied on land cover feature extraction for Alwar region.

Table III: User's Accuracy

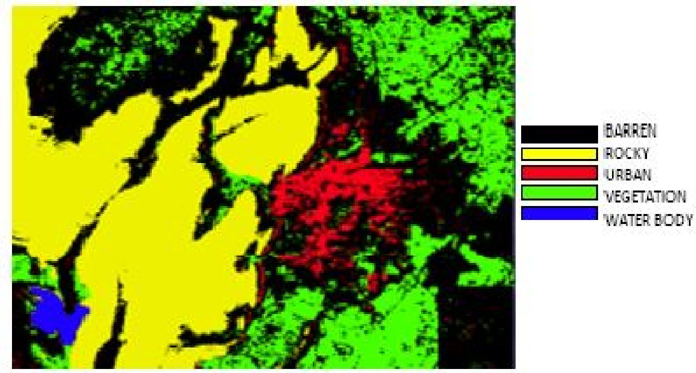
Feature	Accuracy calculation	User's Accuracy
Vegetation	329/329	1
Urban	392/417	0.94
Rocky	280/288	0.972
Water	205/206	0.99
Barren	184/191	0.963



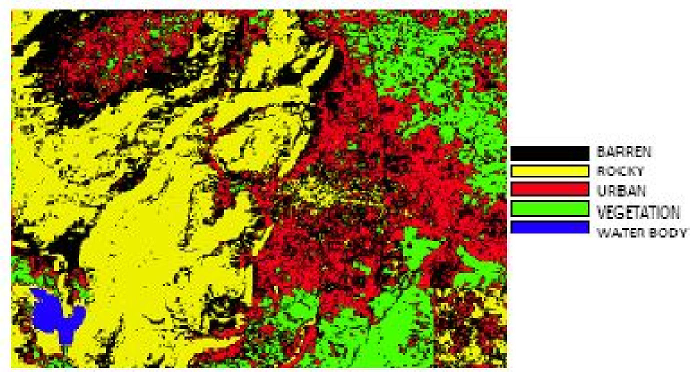
(a) Maximum Likelihood Classifier kappa=0.75



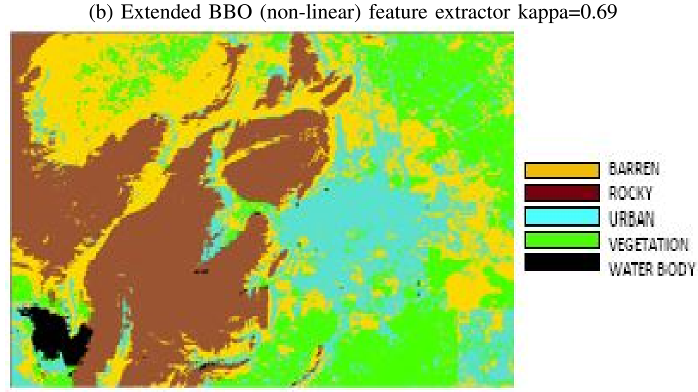
(b) Minimum Distance Classifier kappa=0.73



(a) Membrane Computing Classifier kappa=0.68



(b) Extended BBO (non-linear) feature extractor kappa=0.69



(c) Fuzzy classification kappa=0.91

Figure 13: Comparison of Classfication algorithm

We compare our results with some other soft computing techniques for image classification. We have calculated the Kappa Coefficient for our classifier and we compare it with other algorithms which have already been used for the purpose of land cover feature extraction from the satellite data. Table 4 shows the results of the comparison

Table IV: My caption

Fuzzy Classification	Membrane Computing	Extended BBO	Minimum Distance Classifier	Maximum Likelihood Classifier	MFO based Classifier
0.9134	0.6818	0.6912	0.7364	0.7525	0.9635

VI. Conclusion & Future Work

In our research we modelled a new nature-inspired algorithm moth flame optimization for the purpose of image classification. We created initial clusters to generate the flames then population of moths was generated which was random in nature. These moths transverse- oriented themselves around the flames and in each iteration move in a spiral motion along the line of best flames. We have classified the images of Alwar region in Rajasthan, India obtained from DRDO New Delhi, India. Then we classified the image of the Alwar region and assigned color coding to it. Our classifier gives better kappa coefficient than BBO and MDC for the same dataset. We were able to classify the water and rocky regions with the best accuracy by means of our classifier. Future work is to use hybrid of other nature-inspired techniques like BBO and GSA with MFO to analyze the increase in accuracy. Further work needs to be done to represent the rules set obtained through MFO for classification through some efficient data structure, as classification of the image through the rule set needs to go through all the rules and the result obtained takes a fair amount of time. In future we would like to test the images more number of features so that it can be applied to many other types of images. Apart from this we would like to take a hybrid approach with other nature-inspired algorithm like ACO,BBO,PSO,etc to propose other novel techniques.

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