



Satellite Image Classification using Firefly Algorithm to Identify Natural Terrain Features

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Abstract: In the recent years, swarm intelligence based firefly algorithm has become a great focus for the researchers to solve the real time optimization problems. Here, firefly algorithm is used for the application of satellite image classification. For experimentation, Alwar area is considered to multiple land features like vegetation, barren, hilly, residential and water surface. Alwar dataset is considered with seven band satellite images. Firefly Algorithm is based on the attraction of less bright fireflies towards more brightener one. For the evaluation of proposed concept accuracy assessment parameters are calculated using error matrix. With the help of Error matrix, parameters of Kappa Coefficient, Overall Accuracy and feature wise accuracy parameters of user's accuracy & producer's accuracy can be calculated. Overall results are compared with BBO, PSO, Hybrid FPAB/BBO, Hybrid ACO/SOFM and Hybrid ACO/BBO based on the kappa coefficient and overall accuracy parameters.

Keywords: Image Classification, Firefly Algorithm, Satellite Data, Terrain Feature Identification, Swarm Intelligence

I. INTRODUCTION

Swarm Intelligence is an artificial concept inspired from the collaborative multiagent social species that work intellectually to design intelligent system and optimized algorithm [1]. These social species can be small ants, termites, wasp, bee, flying birds, school of fishes and other animal groups also. The first use of term "swarm" was made by Beni during cellular robotic system in which agents organizes them with nearest neighbour interaction [2]. After that it is being used for the various optimization area like science, industry etc. There is a great importance for the solution of optimization problems both in the field of science and industry. The global cooperation of these social species to work collaboratively is due to strategy of self organization. Self organization is a dynamic strategy where agents create global system by interaction of local level components. Some of the popular swarm intelligence techniques are listed Bat Algorithm, Ant Colony Optimization, Cuckoo Search, Firefly Algorithm, Intelligent Water Drops Algorithm, Biogeography Based Optimization, Particle Swarm Optimization and Artificial Bee Colony Optimization [3]. From the above techniques, we are using firefly algorithm due to its behaviour to find the global solution in short time constraint.

Remote Sensing is the method to get information about any far object without any kind of contact with that [4]. Remote sensing involves the steps to sense the object, record their emitted energy, process that energy and finally analysing that

for the information of object. Generally, remote sensing concept is considered to sense the objects of earth surface using satellites.

Remote Sensing involves a wide spectrum of sensing process. Based on the sensing elements, remote sensing can be categorized into two types as below [5] [6]:

Active Remote Sensing and Passive Remote Sensing

Passive Remote Sensing can be defined as the sensing process that have the need of external energy sources like sun to illuminate the target (as shown in figure 1a). The sensors that can sense the target with the help of external natural illuminists are known as Passive Sensors.

Active Sensing can be defined as the sensing process with the help of Active sensors that can afford their own sources of energy for illumination (as shown in figure 1b). In Active Sensing, no any external source of energy is required. The sensing process works directly from sensors to target object and the reflected radiations are measured by the sensors after detection of target.

In this experimentation, dataset of Alwar region is considered having land cover attributes of Barren, Rocky, Vegetation, Urban and Water [7].

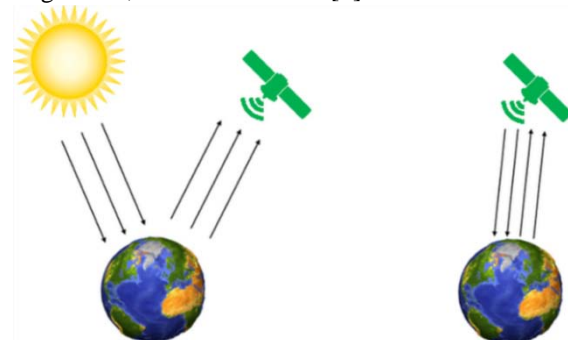


Figure 1: (a) Passive Remote Sensing (b) Active Remote Sensing

The main goal of this satellite image classification is to assign the respective feature class to each pixel of image using

firefly algorithm on the basis of available attributes. Further, results are assessed in terms of error matrix. Error matrix presents the comparison parameters of kappa coefficient, user's accuracy, producer's accuracy and overall accuracy.

Rest sections of paper are discussed here: Section II presents the basic concepts Firefly Algorithm. Section III presents the information about considered dataset. Section IV explains the proposed firefly algorithm for satellite image classification; Section V presents the comparative results and evaluation of concept. Section VI concludes the paper.

II. FIREFLY ALGORITHM

Firefly algorithm is swarm intelligence based metaheuristic algorithm introduced by Xin-She Yang by taking the inspiration from the biological lighting behavior of social species firefly [8]. There is the existence of thousand of firefly species in the world and all these species are produce some rhythmic light flashes. Each firefly species follows some different pattern of flashes by using the bioluminescence process. There are some fundamental aspects behind this flashing of firefly species like protective warning mechanism, mating process and potential to attract prey. The objective function of this firefly algorithm is formulated in association with flashing light behaviour. Firefly algorithm mainly depends upon three idealized rules as mentioned below [9].

1. One firefly attracts other apart from of their sex as all the considered fireflies are assumed as of unisex feature.
2. Fireflies attract each other depending upon their brightness. Brightness value is proportional to attractiveness. So, brighter firefly attracts the lesser brighter firefly. In case there is no possibility of brighter one, then fireflies move randomly.
3. Landscape of objective function is considered to determine the brightness of firefly algorithm.

In firefly algorithm, objective function is used to represent it in mathematical form and to draw some formulation to find the optimized solution of the problems. The pseudo code for the firefly algorithm is given below in figure 2.

Objective function $f(x)$, $x = (x_1, \dots, x_d)^T$
Generate initial population of fireflies $x_i (i=1, 2, \dots, n)$
Light intensity I_i at x_i is determined by $f(x_i)$
Define light absorption coefficient γ
While ($t < \text{MaxGeneration}$)
for $i = 1: n$ **all** n **fireflies**
 for $j = 1: i$ **all** n **fireflies**
 if ($I_j > I_i$), **Move firefly** i **towards** j **in** d -**dimension; end if**
 Attractiveness varies with distance r **via** $\exp[-\gamma r]$
 Evaluate new solutions and update light intensity
 end for j
end for i
Rank the fireflies and find the current best
end while
Postprocess result and visualization

Figure 2: Pseudo Code of Firefly Algorithm

III. DATASET CONSIDERED

Satellite based image classification is performed on the Alwar region situated in Rajasthan State, India. This place is

geographically situated at longitude of 76°31' East and Latitude of 27°34' North, at an elevation of 270 meters from the earth surface.

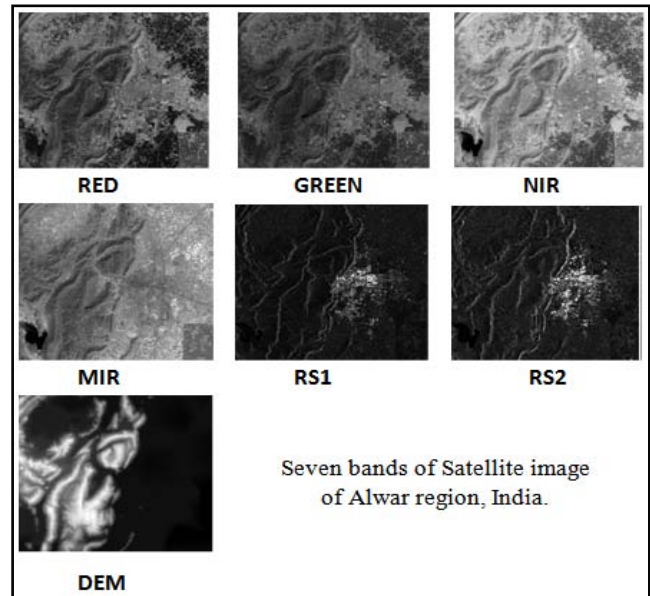


Figure 3: Seven band satellite images of Alwar Region

The reason for the selection of this Alwar region is the availability of various terrain features including water area, urbanization, rocky area, barren and vegetation etc. Satellite data is considered in the form of seven bands as shown in figure 3.

IV. PROPOSED ALGORITHM

In this section, proposed concept of Firefly Algorithm is explained for the identification of natural terrain features. The main goal to use the swarm intelligence based multi agent firefly algorithm is to obtain the optimized results for the identification of natural land cover features. In this methodology the expert dataset of Alwar region is divided into training and testing portion. The dataset portion selected for training purpose is considered for the classification using firefly algorithm. The other dataset portion is used for the evaluation of proposed firefly algorithm. The explained concept of firefly algorithm for satellite image classification is given below.

Input: Expert satellite dataset of Alwar region (Seven Band Images with their respective coordinate values)

Output: Classified Image.

Algorithm

Step 1: Initially, seven band satellite images are considered as the input for the image classification where fireflies are assumed as the pixels of the image.

Step 2: The overall objective of this firefly algorithm in image classification is to find the best match for image pixels to classify them as per their feature class.

Step 3: Firefly works on the fundament to attract other firefly. Attractiveness of firefly is always determined in terms of their Brightness (Intensity) value which is associated with the objective function. Brightness of firefly obeys the inverse square law where brightness decreases as the distance between two firefly's increases. This can be evaluated as shown in equation (1).

$$I \propto 1/r^2 \quad \dots\text{Equation (1)}$$

Where, I is the intensity value and r is the distance.

Step 4: To evaluate the distance between the two firefly i and j, apply the Cartesian distance formula as shown in equation (2).

$$r_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad \dots\text{Equation (2)}$$

Where, r_{ij} is the distance between i and j firefly, and x, y are the coordinates.

Step 5: Calculate the attractiveness value for each pixel (firefly) of the image using the objective function below as shown in equation (3).

$$\beta = \frac{\beta_0}{1 + \gamma r^2} \quad \dots\text{Equation (3)}$$

Where, β is the attractiveness, β_0 is the attractiveness at distance $r = 0$ and γ is the light absorption coefficient.

Step 6: Find the best possible solution for each pixel based on their attractiveness factor. Store the best solution as per their brightness level for each pixel.

Step 7: Evaluate the overall best solution by evaluating the Pearson Correlation Coefficient for the found solution for each pixel using formula given in equation 4.

$$r = \frac{\sum_{i=1}^n (X_i - \bar{X})(Y_i - \bar{Y})}{\sqrt{\sum_{i=1}^n (X_i - \bar{X})^2} \sqrt{\sum_{i=1}^n (Y_i - \bar{Y})^2}} \quad \dots\text{Equation (4)}$$

More the value of correlation, the solution will be more efficient.

Step 8: As per the best solution, assign the best solution class to the pixel as per terrain features.

Step 9: Repeat the steps III to V until all the pixels classified.

Step 10: Obtain the Classified Image.

V. RESULTS AND DISCUSSION

A. Results

The proposed concept is implemented on MATLAB simulation software. The input image considered for image classification is shown in figure 4 (Image is obtained by stacking seven band satellite images). For the classification of Alwar region based land, firefly algorithm is used. The classified image using firefly algorithm is shown in figure 5. The proposed concept classifies the image by considering the color specification of feature classes as water is represented by red color, vegetation is represented by yellow color, urban area is represented by cyan color, rocky area is represented by blue color, and barren is represented by white color.

To evaluate the results of classified image, we have used the data remaining for verification purpose. The dataset experts pixels used for image classification are as Water: 55 Pixels, Vegetation: 125 Pixels, Urban: 127 Pixels, Rocky: 92 Pixels, Barren: 102 Pixels.

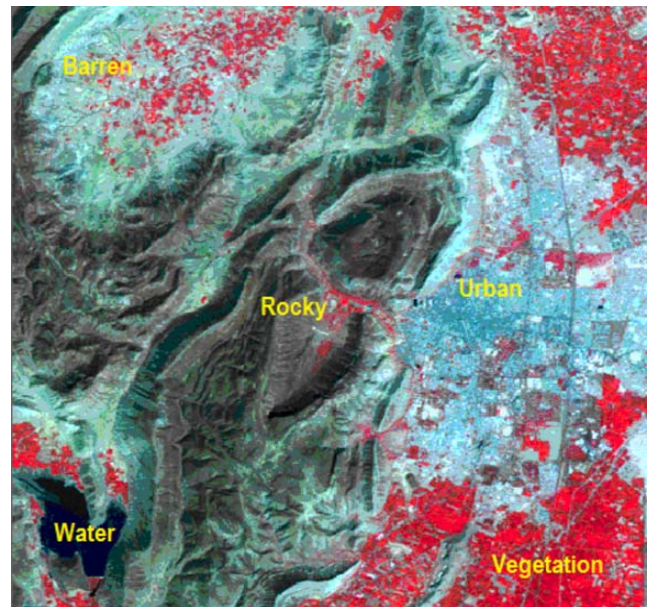


Figure 4: Input Image used for classification

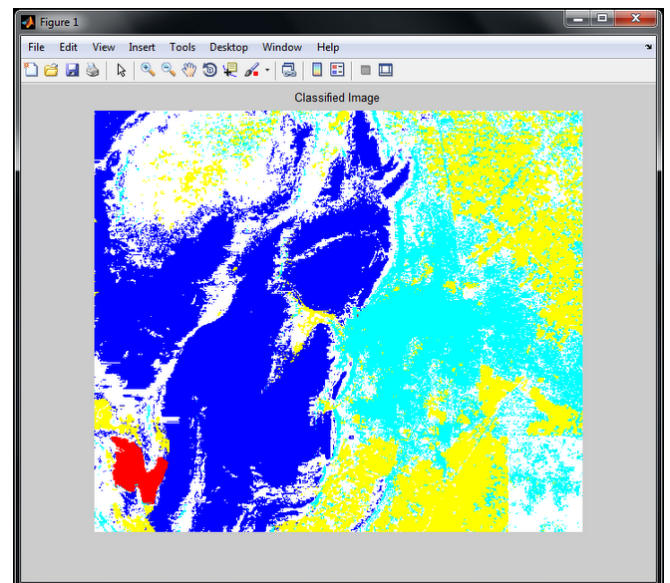


Figure 5: Obtained classified image using Firefly Algorithm

To observe the results of image classification using firefly algorithm, Error Matrix is evaluated. Error matrices describe a relationship between the absolutely classified pixels and erroneous pixels for each terrain class. The obtained Error matrix for firefly algorithm is shown in table 1.

Error matrix provides the evaluation in the form of feature wise evaluation and complete evaluation. Feature wise evaluation parameters are user's accuracy and complete evaluation methods are kappa coefficient and overall accuracy.

Table 1: Error matrix for Firefly Algorithm

Feature	Rocky	Water	Barren	Urban	Vegetation	Total
Rocky	80	0	4	0	0	84
Water	7	54	4	0	4	69
Barren	0	0	93	0	0	93
Urban	3	0	1	110	0	114

Vegetation	2	1	0	17	121	141
Total	92	55	102	127	125	501

User’s accuracy is an extent of how well classification is performed by row wise category. Producer’s Accuracy is an extent of how accurately classification is performed by the column wise category. Feature wise user’s accuracy and producer’s accuracy are shown in table 2.

Table 2: Feature wise User’s Accuracy and Producer’s Accuracy using Firefly Algorithm

Classifier/ Feature	Water	Vegetation	Urban	Rocky	Barren
User’s Accuracy	78.26%	85.81%	96.49%	95.2%	100%
Producer’s Accuracy	98.18%	96.80%	86.61%	86.9%	91.17%

B. Comparative Analysis

Further, firefly algorithm for image classification is compared with BBO [10], PSO [11], Hybrid FPAB/BBO, Hybrid ACO/SOFM and Hybrid ACO/BBO on the basis of kappa coefficient and overall accuracy. Overall Accuracy can be defined as the ratio of number of correct observations divided by the total number of classifications. Kappa Coefficient is evaluated using the error matrix and is considered as the indirect measure of the expert’s knowledge.

The evaluated values of firefly algorithm and other existing concepts are shown in figure 6 and figure 7.

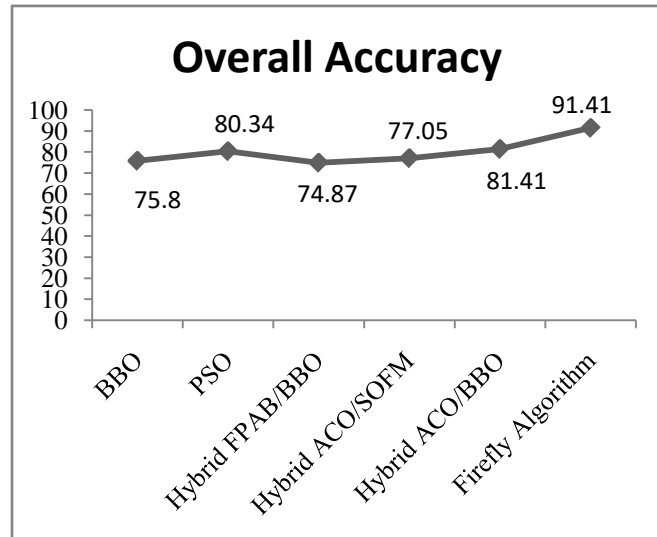


Figure 6: Comparison based on Overall Accuracy

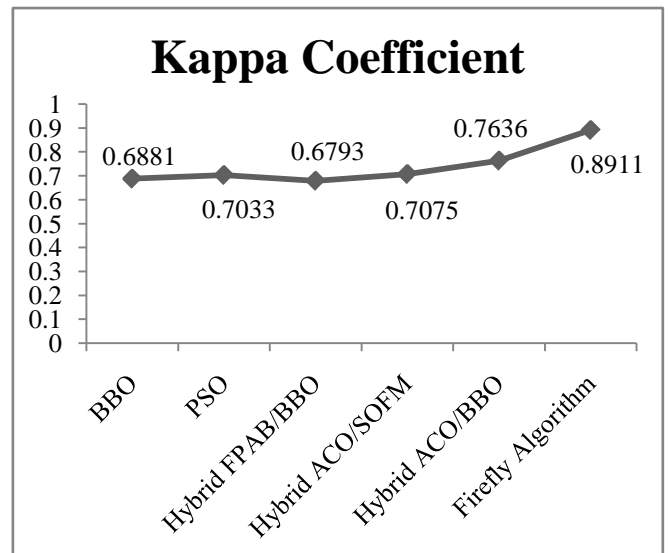


Figure 7: Comparison based on Kappa Coefficient

VI. CONCLUSION

Nature being a source of inspiration has developed various new terminologies like fireflies based firefly algorithm that can be used to optimize the hard problems. In this research work, we have used firefly algorithm for satellite image classification of Alwar area. Results are evaluated based on complete and feature wise evaluation with comparison with BBO, PSO, Hybrid FPAB/BBO, Hybrid ACO/SOFM and Hybrid ACO/BBO approaches. As shown in figure 6 and figure 7, we can say that proposed concept is efficient enough to classify the land cover features.

VII. REFERENCES

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