ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 6, June 2015

Hybridization of Cuckoo Search & Artificial Bee Colony Optimization for Satellite Image Classification

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Abstract: In last few decades, Image classification has become one of the extensively used research area due to its wide range of applications like ground water exploration, environmental disaster assessment, terrain feature extraction, urban planning, & land use monitoring etc. There exist various traditional, nature inspired and other classification approaches that are being used for the satellite image classification. But the results obtained from the existing algorithms are nor much efficient to use for any real life application. In this paper, we are applying the swarm intelligence based hybrid approach to classify the land cover features. The algorithms considered for the hybridization are Cuckoo Search (CS) and Artificial Bee Colony Optimization (ABC). As individual algorithm are not much efficient for classification, so hybrid concept is considered to make the classification more efficient and accurate. The output results obtained from the hybrid concept are compared with the individual CS & ABC algorithms. Also some other algorithms like Particle Swarm Optimization (PSO), Biogeography Based Optimization (BBO), hybrid ACO/BBO, hybrid CS/PSO, hybrid CS/ACO and hybrid ABC/BBO are considered for the comparison purpose.

Keywords: Swarm Intelligence, Cuckoo Search (CS), Artificial Bee Colony Optimization (ABC), Remote Sensing, Image Classification.

I. INTRODUCTION

Remote Sensing is the science or art of getting important information about the surface of earth and its objects without any direct contact with that particular surface/object [1][2]. This is done by sensing & recording the reflected/emitted energy and processing, analysing & applying that information. It is well known that a human being perceives all the information about the surrounding world with the help of his five senses. Formally, Image Classification can be defined as the process by which different pixels of the image are consigned to different feature classes as per their identification found. For this, a remotely sensed multi-spectral image is used to assign the pixel values [3][4]. The overall objective of this image classification is to change the digital image into their respective feature class categorization so that further can be manipulated for the real life problem.

With the extensive use of images classification for the Land Cover Mapping it is required that the approach used for the image classification should be more accurate and efficient.

As the traditional techniques for the automatic Image Classification have their certain shortcomings like high resolution images needed for better information retrieval, and the accuracy limitations are also there. Also the recent Soft Computing approaches for Image Classification are not able to provide good results in case of ambiguity. So for achieving the better accuracy even with the low resolution satellite images and better land cover mapping we are using the Swarm Intelligence for Remote Sensing Image Classification. In this paper, we are applying the hybrid concept of CS and ABC for the classification for natural land cover features of alwar area.

Rest of the paper is organized in the manner as: Section II presents the basic concepts of CS and ABC, Section III briefs about the dataset considered. Section IV explains the proposed hybrid concept, Section V gives the complete experimental results and comparison with individual CS & ABC techniques and other swarm intelligence techniques

II. BASIC CONCEPTS

The Swarm intelligence based basic concepts included for the hybridization are Cuckoo Search and Artificial Bee Colony Optimization. These concepts are explained as below:

A. *Cuckoo Search*

Cuckoo Search (CS) is nature inspired optimization algorithm that came under the category of Swarm Intelligence and introduced by Yang and Deb [5]. The optimization feature of cuckoo bird is based on the shrewd behaviour of cuckoo bird to find its solution. Cuckoo bird works individually and stores their egg in the nest of another bird’s nest by pursuing their clever behaviour. The way to lay the reproductive egg in a parasitic manner is one of the important features of cuckoo bird. There may be chances to strike by other bird if the host bird found the different egg in their nest, then the host bird can destroy the egg. So, the main focus of cuckoo bird is to find the optimized solution that can easily match their living environment and this can be easily completed by the

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 6, June 2015

notion of random walk of Lévy flight [6]. In the end, best optimized solution match is found as per the problem [7].

Lévy flight helps to find the new solution of the problem in terms of solution parameter x_{t+1}. Essentially it gives a random walk to the whole process however the Lévy distribution is used to draw the large steps which has an infinite variance with an infinite mean.

Here, the consecutive steps (jumps) of a cuckoo essentially form a random walk process which obeys the power-law step length distribution with a heavy tail.

$$x_i^{(t+1)} = x_i^{(t)} + \alpha \oplus \text{Lévy}(\lambda)$$

…Equation (1)

$$\text{Lévy} \sim u = t^{-\lambda}, \qquad (1 < \lambda \leq 3),$$

…Equation (2)

Where, $\alpha > 0$ is the step size that is according to the scales of the problem. In most of the cases α is taken as *O* (1) and the product $\oplus$ stands for entry-wise multiplications. This entry-wise multiplication is similar to as used in Particle Swarm Optimization; Efficiency is the main difference in this. In CS the random walk via Lévy flight is more efficient in exploring the search space as compare to PSO because the step length in CS is much longer in the long run.

B. *Artificial Bee Colony Optimization*

Artificial Bee Colony Optimization is originally presented by Dervis Karaboga [8] from the inspiration of collective behaviour of honey bees. In the nature honeybees explore the locality of their hive in search of better nectar sources [10]. There are 3 types of bees depending on their work, employed bees, onlooker bees and the scout bees. The employed bees first leave the hive and search in particular direction for sources of pollen and nectar. After finding a suitable nectar source they go back to the hive and share their information to onlooker bees. Information exchange is done by the bees at the dancing areas in the hive. Bees exchange information (the locations, quantity and quality of existing sources of pollen, nectar) about the food sources by intensity, duration and direction of the bee during 'waggle dance'. The onlooker bee after watching the dances chooses the most profitable source and follows one of the employed bees to the discovered source of food. Upon arrival to the food source, the foraging bee takes a load of nectar and returns to the hive. Scout bees investigate new areas with possible food sources randomly without any prior information [9]. The described process continues constantly, while the bees from a hive collect nectar.

An artificial onlooker bee chooses a food source depending on the probability value associated with that food source, p_i, calculated by the following equation 3:

$$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n}$$

…Equation (3)

Where fit_i is the fitness value of the solution *i* which is proportional to the nectar amount of the food source in the position *i* and SN is the number of food sources which is equal to the number of employed bees or onlooker bees.

The value of fit_i of the i^{th} employed bee can be calculated by equation 4 below:

$$fit_i = \begin{cases} \dfrac{1}{1+f_i}, & if\ (f_i \geq 0 \\ 1 + abs(f_i), & if\ (f_i < 0) \end{cases}.$$

…Equation (4)

Where f_i is the objective function specific for the problem.

In order to produce a candidate food position from the old one in memory, the ABC uses the following equation (5):

$$v_{ij} = x_{ij} + \emptyset_{ij}(x_{ij} - x_{kj})$$

…Equation (5)

Where $k \in \{1, 2, \ldots, SN\}$and $j \in \{1,2, \ldots,D\}$ are randomly chosen indexes. Although *k* is determined randomly, it has to be different from i. Φ_{ij} is a random number between [-1, 1]. It controls the production of neighbor food sources around x_{ij} and represents the comparison of two food positions visually by a bee. As can be seen from (5), as the difference between the parameters of the x_{ij} and x_{kj} decreases, the perturbation on the position x_{ij} gets decreased, too. Thus, as the search approaches the optimum solution in the search space, the step length is adaptively reduced.

If a parameter value produced by this operation exceeds its predetermined limit, the parameter can be set to an acceptable value. In this work, the value of the parameter exceeding its limit is set to its limit value.

The food source of which the nectar is abandoned by the bees is replaced with a new food source by the scouts. In ABC, this is simulated by producing a position randomly and replacing it with the abandoned one. In ABC, if a position cannot be improved further through a predetermined number of cycles, then that food source is assumed to be abandoned. The value of predetermined number of cycles is an important control parameter of the ABC algorithm, which is called 'limit" for abandonment. Assume that the abandoned source is x_i and $j \in \{1,2, \ldots,D\}$, then the scout discovers a new food source to be replaced with x_i . This operation can be defined as in:

$$x_i^j = x_{min}^j + rand[0,1](x_{max}^j - x_{min}^j)$$

…Equation (6)

After each candidate source position v_{ij} is produced and then evaluated by the artificial bee, its performance is compared with that of its old one. If the new food source has an equal or better nectar than the old source, it is replaced with the old one in the memory. Otherwise, the old one is retained in the memory. In other words, a greedy selection mechanism is employed as the selection operation between the old and the candidate one.

III. DATASET CONSIDERED

A well-known multi-featured area Alwar situated at Rajasthan, India is considered for the all the experimental techniques. The feature classes of this area are Barren, Rocky, Vegetation, Urban and Water. The multi-spectral images of Alwar region are taken using Canadian satellite

 DOI 10.17148/IJARCCE.2015.4671

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 6, June 2015

and an Indian satellite named LISS-III having seven bands of spectral images named as Digital Elevation Model (DEM), Radarsat-1 (RS1), Radarsat-2 (RS2), Near Infra-Red (NIR), Middle Infra-Red (MIR), Red and Green. Canadian Satellite Radarsat is used to capture RS1 & RS2 satellite digital images. These 7-band images are shown in figure 1.

All the seven images are geo-referenced and the image dimension is 472×546 pixels. When all of these images are combined using the ERDAS software, a combined stack image is obtained which is considered as the original Alwar image is shown by figure 2.

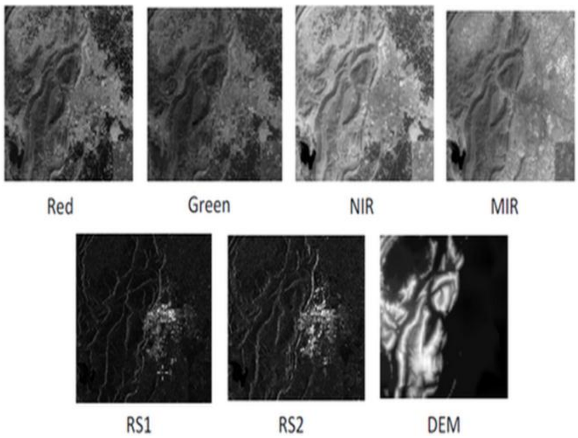

Figure 1: 7- band satellite images of Alwar

IV. Proposed Algorithm

In this paper, hybrid concept of Cuckoo Search and Artificial Bee Colony Optimization is applied for image classification. The main goal of this hybridization concept is to improve the search strategy of cuckoo bird to find the optimized host nest by embedding the global search strategy solution of ABC algorithm. In ABC employed bees, onlooker bees and Scout bees give the quality of the food Nectar by filtering the solution from the all the bees. So, the cuckoo egg would be at best optimized position by using ABC technique. In this we can create a more optimized technique by integrating two best Swarm Optimization techniques and can give a more efficient solution for the classification of satellite image. The proposed algorithm is structured as below:

Input: 7-band satellite image of Alwar and dataset values with respect to x, y coordinates.
Output: Classified Alwar Image.

Algorithm

Step I: Consider the image to be classified. Here, cuckoo egg is considered as the pixels under experimentation of classification and host nest are feature classes.

Step II: Initialise the population of the solutions (host nest) by making use of 7 band image values for the pixels to be classified.

Step III: Find the best solution for the cuckoo egg to store in the host nest.

To find the quality solution for the cuckoo eggs (i.e. best feature class for the pixel under classification experimentation) apply the algorithm of Artificial Bee Colony optimization (ABC).

Here consider employee bees as the solution values. Calculate the nectar quality of the solution by finding the Euclidean distance between the solution value and a specific employed bee using the expression given below:

$$d(p,q) = d(q,p) = \sqrt{(q_1-p_1)^2 + (q_2-p_2)^2 + \cdots + (q_n-p_n)^2} = \sqrt{\sum_{i=1}^{n}(q_i-p_i)^2}$$

…Equation (7)

where, n= 1 to 7 band pixel values, d is the distance between the egg and host, p_i is the ith band pixel of cuckoo egg and q_i is the ith band pixel of host.

Apply the greedy selection by the onlooker bees to check the quality solution found by the employed bees.

Repeat until all the neighbourhood pixels considered.

Find the function (f_i) by using the Euclidean distance value.

Evaluate the fitness function value for the best employed bee. Fitness function can be calculated by equation 8 below:

$$fit_i = \begin{cases} \dfrac{1}{1+f_i}, & if\ \ (f_i \geq 0 \\ 1+abs(f_i), & if\ \ (f_i < 0) \end{cases}.$$

…Equation (8)

Where f_i is the objective function specific for the problem.

Calculate the probability value P_i by using the equation 9 below:

$$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n}$$

…Equation (9)

Maximum the probability value better will be the solution.

Repeat the above inner loop steps until all these pixels are considered.

Store the best solutions and discard the worst.

Sort the above calculated best solution by ABC algorithm for the cuckoo egg.

Step IV. To sort the solutions, calculate the Pearson Correlation between the quality solution calculated by the algorithm and cuckoo egg.

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

…Equation (10)

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

The value of the Pearson Correlation coefficient always varies between -1 to +1. If the value is positive, it

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

IJARCCE

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 6, June 2015

means both the values are positively correlated but if the value is negative, then it means quantities are negatively correlated.

Step V. As per the above mentioned steps, assign the best solution class to the pixel under experimentation.

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

V. Results and Discussion

A. *Image Classification*

In this experimentation, we have used a multispectral 7-band image of the Alwar area, having good terrain features like water, vegetation, rocky, barren and urban. Figure 2 shows the original image with their land cover features. These features are presented by figure 3 after classification with Hybrid CS & ABC algorithm, where water is represented by red color, vegetation is represented by green color, rocky area is represented by white color, urbanization is represented by blue color and barren is represented by cyan color.

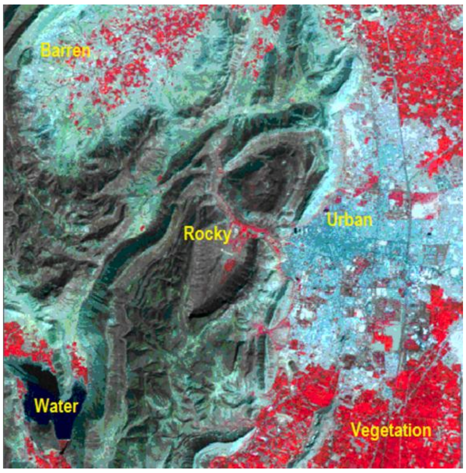

Figure 2: Original Alwar Image

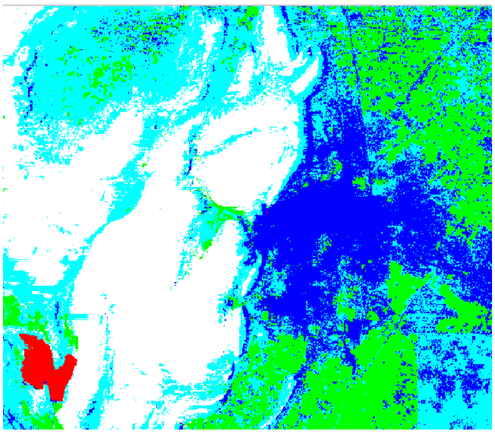

Figure 3: Classified image after applying Hybrid CS & ABC

B. *Accuracy Assessment*

Accuracy Assessment is one of the most important tools of remote sensing to check the accuracy level of the classification done [11]. The goal of this accuracy assessment is to observe how efficiently the pixels are considered into correct feature classes of the investigation area. Accuracy assessment can be determined by *Error matrix* (also known as *Confusion matrix*). The Error matrix obtained after applying hybrid CS/ABC algorithm to Alwar image is shown in table I, where diagonal elements are the correct classified and other are erroneous classified error pixels. The total pixels taken for each feature class are as:

- Water pixels- 74
- Vegetation pixels- 161
- Urban pixels- 160
- Rocky pixels- 101
- Barren pixels- 67

TABLE I: Error Matrix of Hybrid CS & ABC

Feature	Water	Vegetation	Urban	Rocky	Barren	Total
Water	74	0	0	0	0	74
Vegetation	0	161	0	0	0	161
Urban	0	0	158	4	2	164
Rocky	0	0	2	96	0	98
Barren	0	0	0	1	65	66
Total	74	161	160	101	67	563

By using error matrix, we can find the following parameters of kappa coefficient, overall accuracy, user's accuracy, producer's accuracy and overall accuracy for the efficiency of results with proposed hybrid concept. These results are calculated along with the comparison of individual techniques of CS [12] and ABC [13] for image classification in the next section.

C. *Comparison with CS and ABC*

In this comparison the results of hybrid CS & ABC are compared with the individual techniques of CS and ABC by considering the parameters of kappa coefficient, overall accuracy, user's accuracy and producer's accuracy. User's accuracy is the row-wise accuracy level that can be calculated by dividing the correctly classified pixels with the row-wise total pixels of each feature class. User's accuracy of the above there techniques are given by table II as below:

TABLE II: Comparison of User's Accuracy

Classifier/Feature	**Water**	**Vegetation**	**Urban**	**Rocky**	**Barren**
ABC	100	99.09	96.55	100	69.41
CS	100	99.09	97.6	100	78.94
Hybrid CS/ABC	100	100	96.34	97.95	98.48

Producer's accuracy is the column-wise accuracy level that can be calculated by dividing the correctly classified pixels with the column-wise total pixels of each feature class. The producer's accuracy of hybrid CS/ABC and individual ABC & CS are explained as below by table III.

TABLE III: Comparison of Producer's Accuracy

Classifier/Feature	**Water**	**Vegetation**	**Urban**	**Rocky**	**Barren**
ABC	100	100	80.57	100	93.65
CS	100	100	87.76	100	95.23
Hybrid CS/ABC	100	100	98.75	95.05	97.01

ISSN (Online) 2278-1021
ISSN (Print) 2319-5940

IJARCCE

International Journal of Advanced Research in Computer and Communication Engineering
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Kappa coefficient is one of the most acceptance parameter to check the classification accuracy of some algorithm. The kappa coefficient for the CS, ABC and Hybrid CS/ABC are as below by figure 4:

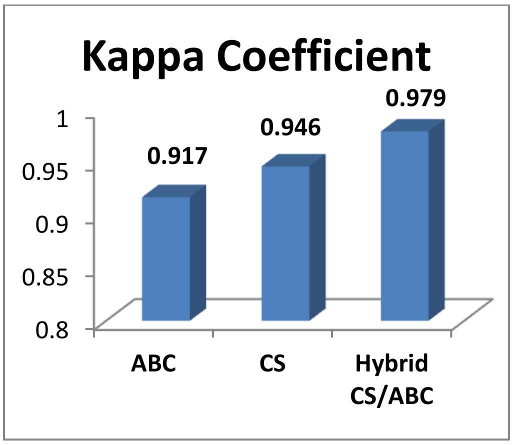

Figure 4: Kappa coefficient of CS, ABC and Hybrid CS/ABC

Overall accuracy can be calculated by dividing the sum total of all the correctly classified pixels (i.e. diagonal elements of error matrix) by the total number of pixels. Overall accuracy of CS, ABC and Hybrid CS/ABC is as given by figure 5 below:

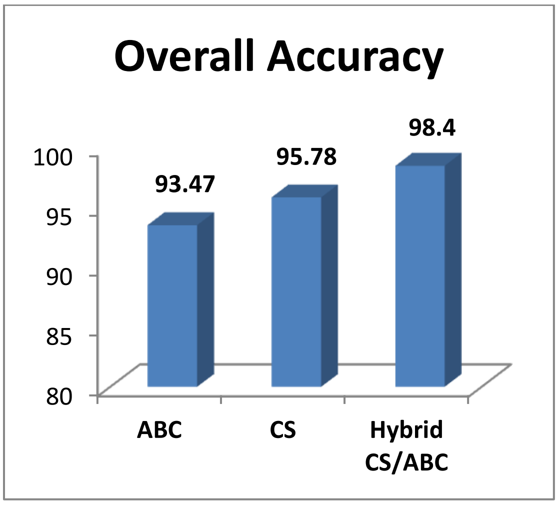

Figure 5: Overall Accuracy of CS, ABC and Hybrid CS/ABC

D. *Comparison with other Techniques*

For the comparison with the other swarm intelligence technique, we are considering the one of well acceptance parameter of kappa coefficient that can be calculated from the error matrix.

The algorithms considered for the comparison are Particle Swarm Optimization (PSO) [14], Biogeography Based Optimization (BBO) [15], hybrid ACO/BBO [16], hybrid CS/PSO [17], hybrid CS/ACO [18] and hybrid ABC/BBO [19].

The kappa coefficient comparison is as explained by figure 6 below:

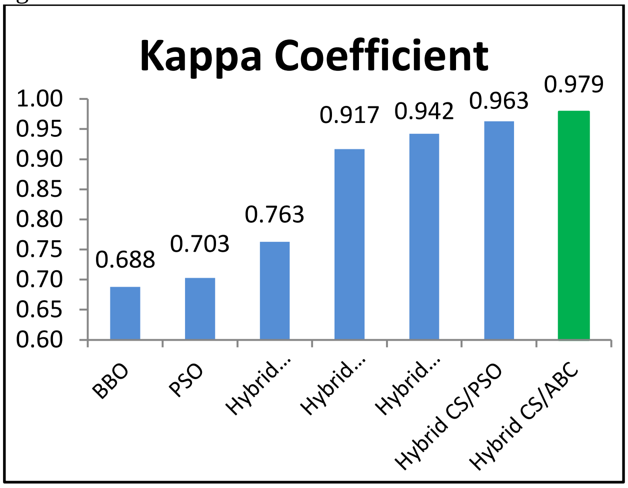

Figure 6: Comparison of Proposed algorithm with other swarm intelligence techniques

VI. Conclusion

In this paper, we have proposed the hybrid concept of CS and ABC for the image classification of Alwar region. The proposed algorithm gives the efficient results as compare to individual CS & ABC and other Swarm intelligence techniques. The results can be determine from the figure 4,5,6.

The kappa coefficient parameter of accuracy assessment perform superlative as an efficiency parameter by giving the result value of 0.979. From the Figure 3, the accuracy of classification of Alwar region can be clearly seen. In this way, the proposed algorithm of hybrid CS & ABC perform better as compare to other swarm intelligence based techniques.

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