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Earth Observation and Satellite Imagery using ACO and GA

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Abstract: *A Satellite image classification is a significant method used in remote sensing for the automated analysis and pattern recognition of satellite data, which facilitate the automated understanding of a large amount of information. These days, there exist many types of classification algorithms, such as parallelepiped and minimum distance classifiers, but it is still essential to get better their performance in terms of correctness rate. Alternatively, over the last few years, cellular automata have been utilized in remote sensing to implement procedure related to simulation. While there is little preceding research of cellular automata related to satellite image classification, they offer much reward that can improve the results of classical categorization algorithms. In this thesis, we are applying a Swarm intelligence based hybrid algorithm of Ant Colony Optimization and Genetic Algorithm Optimization (GA) to execute the satellite picture classification. On merging them, they give an immense impact that is very significant in remote sensing application. The outcomes generated through the hybrid algorithm are contrasted with the outcome attained by means of other swarm intelligence to demonstrate the proofs of our proposed hybrid algorithm. The test of hybrid method is accomplished by categorizing a multi-spectral, high resolution satellite picture of Alwar region.*

Keywords: *Image classification, Multispectral image classification, remote sensing, Swarm intelligence, Ant Colony Optimization algorithm, Genetic Optimization Algorithm.*

I. INTRODUCTION

Image classification plays an important role in remotely sensed data. Often image classification is applied to remotely sensed land use data to generate a map for picture analysis. Consequently, this one is utilized by means of an investigation instrument for the digital data. Image classification is one of the important approaches for recognizing different terrain features [1]. The analysts determine which classification method meets his specific task. At present, numerous techniques like Evolutionary algorithms, Artificial Neural Network, Ant Colony Optimization, Particle Swarm Optimization and Biogeography Based Optimization are being applied to picture classification. This kind of natural computing procedure could even be named as nature motivated technique [2]. Consequently every single analyst chooses which particular classifier is appropriate for the task in hand.

Remote sensing refers to the technology of acquiring information about the earth's surface features (land and water) and atmosphere using space-borne platforms. Satellite remote sensing has been recognized as a valuable tool for making decisions, observing, describing, and analyzing, about our environment [3, 4]. Multi-spectral images capture different terrain topographies similar to barren, water, vegetation, rocky, and urban, that is specifically being classified for further requirement for image analysis [5]. Thus image classification and remote sensing are inter-twined to each other. A Remote sensing has been used in numerous ecological applications with the plan of solve and getting better all sorts of problems: soil quality studies, water resource research, meteorology simulations, and environmental protection, among others [6]. To resolve all of these problems, one must bring together and process huge amounts of satellite data, which create one of the hardest problems facing remote sensing [7]. It is the way to classify the objects on the earth without makes physical contact to it with the help of highly actuated sensors and work on the propagated signals which gets reflected by the ground objects like water, rock, vegetation's soil and many others in the form spectrum that are later on converted in Digital Number or DN values [8]. Amongst all of the techniques used in remote sensing to help forecaster expert understand the data gathered, classification algorithms are the most useful and talented [9]. These classification algorithms for satellite images group together image pixels into a limited number of classes, which helps in interpret a great deal of data controlled in the spectral bands [10]. When applying a classification algorithm to a dependency picture, the information attain through the satellite broadcasting sensors as digital levels are altered into a categorical scale that is easily interpret by analyst experts. The resultant classified image is a thematic map of the unique satellite image, and pixels belong to the same class split alike spectral character [11].

With the help of satellite image classification various features of our nature can be identified. The general features on which scientists generally work are water, barren, urban and vegetation areas. We have worked on Alwar region of Rajasthan as shown in figure 1.

Indeed other features are being recognized but these are commonly available in any kind of land areas. Thus land covers all these common category of topographies. Throughout feature extraction we make effort in the direction of identifying all those features that land is consisting of. As our dataset is Alwar region of Rajasthan thus we have depicted its image to understand land cover feature.

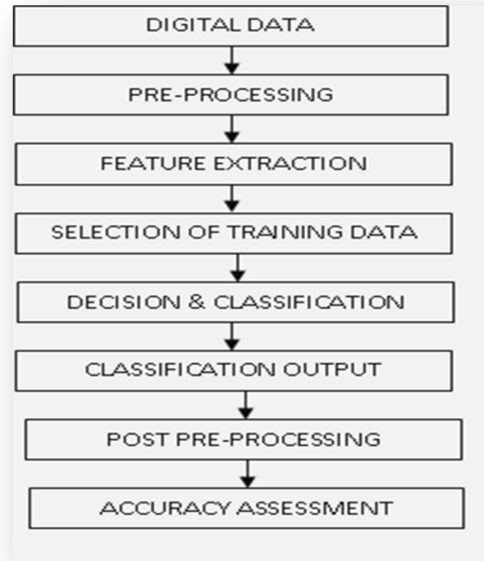

Figure 1: Steps for Image classification

In this paper, we tried to focus on extracting the natural terrain features like urban, vegetation, rocky, barren and water from satellite image using membrane computing. Though water has been already extracted through membrane computing but these papers classified the image into other different terrain features also and show how membrane computing classifies the homogeneous, heterogeneous and sparse regions of the specified area.

2. PREVIOUSLY WORK DONE

S. NO	AUTHORS	WORK DONE
1.	Harish Kundra and Dr. Harsh Sadawarti	In this paper, authors have recommended a novel technique in which they are applying Swarm intelligence based hybrid algorithm of Cuckoo Search (CS) and Ant Colony Optimization (ACO) to perform the satellite image classification. Although both are Meta heuristic bio-inspired methods, but then again still uniting them contributes an abundant influence particularly in the app arena of remote sensing. The key benefit of utilizing the crossbreed notion is that the search approach directed by CS is substituted by the shortest preeminent path establish through the Ants present in ACO procedure for the top host nest essential by cuckoo egg. The consequences formed by the hybrid process are matched with the end result which is further attained by several other swarm intelligence dependent Hybrid procedure FPAB/BBO, ACO/BBO, ABC/BBO, and ACO/SOFM, to display the signs of our anticipated hybrid process. The examination of hybrid procedure is accompanied by categorizing a multi-spectral, great resolution satellite picture of Alwar area.

2	Akanksha Bharadwaj, Daya Gupta and V.K. Panchal	In this by applying a Meta heuristic approach called Cuckoo Search in the area of image classification. The main advantage of this algorithm over other Meta heuristic approach is that its search space is extensive in nature. The proposed methodology is applied to the Alwar region of Rajasthan. The image used is a 7 band image of 472 X 546 dimensions from Indian Remote Sensing Satellite Resiurcesat. This procedure has taken practically all of the terrain features and showed high degree of efficiency for almost all the regions (water, vegetation, urban, rocky, and barren) with a Kappa coefficient is 0.9465.
3	Lavika Goel, Daya Gupta, and V. K. Panchal	This paper extends the blended BBO by considering the statistic that the particular no. of SIVs or else the decision variables possibly will not remain constant for all candidate solutions (habitats) that are part of the worldwide habitat. In the meantime the physiognomies of each and every single habitat diverge significantly hence, matching all the habitats utilizing the identical set of SIVs may be misleading and also may not lead to an optimal explanation. Henceforth, in their dynamic prototypical, they deliberate the fact that HSI of a solution is affected by factors other than relocation of SIVs which are solution characteristics, likewise. These additional aspects can be modeled as several definitions of HSI of a habitat, each single definition based on a diverse group of SIVs which simulates the effect of these additional aspects. They also determine the enactment of the recommended model by running it on the real world problem of land cover feature extraction in a multi-spectral satellite image. They demonstrate its performance on the dataset of Alwar region in Rajasthan where it proves itself to be an efficient feature extractor as an extension to the original biogeography based land cover feature extractor.
4	Daya Gupta, Bidisha Das, and V.K.Panchal	In this document author proposes systematic outline of membrane computing method in land cover feature extraction. Membrane computing is a novel branch of natural computation that has an immense deal of distribution as well as holds maximal parallelism. The bio-inspired method is utilized for picture classification in addition to these specific pictures are known as remote sensing satellite picture. The terrain landscapes similar to vegetation, water, rocky, barren, in addition to urban are required to be categorized as their data arrange for enormous support throughout climatic behavioral changes, natural disaster, as well as in several further regions of environmental variations. They have well-defined constraints of membrane computing in land cover feature abstraction terms consequently displaying that the particular idiom of membrane computing is valuable for picture classification in addition to then they have projected a procedure of P framework. The recommended procedure is implemented to Alwar region of Rajasthan of 472X576 measurement that also contains 7 Band Indian Resources at Satellite Digital Numbers. The procedure has apprehended nearly all types of the terrain structures of these particular area. It demonstrates practically 99% competence on vegetation as well as water area. The KHAT figures displays that suggested procedure has a complete proficiency of about 0.68812.
5	Vinit Kumar, V.K. Panchal, Dinesh Goyal, and Vartika Singh	This paper mainly focuses upon the probability occurrence of honey beef in the direction of choosing their specific nectar quality. On that basis, they will easily classify their picture objects. In this paper, they have offered a probability based honey bee method as a proficient classifier used for high resolution multi-spectral satellite picture of Alwar region. The specific kappa coefficient of 0.941 as well supports their algorithm's competence at this specific time. ABC mechanisms on the complete image captivating each and every single pixel and hence can identify the heterogeneous portions in image and can classify each portion perfectly.

6	Jagdeep Kaur and Kirandeep Kaur	With the intention of having clearness in the satellite pictures they have utilized PSO method. In their work they have used dataset of Alwar region. When assimilated with old-style clustering procedures, complications for instance local optima as well as sensitivity towards initialization, are condensed, consequently discovering a greater region utilizing worldwide search. This segmented picture is later categorized utilizing coefficient of Kappa.

3. PROPOSED TECHNIQUES

3.1 ACO

Assuming Xi= (xi1,xi2,…xiD) the position of i-th ANT COLONY in D-dimension, V_i= (vi_1,vi_2,….,vi_D) is its velocity which represents its direction of searching. In iteration process, each ANT COLONY keeps the best position p best found by it, besides, it

also knows the best positioning best searched by the group ANT COLONYs, and changes its velocity according two best positions. The standard formula of ACO is as follows:

$$v_{id}^{k+1} = wv_{id}^{k} + c_1 r_1 (p_{id} - x_{id}^{k}) + c_2 r_2 (p_{gd} - x_{id}^{k}) \qquad (1)$$

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1} \qquad (2)$$

In which i=1,2,…N,N-the population of the group ANT COLONYs; d=1,2,…D; k-the maximum number of iteration; ,-the random values between [0,1], which are used to keep the diversity of the group ANT COLONYs; c1,c2; the learning coefficients, also are called acceleration coefficients; v_{1d}^{k} -the number d component of the position of ANT COLONY in k-the iterating; pad, the number d component of the best position particles has ever found; pad, the number d component of the best position the group ANT COLONYs have ever found.
The procedure of standard ACO is as following:

1) Initialize the original position and velocity of ant swarm.
2) calculate the fitness value of each ANT COLONY;
3) For each ANT COLONY, compare the fitness value with the fitness value of p best, if current value is better, then renew the position with current position, and update the fitness value simultaneously;
4) Determine the best ANT COLONY of group with the best fitness value, if the fitness value is better than the fitness value of g best, then update the g be stand its fitness value with the[8] position;
5) Check the finalizing criterion, if it has been satisfied, quit the iteration; otherwise, return to step 2.

3.2 Genetic Algorithm

Genetic algorithm (GA) is a stochastic seek strategy that will mimics the actual healthy advancement offered by simply Charles Darwin throughout 1858. GA has been effectively given to a variety of combo issues.

Genetic Algorithm Methodology:

a. At random, produce an initial population M (0).

b. Compute as well as help save the actual fitness f(m) for every specific individual m in the current population M(t);

c. Specify selection probabilities p (m) for every specific individual m throughout M (t) making sure that p (m) is actually proportional to f (m).

d. Crank out M (t+1) by simply probabilistically choosing individuals from M (t) to produce offspring via genetic operators.

e. Repeat step 2 until satisfying solution is actually attained.

4. HYBRIDISATION OF ACO AND GA TECHNIQUES

In our proposed work we have proposed a hybrid of Ant Colony Optimization Algorithm with Genetic Algorithm. Both of the, Ant colony optimization and Genetic Algorithm Optimization are meta-heuristic
Swarm intelligence reliant search optimization procedures which impersonate as the representation of natural biological development as well as social activities of the specific species. The activities of such

category of species is directed through advancement, learning, in addition to adaptation. In these methods fitness factor chooses all kinds of these features. In Ant Colony Optimization, initially Ants deposit some pheromone on the different ways to find the shortest best path for food source. Each Ant initially goes here and there to find the food and deposit same amount of pheromone until they found the best food source. When they become successful to find the food source then each deposited pheromone goes on increasing on the same way to the shortest path of the destination food. In Genetic Algorithm, it first starts by identifying a data set entitled as population. At that time, these are independently programmed utilizing bits, characters or integers and they form a chromosome. The next operation on them is an 'Evaluation Function' used to determine the original chromosome. Throughout this procedure, twofold dissimilar operations namely, crossover and mutation are performed which is used to imitate the breeding and evolution. The selection of the chromosome is biased towards the fittest of the specific species. Ultimately, the fit chromosome is carefully chosen the minute the optimization criterion is met. In our proposed algorithm, we have proposed hybridization of ACO and GA. In this way, we can create a more optimized method by means of assimilating two finest Swarm Optimization methods. In this manner, the proposed algorithm could probably offer a much more enhanced as well as proficient key intended for the complex problems. In this we have taken multi-spectral images of different regions resembling to barren, water, vegetation, rocky, and urban, that are specifically being classified for further requirement for image analysis. And also taken data set of Alwar region multi-spectral images. The proposed algorithm is structured as below:

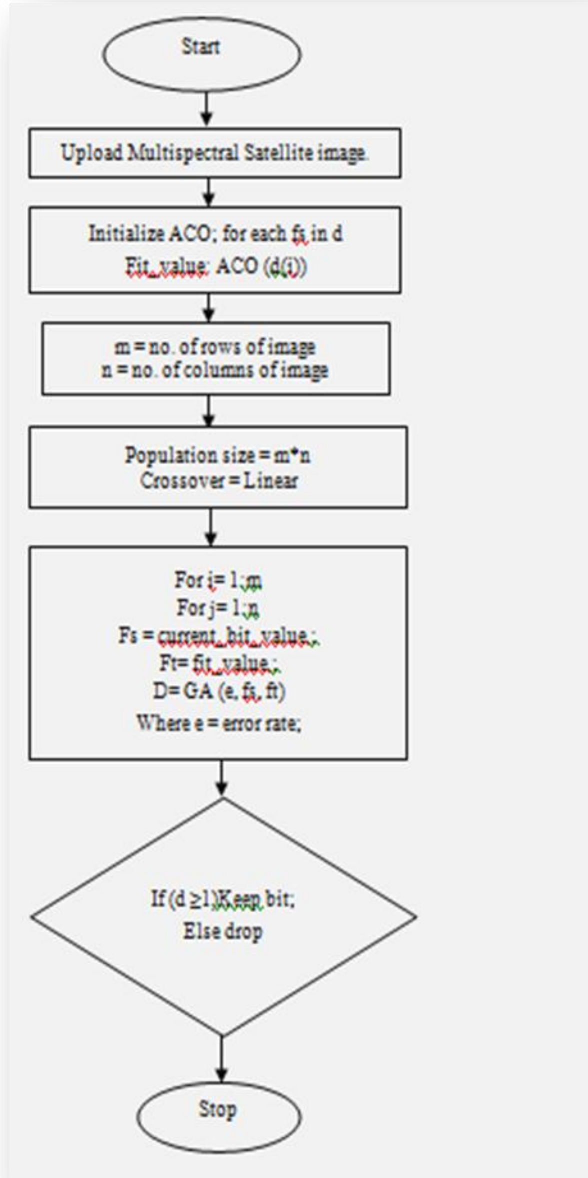

Figure 2: Proposed Work

Methodology

Assumptions:

- Ants are represented by pixels of the image;
- Food sources are the land cover features- water, vegetation, urban, rocky and barren;
- Neighbourhood solutions are the neighbouring pixels of the already classified dataset provided by experts.

- Employed ants are simulated by pixels belonging to classified dataset which contain the pure values of the solution.

Input: Multispectral Satellite image.
Output: Classified image.

Step: 1 Initialization of ACO

⇒ Initialize the population of solutions (food sources).

⇒ Place the employed ants in the food sources.

Step: 2 Selection of destination food foe feature extraction

⇒ The performance of each Ant, i.e., how close the Ant is from the destination food source is measured using fitness function which depends on the optimization problem.

⇒ Here our optimization problem is to find the mean of similarity difference of pixel intensities, given as:

$$f(x) = mean(sqrt((x-y)^2));\ldots$$

⇒ Each Ant starts searching through n- dimensional search space and maintains the following information to find the shortest path:

$\tau_{ij}(t)$ – Revised concentration of pheromone associated with l_{ij}at iteration t

$\tau_{ij}(t-1)$– Concentration of the pheromone at previous iteration (t–1)

$\Delta\tau_{ij}(t)$ – Change in Pheromone concentration

⇒ Each ant is then evaluated according to an objective function. Thus pheromone concentration with each possible route is calculated as follows :

$$\tau_{ij}(t) = \rho\tau_{ij}(t-1) + \Delta\tau_{ij}(t); \qquad t = 1,2,\ldots$$

Where, T is the number of iterations, ρ is the pheromone evaporation rate (0—1) and $\Delta\tau_{ij}(t)$ is the change in pheromone concentration.

The change in pheromone concentration can be calculated as:

$$\Delta\tau ij(t) \sum_{k=0}^{m} \begin{cases} R/fitness_k & \text{if option } l_{ij} \text{ is chosen by ant } k \\ 0 & \text{otherwise} \end{cases}$$

Where, R is the constant called the pheromone reward factor; and $fitness_k$ is the objective function value that is calculated for ant k

⇒ The optimized mean is taken, the lesser the distance similar to the host pixel.

⇒ The host less than the mean are considered and the worst host nests are discarded.

⇒ The similarity host nests are stored

Step: 3 Find the class to which best solution belongs based on the expert data.

The query pixel will also belong to the same class to which the best solution belongs. Hence the query pixel is classified.

End Second Outer Loop.

End First Outer Loop.

Step: 4 Optimization of features using Genetic Algorithm

[Start] Generate irregular populace of n chromosomes (suitable answers for the issue)

[Fitness] Evaluate the wellness f(x) of every chromosome x in the populace

[New population] Create another populace by rehashing after ventures until the new populace is finished.

[Selection] Select two guardian chromosomes from a populace as indicated by their wellness (the better wellness, the greater opportunity to be chosen)

[Crossover] with hybrid likelihood traverse the folks to shape posterity (kids). In the event that no hybrid was performed, posterity is a precise duplicate of folks.

[Mutation] with a transformation likely to change new posterity at every locus (position in chromosome).

[Accepting] Place new posterity in another populace

[Replace] Use new produced populace for a further run of calculation

[Test] if the end condition is fulfilled, stops, and returns the best arrangement in current population.

[Loop] Go to step 2.

Step: 5 Display Classified image

3. EXPERIMENTAL RESULTS

In this paper, we tried to focus on extracting the natural terrain features like urban, vegetation, rocky, barren and water from satellite image using ACO and GA. The whole implementation has been taken place into MATLAB 7.10 environment. Below figures and tables describes the whole process of implementation.

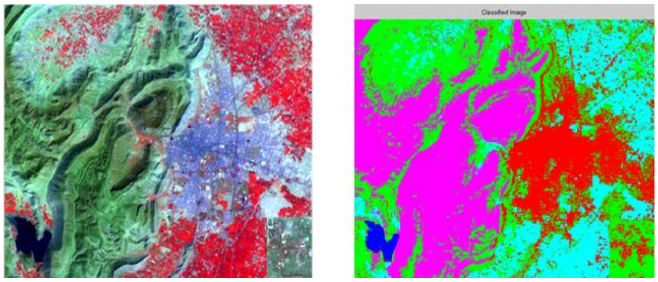

Figure.3 Comparison of Original Alwar image (left) and Classified image (right) using hybrid ACO and GA.

We have taken a multi-sensor, multispectral and multi-resolution picture of a specific region Alwar, Rajisthan in INDIA. The area is selected because it carries some good land cover features like Vegetation, Water, Urban, Barren and Rocky areas. The size of picture used is 548*474 pixels. After applying the proposed algorithms to the Alwar image, the classified image is obtained with different classes. In above figure we have shown the comparison between original Alwar picture and Classified Alwar picture. The different colours define the different terrain features in this image. The Blue colour represents Water region, Cyan colour represent Vegetation region, Red colour represents urban region, Pink colour represents Rocky region and Cyan colour represents Barren region.

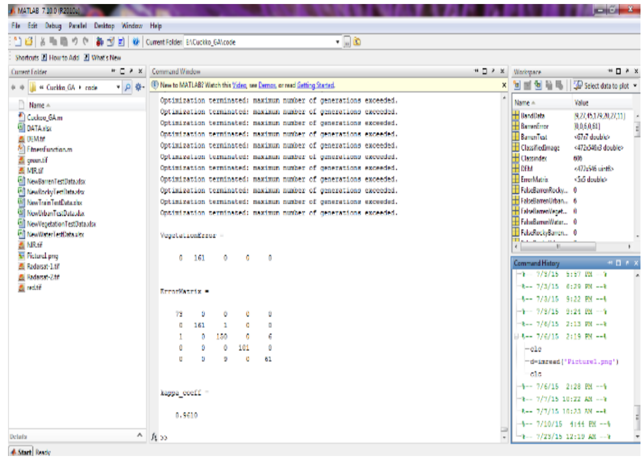

Figure.4 Vegetation matrix, Error matrix and kappa coefficient values

In above figure, we have shown the value of vegetation matrix, error matrix and kappa coefficients obtained after implementing hybrid of ACO and GA on satellite image for classification.

Feature	**Water**	**Vegetation**	**Urban**	**Rocky**	**Barren**	**Total**
Water	73	0	0	0	0	73
Vegetation	0	161	1	0	0	162
Urban	1	0	150	0	6	157
Rocky	0	0	0	101	0	101
Barren	0	0	9	0	61	70
Total	74	161	160	101	67	563

For validation process following number of pixels is taken into consideration in hybrid ACO and GA algorithm:

- Water Pixels - 73
- Vegetation Pixels - 164
- Urban Pixels - 157
- Rocky Pixels - 101
- Barren Pixels - 70

3.1 Calculation of kappa coefficient

The Kappa Coefficient can be defined as the discrete multivariate technique that is used to interpret the results of error matrix. The Kappa statistic incorporates the both the off diagonal observations of the rows and columns and the diagonal observations to give a more robust statement of accuracy assessment than overall accuracy measures. The Kappa Coefficient can be calculated by applying the following formula to the error matrix:

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

Where,
r = no. of rows in the error matrix (r=5 in our case)
x_{ii} = the no. of observations in row i and column i (on the major diagonal)
x_{i+} = total of observations in row i (shown as marginal total to right of the matrix)
x_{+i}= total of observations in column i (shown as marginal total at bottom of the matrix)
N= total no. of observations included in matrix (N=563 in our case)
The Kappa Coefficient of the Alwar image for the hybrid Ant Colony Optimization and Genetic optimization algorithm is 0.9611.

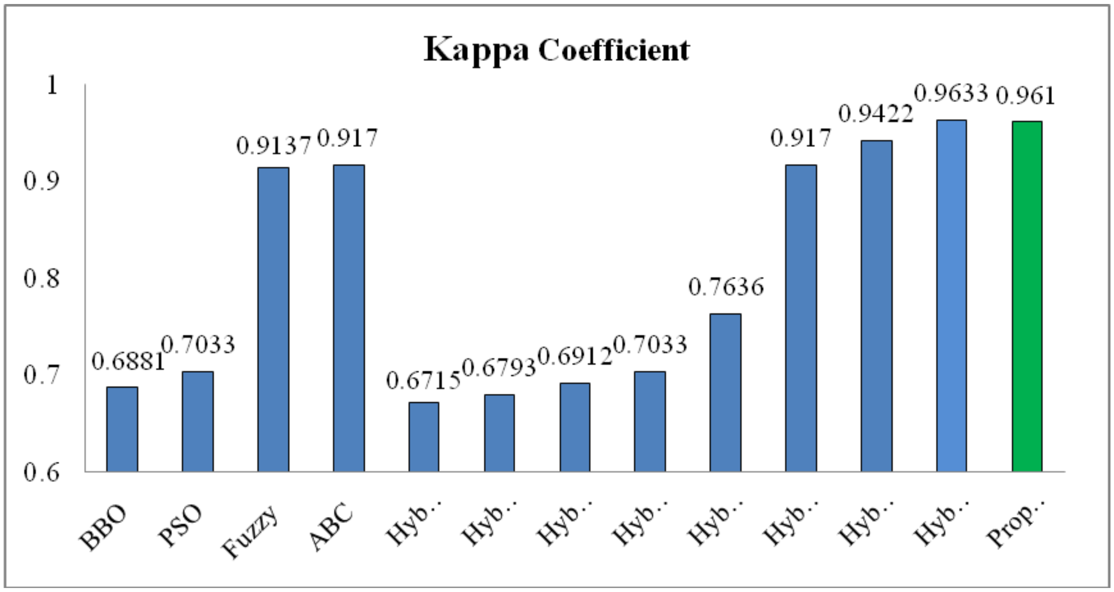

Figure.5 Comparison of result obtained from various past work using kappa coefficient with proposed Work of ACO and GA.

The value of Kappa Coefficient for hybrid of ACO and GA algorithm is 0.961, which shows that the observed classification is better as compared to Kappa Coefficient of some other algorithms as shown in above figure. The Kappa coefficient of Fuzzy set (Banerjee et al., 2012), BBO (Panchal et al., 2009) (Goel L. et al., 2011), PSO (Panchal et al., 2009), ABC (Banerjee et al., 2012), CS (Bhardwaj et al., 2012), hybrid Rough/BBO (Goel S. et al., 2011), hybrid Fuzzy/BBO (Goel S. et al., 2011), Hybrid FPAB/BBO (Johal et al., 2010), Hybrid ACO/SOFM (Goel S. et al., 2011), Hybrid ACO/BBO (Goel S. et al., 2011) Hybrid ABC/BBO (Arora et al., 2012) and Hybrid of CS/ACO as well as CS/PSO (Harish Kundra et.al, 2013) are 0.9137, 0.68812, 0.7033, 0.917, 0.9465, 0.6715, 0.6912, 0.6793, 0.7075, 0.7636, 0.917, 0.9422 and 0.9633 respectively.

3. 2 Calculation of Accuracy

Overall accuracy can be defined as fraction of the number of correct observations to the total number of classifications. This is a very crude measure of accuracy, and can be calculated as:

$$O = \frac{\text{Total number of correct classifications}}{\text{Total number of classifications}}$$

3.3 Producer Accuracy

Producer's accuracy can be defined as measure of how well the land in each category was correctly classified, i.e., how well the analyst analyses the classification of the image data by category (columns). This is calculated as:

$$P = \frac{\text{Number of correctly classified pixels in each category}}{\text{Total number of training set pixels used for that category}}$$

After applying proposed algorithm, the producer's accuracy is calculated as below:

Feature	**Water**	**Vegetation**	**Urban**	**Rocky**	**Barren**
Producer's accuracy for ACO and GA	100%	100%	92.12 %	100%	93.53 %

3.4 User Accuracy

User's accuracy can be defined as the measure of how much accurate the classification performed is performed in the field by category (rows).
This is calculated as:

$$U = \frac{\text{Number of correctly classified pixels in each categor}}{\text{Total number of pixels used classified in that category}}$$

After applying proposed algorithm, the producer's accuracy is calculated as below:

Feature	**Water**	**Vegetation**	**Urban**	**Rocky**	**Barren**
User's accuracy of ACO and GA	100%	94.38 %	93.75 %	100%	90.11 %

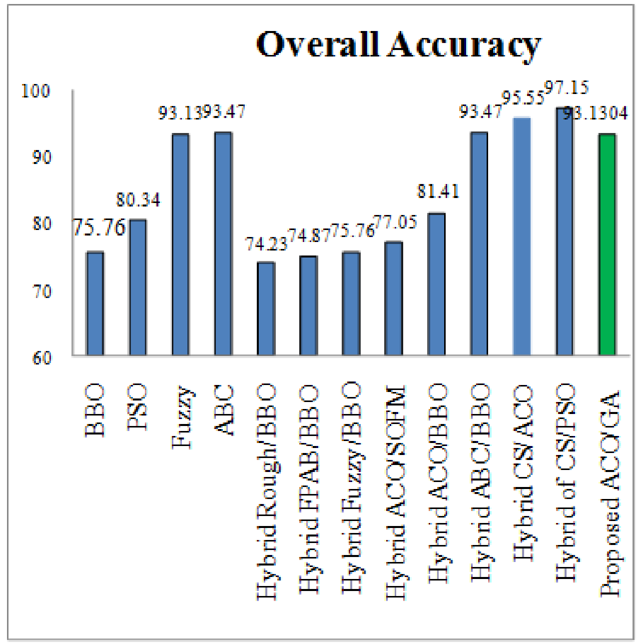

Figure.6 Comparison of result obtained from various past work Accuracy with proposed Work of ACO and GA.

Above figure shows the accuracy of proposed work compared with previous work done in past.

4 .CONCLUSION AND FUTURE SCOPE

Despite being an age old problem, satellite image classification remains an active field of interdisciplinary research till date. No distinct algorithm is acknowledged that will be able to assemble different groups of all real world kind datasets competently as well as without error. To judge the quality of an image classification from images taken from satellite, we need some specially designed statistical-mathematical algorithm. In this paper, we have presented a hybrid technique of Ant Colony Optimization and Genetic algorithm for Optimization to classify multispectral satellite picture. Correspondingly a relative study of the analogous swarm dependent hybrid procedure is discovered.They catalogues data, according to a predetermined taxonomy or organization such as colour, weight and so on, so they can be used for image classification in future.

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