Heuristic Approach for Face Recognition using Artificial Bee Colony Optimization

Astha Gupta and Lavika Goel

Abstract Artificial Bee Colony (ABC) algorithm is inspired by the intelligent behavior of the bees to optimize their search for food resources. It is a lately developed algorithm in Swarm Intelligence (SI) that outperforms many of the established and widely used algorithms like Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) under SI. ABC is being applied in diverse areas to improve performance. Many hybrids of ABC have evolved over the years to overcome its weaknesses and better suit applications. In this paper ABC is being applied to the field of Face Recognition, which remains largely unexplored in context of ABC algorithm. The paper describes the challenges and methodology used to adapt ABC to Face Recognition. In this paper, features are extracted by first applying Gabor Filter. On the features obtained, PCA (Principal Component Analysis) is applied to reduce their dimensionality. A modified version of ABC is then used on the feature vectors to search for best match to test image in the given database.

1 Introduction

Swarm intelligence is a decentralized and self-organized behavior of a natural or an artificial system. This concept was introduced in 1898 by Gerardo Beni and Jing Wang, under Artificial Intelligence in context of cellular robotic systems. SI systems consist of a population of simple agents (also called as boids) which interact with one another in order to share local information. The merit of SI algorithms lies in the simplicity of the rules that each agent follows without any centralized structure to dictate their behavior, thus involving some level of randomness.

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Such interactions lead to globally intelligent behavior without agents worrying about achieving it. Examples of algorithms under SI are Ant Colony, Bird Flocking, Herding, Particle Swarm, Genetic Algorithm, Bacterial Growth etc. Survey on SI by Mishra et al. [1] and Keerthi et al. [2] provides further detail on different algorithms under SI. As ABC belongs to the class of SI algorithms, it shares same nature and advantages as stated above.

ABC has been applied to many different areas like Software Testing, Neural Network etc. In this paper ABC is being applied to Face Recognition. Face Recognition in itself is a huge domain with variety of algorithms. It appears to be a simple task for humans and rarely do we consider the complexity of the problem. Human ability to detect faces under various conditions within seconds has always been intriguing. In case of computing machines, the accuracy and the run time has lagged far behind that of a human's ability. Despite numerous efforts recognition accuracy continues to remains low, about 20 times lower than recognition by fingerprint analysis and matching according to Rawlinson et al. [3]. Therefore, a lot of work is required towards obtaining an efficient solution in this domain.

Apart from the Introduction this paper has 7 sections. Section 2 and 3 describe ABC and Face Recognition briefly. Section 4 states the problem statement and explains the challenges faced in detail. Section 5 contains the methodology used in the paper. Section 6 discusses the results and section 7 gives conclusion and future work. List of references has been provided at the end in section 8.

2 Artificial Bee Colony Algorithm

ABC is one of the algorithms under SI, which was proposed by Karaboga in 2005. It was used by him to optimize numerical problems. Paper by Karaboga et al. [4] provides a deep insight into the algorithm. ABC is inspired by foraging behavior of honey bees specifically based on model proposed by Tereshko and Loengarov in 2005 [5].

ABC algorithm emulates the procedure by which bees share information in order to maximize their honey collection and minimize their efforts. In the algorithm food sources are locations where nectar is available. Optimization is achieved by sharing information and diving responsibility amongst themselves. They organize themselves in three groups.

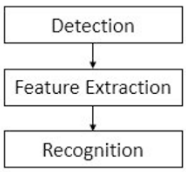
1. ***Employed Bees***: Goes to the food sources to get nectar.
2. ***Scout Bees***: Explore different food sources through random search.
3. ***Onlooker Bees***: Wait at the dance area, for scout bees to come back and do 'waggle' dance which gives information about food sources.

In the beginning, food sources are initialized. As these sources start to deplete, Scout Bees search for new sources. Scout Bees after completion of their search come back to bee hive and report at the dance area. The strength and inclination of the dance is the indicator of the quality and the location of food sources. This information along with prior information is used to select new food sources which will be used by Employed Bees. When food sources deplete, the cycle is repeated. In ABC food sources are searched in a multidimensional space. It provides a procedure for selecting solution based on fitness of new foods position. ABC has been thoroughly explored and experimented with Karaboga et al. [6,7] and Bolaji et al. [8] provide an extensive survey in the algorithm as well as its variants and their application in different fields, from its applications in bioinformatics, clustering and scheduling to various hybrids that have been proposed in past years such as GA, ACO etc. ABC algorithm has a home page [9] listing various developments, work and contribution for reference.

3 Face Recognition

Face Recognition can be classified into a general class of pattern recognition problem. Hence, analogous components are required for facial recognition over a large database. These components can be obtained by extracting features of faces and using them for recognition. An essential requirement for recognition is that the features must be generated for every image and recognition must be robust when subjected to variations in the conditions. Detection of face and recognition have their own challenges, therefore for a Face Recognition system can be thought of three step procedure as shown in Figure 1.

Fig. 1 Flow chart describing three steps involved in a Face Recognition system



An overview of different techniques used in domain of Face Recognition is given in "Volterra Kernel based Face Recognition using artificial bee colony optimization" [10].

Face Recognition has many applications such as surveillance, indexing and search in public or private records, biometric authentication etc. Face Recognition is quite useful and has gained popularity over the years, but is not yet widely used due to low recognition rate. Poor performance can be attributed to the below listed problems:

- ***Occlusion***: Presence of elements such as beards, glasses or hats introduce variability.
- ***Expression***: Facial gestures can hamper with detection
- ***Imaging conditions***: Different cameras and lighting condition

Earlier works in ABC for Face Recognition mostly involve Face Detection and Feature Extraction. Simerpreet Kaur et al. [11] proposes use of ABC for Face Detection. Employing ABC for Feature Selection has been proposed in many papers, not specifically to domain of Face Recognition but Image Processing in general. There are significant works combining ABC and appearance based model but there are very few instances for algorithms using ABC in model based approach. One such work in this domain is modifying Adaptive Appearance Model with help of Artificial Bee Colony [12]. Applications of ABC in Face Recognition is novel and has a lot of room for exploration.

4 Problem Statement and Challenges

Problem Statement: Given a test image and pool of images (different subjects with some changes such as angle of the face with respect to camera, different pose and facial expressions), find the subject that matches the best in the database.

Challenges: Nature of algorithm poses the biggest challenge. In ABC, the optimization of search is generally done in a continuous space (as far as surveyed). Solutions are generated by modifying previous ones with some randomness and adding them to a set. In the case of a continuous search space, all the points in the set will be considered as possible solution but as per mentioned problem statement, only a data point that represents an image (from the given pool of images) can be considered as a possible solution. Hence, if a new solution is produced by randomly modifying existing ones, it is unlikely to be a part of solution set, since values of all attributes in the generated data point may not correspond to any image in the given pool. Thus, it can be said that in the newly generated points most have no meaning which makes it difficult to apply ABC.

Let's say there are only two images in our data set, represented by ***a*** and ***b***, with each attribute in the range [0, 255]. Let ***x*** be a test image which needs to detected as subject ***a*** or***b.*** As mentioned earlier ABC generates new solution from the existing ones, which at the beginning of the algorithm are initialized randomly. Let x1 be a point generated by modifying random initial points.

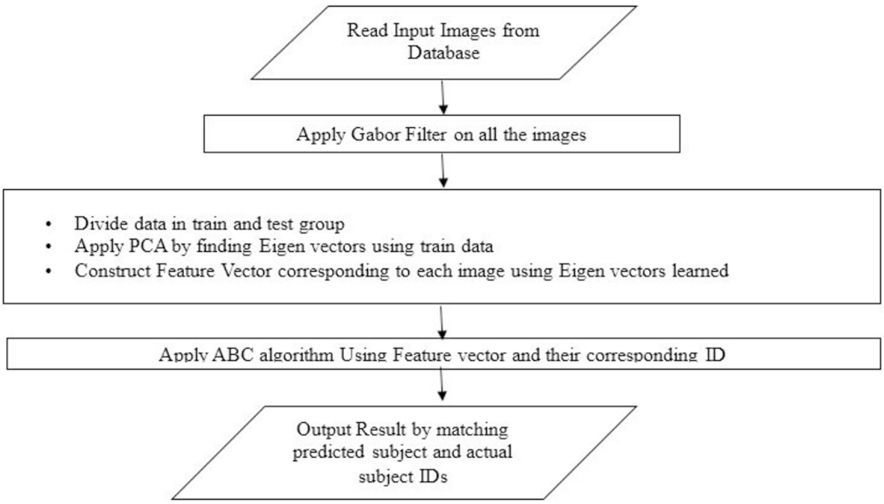
Pool of Images: a = [125, 160, 217], ***b*** = [90, 100, 120]
Test Image: x = [125, 177, 217]
Generated Point: x1 = [124, 165, 216]

If we output x1 directly, then it will have no meaning since it is neither equal to **a** nor **b**. This shows that most of the solutions generated will have no meaning because it is very difficult to generate solutions that can exactly match any of the pool images. Hence, a function is required that can map solutions generated to most similar data point in the pool of image. Mapping function is detailed further in the paper.

5 Methodology

The technique adopted in this paper is to use Gabor Filter and PCA to generate features for the test and training data set, similar to approach applied by Gupta et al. [13]. The best fit solution found during ABC algorithm run is marked as output for a given input image. This approach is also depicted in Figure 2 below in as a 5 step process.

Fig. 2 Overall flow of the algorithm.



Standard ORL database distributed by the Olivetti Research Laboratory, Cambridge, U.K. has been used. Database consists of 40 subjects each having 10 different images in different conditions such as illumination, pose and facial expression. 400 distinct images with size 92 x 112 pixels and 8-bit grey levels are present in dataset [14]. Some of the images from the ORL database are shown below in Figure 3.

Fig. 3 OLR database representation

Sections below provides details about step for Gabor Filter, PCA and Implementation of ABC algorithm. First two sections are used for generating feature vectors and section 5.3 explains the ABC algorithm steps with flow chats.

5.1 Gabor Filters

Gabor Filters are complex band pass filters. In spatial domain 2D Gabor Filter is a kernel function whose values are modulated by sinusoidal wave. They are significant because cells in mammalian brain's visual cortex can be modelled by them. Process of applying these filters on image is considered to be similar to human's visual perception. They are applied in a way same as conventional filters. We create a mask that represents a filter. This mask applied over each pixel is evaluated. Gabor Filter highlights response at edges and texture changes. Main equations of these filters are:

$$\varphi(a,b) = (f_u^2/\pi K n)\exp\left(-1 * \left((f_u^2/k^2)a'^2 + (f_u^2/n^2)b'^2\right)\right)\exp(j2\pi f_u a') \quad (1)$$

$$a' = a\cos\theta + b\sin\theta \quad (2)$$

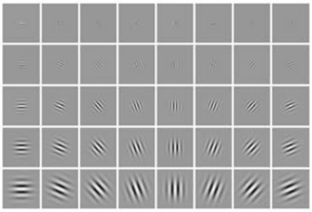
$$b' = -a\sin\theta + b\cos\theta \quad (3)$$

$$f_u = f_m/2^{u/2} \quad (4)$$

$$\theta = v\pi/8 \quad (5)$$

Orientation is given by $\boldsymbol{f_u}$ and $\boldsymbol{\theta}$, respectively. $\boldsymbol{\varkappa}$ and $\boldsymbol{\eta}$ are parameters that evaluates the ratio of central frequency to size of Gaussian envelope. Commonly used values are $\boldsymbol{\varkappa} = \boldsymbol{\eta} = \sqrt{2}$ and $\boldsymbol{f_m} = 0.25$ (***m*** is for maximum). A filter bank of five different scales and eight different orientations is created. Where $\boldsymbol{u} = 0,1\ldots\ldots p-1$ and $\boldsymbol{v} = 0,1\ldots,r-1$, where $\boldsymbol{p} = 5$ and $\boldsymbol{r} = 8$. Figure 4 displays Gabor Filter for different combinations of scale and orientation.

Fig. 4 Filter bank for 40 different combinations of scale and orientation



5.2 Principal Component Analysis

Principal Component Analysis (PCA) is an extensively used and very popular method for feature reduction in Face Recognition. PCA has been used by Bahurupi et al. [15] to create a subspace on which a new data point (image) is projected and classification is done by Euclidean distance. Abdullah et al. [16] provides an insight into PCA algorithm and different optimizations that can be used to overcome its drawbacks. Faces are represented as Eigen Faces which are linear combination of Eigenvectors. Eigenvectors are derived from covariance matrix of training data. Number of Eigen Faces will be equal to no of images in dataset. Eigen Vectors represent new spaces in which faces are represented.

1. Let ***I*** be the training set
   $I = \{i_1, i_2 \dots . i_p\}$
   Where ***p*** is the number of images in data set
2. Represent data set in a 2D Matrix with dimension ***a x p***, where a is equal to number of pixels in an image. Therefore, each column is representing an image in dataset where each element is a pixel value of the image
3. Calculate average face for a given data set
   $$\mu = {}^{1}/_{p} \sum_{r=1}^{p} i_r$$
4. Calculate covariance matrix
   $$c = \frac{1}{p} \sum_{r=1}^{p} (i_r - \mu)(i_r - \mu)'$$
5. Calculate Eigen Vectors and Eigen Values from the covariance matrix
   $cv = lv$
   Where ***l*** is Eigenvalues and ***v***is Eigenvectors for convolution matrix
6. Calculate Eigen Faces using Eigen Vectors
   $\mathrm{U} = (\mathrm{i_n} - \mu) * v$
   n = 1,2…p , U are called Eigen Faces due to ghost like appearance of face.
7. Calculate features using Eigen Faces
   $\mathrm{P_n} = \mathrm{U^T} * (\mathrm{i_n} - \mu)$

$\boldsymbol{P_n}$ represents the weights for each image corresponding to Eigenvectors in $\boldsymbol{c}$ for an image. $\boldsymbol{n} = 1, 2 \ldots p$

While testing, normalize with help of mean computed in step 3. Use steps 6 and 7 to calculate features for test images. After calculating features for both test and train data, recognize subjects for test images. This is done through ABC algorithm.

5.3 Implementation of ABC Algorithm

A merit of ABC that is fundamental to the implementation is the ability to optimize in high dimensional space and solve a complex problem. In contrast to conventional algorithms which are prone to divergence and local extrema, ABC avoids such scenarios by involving randomness to an extent.

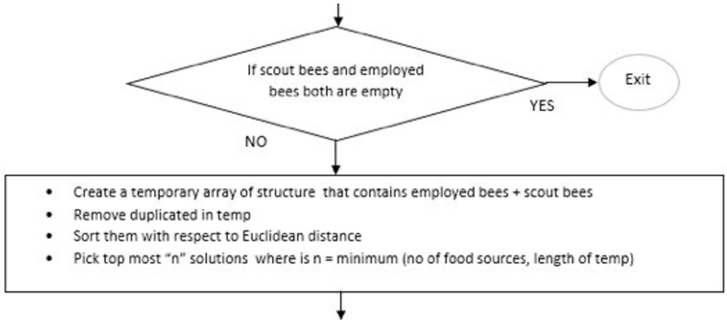
As a pre-processing step Gabor Filter and PCA is applied (explained in previous sections) and feature vectors are generated for both train and test set. On this feature vector set, ABC algorithm is executed for recognition. The main steps of the algorithm are briefly illustrated.

```
Initialize: Initialize all the parameters for example
        Number of Employed Bees (E, no of solution/ no of food sources)
        Number of times main loop should run (cLimit)
        Number of times a food source can stay in the solution space (limit)
REPEAT
        Employed Bees Phase: Going to food source and extracting nectar
        Onlooker Bees Phase: Takes decision regarding fitness of a solution
        Scout Bees Phase: Discover new sources
UNTIL (requirements are met or cLimit reached?)
```

Initially, three parameters ***E***, ***cLimit*** and ***limit*** are set by the user. These parameters can later be tweaked to adjust the performance of the algorithm. The number of Employed Bees is set to a constant ***E***, which can also be considered to be number of solutions or number of food sources. Variable ***cLimit*** serves the purpose of an upper limit on the number of times main loop can be iterated. Variable ***limit*** is used to define the number of iterations after which the algorithm considers a food source to be exhausted and conduct search for new food sources. Figure 5, 6 and 7 detail the three phases of ABC algorithm.

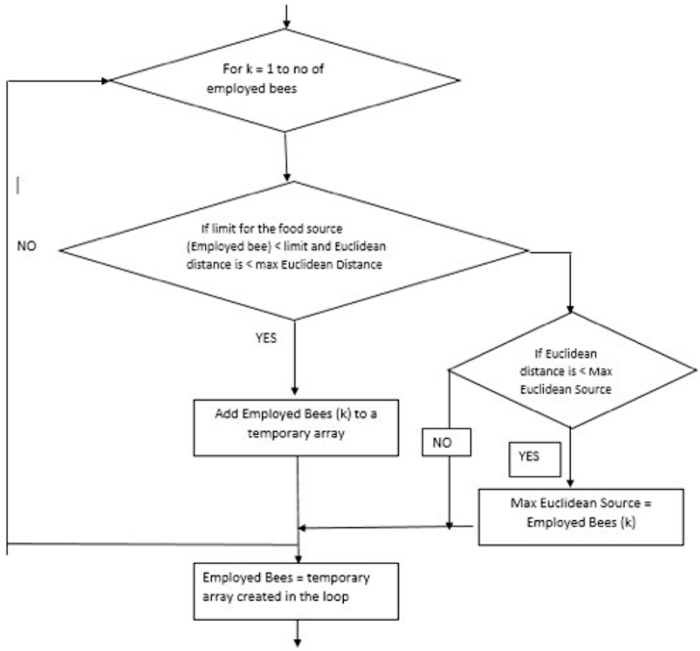
In employed bee phase of each of the iterations, best solutions are chosen to be included in the solution set and rest are removed. In the first iteration, Scout Bees have no information about new food sources, thus the solution set will be composed of randomly initialized Employed Bees. As the algorithm progresses with the implementation food sources are removed from the solution set (for multiple reasons), and new solution set is formed each time considering both current solution set (Employed Bees) and solutions discussed by Scout Bees. The number of solutions in the solution set cannot exceed ***E*** at any given point of time.

Fig. 5 Employed Bee Phase



The onlooker bee phase keeps a check on the solution set. It removes exhausted sources. In this step an upper bound on the Euclidean distance between food source and test image is maintained, such that no image in the solution set exceeds the upper bound.

Fig. 6 Onlooker Bees Phase



A solution that has exceeded the limit variable or has Euclidean distance greater than upper bound is removed from the solution set. If the Euclidean distance of removed solution is lesser than the existing upper bound, then that distance is updated as the new upper bound. The upper bound of Euclidean distance is stored in a variable (Max Euclidean Source).

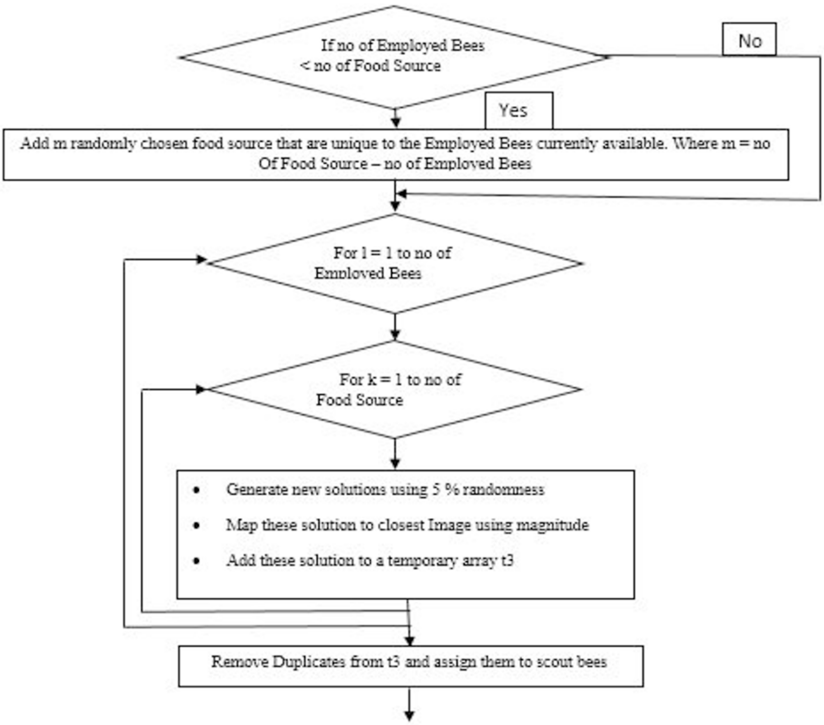
Scout bee phase is the last phase in a given iteration. In this phase, sources that were exhausted in the onlooker phase are replaced with new solutions. New solutions are generated randomly to avoid convergence at local minima and perform a better global search. More solutions are generated in Scout phase using 5% randomness for local search.

$$X' = X_i + r\,(X_i - X^*)$$

Where X' is the new solution generated, Xi is a solution in the solution set around which new solutions have to be generated, X* is the test image for which algorithm is being run and is the randomness that we want to include in the procedure of creating new solution. In this paper results are reported for r= 5%.

As per Flow chart below ***E*** (equal to number of initial Employed Bees), number of sources are generated for each solution in the set. This is done to increase local search capability. Employed Bees represents the number of solutions remaining in the set. Number of Food sources is the number of Employed Bees initially fixed (***E***), this is a parameter that remains constant though the computation.

Fig. 7 Onlooker Bee Phase



The mapping function as mentioned in section 2 is evaluated based on the similarity of the generated solution to an image in the provided database. Most similar image is chosen as an output of the mapping function. Similarity is measured by the closeness of a source's absolute value of the feature vector with respect to absolute value of the images in the data set. All the images are sorted based on absolute value and stored as a pre-processing step to look up the closest image for a given input source. Euclidean distance is used as a fitness function to choose the best solution in the solution set. The best solution has the least Euclidean distance from the given test image.

$$Fitness\ (X_i, X^*) = (X_i - X^*)^{1/2}$$

6 Results and Discussions

Performance of the algorithm was analyzed by measuring the accuracy. Accuracy is percentage of images in which subject was detected correctly, given certain number of test images. Accuracy with different values of the three parameters are calculated in order to find the best values that gives maximum efficiency. As described in section 3 we have three parameters, ***cLimit***, number of Food Sources (***E***) and ***limit***.

Fig. 8 Graph for accuracy when cLimit = 15, for limit = 5 and 3.

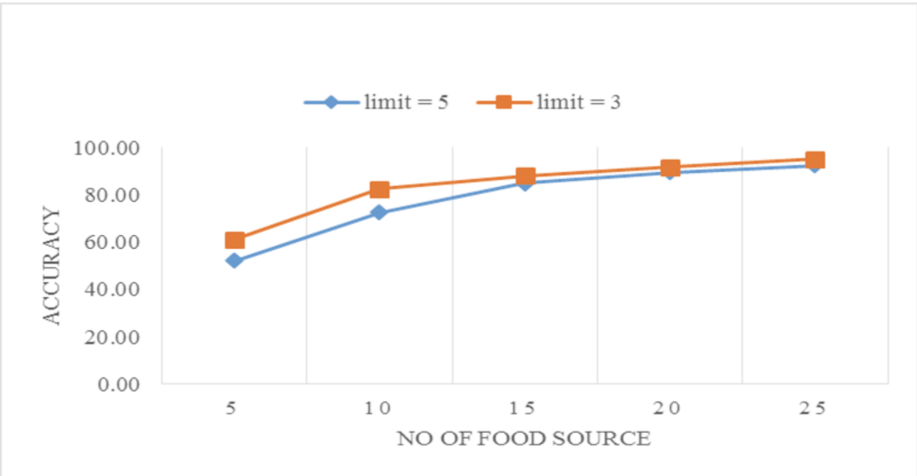


Fig. 9 Graph for accuracy when cLimit = 20, for limit = 5 and 3.

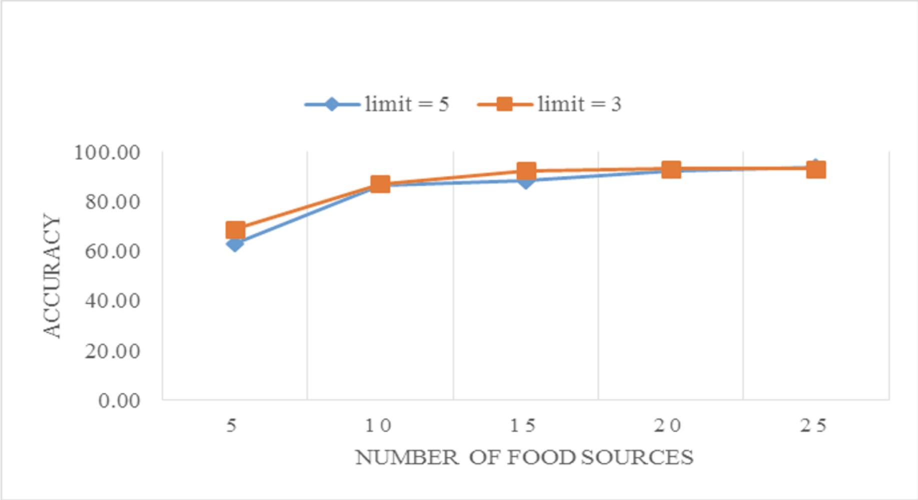


Figure 8 & 9 clearly demonstrates for ***limit*** = 3 accuracy seems to be better than ***limit*** = 5, especially for lower values of food sources. As number of food sources or ***cLimit*** increases difference seems to diminish.

Fig. 10 Percentage Database searched for different parametersfor 4 different case.

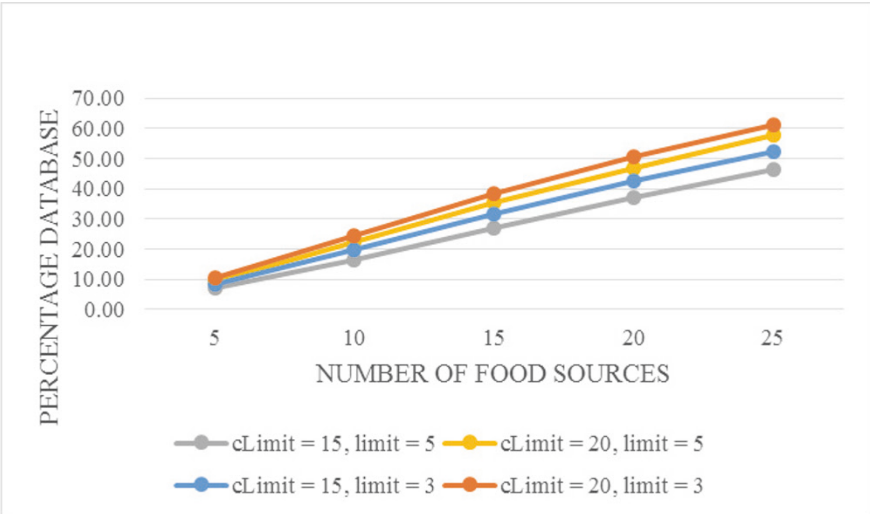
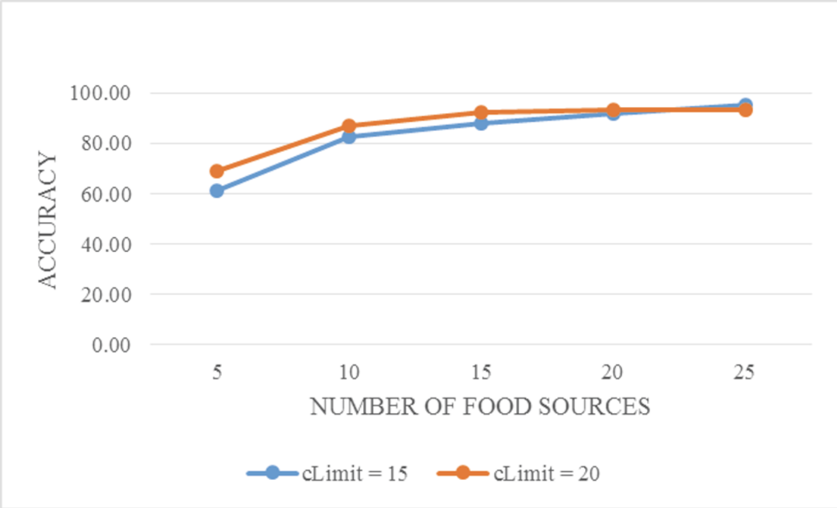


Fig. 11 Accuracy when ***limit*** = 3, for varying number of food sources and ***cLimit***.



Amount of database searched for different parameters is demonstrated in Figure 10. The highest accuracy during experiment is 95.83%, which was achieved with 52.5% database search by adjusting ***cLimit*** = 15, **limit=** 3 and ***number of food sources*** = 25. Figure 11 give accuracy for ***limit*** = 3 and different ***cLimit***.

7 Conclusion and Future Work

ABC algorithm is one of the very efficient algorithms for optimization that can be employed easily in complex domains. In this paper it has been applied to optimizing search for the right subject for a given image. The advantage here is unlike traditional methods, we don't have to search the whole database and go through every image, only by going through few images we can search the database. Previously, knowledge of ABC has been applied in Face Detection and Feature Extraction but this is the first work where ABC has been applied in recognition phase (as far as seen). ABC proves to be helpful in searching database efficiently. In ABC, bees work independently with little communication amongst them, therefore this behavior has natural parallelism and will be quite scalable in parallel domain with complex and multi-dimensional data.

Future work in ABC with Face Recognition pertaining to this paper is to use an implementation of ABC for parallel computation, in a Face Recognition system. Abu et al. Surveyed ABC and its applications, where one of the major contributors were parallel and grid computing [17]. Using hybrids in place of just ABC such as Genetic Algorithm (GA) [18] and Particle Swarm Optimization (PSO) [19, 20] can also be explored. Applying ABC for larger databases, testing ABC with different approaches for Face Detection and Feature Extraction is an integral part of further work.

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