INTERNATIONAL JOURNAL OF RESEARCH IN COMPUTER APPLICATION & MANAGEMENT

IJRCM

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CONTRIBUTIONS TO BOOKS

- Sharma T., Kwatra, G. (2008) Effectiveness of Social Advertising: A Study of Selected Campaigns, Corporate Social Responsibility, Edited by David Crowther & Nicholas Capaldi, Ashgate Research Companion to Corporate Social Responsibility, Chapter 15, pp 287-303.

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- Schemenner, R.W., Huber, J.C. and Cook, R.L. (1987), "Geographic Differences and the Location of New Manufacturing Facilities," Journal of Urban Economics, Vol. 21, No. 1, pp. 83-104.

CONFERENCE PAPERS

- Garg, Sambhav (2011): "Business Ethics" Paper presented at the Annual International Conference for the All India Management Association, New Delhi, India, 19–22 June.

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- Garg, Bhavet (2011): Towards a New Natural Gas Policy, Political Weekly, Viewed on January 01, 2012 http://epw.in/user/viewabstract.jsp

APPLICATION OF ARTIFICIAL BEE COLONY ALGORITHM TO INDEPENDENT COMPONENT ANALYSIS

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ABSTRACT

Artificial Bee Colony (ABC) Algorithm is an optimization algorithm based on the intelligent behaviour of honey bee swarm. The model consists of three essential components: employed and unemployed foraging bees, and food sources. The first two components, employed and unemployed foraging bees, search for rich food sources, which is the third component, close to their hive. The model also defines two leading modes of behaviour which are necessary for self-organizing and collective intelligence: recruitment of foragers to rich food sources resulting in positive feedback and abandonment of poor sources by foragers causing negative feedback. In ABC, a colony of artificial forager bees (agents) search for rich artificial food sources (good solutions for a given problem). To apply ABC, the considered optimization problem is first converted to the problem of finding the best parameter vector which minimizes an objective function. Then, the artificial bees randomly discover a population of initial solution vectors and then iteratively improve them by employing the strategies: moving towards better solutions by means of a neighbour search mechanism while abandoning poor solutions. The results show that ABC outperforms the other algorithms like Genetic Algorithm (GA), Particle Swarm Algorithm (PSO) and Particle Swarm Inspired Evolutionary Algorithm (PS-EA). In this paper, ABC algorithm is used to optimize the cost function that is based on maximisation of independence among components in independent component analysis.

KEYWORDS

Artificial Bee Colony Algorithm, Independent Component Analysis.

1 INTRODUCTION

Artificial Bee Colony (ABC) is a recently defined swarm intelligence algorithm by Dervis Karaboga in 2005, motivated by the intelligent behaviour of honey bees. It uses only common control parameters such as colony size and maximum cycle number. ABC as an optimization algorithm provides a population-based search procedure in which individuals called foods positions are modified by the artificial bees with time and the bee's aim is to discover the places of food sources with high nectar amount and finally the one with the highest nectar. In ABC system, artificial bees fly around in a multidimensional search space and some (employed and onlooker bees) choose food sources depending on the experience of themselves and their nest mates, and adjust their positions. Some bees (scouts) fly and choose the food sources randomly without using experience. If the nectar amount of a new source is higher than that of the previous one in their memory, they memorize the new position and forget the previous one. Thus, ABC system combines local search methods, carried out by employed and onlooker bees, with global search methods, managed by onlookers and scouts, attempting to balance exploration and exploitation process. In this paper, ABC algorithm is used to optimize the cost function that is based on maximisation of independence among components in independent component analysis.

2 SWARM INTELLIGENCE

Swarm intelligence is the discipline that deals with natural and artificial systems composed of many individuals that coordinate using decentralized control and self-organization [4]. In particular, the discipline focuses on the collective behaviours that result from the local interactions of the individuals with each other and with their environment. Examples of systems studied by swarm intelligence are colonies of ants and termites, schools of fish, flocks of birds, herds of land animals. Some human artifacts also fall into the domain of swarm intelligence, notably some multi-robot systems, and also certain computer programs that are written to tackle optimization and data analysis problems.

2.1 PROPERTIES OF A SWARM INTELLIGENCE SYSTEM

The typical swarm intelligence system has the following properties [4]:

- it is composed of many individuals;
- the individuals are relatively homogeneous (i.e., they are either all identical or they belong to a few typologies);
- the interactions among the individuals are based on simple behavioural rules that exploit only local information that the individuals exchange directly or via the environment (stigmergy);
- the overall behaviour of the system results from the interactions of individuals with each other and with their environment, that is, the group behaviour self-organizes.

The characterizing property of a swarm intelligence system is its ability to act in a coordinated way without the presence of a coordinator or of an external controller. Many examples can be observed in nature of swarms that perform some collective behaviour without any individual controlling the group, or being aware of the overall group behaviour. Notwithstanding the lack of individuals in charge of the group, the swarm as a whole can show an intelligent behaviour. This is the result of the interaction of spatially neighbouring individuals that act on the basis of simple rules.

Most often, the behaviour of each individual of the swarm is described in probabilistic terms: Each individual has a stochastic behaviour that depends on his local perception of the neighbourhood.

Because of the above properties, it is possible to design swarm intelligence system that are scalable, parallel, and fault tolerant.

- Scalability means that a system can maintain its function while increasing its size without the need to redefine the way its parts interact. Because in swarm intelligence system interactions involve only neighbouring individuals, the number of interactions tends not to grow with the overall number of individuals in the swarm: each individual's behaviour is only loosely influenced by the swarm dimension. In artificial systems, scalability is interesting because a scalable system can increase its performance by simply increasing its size, without the need for any reprogramming.
- Parallel action is possible in swarm intelligence systems because individuals composing the swarm can perform different actions in different places at the same time. In artificial systems, parallel action is desirable because it can help to make the system more flexible, that is, capable to self-organize in teams that take care simultaneously of different aspects of a complex task.
- Fault tolerance is an inherent property of swarm intelligence systems due to the decentralized, self-organized nature of their control structures. Because the system is composed of many interchangeable individuals and none of them is in charge of controlling the overall system behaviour, a failing individual can be easily dismissed and substituted by another one that is fully functioning.

3 ARTIFICIAL BEE COLONY (ABC) ALGORITHM

3.1. BEHAVIOUR OF REAL BEES

Tereshko developed a model of foraging behaviour of a honeybee colony based on reaction–diffusion equations. This model that leads to the emergence of collective intelligence of honeybee swarms consists of three essential components: food sources, employed foragers, and unemployed foragers, and defines two leading modes of the honeybee colony behaviour: recruitment to a food source and abandonment of a source. Tereshko explains the main components of his model as below[2]:

1. Food Sources: In order to select a food source, a forager bee evaluates several properties related with the food source such as its closeness to the hive, richness of the energy, taste of its nectar, and the ease or difficulty of extracting this energy. For the simplicity, the quality of a food source can be represented by only one quantity although it depends on various parameters mentioned above.
2. Employed foragers: An employed forager is employed at a specific food source which she is currently exploiting. She carries information about this specific source and shares it with other bees waiting in the hive. The information includes the distance, the direction and the profitability of the food source.
3. Unemployed foragers: A forager bee that looks for a food source to exploit is called unemployed. It can be either a scout who searches the environment randomly or an onlooker who tries to find a food source by means of the information given by the employed bee. The mean number of scouts is about 5–10%.

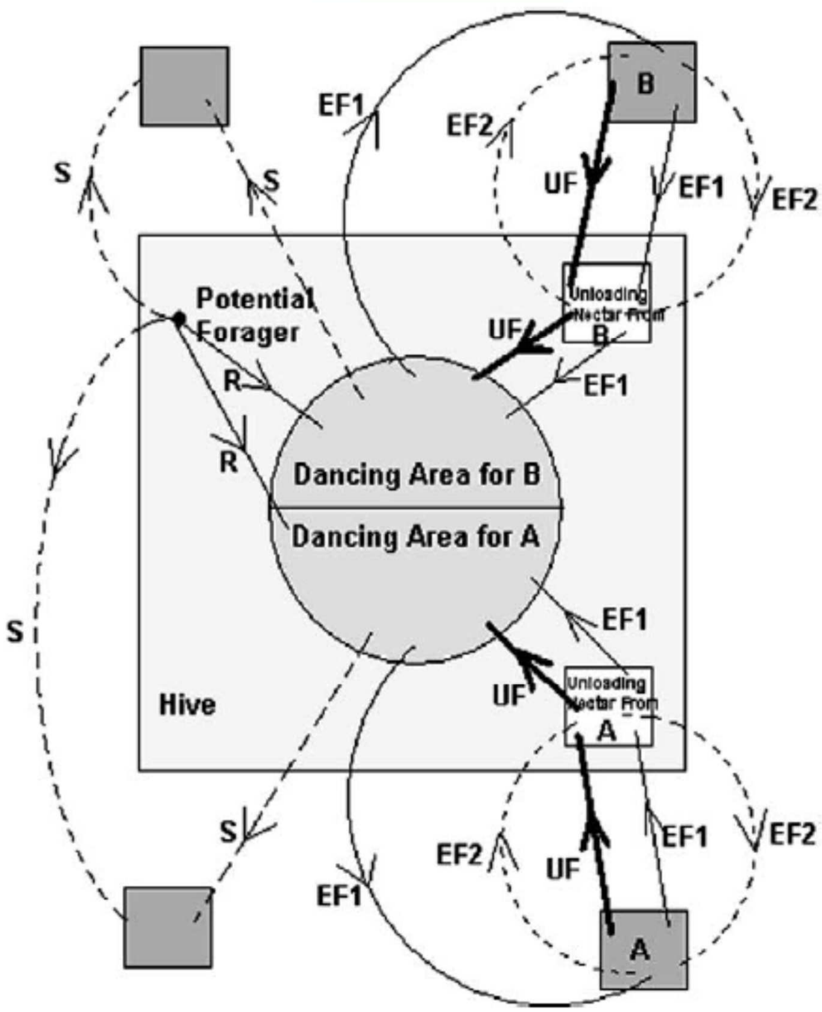
The exchange of information among bees is the most important occurrence in the formation of collective knowledge. While examining the entire hive it is possible to distinguish some parts that commonly exist in all hives. The most important part of the hive with respect to exchanging information is the dancing area. Communication among bees related to the quality of food sources occurs in the dancing area. The related dance is called waggle dance. Since information about all the current rich sources is available to an onlooker on the dance floor, probably she could watch numerous dances and chooses to employ herself at the most profitable source. There is a greater probability of onlookers choosing more profitable sources since more information is circulating about the more profitable sources. Employed foragers share their information with a probability which is proportional to the profitability of the food source, and the sharing of this information through waggle dancing is longer in duration. Hence, the recruitment is proportional to profitability of a food source.

In order to better understand the basic behaviour characteristics of foragers, let us examine Fig. 1[2]. Assume that there are two discovered food sources: A and B. At the very beginning, a potential forager will start as unemployed forager. That forager bee will have no knowledge about the food sources around the nest. There are two possible options for such a bee:

i. It can be a scout and starts searching around the nest spontaneously for food due to some internal motivation or possible external clue (S on Fig. 1).

ii. It can be a recruit after watching the waggle dances and starts searching for a food source (R on Fig. 1[2]).

FIG. 1: BEHAVIOUR OF HONEYBEE FORAGING FOR NECTAR[2]



After finding the food source, the bee utilizes its own capability to memorize the location and then immediately starts exploiting it. Hence, the bee will become an employed forager. The foraging bee takes a load of nectar from the source and returns to the hive, unloading the nectar to a food store. After unloading the food, the bee has the following options [2] :

i. It might become an uncommitted follower after abandoning the food source (UF).

ii. It might dance and then recruit nest mates before returning to the same food source (EF1).
iii. It might continue to forage at the food source without recruiting bees (EF2).
It is important to note that not all bees start foraging simultaneously. The experiments confirmed that new bees begin foraging at a rate proportional to the difference between the eventual total number of bees and the number of bees presently foraging.

3.2. WORKING OF ARTIFICIAL BEE COLONY (ABC) ALGORITHM

In ABC algorithm, the position of a food source represents a possible solution to the optimization problem and the nectar amount of a food source corresponds to the quality (fitness) of the associated solution. The number of the employed bees or the onlooker bees is equal to the number of solutions in the population[3]. At the first step, the ABC generates a randomly distributed initial population P(C=0) of SN solutions (food source positions), where SN denotes the size of employed bees or onlooker bees. Each solution xi (i = 1, 2, . . . , SN) is a D-dimensional vector. Here, D is the number of optimization parameters. After initialization, the population of the positions (solutions) is subject to repeated cycles, C = 1, 2, . . . ,MCN, of the search processes of the employed bees, the onlooker bees and the scout bees[3]. An employed bee produces a modification on the position (solution) in her memory depending on the local information (visual information) and tests the nectar amount (fitness value) of the new source (new solution). If the nectar amount of the new one is higher than that of the previous one, the bee memorizes the new position and forgets the old one. Otherwise she keeps the position of the previous one in her memory[2][3].

After all employed bees complete the search process, they share the nectar information of the food sources and their position information with the onlooker bees. An onlooker bee evaluates the nectar information taken from all employed bees and chooses a food source with a probability related to its nectar amount. As in the case of the employed bee, she produces a modification on the position in her memory and checks the nectar amount of the candidate source. If the nectar is higher than that of the previous one, the bee memorizes the new position and forgets the old one.

The main steps of the algorithm are as below: [3]

1: Initialize Population
2: repeat
3: Place the employed bees on their food sources
4:Place the onlooker bees on the food sources depending on their nectar amounts
5: Send the scouts to the search area for discovering new food sources
6: Memorize the best food source found so far
7: Until requirements are met

In ABC algorithm, each cycle of the search consists of three steps: sending the employed bees onto their food sources and evaluating their nectar amounts; after sharing the nectar information of food sources, the selection of food source regions by the onlookers and evaluating the nectar amount of the food sources; determining the scout bees and then sending them randomly onto possible new food sources. At the initialization stage, a set of food sources is randomly selected by the bees and their nectar amounts are determined. At the first step of the cycle, these bees come into the hive and share the nectar information of the sources with the bees waiting on the dance area. A bee waiting on the dance area for making decision to choose a food source is called onlooker and the bee going to the food source visited by herself just before is named as employed bee. After sharing their information with onlookers, every employed bee goes to the food source area visited by herself at the previous cycle since that food source exists in her memory, and then chooses a new food source by means of visual information in the neighbourhood of the one in her memory and evaluates its nectar amount. At the second step, an onlooker prefers a food source area depending on the nectar information distributed by the employed bees on the dance area. As the nectar amount of a food source increases, the probability of that food source chosen also increases. After arriving at the selected area, she chooses a new food source in the neighbourhood of the one in the memory depending on visual information as in the case of employed bees. The determination of the new food source is carried out by the bees based on the comparison process of food source positions visually. At the third step of the cycle, when the nectar of a food source is abandoned by the bees, a new food source is randomly determined by a scout bee and replaced with the abandoned one. In our model, at each cycle at most one scout goes outside for searching a new food source, and the number of employed and onlooker bees is selected to be equal to each other. These three steps are repeated through a predetermined number of cycles called Maximum Cycle Number (MCN) or until a termination criterion is satisfied.[3]

An artificial onlooker bee chooses a food source depending on the probability value associated with that food source, p_i, calculated by the following expression (1):

$$p_i = \frac{fit_i}{\sum_{i=1}^{n} fit_i} \quad \text{........(1)}$$

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 [5],[3].

In order to produce a candidate food position from the old one in memory, the ABC uses the following expression (2):

$$v_{ij} = x_{ij} + \Phi_{ij}\,(x_{ij} - x_{kj}) \quad \text{....... (2)}$$

where k ϵ {1,2,3…SN } and j ϵ {1,2,3…D } . . . are randomly chosen indexes[3]. 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 neighbour food sources around x_{ij} and represents the comparison of two food positions visually by a bee. As can be seen from equation (1), 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[3].

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[3].

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 [3].

Assume that the abandoned source is x_i and j ϵ {1,2,3…D }, then the scout discovers a new food source to be replaced with x_i . This operation can be defined as in (3)

$$x_i^j = x_{min}^j + rand[0,1]\,(x_{max}^j - x_{min}^j) \quad \text{...... (3)}$$

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 [2].

Totally, ABC algorithm employs four different selection processes[2]:

1. a global probabilistic selection process, in which the probability value is calculated by (1) used by the onlooker bees for discovering promising regions,
2. a local probabilistic selection process carried out in a region by the employed bees and the onlookers depending on the visual information such as the colour, shape and fragrance of the flowers (sources) (bees will not be able to identify the type of nectar source until they arrive at the right location and discriminate among sources growing there based on their scent) for determining a food source around the source in the memory in a way described by (2),
3. a local selection called greedy selection process carried out by onlooker and employed bees in that if the nectar amount of the candidate source is better than that of the present one, the bee forgets the present one and memorizes the candidate source produced by (2). Otherwise, the bee keeps the present one in the memory.
4. A random selection process carried out by scouts as defined in (3).

It is clear from the above explanation that there are three control parameters in the basic ABC: The number of food sources which is equal to the number of employed or onlooker bees (SN), the value of limit and the maximum cycle number (MCN).

In the case of honeybees, the recruitment rate represents a measure of how quickly the bee colony finds and exploits a newly discovered food source. Artificial recruiting could similarly represent the measurement of the speed with which the feasible solutions or the good quality solutions of the difficult optimization problems can be discovered. The survival and progress of the bee colony are dependent upon the rapid discovery and efficient utilization of the best food resources. Similarly; the successful solution of difficult engineering problems is connected to the relatively fast discovery of good solutions especially for the problems that need to be solved in real time. In a robust search process, exploration and exploitation processes must be carried out together. In the ABC algorithm, while onlookers and employed bees carry out the exploitation process in the search space, the scouts control the exploration process. Detailed pseudo-code of the ABC algorithm is given below:

1: Initialize the population of solutions x_i , *i* = 1,2... SN
2: Evaluate the population
3: cycle = 1
4: repeat
5: Produce new solutions v_i for the employed bees by using (2) and evaluate them
6: Apply the greedy selection process for the employed bees
7: Calculate the probability values p_i for the solutions x_i by (1)
8: Produce the new solutions v_i for the onlookers from the solutions x_i selected depending on p_i and evaluate them
9: Apply the greedy selection process for the onlookers
10: Determine the abandoned solution for the scout, if exists, and replace it with a new randomly produced solution x_i by (3)
11: Memorize the best solution achieved so far
12: cycle = cycle + 1
13: until cycle = MCN

4 MANUAL EXECUTION OF ABC ALGORITHM FOR A MINIMIZATION PROBLEM

Considering the optimization problem

Minimize $(x) = x_1^2 + x_2^2, \quad x_1, x_2 \quad \epsilon [-5,5]$

Control Parameters of ABC Algorithm are set as;
- Colony size, CS = 6
- Limit for scout, L = (CS*D)/2 = 6

and dimension of the problem, D = 2

First, we initialize the positions of 3 food sources (CS/2) of employed bees, randomly using uniform distribution in the range (-5, 5).

X =

1.4112	-2.5644
0.4756	1.4338
-0.1824	-1.0323

So f(*x*) values are:

8.5678
2.2820
1.0990

Fitness function:

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

Initial fitness vector is:

0.1045
0.3047
0.4764

Maximum fitness value is 0.4764, the quality of the best food source.

Cycle=1

//Employed bees phase

1st employed bee

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

with this formula, produce a new solution.

k=1 //k is a randomly selected index.
j=0 //j is a randomly selected index.
Φ = 0.8050 // Φ is randomly produced number in the range [-1, 1].

v_0 = 2.1644 -2.5644

Calculate f(v_0) and the fitness of v_0.

f(v_0) = 11.2610 and the fitness value is 0.0816.

o Apply greedy selection between x_0 and v_0

0.0816 < 0.1045, the solution 0 couldn't be improved, increase its trial counter.

2nd employed bee

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

with this formula produce a new solution.

k=2 //k is a random selected solution in the neighbourhood of i.
j=1 //j is a random selected dimension of the problem.
Φ = 0.0762 // Φ is randomly produced number in the range [-1, 1].

v_1 = 0.4756 1.6217

Calculate f(υ_1) and the fitness of υ_1.

f(υ_1) = 2.8560 and the fitness value is 0.2593.

Apply greedy selection between x_1 and υ_1

0.2593 < 0.3047, the solution 1 couldn't be improved, increase its trial counter.

3rd employed bee

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

with this formula produce a new solution.

k=0 //*k* is a random selected solution in the neighborhood of *i.*

j=0 //*j* is a random selected dimension of the problem.

Φ = -0.0671 // Φ is randomly produced number in the range [-1, 1].

v_2 = -0.0754 -1.0323

Calculate $f(\upsilon_2)$ and the fitness of υ_2.

$f(\upsilon_2)$ = 1.0714 and the fitness value is 0.4828.

Apply greedy selection between x_2 and υ_2.

0.4828 > 0.4764, the solution 2 is **improved**, set its trial counter as 0 and replace the solution x_2 with υ_2.

x =

1.4112 -2.5644
0.4756 1.4338
-0.0754 -1.0323

f(x) values are;

8.5678
2.2820
1.0714

fitness vector is:

0.1045
0.3047
0.4828

//Now , Calculate the probability values *p* for the solutions *x* by means of their fitness
//values by using the formula

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

p =

0.1172
0.3416
0.5412

//**Onlooker bees phase**

//Produce new solutions υ_i for the onlookers from the solutions x_i selected
//depending on p_i and evaluate them.

• **1st onlooker bee**

i=2

v_2 = -0.0754 -2.2520

Calculate f(υ_2) and the fitness of υ2.

f(υ_2) = 5.0772 and the fitness value is 0.1645.

Apply greedy selection between x_2 and υ_2

0.1645 < 0.4828, the solution 2 couldn't be improved, increase its trial counter.

2nd onlooker bee

i=1

v_1 = 0.1722 1.4338

Calculate $f(\upsilon_1)$ and the fitness of υ_1.

$f(\upsilon_1)$ = 2.0855 and the fitness value is 0.3241.

Apply greedy selection between x_1 and υ_1

0.3241 > 0.3047, the solution 1 is improved set its trial counter as 0 and replace the solution x_1 with υ_1.

x =

1.4112 -2.5644
0.1722 1.4338
-0.0754 -1.0323

f(x) values are;

8.5678
2.0855
1.0714

fitness vector is:

0.1045
0.3241
0.4828

• **3rd onlooker bee**

i=2

v_2 = 0.0348 -1.0323

Calculate $f(\upsilon_2)$ and the fitness of υ_2.

$f(\upsilon_2)$ = 1.0669 and the fitness value is 0.4838.

Apply greedy selection between x_2 and υ_2

0.4838 > 0.4828, the solution 2 was improved, set its trial counter as 0 and replace the solution x_2 with υ_2.

x =

1.4112 -2.5644
0.1722 1.4338
0.0348 -1.0323

f(x) values are;
8.5678
2.0855
1.0669
fitness vector is:
0.1045
0.3241
0.4838
//Memorize best
Best =
0.0348 -1.0323
//Scout bee phase
TrialCounter =
1
0
0
//There is no abandoned solution since L = 6
//If there is an abandoned solution (the solution of which the trial counter value is
//higher than L = 6); generate a new solution randomly to replace with the
//abandoned one.
Cycle = Cycle+1
The procedure is continued until the termination criterion is attained.

5 INDEPENDENT COMPONENT ANALYSIS

5.1 INTRODUCTION

Independent component analysis (ICA) is a method for finding underlying factors or components from multivariate (multidimensional) statistical data[8]. In simple terms, ICA is a statistical technique for decomposing a complex dataset into independent sub-parts. A related and commonly used term is Blind Source Separation which is the separation of a set of source signals from a set of mixed signals, without the aid of information (or with very little information) about the source signals or the mixing process. ICA can be regarded as one of the most important approaches of blind source separation. Both concepts are based on unsupervised learning.

For example- suppose we are in a room where two people are speaking simultaneously. We have two microphones, which we hold in different locations. The microphones give us two recorded time signals, which we could denote by $x_1(t)$ and $x_2(t)$, with x_1 and x_2 the amplitudes, and t the time index. Each of these recorded signals is a weighted sum of the speech signals emitted by the two speakers, which we denote by $s_1(t)$ and $s_2(t)$. We could express this as a linear equation:

$x_1(t) = a_{11}s_1 + a_{12}s_2$ ……. (4)

$x_2(t) = a_{21}s_1 + a_{22}s_2$ …….. (5)

where a_{11},a_{12},a_{21} and a_{22} are some parameters that depend on the distances of the microphones from the speakers. For the time being, we omit any time delays or other extra factors from our simplified mixing model. As an illustration, consider the waveforms in Fig. 2 and Fig. 3. These are, of course, not realistic speech signals, but suffice for this illustration. The original speech signals could look something like those in Fig. 2 and the mixed signals could look like those in Fig. 3. The problem is to recover the data in Fig. 2 using only the data in Fig. 3.

Actually, if we knew the parameters a_{ij} , we could solve the linear equation in (4) by classical methods. The point is, however, that if we don't know the a_{ij}, the problem is considerably more difficult. One approach to solving this problem would be to use some information on the statistical properties of the signals $s_i(t)$ to estimate the a_{ii}. Actually, and perhaps surprisingly, it turns out that it is enough to assume that $s_1(t)$
and $s_2(t)$, at each time instant *t*, are *statistically independent*. This is not an unrealistic assumption in many cases, and it need not be exactly true in practice. The technique of ICA, can be used to estimate the a_{ij} based on the information of their independence, which allows us to separate the two original source signals $s_1(t)$ and $s_2(t)$ from their mixtures $x_1(t)$ and $x_2(t)$. Fig. 4 gives the two signals estimated by the ICA method. As can be seen, these are very close to the original source signals (their signs are reversed, but this has no significance.)

Independent component analysis was originally developed to deal with problems that are closely related to the cocktail-party problem. Since the recent increase of interest in ICA, it has become clear that this principle has a lot of other interesting applications as well.

FIGURE 2: THE ORIGINAL SIGNALS. [12]

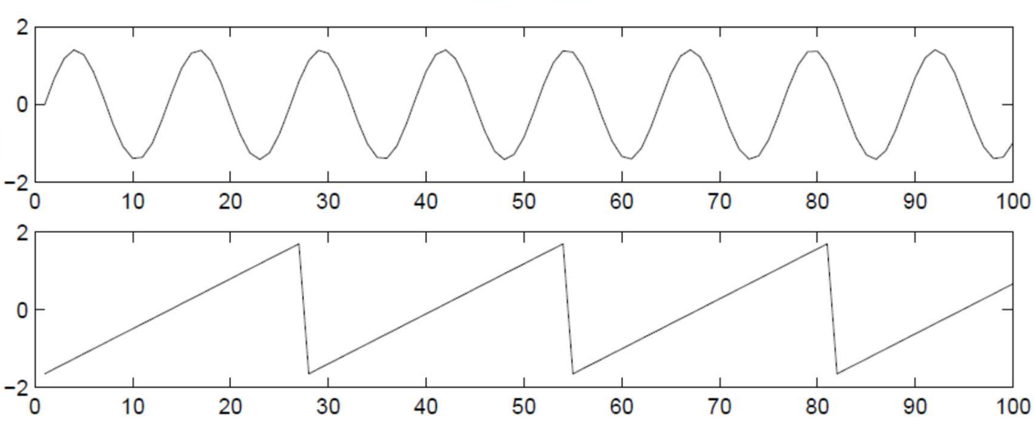


FIGURE 4: THE ESTIMATES OF THE ORIGINAL SOURCE SIGNALS, ESTIMATED USING ONLY THE OBSERVED SIGNALS IN FIG. 3. THE ORIGINAL SIGNALS WERE VERY ACCURATELY ESTIMATED, UP TO MULTIPLICATIVE SIGNS. [12]

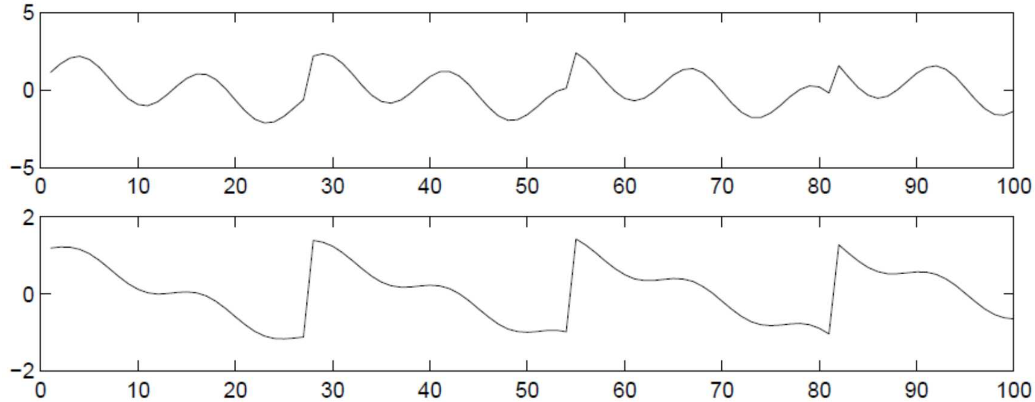
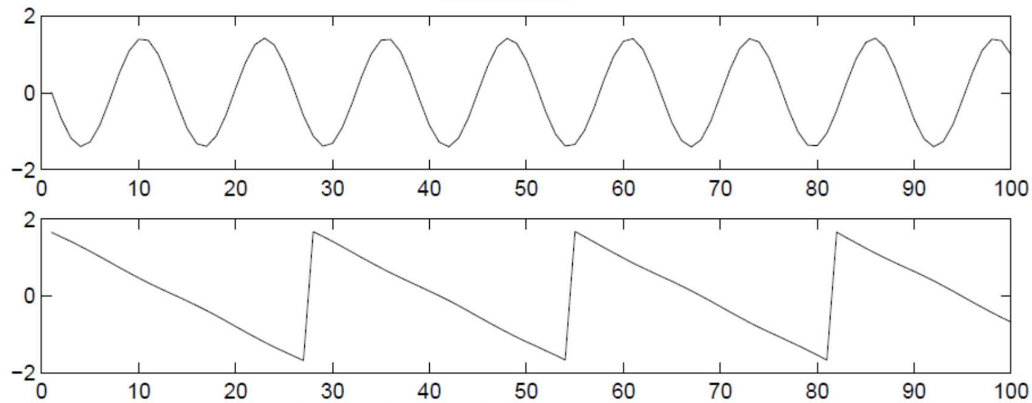


FIGURE 3: THE OBSERVED MIXTURES OF THE SOURCE SIGNALS IN FIG. 2. [12]



Consider, for example, electrical recordings of brain activity as given by an electroencephalogram(EEG). The EEG data consists of recordings of electrical potentials in many different locations on the scalp. These potentials are presumably generated by mixing some underlying components of brain activity. This situation is quite similar to the cocktail-party problem: we would like to find the original components of brain activity, but we can only observe mixtures of the components. ICA can reveal interesting information on brain activity by giving access to its independent components.

Another, very different application of ICA is on feature extraction. A fundamental problem in digital signal processing is to find suitable representations for image, audio or other kind of data for tasks like compression and denoising. Data representations are often based on (discrete) linear transformations. Standard linear transformations widely used in image processing are the Fourier, Haar, cosine transforms etc. Each of them has its own favorable properties (Gonzales and Wintz, 1987).

5.2 MATHEMATICAL FORMULATION OF ICA

To formulate ICA mathematically assume that we observe n linear mixtures $x_1, ..., x_n$ of n independent components[12]

$x_j = a_{j1}s_1+a_{j2}s_2+...+a_{jn}s_n$, for all j. …….. (6)

We have now dropped the time index t; in the ICA model, we assume that each mixture xj as well as each independent component $\mathbf{s_k}$ is a random variable, instead of a proper time signal.[12] The observed values $\mathbf{x_j}$, e.g., the microphone signals in the cocktail party problem, are then a sample of this random variable. Without loss of

generality, we can assume that both the mixture variables and the independent components have zero mean: If this is not true, then the observable variables x_i can always be centered by subtracting the sample mean, which makes the model zero-mean.

It is convenient to use vector-matrix notation instead of the sums like in the previous equation. Let us denote by **x** the random vector whose elements are the mixtures $x_1, ..., x_n$, and likewise by **s** the random vector with elements $s_1, ..., s_n$. Let us denote by A the matrix with elements ai j . Generally, bold lower case letters indicate vectors and

bold upper-case letters denote matrices. All vectors are understood as column vectors; thus x^T , or the transpose of x, is a row vector. Using this vector-matrix notation, the above mixing model is written as

x = As. ………..(7)

Sometimes we need the columns of matrix A; denoting them by a_j the model can also be written as

$\mathbf{X} = \sum_{i=1}^{n} a_i s_i$ ………. (8)

The statistical model in Eq. 7 is called independent component analysis, or ICA model.[12] The ICA model is a generative model, which means that it describes how the observed data are generated by a process of mixing the components s_i. The independent components are latent variables, meaning that they cannot be directly observed. Also the mixing matrix is assumed to be unknown. All we observe is the random vector x, and we must estimate both A and s using it. This must be done under as general assumptions as possible.

The starting point for ICA is the very simple assumption that the components s_i are statistically independent[12]. We also assume that the independent component must have nongaussian distributions. However, in the basic model we do not assume these distributions known (if they are known, the problem is considerably simplified.) For simplicity, we are also assuming that the unknown mixing matrix is square, but this assumption can be sometimes relaxed.[12] Then, after estimating the matrix A, we can compute its inverse, say W, and obtain the independent

component simply by:

s =Wx …………..(9)

ICA is very closely related to the method called blind source separation (BSS) or blind signal separation. A “source” means here an original signal, i.e. independent component, like the speaker in a cocktail party problem. “Blind” means that we no very little, if anything, on the mixing matrix, and make little assumptions on the source signals. ICA is one method, perhaps the most widely used, for performing blind source separation.

In many applications, it would be more realistic to assume that there is some noise in the measurements [12] which would mean adding a noise term in the model. For simplicity, we omit any noise terms, since the estimation of the noise-free model is difficult enough in itself, and seems to be sufficient for many applications.

6 COST FUNCTION FOR ABC ALGORITHM IN ICA CONTEXT

To perform optimization problem based on ABC algorithm, first is very important to define the cost function in ICA context [11]. In this paper, the cost function for ABC algorithm in ICA context is based on maximisation of independence among components. There are two types of contrast function of ICA which are based on information theory and high order statistics(kurtosis).

According to central limit theorem that is totally practical in ICA, the distribution of a sum of independent random variables tends toward a Gaussian distribution. Thus, a sum of two independent random variables usually has a distribution that is closer to Gaussian than any of the two original random variables. In ICA, if the kurtosis of estimated signals is maximized and distanced from the kurtosis of Gaussian signal thenthe reverse of the theorem is confirmed and independence among estimated signals is guaranteed. [13] So the fitness function can be defined based on the sum of the absolute values of kurtosis in estimated signals. Another natural measure of dependence between signals is inspired by information theory that is minimization of mutual information [13] . Thus fitness function which needs to be maximised in order to have maximum independence[13].

$J = -\sum_{i=1}^{n}[|E\{y_i^4\} - 3E^2\{y_i^2\}| + H(y_i) - H(y)]$

The cost function proposed in this paper takes the fusion of two criteria, kurtosis and mutual information which is negative of fitness function which is to be minimised in order to have maximum independence.

That can be defined as:

$f = \sum_{i=1}^{n}[|E\{y_i^4\} - 3E^2\{y_i^2\}| + H(y_i) - H(y)]$ 10

The part (let us say call it Z_1), $|E\{y_i^4\} - 3E^2\{y_i^2\}|$ of cost function represents kurtosis and latter part(let us say call it Z_2) $H(y_i) - H(y)$ is mutual information for estimates of source speech signals $y_1, y_2 \ldots y_n$. E is the expectation operator and H is the entropy associated with the signal which can be defined as, in general

$$E[y] = \sum_{i=1}^{n} y_i p_i$$

and

$H(y) = -\sum_{i=1}^{n} p(y_i)\log(p(y_i))$

Assuming that components are equally likely for simplicity, we have p_i= 1/n, and kurtosis part, Z_1 can be written as

$|E\{y_i^4\} - 3E^2\{y_i^2\}| = |1/n(y_i^4) - 3(1/n(y_i^2))^2|$ 11

Second part of equation (10) Mutual information part, Z_2 can be written as

$H(y_i) - H(y) = -p(y_i)\log(p(y_i) - n(-p(y_i)\log(p(y_i)))$

$= -p(y_i)\log(p(y_i) + n(p(y_i)\log(p(y_i)))$

$= (n-1)p(y_i)\log(p(y_i))$

$= \frac{(n-1)}{n}\log(1/n)$

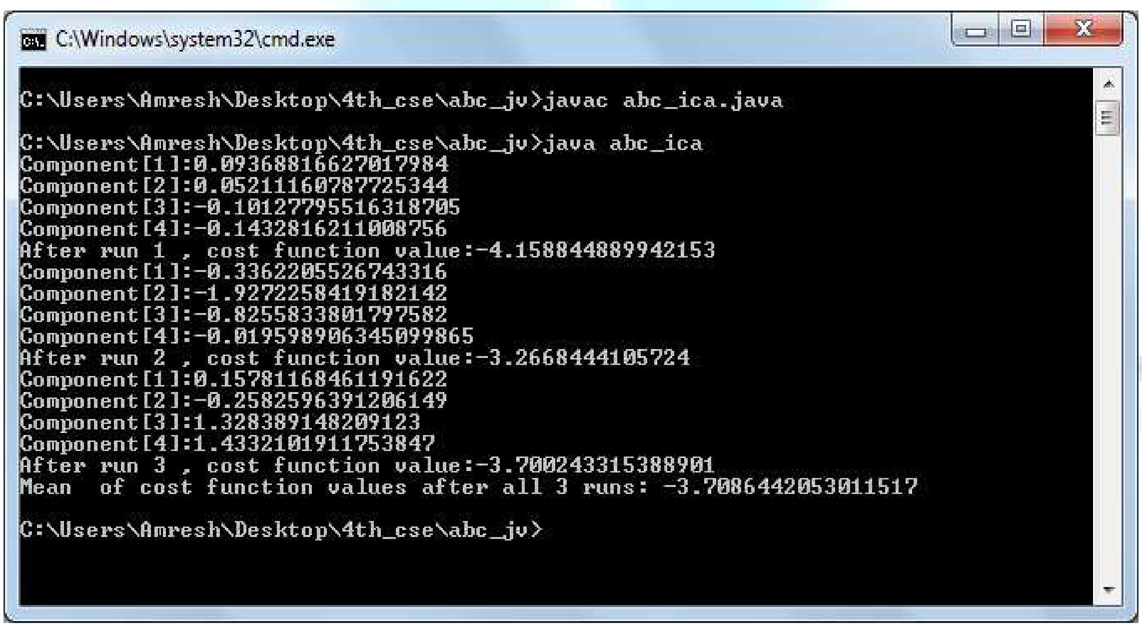
$= -\frac{(n-1)}{n}\log(n)$ 12

Combining equations (10), (11) and (12) , we get

$f = \sum_{i=1}^{n}(|1/n(y_i^4) - 3(1/n(y_i^2))^2| - \frac{(n-1)}{n}\log(n))$ 13

Here we have the cost function of ICA that is to be minimised with the use of ABC algorithm . I have implemented this result in Java.

7 OUTPUT AS AN EXAMPLE



8 CONCLUSION AND FUTURE WORK

In this paper I have optimized the fitness function of Independent Component Analysis in order to attain maximum independence among components using Artificial Bee Colony algorithm which provides better result than other Particle Swarm Optimization algorithm. Purpose of attainment of maximum independence among components is to make the source signals separate easily. In future work, this ABC algorithm can be used to solve the whole ICA problem. I have not considered the presence of noise in this approach, but in real situations there might be many cases where consideration of noise is significant. The inclusion of noise may be considered in the extension of this work.

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