Artificial Bee Colony

Course Title: Computational Intelligence
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Course Leader:

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Objectives of this Session

I wish to:

1. Highlight the interesting facts about honey bees
2. Introduce collective intelligent foraging in honey bees
3. Discuss the different communications that take place in honey bee colonies
4. Introduce the artificial bee colony algorithm (ABC)
5. Discuss the implementation aspects of the ABC algorithm
6. Demonstrate an implementation of ABC algorithm
7. Discuss some applications of the ABC algorithm

Intended Outcomes of this Session

At the end of this session, the student will be able to:

1. Summarize the interesting facts about honey bees in nature
2. Discuss the waggling-dance-based foraging behavior of honey bees
3. Develop the ABC algorithm
4. Choose good values of parameters of ABC
5. List the applications of ABC

Recommended Resources for this Session

1. Karaboga, Dervis and Basturk, Bahriye, *A Powerful and Efficient Algorithm for Numerical Function Optimization: Artificial Bee Colony (ABC) Algorithm*, Journal of Global Optimization, November 2007, Volume 39, Issue 3, pp 459-471

2. Karaboga et al, *A Comprehensive Survey: Artificial Bee Colony (ABC) Algorithm and Applications*, Artificial Intelligence Review, June 2014, Volume 42, Issue 1, pp 21-57.

3. B. Akay and D. Karaboga, *Artificial bee colony algorithm for large-scale problems and engineering design optimization*, Journal of Intelligent Manufacturing, August 2012, Volume 23, Issue 4, pp 1001–1014.

4. V. R. Kulkarni, V. Desai and R. V. Kulkarni, "Multistage localization in wireless sensor networks using artificial bee colony algorithm," *Proceedings of the IEEE Symposium Series on Computational Intelligence (SSCI)*, Athens, Greece, December 2016, pp. 1–8.

Interesting Facts About Honey Bees

- Has been here for millions of years
- Environmentally friendly and vital as pollinators
- Only insect that produces food eaten by man
- Has 6 legs, 2 compound eyes made up of thousands of tiny lenses, 3 simple eyes, 2 pairs of wings, a nectar pouch, and a stomach
- Exceptional olfactory abilities: Kin recognition, social communication, and foraging. They differentiate hundreds of floral varieties and tell whether a flower carries pollen or nectar from meters away
- Can fly for up to six miles at 15 miles per hour
- A hive of bees flies 90,000 miles (three orbits around the earth) to collect 1 kg honey

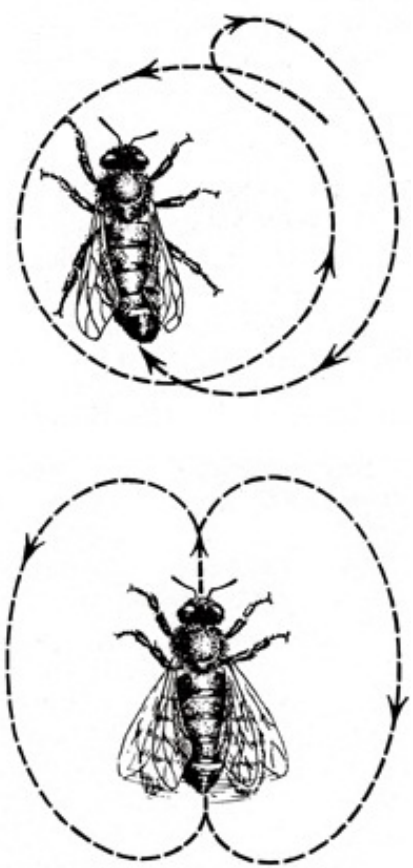
Interesting Facts About Honey Bees

- It takes one ounce of honey to fuel a bee's flight around the world
- A honey bee visits 50 to 100 flowers during a collection trip
- A colony of bees consists of 20000-60000 honeybees and one queen. Worker honey bees are female, live for about 6 weeks and do all the work
- The queen bee's role is to fill the hive with eggs (2500 eggs per day). She has control over whether she lays male or female eggs
- Male honey bees have no stinger and do no work at all. All they do is mating
- They communicate by dancing

Foraging Behavior of Honey Bee Swarm

- **Food Sources:** The value of a food source depends on its proximity to the nest, concentration of its energy and the ease of extracting this energy
- **Employed Foragers:** They are associated with a particular food source which they are currently exploiting or are "employed" at
- They carry the information about this particular source, its distance and direction from the nest, its profitability and share this information with a certain probability
- **Unemployed Foragers:** They are continually at look out for a food source to exploit. There are two types: **Scouts** search the environment surrounding the nest for new food sources
- **Onlookers** wait in the nest and establish a food source through the information shared by employed foragers

Foraging Behavior of Honey Bee Swarm



- The exchange of information is an important occurrence in the formation of collective knowledge
- Communication related to the quality of food sources takes place in the **dancing area**
- Employed foragers share their information with a probability proportional to the profitability of the food source, and this sharing through **waggle dancing** is longer in duration
- An onlooker on the dance floor watches numerous dances and decides to employ herself at the most profitable source
- There is a greater probability of onlookers choosing more profitable sources since more information is circulated about the more profitable sources

Artificial Bee Colony (ABC) Algorithm

1. ABC is a meta-heuristic algorithm based on the foraging behavior of honey bees
2. ABC as an optimization tool, provides a population-based search procedure in which individuals called foods positions are modified by the artificial bees with time and the bees' aim is to discover the places of food sources with high nectar amount and finally the one with the highest nectar
3. 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
4. It is simple and converges faster to the optimal solution with moderate computational efforts

Artificial Bee Colony (ABC) Algorithm

1. The colony of artificial bees consists of three groups of bees: employed bees, onlookers and scouts

2. The number of employed bees is equal to the number of food sources around the hive

3. The employed bee whose food source has been exhausted by the bees becomes a scout

4. ABC defines two leading modes of the behavior: the recruitment to a rich nectar source and the abandonment of a poor source

Essential Components of ABC

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
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%

ABC Algorithm

Algorithm 7B.1. ABC Algorithm

1: Initialize Population
2: **while** stopping criteria is met **do**
3: Place employed bees to their food positions
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: **end while**

Initialization Step in ABC

1. The first step is initialization where values as maximum population S, dimension D, maximum cycles $k_{\max}$ are initialized. Food source is a D dimensional vector represented as $x_{1D}, x_{2D} \ldots x_{SD}$. B is a constant value representing a maximum limit to search for food positions
2. Bees evaluate the given objective function f with initial random food positions to determine the fitness f for each x_{iD} where $i = 1, 2, 3 \ldots, S$
3. Each employed bee explores its neighboring food sources and apply a greedy selection strategy between its food source and food sources of its neighbors. If the f of the new position is higher then employed bee updates its x_{iD} otherwise it remains unchanged

Second Step: Onlooker Phase

1. A probability value is p_i is associated with each onlooker bee
2. Onlooker bee chooses a food source with the probability which is proportional to its quality
3. Different schemes can be used to calculate probability values as roulette wheel selection method or the expression given as $p_i = \frac{f_i}{\sum_{i=1}^{S} fi}$ where f_i is a fitness value for population S
4. A new candidate position from the existing memory is generated using $v_{ij} = x_{ij} + \phi_{ij} \cdot (x_{ij} - x_{oj})$, where $i, o \in 1, 2, \ldots, N$ and $j = 1, 2, \ldots, D$. o is randomly chosen such that $o \neq i$ and $-1 \leq \phi_i \leq 1$.

Third Step: Scout Phase

1. A control parameter B is used to abandon the food source
2. The position of food sources cannot be improved when a count of predetermined trials (T) exceeds B. This is where scout bees are generated
3. Scout bees discover new food position and randomly replace existing food position as given by: $x_{ij} = x^j_{\text{min}} + q(x^j_{\text{max}} - x^j_{\text{min}})$, where q is a random number in $[0, 1]$

Applications of ABC

ABC has been used for solving multidimensional and multi-modal optimization problems

1. For large-scale problems and engineering design optimization
2. Neural network training, cluster analysis, protein structure prediction and stock market forecasting
3. For optimization of power and heating system
4. For Job shop scheduling, generalized assignment problem, to image edge enhancement

Swarm Principles and ABC

ABC satisfies all the swarm principles in order to call a swarm intelligent

1. *Positive feedback*: As the nectar amount of a food source increases, the number of onlookers visiting it increases proportionally
2. *Negative feedback*: The exploitation process of poor food sources is stopped by bees
3. *Fluctuations*: The scouts carry out a random search process for discovering new food sources
4. *Multiple interactions*: Employed bees share their information about food sources with their nest mates (onlookers) waiting on the dance area

Demo of MATLAB Simulation of ABC

Session Summary

1. Collective intelligent foraging in honey bees has prompted the development of the ABC algorithm
2. Different communications take place in honey bee colonies through waggle dances
3. Major phases in ABC: Initialization, onlooker and scout
4. ABC is becoming popular as a competitor to PSO as an optimization algorithm
5. There are innumerable engineering applications of the ABC algorithm: Some have been discussed

Any Questions?

Thank You