The use of Bionic Methods in Intelligent Information Systems

The Bees Algorithm

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Abstract—**A new population-based search algorithm called the Bees Algorithm (BA) is presented. The algorithm mimics the food foraging behaviour of swarms of honey bees. In its basic version, the algorithm performs a kind of neighbourhood search combined with random search and can be used for both combinatorial optimisation and functional optimisation.**

Index Terms—**Bees algorithm, agent, bee colony, bionic method, swarm intelligence, optimization, selforganization.**

I. INTELLIGENT SWARM-BASED OPTIMISATION

Swarm-based optimisation algorithms (SOAs) mimic nature's methods to drive a search towards the optimal solution. A key difference between SOAs and direct search algorithms such as hill climbing and random walk is that SOAs use a population of solutions for every iteration instead of a single solution. As a population of solutions is processed in an iteration, the outcome of each iteration is also a population of solutions. If an optimisation problem has a single optimum, SOA population members can be expected to converge to that optimum solution. However, if an optimisation problem has multiple optimal solutions, an SOA can be used to capture them in its final population. SOAs include the Ant Colony Optimisation (ACO) algorithm [1], the Genetic Algorithm (GA) [2] and the Particle Swarm Optimisation (PSO) algorithm [3].

Common to all population-based search methods is a strategy that generates variations of the solution being sought. Some search methods use a greedy criterion to decide which generated solution to retain. Such a criterion would mean accepting a new solution if and only if it increases the value of the objective function (assuming the given optimisation problem is one of optimisation). A very successful non-greedy population-based algorithm is the ACO algorithm which emulates the behaviour of real ants. Ants are capable of finding the shortest path from the food source to their nest using a chemical substance called pheromone to guide their search. The pheromone is deposited on the ground as the ants move and the probability that a passing stray ant will follow this trail depends on the quantity of pheromone laid. ACO was first used for functional optimisation by Bilchev [4] and further attempts were reported in [4, 5].

The Genetic Algorithm is based on natural selection and genetic recombination. The algorithm works by choosing solutions from the current population and then applying genetic operators – such as mutation and crossover – to create a new population. The algorithm efficiently exploits historical information to speculate on new search areas with improved performance [2]. When applied to optimisation problems, the GA has the advantage of performing global search. The GA may be hybridised with domain-dependent heuristics for improved results. For example, Mathur et al [5] describe a hybrid of the ACO algorithm and the GA for continuous function optimisation.

Particle Swarm Optimisation (PSO) is an optimisation procedure based on the social behaviour of groups of organisations, for example the flocking of birds or the schooling of fish [3]. Individual solutions in a population are viewed as "particles" that evolve or change their positions with time. Each particle modifies its position in search space according to its own experience and also that of a neighbouring particle by remembering the best position visited by itself and its neighbours, thus combining local and global search methods [3].

There are other SOAs with names suggestive of possibly bee-inspired operations [6]. However, as far as the authors are aware, those algorithms do not closely follow the behaviour of bees. In particular, they do not seem to implement the techniques that bees employ when foraging for food.

II. THE BEES ALGORITHM

A. Bees in nature

A colony of honey bees can extend itself over long distances (more than 10 km) and in multiple directions simultaneously to exploit a large number of food sources [7,8]. A colony prospers by deploying its foragers to good fields. In principle, flower patches with plentiful amounts of nectar or pollen that can be collected with less effort should be visited by more bees, whereas patches with less nectar or pollen should receive fewer bees [9,10].

The foraging process begins in a colony by scout bees being sent to search for promising flower patches. Scout bees move randomly from one patch to another. During the harvesting season, a colony continues its exploration, keeping a percentage of the population as scout bees [8].

When they return to the hive, those scout bees that found a patch which is rated above a certain quality threshold (measured as a combination of some constituents, such as sugar content) deposit their nectar or pollen and go to the “dance floor” to perform a dance known as the “waggle dance” [7].

This mysterious dance is essential for colony communication, and contains three pieces of information regarding a flower patch: the direction in which it will be found, its distance from the hive and its quality rating (or fitness) [7,10]. This information helps the colony to send its bees to flower patches precisely, without using guides or maps. Each individual’s knowledge of the outside environment is gleaned solely from the waggle dance. This dance enables the colony to evaluate the relative merit of different patches according to both the quality of the food they provide and the amount of energy needed to harvest it [10]. After waggle dancing on the dance floor, the dancer (i.e. the scout bee) goes back to the flower patch with follower bees that were waiting inside the hive. More follower bees are sent to more promising patches. This allows the colony to gather food quickly and efficiently.

While harvesting from a patch, the bees monitor its food level. This is necessary to decide upon the next waggle dance when they return to the hive [10]. If the patch is still good enough as a food source, then it will be advertised in the waggle dance and more bees will be recruited to that source.

B. Proposed Bees Algorithm

To consider the principles of the beekeeping algorithm, or the method of the bee family (MBF), we will look for an analogy with the real bee family.

Imagine a hive of bees in nature. Their purpose is to find the area with the highest density of flowers within the range of the working bee field. Without any idea of the a priori field, the bees begin to search for colors from random positions with random velocity vectors. Each bee can remember the position where it found the largest number of colors and compare the sources found to have the highest density of flowers with others found by other bee-explorers. Choosing between returning to the place where the bee itself has discovered the largest number of colors, or by studying a place designated by others as the place with the largest number of colors, the bee is directed in the direction between the two points, depending on what will have a greater impact on its solution - personal memories or social reflex. Along the way, a bee can find a place with a higher concentration of flowers than was previously found. In the future, it can be designated as a new place with the highest concentration of flowers, as well as the place of the largest cluster of flowers found by the reconnaissance bees of this family. Accidentally, a bee can fly past a place with a lot of flowers than was found by any other bee family. All the working bee families will then strive to this place in addition to their own observations of each bee (information to other bees is transmitted inside the beehive, with the help of "bee dance"). Thus, bees are exploring the field: flying places with the highest concentration, they slow down in their direction. They continually scan the flying spots, comparing them to previously discovered places with the highest concentration of flowers hoping to find the absolute highest concentration of flowers. As a result, the bee finishes moving in the field with the highest concentration of flowers. Soon all working bees of the family are concentrated around this position. Without being able to detect places with a higher concentration of flowers, bees continuously fly in areas of the highest density of flowers. This behavior of bees and was the basis of this method of optimization.

Particle or Agent - Every bee in the family is considered as a particle or agent. All particles of the family act individually according to one guiding principle: accelerate towards the best personal and best common position, constantly checking the value of the current position. Position - Similar to the location of the bee on the field represented by the coordinates on the plane xy. However, in the general case, it is possible to extend this idea to any N-dimensional space according to the task. This N-dimensional space is an area of solutions for an optimized problem, where each set of coordinates represents a solution. Suitability - by analogy with the example of a bee family, the function of fitness will be the density of flowers: the higher the density, the better the position. Functionality serves as a means of communication between the physical problem and the algorithm of optimization. Personal best position - by analogy with a family of bees, each bee remembers the position where she herself has discovered the largest number of colors. This position with the highest value found by the bee is known as the personal best position (BP). Each bee has its own UBP, which is determined by the way it flew. At each point along the path of the bee, compares the value of the suitability of the current position with the value of the PSP. If the current position has a value above the value, the value of the PBP is replaced by the value of the current position. The Global Best Position - Each family bee also learns about the area of greatest concentration of flowers with the help of "bee dance", the resultant decision is determined by the age of competing dances of each of the bee-explorers. If one of the explorers sees that the source of flowers found by another scout is much better than found by it, it flies and verifies the data. If this is true, then upon arrival to the hive, it connects to the encouragement of bees to collect nectar (or pollen) in the new area of greatest concentration of flowers. This position of greatest suitability is known as the Global Best Position (GBP). For the whole family, this is one GBP, to which every bee strives. At each point throughout the path, each bee compares the suitability of its current position with the BCP. In the event that any bee finds a position of higher fitness, the GBP is replaced by the current position of this bee.

III. STEPS TO EXECUTE THE ALGORITHM

The first step in the implementation of MBS is the selection of parameters that need to be optimized and the definition of the allowable interval to find the optimal values. Then, in the admissible area randomly, bees are located, as well as the vectors and velocities of their movement are given. Then each particle must move through the space of decisions, so if it were a bee in the family. The algorithm acts on each particle separately, moving it to a small value, cycling it through the whole family. The following steps are performed for each share:

- Assessment of the suitability of the particle, comparison with the PBP and GBP. The suitability function, using the particle coordinates in the decision space, returns the validity value for the current position. If this value is greater than the PBP value corresponding to this particle, or GBP, then the corresponding positions are replaced by the current position.
- Correction of particle velocity. Particle speed manipulation is a major element of all optimization. The exact understanding of the equation used to determine the speed is the key to understanding the whole process of optimization. The velocity of the particle varies according to the relative position of the PBP and GBP positions. It strives towards these positions of greatest suitability according to the following equation:

$$\mathrm{v}_n^{i+1} = w \cdot \mathrm{v}_n^i + c_1 rand() \cdot (p_n - x_n) + c_2 rand() \cdot (g_n - x_n) \quad (1)$$

where:

v_n^i – This is the particle velocity in the n-th dimension in the previous step,
x_n – This is the coordinate of the particle in the n-th dimension,
p_n – PBP (personal best position),
g_n – GBP (global best position).

The calculation is made for each of N. From this equation it is seen that the new velocity is derived from the old velocity by simply scaling on w, and adding directions of GBP and PBP for this particular direction.

The c_1 and c_2 are large-scale coefficients that determine the relative mutual attraction to the PBP and GBP. They are sometimes regarded as cognitive and social factors. The c_1 is the coefficient that determines the impact on the share of its memory on the PBP, c_2 is the coefficient that determines the impact on the share of the other family members. The increase involves studying the space of solutions by moving each particle in the direction of its PBP; The increase implies a study of the predicted global maximum.

The random number function *rand()* returns the number in the interval between -1 and 1. In general, the two appearance of the function *rand()* is two different function calls. Most implementations use two independent random variables for stochastic changes in the relative attraction of GBP and PBP. This input of a random element in optimization is intended to simulate a small unpredictable component of real family behavior. w is called "inertial weight" and this number (selected in the range between 0 and 1) reflects to what extent the proportion remains true to its original course, without affecting the GBP and PBP.

We set the boundaries first, but nowhere in formulas and methods were mentioned about them. So how do you take them into account? There are several options.

For example, you can make walls absorbing. When the particle hits the boundary of the decision space in one of the measurements, the velocity in this dimension is zeroed, and the particle will eventually be returned to the given space of the solutions. This means that the boundaries - the "walls" absorb the energy of particles trying to leave the allowed area. Or to reflect the particle velocity when it flies to the wall. But the most effective solution was "invisible walls". A share can safely fly beyond their limits, but being out of the allowed area, the values received by her value are simply not taken into account, until it returns.

The method of a bee family can be effectively divided into several parallel processes, which will significantly increase its speed. In comparison with the genetic algorithm, whose operators can be implemented in different ways, the MBS has only one operator - the calculation of speed, which makes it easier to use.

In the method of the bee family, it is easy to determine the achievements of the global minimum point, while in genetic algorithms it is much more complicated. The concept of these methods is based on two totally different natural processes: MBS is based on the social behavior of the bee family, and the genetic algorithm mimics the process of evolution and natural selection. Due to this, it is possible to combine the two methods.

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