Survey on Swarm Intelligence Algorithms and Applications

Vineetha Pais
Assistant Professor
Department of Information Science & Engineering
AJIET, Mangalore, India

Abstract— This paper is a literature review on swarm intelligence, its algorithms and applications, it mainly focuses on Particle Swarm Optimization (PSO), Ant Colony System (ACS), Stochastic Diffusion Search (SDS), Bacteria Foraging (BF), the Artificial Bee Colony (ABC), and so on. SI can be used in controlling robots and unmanned vehicles, predicting social behaviors, enhancing the telecommunication and computer networks, etc. This paper summarizes different swarm intelligence algorithms and its applications in various fields.

Keywords: Swarm Intelligence (SI); PSO; ACS; SDS; BF; ABC

I. Introduction

Swarm intelligence processes a population of individuals. In swarm intelligence, an algorithm maintains and successively improves a population of potential solutions until some stopping condition is met. The solutions are initialized randomly in the search space, and are guided toward the better and better areas through the interaction among solutions over iterations. With the application of the swarm intelligence, more rapid and effective methods can be designed to solve big data analytics problems Off-line.

Swarm intelligence comes from group of birds, bees, ants, fish schools etc. It goes to the great many organisms that amplify their group intelligence by forming flocks, schools, shoals, colonies, and swarms. Among countless species, nature show us that social creatures, when they work together as unified systems, can outperform the vast majority of individual members when solving problems and making decisions. Scientists call this “Swarm Intelligence”. We human beings didn’t evolve the natural ability to form a Swarm Intelligence. Fish detect tremors in the water around them. Bees use high speed vibrations. Birds detect motions propagating through the flock. But now, with high-speed networking technology, we humans can connect with each other from anywhere in world.

II. Algorithms

A. Ant Colony Optimization (ACO) algorithm

The ant colony algorithm is an algorithm for finding optimal paths that is based on the behavior of ants searching for food. At first, the ants wander randomly. When an ant finds a source of food, it walks back to the colony leaving "markers" (pheromones) that show the path has food. When other ants come across the markers, they are likely to follow the path with a certain probability. If they do, they then populate the path with their own markers as they bring the food back. As more ants find the path, it gets stronger until there are a couple streams of ants traveling to various food sources near the colony.

Because the ants drop pheromones every time they bring food, shorter paths are more likely to be stronger, hence optimizing the "solution." In the meantime, some ants are still randomly scouting for closer food sources. A similar approach can be used find near-optimal solution to the traveling salesman problem.

Once the food source is depleted, the route is no longer populated with pheromones and slowly decays. Because the ant-colony works on a very dynamic system, the ant colony algorithm works very well in graphs with changing topologies. Examples of such systems include computer networks, and artificial intelligence simulations of workers.

B. Artificial Bee Colony (ABC) Algorithm

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 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 (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.

C. Particle Swarm Optimization(PSO) Algorithm

PSO is a population based optimization technique. It shares many similarities with Genetic Algorithm(GA). The system is initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation. In PSO, the potential solutions, called particles, fly through the problem space by following the current optimum particles.

Each particle keeps track of its coordinates in the problem space which are associated with the best solution that it has achieved so far. This value is called pbest. Another "best" value that is tracked by the particle swarm optimizer is the best value, obtained so far by any particle in the neighbors of the particle. This location is called lbest. when a particle takes all the population as its topological neighbors, the best value is a global best and is called gbest.

The particle swarm optimization concept consists of, at each time step, changing the velocity of (accelerating) each particle toward its pbest and lbest locations (local version of PSO). Acceleration is weighted by a random term, with separate random numbers being generated for acceleration toward pbest and lbest locations.

D. Bacteria Foraging Optimization Algorithm (BFOA)

Bacterial foraging optimization algorithm (BFOA) has been widely accepted as a global optimization algorithm of current interest for distributed optimization and control. BFOA is inspired by the social foraging behavior of Escherichia coli. Bacteria search for nutrients in a manner to maximize energy obtained per unit time. Individual bacterium also communicates with others by sending signals. A bacterium takes foraging decisions after considering two previous factors. The process, in which a bacterium moves by taking small steps while searching for nutrients, is called chemotaxis and key idea of BFOA is mimicking chemotactic movement of virtual bacteria in the problem search space.

III. APPLICATIONS

Various applications of Swarm Intelligence algorithms are discussed below:

A. Military Applications

Military applications of swarm intelligence are truth. The Navy recently announced a program that applies swarm intelligence to autonomous watercraft. The underlying program running the swarms is called Control Architecture for Robotic Agent Command and Sensing or CARACaS. These boat swarms have now demonstrated the ability to escort high value targets and surround potential enemy targets. In the near future, small low-cost swarms of watercraft will engage enemy targets without endangering human lives in the process. These same concepts are already being applied to unmanned aerial drones. The US military has unveiled plans to have swarms of autonomous drones flown into combat zones by an unmanned tele-operated mothership. Once released the drones will use swarm intelligence to carry out specific missions as a group without human intervention.

B. Space Exploration

Swarm intelligence is becoming a very common subject in the commercial space economy. There are incredibly high costs associated with doing just about anything in space, and swarms may hold the solution to this problem. We will take asteroid mining as the example. Several firms have emerged in the past few years with the stated goal of enabling asteroid mining. Space mining, while technically feasible, is often dismissed due to the incredibly large cost associated with mining something very far away with large, expensive robotic craft. However, if we can lower the cost of manufacturing spacecraft through 3D printing, economies of scale, and private innovation, things begin to change. Skybox, PlanetLabsand Planetary Resources are already establishing a new paradigm in low cost spacecraft manufacturing and deployment. Once we have access to low cost spacecraft, we can apply swarm intelligence to make difficult tasks, such as asteroid mining, much more feasible and successful. Swarms of robotic spacecraft can encircle an asteroid deep in space and process raw materials and water for delivery back to Earth orbit. Even if several spacecraft are lost, the mission can still be completed. Once these resources are delivered back to Earth orbit, swarms of 3D printing spiders working as a collective group can begin constructing massive orbital structures at a fraction of the cost compared to launching them from Earth.

C. Software Engineering

Software testing is an important and valuable part of the software development life cycle. Due to the time and cost constraints, it is not possible to test the software manually and fix the defects. Thus the use of test automation plays a very important role in the software testing process. Meta-Heuristic algorithms have been applied to three areas of software engineering: test data generation, module construction and cost/effort prediction. The process of test data generation involves activities for producing a set of test data that satisfied a chosen testing criterion. Requirements for test case generation: • Transformation of the testing problem into a graph. • A heuristic measure for measuring the “goodness” of paths through the graph. • A mechanism for creating possible solutions efficiently and a suitable criterion to stop solution generation. • A suitable method for updating the pheromone.

D. Image Segmentation

Image segmentation plays an essential role in the interpretation of various kinds of images. Image segmentation techniques can be grouped into several categories such as edge-based segmentation, region oriented segmentation, histogram thresholding, and clustering algorithms (Gonzalez & Woods, 1992). The aim of a clustering algorithm is to aggregate data into groups such that the data in each group share similar features while the data clusters are being distinct from each other.

SI can help SCL find the global optima using the same parameter set and learning rate as those used in the SCL and recognize the clusters where the SCL fails to do, in some cases. This can be advantageous since for SCL to find the global optima the learning rate should be adjusted in the course of experimentation.

E. Data Mining

Data mining and particle swarm optimization may seem that they do not have many properties in common. However, they can be used together to form a method which often leads to the result, even when other methods would be too expensive or difficult to implement. A new clustering method based on PSO is proposed and is applied to unsupervised classification and image segmentation. The PSO-based approaches are proposed to tackle the color image quantization and spectral unmixing problems. Visual data mining via the construction of virtual reality spaces for the representation of data and knowledge, involves Particle swarm optimization (PSO) combined with classical optimization methods. This approach is applied to very high dimensional data from microarray gene expression experiments in order to understand the structure of both raw and processed data. Cluster analysis has become an important technique in exploratory data analysis, pattern recognition, machine learning, neural computing, and other engineering.

The clustering aims at identifying and extracting significant groups in underlying data. The basic mechanism underlying this type of aggregation phenomenon is an attraction between dead items mediated by the ant workers: small clusters of items grow by attracting workers to deposit more items. It is this positive and auto-catalytic feedback that leads to the formation of larger and larger clusters. The general idea for data clustering is that isolated items should be picked up and dropped at some other location where more items of that type are present. Therefore, various swarm intelligence algorithms can be used together to form a method which often leads to the result, even when other methods would be too expensive or difficult to implement.

IV. Conclusion

The paper presents a brief survey of Swarm intelligence and its algorithms. The paper will act as a good literature survey for researchers starting to work in the field of swarm intelligence.

References

[1] Swarm Intelligence and Image Segmentation by Sara Saatchi and Chih-Cheng Hung, Southern Polytechnic State University, USA
[2] Swarm Intelligence in Data Mining by Monica Chis, Avram Iancu University, Romania
[3] http://www.scholarpedia.org/article/Swarm_intelligence
[4] https://en.wikipedia.org/wiki/Swarm_intelligence
[5] Ant Colony Optimization by Marco Dorigo and Thomas Stützle, MIT Press, 2004. ISBN 0-262-04219-3
[6] Particle Swarm Optimization by Maurice Clerc, ISTE, ISBN 1-905209-04-5, 2006.
[7] C. Blum and D. Merkle (eds.). Swarm Intelligence – Introduction and Applications. Natural Computing. Springer, Berlin, 2008.
[8] D. Karaboga, B. Akay; A Survey: Algorithms Simulating Bee Swarm Intelligence; Artificial Intelligence Review; 31 (1), pp. 68-85, 2009.
[9] D. Karaboga, B.Gorkemli, C.Ozturk, N. Karaboga; A comprehensive survey: artificial bee colony (ABC) algorithm and applications; Artificial Intelligence Review; 42(1), pp.21-57, 2014, DOI: 10.1007/s10462-012-9328-0.
[10] B. Akay, D. Karaboga, "A survey on the applications of artificial bee colony in signal, image, and video processing", Signal Image and Video Processing, vol.9, pp.967-990, 2015
[11] J. C. Bansal, H. Sharma, S. S. Jadon, Artificial bee colony algorithm:a survey. International Journal of Advanced Intelligence Paradigms, 5 (1/2):123–159, 2013
[12] L. Bolaji, A. T. Khader, M. A. Al-Betar, M. A. Awadallah, Artificial bee colony algorithm, its variants and applications: a survey. Journal of Theoretical & Applied Information Technology, 47 (2): 434–459, 2013.
[13] Kumar, D. Kumar, A review on artificial bee colony algorithm. International Journal of Engineering and Technology, 2 (3): 175–186, 2013.
[14] K. Balasubramani, K. Marcus, A comprehensive review of artificial bee colony algorithm. International Journal of Computers & Technology, 5 (1):15–28, 2013.
[15] Kumar, D. Kumar, S. K. Jarial, A Review on Artificial Bee Colony Algorithms and Their Applications to Data Clustering. Cybernetics and Information Technologies, 17 (3): 3–28, 2017.