Swarm Intelligence

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Abstract
Swarm intelligence is the discipline that deals with natural and artificial systems composed of many individuals that coordinate using decentralized control and self-organization. In particular, the discipline focuses on the collective behaviors 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.

Keywords : Swarm Intelligence , Artificial bee colony algorithm, Differential Evolution , Decentralised Control

Swarm Intelligence

Swarm Intelligence (SI) is the collective behaviour of decentralized,self organized systems ,natural or artificial systems.The concept is employed in work on artificial intelligence.SI systems consist typically of a population of simple agents or voids interacting locally with one another and with their environment. The inspiration often comes from nature, especially biological systems. The agents follow very simple rules, and although there is no centralized control structure dictating how individual agents should behave, local, and to a certain degree random, interactions between such agents lead to the emergence of "intelligent" global behavior, unknown to the individual agents. Examples in natural systems of SI include ant colonies, bird flocking, animal herding, bacterial growth, fish schooling and microbial intelligence.

Particle Swarm Intelligence

Particle swarm opt optimization algorithm for dealing with problems in which a best solution can be represented as a point or surface in an n-dimensional space. Hypotheses are plotted in this space and seeded with an initial velocity, as well as a communication channel between the particles Particles then move through the solution space, and are evaluated according to some fitness criterion after each time step. Over time, particles are accelerated towards those particles within their communication grouping which have better fitness values. The main advantage of such an approach over other global minimization strategies such as simulated annealing is that the large numbers of members that make up the particle swarm make the technique impressively resilient to the problem of local minima.

Ant colony optimization
Ant colony optimization (ACO), introduced by Dorigo is a class of optimization algorithms modeled on the actions of an ant colony. ACO is a probabilistic technique useful in problems that deal with finding better paths through graphs. Artificial 'ants'—simulation agents—locate optimal solutions by moving through a parameter space representing all possible solutions. Natural ants lay down pheromones directing each other to resources while exploring their environment. The simulated 'ants' similarly record their positions and the quality of their solutions, so that in later simulation iterations more ants locate better solutions.

Artificial bee colony algorithm
Artificial bee colony algorithm (ABC) is a meta-heuristic algorithm introduced by Karaboga in 2005,and simulates the foraging behaviour of honey bees. The ABC algorithm has three phases: employed bee, onlooker bee and scout bee. In the employed bee and the onlooker bee phases, bees exploit the sources by local searches in the neighbourhood of the solutions selected based on deterministic selection in the employed bee phase and the probabilistic selection in the onlooker bee phase. In the scout bee phase which is an analogy of abandoning exhausted food sources in the foraging process, solutions that are not beneficial anymore for search progress are abandoned, and new solutions are inserted instead of them to explore new regions in the search space. The algorithm has a well-balanced exploration and exploitation ability.

Differential evolution
Differential evolution is similar to genetic algorithm and pattern search. It uses multiagents or search vectors to carry out search. It has mutation and crossover, but do not have the global best solution in its search equations, in contrast with the particle swarm optimization.[1]

The bees algorithm
The bees algorithm in its basic formulation was created by Pham and his co-workers in 2005, and further refined in the following years. Modeled on the foraging behaviour of honey bees, the algorithm combines global explorative search with local exploitative search. A small number of artificial bees (scouts) explores randomly the solution space (environment) for solutions of high fitness (highly profitable food sources), whilst the bulk of the population search (harvest) the neighbourhood of the fittest solutions looking for the fitness optimum. A deterministic recruitment procedure which simulates the waggle dance of biological bees is used to communicate the scouts' findings to the foragers, and distribute the foragers depending on the fitness of the neighbourhoods selected for local search. Once the search in the neighbourhood of a solution stagnates, the local fitness optimum is considered to be found, and the site is abandoned. In summary, the Bees Algorithm searches concurrently the most promising regions of the solution space, whilst continuously sampling it in search of new favourable regions.

Artificial immune systems
Artificial immune systems (AIS) concerns the usage of abstract structure and function of the immune system to computational systems, and investigating the application of these systems

towards solving computational problems from mathematics, engineering, and information technology. AIS are a sub-field of Biologically inspired computing, and natural computation, with interests in Machine Learning and belonging to the broader field of Artificial Intelligence.[2]

Bat algorithm

Bat algorithm (BA) is a swarm-intelligence-based algorithm, inspired by the echolocation behavior of microbats. BA automatically balances exploration (long-range jumps around the global search space to avoid getting stuck around one local maxima) with exploitation (searching in more detail around known good solutions to find local maxima) by controlling loudness and pulse emission rates of simulated bats in the multi-dimensional search space.

Glowworm swarm optimization

Glowworm swarm optimization (GSO), introduced by Krishnanand and Ghose in 2005 for simultaneous computation of multiple optima of multimodal functions.[The algorithm shares a few features with some better known algorithms, such as ant colony optimization and particle swarm optimization, but with several significant differences.[5] The agents in GSO are thought of as glowworms that carry a luminescence quantity called luciferin along with them. The glowworms encode the fitness of their current locations, evaluated using the objective function, into a luciferin value that they broadcast to their neighbors. The glowworm identifies its neighbors and computes its movements by exploiting an adaptive neighborhood, which is bounded above by its sensor range. Each glowworm selects, using a probabilistic mechanism, a neighbor that has a luciferin value higher than its own and moves toward it. These movements—based only on local information and selective neighbor interactions—enable the swarm of glowworms to partition into disjoint subgroups that converge on multiple optima of a given multimodal function.

Gravitational search algorithm

Gravitational search algorithm (GSA) based on the law of gravity and the notion of mass interactions. The GSA algorithm uses the theory of Newtonian physics and its searcher agents are the collection of masses. In GSA, there is an isolated system of masses. Using the gravitational force, every mass in the system force is therefore a way of transferring information between different masses.In GSA, agents are considered as objects and their performance is measured by their masses. All these objects attract each other by a gravity force, and this force causes a movement of all objects globally towards the objects with heavier masses. The heavy masses correspond to good solutions of the problem. The position of the agent corresponds to a solution of the problem, and its mass is determined using a fitness function. By lapse of time, masses are attracted by the heaviest mass, which would ideally present an optimum solution in the search space. The GSA could be considered as an isolated system of masses. It is like a small artificial world of masses obeying the Newtonian laws of gravitation and motion.

Self-propelled particles

Self-propelled particles (SPP), also referred to as the boids model introduced in 1986 by

Reynolds.A swarm is modeled in SPP by a collection of particles that move with a constant speed but respond to a random perturbation by adopting at each time increment the average direction of motion of the other particles in their local neighbourhood.SPP models predict that swarming animals share certain properties at the group level, regardless of the type of animals in the swarm. Swarming systems give rise to emergent behaviours which occur at many different scales, some of which are turning out to be both universal and robust. It has become a challenge in theoretical physics to find minimal statistical models that capture these behaviours.[3]

Stochastic diffusion search

Stochastic diffusion search (SDS) is an agent-based probabilistic global search and optimization technique best suited to problems where the objective function can be decomposed into multiple independent partial-functions. Each agent maintains a hypothesis which is iteratively tested by evaluating a randomly selected partial objective function parameterized by the agent's current hypothesis. In the standard version of SDS such partial function evaluations are binary, resulting in each agent becoming active or inactive. Information on hypotheses is diffused across the population via inter-agent communication. Unlike the stigmergic communication used in ACO, in SDS agents communicate hypotheses via a one-to-one communication strategy analogous to the tandem running procedure observed in Leptothorax acervorum. A positive feedback mechanism ensures that, over time, a population of agents stabilise around the global-best solution. SDS is both an efficient and robust global search and optimisation algorithm, which has been extensively mathematically described.Recent work has involved merging the global search properties of SDS with other swarm intelligence algorithms.

Multi-swarm optimization

Multi-swarm optimization is a variant of particle swarm optimization (PSO) based on the use of multiple sub-swarms instead of one (standard) swarm. The general approach in multi-swarm optimization is that each sub-swarm focuses on a specific region while a specific diversification method decides where and when to launch the sub-swarms. The multi-swarm framework is especially fitted for the optimization on multi-modal problems, where multiple (local) optima exist.[4]

Applications

Swarm Intelligence-based techniques can be used in a number of applications. The U.S. military is investigating swarm techniques for controlling unmanned vehicles. The European Space Agency is thinking about an orbital swarm for self-assembly and interferometry. NASA is investigating the use of swarm technology for planetary mapping. A 1992 paper by M. Anthony Lewis and can see the situation of other masses. The gravitas George A. Bekey discusses the possibility of using swarm intelligence to control nanobots within the body for the purpose of killing cancer tumors.Swarm intelligence has also been applied for data mining.

Ant-based routing

The use of Swarm Intelligence in telecommunication networks has also been researched, in the form of ant-based routing. This was pioneered separately by Dorigo et al. and Hewlett Packard in the mid-1990s, with a number of variations since. Basically this uses a probabilistic routing table rewarding/reinforcing the route successfully traversed by each "ant" (a small control packet) which flood the network. Reinforcement of the route in the forwards, reverse direction and both simultaneously has been researched: backwards reinforcement requires a symmetric network and couples the two directions together; forwards reinforcement rewards a route before the outcome is known (but then you pay for the cinema before you know how good the film is). As the system behaves stochastically and is therefore lacking repeatability, there are large hurdles to commercial deployment. Mobile media and new technologies have the potential to change the threshold for collective action due to swarm intelligence (Rheingold: 2002, P175).

The location of transmission infrastructure for wireless communication networks is an important engineering problem involving competing objectives. A minimal selection of locations (or sites) is required subject to providing adequate area coverage for users. A very different-ant inspired swarm intelligence algorithm, stochastic diffusion search(SDS), has been successfully used to provide a general model for this problem, related to circle packing and set covering. It has been shown that the SDS can be applied to identify suitable solutions even for large problem instances.

Airlines have also used ant-based routing in assigning aircraft arrivals to airport gates. At Southwest Airlines a software program uses swarm theory, or swarm intelligence—the idea that a colony of ants works better than one alone. Each pilot acts like an ant searching for the best airport gate. "The pilot learns from his experience what's the best for him, and it turns out that that's the best solution for the airline," Douglas A. Lawson explains. As a result, the "colony" of pilots always go to gates they can arrive at and depart from quickly. The program can even alert a pilot of plane back-ups before they happen. "We can anticipate that it's going to happen, so we'll have a gate available," Lawson says.

Crowd simulation

Artists are using swarm technology as a means of creating complex interactive systems or simulating crowds.

Stanley and Stella in: Breaking the Ice was the first movie to make use of swarm technology for rendering, realistically depicting the movements of groups of fish and birds using the Boids system. Tim Burton's *Batman Returns* also made use of swarm technology for showing the movements of a group of bats. *The Lord of the Rings* film trilogy made use of similar technology, known as Massive, during battle scenes. Swarm technology is particularly attractive because it is cheap, robust, and simple.

Airlines have used swarm theory to simulate passengers boarding a plane. Southwest Airlines researcher Douglas A. Lawson used an ant-based computer simulation employing only six interaction rules to evaluate boarding times using various boarding methods.

Human swarming

Enabled by mediating software such as the UNU collective intelligence platform, networks of distributed users can be organized into "human swarms" (also referred to as "social swarms") through the implementation of real-time closed-loop control systems. As published by Rosenberg (2015), such real-time control systems enable groups of human participants to behave as a unified collective intelligence.[When logged into the UNU platform, for example, groups of distributed users can collectively answer questions, generate ideas, and make predictions as a singular emergent entity. Early testing shows that human swarms can out-predict individuals across a variety of real-world projections.

Swarmic art

In a series of works which have successfully used two swarm intelligence algorithms – one mimicking the behaviour of one species of ants (Leptothorax acervorum) foraging (stochastic diffusion search, SDS) and the other algorithm mimicking the behaviour of birds flocking (particle swarm optimization, PSO) – to describe a novel integration strategy exploiting the local search properties of the PSO with global SDS behaviour. The resulting hybrid algorithm is used to sketch novel drawings of an input image, exploiting an artistic tension between the local behaviour of the 'birds flocking' - as they seek to follow the input sketch - and the global behaviour of the "ants foraging" - as they seek to encourage the flock to explore novel regions of the canvas. The "creativity" of this hybrid swarm system has been analysed under the philosophical light of the "rhizome" in the context of Deleuze's "Orchid and Wasp" metaphor.[6]

In a more recent work of al-Rifaie et al., "Swarmic Sketches and Attention Mechanism", introduces a novel approach deploying the mechanism of 'attention' by adapting SDS to selectively attend to detailed areas of a digital canvas. Once the attention of the swarm is drawn to a certain line within the canvas, the capability of PSO is used to produce a 'swarmic sketch' of the attended line. The swarms move throughout the digital canvas in an attempt to satisfy their dynamic roles – attention to areas with more details – associated to them via their fitness function. Having associated the rendering process with the concepts of attention, the performance of the participating swarms creates a unique, non-identical sketch each time the 'artist' swarms embark on interpreting the input line drawings. In other works while PSO is responsible for the sketching process, SDS controls the attention of the swarm.[6]

In a similar work, "Swarmic Paintings and Colour Attention",non-photorealistic images are produced using SDS algorithm which, in the context of this work, is responsible for colour attention.

Conclusion

In this paper, we concluded that the swarm robotics inspired from nature is a combination of swarm intelligence and robotics, which shows a great potential in several aspects. as a main part of this paper, the current research on the swarm robotic algorithms are presented in detail, including cooperative control mechanisms in swarm robotics for flocking, navigating and searching applications.

Besides the cooperative algorithms to provide control for the swarm, the manufacturing is a fundamental need for developing the swarm robotics systems. With the help of advance in Micro

Electro Mechanical technology in the aspects of mechanical transmission, sensors, actuators and electronic components, the size and cost of robots have been significantly reduced.

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