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Swarm Computational Intelligence background research

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Swarm Computational Intelligence Research

The swarm computational intelligence field research encompasses the study of complex emergent behaviors in swarms composed by many simple individuals. In nature, swarm behavior is observed in bee or ant colonies, herds, schools of fish, etc. These swarms are characterized by moving together as a group and being able to build huge, self-repairing structures like ant nests. There are other specific characteristics of swarms:

- They lack a swarm leader. Every individual has the same rank and they do not have a guide.
- Individuals of a swarm are typically a lot smaller compared to the collective size of the swarm.
- Individuals do not perform complex tasks on their own, neither do they have outstanding abilities or the collective abilities that the swarm has.
- The swarm intelligence comes from all individuals being restricted to a set of simple rules which cause the emergence of a complex behavior or "hive mind" that enables the swarm to carry out complex actions.
- Individuals do not communicate directly between each other. They recognize patterns and react to environmental changes. This enables an individual at one end of the hive to mimic the action of an individual at the other end of the swarm.

The most important question in swarm intelligence research is, how do individuals communicate? Swarm behavior has a reactive nature, it does not depend on individuals being able to pass definite instructions down a chain of command. The individuals in a swarm recognize and detect patter changes in their environment and in other individuals´ behaviors. For example, when ants are building their nests, they observe the characteristics of the structure and build according to what they observe. This gives the ant swarm the flexibility at the time of building structures because an ant does not need to be told what to do, it just takes advantage of the construction already built by other ants. In bee hives, scout bees explore food sources and every bee returns with the information about the source´s quality. In the hive, every bee performs a dance which is observed by other bees. After polling every bee´s information, a collective best is chosen "democratically" considering every possible data and the optimal food source is selected.

In artificial swarm algorithms, natural behaviors can be emulated with the goal of analyzing a complex problem, consider every possible solution and choose the optimal one. Swarm algorithms are robust because of their reactive properties. The challenge comes at the time of implementation. First, the actual problem to solve needs to be mathematically modelled so an objective function can be established. Swarm individuals are then programmatically created and restricted with a set of rules. These rules can be as simple as:

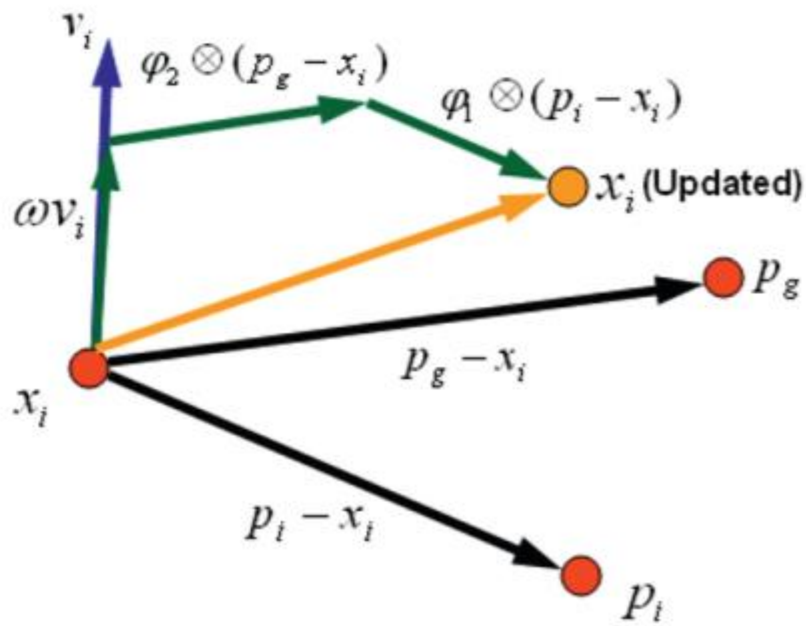
- Staying at a certain distance from other individuals
- Go into the averaged direction of the closest neighbor individuals in the swarm
- Stay inside a certain area where most of the swarm is positioned (cohesive properties)

When the implementation goes from simulation to physical execution, the design of the agents needs to consider the sensors that they need to be able to process their environment and be able to interpret the data (cameras, distance sensors, light sensors, accelerometers, touch sensors, etc.). Since the swarm individuals do not communicate directly with each other and there is no superior software making the decisions for every individual, the individuals need to be able to make their own decisions and act according to their processed sensor data. The simple behavior rules need to be programmatically embedded on their system. The designed individuals do not need to be aware of other robots in the swarm and do not need to have a memory log since their behavior is reactive to what they perceive. One of the most famous used swarm algorithms for optimization is Particle Swarm Optimization (PSO).

<u>Particle Swarm Optimization (PSO):</u> In this algorithm, the solutions of a problem are dubbed particles. These particles are inside a search space V. Each particle has a component X_i and V_i for position and velocity. The velocity of each particle is influenced by it´s prior velocity, it is guided by the particle´s best known position (local optimum value) and it is also guided by the general best-known position in the search space. The velocity formula is then written as:

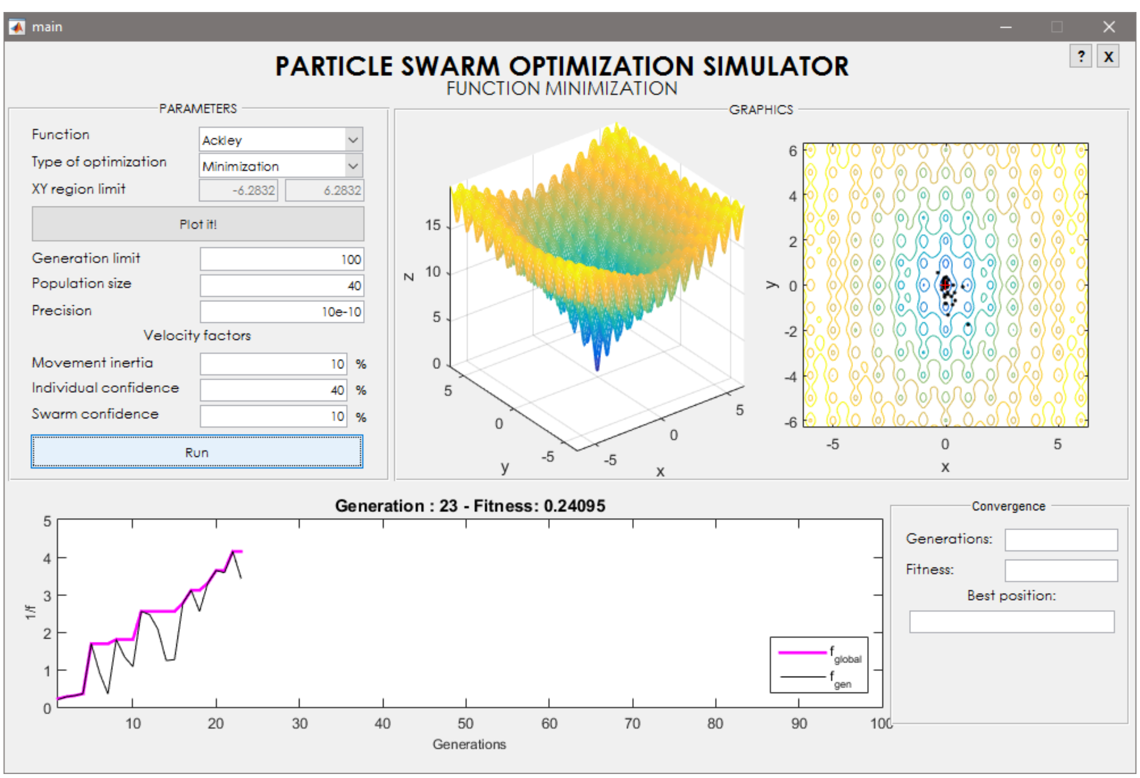
$$v_{i+1} = wv_i + c_1 R_1 (p_i - x_i) + c_2 R_2 (p_g - x_i)$$

In this equation, the W variable is an inertia coefficient that gives weight to the current particle velocity in the calculation of the future velocity. The c_1 variable is the weight coefficient for the cognitive factor which is the difference between the current position and the particle´s personal best location multiplied by R_1 which has a value of [0,1]. The c_2 variable is the weight coefficient for the social factor which is the difference between the current position and the swarm´s general best location multiplied by R_2 which has a value of [0,1]. The graphical representation of this equation is the following:

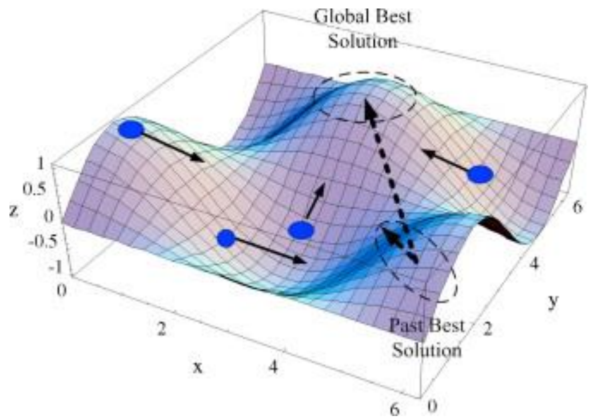


(Blum & Li, 2014).

Here are some PSO algorithm representations used to find the absolute minimum of a mathematical function:



(Biswas, 2016).



(Biswas, 2016).

<u>Other kinds of applications:</u>

- Particle swarm optimization (PSO). Military applications for target allocation.
- Problems solved with Swarm Intelligence (SI): clustering, planetary mapping, controlling nanorobots and a variety of problems in data mining such as feature selection and classification.
- Swarm Intelligence Approach to Optimization Problems using the Artificial Bee Colony (ABC) algorithm: bees divided in onlookers, slaves and scouts look for the optimal food sources and collect all the food in the least amount of time
- Swarm colony that finds absolute minimum of a function: https://www.youtube.com/watch?v=OUHAypWn1Ro
- Robotic Swarm controlled by PSO: https://youtu.be/RLIA1EKfSys
- Other swarm systems: https://www.youtube.com/watch?v=axxXz2BM0yw

References

Biswas, P. (2016). *PSO: Particle Swarm Optimization.* MathWorks, MATLAB Central. [Recuperado el 19 de enero de 2019]. En: https://de.mathworks.com/matlabcentral/fileexchange/43541-particle-swarm-optimization-pso?focused=6457091&tab=function

Blum, C. & Li, X. (2014). *Swarm Intelligence in Optimization.* Spanish National Research Counsil, Universidad Politécnica de Cataluña, Barcelona, España. [Recuperado el 19 de enero de 2019]. En: https://www.researchgate.net/publication/227068137_Swarm_Intelligence_in_Optimization

Buarque, P. (2018). *A Swarm Intelligence Approach to Optimization Problems using the Artificial Bee Colony (ABC) algorithm.* Cesar Update, Medium. [Recuperado el 19 de enero de 2019]. En: https://medium.com/cesar-update/a-swarm-intelligence-approach-to-optimization-problems-using-the-artificial-bee-colony-abc-5d4c0302aaa4