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Swarm Intelligence

Priyanshi Mahendra[1], Rajendra Prasad Pandey[2]
[1]*CCSIT, TeerthankerMahaveer University, Moradabad*
[*]*Assistant ProfessorCCSIT, TMU, Moradabad, India*
[1]*priyanshi.mahendra2014@gmail.com*
[2]rajendra.004@gmail.com

***Abstract*— Swarm intelligence deals with systems composed of many individuals that coordinate using decentralized control and self-organization. In particular, it focuses on the collective behaviors that result from the local interactions of the individuals with each other and with their environment. It is an emerging field of biologically-inspired artificial intelligence based on the behavioral models of social insects such as ants, bees, wasps, termites etc. Swarm Intelligence principles have been successfully applied in a variety of problem domains including function optimization problems, finding optimal routes, scheduling, structural optimization, and image and data analysis.**

***Keywords*—**
Swarm- a large or dense group of insects.
Optimal route- best or most favourable route; optimum route.

Introduction

A swarm is a large number of homogenous, simple agents interacting locally among themselves, and their environment, with no central control to allow a global interesting behaviour to emerge. Swarm-based algorithms have recently emerged as a family of nature-inspired, population-based algorithms that are capable of producing low cost, fast, and robust solutions to several complex problems. Swarm Intelligence (SI) can therefore be defined as a relatively new branch of Artificial Intelligence that is used to model the collective behaviour of social swarms in nature, such as ant colonies, honey bees, and bird flocks. Although these agents (insects or swarm individuals) are relatively unsophisticated with limited capabilities on their own, they are interacting together with certain behavioural patterns to cooperatively achieve tasks necessary for their survival. The social interactions among swarm individuals can be either direct or indirect. **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 behaviours that result from the local interactions of the individuals with each other and with their environment.

EVOLUTION

In 1989, the expression "Swarm Intelligence" was first introduced by G. Beni and J. Wang in the global optimization framework as a set of algorithms for controlling robotic swarm. In 1991, Ant Colony Optimization (ACO) was introduced by M. Dorigo and colleagues as a novel. In 1995, particle swarm optimization was introduced by J. Kennedy.

EXAMPLES

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 artefacts 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.

PROPERTIES OF SWARM INTELLIGENCE SYSTEMS-

The typical swarm intelligence system has the following properties:

- It is composed of many individuals;

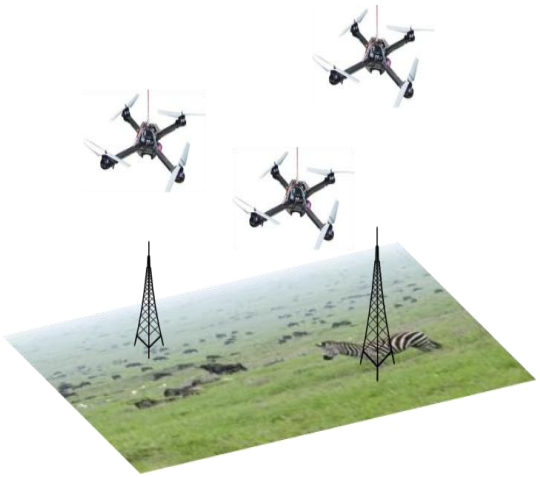
- The individuals are relatively homogeneous (i.e., they are either all identical or they belong to a few typologies);
- The interactions among the individuals are based on simple behavioural rules that exploit only local information that the individuals exchange directly or via the environment (stigmergy);
- The overall behaviour of the system results from the interactions of individuals with each other and with their environment, that is, the group behaviour self-organizes.

APPLICATION AREAS

The areas in which the concept of swarm intelligence is widely used are mentioned below-

- *Adaptive routing in telecom networks-*

  In the past few years there has been a lot of research on the application of swarm intelligence to the problem of adaptive routing in telecommunications networks. A large number of algorithms have been proposed for different types of networks, including wired networks and wireless ad hoc networks.



- *In data mining-*

  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. Ramos proposed ACLUSTER algorithm to follow real ant-like behaviours as much as possible. In that sense, bio-inspired spatial transition probabilities are incorporated into systems.

- *Swarm intelligence in military 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.

- *.Crowd simulating-*

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

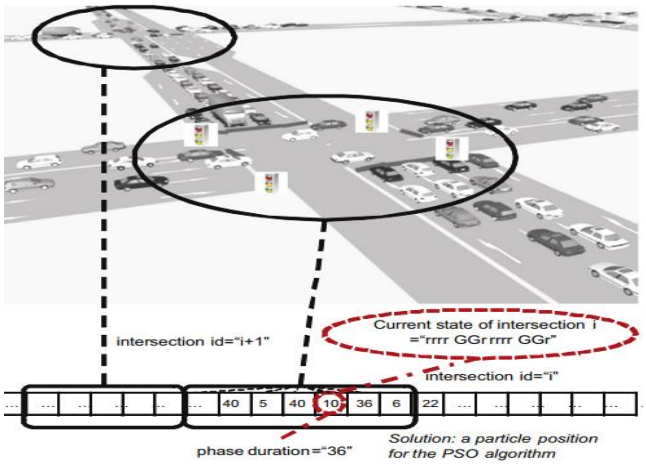
- *Human swarming-*

  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.

- *Swarmic art-*

  The 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".

- *Traffic safety-*



Traffic signal control is an effective way to regulate traffic flow to avoid conflict and reduce congestion. The ACO (Ant Colony) algorithm is an optimization technique based on swarm intelligence.

ALGORITHMS USED

There are a number of algorithms that are used in swarm intelligence for its implementation. Some of them are mentioned below-

A. *Particle swarm optimization-*

The goal of the algorithm is to have all the particles locate the optima in a multi-dimensional hyper-volume. This is achieved by assigning initially random positions to all particles in the space and small initial random velocities. The algorithm is executed like a simulation, advancing the position of each particle in turn based on its velocity, the best known global position in the problem space and the best position known to a particle. The objective function is sampled after each position update. Over time, through a combination of exploration and exploitation of known good positions in the search space, the particles cluster or converge together around optima, or several optima.

B. *Ant colony system optimization-*

The Ant Colony System algorithm is inspired by the foraging behaviour of ants, specifically the pheromone communication between ants regarding a good path between the colony and a food source in an environment. This mechanism is called stigmergy. The objective of the strategy is to exploit historic and heuristic information to construct candidate solutions and fold the information learned from constructing solutions into the history. Solutions are constructed one discrete piece at a time in a probabilistic step-wise manner. The probability of selecting a component is determined by the heuristic contribution of the component to the overall cost of the solution and the quality of solutions from which the component has historically known to have been included. History is updated proportional to the quality of the best known solution and is decreased proportional to the usage if discrete solution components.

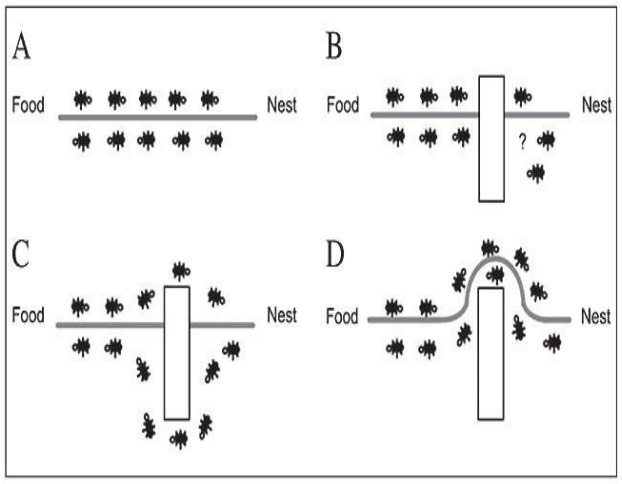


Figure 2. A. Ants in a pheromone trail between nest and food; **B.** an obstacle interrupts the trail; **C.** ants find two paths to go around the obstacle; **D.** a new pheromone trail is formed along the shorter path.

C. *Bees algorithm-*

The Bees Algorithm is inspired by the foraging behaviour of honey bees. Honey bees collect nectar from vast areas around their hive (more than 10 kilometres). Bee Colonies have been observed to send bees to collect nectar from flower patches relative to the amount of food available at each patch. Bees communicate with

each other at the hive via a waggle dance that informs other bees in the hive as to the direction, distance, and quality rating of food sources.

D. *Bacterial foraging optimization algorithm-*

The Bacterial Foraging Optimization Algorithm is inspired by the group foraging behaviour of bacteria such as E.Coli and M.xanthus. Specifically, the BFOA is inspired by the chemotaxis behaviour of bacteria that will perceive chemical gradients in the environment (such as nutrients) and move toward or away from specific signals.

CONCLUSION

It focuses on the collective behaviors that result from the local interactions of the individuals with each other and with their environment. It is an emerging field of biologically-inspired artificial intelligence based on the behavioral models of social insects such as ants, bees, wasps, termites etc. Swarm Intelligence principles have been successfully applied in a variety of problem domains including function optimization problems, finding optimal routes, scheduling, structural optimization, and image and data analysis.

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