

Chapter XVIII

Swarm Intelligence in Production Management and Engineering

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ABSTRACT

This chapter explores the scope of biologically inspired swarm intelligence (SI) into production management with special emphasis in two specific problems of vehicle routing and motion planning of mobile robots. Computer simulations undertaken for this study have also been included to demonstrate the elegance in the application of the proposed theory in the said real-world problems. Possible directions of future research and industrial applications have also been appended at the end of the chapter.

INTRODUCTION

Biologically inspired computing is currently given importance for its immense parallelism and simplicity in computation. In recent times, quite a large number of biologically motivated algorithms have been invented, and are being used for handling many complex problems of the real world. For instance, *neural computing* (Haykins, 1999)

attempts to mimic the biological nervous systems of the living creatures to ensure a significant amount of parallel and distributed processing in computation. *Genetic algorithms* (Golberg, 1989; Holland, 1975) imitate the Darwinian evolutionary process through cross-over and mutation of biological chromosomes. They have successfully been used in intelligent search, optimization, and machine learning applications. *Artificial life*

(Langton, 1995) attempts to model the group behavior of a biological species to interpret complex phenomena of many primitive macrostructures. One typical example of artificial life algorithm includes *artificial immune systems* (Jerne, 1983), which have proved themselves successful in many engineering applications, including behavioral robotics and antivirus vaccines.

In this chapter, we would like to examine the collective behavior of a group of biological creatures such as ants, bees, termites, and wasps. This family of algorithms is called *swarm intelligence* (SI) (Engelbrecht, 2005). The focus of our study is centered on two distinct types of SI algorithms and their applications in appropriate production management and engineering problems.

The behavior of a single ant, bee, termite, and wasp often is too simple, but their collective and social behavior is of paramount significance. A look at National Geographic TV Channel also reveals that advanced mammals including lions enjoy social lives, perhaps for their self-existence at old age and in particular when they are wounded. The collective and social behavior of living creatures motivated researchers to undertake the study of swarm intelligence. Historically, the phrase SI was coined by Beny and Wang in 1989 in the context of cellular robotics. A group of researchers in different parts of the world started working almost at the same time to study the versatile behavior of different living creatures. Inspired by the collective behavior of ants, Marco Dorigo (1992) came up with an interesting solution to a class of optimization problems with his so-called *ant systems*. Dorigo's classical ant systems have undergone an evolution in its fifteen years lifespan, which finally resulted in the *ant colony optimization* (ACO) *algorithm* (Dorigo, Di Caro, & Gambardella, 1999).

Sociological behavior of birds and fish schools also motivated researchers to study their collective characteristics, such as movements in groups, hunting patterns, and selection of breeding places. Kennedy and Eberhart (1995) enunciates an inter-

esting dynamics of *artificial swarm* to determine the optima in a search landscape. Their algorithm is popularly known as *particle swarm optimization* (PSO). PSO has already entered varieties of engineering and scientific design, optimization, classification, control, machine learning, and other applications. In this chapter, we examine the scope of ACO and PSO in production management problems.

General Characteristics of Swarm Intelligence Algorithms

An agent is an entity capable of performing/executing certain operations. SI systems are typically made up of a population of simple agents interacting locally with one another and with their environment. Although there is normally no centralized control structure dictating how individual agents should behave, local interactions between such agents often lead to the emergence of global behavior. Many biological creatures such as fish schools and bird flocks clearly display structural order, with the behavior of the organisms so integrated that even though they may change shape and direction, they appear to move as a single coherent entity (Couzin, Krause, James, Ruxton, & Franks, 2002). The main properties of the collective behavior can be pointed out as

- **Homogeneity:** Every bird in flock has the same behavioral model. The flock moves without a leader, even though temporary leaders seem to appear.
- **Locality:** Its nearest flock-mates only influence the motion of each bird. Vision is considered to be the most important sense for flock organization.
- **Collision Avoidance:** Avoid colliding with nearby flock mates.
- **Velocity Matching:** Attempt to match velocity with nearby flock mates.
- **Flock Centering:** Attempt to stay close to nearby flock mates

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