Chapter 2

A Survey on Ant Colony Optimization, Particle Swarm Optimization, and Cuckoo Algorithms

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ABSTRACT

Nowadays, biologically-inspired optimization algorithms are widely used for solving several engineering problems. Furthermore, there is a wide range of bio-inspired algorithms relative to the various methods of optimization. A detailed description of all these possibilities could take up the whole book. In this chapter, the principles of ant colony optimization, particle swarm optimization, and cuckoo algorithms are presented. A survey on their applications and advantages/disadvantages is also highlighted. An application on the surface roughness minimization of Al Alloy SiC is presented to identify the most suitable optimization method.

INTRODUCTION

The goal of optimization is to find a best solution for a problem. The word “best” means that there more than one solution for the problem and the mathematical model should explore the set of potential solutions in order to find the best one. The main categories of optimization problems can be subdivided as follows: continuous, discrete, constrained, and unconstrained. The bio-inspired optimization algorithms are computation methods inspired by nature. They have the ability to find good optimal solutions in reasonable time.

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The generic mathematical form of most optimization problems is as follows:

Maximize or Minimize \( f(x), \left( i = 1, 2, ..., I \right) \) \( \text{subject to} \)

\[ \begin{align*}
    h_j(x) &= 0, \left( j = 1, 2, ..., J \right), \\
    g_l(x) &\leq 0, \left( l = 1, 2, ..., L \right),
\end{align*} \]

where \( f_i(x), h_j(x) \) and \( g_l(x) \) are functions of the design vector:

\[ x = (x_1, x_2, ..., x_n)^T \]

The components \( x_i \) of \( x \) are called design or decision variables, and they can be real continuous, discrete or a mixture of these two. The functions \( f_i(x) \) (where \( i = 1, 2, ..., I \)) are called the objective functions. The space spanned by the decision variables is called the design space or search space \( \mathbb{R}^n \) whereas the space formed by the objective function values is called the solution space or response space. The equalities for \( h_j \) and inequalities for \( g_l \) are called constraints. These constraints may be linear or nonlinear; likewise, they may be convex or nonconvex.

In the present work, three modern and powerful bio-inspired algorithms are applied to minimize the surface roughness in machining of Al Alloy SiC (AA7075/SiC). The remainder of this chapter is organized as follows: Section 2 describes the principles of ant colony optimization; Section 3 defines the fundamentals of particle swarm optimization; Section 4 presents the main concepts behind the cuckoo search and cuckoo optimization algorithm. The advantages, disadvantages and a survey on the applications of each algorithm are given in each of these sections. Section 5 presents the optimization problem of minimization of the surface roughness in machining Al Alloy SiC. Finally, the last section draws some overall conclusions.

**ANT COLONY OPTIMIZATION**

**Background**

The concepts of the ant colony optimization (ACO) were first introduced by Dorigo in 1992 (M. Dorigo, 1992). The ants live in a colony and have the ability to find the shortest path for finding foods. When moving, they use pheromones in order to communicate the route to the food to other members of the colony. A high concentration of pheromones in a path will increase the probability that the ants select that path. Therefore, each ant chooses the path according to the intensity of pheromones left on the
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