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Configurable Intelligent Optimization Algorithm

Design and Practice in Manufacturing

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Contents

Part I
Introduction and Overview

Intelligent optimization algorithm, which is also called meta-heuristic, is a kind of optimization algorithm that simulates natural phenomena and behaviors with population-based iterations. Its appearance had found a way out for NP-hard problems that are difficult to be solved by many classical deterministic algorithms, and it is able to find feasible suboptimal solutions for complex problems in a relatively short period of time.

The strong versatility, high speed and robustness of intelligent optimization algorithm provide a variety of decision-making solutions for multi-constraint complex numerical and combinatorial optimization problems such as multi-objective service composition, workflow scheduling, manufacturing resource allocation and product quality evaluation and controlling and so on in networked service-oriented manufacturing system. Moreover, it takes advantages of intelligent learning to avoid a large solution space traversal so that the problems can be easily solved. Today, most feasible solutions of these complex manufacturing problems are given by different types of intelligent optimization algorithm. Classic intelligent optimization algorithms, such as genetic algorithm (GA), particle swarm optimization (PSO) and ant colony optimization (ACO) and so on, are also widely reconstructed with various improved and hybrid strategies to adapt different production environments and applications. With highly distributed resources, productions and logistics, more and more improvements or hybridizations are designed to achieve efficient decision-making in every link of product. Intelligent optimization algorithm becomes indispensible in manufacturing.

Therefore, in the Part I of this book, a preliminary introduction of intelligent optimization algorithm and the main optimization problem in manufacturing is presented. This part contains Chaps. 1 and 2. The Chap. 1 presents an overview of the principles, development history and classification of the algorithm. It summarizes the classification of current research emphasis and major trends. The Chap. 2 is a brief overview of complex manufacturing optimization problems, their solution methods and the development of intelligent optimization algorithm in them. From the classification of optimization problems in manufacturing system, this chapter lists the major challenges in solving different sorts of the optimization problems. In view of these challenges, typical problem-solving methods are given and the importance of intelligent optimization technology is pointed out. Based on this, we outline the general design patterns and process of intelligent optimization algorithm, and discuss the application challenges, needs and trends of intelligent optimization algorithm in manufacturing systems.

Chapter 1
Brief History and Overview of Intelligent Optimization Algorithms

Up to now, intelligent optimization algorithm has been developed for nearly 40 years. It is one of the main research directions in the field of algorithm and artificial intelligence. No matter for complex continuous problems or discrete NP-hard combinatorial optimizations, people nowadays is more likely to find a feasible solution by using such randomized iterative algorithm within a short period of time instead of traditional deterministic algorithms. In this chapter, the basic principle of algorithms, research classifications, and the development trends of intelligent optimization algorithm are elaborated.

1.1 Introduction

Intelligent optimization algorithm is developed and integrated from a number of relatively independent sub-fields, including the technology of artificial neural networks, genetic algorithms, immune algorithms, simulated annealing, and tabu search and swarm intelligence techniques. As we all know, the current main intelligent optimization algorithms are based on the mode of population based iteration. They operate a population, which represents a group of individuals (or solutions), in each generation to maintain good information in the solution space and find better positions step by step. It is a common method that is independent from specific problems so that it can handle complex optimization problems that are difficult for traditional optimization methods. Their common characteristics are: (1) all operations act on current individuals in each generation; (2) the searching is based on iterative evolution; (3) the optimization can be easily parallelized by multi-population scheme; (4) most of them can give a satisfactory non-inferior solutions close to the optimal solutions, instead of certainly finding the optimal solution; (4) the algorithm is rather random and cannot guarantee the

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efficiency of finding non-inferior solutions. Therefore we simplify the basic process of intelligent optimization algorithms in Fig. 1.1.

Specifically, the first step in problem solving is the encoding design according to the problem environment, character and constraints. Coding is a mapping of problem variables, and it also directly determines the evolution speed of the algorithm. When an appropriate coding scheme is selected, the algorithm will initialize and generate a certain number of individuals to form a population according to the definition of problem variables. Each variable of an individual is randomly generated in the definition domain, and the fitness value of individual in each generation is calculated according to problem's objective function, i.e. fitness function. Then, according to the coding scheme, the variables are mapped to form a chromosome. After initialization and encoding, the algorithm iteration will be started. In iteration, the combination of operators plays a major role, such as selection, crossover, and mutation operator in genetic algorithm, and path finding and pheromone update in ant colony algorithm. Different operators have different effects in the algorithm, so different composition of operators can usually produce different results in solving problem. Through a few operations, some or the entire individuals in the population are changed. By decoding of the new individuals, a new group of solutions can be obtained. Through the evaluation of population according to fitness function (objective function), the best and the worst individual in the population can be picked out. Then we could update the whole population in generation by using random alternative strategy, elitist replacement strategy or merge-based individual optimal selection. After that, the next iteration will be triggered. When the number of iterations reaches a certain ceiling or the satisfactory feasible or optimal solution has already been reached, we can jump out the iteration loop, and output the global best solutions.

In this evolution mode, problem variables and objectives are reflected by coding and fitness functions, while constraints are embodied in fitness function as penalty function or in coding as a bound. The operators are independent to the problems and can be easily implemented. The unified iterative process can make the design, improvement and hybrid research of intelligent algorithms simpler, more intuitive, and more flexible. With iteration-based sub-optimal searching, intelligent optimization algorithm can effectively avoid the combinatorial explosion when solving NP-hard problem. However, not all operators can be arbitrarily combined to form an effective algorithm. Since the evolutionary process is quite random, and operators have different characteristics and limitations in exploration and exploitation respectively, many intelligent optimization algorithms still have some defects such as premature convergence and large result deviation and so on. Therefore, researchers in various fields still keep looking for bran-new coding schemes, operators, good improvements and hybrid forms of intelligent optimization algorithms. All these works are trying to search better feasible solution with limit iterations and limit size of population.