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Research on Flexible Job Shop Scheduling with Multiple Time Factors based on Group Optimization

Yuxi Wang, Lifei Sun

University of Science and Technology Liaoning, China

Abstract

Production scheduling can improve economic benefits, reduce costs and energy consumption, and promote the sustainable development of enterprises, which is one of the research hotspots in the field of computer integration in the past few decades. With the progress of science, enterprises are increasingly demanding production scheduling. The research and application of effective scheduling methods and optimization techniques have important theoretical and practical significance.According to the requirements of the enterprise's own interests, the strict constraints of delivery date, the pressure of cost and work efficiency, the effective utilization of resources, the problem of reducing waste, etc., it is particularly important for the enterprise to formulate a set of good and effective production scheduling.

Keywords

Flexible Job Shop Scheduling; Multi-time Factors; Hybrid Particle Swarm Optimization Algorithm.

1. Preface

Nowadays, the production scheduling problem has become the focus of all enterprises. With the development of industry, how to get a relatively high profit on the premise of reducing waste is one of the topics that all enterprises are focusing on. Therefore, the effective production scheduling scheme has also become the key research direction.Among them, the job shop scheduling problem has become a key research field. The research of production scheduling originated in 1950s, and Johnson deeply thought and studied the scheduling problem of two-machine flow shop. In the following 50 years, the production scheduling problem gradually became a hot issue studied by scholars in corresponding disciplines. As a complex combinatorial optimization problem,It belongs to NP-hard problem, which is mainly divided into two aspects: the research of scheduling problem modeling and the research of scheduling problem algorithm.

Particle Swarm Optimization (PSO) is one of the hottest research algorithms. However, the research on particle swarm optimization is still less than some earlier heuristic algorithms such as genetic algorithm, especially in the field of production scheduling. Some experts and scholars have made a lot of research on the application of particle swarm optimization in production scheduling, and achieved good results.

2. Basic Principle of Particle Swarm Optimization

PSO is a random optimization algorithm based on swarm intelligence. It is a kind of algorithm that focuses on birds' foraging behavior. The search space of a problem is analogous to the flight space of birds, and each bird is abstracted as a massless particle, which is used to represent all candidate solutions of a problem. The optimal solution found by optimization is equivalent to the food that birds are looking for. For each example, the PSO algorithm formulates a behavior rule similar to bird

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foraging, so that each particle has the same characteristics of bird foraging, and then solves some complex optimization problems.

As a swarm optimization algorithm proposed by simulating the predation phenomenon in nature, PSO algorithm has the ability to remember the best position of each particle and the mechanism of learning and sharing among particles. It can solve the corresponding complex optimization problems through the cooperation and competition among particles. PSO has a very special relationship with evolutionary algorithm,Compared with evolutionary algorithm, PSO algorithm retains the global search ability based on population, adopts velocity-displacement model, avoids a series of complicated genetic operations, and has memory algorithm, which can be used to track the current search situation and adjust its search strategy.

2.1 Basic Particle Swarm Optimization Process and Characteristics

2.1.1 Flow of Basic PSO Optimization Algorithm

The basic flow of the basic particle swarm optimization algorithm is divided into seven steps: step one, randomly initialize the position and speed of each particle in the population, and if the search space is D-dimensional, each particle contains D variables; Step 2, evaluate all particles in the population, and store the current position and target value of each particle in the pbest (individual best) of each particle,The current position and target value of the individual with the best target value in all pbests are stored in gbest (Group Best); Step 3, updating the speed and position of each particle according to a certain formula; Step four, evaluate all particles in that population; Step five, compare the current target value of each particle in the population with its value of pbest. If the current target value is better,Then replace its pbest with the target value and position of the current particle; Step six, comparing all the current target values of pbest and gbest, and updating the value of gbest; Seventhly, if the set termination criterion is satisfied, output the gbest and its target value and terminate the algorithm, otherwise, turn to step three to start again.

2.1.2 Characteristics of PSO Algorithm

The search performance of PSO depends on the balance between global exploration and local improvement, which largely depends on the control parameters of each algorithm, including population size, maximum algebra, maximum speed, acceleration constant, inertia weight factor and so on. However, compared with other algorithms, PSO algorithm requires fewer adjustment parameters and is simpler and more effective.

To sum up, PSO algorithm has the following advantages.

(1) The algorithm is universal and does not depend on the information of the problem itself.

(2) The principle is simple and easy to realize.

(3) Group search, with certain memory ability, can effectively keep the best information of local population and global population.

(4) Collaborative search. At the same time, local information of individuals and global information of groups can be used to guide the search.

Of course, PSO algorithm also has some shortcomings.

(1) Particle Swarm Optimization (PSO) has poor local search ability and low search accuracy.

(2) The theory of particle swarm optimization is not perfect, especially the practical guiding rules for algorithm design are lacking.

(3) Particle Swarm Optimization (PSO) can't absolutely guarantee to find the global optimal solution, and it is easy to fall into the local minimum.

2.2 Discrete Optimization based on PSO Algorithm

For discrete optimization, the solution space is a set of discrete points, not a continuous area. Therefore, it is necessary to make some corresponding adjustments to solve discrete optimization problems by using particle swarm optimization algorithm. It is necessary to change the updating

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formula of correction speed and position, or to deform specific problems. At present, the discrete optimization work based on particle swarm optimization algorithm can be divided into the following three categories.

The first type is the probability of changing the position with the speed. Kennedy et al. put forward discrete binary particle swarm optimization algorithm for the first time. Its particle position is coded in binary mode, and then the velocity is constrained between 0 and 1 by Sigmoid function, which represents the probability that the particle position takes 1. The second category is redefining PSO algorithm. Clerc redefined the position of particles,And speed addition, subtraction, multiplication and other operations, a new discrete PSO algorithm is proposed, and it can solve the difficult traveling salesman problem. Although the effect of this algorithm is not ideal, it also provides a new idea for other scholars to solve combinatorial optimization problems. The third kind is to apply continuous PSO algorithm to discrete problems.Salman et al. use continuous PSO algorithm to solve the problem of distributed computer task assignment. In order to effectively convert real numbers into positive integers, the decimal parts and symbols of real numbers are removed [9]. The results show that this method is obviously superior to the genetic algorithm in terms of solution quality and algorithm speed, and the search performance of particle swarm optimization has a certain dependence on parameters.

3. Basic Introduction of Workshop Scheduling Problem

The basic flow of the basic particle swarm optimization algorithm is divided into seven steps: step one, randomly initialize the position and speed of each particle in the population, and if the search space is D-dimensional, each particle contains D variables; Step 2, evaluate all particles in the population, and store the current position and target value of each particle in the pbest (individual best) of each particle,The current position and target value of the individual with the best target value in all pbests are stored in gbest (Group Best); Step 3, updating the speed and position of each particle according to a certain formula; Step four, evaluate all particles in that population; Step five, compare the current target value of each particle in the population with its value of pbest. If the current target value is better,Then replace its pbest with the target value and position of the current particle; Step six, comparing all the current target values of pbest and gbest, and updating the value of gbest; Seventhly, if the set termination criterion is satisfied, output the gbest and its target value and terminate the algorithm, otherwise, turn to step three to start again.

3.1 Characteristics of Workshop Scheduling Problem

The workshop scheduling problem has the following characteristics.

(1) Multiple constraints. Usually, the processing route of the workpiece is known, and at the same time, it is subject to strict technological constraints, so that each process has a certain sequence of constraints in the processing sequence.

(2) Discrepancy. Workshop system is a typical discrete system, and its scheduling problem is also a typical discrete optimization problem.

(3) Computational complexity. Job shop scheduling is a combinatorial optimization problem constrained by some equality or inequality. It is a NP-hard problem in terms of computational time complexity.

(4) Uncertainty. There are many random factors in the actual job shop scheduling problem, such as the uncertain arrival time of the workpiece, and the processing time of the workpiece will be uncertain with different processing machines.

(5) Multi-objective. According to different manufacturing enterprises and different production environments, the scheduling objectives often take various forms.

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3.2 Research Methods of Flexible Job Shop Scheduling Problem

3.2.1 Accurate Methods

The accuracy methods mainly include integer programming method, mixed integer programming method, Lagrange relaxation method, decomposition method and branch and bound method.

(1) Mathematical programming method: The most commonly used method to solve job shop scheduling problem in mathematical programming method is mixed integer programming method. The mixed integer programming method has a set of linear objective functions and a set of linear constraints. The mixed integer programming method restricts the decision variables to be integers.However, this method will lead to an exponential increase in the number of integers in the operation, so even if a better and more concise formula is used, many constraints are needed.

(2) Branch-and-Bound method: Branch-and-Bound method is to use dynamic tree structure to describe the solution space of all feasible solutions of the problem, and the branch position of the trunk implies the feasible solution to be searched.

3.2.2 Approximation Method

(1) Construction methods: Construction methods mainly include priority assignment rule method, insertion method and bottleneck-based heuristic method. The priority rule method is the earliest approximate method, and its main idea is to assign a fixed priority to all the processed processes, and then the processing process with the highest priority is selected and sorted first.Then sort them in order of priority.

(2) Artificial intelligence methods: Artificial intelligence methods mainly include: neural networks, constraint satisfaction conditions, expert systems and multi-agent technologies, and heuristic algorithms that people later developed by simulating or revealing some natural phenomena, laws and processes.Such as genetic algorithm, immune algorithm, particle swarm optimization algorithm and ant colony algorithm.

(3) Local search algorithm: Local search algorithm is a method inspired by biological evolution and physical process to solve combinatorial optimization problems. It evolved from early heuristic algorithms, among which simulated annealing and tabu algorithm are widely used. Local search should design excellent neighborhood structure according to the problem,Therefore, a better neighborhood solution is generated to improve the search efficiency and ability of the algorithm.

4. Research on Flexible Job Shop Scheduling Problem with Multiple Time Factors based on Hybrid Particle Swarm Optimization

4.1 Problem Description

Flexible job shop scheduling problem is that N jobs are processed on M machines, each job has multiple processes, and the processing equipment of each process can choose one of the multiple processing equipment for processing. The essence of scheduling is to determine the processing sequence of each process of each job on related equipment and the processing equipment corresponding to the corresponding process.The multi-time factor FJSP problem in this paper is based on the consideration of the transportation time of workpieces between different equipments, that is, R industrial robots undertake the transportation work between equipments. The goal is to minimize the maximum completion time.

Since Johnson studied scheduling problem, scheduling problem has been a difficult combinatorial optimization problem, and the scheduling model has gradually changed from simple to complex. With the change of scheduling model, the research method has changed from the initial mathematical method to heuristic intelligent algorithm. At present, there are two methods to solve scheduling problems: accurate method and approximate method.Accurate method is also called optimization method. The optimization method can ensure the global optimal solution of the problem, but it can only solve a class of small-scale problems, and the speed is relatively slow. The approximate method has a fast solution speed, and can quickly find the solution needed by the problem, but it can't

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guarantee that the found solution is optimal, but the approximate method can solve large-scale problems.More in line with the needs of practical problems.

4.2 Accurate Methods

The accuracy methods mainly include integer programming method, mixed integer programming method, Lagrange relaxation method, decomposition method and branch and bound method.

Mathematical programming method: The most commonly used method to solve the job shop scheduling problem in mathematical programming method is mixed integer programming method. The mixed integer programming method has a set of linear objective functions and a set of linear constraints. The mixed integer programming method restricts the decision variables to be integers.However, this method will lead to an exponential increase in the number of integers in the operation, so even if a better and more concise formula is used, many constraints are needed.

Many successful mathematical models depend on decomposition method and Lagrange relaxation method. Lagrange relaxation method relaxes the resource constraints and process constraints to some extent by using non-negative Lagrange multiplier, and finally adds the penalty function to the objective function.Liu Xueying of Shanghai Jiaotong University used Lagrange relaxation method to solve the workshop scheduling problem and achieved good results. The decomposition method is to decompose the original problem into several small and easy-to-solve problems, and then optimize these subproblems[26].

Branch-and-bound method: Branch-and-bound method is to use dynamic tree structure to describe the solution space of all feasible solutions of a problem, and the branch position of the trunk implies the feasible solution to be searched. Balas put forward an enumeration algorithm based on disjunctive graph in 1969, which was first applied to the branch and bound method for solving scheduling problems. Branch-and-bound method is suitable for solving the problem that the total number of engineers is less than 250.But for large-scale problems, it takes a long time to calculate. Therefore, the focus of this method is to combine with intelligent algorithm, reduce the number of nodes in the initial search stage, and improve the solution efficiency and search effect.

4.3 Particle Update Strategy

In discrete particle swarm optimization (PSO), the position of particles can be directly represented by a sequence of jobs, and there is no need to transform the discrete process sequence to the continuous particle position. In this way, the particle position is directly regarded as the job sequence, which generates the potential solution of the scheduling problem. At the same time,The iterative updating formula of particle swarm is no longer updated according to the speed and position in the standard particle swarm, and the next generation of particles is generated according to crossover or mutation operation. This paper uses the particle updating method based on crossover and mutation operation, that is, the speed of generating the next generation of particles through the crossover operation with the best particle history and global optimization.Then, by randomly selecting particles in the population, the velocity of the particles is mutated to a certain extent, and the mutated velocity is crossed with the position of the previous generation of particles to obtain the position of the next generation of particles. According to the random strategy, the position of the particles in the population is mutated accordingly.

5. Simulation Experiment and Analysis.

5.1 Program Development Tools

Matlab is a high-level programming software based on mathematical calculation, which provides various powerful operation functions to process various data sets. Array and matrix are the core of Matlab, and all data in Matlab are stored and represented by arrays. Matlab is a matrix-oriented programming language with similar programming characteristics to other computer programming languages (such as FORTRAN and C).In data processing, Matlab also provides various graphical user interface tools, which is convenient for users to develop various application programs.

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5.2 Examples of Experimental Results

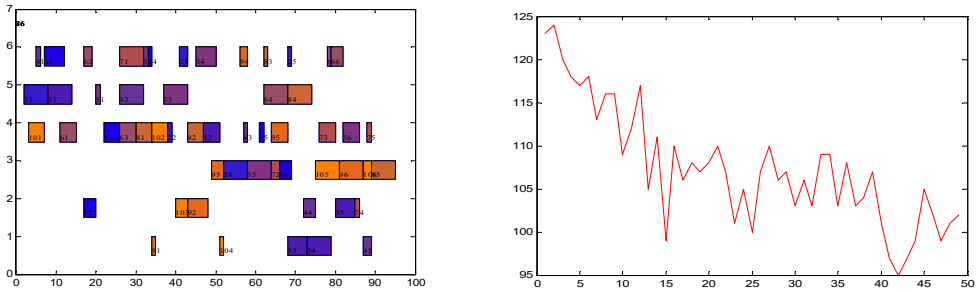

Fig. 1 is a schematic Gantt chart of the result of running MK01 problem in this paper.

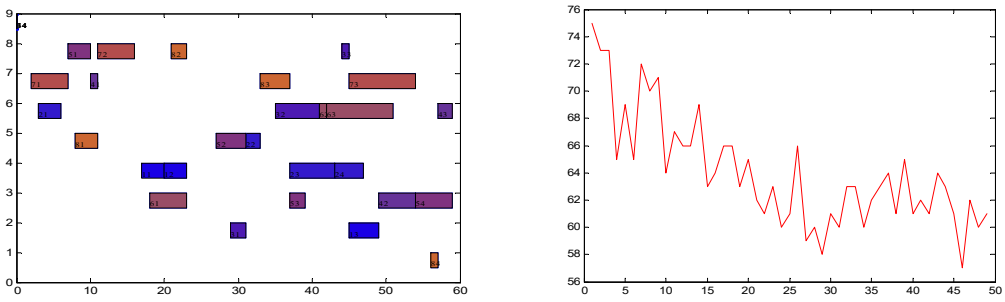

Fig. 2 is a schematic Gantt chart of the result of the Kacem(8*8) problem run by this program.

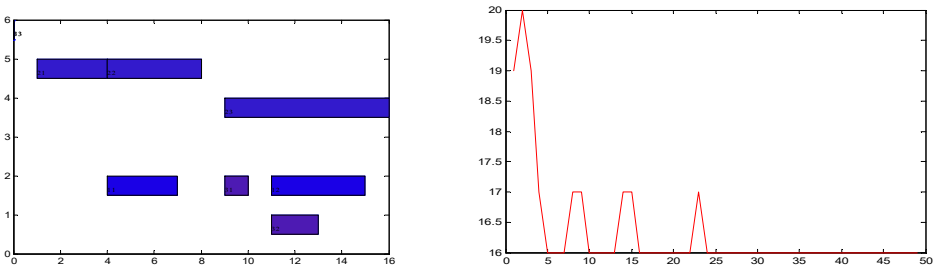

Fig. 3 is a schematic Gantt chart of the result of running Dauzere problem by this program.

The main content is the overall design of flexible job shop scheduling program with multiple time factors based on hybrid particle swarm optimization. Firstly, the overall flow of the program is determined.This paper introduces two initialization methods combining piecewise random and heuristic for the multi-time factor problem of flexible job shop scheduling, and uses the local search method based on heuristic algorithm to design and analyze the algorithm in detail, and writes the program in MatlabR2014a.The running and debugging of flexible job shop scheduling research program with multiple time factors based on hybrid discrete particle swarm optimization is realized, and the simulation experiment of flexible job shop scheduling research program with multiple time factors based on hybrid discrete particle swarm optimization is realized by MatlabR2014a. The function of the algorithm is successfully realized and the expected value of the objective function is achieved.

6. Conclusion

The innovations of this paper are as follows:

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1) Based on the research of flexible job-shop scheduling with multiple time factors based on hybrid discrete particle swarm optimization, this topic has constructed a more stable and efficient method to solve production scheduling, and designed a complete coding process.

2) This topic incorporates multi-time factors. After reading a large number of literatures, we know that in the past research process of workshop scheduling, many problems have not been studied about auxiliary time, but in actual production scheduling, auxiliary time often occupies a large proportion.In this paper, the transportation configuration time of the adjacent processes of the same workpiece on different machines and the equipment adjustment and maintenance time of the adjacent processes of different workpieces on the same machine are considered, forming a multi-time factor scheduling problem, which is closer to the actual workshop production process.

3) In this project, heuristic initialization is used as the initialization method of particle swarm, which is rarely seen in the previous literature. However, the initialization based on heuristic initialization can efficiently solve the problem of uneven distribution of initial solutions, improve the quality of solutions, and improve the convergence speed of the population.

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