Research on Multi-Time Factors Flexible Job Shop Scheduling Based on Hybrid Discrete Particle Swarm Optimization

Yun Zou, Cunli Song

Dalian Jiaotong University, China.

gykwcs@163.com

Abstract

This paper studies flexible job shop scheduling problems based on multiple time factors.The workshop scheduling problem has been studied for more than half a century and has achieved rich theoretical results.As an important branch of production scheduling, flexible job shop scheduling problem is closer to the actual production process. Therefore, it has more important practical significance and theoretical significance for its research.The innovation of this paper is to take into account the certain transportation time required for the equipment to be converted to another machine after processing one workpiece in the production scheduling. The transportation tool is an industrial robot.In this paper, the hybrid discrete particle swarm optimization algorithm is used to solve the problem of flexible job shop. By improving the particle position update method and designing the local search strategy that meets the problem characteristics, the corresponding hybrid discrete particle swarm optimization algorithm is proposed to solve the problem. The use of heuristic initialization methods to initialize the population and the local search of the algorithm by a specific method are of great significance for improving production efficiency and realizing the modernization of advanced manufacturing enterprises.

Keywords

Flexible job shop scheduling; multi-time factor; hybrid discrete particle swarm optimization.

1. Introduction

Nowadays, the problem of production scheduling has become a key issue that all enterprises are paying attention to. As the industry is more developed, how to obtain relatively high profits under the premise of reducing waste is one of the topics that all enterprises are paying attention to. Effective production scheduling has also become a key research direction, and the workshop scheduling problem has become a key research area.The research of production scheduling originated in the 1950s. Johnson deeply studied and studied the flow shop scheduling problem of two machines. In the next 50 years, the production scheduling problem has gradually become a hot issue for the corresponding scholars.As a complex combinatorial optimization problem, the production scheduling problem belongs to the NP-hard problem and is mainly divided into two aspects, the research on the modeling of scheduling problems and the research on the scheduling problem algorithm.

Particle swarm optimization is one of the hottest research algorithms.However, the research on particle swarm optimization algorithm is still less than some early heuristic algorithms such as genetic algorithm, especially in the field of production scheduling.Some experts and scholars have studied the application of particle swarm optimization in production scheduling and achieved good results.

2. Basic principles of particle swarm optimization

The pso algorithm is a stochastic optimization algorithm based on swarm intelligence. It is a kind of algorithm based on the foraging behavior of birds. It compares the search space of the problem with

the flight space of birds and abstracts each bird into one. Massless particles are used to characterize all candidate solutions to a problem, and the optimal solution sought for optimization is equivalent to the food the bird is looking for.The pso algorithm develops a behavioral rule similar to that of birds for each example, so that each particle has the same characteristics of bird foraging, and then solves some complex optimization problems.

As a group optimization algorithm proposed by simulating the phenomenon of predation in nature, the PSO algorithm has the ability to memorize the optimal position of each particle and the mechanism of mutual learning and sharing between particles, and realize the solution through cooperation and competition among individuals. Corresponding complex optimization problems.The pso algorithm has a very special relationship with the evolutionary algorithm. Compared with the evolutionary algorithm, the pso algorithm retains the global search ability based on the population. The velocity-displacement model avoids a series of complex genetic operations and has a memory algorithm. To track the current search situation to adjust its search strategy.

2.1 Process and characteristics of the basic particle swarm optimization algorithm

2.1.1 Process 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 velocity of each particle in the population. If the search space is D-dimensional, each particle contains D variables; Step 2, evaluate the population All the particles, the current position and target value in each particle are stored in the pbest (individual optimal) of each particle, and the current position and target value of the individual with the best target value in all pbest are stored in gbest (In the group optimal), in step 3, the speed and position of each particle are updated according to a certain formula; in step 4, all particles in the population are evaluated; in step 5, the current target value of each particle in the population and the value of pbest are compared.If the current target value is better, replace the pbest with the target value and position of the current particle; in step 6, compare all the current pbest and gbest target values, and update the gbest value; step seven, if the set termination criterion is satisfied, then Output gbest and its target value and terminate the algorithm, otherwise go to step three to start over.

2.1.2 Features of the pso algorithm

The search performance of the pso algorithm depends fundamentally on the balance between global exploration and local improvement capabilities, which depends heavily on the control parameters of each algorithm, including population size, maximum algebra, maximum velocity, acceleration constant, inertia weight factor, etc. .However, compared with other algorithms, the PSO algorithm requires fewer adjustment parameters and is simpler and more efficient.

In summary, the pso algorithm has the following advantages.

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

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

(3) Group search has certain memory ability and effectively retains the optimal information of local population and global population.

(4) Collaborative search, and the local information of the individual and the global information of the group can be used to guide the search.

Of course, the pso algorithm also has certain disadvantages.

(1) The particle swarm algorithm has poor local search ability and the search accuracy is not high.

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

(3) The particle swarm optimization algorithm cannot absolutely guarantee the search for the global optimal solution, and it is easy to fall into the local minimum value.

2.2 Discrete optimization based on PSO algorithm

For discrete optimization, the solution space is a set of discrete points, not a continuous region. Therefore, using the particle swarm optimization algorithm to solve the discrete optimization problem also needs to make some corresponding adjustments. It is necessary to change the update formula of the correction speed and position, or The problem is morphing.At present, discrete optimization based on particle swarm optimization algorithm is divided into the following three categories.

The first category is the probability of using speed as a position change.For the first time, Kennedy et al. proposed a discrete-valued particle swarm optimization algorithm. The particle position coding is binary, and the velocity is constrained between 0 and 1 by the Sigmoid function, which represents the probability that the particle position is taken as 1.The second category is to redefine the PSO algorithm.Clerc proposes a new discrete PSO algorithm by redefining the position, velocity and addition, subtraction and multiplication of particles, and solves the difficult traveling salesman problem. Although the algorithm is not ideal, it is also Other scholars have provided a new way to solve the problem of combinatorial optimization.The third category is the use of continuous PSO algorithms for discrete problems.Salman et al. use the continuous PSO algorithm to solve the problem of distributed computer task assignment.In order to effectively convert the real number into a positive integer, the fractional part of the real number and the symbol are removed [9].The results show that the proposed method has a certain dependence on the parameters of the particle swarm optimization algorithm in terms of the quality of the solution and the speed of the algorithm.

3. Basic introduction to workshop scheduling problems

Workshop optimization scheduling is one of the key technologies to achieve high efficiency, high flexibility and high reliability.Since 1954, Johnson has studied the flow shop scheduling problem of two machines in orderly processing. Many scholars have been studying the problems related to shop scheduling and have achieved remarkable results.In the traditional model of shop scheduling problem, we assume that the resources required for process processing are resources that are not flexible, and the processing machines for all processes of the workpiece are determined and unique, and the machine order is known, then the process can be determined. The processing order on each machine is used to optimize the objective function such as the completion time.As the era of large-scale continuous production is gradually replaced by multi-variety and small-volume production that is more adaptable to market dynamics, the viability and competitiveness of an enterprise basically depends on whether it can produce lower costs in a limited production cycle. The ability to produce multiple varieties of higher quality.Therefore, production systems with certain flexibility, such as flexible manufacturing systems and CNC machining centers, are gradually being produced.

3.1 Characteristics of workshop scheduling problems

The shop 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 process constraints, so that each process has a certain order constraint relationship in the processing order.

(2) Discreteness.The workshop production system is a very typical discrete system, and its scheduling problem is also a particularly typical discrete optimization problem.

(3) Computational complexity.Shop floor scheduling is a combinatorial optimization problem that is constrained by some equations or inequalities.It is an NP-hard problem in terms of computational time complexity.

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

(5) Multi-targeting.For different manufacturing companies and different production environments, the goals of scheduling often vary in variety and variety.

3.2 Research methods for flexible job shop scheduling problems

3.2.1 Accurate method

The precise methods mainly include integer programming methods, mixed integer programming methods, Lagrangian relaxation methods, decomposition methods and branch and bound methods.

(1) Mathematical planning method: The most common method for solving the shop scheduling problem in the mathematical programming method is the 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 limits the decision variables to be integers.However, this method will therefore cause the number of integers appearing in the operation to increase exponentially, so even if you use a better and more concise formula, you need a lot of constraints.

(2) Branch and Bound Method: Branch and Bound Method is a solution space for describing all feasible solutions of a problem by using a dynamic tree structure. The position of the trunk branch implies a feasible solution to be searched.

3.2.2 Approximation method

(1) Construction method: The construction method mainly includes the priority assignment rule method, the insertion method, and the bottleneck-based heuristic method.The prioritized rule method is the earliest approximation method. Its main idea is to assign a fixed priority to all processed processes. After that, the processing with the highest priority is selected first, and then in order of priority. put in order.(2) Artificial intelligence methods: Artificial intelligence methods mainly include: neural networks, constraint satisfaction conditions, expert systems and multi-agent technologies, as well as heuristic algorithms developed by people to simulate or reveal certain natural phenomena, laws and processes. For example, genetic algorithms, immune algorithms, particle swarm optimization algorithms, and ant colony algorithms.

(3) Local search algorithm: The local search algorithm is a method for solving combinatorial optimization problems that is inspired by biological evolution and physical processes. It is evolved from early heuristic algorithms, including simulated annealing and tabu algorithm. The application is more extensive.Local search should design an excellent neighborhood structure according to the problem, thus generating a better neighborhood solution to improve the search efficiency and capability of the algorithm.

4. Multi-time factor flexible job shop scheduling problem based on hybrid particle swarm optimization

4.1 Description of the problem

The flexible workshop scheduling problem is that n workpieces are processed on M equipments, each workpiece has multiple processes, and the processing equipment of each process can select one of the multiple processing equipments for processing. The essence of scheduling is to determine each The processing sequence of each process of the workpiece on the relevant equipment and the processing equipment corresponding to the corresponding process.The FJSP problem of multiple time factors in this paper is based on the consideration of the transportation time of workpieces between different equipments, that is, R industrial robots undertake transportation work between equipments.The objective function minimizes the maximum completion time.

4.2 Mathematical Modeling

Configure the transportation time constraint: the two adjacent processes of the same workpiece are processed on different machines. When the current process is completed, the workpiece is transported to the next machine with a certain transportation and configuration time, and the workpiece is not transported. If you arrive at the next machine, you cannot start machining and running. The formula is as follows:

$C_{\theta kl} - t_{\theta kl} \geq C_{\theta k(l-1)} + tran_{\theta k(l-1),\theta kl}$

Where Jkl represents the first step of the workpiece θk, cθkl represents the completion time of θkl, tθkl is the processing time of the step θkl, tranθk(l-1), θkl represents the adjacent two processes of the same workpiece θk processed on different machines The transportation configuration time between.

The objective function of this paper is to minimize the maximum completion time. The specific expression is as follows:

$$\min c = \min(\max_{j=1}^{N} C_j)$$

Where cj represents the completion time of the workpiece Jj and N represents the total number of workpieces.In all previous studies, minimizing the maximum completion time has always been one of the objective functions studied by researchers. Minimizing the completion time can save enterprise costs and improve the efficiency of the enterprise.

4.3 Particle Update Strategy

In the discrete particle swarm optimization algorithm, the position of the particle can be directly represented by a sequence of the workpiece, and the discrete process sequence is not converted to the continuous particle position. This way directly generates the particle position as the workpiece sequence, which is generated. A potential solution to the scheduling problem.At the same time, the iterative update formula of the particle swarm is no longer updated according to the velocity and position in the standard particle swarm. The next generation of particles is generated according to the crossover or mutation operation. This paper uses the particle update based on the crossover and mutation operations. The way is to generate the velocity of the next generation particle through the particle history optimization and the global optimal cross operation, and then the particle velocity is mutated by the random selection of particles in the population, and the velocity after the mutation is compared with the previous generation particle. The position of the corresponding crossover operation, so as to obtain the position of the next generation of particles, according to the random strategy, and then the corresponding variation of the particle position in the population,

5. Simulation experiment and analysis

5.1 Program development tools

Matlab is a high-level programming software based on mathematical calculations. It provides a variety of powerful computing functions to process various data sets.Arrays and matrices are the core of Matlab. All data in Matlab is stored and represented by arrays.Matlab is a matrix-oriented programming language with programming features similar to other computer programming languages such as FORTRAN and C.In data processing, Matlab also provides a variety of graphical user interface tools, which is convenient for users to develop a variety of applications.

5.2 Experimental Results Example

The main content of this chapter is the overall design of multi-time factor flexible job shop scheduling program based on hybrid particle swarm optimization. Firstly, the overall process of the program is determined. Two kinds of segmentation randomization are proposed for the multi-time factor problem of flexible job shop scheduling. Heuristic combined initialization method, and using the local search method based on heuristic algorithm and detailed design analysis of the algorithm, and writing the program in MatlabR2014a.The operation and debugging of the multi-time factor flexible job shop scheduling research program based on hybrid discrete particle swarm optimization is realized. The simulation experiment of multi-time factor flexible job shop scheduling research program based on hybrid discrete particle swarm optimization is realized by MatlabR2014a. The function of the algorithm reaches the expected value of the objective function.

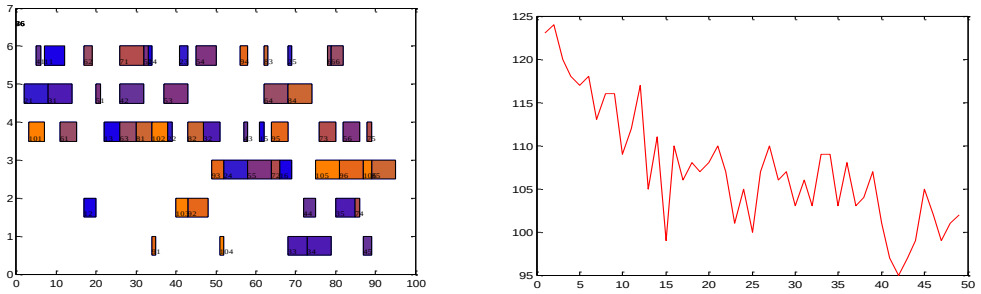

Figure 1 is a result of the program running mk01

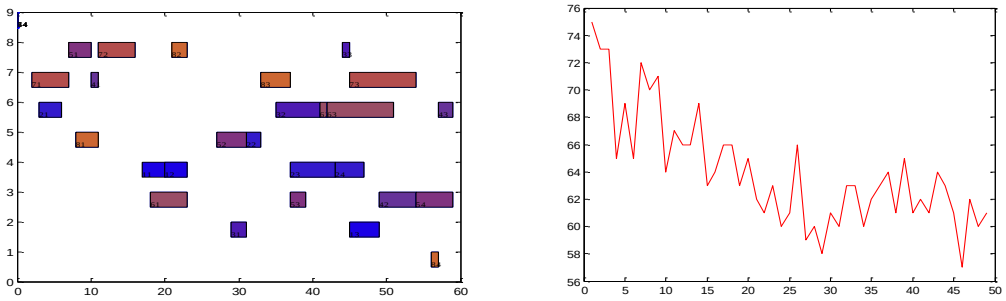

Figure 2 is a result of the program running Kacem (8 * 8)

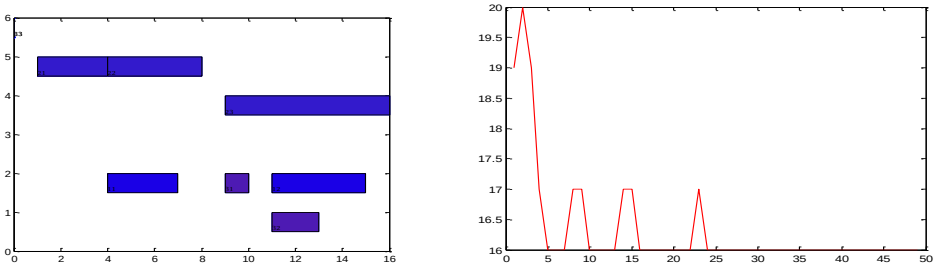

Figure 3 is a result of the program running the Dauzere problem

6. Conclusion

In this paper, we not only consider the processing time when we study the flexible job shop scheduling, but also consider the transportation time, and analyze the specific impact of multiple time factors on the scheduling results.The results show that transportation time is an indispensable factor in scheduling problems.In order to solve the flexible job shop scheduling problem with multiple time factors, this paper combines local search with global search, and proves the effectiveness of the algorithm through simulation experiments.This paper makes a lot of assumptions when studying multi-time factors, but there are still many uncertain factors in the actual production scheduling problem, such as machine failure during the process, machine adjustment time, sudden change of delivery time, etc., considering more The constraints in the actual processing process will have more realistic research significance.

References

[1]. Research on flexible job shop scheduling problem based on hybrid discrete particle swarm optimization algorithm [d]. Zhejiang University of Technology. 2014

[2]. Research and application of stamping shop scheduling and assembly line sequencing method for automobile mixed flow production [d]. Tian Zhipeng. Huazhong University of Science and Technology. 2016

[3] Research and application of improved particle swarm optimization algorithm in flow shop scheduling problem [d]. Jia Yucheng. Shandong Normal University. 2017

[4]Metaheuristics for the multi-objective FJSP with sequence-dependent set-up times,

Auxiliary resources and machine down time[M].Jacomine Grobler,Andries P.Engelbrecht, Department of Industrial and Systems Engineering,University of Pretoria,2010.

[5] Research and application of hybrid group intelligent optimization algorithm [d]. Zhang Chao. Beijing University of Science and Technology. 2018

[6] Research on group intelligent optimization algorithm in flexible job shop scheduling [d]. . Northeast Forestry University. 2011

[7] Basic theory and improvement of particle swarm optimization algorithm [d]. Liu Jianhua. Central South University 2009