Research on Green Logistics Scheduling System of Textile Vehicle Automatic Guided Vehicle

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Abstract. With the rapid development of science and technology, China's modern manufacturing technology has developed and progressed rapidly, and the degree of automation of intelligent production workshops has gradually increased. Enterprises are facing huge challenges in path optimization and energy conservation and emission reduction. This paper mainly studies the problem of AGV green intelligent logistics scheduling in textile workshops. First, an AGV logistics scheduling optimization model with the goal of reducing AGV energy consumption and optimal AGV path is established, and then an improved genetic particle swarm optimization algorithm with task sequencing as the constraint is proposed. Take the actual scheduling data of a textile workshop as an example to verify the method in this paper. From the calculation results, the AGV logistics scheduling model proposed in this paper can better simulate the energy consumption problem of AGV green scheduling. The improved genetic particle swarm algorithm proposed has a better optimization ability and a faster speed in solving such problems. Speed of convergence.

1. Introduction
At present, the production workshops of most domestic textile enterprises still use the traditional manual logistics scheduling method, and the processed products are delivered to the inspection area by manual labor. The traditional manual scheduling method is inefficient, the labor intensity of the workers is large, and the work content of the workers is more complicated. Therefore, it is of great practical significance to use automated equipment instead of manual to complete the workshop logistics scheduling. Since the 1950s, developed countries such as Europe and the United States have used AGV (Automated Guided Vehicle) [1] for more than six decades, the technology of using AGV instead of manual completion of workshop logistics scheduling has been relatively mature. AGV's task in the production hall is to transport finished product bins to the inspection area. The use of AGV for transportation can reduce the labor intensity of workers, reduce the labor cost of enterprises, and improve the production efficiency of the workshop. How to optimize the path of AGV so that it can not only provide timely and effective scheduling according to the actual production situation of the workshop, but also reduce the waste of energy consumption caused by unscheduled scheduling. While ensuring efficient scheduling, actively respond to the national energy saving Schedule the "Twelfth Five-Year Plan".
At present, in the task allocation strategy of the multi-load AGV path optimization problem, an AGV multi-objective load task scheduling model based on vehicle travel distance, task waiting time, and handling task priority [2]. Researchers use reinforcement learning to perform reinforcement learning on the task assignment process of the job shop [3], and use this as an evaluation mechanism to determine the scheduling task assignment scheme.

On the model establishment of the path optimization problem, the researchers studied a new flow operation model and an open operation model to solve the flexible workshop scheduling problem [4]. Researchers focus on the issue of improving AGV operation efficiency and multi-objective optimization of AGV's task scheduling, minimum number of vehicles, and time cost [5]. Researchers have established a flexible workshop scheduling model using AGV handling, and studied the optimal AGV scheduling scheme and the optimal number of AGVs [6]. Researchers use a multi-cycle mixed-receiving logistics scheduling model that considers time windows to study the relationship between cyclic supply and cycle [7]. Researchers have proposed a conflict-free scheduling path model based on mesh topology, which can choose another shortest path when path conflicts occur [8].

In solving the path optimization problem, the researchers proposed a mixed integer linear optimization model based on the tabu search algorithm to solve the simultaneous scheduling problem of machining machine tools and AGVs [9]. Researchers have proposed a multi-objective optimization algorithm that combines particle swarm optimization and distribution estimation, combining the global search capability of the particle swarm optimization algorithm with the good learning and local search capabilities of the distribution estimation algorithm [10], so that the combination algorithm is in the benchmark function ZDT1-The Pareto solution sets obtained on ZDT3, ZDT6 and ZDT6-1 have good convergence and diversity. Researchers proposed an optimization method for job shop scheduling problems based on "demand time window" [11]. Researchers proposed and designed a tabu search algorithm based on multi-stage mixed mutation based on the model, using "reverse order mutation" and "Segment exchange mutation" searches for optimal solution. Researchers aim to minimize the maximum completion time, and use an improved particle swarm algorithm to solve the problem [12].

On the green elements of workshop logistics scheduling, researchers and others have established a multi-objective flexible job shop scheduling model that considers completion time [13], idle time, processing quality, and machine energy consumption. Researchers have proposed a method based on intuitionistic fuzzy set similarity. The genetic algorithm uses the similarity value of the intuitionistic fuzzy set to select the most satisfactory solution. Researchers and others have proposed a comprehensive model of the job to reveal its dynamic characteristics [14] to achieve energy-saving scheduling optimization. Researchers set up a multi-objective function with maximum completion time, machine power consumption, and employee comfort as targets, initialized the group using a weighted method, and obtained fitness values through fast decoding [15].

In the current large amount of related literature, scholars rarely consider the problem of green energy consumption in AGV logistics scheduling. However, in the actual production process of the workshop, the long-term operation of AGV consumes large energy. Therefore, considering the AGV energy consumption factor, the green logistics scheduling has practical significance. This article mainly studies the path optimization of the AGV in the workshop, strives to reduce the response time and travel time of the AGV after the task occurs, and introduces the AGV dispatching energy consumption index as a green factor. The AGV response time, travel time, and energy consumption index are weighted and unified, and a multi-objective and multi-load AGV path optimization model is proposed. The improved GA-PSO with task scheduling constraints is used to solve the path optimization model, which is of great significance to the actual operation of multi-load AGV in the knitting workshop [16].
2. AGV logistics scheduling description and modeling

2.1. The problem description
The AGV trolley initially stops at A (unloading point). When AGV receives the dispatch task, it will drive to the task node that needs to transport the finished product bins, and then load the bins at the task node. Then they headed back to A to perform the unloading task. After the unloading was completed, the new loading task was started. In the actual production process, AGV may not be able to go to the task point to load the bin in time when a new task occurs because the previous task is not completed, resulting in a longer AGV waiting time. The AGV travel path to complete the carrying task of the bin is the key to the research of this paper.

Refer to the following rules when modeling
(1) AGV handling time is fixed and does not time out.
(2) The work of AGV is to load the finished product bin full of socks onto AGV, and then transport it to the unloading point of the full inspection workshop for unloading.
(3) At the beginning of the zero hour, all the loom equipment and AGV are in an operable state.
(4) Ensure that the raw materials of all weaving machines are sufficient and there will be no shortage of raw materials.
(5) The empty bins near the loom are sufficient, regardless of the supply of bins.
(6) The weaving machine does not interrupt the processing of socks, and there will be no failure conditions.
(7) AGV keeps moving at a constant speed, and its carrying time is only related to the length of the logistics path.
(8) The capacity of AGV is limited, and its full load capacity cannot exceed k finished product bins.
(9) When the AGV receives the loading task, it performs the loading task only once at its corresponding task point.
(10) All AGV loading tasks are known at zero time, and the occurrence time of each task is different.

The parameter settings are shown in Table 1 below:
The set of all target tasks is \( X = \{1, 2, 3, 4 \ldots n\} \), \( j \) is the next task of \( i \) \((j = i + 1), i \in X, j \in X\)

| Symbol | Meaning |
|--------|---------|
| \( T_i \) | Occurrence time of task \( i \) |
| \( Z \) | AGV trolley loading time at the mission |
| \( S_{ij} \) | AGV shortest travel distance from task \( i \) to task AGV driving speed |
| \( V \) | Distance from unloading point A in staging area to loading point of task \( i \) |
| \( d_i \) | Distance from unloading point A in staging area to loading point of task \( j \) |
| \( d_j \) | AGV travel time from task \( i \) to task \( j \) |
| \( t_{ij} \) | The moment when task \( i \) is completed |
| \( t_j \) | Time when task \( j \) is completed |
| \( D_j \) | When task \( i \) is completed, the time that the next task \( j \) has occurred is the AGV waiting time |

2.2. Mathematical modeling
In the logistics scheduling of the knitting workshop, the main factors affecting the AGV scheduling time are the travel time of the AGV between the task points and the response time after the AGV receives the loading task. Because it is assumed in this article that the AGV is driving at a constant
speed, the driving time of the AGV at the task point is only related to the length of its driving path. The AGV is not always running in the entire scheduling process. If there is no new task arrangement, the AGV may wait at A or the task point of the previous task. The power of the AGV during operation is much greater than the power during standby. So how to find a better path to reduce the running time, response time and energy consumption of AGV is the key to the problem.

Therefore, considering the main factors such as AGV operating time, response time, and energy consumption, the establishment of a green logistics scheduling model is as follows:

\[ TE = T_z + q_3 \ast E \]  

\[ T_z = q_1 \ast \sum_{j=2}^{n} D_i + q_2 \ast \sum_{i=1}^{n-1} \sum_{j=2}^{n} t_{ij} \]  

\[ E = \sum_{i=1}^{n-1} \sum_{j=2}^{n} (t_{ij} \ast p + |t_i - T_j|) - \sum_{j=2}^{n} D_j \]  

\[ t_{ij} = S_{ij} / V \]  

At that time \( i = ka, a = (1, 2, 3, 4...) \) \( S_{ij} = d_i + d_j \)  

\[ t_j = T_j + D_j + t_{ij} + Z \]  

\[ D_j = t_j - T_j \]  

\[ D_i = 0, \text{ When } t_i < T_j \]  

In the formula: \( q_1, q_2, q_3 \) are weight coefficients, and \( p \) is the ratio of the running power of the AGV car to the waiting power.

Equation (2) is the objective function of AGV scheduling time. Equation (3) is the objective function of AGV scheduling energy consumption. Equation (4) represents the AGV travel time from task \( i \) to task \( j \). Equation (5) indicates that the AGV is loaded with \( k \) finished product bins and then returns to the starting point A to unload, and then performs the next task. Equation (6) represents the time when task \( j \) is completed. Equation (7) indicates that the time that task \( j \) has occurred when task \( i \) is completed is the AGV response time. Equation (8) indicates that all previous tasks have been completed, and subsequent tasks have not yet occurred, and the AGV is on standby at task \( i \).

Equation (1) is the total objective function, which converts the multi-objective model of shop floor logistics scheduling into a single-objective model. In order to quantify the weight coefficients of the three factors of AGV operating time, response time, and energy consumption, an analytic hierarchy process (AHP) [17] was used to assign values. The matrix judgment scale is used to quantitatively display the importance of each element in the matrix. The judgment matrix is constructed, and the weights of each part are calculated by linear transformation. After consistency check, the appropriate weight coefficients are obtained as shown in Table 2.
Table 2 Weight analysis table of analytic hierarchy process

| Matrix judgment scale | q1  | q2  | q3  |
|-----------------------|-----|-----|-----|
| Dj tij E              | 0.295 | 0.649 | 0.056 |
| Dj                   | 1/7 | 1/3 | 7   |
| tij                  | 3   | 1   | 9   |
| E                    | 1/7 | 1/9 | 1   |

3. Algorithm Design

We believe that the traditional GA-PSO is prone to premature convergence when solving this complex search problem in this paper, and the local optimization ability is poor, and the algorithm convergence is too slow. To solve this problem, the author introduces task ordering rules into the algorithm's cross mutation operation and proposes an improved GA-PSO. The improvement method is to introduce task sequencing in the cross mutation of the algorithm to constrain the evolution direction of particles, make the evolution direction of particles more clear, and effectively avoid the premature convergence and slow convergence speed of the algorithm.

3.1. Algorithm coding

According to the established AGV green logistics scheduling model of the workshop, this article uses task sequencing as the encoding method of particles. Each particle represents a target loading task of AGV. The number of the particles is the chronological order of the tasks, such as the particle number 3. Represents the third task that occurred. The order of the particles is the order in which the AGV loads the finished material bin. For example, the individual code is (3,6,4,7,1,2,8,5), that is, the execution order of the task is the first occurrence of the third occurrence. The task will execute the 6th task and so on until all tasks are completed.

We assume that the AGV is fully loaded with 4 finished product bins. After completing the four loading tasks, the trolley needs to return to point A for unloading.

Continue to complete the task. Therefore, the actual driving route of the AGV needs to consider the situation of driving to the unloading point after full load. For example, the individual code is (3,6,4,7,1,2,8,5), then the actual driving route of the AGV is (3,6,4,7, A, 1,2,8,5, A ). The AGV has completed the loading of tasks 3, 6, 4, 7 and then returns to point A to unload, and then completes the loading of tasks 1, 2, 8, 5 and returns to point A to unload.

3.2. Genetic cross operation with task ordering as a constraint

In this paper, the cross method is used to perform the cross operation, and the task sequence is used as a group. The position fragments that need to be crossed are determined by the difference between the order in which the tasks occur (task number) and the task sequence. The positions of the two tasks with the largest and smallest differences are selected as the two ends of the cross segment. Cross-update the segment of the task sequence with the segment corresponding to the extremum of the population. If there are duplicate tasks in the updated task sequence, the tasks that are not included are used to replace the duplicate tasks.

For example: task number (1,2,3,4,5,6,7,8)
Initial task sequence (3,6,4,7,1,2,8,5)
↓
Difference (-2, -4, -1, -3,4,4, -1,3)
↓
Crossed segments (*, 6,4,7,1, *, *, *)
↓
Extreme values (5,1,8,4,3,2,6,7)
Extreme value fragments (*, 1,8,4,3, *, *, *)
↓
3.3. Genetic mutation operation with task sequencing as constraint

In this paper, we use the method of position interchange to carry out genetic mutation operation, and take the task sequence as one of them. Select the two tasks with the largest and smallest differences between the sequence of the tasks (task number) in the task sequence as a group of mutated tasks, and then choose the second largest and second smallest difference between the task sequence and the task number. The two tasks serve as a set of mutation tasks. The positions of the two tasks in each group are interchanged to update the mutation operation.

Example: Initial task sequence (3,6,4,7,1,2,8,5)
Task number (1,2,3,4,5,6,7,8)
Difference (2,4,1,3, -4, -4,1, -3)
The position of the mutation (*, 6, *, *, 1, *, *, *) (*, *, 7, *, 2, *, *)
New task sequence (3,1,4,2,6,7,8,5)

3.4. Algorithm flow chart

After the initial particle is subjected to the cross mutation operation of the order constraint of the improved algorithm, a new particle is obtained. In order to find the optimal solution and reduce unnecessary calculations, the particles are updated only when the fitness of the new particles is better.

![Algorithm flowchart](image_url)

Fig 1. Improved GA-PSO algorithm flowchart
4. The Case research

4.1. The Case brief

This paper takes a smart knitting workshop as the research object and uses MATLAB [18] software platform to calculate and verify the validity and accuracy of the proposed model and algorithm on a 4.00-GB RAM / 3.20-GHz computer. Taking the shop as a whole to receive 12 finished product bins for a certain period of time as an example, the order of tasks is optimized to obtain a better scheduling scheme. The number of particles used by the algorithm is 200, and the number of iterations is 100.

Figure 2 shows the distribution of task points in an intelligent knitting workshop. In the workshop, 54 hosiery knitting machines are arranged in pairs, and each two machines share a bin loading point for a total of 27 task points. In order to facilitate calculation, the position of the task point and the AGV driving path are standardized. The task point and the path are located on the grid in FIG. 2, and the length and width of each grid in FIG. 2 are 0.8 m. The black line in Figure 2 indicates the AGV's driving path, the black circle indicates the loading point of each task, and the black diamond A indicates that the AGV unloading point in the full inspection area is also the initial stop of the AGV.

The AGV trolley departs from point A, goes to the task point corresponding to the hosiery machine that issues the loading task via a feasible path, loads the box full of finished socks on the AGV, and then proceeds to the next target task point until the AGV is full 4 finished product bins, AGV reached full load, then drove to point A for unloading. After the unloading is completed, return to the knitting workshop to carry new task bins, and repeat the cycle until all loading tasks are completed.

The AGV's operating power and standby power are obtained through consultation with relevant domestic AGV suppliers. The operating power of the AGV car is planned to be 144W and the standby power is 36W.

The start time of the target time period of the selected intelligent knitting workshop is set to the zero time of the model, the occurrence time of the 12 target loading tasks Ti, and the corresponding task points are shown in Table 3:
Table 3. Task data table

| Numbering | Hosiery machine | Task point | Ti |
|-----------|----------------|------------|----|
| 1         | 9              | 5          | 9  |
| 2         | 36             | 18         | 16 |
| 3         | 49             | 25         | 21 |
| 4         | 42             | 21         | 120|
| 5         | 38             | 19         | 137|
| 6         | 8              | 4          | 180|
| 7         | 15             | 8          | 343|
| 8         | 28             | 14         | 369|
| 9         | 32             | 16         | 514|
| 10        | 33             | 17         | 677|
| 11        | 43             | 22         | 720|
| 12        | 13             | 7          | 789|

4.2. Comparison of scheduling schemes

The fitness function is determined by the objective function, and then the improved algorithm in this paper is used to solve it. The AGV car's driving path and its corresponding fitness value are obtained. This paper considers the scheduling scheme from three aspects: time priority, energy consumption priority, and comprehensive priority. Time first uses formula (2) as a fitness function, energy consumption first uses formula (3) as a fitness function, and comprehensive priority uses formula (1) as a fitness function. The optimal solutions of the three scheduling strategies are shown in Table 4.

Table 4. Comparison of calculation results

| Project                        | Best task sequence | Best path task point order | Optimal fitness value |
|--------------------------------|--------------------|----------------------------|-----------------------|
| Time-first scheduling           | 1 2 3 4 5 6 7 12 8 | 0 5 18 25 21 0 19 4 8 7 0 | 141.95                |
|                                | 9 10 11            | 14 16 17 22 0              |                       |
| Energy Priority Scheduling Scheme | 3 1 4 2 6 5 7 8 11 | 0 25 5 21 18 0 4 19 8 14 | 1931.8                |
|                                | 12 9 10            | 0 22 7 16 17 0             |                       |
| Comprehensive target scheduling scheme | 1 2 3 4 5 6 7 12 8 | 0 5 18 25 21 0 19 4 8 7 0 | 268.17                |
|                                | 10 9 11            | 14 17 16 22 0              |                       |

The three scheduling schemes are compared in terms of scheduling time and energy consumption. The comparison results are shown in Table 5.

Table 5. Evaluation results of calculation examples

| Project                        | Scheduling time | Scheduling energy consumption |
|--------------------------------|-----------------|-------------------------------|
| Time-first path planning       | 141.95          | 2025.0                        |
| Energy Priority Path Planning  | 160.19          | 1931.8                        |
| Comprehensive target path planning | 142.04          | 1955.8                        |

From Table 5, it can be seen that the planning energy consumption of the path planning that focuses on time is relatively high, and the scheduling time of the path planning that focuses on energy consumption is long. The comprehensive target path planning proposed in this paper effectively
reduces the scheduling energy consumption while maintaining the optimal scheduling time. It has both the optimal scheduling time and the optimal scheduling energy consumption.

Table 6. Comparison of algorithm results

| Algorithm                        | Improved genetic particle swarm algorithm | Conventional genetic particle swarm optimization |
|----------------------------------|-------------------------------------------|-------------------------------------------------|
| Number of runs                   |                                           |                                                 |
| Scheduling time average          | 20                                        | 20                                              |
| solution                         | 142.43                                    | 146.12                                          |
| Scheduling energy average        | 1944.55                                   | 1980.71                                         |
| solution                         | 268.97                                    | 276.04                                          |
| Average solution for             |                                           |                                                 |
| comprehensive scheduling         |                                           |                                                 |

5. Algorithm comparison

The comparison of the average scheduling solutions of the improved GA-PSO and conventional GA-PSO adopted in this paper is shown in Table 6.

The comparison of the convergence results of the improved GA-PSO and conventional GA-PSO algorithms used in this paper is shown in Figure 3, Figure 4, and Figure 5 (the fitness uses the comprehensive fitness function). The black solid line in the figure is the iterative process of the improved algorithm in this paper, and the black dotted line is the iterative process of the conventional genetic particle swarm algorithm. Figure 3 and Figure 4 show the iterative process of the algorithm for processing 12 target tasks. Figure 5 shows the algorithm iterative process for 24 target tasks.

![Algorithm iterative process](image)

Fig.3. Iterative comparison of the algorithm running three times
Figures 3 and 4 show the iterative process of the algorithm running three times and ten times when performing 12 tasks, respectively. Comparing the two figures, it can be seen that the improved GA-PSO in this paper has more advantages than the conventional GA-PSO in each run. Fast convergence speed, better ability to find optimization. Figures 4 and 5 show the iterative process of the algorithm for executing 12 tasks and 24 tasks, respectively. Comparing the two figures, we can see that the convergence speed and optimization capability of GA-PSO in this paper are still obvious when there are many task items.

6. Conclusion
Aiming at the AGV green logistics scheduling problem of the job shop, this paper comprehensively considers the AGV’s scheduling time and scheduling energy consumption. Based on the actual operation of the AGV at the time of scheduling, an optimization model of time and energy consumption indicators for the workshop logistics scheduling is established. Because the scheduling problem of multi-load AGV belongs to the NP-hard [19] problem, this paper proposes an improved
GA-PSO with stronger optimization ability. This algorithm is based on the conventional GA-PSO and considers both scheduling time and scheduling. The energy-consumption task sequencing strategy is used to constrain the evolution direction of the particles, so that the algorithm can converge faster. And the actual case proves that the improved GA-PSO proposed in this paper has better optimization ability, which has great practical significance for solving the green logistics scheduling problem of the job shop. For more detailed problems, such as the impact of AGV charging on scheduling time and scheduling energy consumption, the constraint function of the objective function can be increased for discussion, and further research can be conducted later.

With the continuous advancement of Industry 4.0 [20], the intelligent level of enterprises is getting higher and higher, the intelligent scheduling of AGV will move to a higher level, and multi-AGV collaborative scheduling will become the mainstream of future research.

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