The research on intelligent RGV dynamic scheduling based on hybrid genetic algorithm

Likang Wang, Yaya Mu, Hongmei Gao, Rui Men*
Long Dong University, The Information Engineering College, Qingyang City, China

corresponding author: 531039764@qq.com

Abstract. With the rapid development of automation, mechatronics, information technology and other fields, production and processing systems are constantly moving towards unmanned and intelligent development. The RGV rail-guided vehicle system integrates various high-new technologies and is widely used in modern processing systems. Compared with the circular RGV orbit system, the linear reciprocating RGV system adopts a linear orbit, which is not easy to be blocked during operation, but its scheduling response mechanism is not perfect enough, which makes the operation efficiency of the whole system low. Therefore, how to improve the response mechanism and the operational efficiency of the RGV intelligent processing system has become an important factor in prompting the rapid development of the modern intelligent processing industry.

In this paper, aiming at the intelligent linear reciprocating scheduling problem, the main influencing factors are analyzed according to the shortest distance priority response and the shortest completion time. Mathematical analysis and mathematical modeling are carried out and a rule-based genetic algorithm is designed to solve the problem. The algorithm of replacing the fixed parameters in the traditional genetic algorithm with the adaptive cross mutation probability, and improves the genetic algorithm's tendency to fall into the local optimal solution.

1. Introduction

The intelligent RGV processing system consists of a track-type automatic guided vehicle, a linear track, and a loading and unloading conveyor. It is an unmanned, smart car that can run on a fixed track. According to the track form, it can be divided into linear reciprocating RGV and ring. In this paper, the working mode of the linear reciprocating system is mainly described. According to the command, the moving direction and distance can be automatically controlled, and a robot arm, two mechanical grippers and a material cleaning tank are provided to complete the operations of loading, unloading and cleaning materials. Studies have shown that simple genetic algorithms are difficult to converge to global optimal solutions, especially when solving multi-peak complex optimization problems, it is easy to fall into local optimal solutions. Therefore, the hybrid genetic algorithm is designed to solve the problem. Therefore, the adaptive cross-mutation probability is used to replace the fixed parameters in the traditional genetic algorithm to improve the genetic algorithm's tendency to fall into the local optimal solution. Has better computing and application prospects. Based on the hybrid genetic algorithm, the structure of the domain can be changed. Under the new neighborhood structure, the
exchange principle is simpler and more obvious, the efficiency of the optimal solution is greatly improved, and a large number of infeasible solutions are eliminated. The latter algorithm speeds up the convergence of the solution. Finally, the algorithm jumps out of the local optimum and improves the accuracy of the optimal solution. Therefore, the intelligent RGV dynamic scheduling strategy based on hybrid genetic algorithm can be applied to related fields of multi-objective sorting [1-2]. For example, fresh food has certain reference significance for industries that are vulnerable to environmental impact. Combine the working principle and response mechanism, and set the position at different moments, as shown in the following figure 1:

![Figure 1. Working principle diagram](image)

2. Initial scheduling model

2.1. Study of the operation situation

There are three situations in the intelligent processing systems which are used to study the dynamic scheduling model and the corresponding solving algorithm. According to the working principle of the intelligent processing system, its operation can be divided into three categories: The first situation is the material processing operation of only one process; The second situation is the existence of one process and two processes (there is generally no such thing in real life); The third is in the case of only two processes. Because the CNC will randomly fail during the process, the system failure will be considered from these three cases [3].

2.2. Solution

The completion time of one process and no fault: When equipment failure is irrespective, the scheduling efficiency was described with minimum completion time the initial scheduling model, and it was the time (that) when the last process of the material is completed, \( T_i \) is time which has only one processing operation, and the task \( i \) is the time from start to finish‘as is shown in Table 1. \( T_{total} \) ‘as in equation (1)’ is the time of requiring to complete all work procedures, \( T_{ready} \) ‘as in equation (2)’ is the waiting time between the starting and the starting execution of a single task; \( T_{work} \) ‘as in equation (3)’ is the total time required for the start of the RGV single task to the end of the exclusion [4]; the processing efficiency of signal is determined by algorithm operation efficiency and computer performance, \( T_{material} \) ‘as in equation (6)’ is the preparation time for materials after the task is issued. \( T_{walk} \) ‘as in equation(4)’ is the travel time of the shuttle during the handling; \( t_0 \) is the communication time and positioning time of each part of the system; \( t_{lo and unlo} \) ‘as in equation (5)’ is the time required for the loading and unloading materials; \( t_{wait} \) is the wait time of No-load work; \( \delta_1, \delta_2, \delta_3 \) is the time required for the RGV mobile unit.
\[ T_{\text{total}} = T_{\text{prep}} + T_{\text{work}} \]  
(1)

and

\[ T_{\text{ready}} = \text{signal material} \]  
(2)

and

\[ T_{\text{work}} = t_{\text{walk}} \sum_{i=1}^{n} \left( \delta_{pq} \right) \]  
(3)

and

\[ \delta_{pq} = \begin{bmatrix} 20 & 23 & 18 \\ 33 & 41 & 32 \\ 46 & 59 & 46 \end{bmatrix}, \text{ among them } p, q \in \{1, 2, 3\} \]  
(4)

and

\[ t_{\text{lo and unlo}} = \sum_{i=1}^{n} t_{ij} (\varepsilon_{ef}) \]  

\[ T_{\text{total}}^{1} = t_{\text{signal}} + t_{\text{material}} + \sum_{i=1}^{n} t_{ij} \left( \delta_{pq} \right) + 2 \times \sum_{i=1}^{n} t_{ij} (\varepsilon_{ef}) + t_{\text{clear}} + t_{\text{wait}} + t_{0} \]  
(6)

Table 1. First and second process completion schedules

|                | First group | Second group | Third group |
|----------------|-------------|--------------|-------------|
| One process    | 0.668       | 0.606        | 0.660       |
| Two processes  | 0.527       | 0.466        | 0.439       |

2.3. Single and double process fault conditions

In this paper, the default system fault is only faulty of CNC and always works [5]. Faults include the hand wheel failure shaft and spindle housing failure, rail oil pump and cutting oil pump failure, machining fault, etc. The following is an analysis of the reliability of the model:

Since the data is a small sample, the reliability parameter estimation has certain difficulties. We adopt the fitting experiment method to determine the time distribution mode of fault interval,, and verify its correctness, and then evaluate the reliability of the machine tool.

The theoretical distribution function of the fault interval can be defined as:

\[ F(t) = P[T < t] \]  
(7)

Among them

- \( T \) —— Overall time between failures
- \( t \) —— Arbitrary time between failures

Set as \( t_1, t_2, \ldots, t_k \) be the observation values of the fault interval time, the order statistic of the fault interval time obtained by the set of observations is \( t_{(1)}, t_{(2)}, \ldots, t_{(k)} \).
It can be known from the Glivenko-Cantelli theorem that the theoretical distribution function $F_{i_0}(t)$ ‘as in equation (8)’ can be estimated by the empirical distribution function $F(t)$ ‘as in equation (7)’, and the shape of the probability function $F(t)$ of the fault interval can be preliminarily determined by the shape, so the shape can also be preliminarily judged. The graph is a stepped line graph. For the continuous graph fitted, the empirical distribution function of the fault interval is simplified to:

$$F_{(k)}(t) = i/k, i = 1, 2, \ldots, k$$

According to the formula (8), the observations of the fault interval time $t \in [t_1, t_2]$ are divided into groups, and the median value of each group of time is the abscissa, and the cumulative frequency of each group is the ordinate, and the scatter plot is thus obtained ‘as shown in Figure2’.

![Figure 2. Scatter plot](image)

According to the scatter plot, the distribution of the fault time interval (normal distribution, lognormal distribution, exponential distribution, micro-Boolean distribution) can be judged. Since the test method of $d$ is finer than the test method of $x^2$, the fault interval time distribution function is checked by $d$. Finally, it will be compared with the $D_K$ ‘as in equation (9)’ and $D_{K,a}$ ‘as in equation (10)’. If the following conditions are met, the null hypothesis will be accepted, otherwise the null hypothesis will be rejected ‘as is shown in Table2’.

$$D_K = \sup \left\{ F_k(x) - F_0(x) \right\} = \max \{d_i\} \leq D_{K,a}$$

In the middle

$F_0(x)$ —The original hypothesis distribution function

$F_k(x)$ —Empirical distribution function with sample size $k$.

$D_{K,a}$ —Threshold

$$d_i = \max \left\{ F_0(x) - \frac{i-1}{k}, \frac{1}{k} - F_0(x) \right\}$$

After verification, the probability density function and distribution function of the fault interval can be determined. In turn, the reliability parameters of the machine tool are determined.
Table 2. Two-process system fault detection part of the data

| Processing material serial number | CNC number of process 1 | Feeding start time | Cutting start time | CNC number of process 2 | Feeding start time | Cutting start time |
|-----------------------------------|-------------------------|--------------------|-------------------|-------------------------|--------------------|-------------------|
| 1                                 | 1                       | 0                  | 53                | 1                       | 0                  | 53                |
| 2                                 | 4                       | 73                 | 126               | 4                       | 73                 | 126               |
| 3                                 | 3                       | 126                | 179               | 3                       | 126                | 179               |
| 4                                 | 7                       | 212                | 265               | 7                       | 212                | 265               |
| 5                                 | 8                       | 265                | 324               | 8                       | 265                | 324               |
| 6                                 | 2                       | 370                | 429               | 2                       | 370                | 429               |
| 7                                 | 3                       | 449                | 1234              | 3                       | 1257               | 2042              |
| 8                                 | 5                       | 1254               | 1307              | 5                       | 2062               | 2115              |
| 9                                 | 4                       | 1327               | 1384              | 4                       | 2135               | 2192              |
| 10                                | 7                       | 1417               | 1470              | 7                       | 2225               | 2278              |

1. Perform reliability testing on each CNC. During the test time $t_0 \leq t \leq t_k$, there is a secondary fault, which is recorded as $(1, t_i), i \leq k$. Where is the number of failures at the moment record as $r$. 

2. CNC comprehensive fault data experiment:
   a) Within $t_0 \leq t \leq t_k$ if $r_i = 1$, then a single fault data model, denoted as $s_{(1, t_i)}$.
   b) Within $t_0 \leq t \leq t_k$ if $r_i = 0$, then the fault-free data model, $s_{(0, t_i)}$.
   c) Within $t_0 \leq t \leq t_k$, if there is $0 < r_i < r_2 < \ldots r_m (m \leq k)$, there is $p_0 < p_1 < p_2 < \ldots p_m$, a probability of failure at the $p_j$ and $t_i$ moment, recorded as.

3. Rule-based hybrid genetic algorithm
   Aiming at the trait of time requirement of processing system for scheduling strategy [6], this paper proposes a rule-based hybrid algorithm based on rule scheduling algorithm and modern intelligent algorithm. Rule 3 is proposed in order to guarantee the quality of the algorithm and optimize the initial population coding. (Figure 4).
   The specific schematic is ‘as shown in Figure 3:

   ![Figure 3. Schematic diagram](image)

In rule 3, the RGV scheduling task is performed according to the closest distance, and the starting crossing position of the latter task is as close as possible to the ending crossing of the previous task and does not exceed the starting crossing of the previous task [7].
The scheduling principle of RGV is analyzed by adaptive genetic algorithm, rule-based hybrid genetic algorithm and scheduling optimization algorithm [8]. Due to the different response mechanisms of different scheduling strategies, the production efficiency is quite different. By comparing the adaptive genetic algorithm with the rule-based hybrid genetic algorithm, the minimum short-term completion time is taken as the standard, and the shortest-distance priority response is taken as the criterion, and the hybrid-based genetic algorithm [9] is better.

4. Optimized scheduling model

4.1. Dynamic Planning Task Scheduling Optimization Algorithm

In the case of the above-mentioned conditions, when the total time for completion of all tasks is the shortest ‘as in equation (11)’, it is the best solution for the system scheduling problem. Can be described as:

$$\min \sum_{i=1}^{n} T_{task}$$

(11)

$T_{task}^i$ is the time required for the task $i$ to reach completion from the beginning; since $T_{task}$ cannot be directly measured, the following calculation method can be given:

$$T_{CNC} = T_{\text{wait}} + T_{\text{deal}}$$

(12)

and

$$T_{\text{wait}} = T_{\text{calculate}} + T_{\text{befocal}}$$

(13)

and

$$T_{\text{deal}} = 2 \times t_{\text{upun}} + t_{\text{walk}} + t_0$$

(14)

and

**Figure 4.** Comparison diagram of convergence algebra and optimization effect of algorithm
\[
T_{\text{Walk}} = \sum_{q_1=1}^{n_{\text{acc}}} t_{\text{acc}}(q_1) + \sum_{q_2=1}^{n_{\text{dec}}} t_{\text{dec}}(q_2)
+ \sum_{q_3=1}^{n_{\text{uni}}} t_{\text{uni}}(q_3) + \sum_{q_4=1}^{n_{\text{pause}}} t_{\text{pause}}(q_4)
\]

\(T_{\text{wait}}\) ‘as in equation (15)’ is the waiting time from the request to the receipt of the response; \(T_{\text{deal}}\) ‘as in equation (14)’ is the time from start the work to the end; \(t_{\text{befocal}}\) is the waiting time for the task to be effectively scheduled under the task; \(t_{\text{span}}\) is the loading/cutting time, it is considered as the fixed value in this paper; \(t_{\text{walk}}\) is walking and waiting time of RGV during work; \(t_0\) is the communication time, positioning time, etc. of various parts of the system \((t_0\) is the constant); \(t_{\text{acc}}\) is the acceleration time; \(n_{\text{acc}}\) ‘as in equation (12)’ is the number of acceleration walk; \(t_{\text{dec}}\) is the retarded travel time; \(n_{\text{dec}}\) is the number of decelerated walks; \(t_{\text{uni}}\) is the uniform working time; \(n_{\text{uni}}\) is the number of time of walking at a constant speed; \(t_{\text{pause}}\) is the waiting time for stopping due to road congestion during task execution; \(n_{\text{pause}}\) is the number of waiting times for stopping due to road congestion during task execution. Since the time the task waits for scheduling \(t_{\text{befocal}}\) is mainly related to the completion time \(t_{\text{befocal}}\) of the previous task; \(t_{\text{calculate}}\) is determined by the efficiency of the algorithm, which will be discussed later. Equation (15) showed that \(T_{\text{deal}}\) is the main factor for the task completion time. It can be known from equations (13) and (14) that \(T_{\text{deal}}\) is determined by \(t_{\text{uni}}\) and \(n_{\text{pause}}\). The optimization target can be decomposed into two aspects: the sum of the RGV moving distance is the shortest and the track blockage causes the least number of stops.

Objective function:

Goal 1: Distance and minimum

\[
\min \sum_{j=1}^{m} l_{ij} \times x_{ij}
\]

Where is the distance from the RGV \(j\) along the running direction to the pick-up crossing of the task \(jj\); if it is not assigned, this article considers \(l_{ij}=0, x_{ij}\) which is the state value of the shuttle. If the task cannot be assigned, then \(x_{ij}=0\), otherwise \(x_{ij}=1\).

Goal 2: Minimum number of stop due to track congestion

\[
\min \sum_{j=1}^{m} n_{ji} x_{ij}
\]

Among them, \(n(j, ji)\) shuttle \(j\) was forced to stop because of the jam of \(jj\).

Figure 5 highlights the advantages of hybrid genetic scheduling algorithm through three indexes of data convergence, objective function value and number of times of convergence to the maximum value.
5. conclusion
Based on the hybrid genetic algorithm, the structure of the domain can be changed. Under the new neighborhood structure, the exchange principle is simpler and more obvious, the efficiency of the optimal solution is greatly improved, and a large number of infeasible solutions are eliminated. The latter algorithm speeds up the convergence of the solution. Finally, the algorithm jumps out of the local optimum and improves the accuracy of the optimal solution.

In this paper, we study the multi-objective routing path optimization problem of the distance traveled by the shuttle and the impact of product quality, and establish a model of such problems. One aspect of the solution is the rule scheduling algorithm and the modern intelligent algorithm are merged and improved. The other aspect of the solution is the rule-based hybrid genetic algorithm can speed up the convergence and jump out of the local to obtain the global optimal. Finally, the intelligent RGV dynamic scheduling strategy is extended in a targeted manner. The improved algorithm is also innovative and can be applied to related fields of multi-objective picking. For example, fresh food and other goods are subject to environmental impact.

6. References
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