2017 International Conference on Applied Mechanics and Mechanical Automation (AMMA 2017)
ISBN: 978-1-60595-471-4

Research on Weighing Strategy of Vehicle Entering Plant Based on Fuzzy Operation Time

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Keywords: Vehicle scheduling, Fuzzy operation time, Genetic algorithm, Weighbridge.

Abstract. In order to solve the problem of congestion and disorder in the process of weighing and handling of cement vehicles entering the plant, a new scheduling strategy based on fuzzy operation time is proposed. Firstly, the modeling and analysis of the problem, and then proposes a genetic algorithm to solve the problem. The algorithm was improved and the different algorithm and the improved algorithm optimization results was compared. The results show that the proposed scheme can effectively solve congestion problems and increase weighing efficiency of vehicle entering plant.

Introduction

In 1959, Dantzig and Ramser [1] proposed the vehicle routing problem. From then on, vehicle scheduling problem has been greatly promoted. Jepsen M [2] took the minimum total cost as the goal, studied the vehicle scheduling problem with time windows. Hashimoto H et al [3] were studied with total delivery time and total waiting time as the goal. Since the birth of vehicle scheduling problem, many research results have been obtained in model and algorithm, but the role is limited in practice, and there are often more complicated factors in practical problems.

In the process of cement vehicle into the factory, it requires a reasonable distribution of vehicles, according to the use of resources to optimize the allocation of weighbridge resources, this is a resource scheduling problem. The vehicle scheduling problem and the optimal allocation of resources are combinatorial optimization problems [4-5], the multi machine scheduling problem is also included. Sun F [6] studied the multiple machine scheduling problem based on fuzzy operation time. Liu M [7] used genetic algorithm to solve the multi machine scheduling problem. Based on the above theory, it is very meaningful to apply it to solve the proposed vehicle entering scheduling problem. A multi weigh scheduling strategy based on improved genetic algorithm (GA) was proposed to solve the problem of multi weighbridge weighing scheduling with fuzzy operation time. The performance of the algorithm was analyzed and its availability was illustrated.

Problem Solving and Modeling

Propose Problem

The traditional weighing process is applied by the driver of the vehicle to the factory and queued in front of the gate, and then the weighing task is carried out. This approach is often verbal notification, manual scheduling. In the cement sales season, sales of vehicles, goods vehicles, transport vehicles and other types of vehicles in a continuous line. Due to the random arrival of vehicles, when the peak traffic flow occurs, a large number of vehicles apply for admission to the factory. It cause congestion, confusion, and affecting the entire sales process. The Weighbridge areas is shown in Fig.1. The vehicle enter at the gate. It need weigh and then enter. According to the cement factory sales process, there are large number of transport vehicles on the weighbridge station weighing task, and weighing vehicles often require plant road resources to wait in line, it causes traffic congestion.

The types of vehicles entering the plant are different, different cars have different business processes, some vehicles only need to input the database after weighing weighbridge. They stay in a very short time on the weighbridge. Bulk cement vehicles require identification of the vehicle RFID, and then identification IC cards for vehicle customer binding, the weight house staff issue documents. The analysis of the incoming weighing phenomenon, different types of vehicles weighing on the weighbridge have different operating times, it need to queue into the factory to develop a reasonable weighing weighbridge resource allocation scheme, will greatly enhance the utilization rate of weighbridge. Therefore, a resource allocation strategy is proposed in this paper: weighbridge incoming vehicle driver through SMS application queue into the plant weighing system will be based on the current weighbridge usage for the registration of the assigned vehicle weighing weighbridge, and inform the plan into the factory on the weighing operation time. Through this strategy, with the fastest through time as the goal, the vehicle is assigned a queue weighbridge in advance, and display the LED display in the queue at the entrance of each weighing. The vehicle is expected to entry time by the messages sent to the vehicle driver. The driver of a vehicle according to the message time into the plant selection weighbridge weight reducing the unnecessary waiting time, and effective control of the traffic flow, will greatly reduce congestion and improve the efficiency of weighing. It can make the maximum point area resource utilization.

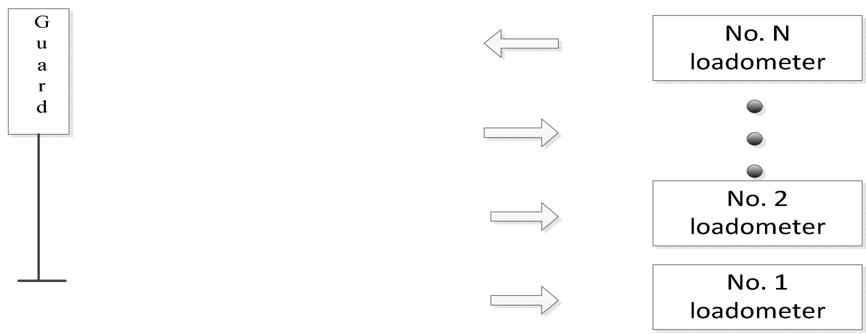

Figure 1. Sketch map of regional weighbridge.

The operation time is not fixed, so the fuzzy mathematics theory is adopted in this paper to deal with the fuzzy number of the operation time of the uncertain vehicles. And this paper make the following assumptions about the scheduling policy:

1. The same number of vehicles scheduling the same priority, all vehicles are subject to scheduling.
2. Vehicles weigh up continuously.
3. Each of the Weighbridge can weigh all types of vehicles and go through all the formalities.

This problem involves how to weigh N vehicles assigned to the M weighbridge and make all vehicles perform weighing tasks, then to make the completion time shortest. It is a multi machine scheduling problem, The multi machine scheduling model is used to analyze and the corresponding algorithm is designed. The following will introduce the relevant definitions involved in this model.

Definition 1. The addition operations of fuzzy numbers are generally triangular fuzzy numbers and trapezoidal fuzzy numbers: for triangular fuzzy numbers $X=(a_{ij}^x, b_{ij}^x, c_{ij}^x)$, $Y=(a_{ij}^y, b_{ij}^y, c_{ij}^y)$

$$Z = X + Y = (a_{ij}^x + a_{ij}^y, b_{ij}^x + b_{ij}^y, c_{ij}^x + c_{ij}^y) \tag{1}$$

Definition 2. Fuzzy numbers is defined: the comparison of the size of fuzzy numbers can be carried out by means of fuzzy mean, for fuzzy numbers $\tilde{M}$, $S(\tilde{M})$ is the support of $\tilde{M}$,The fuzzy mean is defined as follow:

$$\bar{X}(\tilde{M}) = \frac{\int_{S(\tilde{M})} x u_{\tilde{M}}(x) dx}{\int_{S(\tilde{M})} u_{\tilde{M}}(x) dx} \tag{2}$$

For M_1 and M_2, if and only if $\bar{X}(M_1) > \bar{X}(M_2)$, $M_1 > M_2$.

Description of Fuzzy Job Time Multi Weighbridge Weighing Scheduling Problem

The weighbridge busy one-way weighing operation tasks, scheduling and management of global to the entire operation process. There are N independent vehicles, M identical weighbridge; each vehicle weighing only once, and can be composed of any m in a weighbridge operations. Each weighing operation only once and only in a weighbridge. Vehicle i stay on weighbridge j for $\tilde{t}_{ij}$.Each car can be selected. A platform at a time only on a vehicle weighing and registration etc.

MODEL-1

$$T \to \min \tag{3}$$

$$s.t. \tag{4}$$

$$T = \max_{j} \sum_{i=1}^{n} (+)\, \tilde{t}_{ij} * x_{ij} \tag{5}$$

$$\sum_{j=1}^{m} x_{ij} = 1, (i = 1, 2, ...n), x_{ij} \in \{0,1\}, (i = 1, 2, ...n; j = 1, 2, 3...m) \tag{6}$$

In formula (5) $\sum_{i=1}^{n}(+)$ denotes fuzzy operator, max denotes fuzzy max for maximum operator, $\tilde{t}_{ij}$ denotes weighbridge H_j weighing working time on the vehicle J_i, which on balance operation time is fuzzy operation time and coefficient of the objective function is not to solve the fuzzy. In the past literatures, the fuzzy mathematics method was used to deal with the fuzzy job scheduling problem, and the three point estimation method was usually adopted. The expression is similar to the triangular fuzzy number $\tilde{T}= (c_{ij}^{l}, c_{ij}^{m}, c_{ij}^{n})$, in which c_{ij}^{l} is the most pessimistic time, c_{ij}^{m} is the most probable time, c_{ij}^{n} is the most optimistic value. The fuzzy mean is replaced by the calculation, and the optimality is proved in the following. When the fuzzy mean time is used to replace the fuzzy job time, the problem model is shown as follows:

MODEL-2

$$T \to \min \tag{7}$$

$$T = \max_{j} \sum_{i=1}^{n} \bar{t}_{ij} * x_{ij} \tag{8}$$

The following theorems show that the solution of optimality is the same when the fuzzy mean is used to replace the fuzzy operation time.

Theorem 1. Assume that the fuzzy operation time is triangular fuzzy number, the operator of fuzzy mean is formula (2), and the optimal solution of MODEL-2 is the optimal solution of MODEL-1.

Prove:

$\tilde{t}_{ij}$ is a triangular fuzzy number, $\bar{t}_{ij} = (c_{ij}^{l}, c_{ij}^{m}, c_{ij}^{n}) / 3$

Suppose x_{ij}^{s} is the optimal solution in MODEL-2, for any x_{ij} that satisfies for formula (8).

$$\max_{j} \sum_{i=1}^{n} \bar{t}_{ij} * x_{ij}^{s} \le \max_{j} \sum_{i=1}^{n} \bar{t}_{ij} * x_{ij} \tag{9}$$

If theorem 1 is established, there is:

$$\max_{j} \sum_{i=1}^{n} (+)\, \tilde{t}_{ij} * x_{ij}^{s} \to \min \tag{10}$$

For any x_{ij} of formula (6), it is necessary to satisfy the conditions:

$$\max_j \sum_{i=1}^{n} (+)\tilde{t}_{ij} * x_{ij}^s \le \max_j \sum_{i=1}^{n} (+)\tilde{t}_{ij} * x_{ij} \tag{11}$$

By definition, for fuzzy numbers M_1 and M_2, if and only if $\bar{X}(M_1) > \bar{X}(M_2)$, $M_1 > M_2$.

If and only if

$$\bar{X}(\max_j \sum_{i=1}^{n} (+)\tilde{t}_{ij} * x_{ij}^s) \le \bar{X}(\max_j \sum_{i=1}^{n} (+)\tilde{t}_{ij} * x_{ij}) \tag{12}$$

The above formula is established.

$$\begin{aligned}
&\bar{X}(\max_j \sum_{i=1}^{n} (+)\tilde{t}_{ij} * x_{ij}^s) = \max_j \bar{X}(\sum_{i=1}^{n} (+)\tilde{t}_{ij} * x_{ij}^s) \\
&= \max_j \bar{X}(\sum_{i=1}^{n} c_{ij}^l x_{ij}^s, \sum_{i=1}^{n} c_{ij}^m x_{ij}^s, \sum_{i=1}^{n} c_{ij}^n x_{ij}^s) \\
&= \max_j (\sum_{i=1}^{n} c_{ij}^l x_{ij}^s + \sum_{i=1}^{n} c_{ij}^m x_{ij}^s + \sum_{i=1}^{n} c_{ij}^n x_{ij}^s) / 3 \\
&= \max_j \sum_{i=1}^{n} (c_{ij}^l + c_{ij}^m + c_{ij}^n) / 3 = \max_j \sum_{i=1}^{n} \bar{t}_{ij} x_{ij}^s
\end{aligned} \tag{13}$$

According to the above steps in the same way, the following formula was established:

$$\bar{X}(\max_j \sum_{i=1}^{n} (+)\tilde{t}_{ij} * x_{ij}) = \max_j \sum_{i=1}^{n} \bar{t}_{ij} x_{ij} . \tag{14}$$

The synthetic formula (9), formula (13), and formula (14) can obtain the conditional satisfaction of formula (11). The theorem is established.

Genetic Algorithm Design

Step1. Code

First of all, the M number for the weighbridge $\{1, 2, \ldots, m\}$, n vehicle numbers are $\{1, 2, \ldots, n\}$, In this algorithm, the coding form of each gene can be $\{j_1, j_2, \ldots j_i, \ldots, j_n\}$ .Among them, it said the numbers j_i for the weighbridge working on the i vehicle. Such as when the vehicle is N = 10, the number of M =4 weighbridge, which encoding a chromosome structure such as: 1 2 1 4 3 1 4 4 2 2.

Step2. Initial Population Structure

Initial population is generated randomly.

Step3. Determine the Fitness Function and the Reproduction Operator

The choice of objective function in reciprocal values, $Fit = 1/T$.

Copy refers to the individual genetic information of the parent to the next generation, and this choice transfer is a process of survival of the fittest, generally in every generation of individuals with high fitness value is selected more and smaller individual fitness value will gradually be eliminated. Through Monte Carlo method to determine the probability of each individual is selected, the chromosome fitness value, then the probability of chromosome is selected as shown in formula (15).

$$p_k = f_k / \sum_{i=1}^{n} f_i, k = 1, 2, \ldots, n \tag{15}$$

Then calculate the cumulative probabilities for each individual, as shown in formula (16).

$$q_k = \sum_{j=1}^{k} p_j, k = 1, 2, \ldots, n \tag{16}$$

In the replication process, the roulette rate proportional selection method can be used to select the replicated population.

Step4. Crossover Operator

This paper uses the cross exchange method of operation, the first two randomly generated random number between 1 and N, and then the two parent chromosome pairing between the gene exchange in place, the formation of two offspring chromosomes, for i and j in two paired individual specific transformation steps as shown in Fig.2.

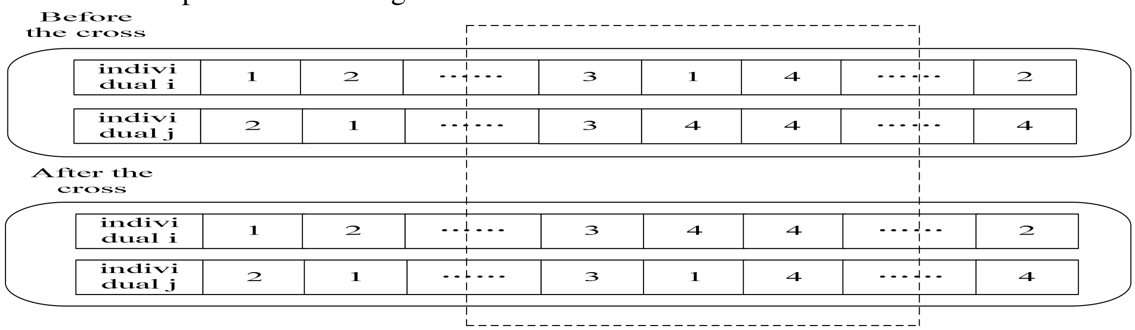

Figure 2. Cross operation.

Step 5. Variation

The algorithm can set a certain probability, random selection of variant genes.

Step 6. Output Result

Because of the general genetic algorithm can not stop the output results, therefore, it need to terminate the algorithm to set a maximum evolution algebra T.

Genetic Algorithm Improvement

Through elitist retention strategy, the individuals with the highest fitness value will not be matched, crossed and copied directly to the next generation of new generation population structure.

The adaptive crossover operator and mutation operator can adapt to a higher degree of individual mutation probability is smaller in the corresponding crossover operation and mutation operation when the crossover probability and smaller, so that the excellent individuals are retained, and the fitness of individuals with a low corresponding to higher probability of crossover and mutation to promote its evolution. The formula of the adaptive crossover rate is shown in formula (17), and the rate of variation formula is shown in formula (18).

$$P_c = \begin{cases} P_{c1} - \dfrac{(P_{c1} - P_{c2})(f - f_{avg})}{f_{\max} - f_{avg}} & , f >= f_{avg} \\ P_{c1} & , f < f_{avg} \end{cases} \quad (17)$$

P_c denotes crossing rate, f_{avg} denotes the population fitness average, $f_{\max}$ denotes maximum population fitness, f denotes the fitness value of larger individuals in paired individuals, $0 < p_{c2} < p_{c1} < 1$.

$$\mathrm{P}_m = \begin{cases} P_{m1} - \dfrac{(P_{m1} - P_{m2})(f - f_{avg})}{f_{\max} - f_{avg}} & , \mathrm{f} >= f_{avg} \\ P_{m1} & , \mathrm{f} < f_{avg} \end{cases} \quad (18)$$

P_m denotes crossing rate, f denotes the fitness value of variation individuals, $0 < p_{m2} < p_{m1} < 1$.

Example Analysis

According to the actual situation of cement factory work vehicle selected five types of vehicles are: bulk cement truck, bagged cement car, goods vehicle, transfer cehicle and other vehicles, vehicle types corresponding to the number and the weighing operation time is shown in Table 1.

Example 1

7 cars, 3 weighbridge is chosen as the example. The vehicle type and operation time are shown in the Table 2. The scheduling results are shown in the Table. 3.

Table 1. Vehicle operation time.

Vehicle type	Bulk cement truck	Bagged cement truck	Goods vehicle	Transfer vehicle	Other vehicles
Type number	a	b	c	d	e
Weighing operation time (c_i^l, c_i^m, c_i^n)	152, 178, 210	98, 124, 138	55, 98, 120	135, 145, 170	43,58, 79

Table 2. The fuzzy operation time of the first example.

Vehicle number	1	2	3	4	5	6	7
Type number	a	a	b	b	b	c	c

Table 3. Scheduling result of the first example.

Weighbridge number	Scheduling scheme	Transit time	Target passing time T_{max}
H1	J1,J3	(250,302,348)	(208,320,378)
H2	J2,J4	(250,302,348)	
H3	J5,J6,J7	(208,320,378)	

Example 2

12 cars, 2 weighbridge is chosen as the example.The vehicle type and operation time are shown in the Table 4. The scheduling results are shown in the Table 5.

Table 4. The fuzzy operation time of the second example.

Vehicle number	1	2	3	4	5	6	7	8	9	10	11	12
Type number	c	e	a	b	d	c	b	b	b	a	c	e

Table 5. Scheduling result of the second example.

Weighbridge number	Scheduling scheme	Transit time	Target passing time T_{max}
H1	J3,J4,J6,J10,J12	(609,756,888)	(609,756,888)
H2	J1,J2,J5,J7,J8,J9,J11	(570,731,862)	

For example 1 and example 2, the proposed algorithm is compared with the natural order scheduling and the greedy strategy, Table 6 shows that genetic algorithm optimizes the effect better.

Table 6. Comparison of different algorithm results.

	FCFS	Greedy Algorithm	Genetic Algorithm
Example 1 mean time	331	331	302
Example 2 mean time	811	751	751

The 40 cars and 4 weighbridge improved algorithm comparison is as Fig.3, p_{c1} =0.9 p_{c2} =0.6, p_{m1} =0.5, p_{m2} =0.01. The algorithm runs thirty times and takes the average. The improved algorithm has better effect than before and there is no distinct difference in running time.

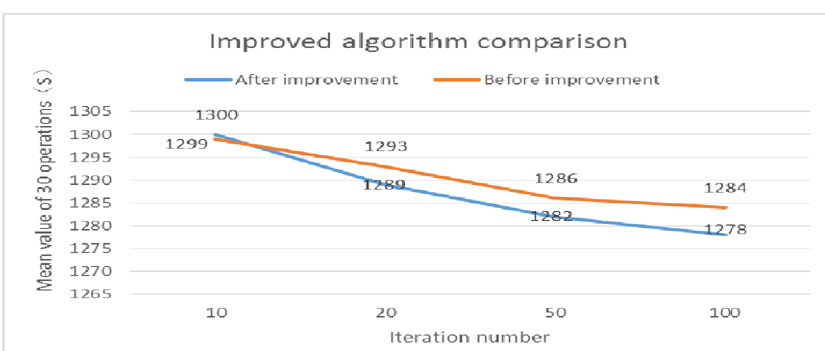

Figure 3. Improved algorithm comparison.

Conclusion

Firstly, the characteristics of different vehicles into the factory weighing operation process was analyzed, then the weighing weighbridge scheduling optimization strategy based on the fuzzy job time was put forward. This paper designed and improved genetic algorithm to solve the problem, the performance of the algorithm was analyzed to clarify the availability. The results show that the proposed strategy can effectively improve the vehicle weighing efficiency, reduce the waiting time of vehicles.

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