A design for simulation model and algorithm of rail transport of molten iron in steel enterprise

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Abstract

An emulation method can be chosen according to the characteristics in rail transport of molten iron in steel companies and a simulation model can be established based on the basic conditions for model, distributed tank mode and path selection, etc. By studying the automatic collision avoidance algorithm, a method of shortest path optimization for rail transport scheduling of molten iron was proposed based on ant colony algorithm. Simulation results show the validity and the feasibility of the algorithm. Programs and strategies of implementing visual simulation platform are proposed laying the theoretical foundation of further research and application for rail transport scheduling model of molten iron and intelligent optimization algorithm.

Keywords: dynamic routing, selection model, ant colony optimization algorithm, collision avoidance algorithm, mode of allocated tank, rail transport of molten iron.

1 Introduction

Rail transport of molten iron is an important step to guarantee steel production. Rail transport of molten iron system transports TPC (Torpedo Car, TPC) which has been ironed under the blast furnace from the blast furnace (BF) to the station before arriving specified point to pre-processed before-steak, desulfurization and after-steak, then it will be transported to the steel factory to pour molten iron. After that, the empty TPC will be hauled back to blast furnace, which completes one course of transporting molten iron [1,2]. In order to better carry out research on the railway transport system of molten iron in steel enterprises, it requires to mimicking the operation of existing systems and simulating progress of future system, and providing a theoretical basis for the simulation and optimazation of transport by improving and perfecting the design.

The research on models and algorithms about rail transport of molten iron has been carried out currently. Some results have also been achieved. Such as: in literature [3], relying on plant railway network. A road collision detection mechanism and reservation model are established and a neighbor distribution. Process scheduling and packet-optimized scheduling for rail transport of molten iron are proposed the with rail transport of molten iron in steel companies as the background and the locomotive and torpedo car TPC as means of transport. The adoption of dynamic programming to determine the optimal number of vehicles is related to the needs of molten iron and transportation distance and other factors. In literature [4] through systems analysis of the molten iron transport, this problem is solved by computer simulation method. The project and the time during rail transport of molten iron are measured. The distribution and the main parameters of random variables are determined by statistical test. Furthermore, there is precision analysis of the computer system simulation and simulation results. In literature [5] using modeling and system simulation technology, the corresponding object model is established through analysis of system objects. The transport path selection of rail transport of molten iron in steel enterprises and automatic collision avoidance algorithm implemented by virtual detection and competition rules are achieved based on the strategy of hierarchical event scheduling simulation.

In order to overcome some shortcomings of static path selection, this paper introduces a dynamic path selection algorithm to solve the problem of adjusting the path of collision avoidance in train operation. When conducting path selection, we change road weights for dynamic under the new constraints reselect path according to the needs of adjusting collision avoidance.

In literature [6,7] using linear programming methods to build analytic model of transportation systems. In literature [8] introducing a heuristic algorithm to study the transportation scheduling problem. Because of a lot of thinking and reasoning process in transport schedule of molten iron, including task allocation, process coordination, time arrangement, vehicle arrangement, route selection and intelligent decision-making behavior of analog and motorists based on dynamic traffic, these mathematical models cannot meet the requirements of simulation research. In recent year's artificial intelligence and expert systems technology is widely used in scheduling research providing a new adjunct of real-time and intelligence, especially the artificial ant colony algorithm for solving scheduling problems of rail transport of molten iron can provide a better solution.

Ant colony algorithm is a new intelligent optimization algorithms proposed by Italian scholar M. Dorigo, V. Maniezzo and A. Colorni [9-11] inspired by the shortest

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path from the nest to a food source when ants foraging. Currently people working on ant colony optimization algorithm have penetrated from the original single traveling salesman problem into a number of applications. Now the algorithm having achieved good results has been optimized in function, combinatorial optimization, graph coloring, vehicle scheduling and so on [12-14].

In this paper, simulation models rail transport of molten and algorithms iron are studied. Pathway selection model collision avoidance algorithm and improved ant colony optimization algorithm are proposed which has been proved to be effective and feasible by the experiment.

2 Simulation method

Depending on whether the continuous state variables change over time Simulation is consisted of continuous system simulation, discrete event simulation and continuous-discrete hybrid system simulation [15]. Continuous system simulation model can be parsed into differential equation; Discrete event simulation can be expressed with logical conditions or flowcharts [16,17]; Continuous-discrete simulation hybrid system is expressed with the first two mixed. However, in the simulation design of molten iron transport system, state of the system only changes at discrete moments. So, discrete event simulation is chosen.

Nevertheless, as there are lots of factors in actual production influencing transportation and production of molten metal, some factors may be left out. Main factors affecting the production are as follows: blast furnace fluctuations, half a deal in principle, car transfer system features, and road traffic. For other factors, such as traffic scheduling, simulation pathways need to consider when selecting models. Thus, the simulative design of molten iron transport system is so complex that we need to make a systematic plan.

2.1 THE ESTABLISHMENT OF SIMULATION MODEL

2.1.1 Model input

The basic conditions for model input are volume X (m^3) of ironworks blast furnace, the average designed tapping speed Y (t/min) of blast furnace, the designed maximum fluctuation coefficient C, maximum and instantaneous tapping speed Y max (t/min), average time Z (min) of two overlapping iron tap hole and tapping of each iron times W (t). It ought to establish the corresponding transport organization program and allocate reasonable transporttation equipment based on design parameters of blast furnace and actual production situation.

2.1.2 Mode of allocated tank

General configuration mode is the "3-2-1" mode. Namely, "tap hole at one time" allocated with 3 TPC", tap hole at next time" allocated with 2 TPC", tap hole at third time" allocated with 1 TPC.

Definite: suppose in an engineering company, there are 6 sets of locomotive cars, assuming the length of locomotive car is 15 cm and locomotive speed is 3-5 km/h, the capacity of mix stickers car is 400t, the length of mix stickers car is 30 cm, load factor is 0.9 [18,19].

Division of locomotive. There are 5 sets of locomotive invested initially with 1 sets of locomotive available. (Locomotive distribution: 2 locomotives for each station of blast furnaces, 1 locomotive for intrusion station), locomotive operation using transport practices with a large loop (BF→ intrusion blast station→ BF). If there is not enough capacity of locomotives, then the sixth car will be put into production.

Mode of allocated tank. Assuming the sequence of using iron mouth is 1#→2#→3#→4#, 4# as a spare overhaul iron mouth, as shown in Figure 1.

Step1. 1#iron mouth railway line 1 ① torpedo car during iron, machine A in line 1 waiting for hanging heavy, machine B hang two cans in a field waiting with empty.

Step2. 1# iron mouth railway line 1 ① torpedocar finished by iron, then swing to iron TPC ② on line 2, TPC ② by iron; machine A hang on heavy TPC ①, changing lanes to a safe location waiting outside the line 2;machine B send ⑦, ⑥ empty TPC to line 1, empty TPC ⑥ registration uncoupling, machine B tow empty TPC ⑦ waiting outside.

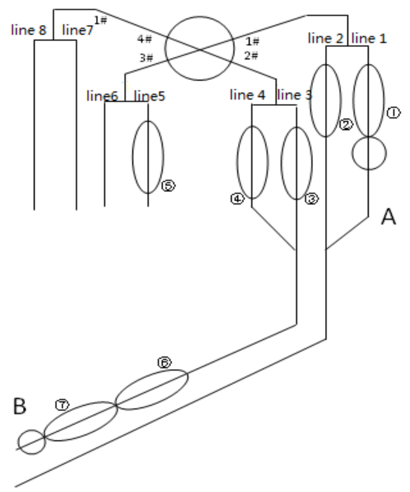

FIGURE 1 The locomotive schedule mode

Step 3. 1#iron mouth railway line ② iron by iron mixed with iron chariots is completed, the nozzle swing after swing stream is mixed with iron chariots of iron a line ⑥ by iron, A machine push ① heavy torpedo car into the iron ② TPC, tow ①, ② TPC to steelmaking intrusion station; machines B and ⑦ empty TPC transfer ran from line 1 to line 2 on the bit, and then turn to line 1 waiting outside after the completion of the ⑥ car to take iron; machine C push two empty torpedo car station to the intrusion from a steel blast furnace operation to its original position of machine B.

At this time, machine A, B, C have completed one bit position conversion, A→C, B→A, C→B.

3 Routing selection model

Regarding the valuable cut-off points at the apex of the rail network as nodes constituting a new network, denoted as G=(v, E), where v={v_1, v_2,...,v_m} is a set of m nodes; E={e_{ij}|1≤i, j≤m} is a set of directed edges(between the junction section).

When searching for the shortest path in the railway network diagram with the help of algorithm Dijkstra, due to the excessive number of network nodes and locomotives and the huge amount of computation, which cause more computation time than simulation step size, the static pathway selection model cannot meet the requirements of simulation system. Therefore, a dynamic pathway selection model is needed to adopt.

Let q denote locomotive number, P denotes a set of locomotives priority; d_{ij} denote the length of directed edge e_{ij}, γ^{kt}_{pij} denote flow from node k to node t of locomotives with priority of p through the directed edge e_{ij}. T_i denotes travelled distance when locomotive i avoid. H_{ij} denote time during which locomotives wait on the directed edge e_{ij}. Gij denotes the driving speed of locomotive on the edge e_{ij}. Dynamic Routing selection model can be defined as follows:

The objective function: opt Z={Z1, Z2, Z3, Z4}.

The shortest total driving distance of locomotive:

$$\min Z_1 = \sum_{k\in V}\sum_{t\in V}\sum_{p\in P}\sum_{n=1} d_{ij} r^{kt}_{pij} . \tag{1}$$

The shortest total mileage of vacant locomotive:

$$\min Z_2 = \sum_{n=1}^{q} T_n \cdot \tag{2}$$

The least total waiting time of locomotive:

$$\min Z_3 = \sum_{n=1}^{q} H_{ij} \cdot \tag{3}$$

The least total driving time of motorcycle:

$$\min Z_4 = \sum_{k\in V}\sum_{t\in V}\sum_{p\in P}\sum_{n=1}^{q} (d_{ij}/G_{ij}) r^{kt}_{pij} + \sum_{k\in V}\sum_{t\in V}\sum_{p\in P}\sum_{n=1}^{q} \mathrm{H}_{ij} r^{kt}_{pij} \cdot \tag{4}$$

4 Research of collision avoidance algorithm

During the study of molten iron transport system, the trains can follow certain traffic laws and avoid colliding with each other through the establishment of collision detection mechanism. According to collision avoidance algorithms and priority of task, high priority trains go first. Meanwhile, every train need to get basic information of others providing more information to support decision-making for the transportation safety.

The length of train T in the simulation model is set n. During driving, the reservation section number of railway is m ($0\le m\le n$), the current section of railway is S_i ($0\le i\le n$), occupancy and reservation path is represented by a collection of array $A(S_i, S_{i+1}, S_{i+2},\ldots, S_{i+m})$. It can be seen that there are many reservation section when $m=n$ and railways are smooth. However, the utilization of the railway and efficiency of running trains are very low. When $m=0$, there is no reservation section, while trains are easily collided. Given the actuality of transport system in steel company and the need of experiment and simulation, we select $m=2$.

Set two trains T_1, T_2, occupation and reservation paths are represented by a collection of array $A_1(S_i, S_{i+1}, S_{i+2})$, $A_2(S_i, S_{i+1}, S_{i+2})$. The task priority numbers are respectively P_1, P_2. T_1 is treated as the research object. S_{i+2} denotes the reservation section in the current road sections S_i of train T_1. Collision avoidance algorithm is as follows:

1) Comparing the size of P_1 and P_2. if $P_1=P_2$ then obeying the rules of FCFS, first appointment S_{i+2} with high default task priority. If $P_1 < P_2$, there will be the same travel in path S_i and T_2 , then T1 need to transfer the right of using S_i to T_2.

2) Appointment success: T_1 traveling on the path S_i.

3) Appointment failed:

- **a.** If $S_{i+2}=S_j$, T_2 is running. P_1 is lower than the b default P_2. Set T_1 is the waiting time. The value of *time* denotes ratio of the traveling distance of train T_2 from current position to the end of path S_{i+2} and speed of the train T_2. At the moment by adjusting the speed mechanism of the train, such as speeding up T_2 to reduce the waiting time of T_1.
- **b.** If $S_{i+2}=S_{j+1}$ or $S_{i+2}=S_{j+2}$, sections S_{i+2} has been reserved by T_2. Appointment T_1 failed.

For the research of multiple trains collision avoidance we can use priority algorithm based on the contents of the train running task space to let high-priority trains go first.

5 The optimization of shortest path algorithm

5.1 DEFINITION OF ALGORITHM

Definition:

Assuming that there are m ants, d_{ij} $(i, j = 1, 2, ..., n)$ denotes the distance between the city i, and the city j, $b_i(t)$ denotes the number of ants located in the city i at the moment t, $\tau_{ij}(t)$ denotes remaining pheromone concentration in attachment between city i and city t. It is equal of initial pheromone concentration on all paths, set $\tau_{ij}(0) = C$ (C is constant), the ants k, $(k = 1, 2, ..., m)$) choose its path in the process of movement according to the pheromone concentration on the path. $p^k_{ij}(t)$ denotes the probability of ants k transferring from city i to city j at the moment

$$p^k_{ij}(t) = \begin{cases} \dfrac{\left[\tau_{ij}(t)\right]^{\alpha}\left[\eta_{ij}\right]^{\beta}}{\sum\limits_{k\notin tabuLk}\left[\tau_{ik}(\mathrm{t})\right]^{\alpha}\left[\eta_{ij}\right]^{\beta}}, & j\notin tabu_{k,} \\ 0\,, & otherwise \end{cases} , \tag{5}$$

where η_{ij} denotes heuristic information transferring from city i to city j. Its value is generally $1/d_{ij}$. α denotes the importance of the residual pheromone on path ij; β denotes the importance of the heuristic information; List $tabu_k$ record cities which ants pass through, it dynamically change as the moving process of the ants.

When all the ants traverse city *n*, we need to calculate path L_k the ant k, then to solve the shortest path $L_{\min} = \min\{L_k \mid k = 1,2,...,m\}$, and update pheromone concentration on every path.

$$\tau_{ij}(t+1) = \max\left(\rho\tau_0(t) + \sum_{i=1}^{n}\Delta\tau_{ij}^k + \sigma\Delta\tau_{ij}^*,\ \tau_{\min}(t)\right), \quad (6)$$

$$\Delta\tau_{ij}^k = \begin{cases} \frac{Q}{Length}, & (i,j)\in T \\ 0, & (i,j)\notin T \end{cases}, \quad (7)$$

$$\Delta\tau_{ij}^* = \begin{cases} \frac{Q}{L_{opt}}, & (i,j)\in T_{opt} \\ 0, & (i,j)\notin T_{opt} \end{cases}, \quad (8)$$

where ρ denotes the pheromone sustained. Parameters, $\Delta\tau_{ij}^k$ denotes the increased concentration of pheromone of ant k on the (i,j) edge from time t to $t+1$, Q is a constant that denotes the total amount of hormone released of the ants by a search. T denotes the exploring path of the ants, *Length* denotes the exploring path length of the ants, T_{opt} denotes the exploring optimal path of the ants, L_{opt} denotes the exploring optimal path length of the ants.

5.2 THE HYBRID ANT COLONY OPTIMIZATION (HACO) ALGORITHM FOR SOLVING OPTIMAL PROCESS ROUTE OF VEHICLE

A colony consists of N ants and all the ants distributed in continuous space S. The point x_i denotes the location of ant i in space S and the corresponding to a random sequence $S_i = \{C_{i(1)}, C_{i(2)}, ..., C_{i(n)}\}$, its adaptive values is $f(S_i) = \sum_{k=1}^{n-1} d(C_{i(k)}, C_{i(k+1)}) + d(C_{i(n)}, C_{i(1)})$.

The new sequence can be acquired by sequence generation mechanism. Algorithm is as follows:

BEGIN

1) Configuring the population size as N, the parameters as ψ_d, a, b, r_i, the number of initializing iterations as t, the position of each ant as $x_i(0)$, its corresponding sequence as S_i and fitness as $f_{i,0}(S_i)$;

2) To calculate the optimal positions $p_i(0)$ of the ants and their optimal adaptive value $f_{i,0}^{best}(S_i)$ at the next step $t=1$, $f_{i,0}^{best}(S_i)$ is the optimal adaptive value between adaptive value $f_{i,0}^{best}(S_i)$ of ant i and adaptive value $f_{k,0}(S_k)$ of its neighbor;

3) While (the number of iterations <= maximum number of iterations)

[a] Calculating the position $x_i(t)$ of each ant, reversing the sequence S_i to a sequence S_i', calculate its adaptation value to get $x_i(t) \to f_{i,t}(S_i')$;

[b] Calculating the optimal positions $p_i(t)$ of the ants and its optimal adaptive value $f_{i,(t-1)}^{best}(S_i')$, $f_{i,(t)}^{best}(S_i')$ is the adaptive value of ant i. $f_{i,0}^{best}(S_i)$ is the optimal adaptive value of ant i between the optimal adaptive value $f_{i,(t-1)}^{best}(S_i')$ in last step and adaptive value $f_{k,(t)}(S_k')$ of its neighbour (ant k and ant i are neighbors each other), (if $t=1$, the optimal adaptive value is $f_{i,0}^{best}(S_i)$ in last step);

[c] calculating $\Delta f_{i,t} = f_{i,t}(S_i') - f_{i,(t-1)}(S_i')$;

[d] If $\Delta f_{i,t} \le 0$. Then

Setting $S_i = S_i'$;

End if

[e] While (cross operation condition is met)

[i] Settings $p_i = S_i$, $f_i(p_i) = f_i(S_i)$;

[ii] Do crossover operation to get p_i', $f_i(p')$ and calculating $\Delta f_i^p = f_i(p_i') - f_i(p_i)$;

[iii] If $\Delta f_i^p \le 0$. Then

Setting $S_i = p_i'$;

End the if

End the While

End the While

4) To choose the optimal solution

END

5.3 THE SIMULATION OF ALGORITHM

In this section, Matlab7.0 was used as the simulation platform to verify the feasibility and performance of the improved algorithm of HACO. In this paper, there are only two instances of the simulation results, which are Eil50 and KroA100. Figure 2 and Figure 3 shows respectively the optimal solution of vehicle route.

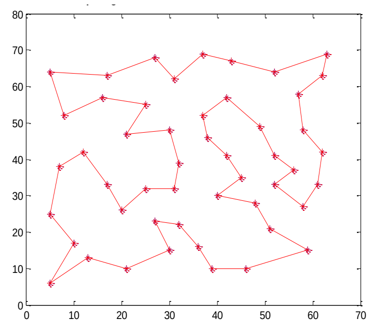

FIGURE2 Optimal solution 428.73 of Eil50

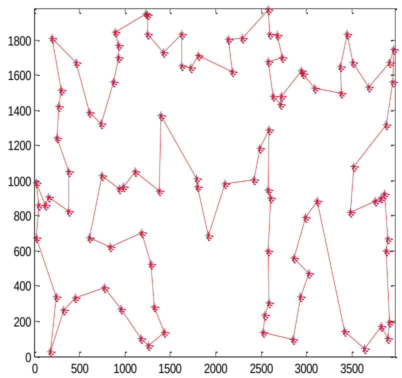

FIGURE 3 Optimal solution 21289.56 of KroA100

The convergence of HACO-TSP algorithm can be seen clearly and it is feasible that solved TSP problem together among ants exchange information each other from Figure 4 and Figure 5. Figure 4 and 5 show the convergence and the good performance of the improved HACO algorithm.

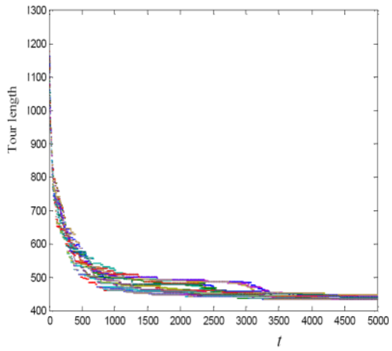

FIGURE 4 Eil50 the dynamic evolution over time of all ants over time

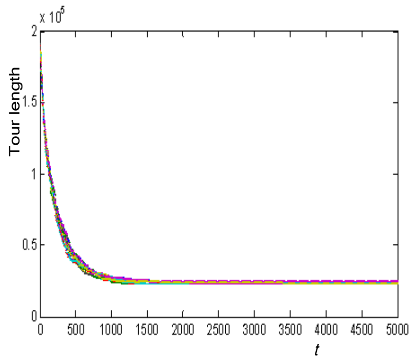

FIGURE 5 KroA100 the dynamic evolution of all ants over time

6 Analysis and implementation of designing

There are many factors to take into account in the process of designing. For instance, the locomotive operating rate, cycle and turnover rate of TPC, utilization of the railway line, the ability of level crossing, etc are analyzed.

It is viable to adopt programming languages such as C, Visual C++ to create model for rail transport of molten iron according to above pathway selection model based on design simulation system. Three-dimensional virtual simulation software Flexsim is used to achieve dynamic pathway selection and conflict-free driving.

Via regarding a simulation system of distributed intelligent hot metal scheduling as experiment platform and recording the raw data adopted to verify scheduling process of molten iron transportation. Intelligent control is applied before and after the key technology of hot metal scheduling, locomotive and TPC running are all got optimization to some degree.

7 Conclusions

Rail transport of molten iron is an important part in steel production. The scheduling simulation model and algorithm research also has important theoretical significance and practical value. This paper presents a simulation model of molten iron scheduling and strategy. Firstly, we propose input conditions of model and then the feasibility of scheme is proposed as complement through simulation studies. Finally, concluding the simulation results. This paper provides an effective and feasible method of simulation programs through research to optimize the in-depth study of intelligent scheduling of molten iron and practical application of the algorithm.

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