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Design of medical track logistics transmission and simulation system based on internet of things[1]

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Abstract. With the quacking pace of hospital modernization, the introduction of efficient automated logistics system has become imminent. In order to realize the efficient operation of the whole system, the scheduling planning and coordination strategy of the object vehicle in TVS system were studied in this paper. First of all, the single TV path planning was studied. Through the research and analysis of the TVS system, the environment map model was established. The Dijkstra algorithm based on the shortest path principle was adopted to realize the optimal path planning of the single TV. On this basis, the dynamic path planning method with time window principle and Dijkstra algorithm was applied to path planning of TVS system, and the path planning of each TV in the system was realized. The final experimental results show that the TVS system can run at the highest working efficiency during the delivery of the logistics tasks, analyze the conflict and its type in the process of driving, and put forward the strategy of conflict coordination.

Key words. Rail logistics transmission system, scheduling planning, coordination strategy.

1. Introduction

Logistics transmission system refers to the system of transporting goods in the set area by means of a series of technologies and facilities, such as information technology, photoelectric technology and mechanical transmission device, which is mainly used in airports, shopping malls, banks, factories, libraries and other fields. With the development of electronic information and control technology, the degree of automation of logistics transmission system is higher and higher. In recent years, the logistics transmission system has been popular because of its efficient transporta-

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tion and manpower saving, and the application field has gradually expanded to the medical field. A hospital is a place where personnel flow and goods flow are very concentrated. Once there is the high incidence of the epidemic, the drawbacks of this logistics mode will be more exposed. However, the automated logistics transmission system can solve this problem very well. It can not only improve the efficiency of hospital work and save the valuable time of patients, but also save the operation cost of hospital and reduce the flow of staff inside the hospital. The logistics system is an important component of the hospital logistics support system. The automated logistics transmission system with the integration of digital control and photoelectric control technology used in the hospital can not only improve the overall operation and management level of the hospital and improve the overall operation efficiency of the hospital, but also provide more efficient service for the patients. The application of logistics transmission system has become an important symbol of modernization of hospital construction and modernization of hospital management, and it has great application value. There are many kinds of hospital logistics transmission systems, among them, the track transmission system is more and more popular because of its small space occupation, large load space, stable operation and high fault tolerance.

2. State of the art

In the developed countries and regions, the introduction of logistics transmission system was relatively early. For example, most of the hospitals in Britain, Germany and France were equipped with automated logistics transmission systems [1]. In 1990s, there were more than ten thousand sets of logistics systems in the use only in Europe. In 1997, a special research project of multi robot system, MARTHA, was set up, namely "a multi autonomous robotic system for handling" [2]. In the past ten years, the application of TVS system has gradually increased. There are hundreds of users in the world only for Swisslog brand track logistics transmission system. A number of research institutes and universities in the United States and Japan have also done a lot of researches on it, and have made fruitful research in theory and practice [3]. Japanese hospitals began using logistics handling equipment in the 1960s to solve the problem of lack of hospital nurses and high labor costs. After decades of development, Japan has developed various large and medium-sized logistics transmission systems, which have achieved rapid promotion and popularization. So far, more than three thousand hospitals in Japan have been equipped with automated logistics systems [4].

Compared with foreign countries, there is a big gap between the abroad and domestic hospital logistics systems both in practice and theoretical research. As a professional field, the research of domestic hospital logistics is still in the initial stage of development. At present, some hospitals with better conditions have begun to equip logistic transmission systems. In 2002, the Affiliated Cancer Hospital of Zhongshan University introduced the first track logistics transmission system in China. In addition, the Third People's Hospital of Yancheng, Suzhou-Xiangcheng People's Hospital, and Ningbo-Beilun District People's Hospital also have introduced the medical TVS system [5]. However, on the whole, the domestic hospital logistics system is still in the functional management stage. The design of the logistics network is not good, and the framework of the hospital logistics system based on process has not yet been established.

3. Methodology

Track logistics transmission system (TVS) is an advanced automated logistics transmission system that is widely used in hospitals. It refers to a system for carrying articles on a predetermined track by means of an intelligent rail vehicle under the control of the computer [6]. Hundreds of sites such as each ward's emergency room, nursing room, operation room, laboratory, blood bank, central pharmacy, central supply room, inpatient department and office area are connected by logistics transmission track in this system. Medical TVS system usually consists of central control system, transceiver workstation, intelligent rail carrying vehicle, logistics track, track converter, automatic isolation door, empty storage area and other equipment [7].

A time window is the time period in which a car enters and leaves. In this period of time, this section can only be used for the car. Other cars are not allowed to pass the section during that time. Based on the traffic condition of the system, the time window method can realize the search for the best path without collision in the bidirectional directed graph. Dynamic path planning method combining Dijkstra algorithm with time window method is used to route planning for TVS system [8].

Suppose that the TVS system has n platform vehicles, and the car set is $R = \{r_1, r_2, \cdots, r_n\}$. There is currently m TVs performing tasks, with the task set of $M = \{m_1, m_2, \cdots, m_m\}$. The starting execution time of each task m_i is $t_{\mathrm{s}}(i)$ with a priority of P_i. For each task m_i, there exists a corresponding path, which is a collection of column edges. From the starting point O_i to the destination point D_i, the path can be represented by $\sigma_i = \{e_j, e_k, \cdots, e_q\}$. And $e_j, e_k, \cdots, e_q \in E$ are the paths in a set of edges of the mathematical model of environmental map. Each task can be represented as shown in formula

$$m_i(t) = (O_i, D_i, t_{\mathrm{s}}(i), \sigma_i(t), r_i, P_i)\,. \tag{1}$$

For each task, the starting point, the target point and the assigned TVs do not change over time. The quantity $\sigma_i(t)$ will not change if the paths of the TV do not conflict during the run. If a collision occurs when the vehicle is executing the task, which only the changing path can be resolved, then the traffic path will be changed dynamically. Each TV has a priority when it is initially assigned tasks. In the course of task execution, as the time goes on, the priority of the task is kept unchanged or set gradually higher according to the actual demand [9].

In the course of running, the carrier vehicle continuously enters and drives out the section in the path. During that time, the section is occupied by the TV, and other TVs are not allowed to enter. For task m_i, the time window S_{ij} for the vehicle r_i to enter the section e_j is defined by the formula

$$S_{ij} = \{m_i, r_i, l, t_{ij}^{\mathrm{in}}, t_{ij}^{\mathrm{out}}\}\,. \tag{2}$$

The upper formula defines the time window of the section e_j, where l represents that the section e_j is the l edge in the path $\sigma_i(t)$ among the paths found by the car r_i within the task m_i. Time t_{ij}^{in} is the time to get into the section e_j, and t_{ij}^{out} is the time to leave the section e_j. Now, the formula

$$t_{ij}^{\text{out}} = t_{ij}^{\text{in}} + \omega_j \tag{3}$$

is satisfied. Here, ω_j represents the running time of the car on the section e_j, as shown in the formula

$$\omega_j = L_j / v_{ij} + t_j \, , \tag{4}$$

where, L_j represents the actual length of the section e_j, and v_{ij} represents the speed of the car r_i on the section e_j. Time t_j is the buffer time on the section e_j, and it is usually taken as $0.05 L_j / v_{ij}$.

Generally, in order to improve the adaptability of the system, it is acceptable for the car to reach the end of the section e_j within the range of $[t_{ij}^{\text{out}} - t_j, t_{ij}^{\text{out}} + t_j]$.

If the section e_j is the starting edge of the path $\sigma_i(t)$, the time for the car to enter the section e_j is the start time $t_s(i)$ of the task. If e_j is not the starting edge, the time to drive into e_j is the time when the car leaves the $l-1$ edge of $\sigma_i(t)$, as shown in the formula

$$t_{ij}^{\text{in}} = \begin{cases} t_s(i), l = 0, \\ \\ t_{i(j-1)}^{\text{out}}, l \geq 1. \end{cases} \tag{5}$$

Through the constant iteration of formula (3) and formula (5), the time window of the car r_i into and out of all the sections and nodes in the path $sigma_i(t)$ can be obtained.

The time window of all cars passing through the section e_j is represented by the time window vector $\boldsymbol{e}_j = \{S_{1j}, S_{2j}, \cdots, S_{mj}\}$. The dimension of the vector is equal to the number of cars, and it varies with time. If the task m_i does not enter the section, the driving time and departure time are set to be 0.

By introducing the time window method, the overlap of each task time window is checked. It can detect the conflicts between each task and the type, and then adjust the path with relevant policies, so that the time windows of each task are not overlapped. The path planning of TVS system is realized by checking the node time window [10].

The task scheduling is made according to the generation time of system tasks. If two or more tasks are generated at the same time, they are sorted based on the priority. Then the scheduling strategy based on the priority is used to schedule the tasks. Firstly, the task with the highest priority is selected to search for an idle TV. By using the Dijkstra algorithm, the shortest running path of this TV is designed to perform the task. Then the time of arrival and departure of all occupied nodes during the execution of the task is calculated, and the time windows of each node are initialized [11]. Secondly, the secondary task is the planning path, whether there is the free TV searched. If not, it will enter the waiting state. If so, the Dijkstra algorithm will be used to compute the time windows of all nodes passing in and out of the task, and update the time window vector tables of each node. Thirdly, the time window vector table has conflicts is checked, and if not, path planning is complete. If it exists, the conflicting nodes are labeled, and the conflict type is judged. The relevant coordination strategy is adopted to eliminate the conflict, and the algorithm is re-programmed by solving the invalid problem. The process is repeated until there is no conflict [12]. Fourthly, the new generation task is assigned to the car and the path is planned. The time window vector table of the system is updated, and the conflict is checked. The above process is repeated. Through such continuous calculation, multi-task scheduling can be completed and a collision free path is planned for the car [13].

Generally, the simulation steps of track logistics transmission system include system investigation, system analysis, system modeling and simulation, strategy scheme optimization, simulation result analysis and so on. The concrete steps are shown in Fig.1.

TVS system simulation can be divided into single vehicle simulation and multi-vehicle simulation. Single simulation can be divided into single point simulation, multi-point simulation and the shortest path simulation. Single point simulation is the simulation of TV running from one transceiver station to any other transceiver station. Multi-point simulation is a simulation of TV running between a transceiver station and a plurality of transceiver stations (n_2). The shortest path simulation is the simulation of TV running according to the shortest path between two or more points [1]. Multi-vehicle simulation refers to the simulation of multiple object vehicle (r_2) running between designated transceiver stations. It is divided into the shortest path simulation and anti-collision simulation. The shortest path simulation is the same as the single vehicle process. Anti-collision simulation is the simulation to take corresponding actions according to the coordination strategy when multiple vehicles receive the task at the same time, in order to prevent collisions during the running.

Simulation target is the foundation and premise of establishing simulation model. The main target of TVS system simulation is to help researchers understand the behavior and performance of the carrier vehicle in the idle state, the movement with the object and the coordination of the conflict, and assist the effective operation management and scheduling planning of TVS system in the practical application, so as to make the system achieve higher work efficiency during operation [2]. The overall goal of TVS system simulation is to make the whole logistics transmission system run efficiently and orderly, so as to give full play to the efficiency of the carrier car. It can verify the TVS system scheduling planning algorithm, so as to achieve the shortest path between stations for a single TV. During the operation of TVS system, the logistic task is realized and the automatic allocation of the carrier is carried out. In the multi-vehicle system with multiple cars, the shortest path planning of each TV is completed, and the collision between each other can be avoided and the normal operation of the system can be realized.

4. Results analysis and discussion

As shown in Table 1, the TVS system studied in this paper consists of 13 transceiver workstations and 7 carrier TVs. The performance parameters of the

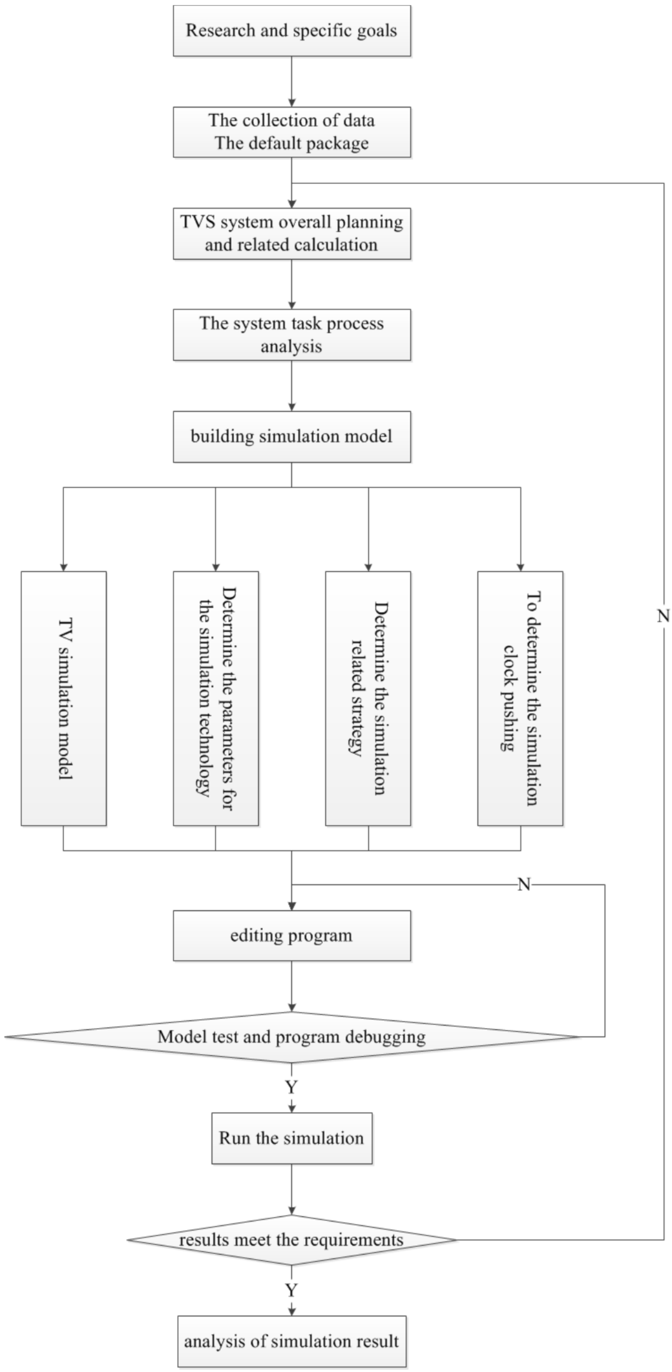


Fig. 1. Flow chart of TVS simulation system design

TVS system are shown in Table 2.

Table 1. Composition of TVS system

The number of transceiver stations	13
The number of empty storage stations	1
The number of junction	21
The number of total nodes	45
The number of TV n	7

Table 2. Performance parameters of TVS simulation system

Number of storage paths between two points k	5
Safe distance d	2 m
Deceleration distance s	5 m
TV normal running speed	0.5 m/s
TV speed regulation range	0–1 m/s

According to the TVS system model set up above, it is assumed that the logistics tasks of the hospital in a given period of time are shown in Table 3. Through simulation, the task allocation and operation of the entire system was achieved.

Table 3. Logistics task assignment table for TVS system

Vehicle No.		Logistic task (€)				
		Speed (m/s)	Start station	Passing station	End station	Priority
1	TV#1	0.5	ID05	ID01	ID06	I
2	TV#2	0.5	ID04	ID11	ID09	III
3	TV#3	0.5	ID03	ID10	ID08	II
4	TV#4	0	\	\	\	III
5	TV#5	0.5	ID12	\	ID05	II
6	TV#6	0.8	ID02	\	ID07	I
7	TV#7	0.5	ID03	\	ID07	I

Notes: The \ indicates no input information, and indicates that the carrier vehicle TV travels back and forth between the two sites. The lower the priority value is, the higher the priority is.

After entering the TVS simulation system, the initialization parameters were set up, then the simulation was run. The whole process was displayed in animation. The various states of collisions during the operation are shown in Figs. 2–8.

Figures 2 and 3 show the process of simulating the sending and receiving of an item in a TVS system from the sending station and the receiving station. Figure 4 is a simulation effect diagram for simulating the shortest path of a single vehicle.

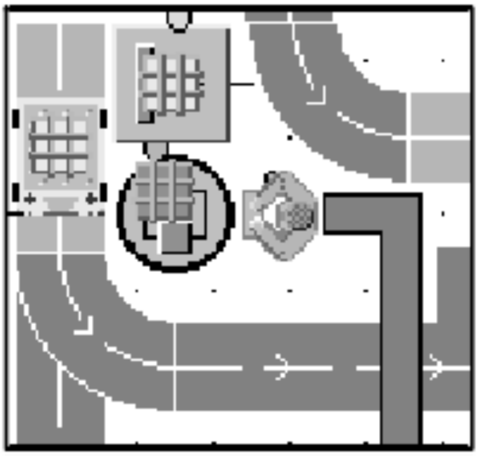


Fig. 2. Delivery at the transmitter station

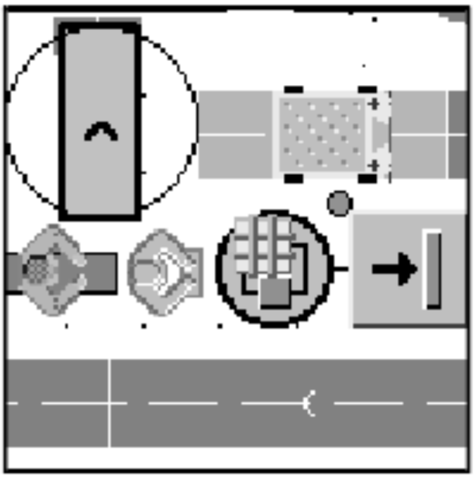


Fig. 3. Unloading at receiving station

Figures 5–8 simulates that in the running process of TVs, the cars can reasonably avoid a variety of possible conflicts. Figure 5 shows the changed path and waiting policy to avoid the first type of conflict. Figure 6 shows the change path policy taken to avoid the second type of conflict. Figure 7 shows the waiting and changed path policy to avoid the third type of conflict. And Fig. 8 shows the waiting strategy used to avoid the fourth type of conflict.

The simulation results show that the proposed scheduling planning algorithm and coordination strategy are feasible and correct. Using eM-Plant to simulate the actual situation of the system can provide good decision-making basis and technical support for the scheduling and planning of the TVS system and the reasonable selection of the driving route. Moreover, the 3D visual animation can provide more

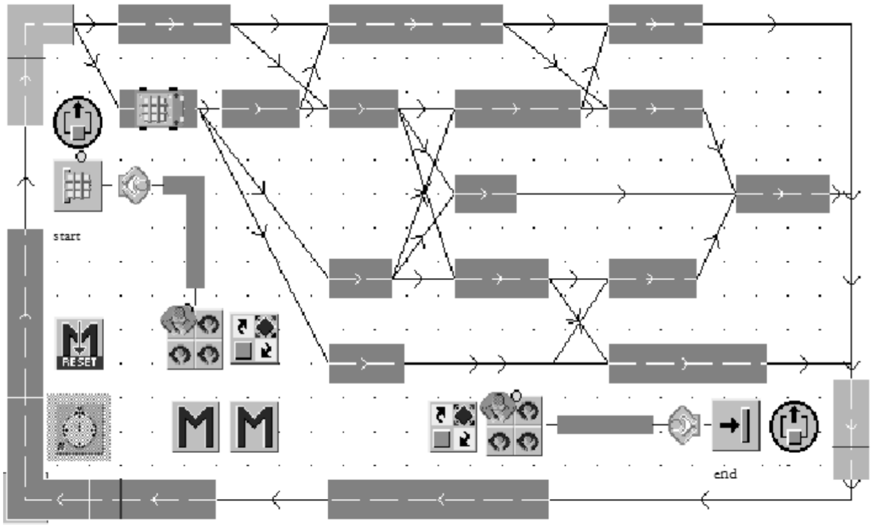


Fig. 4. Simulation effect diagram of the shortest path of the single vehicle

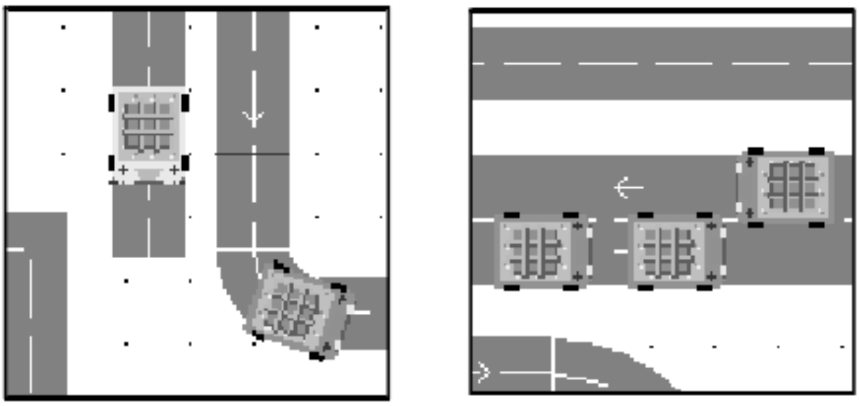


Fig. 5. The first kind of conflict

intuitive running effect for researchers, as shown in Fig. 9.

In addition, for the same logistics task, the general online scheduling strategy and the two-stage scheduling strategy were adopted to simulate the running process of two cars respectively. The resulting run time profile is shown in Fig.10.

In the above figure, the generally online scheduling strategy is used in the left figure, and the two-stage scheduling strategy is used in the right picture. In the same picture, the left histogram shows the first car, and the second car is shown on the right side of the histogram. The meaning of the four time distributions is as follows: red means the car is in the running state. Green means that the car is in idle state, which mainly refers to the time of stay in the work site. Blue indicates the dwell time of the car in the empty storage area. Yellow means the car is in a wait state,

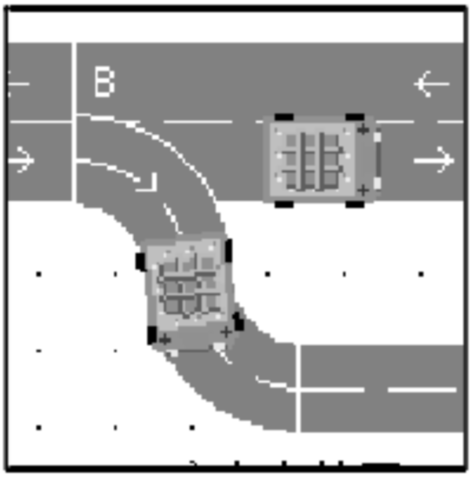


Fig. 6. The second kind of conflict

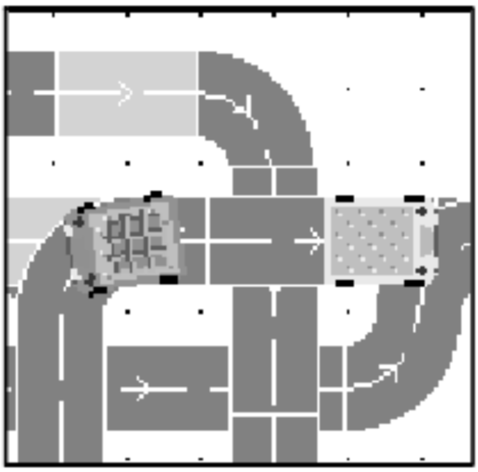


Fig. 7. The third kind of conflict

including the time of command waiting, collision waiting, and troubleshooting. As can be seen from Fig. 10, the two-stage scheduling strategy reduces the waiting time of the logistics car to a certain extent. This is because the collision problem of the car in the off-line phase has been considered by the-two phase control scheduling strategy, which can reduce the on-line computation time and the waiting time, so that the efficiency of the whole system is improved.

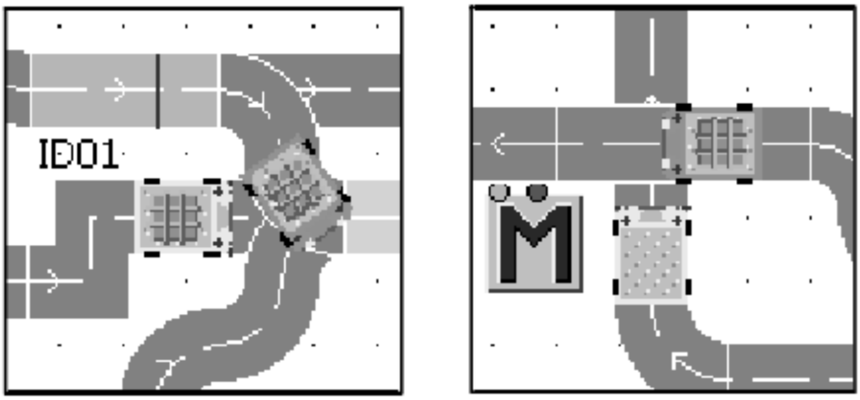


Fig. 8. The fourth kind of conflict

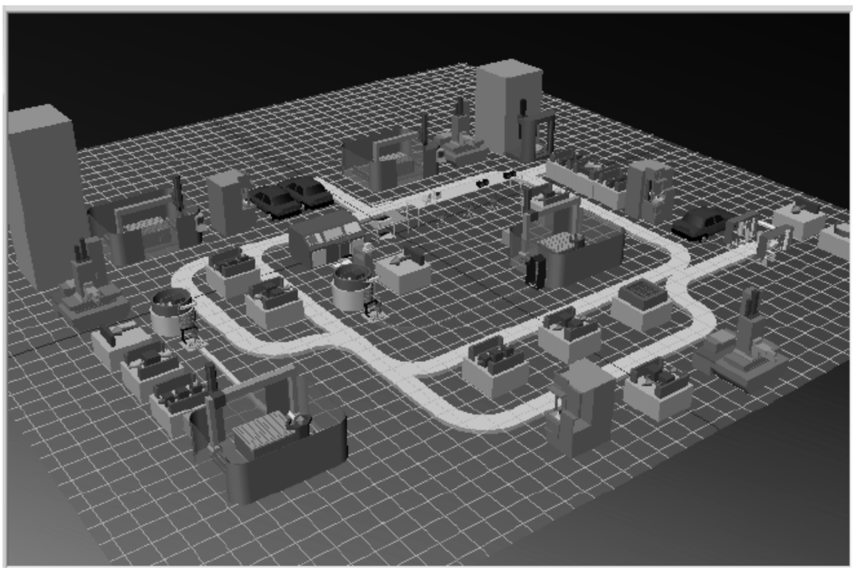
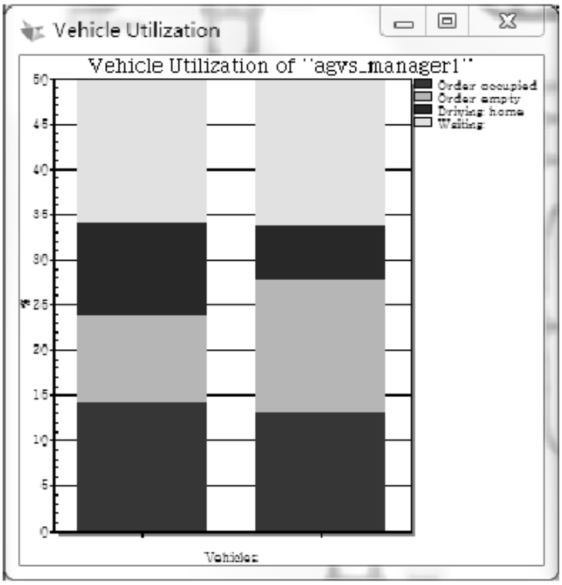


Fig. 9. 3D visual simulation model of TVS system

5. Conclusion

At present, the track logistics transmission system is used more and more widely, and the planning of the car is the key problem in the whole system, which is also the purpose of this paper. In this paper, the structure of TVS control system, the function of each part and requirements were studied. Based on the modeling of system path and stations, examples of practical application were given. The environment map modeling was completed, and the TVS scheduling system model was formed. The results of this research show that on the basis of single TV path planning, the dynamic path planning method combining Dijkstra algorithm with time window method can realize the path planning of TVS system, ensure the collision



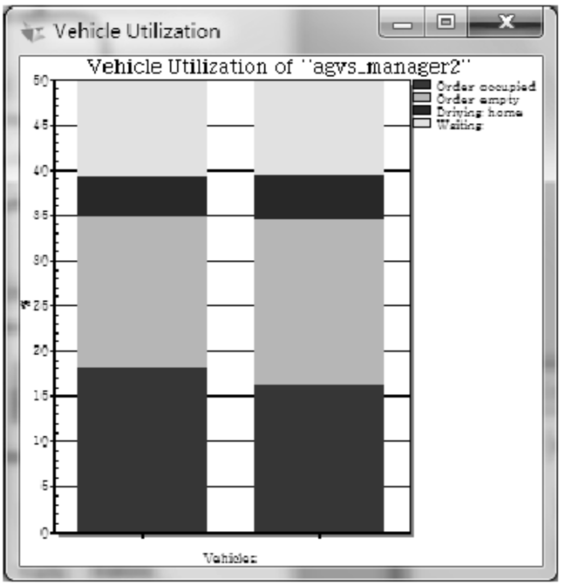


Fig. 10. Comparison of TVS running time under different strategies

free running between the cars, and solve the problem of online traffic control as well as realizing the collision free running TV with each other. In addition, a conflict coordination strategy based on speed regulation and path regulation was proposed, and the automatic collision between TV in TVS system was realized. It can provide a lot of convenience for the adjustment process of the system, and improve the overall operation efficiency of the system. However, the research of this paper is still in the early stage. When the number of cars is large, the existing system will have some limitations, which needs further study.

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