Research on Unmanned Logistics Path Optimization Considering Line Crossing and Multiple Disturbance Factors

Yunting Wei

School of Economics and Management, Shanghai Maritime University, Shanghai, 201306, China

aiheiwei@163.com

Keywords: Line crossing, Unmanned logistics, Path optimization

Abstract: With the increasing demand for online shopping, the volume of express delivery is also increasing, and the requirements for delivery time are also increasing. Drone delivery has become inevitable. In the wave of intelligence and integration, unmanned streaming cars have become a research hotspot. With the rapid development and technological breakthroughs of drones, they have been widely used in the logistics industry due to their advantages of low cost and fast speed. As the market size of logistics in China increases year by year, consumers' requirements for the quality of goods have significantly increased. At the same time, national regulations and policies supporting the development of logistics have also been introduced, which has led to the rapid development of logistics related fields. This article studies the direction of path optimization for unmanned logistics under line crossings and various disturbance factors. By considering factors such as task requirements, airspace environment, and drone performance, a logistics drone path optimization model is constructed.

1. Introduction

With the development of technology, online shopping has become an indispensable and important part of people's lives, driving the rapid development of the express logistics industry, and various new express services have developed in sequence. With the development of autonomous driving technology, its application fields and scenarios have been further expanded[1]. However, with the rapid development, the problems existing in the logistics industry have gradually been exposed, and the overall level of development is not high, with extensive development methods. Many logistics enterprises have started to layout the rural market, but due to the scattered distribution areas, high difficulty in delivery, and high delivery costs in rural China, most rural logistics distribution is limited to townships or even county towns, and is in a primary distribution state and not directly targeting rural customers. Therefore, the overall experience of rural logistics is poor[2]. During use, unmanned vehicles encountered many issues in route congestion that were not noticed during design. With the development of the economy, people's requirements for logistics delivery services are becoming higher and higher. Logistics drones, with their characteristics of being free from traffic restrictions, convenient and flexible scheduling, and fast speed, can effectively solve the problem of “the last mile” at the end of logistics[3]. Early research on drone path planning mainly focused on areas such as route cruising, reconnaissance and exploration. But with the increasing maturity of drone technology, drones have been widely used in fields such as agricultural production and logistics transportation. Drone delivery has issues such as small load capacity and short flight distance. The characteristics of logistics drones in aviation logistics lead to more factors being considered in path planning, so path planning for logistics drones in low altitude environments is currently the focus of research. In recent years, many domestic and foreign experts have conducted a series of studies on the application of logistics drones. They have discussed the distribution prospects and systems of drones in various industries and designed relevant optimization scheduling schemes and path planning models. At the same time, they have also conducted a systematic analysis of the cost of drone logistics distribution[4]. Unmanned aerial vehicle delivery disregards terrain restrictions, making it easy to cross areas that are difficult to achieve by manpower. It can be delivered to any designated location, solving the delivery problem in remote areas, improving efficiency and reducing costs[5]. But in adverse weather conditions, it can also be affected accordingly.

Although logistics drones have advantages such as fast speed, low cost, and environmental protection and energy conservation, they have limited battery capacity, which leads to the inability of logistics drones to fly for a long time and limits their distribution range. For this reason, relevant scholars have proposed a new delivery mode, namely "delivery vehicle+drone mode". The characteristic of in vehicle unmanned aerial vehicle collaborative delivery is that vehicles and drones are two cooperative and independent transportation vehicles, including customers visited by vehicles and drones in one delivery path; Each vehicle has only one path and the starting and ending positions are in the distribution center, while drones have multiple paths and different starting and ending positions; The collaborative delivery mode of vehicle mounted drones fully leverages the advantages of large capacity, long distance, high efficiency, and low cost of drones[6].

2. The Concept and Development of Unmanned Traffic Vehicles and the Problem of Route Congestion

2.1 The Concept and Development of Unmanned Traffic Vehicles

Unmanned vehicles are the application of unmanned driving technology in the logistics field, which is developed based on technologies such as intelligent networking, human-machine interaction, and complex environment recognition. China attaches great importance to the development of autonomous driving technology. Traditional logistics methods such as plane and train delivery, truck delivery, and electric vehicle human delivery are time-consuming and labor-intensive. For residents in remote areas, online shopping, which should have made life more convenient, has instead complicated their lives. Since 2000, unmanned technology has developed rapidly in terms of application. With the rise of internet e-commerce, the logistics industry has also become a direction related to the future of e-commerce. Whoever can reduce logistics costs has an advantage in competition. Therefore, unmanned logistics is a necessary part of the development process for e-commerce[7].

Fig.1 A Factory with No Human Traffic

If drone logistics is applied to daily life, it can integrate idle resources in society and solve the problem of a shortage of couriers. From the current situation, the proportion of labor force has declined, and in the future, it is likely to only serve as the most flexible supplement for express delivery. Unmanned logistics can efficiently save logistics costs, improve the speed of express delivery business, and improve user satisfaction. Unmanned logistics has gradually become a competitive field for the development of e-commerce. However, the application of unmanned logistics vehicles is not only in the e-commerce field, but also plays a significant role in factory logistics, as shown in Figure 1. By using unmanned flow vehicles to deliver factory components, factories can greatly save on logistics and labor costs.

2.2 Congestion Problem of Unmanned Traffic Routes

Urban vehicle congestion generally occurs in narrow, intersections, and sections with a high number of turning vehicles. In the factory area, with the increasing number of unmanned vehicles and the increasing number of driving routes in the factory area, the complexity of the road network continues to rise, and situations where cars and other objects meet occasionally occur. On a relatively narrow road surface, two unmanned vehicles traveling in opposite directions recognize obstacles ahead through the obstacle recognition function of the on-board radar, which means that the two vehicles recognize each other as obstacles, which will cause both vehicles to be unable to resume automatic driving mode and cause congestion on the route. On a road surface with two opposing routes, there is a loading and unloading point on one side, and vehicles on the opposite side need to enter this loading and unloading point. In this situation, the road section is prone to vehicle congestion[8].

If there are loading and unloading points on one side of the route, the vehicle needs to load and unload material boxes at the loading and unloading points. Due to management issues, there may be accumulation of material boxes next to the road network at this location. When the logistics vehicle passes through this loading and unloading point, it will detect the material boxes as obstacles, resulting in obstacle avoidance parking and inability to automatically restore automatic driving mode. During the process of driving, vehicles may sometimes deviate and stay at the edge of the road network, causing subsequent vehicles to be blocked and stopped as obstacles on the road network, resulting in route congestion. In order to provide timely feedback on the frequency and frequent occurrence of the problem, it is necessary to establish judgment criteria, record and provide feedback in a timely manner. Meanwhile, there are still some issues with unmanned logistics. Logistics costs are high, efficiency is low, and the level of informatization is low. Modern warehousing, multimodal transportation and other facilities are still insufficient, and advanced technology has not been promoted, which cannot meet the requirements of modern logistics development; A logistics park system with reasonable layout and complete functions has not yet been established, and an efficient, smooth, and convenient comprehensive transportation network is not yet sound[9].

3. Optimization Model for Traffic Routes without Characters

3.1 Optimization of Vehicle Flow Path without Characters

There are many schemes for the selection and optimization of routes without people and vehicles, such as optimizing route selection by improving ant colony algorithm through bidirectional search strategy. Based on the universality of reality, we will only discuss the problems caused by the most common logistics vehicle route selection methods currently available. Due to the increased risk of vehicles heading in opposite directions due to the narrow road surface, a wider road surface should be selected for planning, with two lanes planned to separate opposing vehicles on the route to solve the problem of heading. A wide road surface with less obstruction can also solve the problem of vehicle deviation caused by poor network signal. The problem of material frame obstruction is largely caused by inadequate on-site management. The location of the storage frame should be reasonably planned and clearly indicated, and it should not obstruct the flow of vehicles without people. The operation of loading and unloading the material frame by employees should also be constrained, executed at the prescribed pace, to ensure that the material frame is stored in the prescribed position[10].

In the “delivery vehicle+drone” delivery mode, the goal of the entire path optimization problem is to minimize the transportation cost of the delivery system, the total distance of the delivery path, and the time to complete all delivery tasks. For the scheduling problem of vehicle intersections, based on the principles of cost saving, leading efficiency, and moderate complexity, an additional electronic fence is adopted to solve the problem. As shown in Figure 2, this plan mainly involves adding an electronic fence at the entrance of the loading and unloading points on the left side of the road. When a vehicle is detected in the fence, other vehicles are not allowed to pass through until the fence is empty. The background will issue a driving command to allow the next vehicle to pass through the electronic fence.

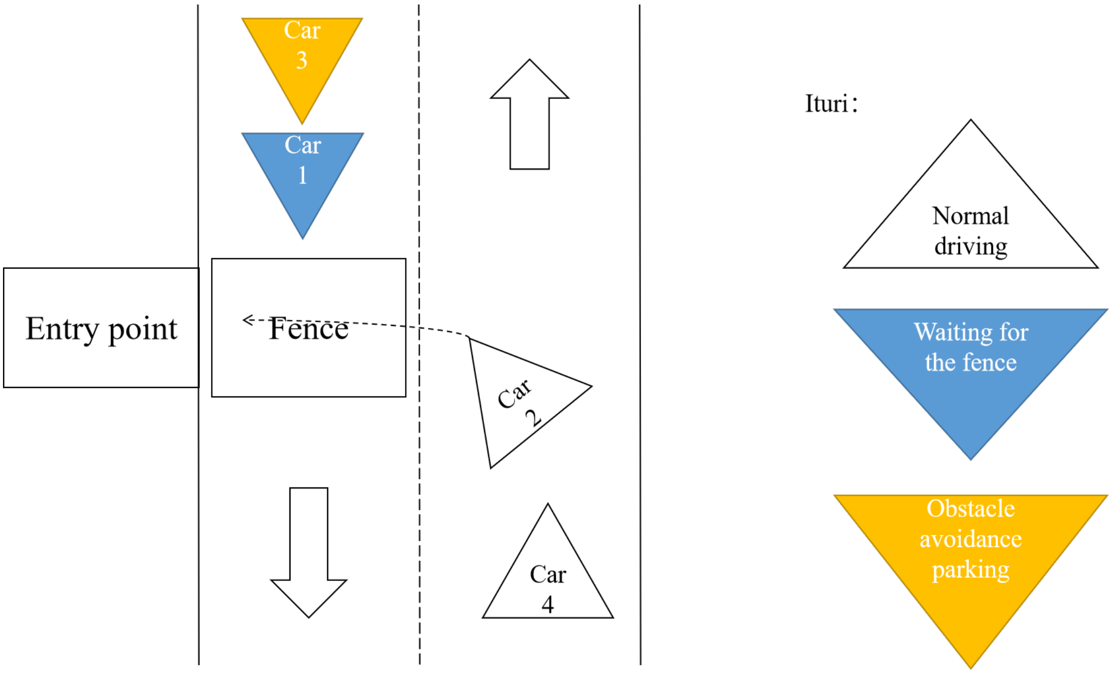

Fig.2 Solution to Intersection Scheduling Problem

The logistics update status is as follows:

$$w(t) = w_{end} + (w_{start} - w_{end}) \times \exp\left(-k \times \left(\frac{t}{t_{\max}}\right)^2\right) \tag{1}$$

Among them, k is the control factor; Control the smoothness of w and t curves. Calculate the total path index:

$$S_k = \frac{1}{F}\left(\frac{n+1}{h_y \cdot j}\right) \tag{2}$$

Where S_k represents the distance between the k distribution points; 1/F represents the distance returned after the delivery is completed; $h_y \cdot j$ is the adjustment coefficient of the total path; n is the total path index value.

3.2 Model Test

In order to better verify the optimization ability of logistics path optimization algorithm in solving the model, this paper carries out experiments with different algorithms respectively, and obtains the best iteration times of the algorithm after each execution. The accuracy comparison of the algorithm is shown in Figure 3.

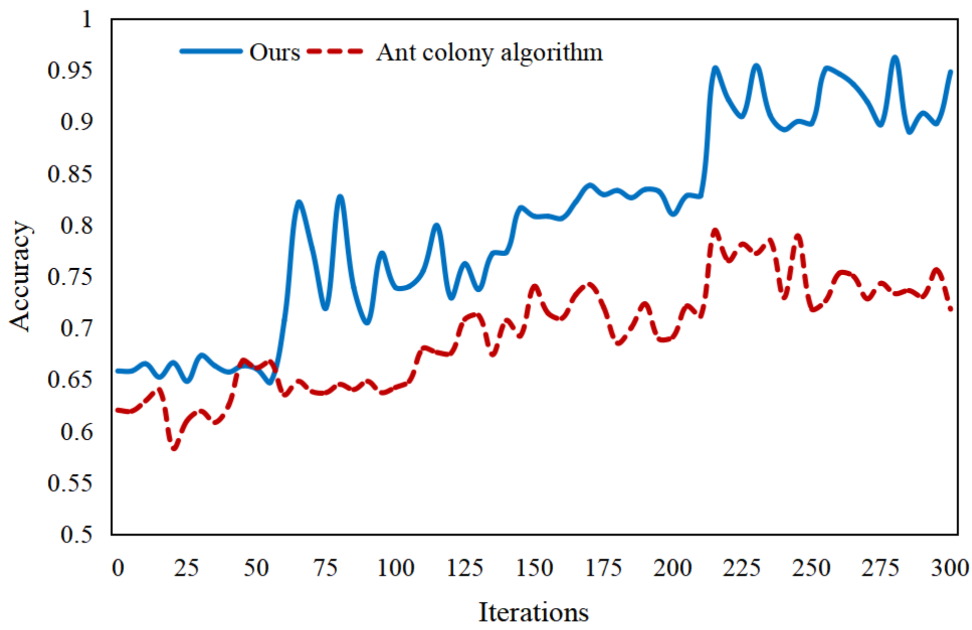

Fig.3 Comparison of Algorithm Accuracy

It can be seen that the accuracy of this algorithm is higher than the other two algorithms. The reasoning method for optimal selection of unmanned logistics path based on the algorithm in this paper has good adaptive ability, and can infer the relationship between input and output of the model through learning and training according to the provided logistics network data, so as to select the optimal distribution path. The comparison of the search efficiency of the algorithm is shown in Figure 4.

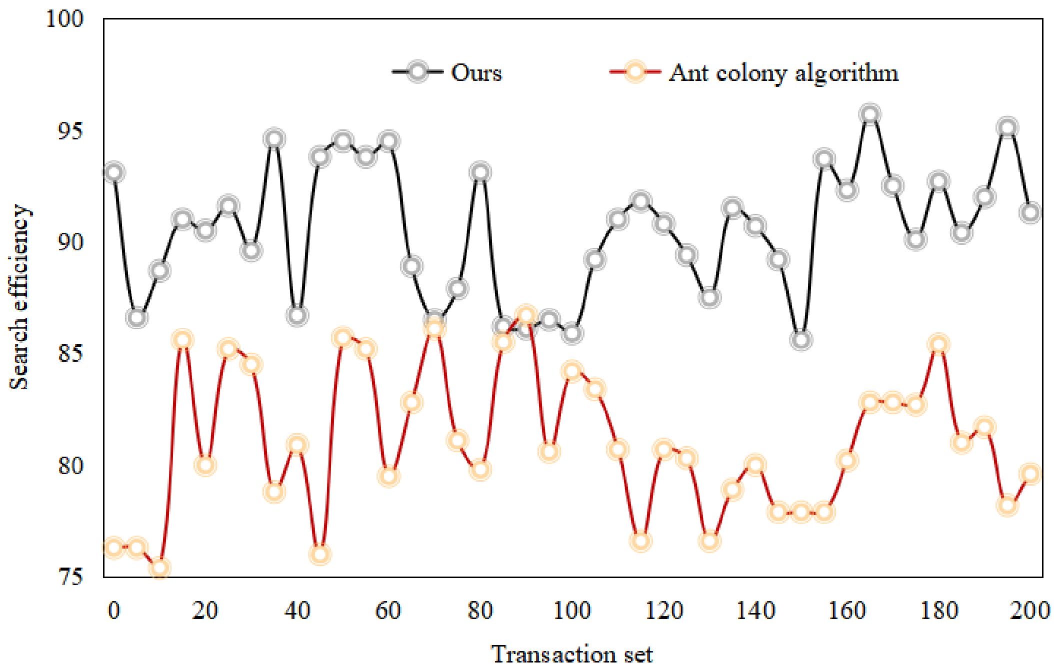

Fig.4 Comparison of Search Efficiency of Algorithms

It can be seen that the optimization of unmanned logistics path based on this algorithm has obvious advantages in operation efficiency. In the process of execution, the algorithm does not directly affect the parameters related to the problem, but directly affects the code space where the algorithm runs. Therefore, choosing a scientific and reasonable coding scheme is helpful to improve the overall operation efficiency of the algorithm.

4. Conclusions

With the rapid development of the express delivery logistics industry, unmanned aerial vehicle logistics systems have developed rapidly, but they still have limitations in many aspects. Although China has made certain achievements in the development of logistics, there are still certain drawbacks: due to unexpected situations such as the epidemic in real life, there are huge challenges to optimizing the distribution path in logistics. This article proposes corresponding solutions based on the practical problems encountered during the use of the character free streaming car. The results indicate that optimizing unmanned logistics paths based on the algorithm proposed in this paper has significant advantages in path planning accuracy and operational efficiency. Future research can consider incorporating factors such as road network and time constraints. The multi depot vehicle routing problem is a more general and practical vehicle routing problem for single depot vehicles. Due to the advantage of drones being able to improve the efficiency of point-to-point delivery, incorporating these factors can further highlight the utility of drones and be more practical.

References

[1] Shi Zihan. UAV logistics distribution path and layout optimization design [J]. Electronic production, 2018(23):4.

[2] Li Hengyue, Zhang Liang, Li Xuesong, et al. Research on route congestion optimization of unmanned logistics vehicles [J]. Information and Computer, 2022(001):034.

[3] Xu Wenxin, Zhang Min, Xiong Guowen. Rural logistics distribution path optimization simulation of distribution vehicles and drones [J]. Computer Simulation, 2022(006):039.

[4] Du Maokang, Luo Juan, Li Bowen. Vehicle-borne UAV collaborative distribution path optimization based on multi-parking lot [J]. System Engineering, 2021, 39(6):9.

[5] Zhang Sensen, Chen Ken, Li Keyang. Path optimization of logistics UAV based on improved A* algorithm [J]. Modern Computer, 2022, 28(11):5.

[6] Yan Fang, Chen Kai, Wu Ke. Research on the model and algorithm of multi-period LTL logistics path optimization problem [J]. Industrial Engineering and Management, 2019.

[7] Zhang Honghai, Li Han, Liu Wei, Xu Weiwei, Zou Yiyuan. Path Planning of Urban Regional Logistics UAV [J]. journal of transportation systems engineering and information technology, 2020, 20(6):8.

[8] Guo Xiuping, Hu Yunxia. Study on the Optimization of Logistics Scheduling under the Joint Distribution Mode of Truck and UAV [J]. Industrial Engineering and Management, 2021, 26(1):8.

[9] Liu Yajing, Lv Wenhong, Wang Guojuan, et al. Overview of terminal UAV logistics path planning [J]. Logistics Technology, 2019, 38(6):6.

[10] Ma Yonghong. Research on the Application of UAV in Logistics Terminal Distribution [J]. Logistics Science and Technology, 2022, 45(11):56-58.