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Integration of UAVs in Logistics: Trends and Feasibility

Sarah Thompson
Department of Transportation and Supply Chain Management, Northern Plains Technical Institute
Fargo, United States
sthompson.u@npti.edu

Abstract: With the onset of the Industry 4.0 era, there has been an increasing interest in unmanned aerial vehicles (UAVs), leading to the gradual emergence of the UAV market. As UAV technology advances, its applications have broadened significantly, with a notable trend towards utilizing UAVs in logistics. This paper reviews the current state of UAVs in the logistics sector, examines their technical feasibility, and offers recommendations for the continued advancement of UAVs in this field.

Keywords: Logistics UAV; development status; technical feasibility analysis.

1. Introduction

UAV is a non-manned aircraft that can complete a variety of missions through remote control or autonomous control. It has a wide range of uses, low cost, and can avoid casualties [1]. The UAV was first used in the military field, and it played the role of intelligence surveillance, fire attack, electronic interference, deception, and damage assessment in the war [2]. As UAVs are becoming more mature, the research on UAVs is not limited to UAV operations, but has gradually expanded into the logistics field. On the military side, the UAVs participated in the logistical support work gradually, and experienced many actual tests. In civilian use, many companies have begun to develop UAVs that can transport parcels independently, with a view to using UAVs to solve the last one kilometer problem. Therefore, the application of UAVs in the field of logistics will become an important direction for the development of UAVs.

With the development of the application of UAVs in the field of material transportation, a number of research results on the optimization of UAV transportation routes have emerged. Dorling et al. proposed a multi-stroke vehicle routing problem that allows the UAV to travel to and from the base multiple times. The hybrid integer programming model was constructed with minimum delivery time and lowest delivery cost, simulated by simulated annealing algorithm, and mathematically derived and simulated. The calculation proves that the UAV energy consumption is approximately linear with the load and battery weight [3]. Coelho et al. studied multi-target path optimization of heterogeneous aircraft fleets to minimize the total distance traveled, the maximum speed of UAVs, the number of UAVs, the latest return time, the average service time, and the remaining battery capacity. The multi-objective mixed integer programming model is constructed, and the constraints such as flight time, endurance, load capacity and other traffic control measures are considered. The intelligent pool search algorithm based on black box optimization solver is designed to solve multi-objective programming [4]. However, above papers have not considered the option to abort the UAVs in case that the UAVs have experienced some shocks during the flight or service. Peng R. explored the joint path and abort optimization problem for cooperative UAVs in a risk environment,pointing out that for any given path plan, the abort strategy needs to be resolved for all

UAVs. Based on the optimal suspension strategy for any path plan, the tabu search algorithm is used to study the optimal flight path with the total cost minimized. The simulation results show that the application of the suspension policy when the UAV performs the task in the risk environment will reduce the total cost of the task [5]. The above study considers the constraints of UAVs carrying out transportation tasks, but does not consider the problem of co-delivery of UAVs with other means of transport.

This paper summarizes the development status of logistics UAVs, discusses the technical feasibility of its extensive application, and proposes rationalization suggestions for the further development of logistics UAVs.

2. The Development Status of Logistics UAVs

2.1. Military Field

In 1917, the world's first UAV was successfully developed in the UK. Since then, the UAV has passed the development process of unmanned UAV, pre-programmed unmanned reconnaissance aircraft, commanded remote unmanned reconnaissance aircraft and composite controlled multi-purpose UAV. Early applications in the military field of UAVs, mainly to perform intelligence reconnaissance, precision strikes, information confrontation, communication relay and other tasks. With the rapid development of sensor technology, navigation and positioning technology, artificial intelligence technology, and the continuous improvement of the performance of related equipment and the continuous improvement of system integration, the development of UAV technology has become increasingly mature, and its use has gradually expanded to the field of logistics.

As early as in the Afghan war, the US military successfully used the K-MAX unmanned cargo helicopter to stay on the short-distance, small-volume materials and resupply tasks of the forward base around the clock. This K-MAX unmanned cargo helicopter has a hanging capacity of 2,720 kilograms. It has been used in Afghanistan for many years. It has transported more than 2,000 tons of supplies to the US Marine Corps. It has performed thousands of replenishment missions and has undergone numerous practical tests.

On January 28, 2018, for the first time, the Chinese Air Force adopted the UAV airdrop material experiment of “military and civilian integration”. This is the first time that our army has used the UAV to carry out a joint replenishment exercise, and it has also opened a new page in the history of the world military logistics. In this exercise, the UAV successfully completed the emergency transportation tasks of radar maintenance equipment and anti-venom serum. On the large screen of the Air Force Logistics Command Center thousands of miles away, the real- time display of the UAV flight aerial picture, the material supply route trajectory, the airport to delivery route planning map, the pod airdrop schematic, and the delivery site real-time situation. This UAV joint replenishment drill has a significant significance, in line with the future unmanned, intelligent battlefield evolution trend.

Unmanned technical support for logistics support is a new trend in the logistics construction of the world's military powers. In the future, military logistics will develop in the direction of smart logistics. The continuous breakthrough in the technology of integrated combat UAVs, brain-controlled UAVs and UAV clusters will also drive the UAVs in the military logistics field from “single guarantee” to "Cluster security", from "hand control" to "brain control" to achieve milestone, leapfrog development. The use of UAVs for military materials transportation can be said to have added "new wings" to military logistics and increased the "new engine", which greatly improved the time and space benefits and guarantee efficiency of military logistics. Compared with traditional military transportation methods, UAV transportation has the advantages of low casualty rate, fast speed, accurate positioning and flexible adjustment. As an efficient, modern and low-cost emerging transportation mode, UAV transportation will become a reliable link in the military material security system.

2.2. Civil Field

In recent years, the development of UAVs in the civilian sector has also been very rapid. UAVs are widely used in civil applications for aerial photography, plant protection, intelligent inspection,

earthquake relief. It also can be used to perform high-risk tasks that humans cannot operate, or work tasks that are harmful to human health. In view of the fact that the UAV can take off and land vertically, the operation is flexible, the transportation is convenient, the efficiency is higher, and it is not affected by natural phenomena such as the environment and the weather. The UAV is favored in the field of logistics and is currently at a critical stage of research and development. Related technologies have been highly valued by major logistics companies.

The development wave of logistics UAVs began with Amazon.com. After Amazon introduced the UAV delivery, major logistics companies have put forward the concept of logistics UAVs. At the end of 2016, Amazon completed the first single UAV express delivery in the UK and successfully achieved its first flight. Amazon did not stop the development process. After upgrading the equipment, it completed the first single UAV express service in the US in Texas in March this year. At the same time, Amazon plans to build a "multi-level order fulfillment center", which not only focuses on the research of logistics UAVs, but also comprehensively develops route planning, conceptual design and overall system construction for UAV distribution. The research work is intended to build a complete UAV logistics system.

In China, logistics UAVs are also facing an alarming development speed and huge market space. Many express logistics companies are deploying UAVs, and Jingdong and SF are at the forefront. However, due to restrictions on UAV regulations and technical bottlenecks, the current UAV logistics is still in the pilot phase of some regions, and has not yet been realized on a large scale. It is worth noting that several logistics leading enterprises in China have put the research and development of logistics UAVs on the agenda and achieved certain results. On June 29, 2017, SF Express realized the flight test of the logistics UAV in Nanchang District of Ganzhou City, which tested and realized the flight of the four-axis multi-rotor model and the tilt-rotor model. SF announced that it has developed a variety of models to suit different business applications. The maximum effective load after take-off can reach 5 to 25 kg, and the cruising range can be 15 to 100 km. On June 8 of the same year, Jingdong completed the first batch of UAV delivery in Suqian,Jiangsu, claiming that the UAV was officially put into the pilot operation of rural logistics.

3. The Technical Feasibility Analysis of Logistics UAV

In view of the fact that the current logistics UAV has just started in the civilian field and has not been widely used in the market, there are still many problems in the technology to be solved.

3.1. How to Carry Out Route Planning and Automatic Obstacle Avoidance

UAV path planning usually refers to designing an optimal or satisfactory flight path for the UAV under the premise of considering the UAV arrival time, energy consumption, threat and flight area to ensure its complete the flight missions and return to the base safely. Due to the complicated road conditions, it is still difficult for the UAVs to plan their own routes. In order to achieve autonomous path planning, it is imperative to solve the problem of automatic obstacle avoidance. How to safely let the aircraft avoid obstacles without deviating from the route is one of the main problems faced by UAVs.

When studying the problem of UAV path planning, scholars consider the UAV flight time, flight distance, fuel consumption, time window, target priority and other related constraints to plan a better UAV flight routing. On the basis of considering the relevant constraints, some scholars have established models such as mixed integer linear programming, multi-traveler problem, vehicle routing problem, dynamic network flow optimization, collaborative task assignment, etc., and adopted genetic algorithm, tabu search algorithm, ant colony algorithms, particle swarm optimization algorithms and other suitable heuristic algorithms are used to solve the problem of UAV route planning and automatic obstacle avoidance.

3.2. Problems of Improving Endurance and Load Capacity

The UAV transporting materials have two constraints: short cruising time and weak load capacity. Under normal circumstances, the small-rotor UAV can only load tens of kilograms and cruise for one hour. The US K-MAX cargo UAV can only load about 1.5 tons, round-trip flight 200 kilometers. In

recent years, with the continuous improvement of the UAV control system and the rapid development of collaborative optimization technology, the cooperative distribution of UAVs has gradually become an ideal choice. UAV transportation has formed a relatively complete mode of operation, especially in the US Amazon. The company's UAV delivery test mode uses "distribution car + UAV" to provide a reference case for domestic use. This mode is mainly the "last mile" of the UAV responsible for logistics and distribution.

In addition, due to the weight and volume of the battery, current UAVs cannot be equipped with large batteries with high storage capacity in order to reduce the take-off quality of the battery. However, logistics UAVs must ensure long-term, large-range operations. Therefore, reducing energy consumption and improving energy utilization efficiency are relatively feasible solutions. One of the new solutions is the development of oil-powered tilt-rotor UAVs and the use of electro-pneumatic systems similar to automotive technology to control the injection time and fuel injection by electrical signals to provide fuel power to provide rotor power. The purpose is to greatly increase the endurance of the UAV.

The light-duty UAVs that are commonly used in the market today are mainly developed by DJI Innovation company. This integrated quadrotor aerial camera is mainly for the masses of consumers. It is easy to operate, no assembly, out of the box, and recognized in the international market. The recent solar cell technology on the market can guarantee that the UAV will continue to fly for a week or even longer.

3.3. Security Issues

The safety issue during the flight of a UAV is the key to its ability to successfully carry out its transportation tasks. Especially in the military context, UAVs often perform tasks in very severe risk environments and may be subject to unknown threats and shocks, which may come from enemy attacks, bad weather, electromagnetic shocks, etc. For example, in bad weather, especially in heavy rain, how to ensure the safe flight of logistics UAVs is also an important issue that needs to be solved now. Since most of the control systems of the UAV are composed of electronic components, if the waterproof performance of each component cannot be guaranteed or the waterproof measures are not taken under rainy weather, the short circuit of the UAV will be interrupted, the work task will be interrupted, and even others will be harmed. Life safety. This problem is a problem that must be solved when the UAV moves from the laboratory to the product application.

To solve the safety problem during the flight of the UAV, on the one hand, it should focus on improving the performance of the UAV's body. On the other hand, it is necessary to take into account the risk factor constraint when planning the flight path of the UAV. In view of the risks that may be encountered during the flight of the UAV, relevant scholars recommend applying the suspension policy to the process of performing the mission. The suspension policy refers to a strategy in which the UAV does not continue to perform tasks after encountering certain risks in the course of performing tasks but instead returns to the base directly, which can reduce the large losses caused by the destruction of UAVs and goods. Simulation analysis shows it will reduce the total cost of performing tasks.

4. Conclusions and Future Study

4.1. Conclusion

Whether in the military field or in the civilian field, logistics UAVs have begun to be applied, and the application of UAVs in the field of logistics is a very novel development trend. At present, the UAV logistics has not yet been scaled up, and the development of logistics UAVs is still in its infancy. There are still many problems in the wide application of UAVs in the field of logistics that require further research to solve.

For the UAV path planning problem, the various constraints in the UAV flight process should be considered to establish the relevant model, and the appropriate algorithm should be used to optimize the flight routing of the UAV. For the problem of unmanned aircraft's load capacity and endurance, it can be solved by “distribution car + UAV” collaborative distribution or improving UAV performance, reducing energy consumption and improving energy efficiency. In view of the safety

issues during the flight of the UAV, it is necessary to take into account the risk factors when planning the flight path of the UAV, and plus the application of the suspension policy to reduce the total cost of the transportation task.

4.2. Future Study

The application potential of UAVs in the field of logistics is huge and the application prospect is broad. In the next few years, logistics UAVs will be a good development direction. Therefore, both the country and the logistics enterprises should raise their awareness and do a good job in the research of UAVs in the field of e-commerce logistics to promote the better application and promotion of this technology.

In order to ensure the better application of UAVs in the logistics field, operating companies should actively take measures to clarify the operating model, strengthen operational cost control, actively improve the internal management system, and do a good job in staff and UAV management. At the same time, government functional departments should actively introduce relevant laws and regulations to regulate the application of UAVs in the field of logistics.

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