Systematic Analysis of The Principle and Application Cases of UAV In Logistics

Yize Cheng [1, *], Bowen Li [2]

[1] Department of electronic information and automation, Tianjin University of Science and Technology, Tianjin, 300000, China

[2] School of advanced technology, Xi'an Jiaotong-Liverpool University, Suzhou, 215000, China

* Corresponding Author Email: 2198958751@mail.tust.edu.cn

Abstract. With the rapid development of technology, the Unmanned Aerial Vehicle (UAVs) are used in various fields, the most common of which are economic material transportation, military surveying, and data mapping in engineering. The powerful aircraft can ensure better power and load capacity, and the flight control system and high-precision navigation system of the UAV have accurate control algorithms and real-time monitoring capabilities of aircraft parameters. Firstly, before takeoff, safety checks including battery charging and equipment debugging will be carried out. After that, flight path planning and target location selection will be carried out according to the requirements of the delivery mission. After the successful delivery of the logistics drone, the delivery data will be reported in real time and automatic return. However, logistics drones also have some technical problems to be overcome, such as short battery life, low perception and obstacle avoidance. However, these problems can be solved by changing the fuselage material, improving the glide ability of the UAV, optimizing the fuselage impact point, and improving the HPSO algorithm framework. The promotion and application of logistics drones can effectively reduce part of the labor and labor costs, and at the same time, make the entire transportation work automated.

Keywords: UAV; algorithm; flight control system; cargo handling system.

1. Introduction

Unmanned aerial vehicle (UAV) is a new type of autonomous flying aircraft, whose main functions include data survey, resource collection, transportation and distribution. With the development of a new round of science and technology industry, drones are widely popular, and their application fields cover express transportation, military aerial photography, agricultural plant protection, micro reconnaissance, disaster relief, wildlife tracking and positioning, monitoring the mapping scope of infectious diseases, surveying and mapping geographic information, power inspection, film and television shooting and other fields [1]. In the field of engineering construction, UAVs can carry out 3D imaging technology to collect a large amount of geographic information. At the same time, it can also assist in pay-off, monitor pipeline safety, and use infrared thermal imaging to assist the construction process of external walls. In the field of agriculture, drones can diagnose and detect pests and diseases on plants, and carry out variable fertilization, quantitative watering, weed clearing and operation management on crops according to the actual situation. It can effectively increase the yield of crops, reduce the burden of farmers' land work, reduce the cost and waste of agricultural production, and optimize crop cultivation [2]. In addition, drones are also popular in the logistics industry, and a number of well-known companies use their remote sensing autonomous flight technology to carry out long-range logistics distribution. The technology of UAV in logistics distribution is relatively perfect, its prospect and feasibility are good, and it has high research and development value.

2. The General Scheme of logistics UAV technology principle and application

2.1. Principles and components of logistics UAV technology

2.1.1 The structure of logistics UAV

UAVs are made up of airframe components, power systems and flight control systems. Among them, the flight control system is the most important component, which is equivalent to the "Brain" of the UAV, helping the UAV to achieve autonomous flight, the flight control technology includes navigation technology, interface technology, interaction technology, communication technology, Chip Technology and platform technology [3]. Since UAVs are not piloted by humans, ground control systems or communications management software play an important role in their operation and are therefore considered part of the UAV system.

2.1.2 Major components

UAV distribution technology mainly depends on the UAV flight control system, navigation and positioning system and cargo handling system and other technologies.

(1) flight control system. The flight control system is the core of the whole flight process of UAV, such as taking off, flying in the air and executing tasks. Flight control includes sensors, on-board computer and servo-actuated equipment, which mainly realizes three functions of UAV attitude stabilization and control, UAV mission equipment management and emergency control.

(2) navigation system. Navigation and positioning system: the navigation and positioning system of UAV realizes the precise positioning and navigation of UAV by using the technologies of global satellite navigation system (GNSS) and inertial navigation system (INS) [4-6]. The navigation system provides the position, speed, attitude and other information of reference coordinate system for the UAV and guides the UAV to fly according to the designated route. There are two kinds of navigation system for UAV, GPS and inertial guidance, but they are easy to be disturbed and error accumulation increases.

(3) power system. There are usually two types of power systems: electric motors and internal combustion engines (reciprocating engine, turboshaft engine, turbojet engine). Small uavs are powered mainly by electric motors, while medium and large uavs are powered by internal combustion engines.

(4) communication link system. UAV information interactive communication system is one of the main technologies of UAV, which is mainly responsible for remote sensing, remote observation, tracking and positioning, and sensor transmission, the UAV remote control and UAV downlink data link perform remote sensing and data transmission functions.

(5) cargo handling system. The cargo handling system of UAV mainly includes airborne pods, cargo containers and other equipment.

2.2. Major requirements for the application of logistics UAV technology principles

In order for logistics UAVs to be able to serve humans within a controlled range, as can be known the requirements of UAV itself has brought some challenges to the application of the logics UAV, listed here. The first is that UAV should have enough flight stability. It can adapt to the flight environment under different climate conditions and equipped with adequate power and load capacity. And after that the requirements of flight control system are the flight control system should have accurate control algorithm and real-time monitoring capability of aircraft parameters. There's more, navigation and positioning system requirements: Navigation and positioning system should have high-precision positioning and navigation capabilities to ensure that UAV can reach the designated location. The last point is cargo handling system requirements: the cargo handling system should have a stable handling capacity, can safely and efficiently complete the loading and unloading of goods.

2.3. Logistics UAV technology principles and processes-flow Charts

Drone Delivery Technology Operational Processes is shown in figure 1.

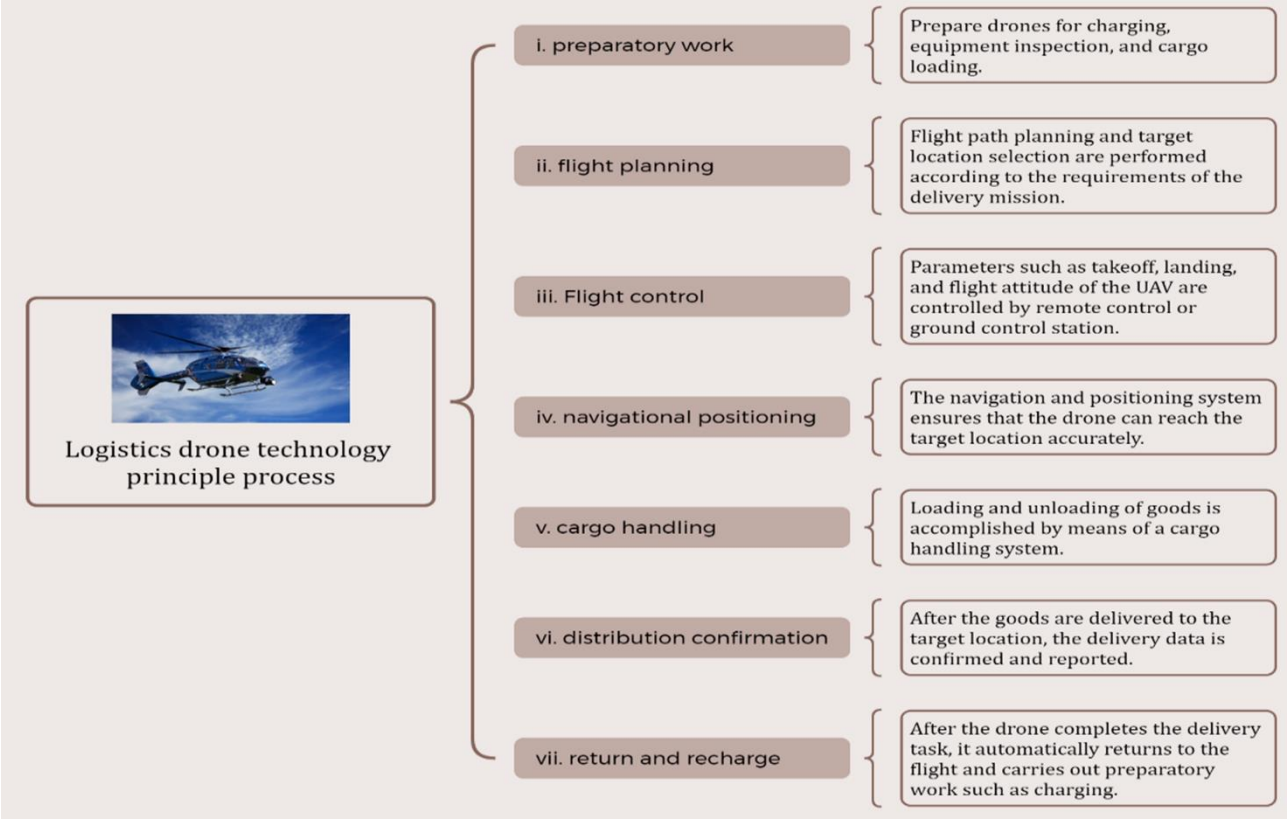

Fig. 1 Drone Delivery Technology Operational Processes (Photo/Picture credit: Original)

Firstly, prepare drones for charging, equipment inspection, and cargo loading. And then, flight path planning and target location selection are performed according to the requirements of the delivery mission. And parameters such as takeoff, landing, and flight attitude of the UAV are controlled by remote control or ground control station. Moreover, the navigation and positioning system ensures that the drone can reach the target location accurately. What's more, loading and unloading of goods is accomplished by means of a cargo handling system. Then, after the goods are delivered to the target location, the delivery data is confirmed and reported. At last, after the drone completes the delivery task, it automatically returns to the flight and carries out preparatory work such as charging.

2.4. Implementation of key technologies

In fact, there are three key technologies to realize UAV logistics distribution: UAV Data Link system, Flight Control and Navigation system and autonomous control technology. It is reported that the UAV Data Link, as a neural network in the UAV system, is inside the UAV system and between the UAV system and other combat systems, a real-time and flexible network system of reconnaissance and Reconnaissance, information exchange and cooperative operation is built, reliable communication is achieved. Flight control system is one of the key core systems of UAV [7]. In some cases, it can be divided into two parts: Navigation Subsystem and flight control subsystem.

Navigation Subsystem: provide the UAV with position, speed and attitude relative to the selected reference coordinate system to guide the UAV to fly safely, punctually and accurately along the designated route.

Flight Control Subsystem: the core system of the whole flight process, such as taking off, flying in the air, carrying out the mission, returning to the factory and so on.

Autonomous Control Technology is also the key technology of UAV [8]. This system can realize path planning and cooperative control by acquiring information and modeling task environment independently, including extracting 3D environment features and evaluating situation.

3. Application of logistics UAV technology

3.1. Prospects and feasibility of logistics UAV technology

Due to the massive popularity of online shopping culture, the volume of express transportation in the logistics industry has risen sharply, as a result, the daily workload of the logistics station increases sharply, so the human resources required, and the cost of labor will be greatly increased. UAV technology can solve the problems faced by the logistics industry in this respect [9]. In the first half of 2018, the total amount of social logistics in China reached 131.1 trillion yuan, and the total cost of social logistics was 6.1 trillion yuan. It can be seen that in China's logistics industry, the demand for UAV distribution is large, the suitability of UAV and logistics industry is high, and the application prospect is great.

At the same time, based on the above application prospects, the application feasibility of UAV technology is very high. First of all, the drone industrial park has set up a number of sites around the world, and the drone industrial cluster has developed well with the policy support of various governments, so it can provide help to a large extent for the supply of the use of drones in the logistics industry and related technical guidance. Secondly, UAV has become a strategic opportunity for intensive innovation and rapid growth of low-altitude economy. The logistics and transportation photos are a perfect match for the remote sensing, mapping and geographic information and communication link technologies covered by UAV [10]. With the existing and advancing low-altitude flight technology and satellite navigation technology, smooth flight and path planning can be better maintained, and accurate delivery to the destination. Third, the UAV market is increasingly broad, and the demand is gradually increasing [11]. UAV logistics has gradually emerged in recent years, which is not limited by ground traffic conditions in the end distribution process, has the advantages of short time and high efficiency, and can be developed into the main force of the "last kilometer" logistics distribution of urban air traffic in the future.

3.2. Application case analysis

Amazon's latest iteration of the drone model MK27-2, it uses a six-rotor, the weight of the fuselage is 40kg, the maximum speed of 111km per hour, the maximum flight height of 122m, in low-altitude flight can carry the heaviest 2.3kg package, the longest range of 14km. In the drone airport of Amazon warehouse, the package is put into the position of the drone belly by the operator, after the path algorithm planning, the drone takes off to the cruise altitude, and with the support of the onboard sensor, the drone flies to the destination according to the predetermined route. The vision sensor on the fuselage is used to ensure the avoidance of obstacles during the flight, and at the same time, the two-dimensional code on the ground is recognized for positioning when it reaches the destination. The drone is precisely adjusted to the above two-dimensional code in a small area, and opens the cargo hold, drops the package, and then takes off for home. In addition, Amazon changes the design of the body and the delivery machines for different environments. However, such drone delivery has crashed five times within four months of its implementation in 2021, causing certain harm to public property and citizens' personal safety. Several of the drone's safety features were found to have failed at the time of the crash, failing to complete its goal of 2,500 flight tests. Although Amazon has been approved by the Federal Aviation Administration (FAA) for commercial drone delivery services, there are still safety concerns and other issues.

Sf Express UAVs have launched a number of projects, including multi-rotor UAVs, vertical take-off and landing fixed wing UAVs, operation control systems, communication systems, drone express docking cabinets and so on. The most commonly used UAV is Manta Ray, which has a maximum takeoff weight of 38kg, a maximum range of 100KM, a cruise speed of 26M/S, and a small geometric size. Fully automatic flight, autonomous cruise capability, with ducted fans to increase range. The Manta Ray is a hybrid multi-rotor and fixed-wing UAV. Its two major advantages are multi-rotor independent runway take-off and landing and fixed-wing efficient cruise flight. The wing body is a

pneumatic shape with high integration and strong endurance, which is used for long-distance end distribution business, and can even distribute goods to plateau areas, remote mountains and islands.

4. logistics UAV technology challenges and prospects

4.1. Application problems of logistics UAV technology

Although drone technology has the advantages of fast delivery speed, low transportation cost, and low fit requirements for the transportation environment, it also has the disadvantages of short battery life, low sensing and obstacle avoidance ability, and straying into no-fly zones to touch the law. In order to facilitate the UAV to carry more payloads, its internal power supply is usually small in size, light in weight, and has a short service life. In the distribution process, the package carried will increase the overall carrying weight, making the work required by the UAV greater. Under the same amount of electricity, the electric energy is transformed from the whole into the potential energy and kinetic energy of the drone to the partial transformation into the kinetic energy and potential energy of the delivery object, which reduces the battery endurance and limits the maximum distance of distribution [12]. Under the existing technical conditions, the driving system of consumer drones is mainly lithium batteries, with a battery life of about 20 minutes, however, with the increase in the payload capacity of drones, the corresponding decline in the endurance of drones, which greatly limits the distribution distance and categories. For instance, DHL's tests used a small, time-limited drone, the “Paketkopter”, to deliver the drug, but its maximum range was just 3 kilometers. Therefore, short battery life has become one of the shortcomings of drone delivery.

In addition, the second disadvantage of drone delivery technology is that the sensing and avoidance functions are turned off at certain times, resulting in crash accidents. Flying low over the city, Due to the light pollution caused by urban building materials, the thermal circulation between cities and suburbs, and the impact of extreme weather, the environment of drones flying in cities will become complicated and changeable. In addition, it takes a certain amount of time for drone sensors to transmit the surrounding geographic information to the host computer and carry out a series of operations such as algorithm processing and path planning. Therefore, the drone cannot avoid obstacles in time. Identification systems for drones are also often present [13]. At the current technical level, military UAVs and high-end commercial UAVs are widely used in the field of obstacle avoidance, but few manufacturers have been able to implement the technology on a large scale. Therefore, when using ordinary UAV for logistics express delivery, UAV is very vulnerable to external environment interference, and how to automatically sense and avoid obstacles. Although some drones can identify obstacles and activate obstacle avoidance systems, it is difficult to achieve automatic circling and only stop within a few meters. The blind spot problem might be solved by installing a large number of sensors for simultaneous multi-directional identification transmission, However, due to the excessive weight of its own multiple sensors, it will indirectly affect the endurance of the drone, which is not worth the loss.

4.2. Logistics UAV technology application solutions

First, the payload capacity of the UAV can be improved by changing the design of the fuselage, such as changing the fuselage material, fuselage constraints to increase the UAV's glide ability and optimizing the fuselage impact point. Because the motor, electronic equipment and load are the main source of fuselage load. Therefore, we can not only improve the airflow sensing system, but also add a seven-hole probe structure [14]. The length of the seven-hole probe is 125 mm, the diameter is 4.6 mm, and the head taper is 30°. When the angle between the direction of gas flow and the axis of the UAV probe is too large, the flow separation phenomenon will occur. The suitable common force point can also be found to optimize the mass distribution position of the sensor and the camera [15]. The result of the strength of the fuselage parts of the four-rotor UAV after the lightweight design is that the maximum displacement is 0.785 1 mm, the minimum safety factor is 3.0, and the maximum rice effect is 15.02 MPa. The total mass of the four-rotor UAV fuselage components before

optimization is 66.158g, and after lightweight design, the total mass is 31.398g. The design space mass of the fuselage parts of the four-rotor UAV before optimization is 48.391 g (material ABS), and the design space mass after lightweight design is 13.630 4 g, achieving a 71.8% weight reduction.

Second, the RRT algorithm can be improved to solve the problem of unmanned performance [16]. The objective bias optimization strategy based on probability is introduced. Expand the sampling points in the direction of the replanning target point with a certain probability. In the smoothness optimization strategy, the redundant points in the initial track are selectively removed and the performance constraints of UAV are taken into account.

Thirdly, the correct and proper flight path of UAV is planned by optimizing the algorithm design of internal environment. For example, based on the HPSO algorithm framework, VND is combined to enhance local optimization ability, and the improved A algorithm is added for obstacle avoidance processing, so as to save the path planning problem of the logistics UAV group when facing obstacles, so as to avoid the collision of the UAV or the collision with the building.

5. Conclusion

The principles of logistics UAV systems can be summarized as follows: Safety principle: UAV logistics must ensure safety during operation and avoid collision with other aircraft or obstacles. Efficiency Principle: the design and operation of logistics UAV system should aim at improving logistics efficiency. Environmental principles: UAV logistics should minimize the impact on the environment, the use of environmental materials and clean energy, reduce carbon emissions, to achieve green logistics. Adaptability principle: the UAV system should have strong adaptability, can adapt to various complex environment and different scenarios of the logistics needs. Through the adjustment of routes, replacement of equipment and other ways to achieve a flexible response to various logistics needs. These principles together constitute the basic framework and operational criteria of UAV logistics system and provide a strong guarantee for the rapid development of UAV Logistics.

In this paper, the challenges of the current UAV, such as short battery life, low ability of sensing and obstacle avoidance, are analyzed. In the future, the payload capability of UAVs can be improved by changing the design of the fuselage, such as changing the fuselage material, fuselage constraints, improving the glide capability of UAVs and optimizing the impact point of the fuselage, based on the framework of HPSO algorithm, an improved algorithm is added to avoid collision between UAV and buildings.

Authors contribution

All the authors contributed equally and their nameswere listed in alphabetical order.

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