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Research on relevant contents of carrier design based on unmanned aerial vehicle

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Abstract: With the increasing popularity of online shopping, e-commerce has become a time-saving and labour-saving way to shop for people. Consequently, the express industry has emerged as an indispensable part of the supply chain. However, due to the shortage of human resources, express delivery services often face the challenge of overstocked delivery stations, leading to decreased efficiency in the traditional delivery mode. To address this problem, the development of a drone delivery mode that can cooperate with unmanned vehicles has been proposed. In the context of express delivery, key technologies that need to be resolved are elaborated, including UAV material structure, sensors, visual positioning and navigation technology, and path planning. By addressing these issues, this study aims to provide insights into the research and development of unmanned distribution and logistics industries. Furthermore, this study highlights existing problems and proposes solutions for the combined distribution of unmanned aerial and unmanned ground vehicles. The combination of these two modes of delivery presents both opportunities and challenges, which this study aims to identify and address. Ultimately, the findings and recommendations presented in this study contribute to the efficient and effective operation of the express delivery industry in the era of e-commerce.

Keywords: UAV logistics, intelligence, terminal delivery.

1. Introduction

Despite the relatively well-developed management system in the traditional distribution industry, there are still some persistent issues. For instance, delivery personnel must first confirm the delivery address and then select the optimal path accordingly. However, uncertainties can often affect the efficiency of the entire process [1]. According to China's 2023 National Conference on Postal Administration report, approximately 110.58 billion express deliveries were completed in 2022. The last stage of delivery is particularly challenging in rural areas. In comparison to urban areas, the economy and infrastructure development in rural areas are usually less advanced. As a result, express stations are less frequently distributed in these areas. Furthermore, due to the complex terrain, remote mountainous regions, in particular, present significant challenges for delivery personnel. Slow delivery efficiency and high labour costs are common problems encountered in these areas. This issue remains an unexplored market opportunity for profit-oriented express delivery companies, many of which do not even offer delivery services in remote rural areas. In the future, it is the general direction of development that the basic and repetitive distribution work should be completed by robots. Intelligent distribution reduces the distribution cost and operation time and improves distribution efficiency by changing the distribution form and optimizing the distribution route in the logistics process. The UAV is designed as a logistics terminal to cooperate with unmanned vehicles. Unmanned vehicles are regarded as small mobile warehouses, which can solve the problem of the small carrying capacity of the unmanned vehicle, to realize a large batch of transportation and improve the efficiency of distribution. Drones are seen as logistics terminals for the last kilometer of delivery. UAVs can deliver goods to Windows, allowing people to get them without leaving their homes. Repetitive and mechanical tasks such as going up and down stairs could be replaced by drones. This is especially true in rural areas, where drones can fly directly over difficult terrain areas, thus improving delivery efficiency and reducing labor costs. Now the model of unmanned vehicle distribution has been relatively mature, but there is no such project for the delivery of UAVs, the focus of the project will be on the realization of unmanned delivery.

The aim of this project is to compare various emerging technologies, including AI, 3D printing, and sensors, and select the corresponding techniques to optimize the software and hardware of existing drones. The use of 3D printing and new materials can effectively reduce the weight of the drone's fuselage. By decreasing the self-weight, the drone can carry more weight with the same force.AI is currently a hot topic in research and development, and it has significant advantages in intelligent path planning. The use of AI in combination with the values obtained from sensors can help the AI to make intelligent decisions. As such, by adopting a comprehensive approach that integrates these advanced technologies, we aim to optimize the performance of existing drones and develop more efficient and reliable drone delivery solutions. Overall, the findings of this study will provide valuable insights into the optimization and innovation of unmanned aerial vehicles and their associated technologies.

2. Current research status of key technologies

2.1. 3D printing

Compared with traditional technology, 3D printing technology has a higher utilization rate of materials, can make models faster, and can easily make parts with complex structures. Many advantages make it a new trend in manufacturing applications.

Now there are three main 3D printing technologies on the market: vat photopolymerization, material extrusion, and powder bed fusion. Each of them has both pros and cons, and their selection will be described in detail later. As for the materials used for printing, at present, the main types of 3D printing materials are plastic, liquid resin, and metal powder. On August 1, 2011, the world's first "printed" UAV SULSA came out, marking the arrival of the era of UAV 3D printing [2].In 2014, the British Air Robotics Laboratory (Aerial Robot ics Lab) unveiled a propeller drone at Imperial College in London, Its frame is printed by a 3D printer [3]. As shown in Figures 1-2.

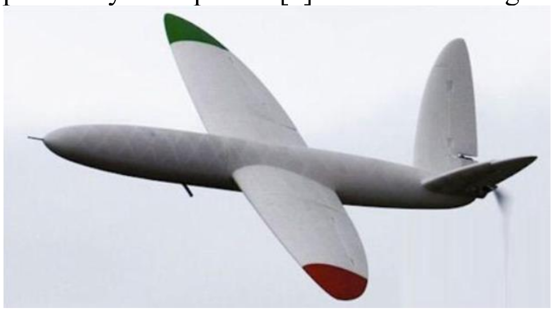

Figure 1. SULSA unmanned aerial.

Figure 2. Spike drone.

2.2. Sensors

2.2.1. Ultrasonic obstacle avoidance sensor. Obstacle avoidance technology is a key technology of robot motion control. At present, the common obstacle avoidance sensors mainly include visual sensors, laser sensors, infrared sensors, ultrasonic sensors, etc. Compared with other types of obstacle avoidance sensors, ultrasonic obstacle avoidance sensor has high sensitivity and penetration, which makes it easier to detect deep objects from the outside. Moreover, unlike sensors that rely on light sources or cameras, they can be used at night and in dark environments. It detects the movement and distance of the object by calculating the time of the relevant object to reflect the ultrasonic wave. In this way, the delivery of UAVs can continue no matter the day or night. Additionally, this sensor has a higher measurement accuracy than other sensors. Because object color or transparency does not affect the measurement, its resolution to obstacles is high.

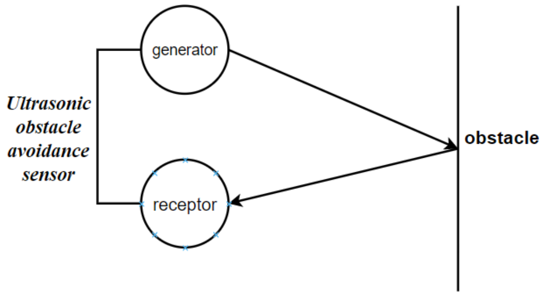

Figure 3. A Schematic diagram.

Figure 4. Ultrasonic obstacle avoidance sensor.

2.2.2. Force sensor. The force sensor is a device that converts the magnitude of force into relevant electrical signals. The resistance strain gauge sensor is the most widely used in high-precision force sensors. It converts the non-electrical signal to the electrical signal through the change of the electrical parameters to achieve the purpose of measuring the non-electrical quantity. Because of its advantages of high measurement accuracy, small environmental impact, and good stability, it is very suitable for force measurement and force control at robot joints [3]. Compared with other force sensors, the resistance strain sensor has high accuracy, a large measuring range, and good frequency response characteristics. The strain gauge is small in size, light in weight, convenient in use, and fast in measurement. The measurement has no effect on the Antai and stress distribution of the tested working group. It can be used for both static and dynamic measurements. And this strain gauge has strong adaptability. It can be used in harsh environments such as high temperature, ultra-low temperature, underwater, strong magnetic field, and nuclear radiation. As shown in Figure 3 and 4. The strain measurement has high sensitivity and accuracy, stable and reliable performance, and the error is less than 1%. Moreover, it is cheap, with many varieties and mature technology.

2.3. AI principle

Path planning refers to selecting the optimal path from all possible paths given the starting point and target point within the specified area so that the intelligent machine can avoid obstacles and reach the target point in the shortest time. Based on its huge computational amount and complex path modelling analysis, AI has become an important auxiliary tool to help humans make decisions in path planning.

According to different known environmental information, path planning is divided into global path planning and local path planning [5]. Compared with local planning, global path planning needs to master all environmental information and plan according to the known information [6]. At present, the commonly used global planning methods include Dijkstra, A*, D *, and other classic algorithms, as well as intelligent algorithms such as the ant colony algorithm and genetic algorithm. Dijkstra and A * algorithms are more suitable for solving static maps. In the dynamic map, the UAVs need to keep trying, which may cause the problems of a huge amount of computation, high time complexity, and no solution. The traditional ant colony algorithm is prone to fall into the local optimal solution.

Local planning is to determine the location of the map according to the current real-time environmental information collected by sensors. In addition, the method of planning the optimal path from the current node to the next target sub-node can be calculated based on the map information and the distribution of local obstacles. The commonly used methods include the dynamic window method (DWA) and artificial potential field algorithm.

3. Methodology

3.1. 3D printing

3.1.1. Technical selection. Use the Powder bed fusion method to make all parts and connectors. The reason for choosing this method is: 1) It can shape parts with complex shapes, which cannot be achieved by other methods. 2) It is very suitable to use metal materials (such as stainless steel). 3) Structural strength can be obtained with fewer materials and lighter weight. Material extrusion is used to produce a protective shell. Plastic can be used in this method and is very easy to obtain. Although the precision of the final model is limited to the thickness of the material nozzle. However, the accuracy is sufficient to ensure that the protective enclosure can be installed on the internal structure.

3.1.2. Material selection. The UAV frame is made of carbon fibre, which is a strong and durable material. Carbon fibre has extremely high strength, is extremely lightweight, and has good corrosion resistance. This part is produced by the traditional manufacturing industry instead of 3D printing. It is because carbon fibre material has not joined the ranks of 3D printing at present. There is no mature technology for the use of continuous carbon fibre-reinforced composites [7]. Some other components of the UAV are produced by the 3D printer, and the printed parts are integrally formed, which greatly improves production efficiency and is durable. Stainless steel shall be used for important connections. It is necessary to ensure that they will not be rusted due to wetting in bad weather such as rain. In addition, it also needs to have high hardness and strength to ensure that it will not have too much wear after a long time of work. And through consulting the literature, stainless steel parts are indeed used in UAVs [8], The weight of stainless steel does not have a significant impact on the whole structure.

Other parts are made of plastic materials such as ABS-CF10 and PLA. PLA has good tensile strength, a high stiffness ratio, a low melting point, and a low thermal deformation temperature (HDT). It consumes less heat and electricity when printing parts and can generate an economic design in a short time. In addition, PLA can maintain a good state under high-speed operation, not only printing speed is super-fast, but also the quality of printed products is stable, and suitable for mass production. ABS-CF10 is an engineering thermoplastic. It not only has the mechanical properties and ease of use of ABS but also combines the advantages of carbon fiber material. Its performance is stronger than ordinary ABS material. In addition, combined with soluble support, ABS-CF10 can make many complex geometric shapes that cannot be machined.

3.1.3. Design specifications. First of all, the modeling of the part should be reviewed. Every detail in the STL file will be checked to ensure the feasibility of printing, and then import the file into the printer to set the appropriate parameters. Secondly, using the electron microscope to observe the shape of the material powder particles to ensure the quality of the powder, which involves the image recognition technology of AI. After the parts are manufactured, it is also important to measure the surface roughness of the parts to ensure the correct assembly and consistent fit of multiple parts.

3.2. Sensors

3.2.1. Ultrasonic obstacle avoidance sensor. Due to the complex and changeable traffic environment and numerous obstacles, the delivery of UAVs has increased a lot of difficulties. In this paper, an ultrasonic obstacle avoidance sensor is used to provide a new implementation scheme for UAVs avoidance function and path selection. The main reasons for choosing an ultrasonic sensor are: Ultrasonic sensors can reliably detect dark environments without light. The production of this technology provides great security for the delivery of UAVs.

The principle of ultrasonic distance measurement is: to obtain the distance between the obstacle and its own through ultrasonic distance measurement and to determine the general orientation and distance of the target. A drone delivery robot measures ultrasonic flight time at work. Because the speed of the ultrasonic wave in the air is related to temperature and humidity, the change in temperature and humidity and other factors should be taken into account in a more accurate measurement. The ultrasonic generator T sends out an ultrasonic signal at a certain time, which is reflected after encountering the measured object and received by the ultrasonic receiver R. In this way, as long as the acoustic and optical signals obtained from the ultrasonic signals and sensors are calculated and collected, and analyzed, on the one hand, they can be provided to the management personnel in the form of diagrams and tables to provide an accurate basis for the management personnel to make appropriate decisions, on the other hand, they can also make decisions automatically according to the control requirements, and send the decision instructions to IoT through the communication network [9].

3.2.2. Force sensor. In this project, the UAV cargo robot senses and stores objects in the cargo box through the force sensor in the mechanical arm, breaking the traditional stage of semi-intelligent distribution.

In the verification system of the perceptive robot, the perceptive robot's perception of the environment depends on the accurate measurement of the sensor. The space manipulator can obtain the force information in the object and the environment through the force sensor and detect or sense the force signal of the interaction between the robot and the environment for a certain task. After the operation management system sends instructions to the manipulator, verifies the force information received by the system, and then calculates the various characteristics of the environment, including the relative position, shape, size, etc. of the target. According to the force feedback information obtained from the multi-dimensional force sensor and calculated, the operator in interactive teleoperation can use the hand controller to accurately operate the manipulator at the teleoperation end and complete the task. At the same time, a three-dimensional model of the grasping device is established to add the corresponding environmental parameters. Through many simulation experiments, the force needed to grasp the corresponding weight object can be predicted through deep learning. In addition to grasping the objects, it can also avoid damage to the goods caused by excessive force.

3.3. Analysis of deep learning algorithms

3.3.1. Autonomous positioning technology. The same important positioning technology is needed for path planning. A drone can plan a path only if it knows where it is. To solve this problem, dense modeling using slim becomes an essential part. Current slim technologies are diverse and can be divided into laser slim and visual slim. Laser lam is using lidar to collect surrounding data, which has the advantage of high stability. However, it will be much more expensive than a visual slam. Moreover, the field of autonomous driving is more inclined to use 3D SLAM modelling technology.

The 3D slam technology is selected for the autonomous positioning of drones, which requires a binocular camera. By analyzing the image information collected by the camera, analyzing the relationship between each frame of the image can solve the location of the UAV. The ORB-SLAM3 algorithm provides the storage and splicing of Altas multi-maps, which can try to match and integrate existing maps and historical maps, and timely update current active maps [10].

3.3.2. Path planning technology. In the path planning of UAVs, using D * Lite algorithm. D * algorithm is an improvement on the A * algorithm. Although it is also a heuristic search method, unlike A *, it uses reverse search, so it is more suitable for dynamic planning problems [11]. The D * Lite algorithm is proposed on the basis of LPA *and is an efficient version of the D * algorithm. It is a heuristic algorithm based on graph search, which can realize two-way dynamic search in the location environment without searching and re-planning a large number of nodes [12], which can effectively save time.

4. Future development prospects and difficulties analysis

Delivery drones require high performance and intelligence, and all the parts of the aircraft must be strong enough to withstand bad weather and the weight of the cargo. Harder stainless steel is used at key

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connections, and the overall structure is a carbon drill to cope with traditional weather such as rain. However, in extreme weather conditions, such as strong winds and heavy rain, the light weight of the drones can disrupt their flight. In terms of intelligent path planning, the planning problem of a single UAV has been relatively mature. However, the accuracy and efficiency of the algorithm are still insufficient, and at the same time, it is necessary to realize the terminal distribution, so the planning problem of multi-UAV needs to be considered. This requires further consideration of UAV assignment, complex constraints between UAVs, and common optimization target in a single unmanned planning problem [13]. Therefore, scholars from all sides should systematically and reasonably plan the path planning of UAVs by combining the development status and the task allocation of UAV.

In view of the fact that there is no delivery UAV for real life, the current regulatory policy for UAV is not clear, and the corresponding laws and regulations are not perfect. The autonomous flight of UAV needs to be approved by the Civil Aviation Administration and other national administrative organs. At the same time, as an ultra-low altitude flying aircraft carrying cameras, the UAV needs to accept strict management and monitoring during its operation. Its flight area will be limited by high-rise buildings, sensitive facilities. Therefore, it is necessary to establish a regulatory system in low-altitude areas through coordination and cooperation between governments and enterprises, so that the flight of UAV can be under the condition of transparent and open conditions. At the same time, a one-stop approval platform for UAV distribution will be established to speed up the approval process and improve the approval efficiency.

5. Conclusion

This study aims to develop a method for constructing lightweight and sturdy UAVs using the powder bed fusion method and material extrusion method. Carbon fibre, stainless steel, and plastic are selected as the primary materials, which can increase endurance and make these UAVs suitable for use in remote areas and harsh environments. To enable AI path planning, this study adopts two algorithms, including the Lam algorithm and D* Lite algorithm. These algorithms are used to create real-time maps and locate UAVs. To achieve high-precision obstacle avoidance and object grabbing, an ultrasonic obstacle avoidance sensor and a resistance strain sensor are combined. The project aims to establish a complete and efficient Internet of Things system by combining 3D printing, sensing, and AI to solve current issues within UAV express. The integration and mutual operation of 3D printing, artificial intelligence, and sensors will bring significant innovation and change to people's lives. Although the project has shown great potential, there are still challenges that need to be addressed. For example, the carbon fibre skeleton and plastic shell may result in poor connections between parts, eventually impacting the overall structure’s stability. Additionally, the impedance mismatch between the two sensors may result in data overrun and fault reporting, thus affecting the accuracy of the obstacle avoidance function. Furthermore, while the study has achieved real-time mapping and flight path planning through AI, further technical support is required in other aspects of AI. Overall, the integration of these three advanced technologies poses challenges to the implementation, and further research is needed to address these issues.

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