Design of a relief materials delivery system based on UAV

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Abstract. The quality and efficiency of traditional rescue work are seriously affected by the destruction of roads and road traffic. In view of these existing problems, the current work investigates the delivery of relief materials using an unmanned aerial vehicle (UAV). At present, studies investigating the delivery of emergency relief materials are few, the technology is not mature, the disadvantage is bigger. In this paper, the UAV material delivery system can realize the function of automatic navigation and automatic delivery of materials. The experimental results show that, in a large number of delivery tests, 97% of deliveries contained a delivery error within 4 m, 64% of deliveries contained a delivery error within 2 m. The average delivery error was 1.86 m. The results of the experiment show that the accuracy of the UAV material delivery system is high, and the test results can provide reference for the further study of the robot.

1. Introduction

Naturally-occurring disasters, such as earthquakes, floods and mudslides, are unavoidable, causing great loss to people and threatening their livelihood and safety. In the face of these emergencies, those in danger often require emergency supplies (water, food, medicine, etc.). However, the emergencies often result in the destruction of roads and traffic jams, slowing the arrival time of rescue teams and seriously affecting the quality of any relief effort. Emergency supplies struggle to reach the scene quickly, such that they are unable to guarantee the safety of victims. In recent decades, UAV has developed rapidly, tending to be associated with military applications. In recent years however, the rapid rise of civilian unmanned aerial vehicles (UAVs) has had a great impact on a number of fields, including communications, agriculture, environmental protection and the film and television industry[1-4]. At present, UAV is developing into a technology for use in logistics transportation, by companies including UPS[5] and Amazon[6], some of whom have already registered the relevant patents. After two years of clandestine research and development of its UAV program, Google has conducted a public demonstration in Australia of the use of UAV in the delivery of relief materials[7]. The application of UAVs to rescue work can solve the problems associated with traditional methods. Moreover, the new approach can greatly improve the efficiency of rescue efforts and better ensure the safety of the lives of the victims.

There are few studies on the use of UAV for the delivery of emergency relief materials, and they have not been popularized in the fields. Recently, the large heavy-duty (up to 1.2 ton) unmanned aerial vehicle developed by SF-express was demonstrated. The UAV achieves unmanned autonomous control, can automatically plan routes, take off and land at the press of a button, and has the ability to...
provide emergency treatment autonomously. In the case of a major natural disaster, the UAV can be used to deliver medicine and emergency supplies[8]. In addition, Seguin C et al. proposed UAV for the safe and timely delivery of flotation devices to swimmers, improving the quality and speed of first aid and keeping lifeguards away from the dangerous maritime environment[9]. Zipline's autonomous fixed-wing UAV has now become part of the medical supply infrastructure in Rwanda, transporting blood products from central distribution centres to hospitals across the country, helping to address the challenging issue of rural healthcare[10].

The speed quality of traditional ground rescue work are inherently limited. Nonetheless, studies investigating the use of UAV for the delivery of emergency relief materials are few. Hence, the aim of this paper is to design the hardware and software systems of a UAV, to be used as a relief delivery system in the case of emergency events. The software system is used to obtain the real-time position and delivery request sent by the client, while the hardware system performs automatic navigation and delivery. In order to analyze the novel UAV delivery system, experimental tests are carried out to investigate whether the system can realize automatic fixed-point delivery with the desired accuracy. Hence, the content of this research paper will provide reference for the future application of UAV in rescue work.

2. Embedded hardware system

2.1. Design of mechanical delivery device

The mechanical delivery device, shown in figure 1, is a key component of the UAV delivery system. The frame of the delivery device is built from PMMA material and provides support for the battery, motor, motor drive, embedded system, global positioning system (GPS) module, ESP8266 Wi-Fi module and SIM900A communication module. The delivery device contains six storage compartments, which can carry 5 kg of emergency rescue materials. Six independent deliveries to multiple target locations can be carried out during each mission. A hardware module storage bin, used to store hardware modules such as the Micro Control Unit (MCU), is located at the center of the delivery device. In this way, ensures the safety of the UAV delivery system.

(a) Front view
1-2. Signal amplifier 3. Storage space of battery 4. The supplies warehouse 5. The hardware warehouse 6. Motor 7. Fixed plate 8. Hinges 9. Door slot 10. Shaft

(b) Vertical view

Figure 1. Structure diagram of delivery device.

The delivery device is designed to contain six storage compartments for emergency rescue materials, each with a corresponding delivery control door slot. The door slot width is 5mm. The structure of the rotating shaft is a cuboid, as shown in figure 2, with a cross-sectional area of 3x8 mm². Before delivery, the axis of the rotating shaft in 0° Angle. That is to say, the 8mm part of the rotating shaft is relative to the door slot, and the conveyor cabin is closed. During delivery, the control motor rotates 90°. The 3mm part of the rotating shaft is relative to the door slot. At this point the hatch opens to deliver supplies to the customer. This is the operating principle of material delivery system.

Figure 2. Structure of rotating shaft.
2.2. Hardware circuit
The hardware circuit includes the main control system, including a high-performance MCU based on the ARM cortex-m3 kernel by ST. This has the advantages of high performance, low cost, low power consumption and powerful software support. The GPS module contains a u-blox neo-7n chip - with high sensitivity, low power consumption, small footprint and extremely high tracking sensitivity - greatly expanding coverage and achieving high positioning precision in the narrow urban sky and dense jungle environment. The ESP8266 Wi-Fi communication module is equipped with an ultra-low-power Tensilica L106 32-bit RISC processor, and the CPU clock speed can reach up to 160 MHz. It has the advantages of low power consumption, high integration and stable performance. The SIM900A is a two-frequency GSM/GPRS module that is an SMT package. It has stable performance, small size and low cost advantage.

The MCU of the hardware circuit connects with the GPS, Wi-Fi and SIM900A modules through the USART interface and implements the data transmission and positioning functions. When the MCU receives a delivery instruction, it will deliver a PWM signal to the L298 drive. The drive motor will then rotate 90°, delivering the relief materials at the target location.

3. System framework and algorithm design
3.1. System framework
The delivery system is composed of the hardware and software systems. Through computer and Internet of Things (IoT) technology, data transmission between these systems is achieved, such that the software system can control the hardware system. The client, the administrator control center and the embedded hardware system communicate with each other through the public cloud platform. The client sends a delivery request and geographic location to the public cloud platform. The administrator control center obtains the user information from the public cloud platform, and issues a delivery instruction to the embedded hardware delivery system through the cloud platform.

A distressed person in need of relief supplies sends a delivery request and geographic location to the control center through the client application, as shown in figure 3. When the administrator control center receives the information, it automatically sends the UAV delivery robot, equipped with rescue supplies, to the target location. By delivering the necessary goods and medicine quickly, the safety of the distressed person is ensured. Subsequently, the robot moves on to next delivery.

![Figure 3. System framework.](image)

3.2. Algorithm design based on GPS threshold
The biggest distance for a delivery to occur is defined as $l_i$. When the UAV delivery robot flies to the center of the site, $l_i$ is the radius of the circle, within which, the robot will deliver the relief materials. The real-time displacement of the delivery robot from the delivery destination is $l$. When the following conditions are met, the delivery robot will deliver the rescue materials:

$$l < l_i$$  \(1\)

As shown in figure 4, the initial position of the UAV delivery system is $A(J_o, W_o)$. The position of the materials requested by the person in danger is $B(J_p, W_p)$. The origin $O$ (0, 0) is positioned at the center of the earth. By using the trigonometric theorem, the distance from the drone to the delivery locate is $l$. 

3
4. Test results and analysis

4.1. Mechanical delivery tests

100 delivery tests were carried out on the 6 storage compartments of the mechanical delivery device. The test results show in figure 5, that the delivery success rate of each storage compartment is above 95%. Thus, the mechanical and structural design of the delivery device achieves the desired results successfully.

![Validation test](image)

**Figure 5.** Validation test.

4.2. Delivery accuracy tests

An experiment is designed in order to verify the delivery accuracy of the UAV delivery robot. As shown in figure 6, the target delivery points are set at A, B and C ($L_{AB}=L_{AC}=L_{BC}$). R is the delivery tolerance error value. The starting point of the UAV is located in the center of the three target delivery points, to investigate its autonomous navigation and relief material delivery performance. The relevant parameters of the accuracy test are shown in table 1.

| Parameters | $R$ | $L_{AB}$ | Number of groups | Number of targets |
|------------|-----|----------|------------------|------------------|
| Value      | 2-8 m | 30 m     | 10               | 3                |

![Table 1](image)

**Table 1.** Accuracy test parameters.

![Figure 6](image)

**Figure 6.** Precision test analysis.

The results of the delivery accuracy test are shown in figure 6(a). When $R=5-7$ m, the delivery success rate of the UAV delivery robot reaches 100%. With $R<5$ m, the delivery success rate gradually decreases. The mean error of the delivery is $R$, at different values is shown in figure 6(b). When $R=5$ m, the mean error of the delivery is 1.86 m. Figure 6(c) shows the proportion of the delivery error range...
when $R=5$ m. The proportion with a delivery error less than 3 m is 94% and the proportion with a delivery error less than 4 m is 97%. When $R=5$ m, the delivery success rate of the UAV is the highest and the delivery error range is smallest. Therefore, the allowable delivery error of the delivery robot should be set at 5 m, where the deliveries are the most accurate.

4.3. Verification of UAV delivery robot
The UAV delivery robot is based on the Four-axis drone, as shown in figure 7, and delivers a payload up to 5 kg. During a mission, the robot can carry out six independent deliveries to multiple locations, carrying a diverse array of delivery materials and emergency relief supplies.

![Figure 7. Delivery robot.](image)

The software of the delivery system, based on Internet of Things technology, is divided into client and administrator control center applications. The client application has functions such as login, registration, localization and material request. When someone is in distress, the user can send a material delivery request command through the client to the control center with the real-time geographic location of the victim. The control center can display the client's request and position, and send the target position to the UAV delivery system, such that it can automatically move to the destination and provide emergency relief materials to the victims.

5. Conclusion
In this paper, an emergency relief material delivery robot is designed based on UAV technology. The mechanical structure is designed and establishes the relevant mathematic model and automatic delivery algorithm, and carries on the precision test of the delivery robot. The delivery success rate of the six storage compartments of the mechanical delivery device was found to reach more than 96%, with most of the storage compartments near 100%. When $R<5$ m, the allowable error $R$ decreases, the success rate of automatic delivery of the delivery robot decreases, and the actual delivery error increases slightly. $R$ increases the delivery success rate to 100%, but the error of delivery will be greater. The delivery accuracy tests investigated the most suitable parameters for the delivery robot. When the delivery tolerance error is $R=5$ m, the delivery success rate of the delivery robot is 100%. The actual average delivery error is 1.86 m, where the vast majority of the actual delivery errors are within 2 m.

Although the experimental results of the UAV delivery robot studied in this paper are satisfactory, further research is required to investigate the optimal delivery parameters and achieve more accurate deliveries.

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