

# The analysis of UAV application in forest fire prevention

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**Abstract** This paper illustrated the types and system compositions of UAV used in forest fire prevention, and the effectiveness of UAV on carrying out forest ground-cover fuel survey, forest patrolling, wild fire source management, fire monitoring and reconnaissance, post-fire survey and assessment. This paper provides the insight into application of the different type of UAV for forest fire prevention and control and new requirements.

**Keywords** UAV · Forest fire protection · Application

## Introduction

Forest is an ecosystem of openness, so the forest fire as a natural disaster often has the characteristics of sudden

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strong, great damage, and extremely difficult on disposition (Hu 2005). Guangdong is the mountainous province in the southern China, and is also a prone area of the forest fire. The forests in the area is mainly distributed in complicated terrain, steep mountainous and hilly land, which have the lush grass-shrub, rich vegetation, and significant forest combustible load (Wang et al. 2015).

The Unmanned Aerial Vehicle (UAV) is an aircraft with remote control navigation. Through the airborne equipment and systems, the UAV can achieve the long-range reconnaissance in the relevant region, and can provide the surveillance and reconnaissance methods of easy operation, safety in use, and wide application. For the forest fire prevention with poor traffic conditions and high-risk, the UAV provide a valuable approach to the forest combustible materials investigation, the field fire monitoring, the forest fire patrol, the coordination of forest fire suppression, and the post-disaster assessments (Cui et al. 2014; Ren 2015; Li et al. 2015). This paper analyzes the use of the UAV in forest fire prevention and provide insight into application direction in the future.

## UAV type and its system components

The common UAV in forestry applications include fixed-wing UAV and multi-rotorcraft UAV, which consists of airframe, flight control systems, camera systems, data transmission systems, power systems, etc., and the

fixed-wing UAV also has a launch and recovery system. The flight control system is mainly responsible for UAV flight planning and controlling; the camera system is designed for shooting related images and videos from high altitude; the data transmission system transfers telecommand and the real-time image data between control and aircraft; the power supply system adopt the high energy battery and electrical machinery, and the others use chemical engine; the launch and recovery system ensure the UAV lift-off to achieve safety height and flight speed, and safely landing on the ground after performing the mission. The payload of UAV is equipped according to the requirement of use, and it usually contains a variety of imaging devices and sensors for reconnaissance. Besides, others need to equip the forest fire-fighting equipment and pest control equipment. At present, with the development and improvement of technology, UAV is of a potential wide application (Xia 2015; Chen et al. 2015; Li et al. 2015).

### UAV application in forest fire prevention

The UAV applications in forest fire prevention are mainly focused on the investigation of fire situation, real-time exploration and burned forest. The UAV system is used in the forest fire prevention due to the characteristics of excellent battery life, convent operation, real-time image transmission, flexible, functional diversity, quick emergency response, high ability of real-time inspection, etc., (Li 2015). UAV presents the advantages in the forest fire patrol and the reconnaissance of forest fire suppression.

### Forest patrol and wild fire source management

UAV is more flexible than aircraft, which obtains the large-scale information about forests. At the same time, it has advantage of safety, low cost, easy operation, and easy maintenance, etc. Compared with the ground inspection, UAV has unique advantages in monitoring areas, especially in those inaccessible areas to people and vehicles. The UAV carries the thermographic camera, HD mist camera, global positioning system(GPS), HD digital image processing and transmission technology to constitute the fire monitoring system. Therefore, UAV is suitable for conducting the air patrol according to the

scheduled course to transmit the acquired image data to the command center. In the process of video image capture in the forest near the monitoring base-station, the UAV can realize the monitoring from the angle of 360° horizontally and 120° vertically. The system can automatically locate the fire to achieve the intelligent recognition on fire, and can also be applied to change the flight path of UAV through remote control to focus on the key area and suspicious fire.

The application of UAV can highly improve the monitoring and management level of forest fire, greatly reducing the workload of forest ranger, improving the work efficiency of forest-warden, enhancing the accuracy of forest fire report, providing the precious time on the forest fire fighting. In recent years, the forest ranger and forest fire brigade in Shenzhen city and Zhuhai city of Guangdong province have all equipped with the Multi-rotorcraft UAV, and the UAV has played an important role in inspection and monitoring of the forest-warden and the field fire (Fig. 1).



**Fig. 1** UAV Image from Dapeng new district, Shenzhen district, China

### Fire monitoring and reconnaissance

After the forest fire, the surroundings will become more complex, the smoke produced by burning under the variable wind directions will lead to extremely low visibility. Through the UAV shooting on fire situation for continuous observation, ground personnel can receive the UAV data and decode the fire scene image data. These real-time image data can be transferred to the command

staff through a network and the front-line headquarters, so that the fire command department can quickly and effectively organize the deployment of fire brigades, improving the efficiency of firefighting and reducing the number of fire casualties. Through the UAV's aerial survey of the fire extinguished area, and the thermal infrared imager finding dying fire in time, the prevention of fire reburning can be achieved by the effective alarm. In addition, UAV combines with HD video, sensors, and other monitoring methods, so it can provide real-time monitoring of the fire status, providing the bases for firefighting decision-making, to eliminate forest fires in the initial stage (Zhou et al. 2012; Li et al. 2015).

On March 31, 2011, the UAV was used to monitor the forest fire (About 113 hm<sup>2</sup>) in Zhukeng village, Renhua county, Shaoguan city, Guangdong province, China. In the monitoring process, the real-time image data filmed by UAV could reflect the occurrence of forest fire, the fire intensity during its development, the fire spread direction and the firing area intuitively. Combined with the survey data of mountain environment, combustible, and meteorological factors on the surface, it provided assistant decision for the firefighting plan, and provided strong technical support for the post-disaster assessment (Fig. 2).



**Fig.2** UAV Image of fire sense in Zhukeng village, Renhua county, Shaoguan city, Guangdong province, China

### Investigation and Assessment of post-disaster

The SUAV (Small Unmanned Aerial Vehicle) has the advantages of portability and convenience, easy operation, well-adapted function, reducing the field workload, and improving the work efficiency and accuracy. In the post-disaster investigation, the aerial images can be used to determine the terrain and surface features, location,

and the size of the fire. The pictures not only present the fire boundary clearly and the location of the affected stand edge, etc., but also directly reflect the extent of the damage to the standing forest after the disaster. Combined with the forest GIS and GPS, the ground crew can accurately determine the affected area by forest fire, the extent of damage, and provide the technical support for the post-disaster assessment of forest fire. Through the image data recorded by the UAV and the characteristics of combustible residue in the fire, the spreading direction of forest fire and the initial ignition point can be analyzed, which help the investigation of forest fire cases. Since 2014, the PHANTOM-2 UAV was applied to a number of the investigation of forest fires in Qingyuan city, Heyuan city, Chaozhou city and other cities. According to the image analysis of the spreading direction of forest fire and the initial ignition point, the commanders can determine the ignition point and the cause of the fire, thus speeding the investigation of the cases (Fig. 3,4).



**Fig.3** UAV Image of burned forest in Chao'an district, Chaozhou city, Guangdong province, China



**Fig.4** UAV Image of burned boundary in Dongyuan county, Heyuan city, Guangdong province, China

### Investigation into forest flammable ground-litter

The UAV also can be used in the investigation about forest flammable ground-litter. For example, the fixed-wing UAV to take the aerial photographs in investigation. The UAV equipped the visible light cameras and multispectral cameras can shoot the investigation area according to the predetermined altitude and scheduled course. Through the software to capture the image of the splicing, correction, and other pre-processing to provide full-wave band, multi-spectral, and sub-band image data, and then these data will be analyzed by the vegetation index operation. The UAV was carried out to determine the forestland type, standing forest composition, tree height, diameter at breast height (DBH), canopy density, and so on, and it is possible to investigate the type, composition, and capacity of flammable ground-litter in forest. By means of field investigation data to verify the data model of forest flammable ground-litter, which was created by the UAV images, it is used to determine the forest flammable ground-litter under different forestland types and varieties of trees.

On December 28, 2015, the AS-2 fixed-wing UAV was used to investigate the mountain ground (About 1 000 hm<sup>2</sup>) in Chongkou village, Huizhou city, Guangdong province, China. This UAV carries the visible light cameras and multispectral cameras to shoot the survey area at a height of 300 m. During the filming process, it is ensured that the photo course overlaps more than 80%, the side overlaps more than 60%, the flight time of about 90 min, the aerial range of about 1 600 hm<sup>2</sup>, and completed the data collection of the full-wave band, multi-spectral, and sub-band images, and got through the NDVI vegetation index analysis (Fig. 5,6).



**Fig. 5** Path planning of aerial photography in Boluo county, Huizhou city, Guangdong province, China



**Fig. 6** Take-off preparation of the fixed-wing UAV

## Recommendations

### UAV type matching the respondents

UAV, as a new technology, shows the superiority in the forest fire prevention and forest monitoring. The main types of UAV use in forestry fire include fixed-wing UAV and multi-rotorcraft UAV. The monitoring range of fixed-wing UAV is wide, and it can carry a multispectral camera system to shoot the monitoring area according to the programming height and scheduled course. The take-off and landing of the fixed-wing UAV need the ejector rack and a wide area, and the shooting content should be processed by professional software. The fixed-wing UAV needs to be manipulated by professionals with a high level of skill, so that it mainly applied to the investigation of flammable ground-litter in the

forest and burned areas. The fixed-wing UAV is difficult to achieve the ideal effects in on-site monitoring of the general forest fire scene because it cannot carry the fixed-point observation and requires more complex technical support.

The advantages of multi-rotor UAV is convenient for carrying, simple to controlling, and has the lower requirements for take-off and landing conditions. The multi-rotor UAV in practical use can be based on the flight code fly to the coordinate point of shooting and recording, and transmits the real-time image to the ground terminal. The real-time image plays an important role in the management of wild fire source, the organization of forest fire-fighting, and the post-disaster assessment. The disadvantages of multi-rotor UAV cannot be ignored in terms of its poor wind loading rating, susceptibility in a strong flow, narrow range of monitoring, and its poor cruising power. Therefore, the multi-rotor UAV was usually used for the aerial photography in the height below 500 m, and distance within 5 km.

#### **The establishment of UAV professional team**

The application of UAV in forest fire prevention is also limited by many factors. Firstly, the UAV belongs to a new technology, the actual use of pricing is not standardized, and the price is too high, if the large-scale application in the forestry industry will lead to an excessive cost. Secondly, the forest fire belongs to emergency incident, it is necessary to establish a professional team to ensure that the UAV arrives at the emergency scene in the first place. In addition, the government regulations confirmed the flight height and no-fly zones of UAV in China. UAV operation is a professional work, especially for the fixed-wing UAV, which the operator needs to be trained to obtain the qualification for the flying operation, which leads the UAV to promote in the general customer difficultly. Therefore, the government should strengthen the investment in the establishment of UAV professional team to meet the forest customer demand providing the professional guidance for completing the flight mission.

#### **Strengthen the application of UAV in forest fire**

With the development of UAV technology in China, the UAV has been widely used in meteorology, agriculture, forestry, and monitoring field, etc. When the forest fire occurs, the high temperature will cause the small-scale meteorological change which will lead to a great security risk in aircraft flight. However, the UAV, equipped with photographic equipment for fire detection, does not have such a risk factor. Through the UAV image data, the fire commander can find the emergency fire in time then, making a real-time monitoring, taking correct decision-making actions on the fire-fighting timely and effectively.

#### **Conclusion**

Since the first application of UAV to forest fire monitoring in the United States in 2006, UAV has been widely used in the forest fire prevention and control in many countries in the world. However, the application of UAV on the forest fire prevention and control in China started in 2012, and it is still in the early stage. Because of the adverse conditions, the industry scale and technical indicators have not been developed. To better promote the application of UAV, the police and financial support should be ensured at the management level, in addition, the performance, friendly operation, and remote sensing image processing of UAV should be enhanced at the technical level.

UAV can obtain the large-scale forest fire real-time image data at high altitude, which is an effective technique for monitoring forest fires. This technique will have a bright future and potential in the forest-warden and forest fire suppression. With the application of UAV in the forest fire prevention, the monitoring and management level of forest fire control will be greatly improved. Meanwhile, it can be used for protection of forest resources, boosting the development of forestry economy.

## References

- Chen ZY, Gao Y, Chou CL, Wang GB, Xie CX, Xiong DB (2015) Consideration on speeding development and application of forestry UAV in Jiangsu Province. *Journal of Jiangsu Forestry Science and Technology* 42(4): 48-51
- Cui XY, Liu YP (2014) About UAV explore aspects of forest fire monitoring. *Science and Technology & Innovation* 2014(7):128-130
- Hu HQ (2005) *Fire ecology and management*. Beijing: China forestry publishing house
- Li B, Wang HY, Yang XT (2015) Unmanned aerial vehicle(UAV) system in the application and development of forest fire prevention. *Electronic Technology*, 2015(5):15-18
- Li B (2015) UAV: Clairvoyance in forestry industry. *China Forestry Industry*2015 (10): 53-55
- Li XW, Zhou YF, Li XC, Wu ZP, Zeng Y, Hou GS (2015) Intelligent monitoring of forest fires based on internet study on measurement technology. *Guangdong Forestry Science and technology* 31(2): 73-77
- Ren WL (2015) Discussion on application of UAV in forest fire prevention. *Agricultural and Technology* 35 (16): 54-55
- Wang ZS, Zhou YF, Wu ZP, Li XC, Li XW (2015) Investigation and analysis of ground-litters decrement and CO<sub>2</sub> emission during forest fires in Guangdong province. *Journal of Central South University of Forestry & Technology* 35 (9): 93-96
- Xia XF (2015) Discussion on the application of unmanned aerial vehicle into the forest production. *Forestry Science and Technology Information* 47 (2): 40-43
- Zhou YF, Wang ZS, Li XC, Li XW, Wu ZP (2012) Forest fire real-time monitoring technology research with multi-platform. *Guangdong Forestry and Technology* 28(5): 51-56