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# The Mobile Command System of UAV Operation Inspection and Dispatching Oriented to Fusion Multi Sensors

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# The Mobile Command System of UAV Operation Inspection and Dispatching Oriented to Fusion Multi sensors


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***Abstract*—In order to improve the intelligent inspection level of transmission lines and improve the efficiency of inspection work, this paper proposes a mobile command cabin for the operation inspection and scheduling of UAVs based on multi-sensor fusion. The cabin can be equipped with 2 unmanned aerial vehicles for autonomous multi mission flight in formation to achieve comprehensive collection of patrol data and comprehensive perception of operation status. This paper adopts wide area/local area communication technology to realize patrol while walking and take off and landing in different places; 12 bit intelligent charging cabinet is configured to realize remote control addressing charging relay; Configure GPS/RTK dual-mode navigation system, and realize one click defect analysis report generation and intelligent inspection APP approval defect elimination function by using front-end identification+edge computing+back-end identification+deep learning technology. The results show that the application has been implemented in the 253000 km2 operation and maintenance area of a certain place, and 20 1409 km transmission lines and channels have been inspected intelligently, 225 defects have been found and analyzed, and 66 hidden dangers have been eliminated. The operation inspection efficiency is 60% higher than that of manual processing, saving 2200 hours of working time, saving more than 4 million yuan of labor costs, and saving about 300000 yuan of maintenance costs for vehicles, drones and other equipment. Conclusion: The mobile engine room has been used for patrol inspection in a certain place, and the effect is remarkable.**



***Keywords-Fusion multi-sensor; Power transmission line patrol inspection; UAV; Mobile engine room; Off site takeoff and landing; Relay endurance; Multi type diagnosis***


## I. INTRODUCTION

In 2013, State Grid Corporation of China began to promote a new type of transmission line patrol inspection mode that combines manned and unmanned aerial vehicles with manual patrol inspection, thus creating an all-round three-dimensional patrol inspection mode that combines manual ground patrol inspection, manned helicopter patrol inspection and unmanned aerial vehicle patrol inspection, greatly improving the efficiency and efficiency of patrol inspection operations, and ensuring the safe and stable operation of large power grids.

However, a large number of flight practices have found that the existing UAV patrol system is still in its infancy and can only be used in small-scale and small-scale operations. The main reasons are:

(1) Lack of centralized management mode for UAV patrol inspection

There is no unified planning management from the formulation and implementation of patrol tasks to the processing of result data. The patrol personnel, patrol equipment, power transmission equipment and route data are lack of unified maintenance, which cannot support the large-scale application of UAV power transmission line patrol.

(2) Lack of automated resource scheduling process

The objects of UAV patrol mainly include power transmission lines and towers. The patrol work needs to be carried out by inspectors operating UAV and other patrol equipment, which involves the scheduling and planning among the inspected objects, personnel and equipment. On the basis of ensuring that a single inspection task carries complete tools and equipment required for inspection, reasonably dispatch inspection vehicles, unmanned aerial vehicles and inspection personnel, and at the same time, reasonably plan tasks, so as to achieve full coverage of the inspection of transmission lines and poles and towers, and achieve an automated resource scheduling process.

(3) Lack of means for collecting, managing and analyzing the whole process data of UAV patrol inspection

At present, there is a lack of effective management means for the real-time flight data, environmental data of

UAV equipment, transmission line and tower image information obtained from the inspection, and defect data analyzed from the inspection of UAV transmission lines at home and abroad.

(4) No interface with the national grid geographic information positioning system and equipment management system

The existing UAV patrol system cannot obtain the patrol plan from the equipment management system and implement it. The patrol report is fed back to the equipment management system to form a closed-loop defect elimination process. The graphics and model data, map data, meteorological data, etc. of transmission lines cannot be obtained in real time from the grid geographic information positioning platform.

In view of the above problems, the research on centralized management and control technology of UAV patrol inspection has been carried out. The main purpose and significance is to realize the informatization and automatic management and control of the whole process for the key links in the patrol inspection process, improve the safety and efficiency, and improve the economic benefits of UAV patrol inspection [1].

## II. Literature review

Unmanned aerial vehicles (UAV) have broad application prospects in performing civil tasks (such as monitoring and rescue) and military tasks (such as reconnaissance and strike), especially in remote, dangerous or inaccessible working environments. With the increasing demand, scale and complexity of the task, the task scheduling technology of UAV group has become one of the hotspots in the field of UAV research. The task scheduling technology of UAV group is to reasonably arrange tasks and limited task resources for UAV under the premise of meeting various constraints and for the purpose of maximizing revenue, which is of great significance to improve task execution efficiency and resource utilization.

The search task of UAV group is mainly reflected in the search demand for uncertain or dynamic targets. For civil use, Chen, D. Q designed an evolutionary algorithm based on constraint sampling for searching for shipwrecked people, which makes the search process self-organized and guided, showing high discovery probability and robustness [2]. Chen, B. studied the search problem of missing targets in uncertain environments, effectively guided cluster search through expected observation information, and constantly updated observation information based on rolling time domain, which greatly improved the target discovery probability and cluster search efficiency [3]. Fu, J. divided the search task of UAV group into two stages: path planning and task allocation, and used obstacle free graph search algorithm and mixed linear integer programming method to solve them [4]. In terms of military, Wong, S. Y. studied the problem of cooperative reconnaissance task scheduling of UAV moving targets against the ground. On the basis of communication and interaction among UAV group members, he considered the current search cost and long-term search cost of UAV based on predictive control idea, and improved the cooperative search efficiency of UAV group [5]. In order to reduce the impact of uncertain target motion, Wang, C. updated the probability map of enemy aircraft motion in real time based on Bayesian theory through airborne sensor detection and analysis of potential range of motion of enemy aircraft, effectively improving the probability of detection of enemy aircraft in the three-dimensional battlefield environment [6]. To solve the problem of cooperative reconnaissance of UAV group under the general tactical network environment, Yin, L. assigned the control task of UAV group to different ground control centers, and realized the search and traversal of random dynamic targets based on UAV network information communication [7].

This paper has developed a multi machine formation intelligent autonomous inspection mobile cabin (hereinafter referred to as intelligent mobile cabin) based on fusion of multi-sensor, which integrates many functions such as UAV remote accurate positioning, multi machine formation intelligent cooperative inspection, data intelligent real-time analysis, etc., greatly improving the inspection efficiency and reducing the line operation and maintenance costs[8-9].

## III. Research Methods

### *A. Function introduction*

The intelligent mobile engine room is mainly composed of mobile engine room, UAV cluster operation system, UAV remote ground station, professional mapping workstation and data intelligent analysis system, which can realize multi UAV formation and intelligent cooperation to carry out transmission line inspection, and solve the problem that existing UAVs can only carry out single tower body fine inspection or channel inspection; The UAV off-site takeoff and landing technology has been developed, and the on-board charging function has been introduced to realize the UAV relay endurance, shorten the return and transition operation time of existing UAVs, and greatly improve the UAV endurance; The intelligent analysis system of patrol data (image and video) is equipped to conduct intelligent analysis of data through convolutional neural network algorithm, generate data report with one key, and independently mark patrol defect information, reduce the labor intensity of staff, improve the timeliness and accuracy of patrol data analysis, and solve the problem of long time consuming and low timeliness of UAV patrol data analysis and comparison[10-12].

The intelligent mobile cabin covers layer management, real scene model, tower management, line management, patrol task management, patrol video playback, patrol photo management, etc. It realizes the intelligent patrol operation and flow management of UAVs based on test lines, as well as the accurate and visual management of patrol data. As shown in Figure 1:


Figure 1. Construction logic of UAV patrol management platform.

### B. *Functional design*

#### 1) *Multi task intelligent autonomous patrol inspection*

The intelligent mobile engine room is designed and modified by using the existing patrol vehicles, and two UAV cabins are designed, including one medium-sized UAV, equipped with RTK (real-time dynamic control system), responsible for lean patrol inspection; one small and medium-sized UAVs (equipped with RTK) are responsible for channel inspection and infrared temperature measurement, which can effectively solve the problem of single inspection mode of traditional UAVs. The mobile cabin can carry two UAVs in formation at the same time[13]. Through GPS (Beidou) and RTK module differential, visible light guidance, infrared guidance, radar obstacle avoidance, optical flow velocity measurement, binocular obstacle avoidance and other advanced technologies, it can achieve precise positioning, takeoff and landing, hovering, intelligent and autonomous inspection of multi aircraft formation, and ensure flight safety. After determining the transmission lines and towers for patrol inspection, the formation mode shall be selected according to the site conditions, the patrol command shall be issued to UAVs, and multiple UAVs can independently complete the patrol task with one key to start. UAV can operate synchronously from multiple angles, directions and modes, and sense the line status comprehensively and efficiently, thus ensuring the efficiency, autonomy and safety of patrol operations[14].

In order to reflect the precise coordinate position collected by UAV to the patrol management platform, it is also necessary to transform the three-dimensional space model to the display screen. The transformation of 3D model to 2D screen requires model position transformation, observation angle (camera angle) transformation and projection mode transformation, which correspond to model transformation matrix M, angle transformation matrix V and projection transformation matrix P. Its transformation expression is equation (1):

$$p = P \times V \times M \times v \tag{1}$$

Where: vector v is the vertex coordinate of the model in the original three-dimensional space; The vector p is its coordinate on the display screen; Matrix M contains the position transformation of model vertices in three-dimensional space; Matrix V contains the transformation of 3D model to camera or viewpoint; The matrix contains the projection method used by the viewpoint, and perspective projection is usually used in 3D space. Matrix V and matrix P are usually set by the running environment where the analytical model is loaded, and matrix M is generally saved in the data file where the model is stored. When it is necessary to make the model move and flip in space, the value of matrix M needs to be recalculated, which is also the key point to make the model move or change its position in 3D space.

#### 2) *Multi terrain relay endurance*

Due to the limitations of natural environment and overall planning, transmission lines are often located in the complex environment of mountains, rivers, lakes, marshes and deserts. Many towers are located in no man's land and no signal area, which is difficult for line patrol personnel to reach. The author uses the traditional UAV for patrol inspection. Due to the insufficient cruise capability of a single machine and the weak image transmission signal of the UAV, the effective operating distance is only 3 km. The intelligent mobile cabin has obvious advantages in communication ability, endurance and stability, which solves the above problems[15-16].

##### a) *Communication capability*

In the design of intelligent mobile cabin, the 2.4 GHz and 5.8 GHz dual frequency communication+remote 4G positioning technology is used to increase the operating distance in complex environments to 5 km. The wide area/local area communication technology (GPS/GLONASS) dual-mode positioning is adopted, and the vehicle body is equipped with a gain antenna to enhance the radio transmission signal and expand the local area communication range. The remote communication 4G module is deployed on the UAV, which improves the wide area communication capability. It can communicate with the ground station in the vehicle in real time and data interconnection. It can patrol while walking and take off and land in different places, realizing the mobile inspection mode of the UAV, and will not interrupt the communication due to the dynamic change of the vehicle position. When the UAV takes off, the vehicle can directly drive to the end of the operation section to receive the returning UAV, so as to shorten the return time of the UAV and the vehicle transition time, thus extending the UAV operation time and improving the UAV patrol efficiency[17].

##### b) *Endurance*

It is equipped with a 12 bit on-board intelligent charging cabinet, which can charge 12 batteries at the same time to realize remote control addressing and charging relay. The patrol operation efficiency of individual soldier channel can reach 60 km/d, and the lean patrol operation efficiency of individual soldier tower can reach 30 km/d. At the same time, it is equipped with meteorological monitoring devices to solve the problem that existing UAVs cannot take off and land due to poor weather conditions[18].

##### c) *Stability*

The UAV carrying take-off and landing platform is slide rail type, which can be smoothly pushed and pulled out. According to different size models, double deck multiple take-off and landing platforms are designed, and a limit is designed to prevent the UAV from shaking during transportation. The bottom of the UAV foot rest is fixed on the sponge foam material by using the spring type binding and fixing method to reduce the damage to the UAV caused by vibration during transportation[19].

#### 3) *Intelligent analysis of multi type on-site diagnosis*

*a) Composition and function of on-site operation command system*

The intelligent mobile engine room on-site operation command system is mainly composed of on-site operation command vehicle and its supporting on-board intelligent components, high-precision autonomous flight patrol UAV, remote controller, control terminal (tablet computer) and workstation (intelligent cluster operation control center and transmission line intelligent operation inspection and control platform) and other components. 4G network remote control, which integrates command, control, supervision, data intelligent analysis and processing, can understand the site situation in real time, upload data to the workstation in real time, automatically analyze and process, and achieve intelligent, efficient, safe and visual operation mode; It can find hidden dangers, collect on-site data and deal with problems in a timely manner, and is not limited by region and signal transmission distance. It can also operate efficiently even in remote mountain areas. The architecture of the intelligent mobile engine room on-site operation command system is shown in Figure 2.

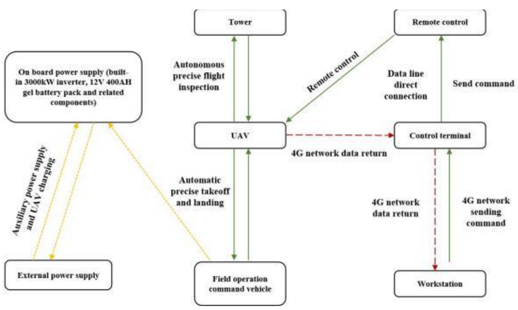


Figure 2. Architecture of the intelligent mobile engine room on-site operation command system.

*b) Intelligent cluster operation control center*

The intelligent cluster operation control center is a B/S (browser/server architecture mode) architecture application, which is deployed on the remote ground workstation. The workstation on the field operation command vehicle can open this center through the browser, and control 5 UAVs in real time. The route task is sent to the cloud through the fleet operation control center, and then forwarded to the corresponding control terminal through the Internet of Things protocol. The control terminal then sends the route task to the unmanned aircraft terminal. The control process is shown in Figure 3. The intelligent cluster operation control center can realize seven independent operation modes, including tower body fine patrol, channel patrol, tree obstacle patrol, 360 ° panoramic acquisition, tilt photography, orthophoto and infrared special patrol, and can comprehensively collect transmission line patrol data[20-21].

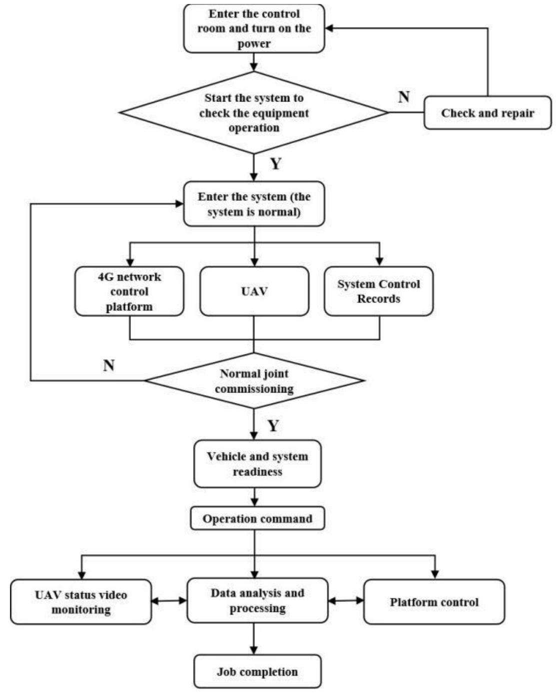


Figure 3. Intelligent Cluster Operation Control Process.

The intelligent mobile cabin is equipped with a remote controller to remotely control the UAV. The control terminal is connected to the remote controller, and communicates with the cloud control center through the 4G network. After the UAV performs the task, it hovers at the terminal. When the control terminal reconnects with the UAV, it automatically issues the task, and the UAV lands on the field operation command vehicle. When the UAV flies to the field operation command vehicle, the pictures can be downloaded through the control terminal and automatically forwarded to the cloud for intelligent identification of the cloud; You can also copy pictures directly from the unmanned terminal and access the workstation for rapid data processing[22].

The intelligent aircraft cluster operation control center can manage mobile operation vehicles, unmanned aerial vehicles, route tasks and inspection results. Its intelligent patrol control platform system includes such functional modules as planned line patrol cycle, patrol process control, data achievement management, defect elimination management, statistics and early warning analysis.

*c) Data intelligent analysis system*

The data intelligent analysis system of intelligent mobile engine room is based on ubiquitous Internet of Things remote communication, which can realize real-time display of UAV working attitude, real-time collection of tower information, and real-time data analysis. The data (image and video) intelligent analysis system is equipped with a GPS/RTK dual-mode navigation system. The front-end identification+edge computing+back-end identification+deep learning technology is used to generate a defect analysis report with one click, and the intelligent inspection APP is approved to eliminate defects. The intelligent patrol APP includes tower intelligent navigation, online office, online approval and other functions. Among them, the front-end identification is the defect identification of transmission line equipment at the unmanned terminal; Edge computing is based on Huawei Atlas 200 AI acceleration module, and 16 channels of high-definition video are analyzed in real time; The back-end identification is the defect identification of station end transmission line equipment; Deep learning is based on convolutional neural network algorithm to intelligently identify defects in the image, so as to achieve efficient analysis of massive inspection data.

The intelligent defect recognition system is an image recognition method based on the deep learning convolutional neural network and wavelet moments. It can quickly identify and analyze the machine patrol and human patrol data. The recognition rate for the channel type hidden dangers can reach more than 85%, and the recognition rate for the defects of hardware fittings, insulators, shock absorbers and pin level tower body components can reach 40%~80%. The system is equipped with self-learning function, which can optimize the intelligent identification algorithm of transmission line tower small target at any time, and continuously improve the defect identification rate and diagnosis accuracy. The intelligent defect recognition system is based on image dense point cloud matching and stereo mapping technology, which can clearly reflect the horizontal distance value, vertical distance value and sag distance value of the lowest point of the conductor of the tower; It can automatically analyze the sag change under different temperatures and the safe distance of tree block/crossing span; It can model the conductor sag of the transmission line channel, analyze the safe distance of the tree block, measure the cross span distance, and automatically generate the tree block defect report; The system supports diversified data collected by multi rotor UAV, and its analysis results can be shared with the power transmission inspection and control system.

The patrol platform system mainly includes transmission line table, power tower table, flight mission table, patrol record table, patrol line table, patrol video table, patrol photo table, etc. according to business division. The main model logic relationship is shown in Figure 4. From the model relationship, it can be seen that the data core of the patrol platform is transmission line data, and the main business of patrol is around transmission lines, including transmission line management, line based flight mission management, mission based trajectory management, mission based results management, etc[23].

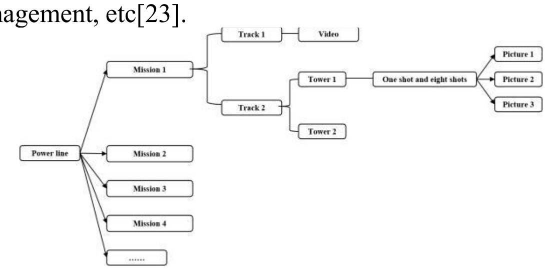


Figure 4. Schematic diagram of model relationship.

## IV. RESULT ANALYSIS

The main functions of the intelligent mobile engine room implemented in the 253000 km2 operation and maintenance area of a certain place include:

(1) Layer management. Including base map switching, map positioning and data display.

1) Underlay switching. Depending on the sky map, the satellite image map and electronic map can be switched as the base map of the system at will.

2) Data display. The geographical scope of the test line can be directly displayed on the map, and the full view of the line can be viewed on the image, so as to realize a visual picture of the transmission line and location information.

3) Route positioning. According to the name of the line, automatically locate the test line on the map, change the traditional line list management mode, and flexibly access the transmission line files with the map as the entrance.

(2) Loading and management of live model of transmission line. The network tile loading method is used to request a large transmission line model.

(3) Tower management. It includes quick name retrieval, direct graph query, and patrol inspection data view.

1) Quick name retrieval. According to the name of the tower, quickly search and locate the correct position on the map at the first time.

2) The drawing can be viewed directly. Click the tower graph on the map to quickly access the tower archive data.

3) Check the patrol inspection data. Directly obtain the patrol photos of the relevant patrol operations of the power tower for easy management.

(4) Task management. It includes task process establishment, task implementation and task result query for UAV operation.

(5) Patrol photo management. Based on the precise position of power poles and towers, the patrol photos are managed objectively.

(6) Line patrol video management. Data management of line patrol inspection video based on a single flight mission. The 3D channel data of transmission line and the 2D line data of GIS map can be viewed and compared on the same screen.

The intelligent mobile engine room is suitable for desert, grassland, forest, marsh, mountain area and other environments. It has been applied in 253000 km2 operation and maintenance area of a certain place. 20 1409km transmission lines and channels have been inspected intelligently, 225 defects have been found and analyzed, and 66 hidden dangers have been eliminated. The operation inspection efficiency is 60% higher than that of manual processing, saving 2200 hours of working time, saving more than 4 million yuan of labor costs, and saving about 300000 yuan of maintenance costs for vehicles, unmanned aerial vehicles and other equipment. The application effect is remarkable[24-25].

## V. CONCLUSION

The intelligent mobile cabin integrates cloud computing, big data, Internet of Things, mobile Internet, and smart grid technologies to achieve interconnection and human-computer interaction in power transmission operation and maintenance. Data intelligent identification+intelligent operation inspection management and control platform+intelligent inspection APP realizes the closed-loop management of the whole process of transmission line inspection from formulating inspection tasks to defect identification, and finally to eliminating defects. It solves the problems of short endurance, strong dependence on manpower, single data acquisition mode, etc. of traditional UAV, and has the advantages of low production investment and late maintenance cost, multiple machine collaborative one button autonomous operation efficiency doubling, significantly reduced personnel investment cost, and higher comprehensive cost performance. It is not only applicable to the power industry, but also can be extended to petroleum, pipeline, communication and other industries.


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