Automatic Safety Routing Inspection of the Electric Circuits Based on UAV Light Detection and Ranging

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Abstract. With the higher and higher demands on the electric circuits of our country, the scale of overhead transmission line and its covering area have been expanding. As a result, the traditional regular routing inspection of electric circuits by man can’t meet the needs of people’s demands on the stability of power system. The application and development of UAV LIDAR and scanning technology has provided a new platform for the automatic safety routing inspection of electric circuits. Moreover, the modern safety routing inspection of electric circuits has been deeply studied and widely applied due to the UAV remote sensing technology and LIDAR and electronic scanning technology.

1. Introduction
Nowadays, with the higher and higher demands of people on the stability of the power system, the traditional regular routing inspection by man can no longer meet the needs of the current demands of state grid on the stability of power system because of its high labor intensity, long time-consumption and low efficiency. The UAV devices for the routing inspection of electric circuits may always be equipped with infrared camera, digital camera, high resolution telescope and visible light video recorder, which may all be used to inspect and record routes and finally acquire videos and images of route corridors. The application of the UAV LIDAR technology to conduct the automatic safety routing inspection of electric circuits can not only extremely lower material and human costs but also considerably reduce the cost of data collection. However, the application of UAV to conduct the safety routing inspection of electric circuits remains to possess shortcomings, such as low accuracy of spatial orientation, which may lead to that it will be hard to accurately calculate the route distance and the distance between corridor features like trees based on the data from UAV video. Thus, it may also cause the errors on the measurement of the vegetation points that may threaten the safety of electric circuits, which may eventually cause circuit flashover or even the trip of circuits. However, the material and human costs will be considerably reduced when conducting the routing inspection of electric circuits by UAV compared to the traditional way. With the mature development of UAV LIDAR technology, it can greatly solve the problems of spatial orientation and measurement accuracy. Therefore, the automatic safety routing inspection of electric circuits based on UAV LIDAR will be the major way to detect electric circuits. Above all, the study of the automatic safety routing inspection of electric circuits based on UAV LIDAR may possess the crucial research value and promise a bright application prospect.

2. UAV LiDAR Cloud Data Technology

2.1 Light Detection and Ranging (LiDAR)
LiDAR, light detection and ranging, combines both laser technology and modern optical detection technology, which is to acquire the object information such as spatial position by emitting high frequency pulsed laser towards target of detection through a laser device. The LiDAR system integrates laser ranging, GPS and IMU, so it can acquire 3D spatial information of the target more quickly and accurately than by the traditional photogrammetric technology. LiDAR scanner may get
the reflecting laser point data by scanning the ground. All the laser point data may show us its irregular distribution of points set in the three-dimensional space that we may call stochastic discrete Points Cloud. Furthermore, laser point data may acquire not only the X, Y, Z coordinate information of Points Cloud but also its spatial form. And it will contain the information of object reflection strength that can be recognized by filtering processing. Currently, the formats of laser point data may be the general formats such as ASCII code and LAS and the two formats can be transformed mutually. Among these laser point data, some of them are located in the terrain surface and other may locate in artificial building or natural vegetation. Finally, DEM can be acquired by filtering the echo points of the ground features from laser points cloud data.

2.2 Working Principle of LiDAR
UAV may conduct the automatic routing inspection on electric circuits by the LiDAR system and then collect and process the points cloud data along the electric circuits, which may eventually help acquire the corridor map of how to modify the electric circuits that may also contain the X, Y, Z coordinates information of points cloud. That can realize the real three-dimensional reconstruction of electric circuits by some related software, that is to say it can reconstruct surface configuration of the buildings or natural vegetation and of it along the electric circuits and tower, which may lead to acquiring the three-dimensional model. At the same time, LiDAR technology can also acquire points cloud data that can demonstrate in 3D and also deal with the measurement, which will help extract the data of superficial area and volume of the certain object in the points cloud. This kind of function makes the LiDAR technology surpass the traditional optical remote sensing and the microwave remote sensing.

![Figure 1. Schematic Diagram of the Working Principle of the LiDAR System.](image)

2.3 Classification of the Points Cloud of Surface Features
Transmission line corridor is the most important part of both the grid construction and the power safety inspection. All the parts such as terrain, landform, natural vegetation, buildings, electric towers and points of hanging lines in the corridor should be paid the greatest attention to during the construction, maintenance and detection of power grid. During the process of the automatic safety routing inspection based on the UAV LiDAR, LiDAR will get the original points cloud which contains not only transmission line corridor but also all the coordinates in the corridor. From that, we can understand the following part of the job is to separate the laser points of different surface features, which can be achieved by filtering and classification.
2.4 Filtering of the Data of LiDAR
The filtering of the data of LiDAR actually is the process of the extraction of the DTM/DEM of the data from laser points cloud, which is to remove the foot point data of the ground features from the original points cloud and then get the final demand data. The classification of the LiDAR data is merely the classification of the laser foot point data and then to separate the vegetation data points and artificial ground features, which can extract points cloud series of different classification in the end. The extraction of the points of power line is mainly to separate the ground point and ground feature through filtering first and then to separate the power line point and vegetation point by the LiDAR data classification. For the process of filtering, generally speaking, it will take about 60% to 80% of the whole time to filter the data of the laser points cloud, which is to say that the algorithm of filtering will directly decide the DEM qualification of the model construction.

2.5 Safety Routing Inspection of Electric Circuits
After the digital modeling of the power line corridor, we can directly see the location relation between the power line and power tower and the location relation between the other ground features in the corridor. Then the construction of model can be achieved through the detection data from monitoring devices equipped on the tower itself to detect temperature, humidity and wind speed, which can lead to the analysis and operation on the power job based on three-dimensional digital power grid. Then we can simulate the changes of power line and the growth situation of the dangerous trees in the corridor. Furthermore, we can simulate the sag changes under the different circumstances of temperature, wind speed and ice coating and the growth of trees also.

3. Function and Result of Routing Inspection of Electric Circuits Based on UAV LiDAR Technology

3.1 Function
The safety routing inspection of electric circuits based on UAV LiDAR technology may provide not only the basic data support for monitors of electric circuits but also find the potential safety hazard of electric circuits and its devices in advance, which can help avoid the threats of the ground features to the electric circuits in the corridor. Furthermore, we can analyze and detect hazard rating of buildings, vegetation and crossing that may affect the electric circuits based on the points cloud data from equipped LiDAR device. Three-dimensional modeling of ground features, surface configuration and overhead line structure along the electric circuits can be realized on the basis of standard DOM and DEM files according to points cloud.

3.2 Application Effect
The safety routing inspection of electric circuits based on UAV LiDAR technology can definitely raise the efficiency and decrease the field work at the same time, compared to the traditional routing inspection by man, which will considerably lower the cost. Mentioning the traditional routing inspection of electric circuits, it may take one-day work of nearly 20 persons to detect 100km-long power line while it may take only one-day work of 2 persons using the UAV. Furthermore, the restriction of geographical conditions can also be reduced substantially, which can be showed in the Fig.2 that workers are using the UAV LiDAR to inspect the electric circuits.
The real three-dimensional model of the electric circuit corridor can be reconstructed based on the collected data and processing of the points cloud of transmission lines, towers and ground vegetation, which can be demonstrated as Fig.3 that is the extraction effect picture of the points cloud of the electric circuits. The accurate measurement of ground vegetation and power lines will be well confirmed based on the three-dimensional modeling reconstruction and further discover the potential risks of electric circuit, which can eventually help avoid the power outage and save the substantial loss.

4. Conclusion
As all mentioned above, UAV LiDAR technology and its high accurate data may realize the digitization of the geographic information of the transmission line corridor and terrain, height of trees, towers, sag point of transmission line and crossover in the corridor, which will not only greatly help find the shortcomings of the electric circuit but also locate the accurate point of defects. It may boast the great improvement compared to the traditional iconography. I believe that with the deeper research and development and widespread application, the automatic safety routing inspection of the power line based on the UAV LiDAR technology will become maturer and maturer and gradually be applied by the power inspection department.

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