Fast detection method of transmission line defects and faults based on airborne laser LiDAR

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Abstract. In view of the fact that it is difficult for transmission line operators to find transmission line defects and accurate location information in time, and in the face of the discovered transmission line defects, they are unable to quickly and accurately return detailed defect information to provide urgent repair to provide rectification solutions, etc., this paper proposes a fast transmission line defect fault detection method based on airborne laser LiDAR, and compares and analyzes it by using laser point cloud data in different periods. It is found that there are some defects such as the interruption of the transmission line channel and the sinking of the tower foundation. Using laser point cloud data, the tilt detection and deformation of poles and towers are found, and large-scale topographic maps are quickly generated to quickly restore the three-dimensional channel environment of transmission lines, so as to provide auxiliary decision-making for transmission line defects and fault rectification schemes. The digital and scientific management of transmission line defects and equipment fault detection are realized through laser point cloud.

1. Introduction

Due to the complexity of transmission line channel environment, the vulnerability of equipment and the complexity of manual detection, it is difficult for operators to find transmission line defects and accurate location information in time. Moreover, in the face of the discovered transmission line defects, it is unable to quickly provide accurate and detailed defect information for emergency repair, which delays the repair time and reduces the efficiency of emergency repair[1-13].

Therefore, a fast detection method of transmission line defects and faults based on airborne laser LiDAR is proposed in this paper, which can realize the rapid detection and accurate location of typical defects and faults of transmission lines, and quickly generate large-scale topographic maps on the scene of emergency transformation of transmission lines, quickly restore the three-dimensional channel environment of transmission lines, provide auxiliary decision-making for emergency transformation of transmission lines, and improve the efficiency of defect and fault detection of transmission lines. The emergency response ability of transmission line defects and faults is improved to ensure the safe operation of transmission lines.
2. Materials and Methods
The technical route of rapid fault detection method for transmission line defects based on airborne laser LiDAR is shown in Fig. 1, including transmission line foreign body detection technology based on laser LiDAR, tower tilt, base subsidence and displacement detection technology, and transmission line equipment fault detection technology based on laser LiDAR. Aiming at emergency relocation and emergency repair, there are some key technologies, such as on-site three-dimensional rapid reshaping assistant decision-making technology and large-scale topographic map rapid mapping technology.

![Diagram of Technical Route of Fast Detection Method for Transmission Line Defects and Faults Based on Airborne Laser LiDAR](image_url)

**2.1 overlay Detection Technology for Foreign bodies in Power Lines of Transmission Lines**
The common hanging foreign bodies in the power line are classified and summarized, the three-dimensional laser point cloud spatial structure of the foreign body is studied, and the representation form of the foreign body is analyzed.

The linear and smooth characteristics of the power line are studied in order to restore the three-dimensional spatial structure of the power line in the point cloud data of the transmission line corridor, and to analyze the overall structure change and judgment mode of the point cloud of the power line channel when the foreign body is hanging on the power line. To realize the detection and location of power line foreign bodies (including absolute coordinates, hanging position (wire, ground wire), distance from tower, etc.).

After image processing technology-assisted detection, laser LiDAR technology is used to locate the unobvious foreign body in the point cloud structure. According to the spatial relationship between the foreign body and each phase power line, the influence of the foreign body on the safe operation of the line is analyzed, and the graded early warning of the foreign body hanging defect is realized.

**2.2 testing technology of tower inclination, base subsidence and displacement**
For different types of towers, the characteristic points representing their spatial shape and orientation (such as tower apex, tower foot point, transverse bearing point, etc.) are selected, and the tower feature point database is established to realize the accurate mapping of the whole spatial position of different types of towers. As a spatial monitoring point for tower tilt, base subsidence and displacement detection.
In this paper, the extraction technology of tower feature points of point cloud data in transmission line corridor is studied, and the accurate and automatic extraction of tower feature points of different structural types is realized.

Through the matching and comparison technology of multi-period feature points, the deviation of the coordinates of feature points is analyzed, and the corresponding relation model between the deviation of feature points and tower tilt, base subsidence and displacement is established. Accurately detect the position and degree of tower tilt, base subsidence and displacement, and then judge the stability of the whole tower, and realize the early discovery and early warning of tower geological defect risk.

2.3 Transmission line equipment fault detection technology based on laser LiDAR

Aiming at the faults of bulk equipment such as towers, ground wires and insulators, a typical equipment fault library based on laser LiDAR is established, and the fault forms and spatial changes are analyzed. The equipment faults are classified and detected according to spatial deviation faults (such as insulator string tilt, cross pole skew, sag deviation between ground wires.) and surface faults (such as broken strands and broken wires.).

For equipment spatial deviation faults, the equipment spatial deviation faults are classified and studied according to the spatial deviation faults (such as insulator string tilt, cross pole skew, inter-phase sag deviation, etc.). This paper studies the reproduction technology of the key structure of the three-dimensional space of the equipment in the laser point cloud data, studies the digital definition model that characterizes the spatial shape of all kinds of equipment, realizes the accurate expression of the spatial position relationship of the equipment, and uses the spatial analysis technology to realize the accurate detection and location of the spatial deviation fault of all kinds of equipment.

For the equipment surface fault, using the combination of three-dimensional laser point cloud data and picture data analysis, the intelligent recognition technology is studied to detect the equipment surface change. Through the mutual registration technology of LiDAR data and aerial image, the accurate spatial location coordinates of the fault are obtained, the equipment fault degree is analyzed, the equipment fault classification and classification is realized, and the maintenance basis is provided for maintenance personnel.

2.4 On-site three-dimensional rapid reshaping assistant decision-making technology for emergency relocation and emergency repair

In view of the problems of tower foundation caused by tower upside-down, uneven settlement, construction damage and landslide, it is necessary to urgently formulate a relocation plan, study the point cloud surface reconstruction technology, and based on the high-density and high-precision three-dimensional point cloud data obtained on the spot, three-dimensional reconstruction of the site A high-precision and high-resolution digital terrain model is established to generate a field measurable three-dimensional scene with a precision of 1RU 2000, which provides a visual platform technical support for the investigation and decision-making of emergency tasks in the emergency relocation of transmission lines.

This paper studies the three-dimensional measurement method of measurable real scene, and realizes the automatic or semi-automatic measurement of the target area, including excavation and filling quantity calculation, distance measurement, volume measurement, perimeter measurement, etc., based on the on-site 3D analysis of remodeling, extract detailed information such as geographical location, scale, scope, safe distance and so on, realize the rapid survey of the site and surrounding conditions, and provide material support for the formulation of the relocation and emergency repair plan. Improve the efficiency of emergency repair

2.5 Fast mapping technology of large-scale topographic map

A new surveying method for topographic map of electric power engineering is proposed, which solves the problem of rapid acquisition of topographic data and overcomes the time-consuming problems of traditional mapping, including accurate collection of laser point cloud data, rapid classification, TIN
construction, contour generation, content and expression, quality control, field mapping and modification and other key technologies.

Through the data sampling technology to ensure the completeness of the sampling of the key topographic points in the emergency relocation and emergency area, through the point cloud gross error elimination and filtering technology, and for the irregular triangulation network "triangle networking" (the so-called tin) to check whether the network construction is reasonable.

Point cloud filter classification algorithm is used to classify pure ground laser point cloud data, contour lines are generated by constructing TIN and editing, secondary editing and smooth processing of contours are carried out with reference to digital orthophoto image, obvious ground objects are drawn intuitively and efficiently through orthophoto image and laser point matching technology, the interpretation technology of key features in orthophoto map and tilt correction technology of high-rise buildings are studied, and the precision and quality of topographic map are accurately controlled. Finally, the finished product of large-scale topographic map is formed, which can quickly provide basic data for the emergency relocation of transmission lines.

3. Results & Discussion

3.1 Experimental data
UAV throwing and tower climbing operation are used to simulate the layout of line defects such as power line floating objects and wire broken strands, including plastic film, color stripe cloth, kites, ropes and other common floating objects, one strand, two strands, multiple strands and other different forms of broken strands.

After the simulated defects are arranged, the lidar + visible light equipment enters the field flight test, and the laser point cloud data and visible light data are collected at the same time, as shown in Fig.2 and Fig.3.

![Fig.2. Overall point cloud data](image)

![Fig.3. The situation of floating objects in point cloud data](image)
3.2 Result analysis.
The specific effects of the technical methods described in the second chapter of this article are shown in Fig.4–Fig.6.

Fig.4. Test results of power line hanging objects

Fig.5. Test result of tilt of insulator string

Fig.6. Topographic map result

4. Conclusions
(1) A new method of transmission line channel defect detection based on laser LiDAR is proposed. By analyzing the change of the whole structure of power line channel point cloud when the foreign body is hanging on the power line, the defect of power line foreign body is found; through the establishment of tower characteristic point database and the comparison and analysis of tower characteristic points in different periods, some defects are found, such as tower tilt, base sinking, displacement and so on.

(2) A set of transmission line equipment fault detection method based on laser LiDAR is proposed. Three-dimensional spatial analysis is used to detect equipment spatial deviation faults such as insulator string tilt and crossbar skew, and three-dimensional laser point cloud data and image data analysis are used to detect power line broken strands, broken lines and other equipment surface faults.

(3) A set of rapid investigation assistant decision-making method for emergency relocation of transmission line based on laser LiDAR is proposed. Large-scale topographic map is generated by using TIN constrained by 3D laser point cloud data, 3D surface reconstruction technology is used to realize on-site 3D rapid reconstruction, and 3D channel of transmission line is quickly restored.
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