Research on precise maintenance method for green belt of municipal road based on UAV image sequence

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Abstract. Urban road greening refers to the planting of trees, flowers and grass and road protection forests on both sides of roads and separation belts to achieve the purpose of noise isolation, air purification and environment beautification. It will bring a huge amount of work to the maintenance of the road green belt, because of the conflict between the diversity of plant growth and the standardization of road greening. However, with the rapid development of high technology, it is of great significance to develop a high-throughput inspection and monitoring platform for the qualitative and quantitative evaluation of road greening projects. The high-throughput unmanned aerial vehicle (UAV) platform can be used for monitoring the plant canopy structure of road greening belt, which has the advantages of high efficiency, high reduction degree, low cost and so on. In the future, it will become a feasible technical means of road greening project maintenance. Based on the acquisition of plant growth status information of road green belt, the application prospect of high and new technology in the monitoring of functional indexes of road green belt is explored. Then, it can be a technical support for road safety, green belt design, structure optimization and maintenance management.

1. Introduction

1.1. The significance of road greening

With the rapid development of the national economy, the urban construction has shifted from the previous only function to the combination of function, landscape and ecology, gradually. As the artery of urban infrastructure, road greening takes up a relatively heavy weight. Road greening can not only play the role of ecological protection, but also form the green isolation belt and linear green landscape of urban¹. There are three main functions for road greening, environmental protection, landscape effect and traffic safety. Environmental protection can be achieved through air purification, noise reduction and water and soil conservation. The landscape effect can be achieved through the combination of a variety of plants and pruning of the canopy structure of plants, then improving the stiff monotonous driving environment². Road central green belt is an important part of highway construction to realize the traffic safety function by the anti-glare effect, the guidance to the driver's vision and the alleviation of mental fatigue. It can alleviate the driver's visual fatigue in the daytime and prevent glaring at night effectively by planting green plants with a recommended height and canopy width in the edge of the road and the central separation zone, so as to guarantee the driving safety³.
1.2. Road greening maintenance status

There always are a variety of landscape plants planted in the green belt of municipal road, whose growth conditions vary from one to the other. It can affect the normal driving of vehicles when plants grow too much, that will encroach on the driveway and requires inspection and pruning regular \([4]\). Dwarfness or death from disease or traffic accident will affect the landscape of municipal roads, so the treatment or retransplantation was required regular. At the present stage, as most of the maintenance work of road greening projects still relies on sampling test in China, which is mainly based on the inspection by workers and vehicles. It can be a lot of work but not very accurate. At the same time, due to the particularity of the location of road green belts, the personal safety of maintenance workers cannot be guaranteed in the high-risk working environment.

1.3. Advantages of UAV in road greening application

UAV has the characteristics of remote operation, real-time acquisition of high-resolution data and low cost. So that it can solve the difficulties in maintaining heavy workload, labor cost and work safety of road green engineering by applying UAV to the daily maintenance and monitoring of vegetation in municipal road green belt at present \([5]\). Meanwhile, UAV aerial survey has included in the recommended application method of road greening engineering detection in the newly revised highway engineering quality inspection and evaluation standard of 2018 (JTG F80/1-2017) \([6]\), which will also provide policy support for the application and promotion of UAV technology in road greening maintenance.

1.4. The foreground of UAV in road greening application

With the development of computer technology, a comprehensive evaluation method combining qualitative characteristics with quantitative analysis of the highway greening way is proposed based on the development and application of efficient intelligence testing platform. It can directly reflect the function, status and maintenance level of road greening, and provide reference basis for rational utilization, management and improvement of road greening. At present, only qualitative description and evaluation of highway greening is carried out, lack of quantitative parameter evaluation system. Based on the maintenance needs of the greening project and the quantitative analysis of aerial image data of UAV \([7]\), a quantitative monitoring platform was founded for road greening in the paper. The efficient and non-destructive technology based on UAV platform is explored to meet the quantitative monitoring of highway greening function index in the transportation field.

2. Materials and methods

In this study, there were 6 basic processes for each aerial photography experiment (figure 1). It includes setting of aerial photography equipment, sensor parameters and flight parameters of aircraft, design and pre-flight simulation of specific flight missions according to aerial photography requirements, planning of autonomous flight routes after adjustment; calibration of original aerial images and reference of geographic information; the reconstruction of ortho-mosaic, three-dimensional point cloud and digital surface model (DSM) for the whole monitoring scene based on the preprocessing of the calibrated aerial image sequence, and target region identification and feature parameter extraction according to different research purposes.
2.1. UAV aerial photograph system and route planning
A four-rotor UAV monitoring platform was selected for the experiment (Figure 2C), the main hardware components including the UAV (Inspire 1 Pro), holder, and the aerial photography sensor (Chan Si X5 camera). The process of UAV aerial photography is as follows: locate the target aerial photography area on the satellite map before aerial photography, plan the flight path, set UAV and camera parameters. The open source software Mission planner for UAV was used for planning the route. The flight speed could be calculated and generated in the software after the flight height, image overlap and shooting interval are set, automatically (Figure 2A and B). The overlapping degree of the adjacent images setting was about 80%, and the camera's shooting interval was set to 2 s. In order to ensure the aerial photography area cover the target area fully, the possible deviation between satellite map and actual area was taken into account in the route planning.

2.2. Aerial image sequence processing
After exporting aerial images from drone storage devices, ortho-mosaic, 3D point clouds and DSM were generated using Agisoft PhotoScan software. The GPS positioning system, which is carried by the drone, can get geographic information of the image sequence. Firstly, feature matching points between adjacent image pairs were found in the original image sequence, and dense 3D point cloud of the whole monitoring area was generated based on the key matching points. The generated 2D ortho-mosaic and DSM carried the color and elevation values of each reconstruction point, respectively. Both of the
reconstructed 3D point clouds carried the color and height value, and 2D ortho-mosaic covered the entire scene within the flight area.

3. Results

3.1. Reconstruction and visualization of road target section scene based on UAV platform

After obtaining the image sequence based the UAV near-sensing platform, the image data can be processed to obtain different forms of panoramic reconstruction models. The aerial shot monitors the target section with an actual length of 252 m, and adopts the flight height of 30 m with a total of 8 routes, and the flight duration is 6 min. A total of 184 effective original graphs are obtained. Thus, the 2D ortho-mosaic, 3D point clouds reconstruction and DSM of the target monitoring scene can be obtained (Figure 3). The reconstructed 3D dense point cloud is composed of about 17,300,000 points, and each point carries the spatial position coordinates and RGB information. The corresponding pixel of reconstructed DSM carries its relative elevation value, which can be used to represent the elevation change of target monitored section.

3.2. Identification of problem areas

The original image size of the single image obtained by the camera on the UAV platform is 4000 × 2250, and when the flight height is 30 m, the corresponding GSD is 0.67 cm. This resolution can be used to identify individual plants with the naked eye, and the morphological differences between neighboring plants can be compared by visual discrimination. The volume of single-row trees on both sides of the road can be extracted through pixel classification, and the growth difference between adjacent trees on both sides of the road can be compared and analyzed, so as to identify unhealthy plants effectively and accurately (Figure 3 red box marked). It can identify the area where excessive foliage needs to trim in the central green belt accurately (Figure 3 yellow box marked), through the comparison of area of central green belt in the early stage of road planning and the actual growth obtained from the reconstruction based on UAV.

Figure 3. Reconstruction, visualization and accurate recognition of road target section scene based on UAV platform
4. Conclusions
According to the actual requirements of road green belt maintenance work, the functional indexes of the greening project are qualitatively described in this paper, systematically. Then, a precise monitoring method of municipal road green belt based on the UAV near-sensing telemetry platform is proposed, combined with the requirements of quantitative analysis technology in the later maintenance work. The feasibility in the research and application of UAV aerial image in road green belt vegetation is further determined through the overall study of the method for the plant structure characteristic parameters obtaining based on image data at the present stage. Through the geographic information carried by aerial images and image information interpretation technology, the location of the green belt areas that need to be pruned or replanted can be found accurately. A lot of road green belt parameters can be extract automatically, such as the quantification of greenbelt richness, plant morphology and health status, based on the UAV precise maintenance platform of road green belt, which is equipped with multi-spectral sensor and high-resolution camera to obtain multi-source image set. Combined with the evaluation of the design parameters of road green belt, the application direction and prospect of aerial image of UAV in the precise maintenance of road green belt can be further clarified. In the future, the dynamic growth changes of structural characteristic parameters of road green belt will be realized based on the high-throughput UAV platform, which can monitor the target road section periodically, providing theoretical and technical support for the design, tree species selection, structural optimization and pruning management of road green belt.

Acknowledgements
We would like to acknowledge Bangyou ZHENG (CSIRO) for his generous help with the photography and software used for 3D reconstruction, Wei GUO (The University of Tokyo) for his help in image interpretation algorithm, and Yan GUO (China Agricultural University) for his hardware support of UAV field experiments and image data processing. This study is supported by the National Key Research and Development Program of China (2017YFC0804904) and National Natural Science Foundation of China (31771678).

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