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Application of UAV in 3D Real-Scene Surveying and Mapping of Jilin West Railway Station

Yanqiu Shi[1], Lingwei Kong[2]

[1]JiLin TieDao University, Jilin 132000, China
[2]China Railway Northwest Research Institute Co., Ltd., Lanzhou 730030, Gansu, China

Abstract: ***Unmanned Aerial Vehicle (UAV) aerial surveying and mapping is an emerging technology with wide applications, playing a significant role in civil engineering. Compared with traditional surveying and mapping methods, UAV tilt photogrammetry technology is of great significance for reducing field survey personnel, surveying workload, and saving expenses on personnel and equipment. In this study, the DJI Phantom 4 RTK UAV was used for field surveys to obtain data and images of Jilin West Railway Station. DJI Terra 3D modeling software was employed to establish a 3D real-scene model, and the 3D Mapping Special Edition of eps2016 Geographic Information Workstation was utilized to draw 2D topographic maps (CAD) of the station. This work realizes the 3D real-scene construction of Jilin West Railway Station, a cultural relic protection building, explores the practical application of UAVs in the field of cultural relic protection, and practices the transformation path and implementation method of replacing the traditional measurement production system with a digital one.***

Keywords: Phantom 4 RTK, Aerial Survey, Cultural Relic Protection, Jilin West Railway Station, 3D Real Scene.

1. Introduction

Topographic maps have a long development history and are crucial basic geographic information materials for a country. Geographic information and topographic maps of varying accuracies are indispensable for daily life, development planning, and resource surveys. Topographic maps have evolved from paper-based to digital formats, and from 2D to 3D representations. In terms of measurement methods, a transformation has occurred from the traditional measurement production system to a digital system [1]. The emergence of cutting-edge technologies such as electronic tachometers, GPS-RTK, and Terrestrial Laser Scanning (TLS) has brought significant changes to digital measurement, greatly improving production efficiency and accuracy. Aerial photogrammetry and satellite mapping have expanded surveying and mapping methods to include aerial and space-based approaches. However, aerial operations are limited by high costs and inadequate accuracy, failing to meet the requirements of most topographic maps. This has created an opportunity for the introduction of UAV low-altitude photogrammetry technology. Benefiting from China's manufacturing advantages, domestic UAVs offer flexibility, controllable costs, and high resolution. With the assistance of ground control points, they can achieve field surveying and mapping of large-scale topographic maps. Currently, many engineers and technicians are dedicated to researching UAV aerial surveying and mapping technology. References [2-8] explore the production of Digital Orthophoto Maps (DOM) and Digital Elevation Models (DEM) using different types of UAVs equipped with various devices, adjusted angles, and aerial survey methods in diverse locations. They also investigate how to connect different software for indoor processing to output 3D models and 2D drawings. UAVs have been applied in 2D and 3D surveying and mapping of different scales, terrains, scopes, and accuracies in fields such as agriculture, forestry, architecture, environment, and transportation.

In this study, UAV aerial photography was used to obtain image data of Jilin West Railway Station. Field surveys were conducted to collect data and images, DJI Terra 3D modeling software was used to establish a 3D model, and the 3D Mapping Special Edition of eps2016 Geographic Information Workstation was employed to draw 2D topographic maps (CAD) of the station. This work realizes the topographic surveying and mapping of Jilin West Railway Station and explores the transformation path and implementation method of replacing the traditional measurement production system with a digital one.

2. Project Introduction

2.1 Project Overview

Located in Jilin City, Jilin Province, China, Jilin West Railway Station is affiliated to China Railway Shenyang Bureau Group Co., Ltd. and currently operates as a freight-only line. Designed by the renowned Chinese architect Liang Sicheng and reviewed by the famous architectural designer Lin Huiyin, the station's main building and ticket office were completed in 1928, the clock tower in 1929, and the tower pavilion in 1930. Covering an area of 897 square meters, it is a large Gothic-style building with a pointed roof. The main structure of the station is made of square stone, the roof is a folded wooden structure covered with glazed tiles outdoors, and the interior is decorated with murals. The top of the clock tower is 29 meters above the ground, and there is a spiral wooden staircase inside, allowing visitors to overlook the surrounding area from the top. Facing south, the station is shaped like a lying lion, with its tail ingeniously designed as the clock tower. As a blend of Chinese and Western architectural styles, Jilin West Railway Station embodies the essence of traditional Chinese architecture and the characteristics of Western medieval architecture, making it a masterpiece in China's modern architectural history. It was listed as a National Key Cultural Relic Protection Unit on March 5, 2013. Taking advantage of the unique features of UAV surveying and mapping technology, this study constructs a 3D real-scene model of the cultural relic building of Jilin West Railway Station and discusses the specific application of UAV surveying and mapping technology in real-scene construction.

Figure 1: Gothic Architecture of Jilin West Railway Station

2.2 Low-Altitude UAV Platform

The DJI Phantom 4 RTK UAV is equipped with a centimeter-level positioning system and an excellent workflow system. Dual redundant IMUs and compasses enhance flight safety, while dual backups and a high-precision GNSS system enable real-time differential positioning. Centimeter-level precise positioning ensures the accuracy of flight routes and the stability of flight attitudes, reducing the impact of changes in flight altitude on the scale between images. The DJI Phantom 4 RTK can be connected to the DRK2 high-precision GNSS rover station, or via a 4G wireless network card or WiFi hotspot. It supports the access of RTK cm-level v3 data format through the NTRP protocol network RTK/CORS service and also allows for the independent setup of RTK base stations. The remote controller has a built-in GS RTK App, which provides photogrammetry and route planning modes in addition to the traditional manual flight mode. This reduces the number of control points required in traditional surveying and mapping operations, simplifies workflow steps, lowers economic costs and field work time, and improves field work efficiency. It has obvious advantages in emergency support and topographic surveying and mapping of areas with special geographical environments and local small regions [9-12].

3. Workflow

3.1 Pre-operation Preparation

The main preparation work includes data collection, equipment debugging, and site reconnaissance.

1) Collect existing data of Jilin West Railway Station, including basic topographic maps and structural characteristics, and understand its traffic location and operation status.

2) Calibrate equipment, including checking the remote controller, UAV-mounted devices, and batteries.

3) Verify that the software of the remote controller and UAV is upgraded and compatible.

4) Check the weather and wind speed in advance, and select a suitable take-off and landing site around Jilin West Railway Station through reconnaissance.

3.2 Aerial Photography Operation

3.2.1 Route Design

The DJI Phantom 4 RTK UAV, a four-rotor high-precision aerial survey UAV suitable for low-altitude photography, was used for this aerial surveying and mapping task. In the route planning mode, the UAV's flight route can be selected independently, and the overlap rate, altitude, and other aerial survey parameters can be adjusted freely manually, enabling a high degree of automation and intelligence in the operation process. To meet the accuracy requirements of real-scene model construction, improve flight efficiency, and ensure flexibility, a lens angle of 60° was adopted. The route design included five-directional flight, with a designed forward overlap rate of 80%, a side overlap rate of 80%, a ground resolution of 2 cm, and a flight altitude of 50 m.

The 2D plans and 3D models generated through aerial surveying and mapping with the DJI Phantom 4 RTK UAV and post-processing software meet the accuracy requirements of the planning topographic map of Jilin West Railway Station, and the accuracy can be adjusted according to the vertical height. The UAV is equipped with a built-in obstacle avoidance system, which can greatly reduce the risk of collision. Due to its light weight, the DJI Phantom 4 RTK UAV cannot take off normally under strong wind conditions. Therefore, the aerial surveying and mapping task of Jilin West Railway Station was carried out on a sunny day with light wind. Prior to the operation, the optimal route was planned through reconnaissance of Jilin West Railway Station and calibration with the Amap Interactive Map. The UAV parameters were adjusted before the flight mission, and the pre-planned optimal route was used during the flight. There are two route planning methods for the DJI Phantom 4 RTK UAV: one is to directly plan the survey area and route on the map interface of the UAV remote controller; the other is to use computer software (Amap Interactive Map) to delineate the survey area in advance, generate a KML file, and import it into the memory card of the UAV remote controller. During field operations, the KML file can be directly called by the remote controller for operation.

3.2.2 Acquisition of Aerial Image Data

The acquisition of aerial image data of Jilin West Railway Station includes equipment inspection before takeoff, planning and execution of UAV route tasks, on-site sorting of flight data, and manual supplementary flight of key areas.

1) Equipment Safety Inspection Before TakeoffTo ensure the safety of the UAV aerial photography, the UAV needs to undergo a self-inspection after startup, as follows: (1) Check the network RTK status, including wireless network connection, GNSS antenna visibility, number of connected satellites, and compass calibration to eliminate geomagnetic interference. (2) Inspect the memory card, check camera settings, and clean the camera lens. (3) Inspect the rotors to ensure that the gray and black rotors are correctly installed. (4) Check the UAV's positioning and return-to-home point. After turning on the remote controller and the UAV, wait for the

system to connect normally before taking off.

2) Planning and Execution of UAV Route TasksAfter the UAV takes off, it collects data and images according to the planned route. The UAV's working status and environment are monitored in real-time through the remote controller. The operator should constantly pay attention to the UAV's flight status, current wind speed, flight altitude, and other indicators. If any abnormalities occur, immediate measures should be taken to ensure the UAV's safety. If everything is normal, the UAV will collect data according to the planned route by default and return automatically after completion. A total of 3 flight sorties were conducted in this operation, collecting 900 image data.

3) On-site Data SortingSort the flight data on-site to check whether the number and clarity of the captured photos meet the requirements and whether there is any missing shooting. If there are no other issues, the shooting task of the planned route is completed, and a second supplementary shooting of key areas can be considered as appropriate.

4) Manual Supplementary Flight of Key AreasBased on the on-site data sorting results, conduct another safety inspection of the UAV. After confirming that everything is correct, manually take off for supplementary shooting. Close-range, multi-angle, and high-overlap supplementary shooting are performed for railway tracks, Gothic architectural spires, building eaves, and shadow areas. The lenses and angles for key supplementary shooting are shown in Figure 2.

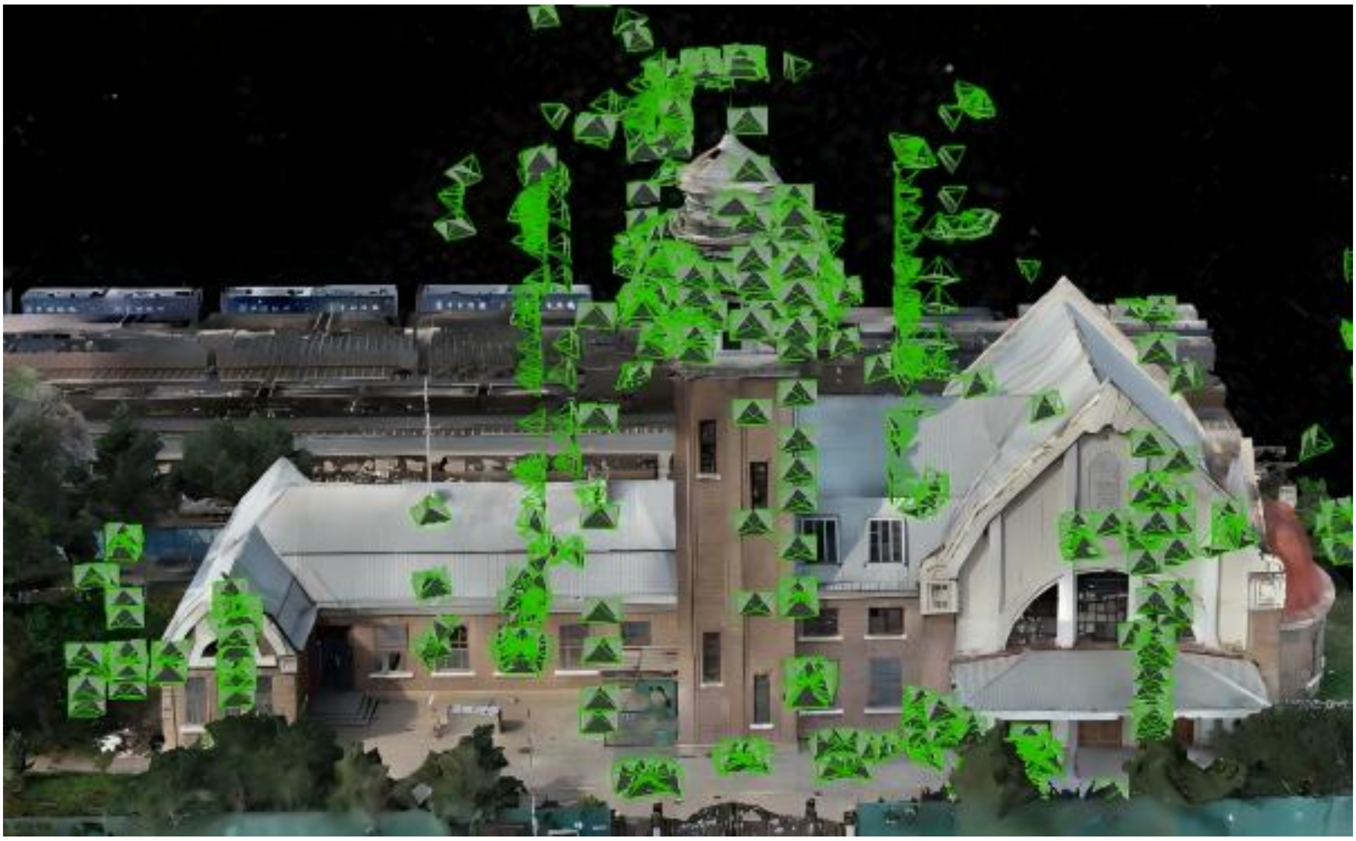

Figure 2: Supplementary Shooting of Key Areas

3.3 Data Processing

The DJI Phantom 4 is equipped with a 20-megapixel lens, capable of capturing high-resolution images with a Ground Sample Distance (GSD) of 2.74 cm at a flight altitude of 100 meters. Each photo can be strictly calibrated, ensuring high imaging accuracy, and distortion data can be stored in the metadata. After the completion of UAV field operations, the data is copied for indoor post-processing. A 3D real-scene model is established using DJI Terra software, which includes three steps: data import, aerial triangulation, and post-modeling output [13-15]. Data import mainly involves sorting aerial image data, camera files, POS data, and ground control point data to meet the operational requirements of DJI Terra software. In this operation, the non-ground control point UAV tilt photogrammetry technology was adopted. When building the 3D model with DJI Terra, the process of point marking was omitted. The images were directly imported, the modeling area of interest was set, the output coordinate system (CGCS2000/3-degree Gauss-Kruger CM 126E) was managed, and aerial triangulation was submitted. After completion, a new reconstruction project was created to finally generate the 3D model [16-19]. Since the generated 3D model needs to be imported into the Tsinghua eps 3D mapping software, the final 3D model format was set to osgb when submitting the new project. The 3D model of Jilin West Railway Station was constructed using DJI Terra 3D modeling software. Based on the constructed 3D real-scene model, the topographic map of Jilin West Railway Station was drawn using eps 3D mapping software by collecting feature points, lines, and surfaces of ground objects and landforms, and finally edited indoors to produce the topographic map. The 3D real-scene base map eliminates the cumbersome field mapping work. Open the 3D Mapping Special Edition of eps2016 Geographic Information Workstation, import the osgb model into the workspace, select elevation points in the landform module of the toolbar, click on the 3D model with the mouse to extract all required elevation points according to the actual landform and control elevation points, extract all building boundaries according to the residential area module, and extract the boundaries of main and secondary roads as well as paths according to the transportation module. After extracting all elevation points with the eps software, proceed to terrain processing - generate triangulation network - generate contour lines - close the triangulation network - export external data in dwg format, and import it into CAD for editing and processing [20-22].

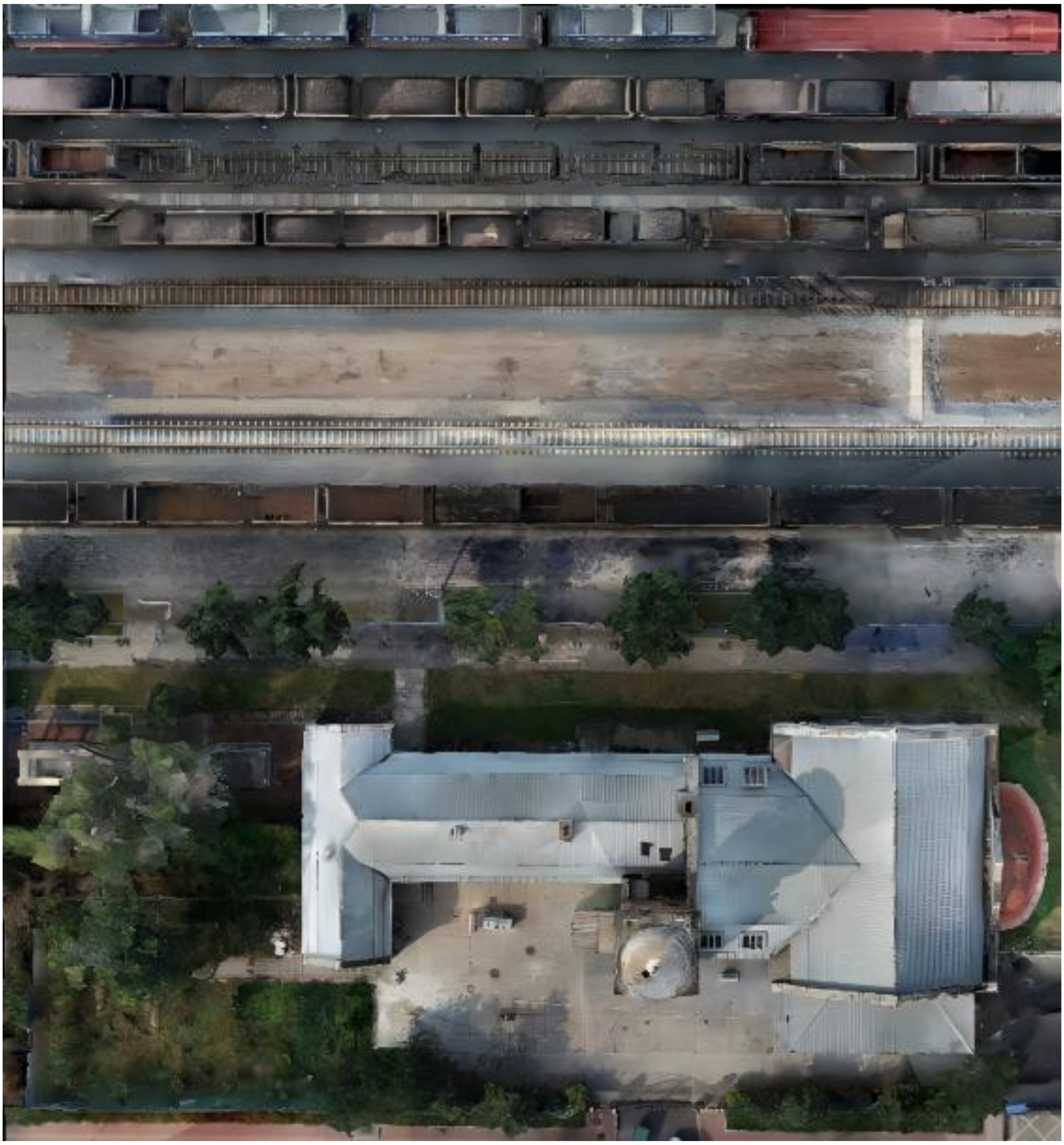

Figure 3: Orthophoto Image of Jilin West Railway Station

4. Conclusion

In this study, the DJI Phantom 4 RTK UAV and tilt photogrammetry technology were used to obtain image data of Jilin West Railway Station. DJI Terra software was employed to build a 3D real-scene model of the station with a precision of 2 cm, which realistically displays the existing buildings and operation status of Jilin West Railway Station. The eps 3D mapping software was used for data collection to draw a 1:4000 topographic map of Jilin West Railway Station.

Compared with traditional surveying and mapping, UAV surveying and mapping of Jilin West Railway Station offers convenient operation, significantly reduces labor costs, and improves work efficiency. The field operation for the 900-square-meter Jilin West Railway Station took only 50 minutes. However, UAV surveying and mapping is limited by weather conditions and battery life. With technological advancements, UAV surveying and mapping technology will better serve basic surveying and mapping industries, such as railway line inspection, special landform surveying and mapping, architectural design and planning, and low-altitude remote sensing data acquisition. Especially in areas where it is difficult to set up ground control points, such as cliffs, swamps, glaciers, and regions prone to geological disasters, the DJI Phantom 4 RTK UAV tilt photogrammetry technology is more practically significant for conducting local emergency surveying and mapping and displaying 3D real scenes.

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