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Effective Application of UAV Surveying and Mapping Technology in Engineering Measurement

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Abstract: The construction industry is progressing towards refinement and efficiency, revealing the shortcomings of traditional engineering measurement technologies prevalent in complex terrain operation–data acquisition efficiency, data analysis timeliness and cost control. With its mobility, high efficiency, reliable data accuracy and adaptability of complex environments, AV surveying and mapping technology has become an engineering measurement core techno-logical means. This paper combines the technical characteristics of UAV surveying technology, analyzes the specific application scenarios and implementation methods in four stages of engineering investigation and design, construction process monitoring, completion quality acceptance and post-operation maintenance management respectively to provide reference for promoting and deepening application of UAV surveying technology in engineering measurement.

1. Introduction

Engineering measurement is an important part of the whole process of construction projects, and the accuracy and efficiency of data acquisition will directly determine the rationality of engineering design, construction safety and final quality. The conventional measurement equipment is based on total stations, GPS receivers, and similar devices to serve the needs of surveyors in the field by putting out control points and obtaining data point-by-point. In rugged and complex environments like mountains, ravines, and waters, these methods also struggle with high difficulty, long cycles, risk of personnel safety in the field, and difficult to achieve rapid large-area data coverage. Driven by the current trend of integrated development of UAV technology, remote sensing and GIS (Geographic Information Systems), UAV surveying technology has also been developed. It acts as various data acquisition devices including high-definition cameras, LiDAR, multispectral sensors and so on taking advantage of the UAVs flight platform to achieve autonomous or manual flight for image and geographic data collection from special regions. The original images are further processed through specialized software to produce digital orthophoto maps (DOM), digital elevation models (DEM) and 3D point cloud models, which provides spatial data support for construction projects.

2. Technical Characteristics of UAV Surveying Technology

UAV surveying technology has four main advantages over traditional engineering measurement technologies:

2.1 High Mobility and Flexibility

UAVs are compact and lightweight (consumer-grade UAVs typically weigh less than 5kg; industrial-grade UAVs range from 10–30kg), enabling takeoff and landing in narrow spaces and complex terrains such as mountains, mining areas, and water bodies without requiring large-scale site leveling. For areas like cliffs and deep valleys that are inaccessible to traditional surveying, UAVs achieve all-around data acquisition through low-altitude flight, effectively overcoming terrain limitations.

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2.2 High Operational Efficiency

One UAV flight can cover tens to hundreds of hectares, performing in one day the work of a conventional survey team over 3–5 days. Take highway investigation as an example, traditional methods need to deploy control points along the route at first, and then collect terrain data segment by segment, which can take 20–30 days on a single 100 km of the line. This avoids the cumbersome project notifications associated with aerial surveying and reduces content acquisition time to full-line data: in just 5–7 days UAV surveying can obtain all data in one stop, effectively shortening project cycles [1].

2.3 Reliable Data Accuracy

The accuracy of UAV surveying results has been greatly improved with the development of sensor and positioning technology. RTK enables UAVs with RTK modules to accurately position themselves within the centimeter range. In challenging mountainous regions, UAVs with LiDAR penetrate the environment to acquire actual ground model data, where the precision of elevation collection can reach a resolution of 5–10cm that more than meets the requirement for accuracy across each engineering measurement stage.

2.4 Low Costs and High Safety

Traditional teams of 5–8 members can now be reduced to groups of only 2–3 personnel (one pilot, one data processor), drastically lowering labor costs for UAV operations. UAVs minimize personnel safety risks as no one need enter dangerous areas, such as high altitude and steep slopes or flammable/explosive zones.

3. Applications Across Engineering Measurement Stages

3.1 Engineering Investigation and Design Stage

UAV surveying overcomes the problem of incomplete data coverage and unintuitive terrain representation in traditional investigations, with three major applications:

Ground-Scale Topographic Mapping — UAVs quickly capture large-scale top of surface images, as well as elevation data for generating DOMs and DEMs, useful in projects such as highways and railways construction or hydropower hubs [2]. For example, DOMs in conjunction with DEMs are used by designers to visualize vegetation distribution, building locations and road alignments and they can measure slope, aspect and catchment area trends for route selection and site selection. 50km topographic mapping using UAVs for a highway project within 3 days with DEM data accurately carrying out the mountainous and valley terrain, optimizing three route bends while avoiding bridge/tunnel construction and effectively reducing costs.

Geological Disaster Identification: For mountain investigations, UAVs with high-definition cameras and infrared sensors conduct low-altitude surveys for hidden dangers such as landslides and rockfalls [3]. High-resolution imagery identifies cracks and exposed rock, while infrared data establishes moisture distribution to help gauge landslide potential.

3D Scene Modeling: The steep terrain stereoscopy is difficult to be questioned and expressed by 2D drawings, leading to spatial misunderstanding. UAVs make use of 3D point clouds and realistic models to recreate terrain and features.

3.2 Construction Process Monitoring

Earthwork Volume Calculation and Site Leveling Monitoring in construction and road projects: UAV periodic survey generates DEMs. Earthwork volume differences are calculated by comparing DEMs from different periods, while the variability of work in relation to plans is controlled through DOMs during the practical aspect.

Structural Deformation Monitoring: Bridges, skyscrapers and dams are subject to deformation from load variations and geological settlement. Single-point traditional monitoring via total stations/GPS cannot reflect the full range of deformation. If UAVs record LiDAR/cameras, the images will generate 3D point clouds; comparison of models across periods determines displacement trends to detect localized deformation hazards [4].

Construction Progress Monitoring: Large projects usually consist of different work sections and teams. But traditional tracking of progress is behind and inefficient. Weekly/monthly images from the UAVs are obtaining; these formats compared designs with actual imagery that generates reports of progress towards timely coordination of resources [5].

Construction Safety Surveillance: UAVs examine temporary structures (scaffolds, crane bases) and neighboring settings (neighboring structures, highways) using high-res images for verification of regulatory adherence (e.g., scaffold separation distance) and impact assessment (e.g. dust drift, earthworks infringement).

3.3 Completion Quality Acceptance

For roads, bridges and factories where dimensional checks are important, UAVs produce 3D models and digital line graph (DLG) which then provides means for comparing it with designs instead of using man power contingency for labourintensive manual measurements.

Appearance Quality Inspection: It is difficult to manually inspect high-altitude/large-span structures. UAVs are able to capture high-resolution imagery, enabling detailed defect detection (wall hollows, crack width, concrete honeycombing) with location/size marking [6].

Digital archived completion data: The physical archives would be damaged/lost. 3D realistic models and DOMs generated by UAV serve as a digital archive, which facilitates quick access on a computer. They then used UAV models in a hydropower project to capture dam, spillway, and powerhouse states for condition-based maintenance.

3.4 Post-Operation Maintenance Management

Structural Defect Monitoring: Long-time use will cause cracks, concrete spalling and steel corrosion. Cameras/Infrared/LiDAR are mounted on the UAVs: (1) High-resolution imagery is used to detect and monitor structural cracks; (2) Infrared technology detects internal voids/corrosion for buildings; (3) Laser—LiDAR measures displacement. A bridge monitoring project detected a 0.2mm–0. (FleekEye: 5mm crack widen, timely repair [7].

Peripheral Environment Monitoring: Alterations such as construction settlement, road excavation or vegetative growth could affect operations. Drones fly over peripheries for monitoring at periods to compare data for analysis regarding settlement, excavation impacts, or vegetation obstructions (power lines) [8]. A dam project identified 5cm of settlement in neighboring villages as water levels induced groundwater changes, prompting re-working of schedules to stave off additional settlement.

4. Conclusion

UAV surveying technology has a wide range of applicability in the field of engineering measurement. As technology matures and industry environments are optimized, it will increasingly highlight value with respect to different engineering scenarios, enabling high-quality development. The combination with AI, 5G and applications such as BIM/GIS will promote UAV surveying towards "intelligence, integration and cooperation". AI algorithms will enable highly automated workflows (flight planning, data acquisition, and processing); integrated air-space-ground systems (UAV + ground robots + satellite remote sensing) for complete high-precision coverage; deep integration & collaboration with BIM/GIS for full-lifecycle digital management (surveying-design-construction-operation).

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