Effective Application of UAV Surveying and Mapping Technology in Engineering Measurement

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Abstract: As the construction industry advances toward refinement and efficiency, traditional engineering measurement technologies increasingly reveal limitations in complex terrain operations, data acquisition efficiency, and cost control. AV surveying and mapping technology, leveraging advantages such as mobility, high efficiency, reliable data accuracy, and adaptability to complex environments, has emerged as a core technological approach in engineering measurement. This paper integrates the technical characteristics of UAV surveying technology to analyze its specific application scenarios and implementation methods across four key stages—engineering investigation and design, construction process monitoring, completion quality acceptance, and post-operation maintenance management—aiming to provide reference for further promotion and deepened application of UAV surveying technology in engineering measurement.

1. Introduction

Engineering measurement is a critical link throughout the entire lifecycle of construction projects, with its data accuracy and acquisition efficiency directly determining the rationality of engineering design, construction safety, and final quality. Traditional measurement technologies primarily rely on total stations, GPS receivers, and other equipment, requiring surveyors to deploy control points on-site and collect data point-by-point. When facing complex terrains such as mountains, ravines, and water bodies, these methods face challenges including high difficulty, long cycles, personnel safety risks, and difficulty in achieving rapid large-area data coverage. With the integrated development of UAV technology, remote sensing, and geographic information systems (GIS), UAV surveying technology has emerged. Using UAVs as flight platforms equipped with high-definition cameras, LiDAR, multispectral sensors, and other devices, it completes image and geographic data acquisition in designated areas through autonomous or manual flight. Specialized software then processes these data to generate digital orthophoto maps (DOM), digital elevation models (DEM), and 3D point cloud models, providing comprehensive spatial data support for construction projects.

2. Technical Characteristics of UAV Surveying Technology

Compared to traditional engineering measurement technologies, UAV surveying technology exhibits four significant advantages.

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.

2.2 High Operational Efficiency

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A single UAV flight can cover tens to hundreds of hectares, completing in one day the workload of a traditional survey team over 3–5 days. For example, in highway investigation, traditional methods require deploying control points along the route and collecting terrain data segment-by-segment, taking 20–30 days for a 100km route. UAV surveying completes full-line data acquisition and processing in just 5–7 days, significantly shortening project cycles[1].

2.3 Reliable Data Accuracy

Continuous upgrades in sensor and positioning technologies have enhanced the accuracy of UAV surveying outcomes. UAVs equipped with RTK modules achieve centimeter-level positioning accuracy. LiDAR-equipped UAVs penetrate vegetation to capture true ground elevation data in complex terrains, with elevation accuracy reaching 5–10cm, fully meeting precision requirements across all engineering measurement stages.

2.4 Low Costs and High Safety

UAV operations require only 2–3 personnel (one pilot, one data processor), significantly reducing labor costs compared to traditional teams of 5–8 members. By avoiding hazardous areas such as high altitudes, steep slopes, and flammable/explosive zones, UAVs effectively mitigate personnel safety risks.

3. Applications Across Engineering Measurement Stages

3.1 Engineering Investigation and Design Stage

UAV surveying addresses issues of incomplete data coverage and unintuitive terrain representation in traditional investigations, with three key applications:

Large-Scale Topographic Mapping: For projects like highways, railways, and hydropower hubs, UAVs rapidly acquire panoramic imagery and elevation data, generating DOMs and DEMs[2]. Designers use DOMs to visualize vegetation distribution, building locations, and road alignments, while DEMs analyze slope, aspect, and catchment areas to support route selection and site selection. In a highway project, UAVs completed 50km topographic mapping in 3 days, with DEM data accurately reflecting mountainous and valley terrains, optimizing three route bends to reduce bridge/tunnel construction and lower costs.

Geological Hazard Identification: In mountainous investigations, UAVs equipped with high-definition cameras and infrared sensors perform low-altitude surveys to identify hidden risks like landslides and rockfalls[3]. High-resolution imagery detects cracks and exposed rock areas, while infrared data assesses moisture distribution to evaluate landslide risks.

3D Scene Modeling: Traditional 2D drawings struggle to convey terrain stereoscopy, leading to spatial misjudgment. UAVs generate 3D point clouds and realistic models to restore terrain and features. Designers conduct virtual site selection and scheme simulation in 3D models to intuitively assess environmental impacts.

3.2 Construction Process Monitoring

Earthwork Volume Calculation and Site Leveling Monitoring: In construction and road projects, UAVs periodically survey sites to generate DEMs. Comparing DEMs from different periods calculates earthwork volume differences, accurately tracking progress and identifying deviations via DOMs.

Structural Deformation Monitoring: Bridges, high-rises, and dams are prone to deformation from load changes and geological settlement. Traditional single-point monitoring with total stations/GPS fails to capture overall deformation. UAVs equipped with LiDAR/cameras generate 3D point clouds; comparing models across periods analyzes displacement trends to detect localized deformation hazards[4].

Construction Progress Monitoring: Large-scale projects involve multiple work sections and teams. Traditional progress tracking is inefficient and lagging. UAVs capture weekly/monthly progress imagery; comparing designs with actual imagery generates progress reports for timely resource coordination[5].

Construction Safety Monitoring: UAVs inspect temporary facilities (scaffolding, crane foundations) and surrounding environments (adjacent buildings, roads) via high-resolution imagery to check compliance (e.g., scaffolding spacing) and monitor impacts (e.g., dust dispersion, earthwork encroachment).

3.3 Completion Quality Acceptance

Dimensional Verification: For roads, bridges, and factories, UAVs generate 3D models and digital line graphs (DLG) for dimensional comparison with designs, replacing labor-intensive manual measurements.

Appearance Quality Inspection: High-altitude/large-span structures are difficult to inspect manually. UAVs capture high-resolution imagery for detailed defect detection (e.g., wall hollows, crack widths, concrete honeycombing) with location/size marking[6].

Digital Archiving of Completion Data: Traditional paper-based archives are prone to damage/loss. UAV-generated 3D realistic models and DOMs serve as digital archives for quick computer-based access. A hydropower project used UAV models to record dam, spillway, and powerhouse states for precise maintenance data.

3.4 Post-Operation Maintenance Management

Structural Defect Monitoring: Long-term use leads to cracks, concrete spalling, and steel corrosion. UAVs equipped with cameras/infrared/LiDAR monitor structures; high-resolution imagery tracks crack expansion, infrared detects internal voids/corrosion, and LiDAR measures displacement[7]. A bridge monitoring project identified a 0.2mm–0.5mm crack widening, enabling timely repair.

Peripheral Environment Monitoring: Changes like building settlement, road excavation, or vegetation growth may impact operations. UAVs periodically survey peripheries; data comparison analyzes settlement, excavation impacts, or vegetation obstruction (e.g., power lines)[8]. A dam project detected 5cm settlement in nearby villages due to water level-induced groundwater changes, prompting schedule adjustments to prevent further settlement.

4. Conclusion

UAV surveying technology holds broad prospects in engineering measurement. As technology matures and industry environments optimize, it will deliver greater value across diverse engineering scenarios, supporting high-quality development. Future integration with AI, 5G, and technologies like BIM/GIS will drive UAV surveying toward "intelligence, integration, and collaboration". Automated workflows (flight planning, data acquisition, processing) via AI algorithms; "air-space-ground" integrated systems (UAVs, ground robots, satellite remote sensing) for comprehensive high-precision coverage; and deep integration with BIM/GIS for full-lifecycle digital management (surveying-design-construction-operation) will advance the industry toward smart construction.

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