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Surveying of Inaccessible Topographical Area at Remote Location by UAV

Banoth Praveen[1], Banothu Rakesh[2], Sriram Nikhil[3], Mr. B. Narsimha[4], Mr. M. Harish Kumar[5]
[1, 2, 3] *Department of Civil Engineering, Holy Mary Institute of Technology & Science, Hyderabad, India*
[4, 5] *Assistent Professor and HOD, Holy Mary Institute of Technology & Science, Hyderabad, India*

Abstract: Surveying remote and inaccessible terrains using conventional methods is difficult due to terrain complexity, safety risks, time consumption, and high costs. This study demonstrates the use of an Unmanned Aerial Vehicle (UAV) for efficient and accurate topographical surveying. A multirotor UAV equipped with a high-resolution camera and GNSS module was used to capture aerial images following a planned grid pattern with 75% forward and 65% lateral overlap. Ground Control Points (GCPs) were established using RTK GNSS for accurate georeferencing. The collected images were processed using Open Drone Map (ODM) to generate orthophotos, Digital Elevation Models (DEM), and 3D point clouds, which were further analyzed in QGIS. Results showed a Ground Sample Distance (GSD) of 3.2 cm/pixel, horizontal accuracy of 0.032 m, and vertical accuracy of 0.048 m. Compared to traditional methods, UAV surveying reduced field time from 3–5 days to under 4 hours and significantly lowered costs. This study confirms that UAV-based surveying is a reliable, cost-effective, and efficient solution for mapping inaccessible terrain.
Keywords: UAV Survey, Photogrammetry, Open Drone Map, QGIS, Digital Elevation Model, Orthophoto, Ground Control Points, Remote Sensing, Topographical Mapping, GSD.

I. INTRODUCTION

A. Background
Topographical surveying is essential in civil engineering, environmental monitoring, and infrastructure planning. Traditional methods like total stations and GNSS require physical access, making them unsuitable for difficult terrains such as forests, hills, and flood-prone areas Historically, topographical surveys have been conducted using ground-based instruments: theodolites, total stations, optical levels, and more recently, GNSS receivers. These methods are accurate and well-understood, but they share a common operational constraint: they require human surveyors to physically access every part of the area being mapped. For accessible, flat terrain with good road networks, this is manageable. For remote, inaccessible, or hazardous terrain, it becomes either impractical or dangerous.

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B. Limitations of Conventional Methods
- Requires physical access to all points
- Time-consuming and labor-intensive
- Safety risks in hazardous terrain
- Low data density (discrete points only)
- High operational cost

C. UAV Technology in Surveying
UAVs overcome these limitations by:
- Providing aerial access to difficult areas
- Capturing high-resolution overlapping images
- Generating dense 3D data
- Reducing time and cost

D. Problem Statement
Conventional survey methods are inefficient or unsafe in inaccessible terrains. This project evaluates UAV-based surveying as an alternative.

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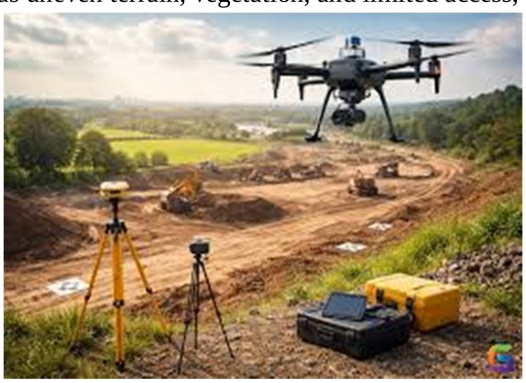
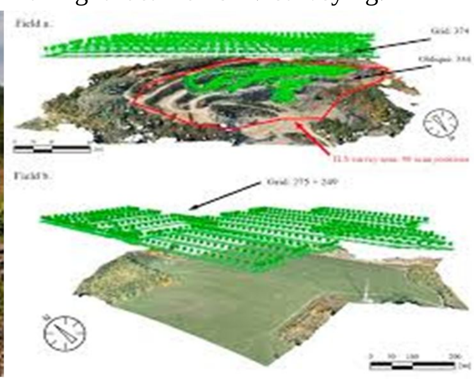
E. Objectives
- Design and deploy a UAV system
- Capture aerial imagery with proper overlap
- Establish GCPs using RTK GNSS
- Process data using ODM
- Generate maps using QGIS
- Evaluate accuracy, cost, and efficiency

II. LITERATURE REVIEW
Research shows UAV photogrammetry is highly effective for mapping:
1) Early studies proved UAVs can achieve <5 cm accuracy
2) Structure-from-Motion (SfM) enables 3D reconstruction
3) GCPs significantly improve accuracy
4) UAV surveys achieve comparable results to LiDAR in some cases
5) Open-source tools like ODM provide cost-effective processing

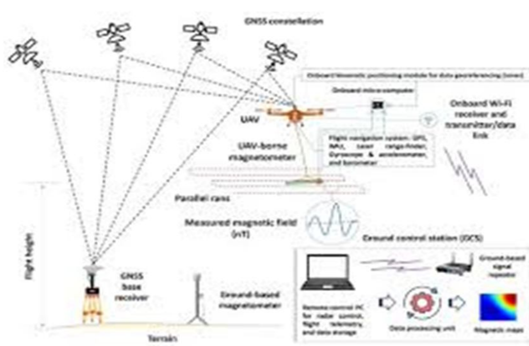
Key findings:
- Minimum 5–6 GCPs sufficient for accuracy
- Image overlap above 60% is necessary
- UAV surveys are faster and safer than traditional methods

III. STUDY AREA AND METHODOLOGY
A. Study Area
The selected site has uneven terrain, vegetation, and limited access, making it ideal for UAV surveying.





B. UAV Platform
- Quadrotor (450 mm frame)
- 12 MP camera
- GNSS module (GPS + GLONASS)
- Flight time: 18–22 minutes



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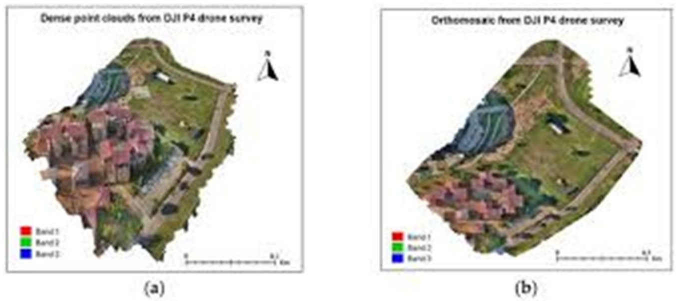
C. Flight Planning

- Altitude: 80 m
- GSD: 3.2 cm/pixel
- Overlap: 75% forward, 65% side
- Speed: 6 m/s
- Grid (lawnmower) pattern



D. Ground Control Points

- Total GCPs: 12
- Measured using RTK GNSS
- Accuracy: < 0.02 m
- 9 used for processing, 3 for validation

E. Image Acquisition

- Low wind conditions
- Automatic flight mode
- High shutter speed to avoid blur

F. Data Processing (ODM)

Steps:

- Feature detection
- Image matching
- Bundle adjustment
- Dense point cloud generation
- DEM and orthophoto creation

G. QGIS Analysis

- Contour generation
- Slope and aspect maps
- Hillshade
- Volume estimation
- Final map layout

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IV. EQUIPMENT AND SOFTWARE

A. Hardware

- UAV with Pixhawk controller
- GNSS RTK receiver
- Camera and gimbal
- Batteries and telemetry system

B. Software

- Mission Planner – flight control
- Open Drone Map – processing
- QGIS – analysis and mapping
- CloudCompare – point cloud visualization

All software used is open-source, reducing cost to zero.

V. RESULTS AND DISCUSSION

1) Orthophoto
- Resolution: 3.2 cm/pixel
- High clarity and full coverage
- No visible distortions

2) Digital Elevation Model (DEM)
- Resolution: 10 cm
- Accurate terrain representation
- Suitable for contour mapping

3) 3D Point Cloud
- Millions of data points
- High density and detail
- Minimal errors

4) Accuracy Assessment
- Horizontal RMSE: 0.032 m
- Vertical RMSE: 0.048 m
- Meets 1:500 mapping standards

5) Comparison with Traditional Methods

Parameter	Conventional	UAV
Accuracy	Moderate	High
Data Density	Low	Very High
Time	3–5 days	< 1 day
Cost	High	Low
Safety	Risky	Safe

6) Cost and Time Analysis
- Cost reduced by ~75–85%
- Time reduced significantly
- Minimal manpower required

VI. APPLICATIONS

1) Civil Engineering

- Road and pipeline surveys
- Earthwork calculations

2) Disaster Management
- Rapid damage assessment
- Flood and landslide mapping

3) Environmental Monitoring
- Forest analysis
- Land-use change detection

4) Mining
- Volume estimation
- Site monitoring

5) Agriculture

- Land leveling
- Irrigation planning

6) Urban Planning
  - Cadastral mapping
  - Infrastructure development

VII. CONCLUSION AND FUTURE SCOPE

A. Conclusion

The project successfully demonstrated UAV-based topographical surveying. The method provides:

- High accuracy
- Fast data collection
- Low cost
- High safety

UAV surveying is a practical alternative to conventional methods, especially in inaccessible areas.

B. Limitations

- Limited flight time
- Processing requires high computing power
- GCP setup needed
- Regulatory permissions required

C. Future Scope

- RTK/PPK drones (no GCP needed)
- LiDAR integration
- Multispectral sensors
- Automated missions
- Real-time processing

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