SMART SURVEYING WITH DRONE TECHNOLOGY USING AI BASED OBJECT DETECTION AND AUTOMATED CONTOUR MAPPING

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Abstract: The rapid advancement of drone technology combined with Artificial Intelligence (AI) has significantly transformed modern surveying techniques. This research Paper Presents a smart surveying approach using unmanned aerial vehicles (UAV_s) integrated with AI-based object detection and automated contour mapping. The proposed system utilizes high-resolution aerial imagery captured by drones and processes it using machine learning algorithms to detect and classify ground objects efficiently. Additionally, contour mapping is automated through advanced image processing and elevation data extraction, reducing the need for manual intervention. This method improves accuracy, reduces time consumption, and enhances cost- effectiveness compared to traditional surveying techniques. The study highlights then potential of integrating AI with drone technology in application such as land surveying, urban planning, agriculture, and environmental monitoring.

Keywords: Drone Technology, Smart Surveying, Contour Detection, Object Detection

Introduction

In recent years, drone technology has emerged as one of the most innovative tools in the field of civil engineering and land surveying. Traditional land surveying methods often require a large workforce, significant time, and physical effort, especially in rough or inaccessible terrain. Drone-based surveying, on the other hand, provides a faster, safer, and more accurate alternative for collecting spatial and topographical data.

Drones, also known as Unmanned Aerial Vehicles (UAVs), are equipped with high resolution cameras, GPS modules, and advanced sensors such as LiDAR or photogrammetry systems. These drones capture multiple overlapping aerial images of the land surface, which are then processed using mapping software to generate precise 2D and 3D models. These models are used to determine land boundaries, surface elevations, and terrain features with high accuracy.
By integrating drone technology into surveying and contour mapping, engineers can significantly reduce project duration, minimize human errors, and enhance safety. The ability to capture real-time, high-precision data also makes drones an essential part of smart infrastructure development and modern geomatics engineering.

Background of the study

Surveying is one of the oldest professions in human history and has been essential for planning, development, and management of land resources. Since ancient times, surveying has been used to establish land boundaries, construct buildings, and develop infrastructure such as roads, bridges, and irrigation systems. Early civilizations like the Egyptians and Romans used basic tools and geometric principles to measure land and create maps.

Traditional surveying methods relied heavily on manual instruments such as chains, tapes, compasses, and theodolites. These tools required surveyors to physically visit sites and perform measurements on the ground. Although these techniques laid the foundation for modern surveying, they were often time-consuming, labour-intensive, and prone to human error. Surveyors faced several challenges, especially when working in difficult terrains such as mountains, forests, or disaster-affected areas.

The technological advancements in the late 20th century, surveying methods improved significantly. The introduction of electronic instruments such as Total Stations and Global Positioning Systems (GPS) allowed surveyors to collect more accurate data with greater efficiency. These technologies reduced human effort and improved precision, but they still required field presence and were limited in terms of coverage speed and accessibility.

The rapid development of digital technologies in recent years has led to the emergence of smart surveying techniques. Among these, drone technology has become one of the most significant innovations, transforming the way surveying is conducted.

Objectives of the study

The main objectives of this study on smart surveying with drone technology are as follows:

1. To understand the concept and working of drone-based surveying systems.
2. To analyze the advantages of drone technology over traditional surveying methods.
3. To study the applications of smart surveying in various industries.
4. To evaluate the accuracy, efficiency, and cost-effectiveness of drone surveying.
5. To explore the future scope and technological advancements in this field.
6. To identify challenges and limitations associated with drone-based surveying.

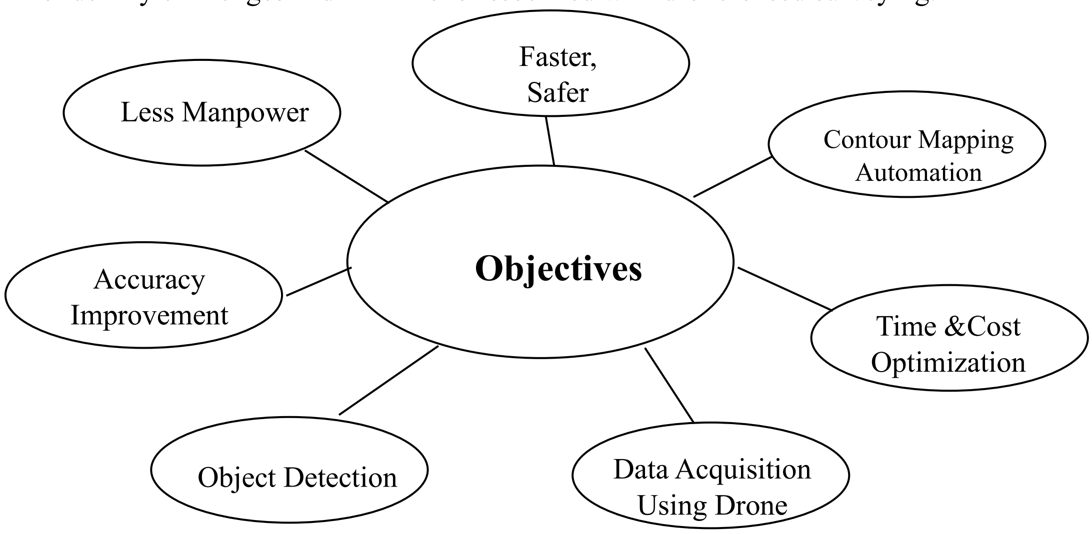


Figure 1: Objectives of study

Importance of Surveying

A. In the past, surveying played a fundamental role in shaping civilizations and supporting development activities. It was primarily used for:

1. Land Measurement and Boundary Identification: Establishing property boundaries and resolving land disputes.
2. Construction and Infrastructure Development: Planning and Constructing buildings, roads, bridges, and canals.
3. Agricultural Planning: Managing land for irrigation, crop planning, and resource allocation.

4. Mapping and Navigation: Creating maps for exploration, military operations, and trade routes.

Despite its importance, traditional surveying methods had several limitations. These included:

1. Time Consumption: Large areas required significant time to survey manually.
2. Labor Intensity: Required skilled workers and physical effort.
3. Limited Accessibility: Difficult to survey remote or dangerous locations.
4. Human Errors: Manual measurements often resulted in inaccuracies.

These challenges highlighted the need for more advanced and efficient surveying techniques.

B. In the present era, drone-based smart surveying has gained widespread importance due to its efficiency and accuracy. The integration of drones into surveying has significantly improved the overall process and reduced many of the limitations associated with traditional methods.

Some key advantages of drone surveying include:

1. **High Accuracy and Precision:** Advanced sensors and GPS systems provide highly accurate data.
2. **Time Efficiency:** Large areas can be surveyed within hours instead of days or weeks.
3. **Cost-Effectiveness:** Reduces the need for extensive manpower and equipment.
4. **Safety:** Minimizes risks by eliminating the need for surveyors to enter hazardous areas.
5. **Accessibility:** Enables data collection in difficult terrains such as mountains, forests, and disaster zones.
6. **Enhanced Data Visualization:** Provides 3D models, maps, and real-time analysis for better decision - making.

Currently, smart surveying with drones is widely used in various sectors, including:

1. **Construction and Civil Engineering:** Site planning, progress monitoring, and volume calculations.
2. **Agriculture:** Precision farming, crop monitoring, and irrigation management.
3. **Mining:** Mapping and monitoring mining operations.
4. **Urban Planning:** Smart city development and land-use planning.
5. **Environmental Monitoring:** Tracking changes in ecosystems and natural resources.

The use of drone technology has made surveying faster, safer, and more efficient, making it an essential tool in modern industries.

C. The future of smart surveying with drone technology is highly promising and continues to evolve with advancements in science and technology. Emerging technologies such as Artificial Intelligence (AI), Machine Learning (ML), and the Internet of Things (IoT) are expected to further enhance the capabilities of drone-based surveying systems.

Some potential future developments include:

1. **Autonomous Drones:** Fully automated drones capable of conducting surveys without human intervention.
2. **AI-Based Data Processing:** Faster and more accurate analysis of large datasets.
3. **Integration with IoT Systems:** Real-time data sharing and monitoring across connected devices.
4. **Improved Battery Life and Range:** Enabling drones to cover larger areas more efficiently.
5. **Advanced Sensors:** Use of improved LiDAR, thermal imaging, and multispectral sensors for better data collection.
6. **Real-Time Mapping:** Instant generation of maps and models during flight operations.

In the future, drone technology is expected to replace many traditional surveying methods and become the standard approach for geospatial data collection. It will play a crucial role in infrastructure development, disaster management, environmental conservation, and smart city planning.

Statement of the problem

1. Environmental & Site Conditions

- Wind and weather issues: Strong wind, rain, or fog can affect drone stability and image quality.
- Lighting conditions: Poor sunlight or shadows reduce accuracy of captured images.
- Obstacles on site: Trees, buildings, towers, and wires can disturb flight paths.

2. Accuracy & Data Errors

- GPS inaccuracies: Low-quality GPS signals can lead to incorrect positioning data.
- Image distortion: Camera calibration errors affect measurement accuracy.
- Ground Control Point (GCP) errors: Improper placement leads to wrong survey results.

3. Technical Problems

- Battery limitations: Drones have short flight time (20–40 minutes), limiting large area coverage.
- Signal loss: Communication between drone and controller may get interrupted.
- Hardware failure: Motor, propeller, or sensor malfunction can stop operation.

4. Data Processing Issues

- Large data size: High-resolution images require heavy storage and processing power.
- Software errors: Problems in Python-based or photogrammetry software can delay results.
- Time-consuming processing: Generating contours, DEM, or 3D models takes time.

5. Legal & Regulatory Issues

- Flight permissions required: In India, DGCA rules must be followed.
- Restricted zones: Cannot fly near airports, military areas, or urban zones without approval.
- Privacy concerns: Capturing images in public/private areas can raise legal issues.

6. Skilled Operation Requirement

- Need for trained operators: Improper handling may cause crashes.
- Survey knowledge required: Understanding of contouring, mapping, and coordinate systems is necessary.

7. Cost & Maintenance

- High initial cost: Drone, sensors, and software are expensive.
- Maintenance cost: Repairs and spare parts add extra expenses.

Methodology

1. Data Collection

In this project, aerial data is collected using a drone equipped with a high-resolution camera. The drone is flown at different altitudes and angles to capture multiple images of the survey area. Capturing images from various perspectives is important to ensure that all features such as terrain variations, objects, and boundaries are clearly visible. Special care is taken to maintain image clarity, proper lighting, and overlap between consecutive images, as these factors directly affect the accuracy of further processing.

2. Data pre-processing

After collecting the raw images, a pre-processing step is performed to improve their quality. This includes resizing the images to a uniform resolution, removing noise, and adjusting brightness and contrast levels. These operations help in making the images more consistent and suitable for analysis. Pre-processing can be considered as an "image cleaning" step, which ensures that unnecessary distortions do not affect the model's performance.

3. Dataset Labelling

In this stage, the collected images are manually annotated to mark important features such as object boundaries, terrain edges, and contours. This labelled dataset acts as the foundation for training the model. By marking these features, the system learns how to identify and differentiate between various shapes and regions in an image. Accurate labelling is crucial, as it directly influences the quality of model predictions.

4. Site Selection and Planning

Select the area to be surveyed and mark boundaries. Plan the drone flight path, altitude, overlap, and camera angle using flight planning software

5. Model Selection

For the purpose of image segmentation, deep learning models such as **U-Net** are selected. These models are highly effective in analyzing images at the pixel level. They classify each pixel into different categories, allowing precise detection of contours and boundaries. The selection of such a model ensures high accuracy in identifying terrain features from aerial images.

6. Model Training

The labelled dataset is then used to train the selected model. During training, the model learns patterns and relationships between image features and their corresponding labels. This process involves multiple iterations where the model continuously improves its predictions. Proper training ensures that the system can accurately detect contours and shapes even in complex environments.

7. Contour Extraction

Once the model is trained, it is used to process new images. The output generated by the model is further analyzed using tools like OpenCV to extract contours. This step helps in identifying object boundaries and terrain structures clearly. The extracted contours provide a representation similar to surface mapping, which is useful for surveying applications.

8. Depth Approximation

To enhance the system, depth estimation techniques are applied using multiple images or stereo vision methods. By analyzing differences between images captured from different angles, approximate distances and elevations can be calculated. This allows the system to perform terrain mapping and detect obstacles effectively, similar to LiDAR-based systems but at a lower cost.

9. Testing and Validation

The developed model is tested using new and unseen images to evaluate its performance. Accuracy, precision, and reliability are measured during this phase. If the results are not satisfactory, improvements are made by refining the dataset or retraining the model. This step ensures that the system performs well in real-world conditions.

10. Deployment on Drone System

Finally, the trained model is integrated into the drone system or ground control software. This enables real-time contour detection and analysis during flight operations. The deployed system can assist in applications such as land surveying, mapping, and obstacle detection, making the entire process faster and more efficient.

Hardware Components

1. Fly Sky FS-i6 2.4GHz 6CH AFHDS RC Transmitter
- Type: 6- Channel radio Transmitter with receiver
- Frequency: 2.4GHz
- Protocol: AFHDS (Automatic Frequency Hopping Digital System)
- Use in your drone: Remote control for manual Flight, mode switching, and triggering image capture.

2. Quadcopter Drone Combo with APM 2.8 kit
- These kits include:
- APM 2.8 Flight Controller (ArduPliot mega)-open-source autopilot
- Use in your drone: This quadcopter combo kit includes almost all parts for the basic quadcopter drone; it includes everything to make and fly your own quadcopter. The flight controller comes with this drone is APM 2.8 which is a very popular and stable flight controller.

3. Motors & ESCs (Electronics Speed Controller)

• Use in your drone: An electronic speed control (ESC) is an electronic circuit that controls and regulates the speed of an electric motor. It may also provide reversing of the motor and dynamic braking. These generate thrust to lift and move the drone.

4. Propeller

• Use in your drone: A drone propeller is a rotary fan or a spinning blade that is connected to a motor that produces lift & thrust by allowing the drone to fly, maneuver, and hover. The drone propeller works by using the motor force to rotate.

5. Frame (typically F450 or similar)
   - Use in your drone: The structural body of the drone that holds all components together.

6. Power Module (for battery voltage /current sensing)

7. Telemetry modules (optional, often included)

• Use in your drone: Telemetry modules generally operate using radio frequency (RF) communication, commonly in bands such as 433 MHz or 915 MHz.

8. GPS module (usually NEO-6M or NEO -8M)
   - Use in your drone: Used for determining the drone's position, altitude, and navigation.

9. ESP32-CAM
- Camera: OV2640 (2MP) or OV7670
- Processor: ESP32 (Wi-Fi + Bluetooth)
- GPIO pins: For triggering capture, External control
- Use in your drone: Multiple images at same location but different altitudes. Take images at 5m, 7m,9m,11m,13m. Compute Scale change of known object (e.g., landing pad)

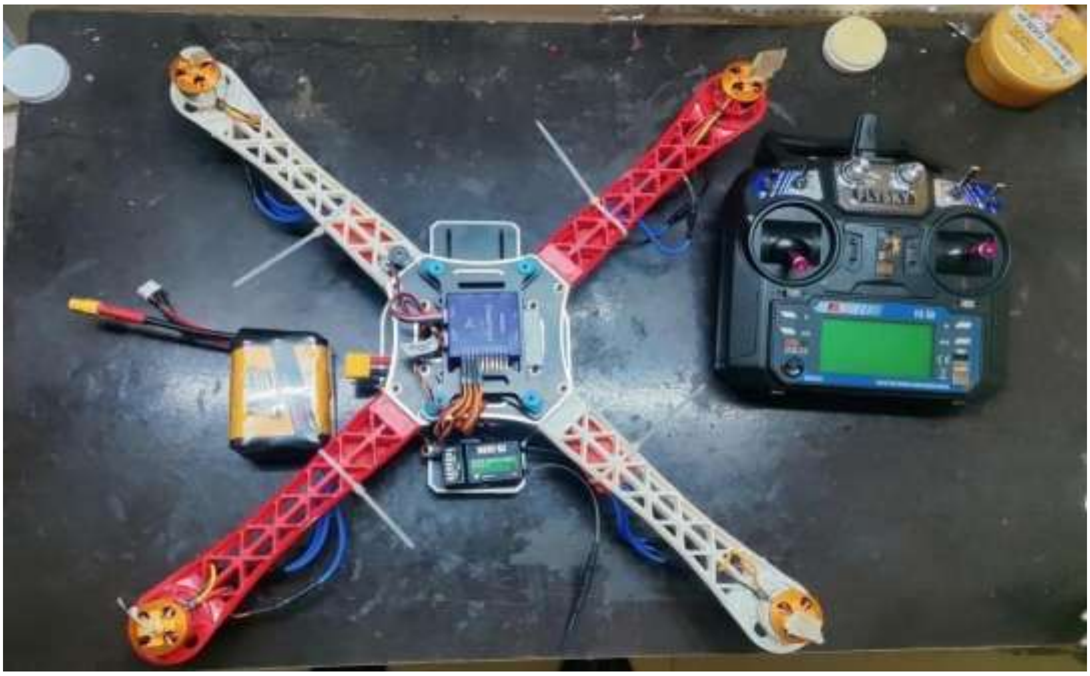


Figure. 2: Drones with remote controller

Software Tools

1. Arduino ide

The Arduino IDE is used for writing, compiling, and uploading code to microcontrollers used in the system. It provides a simple programming environment where embedded code is developed for controlling sensors, communication modules, and other hardware components. In this project, it is mainly used for interfacing and testing hardware modules such as telemetry, sensors, and control units.

2. Cloud Server – Firebase

Firebase is used as a cloud-based backend service for storing and managing real-time data. It allows the system to upload drone data such as GPS coordinates, images, and sensor values to the cloud. Firebase also provides real-time database functionality, which enables instant data synchronization between the drone system and user interface.

3. Cloud Storage – (Firebase Storage)

Cloud storage is used to store large files such as images and survey data collected by the drone. In this project, Firebase Storage is used to securely upload and access captured images. This ensures that data is not lost and can be accessed anytime for further processing and analysis.

4. Map API

The Map API is used to visualize the drone's location and survey area on a map interface. It helps in displaying GPS coordinates, flight paths, and marked boundaries. This improves user understanding of the surveyed area and allows real-time tracking of the drone during operation.

5. Camera X API

Camera X API is used for handling camera operations in Android-based applications. It simplifies image capture, preview, and processing. In this project, it is used to capture images from the drone or mobile device, which are then used for further processing such as contour detection and mapping.

Development and Data Collection

A. Software Implementation using Python
The image shows the execution of a Python-based application developed for the project "Smart Surveying with Drone Technology". The system is run using the "Windows PowerShell/Command Prompt" environment and demonstrates the backend operation of the developed software.
Some Process are followed in given software:

1. Environmental Setup
   - The process begins in Windows PowerShell, indicating that the system is being executed on a Windows operating system.
   - The user navigates to the project directory: C:\Users\Asus\Desktop\Drone
   - Python virtual environment (env)* is activated: env\Scripts\activate

2. Running the python Application
   - The main application file is executed: py app.py
   - This file acts as the core backend script of the system.
   - Observation:
     The message: model is loaded
   - Indicates that:
     A pre -trained model (possibly for image processing, contour detection, or measurement) is successfully loaded.

3. Flask Web Framework Execution

- The application uses the Flask framework, as shown: Serving Flask app 'app' Debug mode: on
- Flask is used to:

Create a web-based interface

- Display drone survey outputs such as:

Captured images
Measurements
4. Server Deployment Details

- The system runs on:

http://127.0.0.1:5000 http://192.168.137.129:5000

- Explanation: 127.0.0.1:5000

Localhost (access from same computer)
192.168.137.129:5000
Network IP (accessible from other devices in same network)

5. **Development Mode Warning**
WARNING: This is a development server. Do not use it in production deployment.

- Explanation:

Flask is running in debug mode

- Suitable for:

Testing
Development

- Not secure for: Large-scale deployment

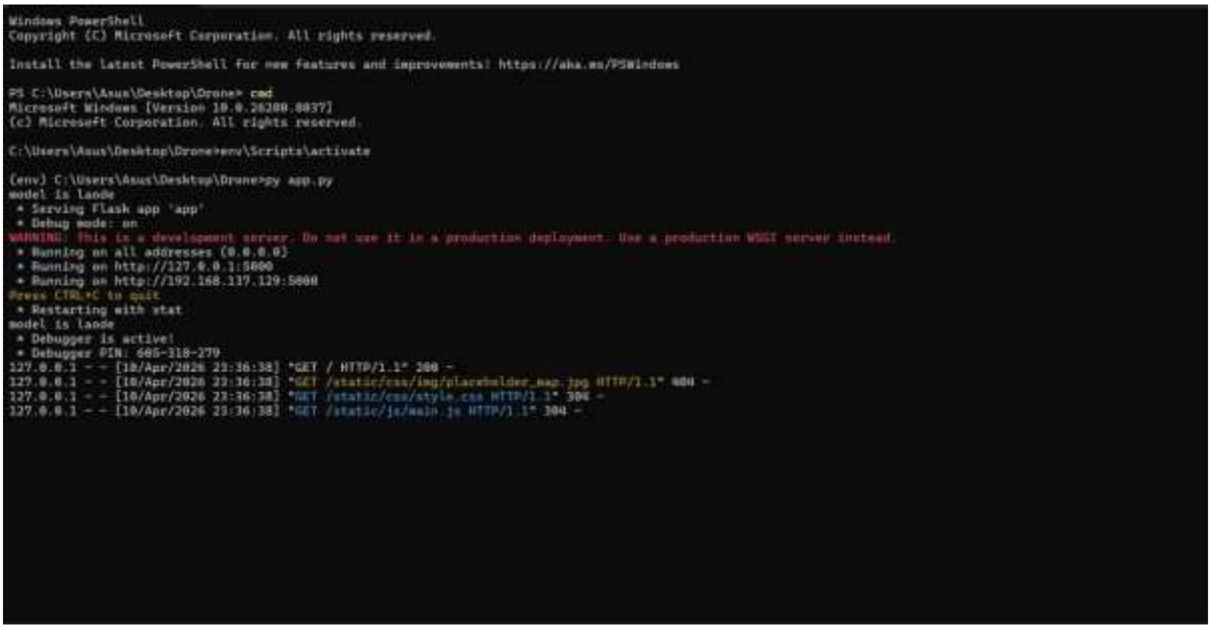


Figure. 3: Software Implementation using python

B. Software Interface

The image shows the web-based dashboard interface of the developed system titled "Drone opt – Dashboard", which is designed for Smart Surveying using Drone Technology. This interface is built using Python (Flask backend) along with HTML, CSS, and JavaScript for frontend interaction.

1. Web Application Overview

- The application is running on:

http://127.0.0.1:5000

- This indicates:

The system is hosted locally using a Flask server. The interface is accessible through a web browser.

2. Left Panel – Control Section

This section allows the user to configure and control the drone camera.

Parameters

- Camera IP: 192.168.1.9 IP address of the drone camera

- Port: 8 0

Communication port

- Stream Path: /stream

Used for live video streaming

- Snapshot path: /Capture

Used to capture images

- Poll(sec):0.2

Time Interval for refreshing frames

- Control buttons: Start Stream / Stop Stream

Starts or stops live video feed from drone

- Take Snapshot

Captures a still image from the drone

- Record (10s)

Records video for 10 seconds

- Additional Settings

Record Duration: 10 seconds
FPS: 10 frames per second
Flash ON Path: Used to control camera LED/flash (useful in low light)

3. Centre Panel – Live Display Area

This large black section is meant for: Live video stream from drone or displaying captured images.

4. Right Panel – Tools Section

This section provides advanced data processing features.

- Contour / Render Tool

Button: Send to Contour API

- Output

Contour result preview

- YOLO Detection Tool Button: Run Detection

Function: Uses YOLO (You Only Look Once) algorithm, Detects object in captured drone images.

5. Role in Smart Surveying System

This dashboard represents the complete integration of drone hardware and software system.

- Workflow:

1. Drone captures live data
2. Data is streamed to the web interface
3. User captures images or videos
4. Backend processes data using: Contour mapping, YOLO detection 5. Results are displayed on dashboard

6. Importance in Data Collection Enables real-time data acquisition

Reduces manual surveying effort
Provides: Instant visualization, Automated analysis

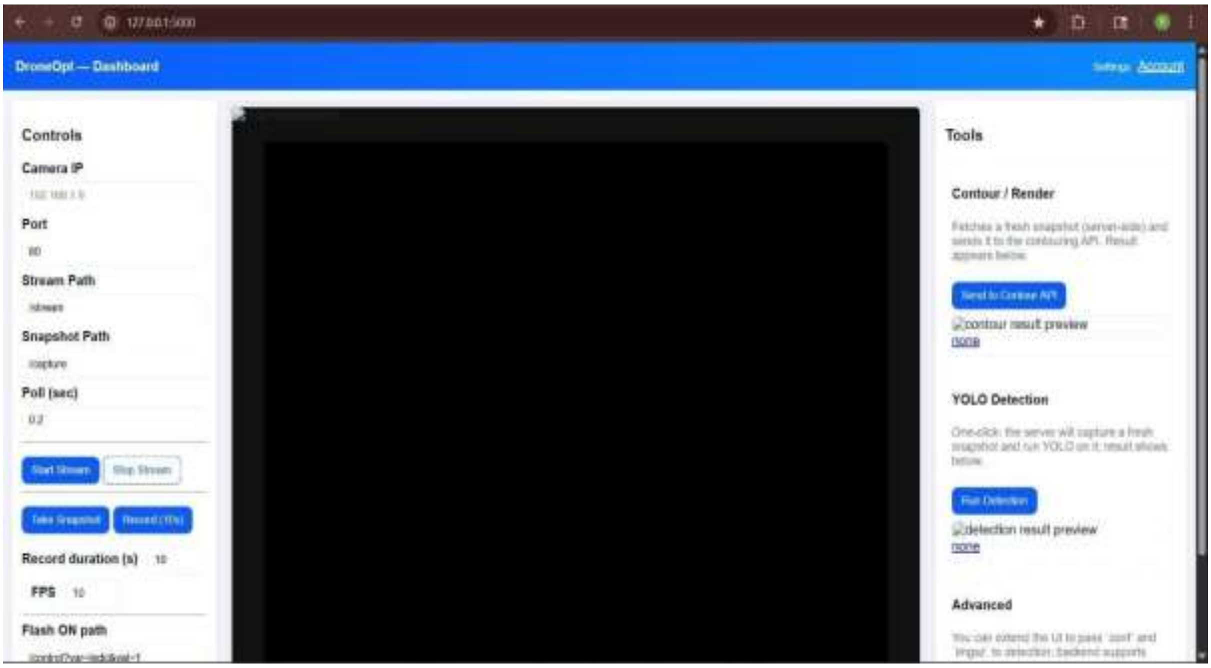


Figure. 4: Software Interface

Conclusion

i. The image represents the functional user interface of the developed drone surveying system.
ii. It provides tools for real-time video streaming, image capture, and intelligent data processing using contour mapping and YOLO-based object detection.
iii. This interface significantly enhances the efficiency, accuracy, and automation of modern surveying techniques.

Result and Analysis

1. Introduction of Result

This chapter presents the results obtained from the implementation of the smart drone surveying system. The system was tested for image capture, contour detection, mapping accuracy, and data transmission. The performance of each module is analyzed in detail.

2. Data Collected from Drone

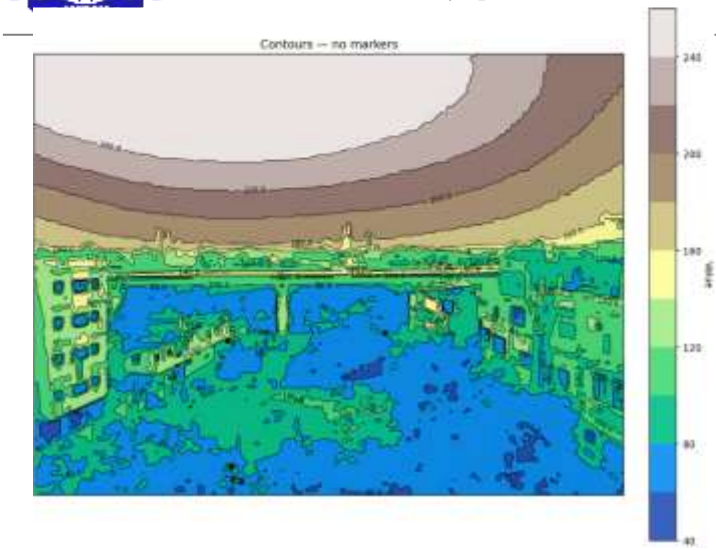
The Drone was Used to Capture high- Resolution aerial images of the survey area. The collected data includes spatial coordinates, which were further processed using python-based software.

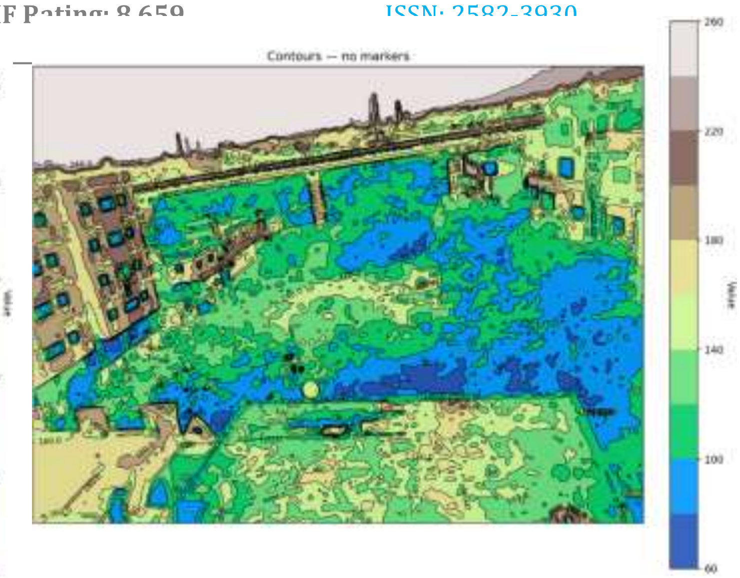
3. Data Processing (Software Output)

i. Image Processing (Python)
ii. Contour generation
iii. Object Detection (AI)

4. Final Output

i. Contour Detection
ii. Object Detection
iii. Accuracy Comparison





5. Contour Detection Result

A. Contour Map

The above contour map represents the elevation distribution of the surveyed area generated using drone data. The contour lines indicate different height level, with values ranging from low (blue region) to high elevation (brown region). The smooth variation shows accurate terrain modelling without noise, which is useful for land analysis and planning.

i. Elevation Levels using Contour lines
ii. Smooth Gradient (40-240 values approx.)
iii. No markers – Clean terrain model

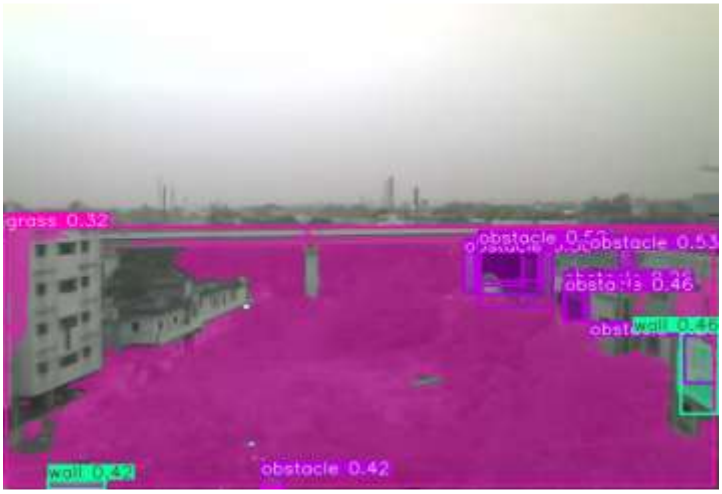


Figure 5. Contour Detection Mapping

Figure 6. Object Detection Mapping

B. Object Detection (AI Output)

The above image represents the AI-based object detection system integrated into the drone surveying process. The model successfully identifies features such as grass, walls, and obstacles with confidences scores. This helps in automatic feature recognition, reducing manual effort and improving survey efficiency.

i. AI detecting: Grass, Obstacles, Walls

6. Limitation

The system performance is affected by environmental conditions such as wind and lighting. Additionally, battery limitations restrict long-duration surveys.

- Weather dependency
- Limited battery life

7. Comparison Table

Features	Traditional survey	Drone survey
Time Required	High	Low
Cost (long term)	Medium	Moderate
Accuracy	Medium	High
Area Coverage	Limited	Large
Human effort	More	Less

Analysis of Result

The performance of the proposed smart drone surveying system was analyzed based on various parameters such as speed, accuracy, efficiency, and ease of operation. The analysis highlights the advantages of drone-based surveying over conventional methods.

1. Faster Surveying Compared to Traditional Method

The results clearly show that drone surveying significantly reduces the time required for data collection. Unlike traditional surveying methods, which involve manual measurements and require more manpower, the drone can cover a large area within a short duration. The automated flight path and continuous image capture allow rapid data acquisition. This makes the system highly suitable for projects where time is a critical factor.

2. Higher Accuracy Due to Digital Data Processing

The system provides improved accuracy as it relies on digital image processing and automated algorithms. The use of GPS data and image-based contour detection reduces human errors that are common in manual surveying. Additionally, software tools and models ensure consistent and precise identification of boundaries and terrain features. Although it may not fully match high-end equipment like LiDAR, the achieved accuracy is sufficient for most practical applications.

3. Reduction in Manual Work

One of the major advantages observed is the reduction in manual effort. Traditional surveying requires field personnel to physically measure distances and mark points, which is time-consuming and labour-intensive. In contrast, the drone performs automated data collection, and most of the processing is handled by software. This minimizes human involvement and reduces the chances of errors.

4. High Efficiency for Large-Scale Areas

The system is highly efficient when used for large survey areas. The drone can easily access difficult or unsafe locations, such as uneven terrain or construction sites. With proper flight planning, large regions can be surveyed in a single flight. This improves productivity and makes the system more suitable for modern surveying requirements.

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