Pioneering UAV Autonomy: Advancing 3D Modeling

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Abstract

This project aims to solve a critical limitation in Unmanned Aerial Vehicle (UAV) technology that requires drones to fly at higher altitudes to avoid collisions with objects. This constraint prevents UAVs from capturing detailed images close to buildings or other structures, significantly impacting the quality of 3D models and the effectiveness of obstacle avoidance systems.

This research focuses on developing advanced autonomous flight planning techniques that enable UAVs to navigate closer to structures while avoiding obstacles. By refining UAV operational capabilities and integrating sophisticated pathfinding methods, the goal is to enhance the accuracy and detail of 3D modeling. This work aims to create a system that supports dynamic altitude adjustments, allowing UAVs to maintain safe distances from obstacles while capturing high-resolution images.

Introduction

Initially, a scan of the Austin Building was conducted from a static height of 33m to capture detailed images for creating a 3D model and developing a precise flight plan. However, to ensure the safety of the UAV’s camera and validate the methods without risking equipment damage, the generated flight plan was not immediately tested in this complex environment. Instead, testing was relocated to a more controlled setting—a tent situated in the middle of an empty field. During the first flight in this new location, essential data was gathered, which was then used to generate a refined flight plan. This subsequent flight plan was tested to evaluate the UAV's navigation.

Figure 1.
3D Model of SFA Austin Building

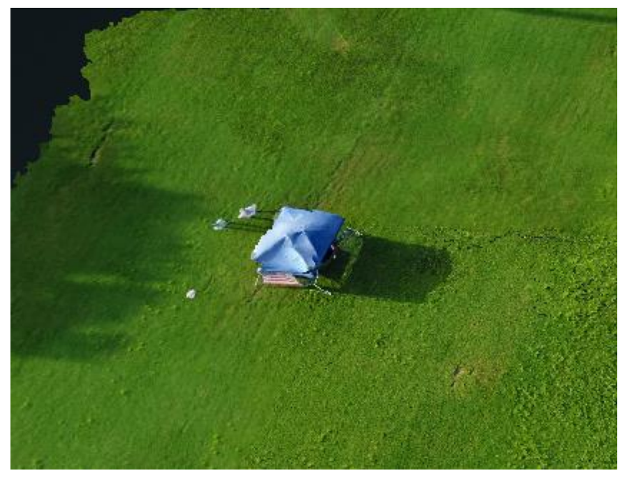

Figure 2.
3D Model of Tent at SFA intermural field

Development Tools and Tasks

Map Pilot Pro: Used for initial flight planning and drone control, providing a simple interface for creating and uploading flight plans to drone.
OpenDroneMap (ODM): Used for processing drone images into detailed 3D models and creating point cloud files.
ArcGIS Pro: Utilized for creating and visualizing 3D models and buffer zones, offering advanced GIS capabilities.
Python: Used for developing scripts to analyze data, find intersecting points, and convert coordinate systems.

Methodology

The approach to enhancing UAV flight planning and 3D modeling involved several steps:

1. **Initial Scan and Analysis:**
   - Conducted a standard height scan using UAVs to establish a baseline for object heights and 3D Modeling accuracy.
2. **3D Buffer and Fishnet Creation:**
   - Utilized the data from the first scan to create a 3D buffer around the area of interest, to avoid potential obstacles.
   - Generated a 2D fishnet grid on the ground over the area where the flight was to take place for detailed spatial analysis.
3. **Intersection Analysis:**
   - Developed code to find highest intersecting points between the 2D fishnet grid and the 3D buffer. These intersecting points determined where the drone would fly to avoid obstacles.
4. **Data Conversion and Formatting:**
   - Used additional code to convert the data from the intersection analysis to the correct coordinate system and format it properly for use in the drone’s flight plan.
5. **Field Tests:**
   - Executed multiple flight tests using the refined flight plans to compare planned vs. actual flight paths and assess the impact on 3D model quality.

Intersection Finder

Coordinate Converter

Real-Life Use Cases

The advancements in UAV flight planning and 3D modeling have significant implications across various fields:

- **Energy Sector:**
  - Drones can inspect power lines, pipelines, and wind turbines up close, identifying potential issues and enabling preventative maintenance without the need for costly and hazardous manual inspections.
- **Agriculture:**
  - Improved UAV navigation can enhance crop monitoring and management.
- **Urban Planning:**
  - Urban planners can benefit from detailed 3D models of cityscapes to make informed decisions about infrastructure development, traffic management, and public safety.

Results

1. **Initial flight of Austin Building:**
   - The scan from a static height produced detailed images that facilitated the creation of a comprehensive 3D buffer. However, due to safety concerns, the flight plan generated from this data was not immediately tested.
2. **First Test Flight in Field:**
   - Conducted in a controlled environment featuring a tent, the initial flight yielded essential data. The UAV successfully captured images, which were subsequently processed to generate a refined flight plan.
3. **Flight Plan Testing:**
   - The flight plan derived from the tent data was tested. However, the UAV did not follow the expected path, indicating that the 3D buffer created was not detailed enough, likely due to the small size of the tent. This highlighted the limitations of the current modeling process in accurately representing smaller objects.
   - To address these limitations, future testing on larger structures will be required. This will help ensure that the 3D buffer and flight plans are detailed and accurate enough for reliable UAV navigation.
4. **Software Limitations:**
   - Given that there is an adjust height for terrain option, MPP likely supports variable height flight plans. However, something prevented the flight from using the altered heights. This may be due to a subscription level issue or a missing header option to turn on non-level flight. The exact cause is unclear, as editing the flight plan outside their GUI is an undocumented feature. With another two weeks, more work could have been done on this, but initial ArcGIS Pro software issues reduced the available timeframe.

Future Improvements

- The current software, Map Pilot Pro, does not support variable height flight plans. To allow for dynamic altitude adjustments, it is necessary to switch to a more advanced flight planning software that can accommodate variable heights.
- To further mitigate the risk of edge collisions, the code should be updated to detect potential collision points. If a potential collision is identified, the system should automatically generate an additional flight point that pulls the UAV outside the buffer, ensuring a safe distance from the structure.
- After successfully implementing variable height flight plans, the next step would be to develop a system where the UAV's camera consistently points at the structure being scanned. This improvement will enhance the quality and detail of the captured images, providing better data for 3D modeling.

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