Construction Earthwork from Small Imprecise Non-Metric Cameras (Photogrammetry Unit)

The NCDOT Photogrammetry Unit is testing recent computer vision advances called Structure from Motion (SfM) to generate elevation data for construction earthwork quantity validation as a pilot program on new location projects. Due to small imprecise cameras on UAS (drones), significantly more images must be processed as compared to a large format mapping camera on a manned aircraft. SfM software can semi-automatically generate elevation data from UAS images which can be used to validate construction earthwork quantities while saving time and providing more accuracy than truck counts.

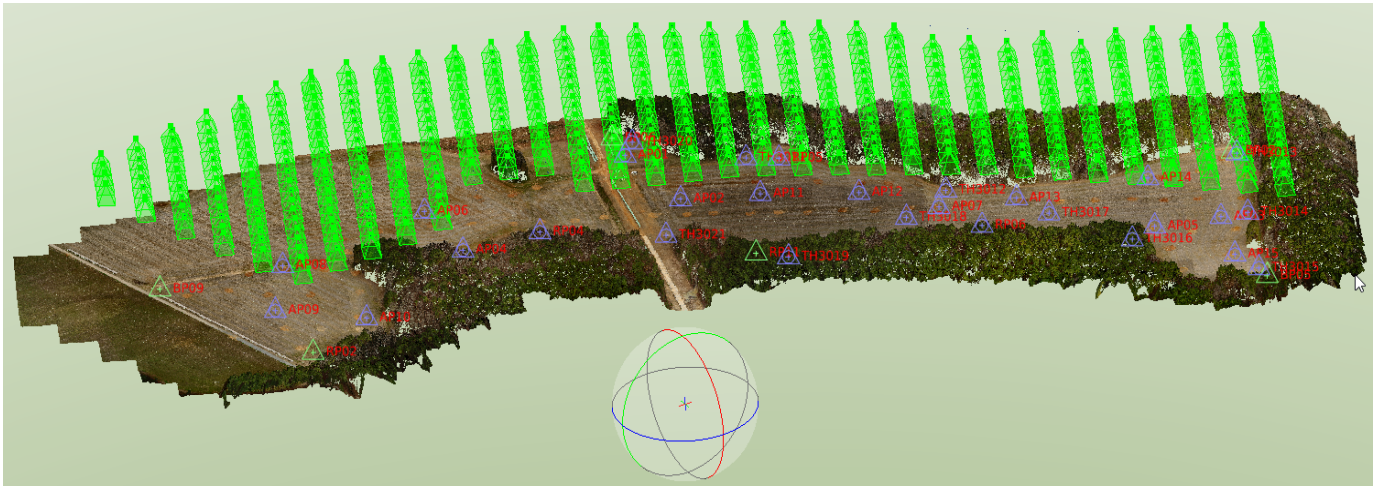

FIG.1: R-2582A ROBINSON 2 PIT - ORIGINAL FLIGHT DENSE POINT CLOUD, CONTROL POINTS, CHECK POINTS, & NADIR FLIGHT LINES

NCDOT BUSINESS UNITS

- Photogrammetry Unit
- Division Resident Office

PRODUCTS PRODUCED

Classified Point Cloud – A point cloud is a set of ultra-high dense data points, each defined with a horizontal X and Y coordinate and an elevation (Z coordinate), that are tied to a known coordinate system. Point clouds are collected to represent the external surface of an object. UASMaster is a stand-alone SfM product that performs photogrammetric processing of non-metric camera digital images and generates 3D spatial data in the form of a point cloud to be used in different applications. This ultra-high dense point cloud can be classified to extract ground elevations. Tools found in the ArcGIS software allow a user to add attributes to the unclassified spatial data that breaks it into different classifications. While there may be many different classes that the data can be broken down into, the NCDOT Photogrammetry Unit defines the points into one of two classes: ground and not ground. Once all data has been moved into one of these classes, the ground data is used to create both a 1.0 foot and 2.5 foot Digital Elevation Model (DEM) that now represents the ground as seen in the imagery.

Below is an example of what a classified point cloud looks like when viewed in a 3-D environment.

FIG.2: R-2582A WILLIFORD PIT - INTERMEDIATE FLIGHT CLASSIFIED POINT CLOUD

1-foot & 2.5-foot DEM- Gridded DEM generated from the Classified Point Cloud with areas identified as bare earth.

Orthophoto – An orthophoto is an accurate image map with horizontal coordinates produced with mosaicked UAS images that have been corrected for tilt and relief displacement using camera position and attitude and elevation data.

AGOL Swipe Map -This tool uses different dates of orthophotos that allows the user to do a visual comparison of the original flight and one of the intermediate or final flights by simply moving the slide bar to see how the pit has changed between flights. Click here to see the interactive swipe map of the Williford Borrow Pit Site.

FIG. 3: R-2582A WILLIFORD BORROW PIT - AGOL SWIPE MAP

UAS PLATFORM

- **Aircraft** - Inspire2
- **Camera** - DJI Zemuse X4s
- Flight Management Software – DJI GS-pro
- Airborne GPS System – Airgon LOKI

Requirements

- **Operator Training/Certification:** FAA Part 107 Remote Pilot Certification, Certificate of Authorization (COA), FAA Part 137 Authorization.
- **North Carolina (NC) Registered Professional Land Surveyor (PLS):** These procedures and products must be done under the responsible charge of a licensed North Carolina Professional Land Surveyor. See North Carolina Engineering and Land Surveying Act (NCGS 89C-3(7).a.5) and Board Rules (21 NCAC 56 .1606).

UAS PHOTOGRAMMETRY COMPARED TO TRADITIONAL PHOTOGRAMMETRY METHODS

Traditionally there are two methods used to calculate construction earthwork quantities. One method that contractors typically use are truck counts, which can be inaccurate. The second method is the use of a conventional photogrammetric workflow in which a large format mapping camera acquires aerial imagery using a manned aircraft and a stereo compiler manually collects elevation data by placing break lines and mass points over the terrain. While the conventional photogrammetric method may take more time than the semi-automated SfM approach with non-metric camera imagery, it is time tested and has proven to always be accurate, especially in project areas where heavy shadows, extreme breaks in terrain, or obscured areas exist and the SfM elevation data is less accurate due to its inherent automated approach.

Photogrammetry Unit testing has proven that UAS derived digital data does produce highly accurate elevation data that is ideal to use on bare earth construction sites and borrow pits. Monthly flying of construction sites, borrow pits, or stockpiles with UAS and SfM post processing to monitor the amount of material moved can replace truck counts and provide more accurate volumetric data. On sites that are conducive, utilizing UAS technology has proven to be yet another valuable tool for acquiring accurate digital elevation data in a timely and cost-effective manner.

EFFECTIVENESS

UAS and non-metric camera SfM are very effective for small project areas where the open ground can be seen. Bare earth sites, such as construction areas, borrow pits, and stockpiles are ideal candidates for UAS aerial imagery collection. SfM software such as UASMaster allows easy modeling of target areas using aerial imagery captured by the UAS. UAS can even work effectively in conditions where the manned systems are not able to function safely, such as a day with low and overcast clouds. However, the UAS can be ineffective in areas with shadows and vegetation. Using methods and procedures that have been developed over the past few years, allows production of high-quality geospatial products with root mean square error (RMSE) values of equal to or less than 0.12 foot in the horizontal (X & Y) components and 0.18 foot in elevation (Z).

Independent Checkpoint Accuracy
6 GCP + Exposure Stations

	Point ID	X error (ft)	Y error (ft)	Z error (ft)
No. Points =		29	29	29
Min (ft) =		-0.051	-0.076	0.028
Max (ft) =		0.137	0.067	0.118
Mean (ft) =		0.026	0.002	-0.027
Std Dev (ft) =		0.051	0.039	0.080
RMSE (ft) =		0.056	0.038	0.084
FVA (ft) =				0.164
RMSE R (ft) =		0.068		
Case 1 95% CE(ft) =		0.118		
Case 2 ~ CE(ft) =		0.116		

No GNSS Block Shift applied

EFFICIENCY

UAS provide more flexibility for aerial imagery collection over small project areas at a lower cost than manned aircraft collection. Semi-automated SfM processing generates accurate geospatial products for bare earth sites in less time as compared to other processes such as ground based surveys and traditional large format camera photogrammetry. However, FAA rules governing UAS define operational limits such as permissible hours of flight, line-of-sight observation, and altitude. These operational limits also restrict flying a UAS over people not participating in the aerial survey or UAS mission and over moving vehicles on transportation facilities which is the case for NCDOT preconstruction projects.

SAFETY

When utilizing a UAS, for the safety of NCDOT personnel and for other people on site, a request is made for all work in the area to be discontinued for the duration of the flight. This will also allow landing of the UAS with minimal interference and avoid any damage in case of an emergency. In addition, this allows the non-metric camera to capture data from a non-dynamic scene thus avoiding potential image matching issues during processing.