Streamlining unmanned aerial systems image post-processing using Pix4D, Quantum Geographic Information System, and the System for Automated Geoscientific Analysis grid volume algorithm

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Introduction

In an effort to stimulate collaborative research between faculty and students, the Regent Scholar program was introduced at the Universities in Wisconsin through the Research, Economic Development, and Innovation (REDI) Committee to help foster the growth of undergraduate research. Dr. Joseph Hupy was awarded this grant to continue his research in unmanned aerial systems (UAS), industrial sand and aggregate mining operations currently estimate operations outputs by using imagery products derived from either manned aircraft flyovers or by performing traditional ground-based surveys. These two techniques are costly, labor intensive, and are sometimes inaccurate. This research collaboration specifically will involve the use of UAS to capture imagery of an undiscovered sand mine located in Western Wisconsin. This imagery will then be post-processed using Pix4D software to generate high precision, three-dimensional (3D) product derivatives to facilitate the volumetric analysis of the removed sand material. A unique partnership with Martin Goetti, One of the only companies in the state with a commercial UAS pilot license, will provide UAS imagery with highly precise horizontal and vertical coordinates captured from a UAS. Pix4D will then be used to generate an orthomosaic and digital surface model (DSM) as well as georectified images in March, 2016 without ground control points (GCPs) to images taken in October, 2015 with GCPs. Root Mean Square Error (RMSE) will be used to quantify the accuracy of the October images. This study hopes to reduce the time and labor intensive post-processing workflow of images in the lab using Quantum Geographic Information Systems (QGIS). Image post-processing will be further reduced through the creation of a custom python script to streamlining the repetitive extraction of sand aggregate pile volume.

Data Preparation & Study Area

Application of UAS for use in the mining and earthworks surveying industries is prudent because of the recent reduction in costs, quick temporal deployment, and accuracy of the captured imagery (Watts et al. 2012). Current methods of measuring aggregate stockpiles for large operations involve either costly manned flights with attached light intensity detection and ranging (LiDAR) sensors to generate DSMs or time-intensive ground-based surveys using a terrestrial laser scanning (TLS) unit such as a Total Station with a real-time kinematic (RTK) GPS unit. Smaller scale operations use GPS units and an inaccurate huck tattle system where the volume of removed gravel is estimated by calculating weight divided by density (Hugenholtz et al. 2014). Advances in autostop features on UAS allow for the pre-planning of flights based on course speed, altitude, photo overlap, and number of photos needed per distance traveled (Goettl et al. 2014). The study was conducted at two time stamps a mine located in the southwest of Eau Claire, Wisconsin (Figure 1): one on October 10th, 2015 and the second on March 13th, 2016.

Works Cited


Data Analysis

After the flights were finished post-processing in Pix4D, estimation of the resulting RMSE (Figure 8 & right) was calculated for four October GCP’s (Table 2 – right). The October, 2015 flight used GCPs and was measured with the highly accurate RTK GPS unit, resulting in a horizontal and vertical RMSE error of a few centimeters. Comparatively, the March, 2016 flight was georectified with features that did not move between flights. Volume from the eight pre-digitized piles were then employed using the SAGA grid volume algorithm in QGIS. A model was created in QGIS to automate the estimation of the base elevation plane and was subsequently exported as a python script. This script was customized to output files to a specific directory without the need to change each individual input/output path (Figure 9: below). The workflow is included in Figure 9 (below). Further customization of the script is necessary to save the output consiste of a text file and iterate over each digitized pile. The entire process was then estimated using the Pix4D report and a python script (Table 4).

Volume Model Steps

1. Digitize a polyline around the pile of sediment.
2. Import OLS, QGIS, and Processing Python libraries
3. Center the line to a pile.
4. Clip the DSM with the polygon.
5. Buffer the polyline with .05 cm.
6. Clip DSM with buffered polygon.
7. raster stats on clipped DSM to get the mean base elevation (saved to text file).
8. Input clipped DSM and mean base elevation into SAGA grid Volume tool.

Table 2: Comparison of the two platforms used to view the October and March Flights.

Figure 5: Orthophotos taken by the commercial UAS, images displayed with the automated tool in Pix4D, and the USGS product.

The 312 overlapping UAS JPG images from October, 2015 were imported into Pix4D along with the coordinates of four GCPs recorded with an RTK GPS unit (Figure 2-top right). The remaining four GCPs will be used to calculate RMSE. The horizontal coordinate system was set to the World Geodetic System 1984 (WGS84) Universal Transverse Mercator (UTM) Zone 15 to align with the onboard UAS GPS and RTK GPS. The vertical coordinate system was set to mean sea level (MSL) WGS84. Initial processing was run to georectify the images. The next step included using the GCP/manual tie point manager to further correct the 3D product. The final two steps generated a point cloud and mesh along with a DSM, orthomosaic, and processing report. The DSM and orthomosaic were subsequently added to QGIS and the eight pre-digitized piles of sand were digitized (Figure 3-top right). The same workflow was then applied to the orthomosaic imagery captured in March, 2016 (Figure 4-bottom right). The only difference was employing arbitrary GCPs on features that did not change between the two time stamps instead of using coordinates from the RTK GPS to generate the March DSM (Figure 3-bottom right). A visual of the GCPs can be viewed from examples from Figure 4 (top right) and Figure 7 (top right). Platform parameters can be viewed in Table 1 (for bottom right). The new piles were then again digitized and volume was extracted using the SAGA Grid Volume algorithm. The piles for both time stamps were then used as inputs in the System for Automated Geoscientific Analysis (SAGA) grid volume algorithm to calculate the amount of material above an estimated plane.

Conclusions

By employing UAS to capture images of sand and fracking operations in Western Wisconsin, frequent temporal deployment can measure these earthwork operations. Post-processing the georectified images without using an RTK GPS unit to measure GCPs can be accomplished using arbitrary GCPs; however the accuracy of the resulting images is depreciated. Although set-up time without GCPs can be decreased, the reduced accuracy of the 3D products is significant enough to warrant GCPs in future studies. The study accomplished the streamlining of the post-processing workflow by creating a customized Python script to automate the volume calculations using SAGA Grid Volume. Additional work on this script is necessary to completely automate both the digitization of piles and iteration over each subsequent pile.

Acknowledgements