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 to 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 operational 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 using UAS to capture imagery of an undisclosed 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 Menet Aero, 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 georectify images taken 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 time will be further reduced through the creation of a custom python script to streamline 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 images (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 haul ticket system where the volume of removed gravel is estimated by calculating weight divided by density (Hugenholtz et al. 2014). Advances in autopilot features on UAS allow for the pre-planning of flights based on craft speed, altitude, photo overlap, and number of photos needed per distance traveled (Hugenholtz et al. 2014). The study was conducted at two time stamps a mine located to the southwest of Eau Claire, Wisconsin (*Figure 1*): one on October 10th, 2015 and the second on March 13th, 2016.

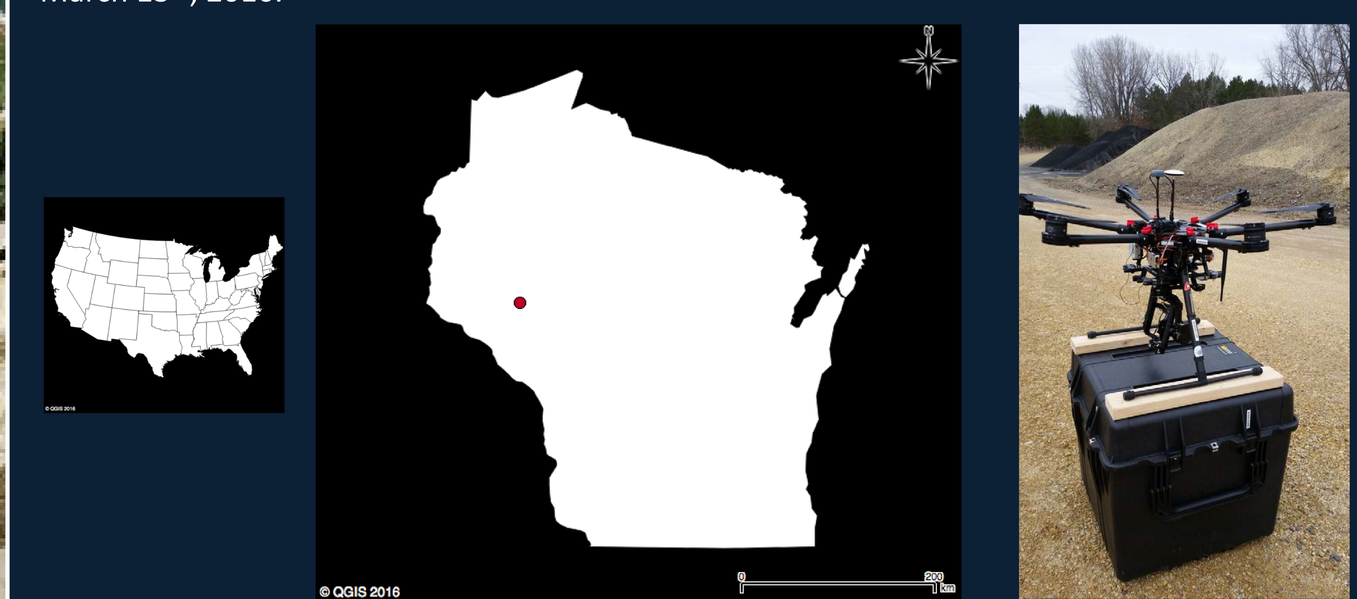

Figure 1: (From left to right) A map of the continental 50 states, a map of Wisconsin with the Litchfield Mine in red, and the UAS platform.

The 312 overlapping UAS JPEG 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 and 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 was subsequently added to QGIS and the eight predefined piles of sand were digitized (*Figure 3-top right*). The same workflow was then applied to the orthomosaic imagery taken 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 5-bottom right*). A visual of the GCPs can be viewed in examples from *Figure 6* (*top right*) and *Figure 7* (*top right*). Platform parameters can be viewed in *Table 1* (*far 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.

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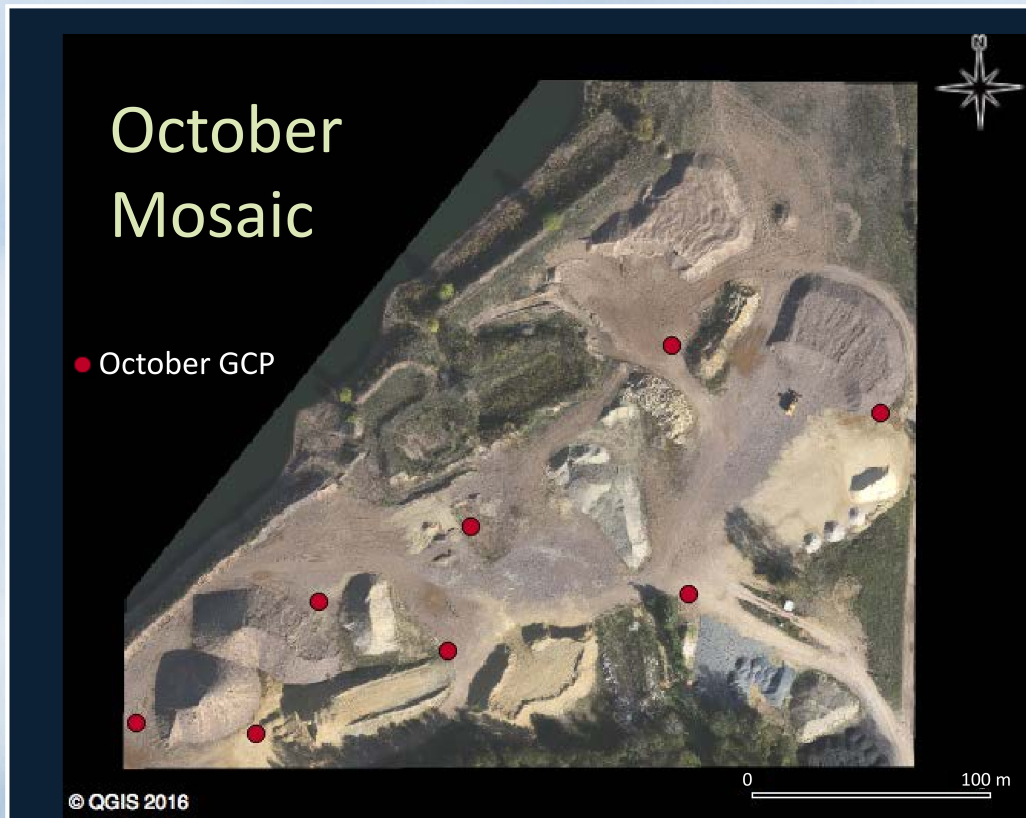

Figure 2: Pix4D orthomosaic from the October 10th, 2015 flight with ground control points.

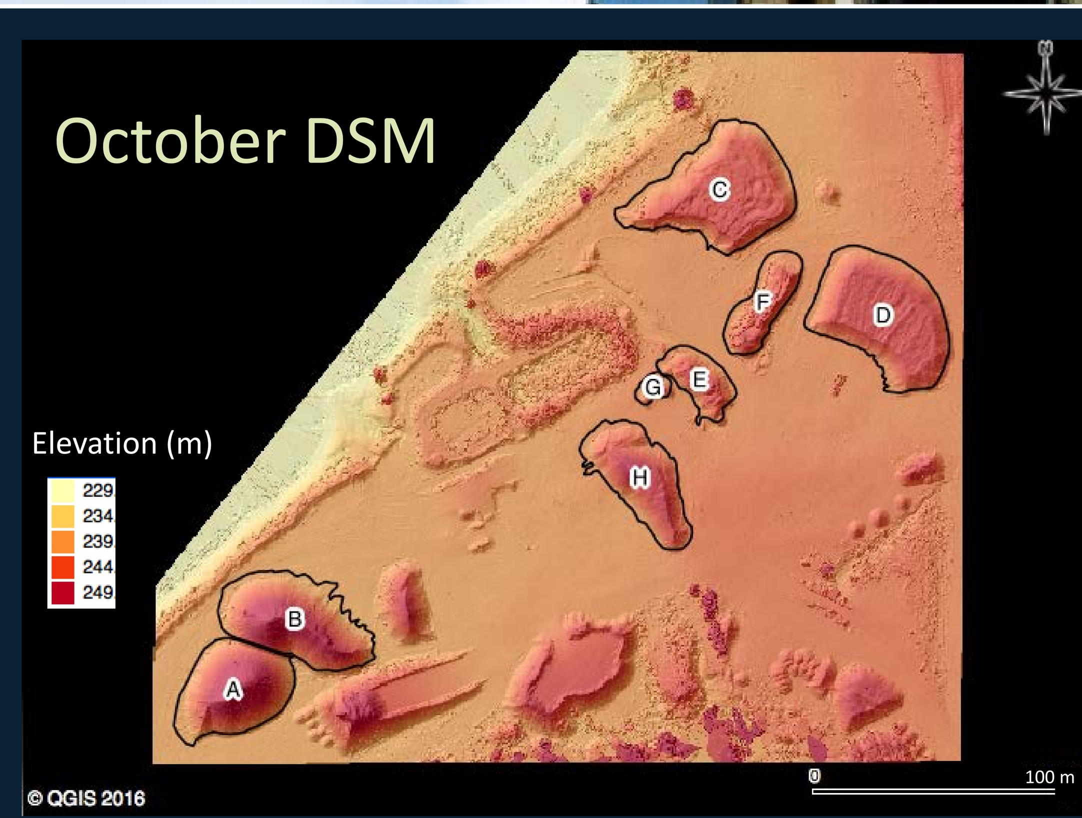

Figure 3: DSM and digitized piles from the October 10th, 2015 flight with ground control points.

Figure 4: Pix4D orthomosaic from the March 13th, 2015 flight using GCPs from features that didn't move.

Figure 5: DSM and digitized piles from the March 13th, 2016 flight with arbitrary ground control points.

Figure 6: The October flight employed eight plastic GCPs to facilitate the georecitification of the images in Pix4D.

Figure 7: In order to reduce set-up time, no plastic GCPs were used in the March flight. Features that didn't change between the two flights were used instead to georectify the images in Pix4D.

UAS Platform Parameters

Flight Date	October, 2015	March, 2016
Image Resolution (mp)	24	12
Camera Name	ILCE 6000 EPZ16 50mmF3.5-5.6OSS_16.0_6000x4000	Voigtlander 15mm lens
Camera Height (Ft)	200	200
Camera Dimensions (mm)	23.333 x 15.556	49.600 x 33.129
Pixel Resolution (cm/pixel)	1.66	2.43
Computer Processing Specs (GB RAM)	64	64

Table 1: Comparison of the two platforms used in the October and March flights.

Data Analysis

After the flights were finished post-processing in Pix4D, estimation of the resulting RMSE (*Figure 8- right*) was calculated for four October GCPs (*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. Volumetrics on the eight predefined 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 console to a text file and iterate over each digitized pile. The entire time was then estimated using the Pix4D report and a phone clock (*Table 4*).

October GCP Error Report

GCP	X Image	X GCP	X Error	Y Image	Y GCP	Y Error	Z DSM	Z GCP	Z Error
102	613051.13	613051.17	-0.04	4958843.4	4958843.4	-0.01	234.98	234.87	0.11
103	612993.14	612993.16	-0.02	4958814.6	4958814.6	-0.04	234.47	234.31	0.17
105	612968.81	612968.82	-0.02	4958764.1	4958764.1	0.01	234.32	234.53	-0.21
107	613134.75	613134.78	-0.02	4958817.4	4958817.4	0	236.31	236.22	0.09

Table 2: The horizontal and vertical error for each GCP in the October flight.

$$RMSE_x = \sqrt{\sum_{i=1}^{n} \frac{(X_{Act\,i} - X_{Obs\,i})^2}{n}} \quad RMSE_y = \sqrt{\sum_{i=1}^{n} \frac{(Y_{Act\,i} - Y_{Obs\,i})^2}{n}} \quad RMSE_z = \sqrt{\sum_{i=1}^{n} \frac{(Z_{Act\,i} - Z_{Obs\,i})^2}{n}}$$

$$Total\ RMSE = \sqrt{RMSE_x^2 + RMSE_y^2 + RMSE_z^2}$$

Figure 9: The RMSE equations used to estimate error.

SAGA Volume

Flight Date	October, 2015	March, 2016
QGIS SAGA (m^3)		
Pile A	5039.54	5006.42
Pile B	5650.96	5502.21
Pile C	5442.93	2403.46
Pile D	4800.45	2882.99
Pile E	842.73	821.85
Pile F	997.99	973.81
Pile G	90.24	88.29
Pile H	2749.81	2787.91

Table 3: The volume in cubic meters of each designated pile.

Time Report

Flight Date	October, 2015	March, 2016
Time (minutes)		
Setup	30m	15m
Flight	10m	10m
Initial Processing	72m16s	35m 21 s
Point Cloud	65m18s	57m 01s
DSM Generation	17m52s	26m04s
Orthomosaic	49m25s	58m53s
Volume Model	30m	30m
Total	294m51s	232m19s

Table 4: Total start to finish time estimating volume.

```python
help.py  help2.py  test3.py  test4.py  volcalc.py
import os
import sys
import processing

#set the directory
os.chdir('/Users/davidleifer/Desktop/qgis_python_prog/model-builder')

#set the variables#
#dsm of the mine site
a_dsm = QgsRasterLayer("a_dsm/flight2_(12mp_200ft)v4_dsm.tif", "Mine DSM")
if not a_dsm.isValid():
    print "Layer %s did not load" % a_dsm.name()
#poly line digitized around the pile
b_pileline = QgsVectorLayer("b_pileline/pileA.shp", "Digitized Line A")
if not b_pileline.isValid():
    print "Layer %s did not load" % b_pileline.name()

#start running the tools#
#convert the digitized polyline to a polygon to clip the raster of the mine
outputs_QGISLINESTOPOLYGONS_1=processing.runalg('qgis:linestopolygons', b_pileline,"c_pile_line2poly/c_p
#clip the raster of the mine with the polygon of the pile
outputs_SAGACLIPGRIDWITHPOLYGON_2=processing.runalg('saga:clipgridwithpolygon', a_dsm,outputs_QGISLINEST
#buffer the polyline by .05 meters to create a polygon around the base of the pile
outputs_QGISFIXEDDISTANCEBUFFER_1=processing.runalg('qgis:fixeddistancebuffer', b_pileline,0.05,5.0,Fals
#clip the mine dsm with the polygon from the buffered polyline
outputs_SAGACLIPGRIDWITHPOLYGON_1=processing.runalg('saga:clipgridwithpolygon', a_dsm,outputs_QGISFIXEDD
#run raster layer stats on the clipped dsm buffer to get the mean base level of the pile
outputs_QGISRASTERLAYERSTATISTICS_1=processing.runalg('qgis:rasterlayerstatistics', outputs_SAGACLIPGRID
#input the pile dsm and and mean of the base elevation of the pile into SAGA volume
outputs_SAGAGRIDVOLUME_1=processing.runalg('saga:gridvolume', outputs_SAGACLIPGRIDWITHPOLYGON_2['OUTPUT'
print "script is complete"
```

Figure 9: The customized python script to calculate pile volume.

Volume Model Steps

1. Digitize a polyline around the pile of sediment
2. Import OS, SYS, core QGIS, and Processing Python libraries
3. Convert the line to a polygon
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 algorithm Grid Volume tool

Figure 9: Volume model steps in English.

Conclusions

By employing UAS to capture images of sand 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 these 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

Principal Investigator: Dr. Joseph Hupy; Internship Coordinator: Christina Hupy; Geospatial Technological Facilitator: Martin Goettl; Capstone Instructor: Garry Running
Research Assistants: Syler Behrens, Michael Bomber, Nicholas Berg, Scott Nesbit, Peter Sawall, Mattheus de Waard; UW- Eau Claire Geography Department