Fun with Drones

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2 types

(1)Fixed wing (airplane)

-can be cheaper

-can be faster and last longer on a battery

-Need a take-off and landing area

-turns between flight lines take space

(2) Rotary (helicopter-ish)

- **Can be more expensive**
- **Less space required**
- **More non-survey applications (inspection)**

http://www.uavinsider.com/rotary-wing-vs-fixed-wing-uavs/

http://www.questuav.com/news/fixed-wing-versus-rotary-wing-for-uav-mapping-applications

http://www.ua-sp.com/rotary.html

Non-Ray assessments of fixed wing vs. rotary drones

Can a hybrid fixed wing/rotary drone be created? Of course!

http://rotordronemag.com/fixed-wing-vtol-uav-combination-designs/

The California company Arcturus UAV have developed a drone that combines the best of both fixed wing and multi-rotor aircraft. The vertical takeoff and landing system of their T-20 and T-16 fixed wing UAVs allows the plane to make vertical takeoff using A multi-rotor design built into the aircraft wings. Once the plane is high enough in the air the front motor of the aircraft takes over and converts the plane from hover to forward flight. Really, when you think about it, a very logical design. All flight control is fully autonomous.

But battery life stinks!!!!

http://www.digitaltrends.com/cool-tech/yeair-gas-powered-drone-kickstarter/

So German inventor Holger Willeke took a different approach with his Yeair drone, unveiled on Kickstarter today. Instead of relying solely on batteries and electric motors, it uses a mixture of battery power and good old-fashioned combustion engines. The result? A quadcopter that can do 60 mph, carry nearly 12 pounds, and stay airborne for 60 minutes straight.

In a lot of ways, drone’s hybrid gas-electric approach gives it the best of both worlds, like a Prius. Combustion engines allow it to harness the incredible energy density of hydrocarbon fuel, while electric components help keep the craft light and responsive. And when you do run out of power, you don’t have to twiddle your thumbs for two hours while you wait for a battery to recharge — you can just refuel and start flying again right away.

http://www.digitaltrends.com/cool-tech/hycopter-hydrogen-powered-drone/

4.2 oz of hydrogen at 5076 psi gives up to 4 hours of flight time

Drones usually have

(1)Camera (small and light)

(2)GPS – could be real time or post processed RTK but that adds to cost

(3)IMU – measure 3 angles of camera – actually an accelerometer and gyroscope with a stabilizer

(4) wind speed monitor

(5)Ground sensing device

(6)Radio communication to lap top

Etc.

Could have

(1)Gimball mount – allows camera to be easily pointed non-vertical (building, bridge, or dam face)

(2)Different camera sensors (thermal)

(3)Lidar (heavy, expensive)

Terminology (from eBee)

AMSL Above Mean Sea Level

Your *eBee*'s altitude can be shown and set in *eMotion* using ATO or AMSL.

Your drone uses the EGM96 mean sea level standard for navigation.

ATO Above the Take-off Altitude

Your *eBee*'s altitude can be shown and set in *eMotion* using ATO or AMSL.

Altitudes in ATO are relative to the place your *eBee* started its motor just

before take-off.

DSM Digital Surface Model

A 3D digital representation of a surface.

Terminology (from eBee)

geo-reference A data point associated with a specific location on the earth's surface.

GSD Ground Sampling Distance

The distance measured on the ground between pixel centres in an image or DSM. The smaller the GSD, the higher the spatial resolution of the image. For example, a GSD of 5 cm means that one pixel in the image represents 5 cm on the ground.

mosaic A single map or terrain model created from several map sections that have been placed side-by-side and merged together.

orthomosaic A single, corrected image constructed either from several images taken from different angles, or from several orthophotos. Distortions due to different camera positions, ground curvature and relief are corrected for so that the image displays accurately in the given map projection.

Terminology (from eBee)

photogrammetry A technique in which measurements taken from photographs
are used to reconstruct a 3D surface or a series of points in space.

point cloud A set of data points within a coordinate system.

rayCloud A feature unique to *Postflight Terra 3D* that combines the 3D point cloud
with the original images. Multi ray matching with the rayCloud extends the
stereo view triangulation and increases the accuracy of 3D point estimates
while providing a full understanding of 3D results.

triangle model An approximate representation of a surface, constructed from
connected triangles.

In a perfect world see

https://www.sensefly.com/drones/postflight-terra-3d.html

(1)Check image quality in the field – quality report with low resolution ortho mosaic preview

(2)Generate orthomosaics, 3-D models, and point clouds

(3)Assess and edit (or import to GIS, CAD, photogrammetry softwares

(4)Compute – break lines, contours, profiles, earthwork/volumes, etc.

Need examples

https://www.sensefly.com/drones/example-datasets.html

You can download a wide variety of different types of information for a wide variety of projects.

Planning a flight

-**Software accesses "all" available photography such as Google, Mapquest, etc.**

-**You have a visual interface that first allows you to enter a location by lat./long or by city/state/country**

-**You then use graphics to zoom in on your desired flight area**

Planning a flight

Mission planning

(1)Flight area is selected graphically by moving, scaling and rotating a flight area rectangle (note complex areas can use a polygon)

(2)Correct camera is selected along with desired flying height or desired pixel resolution (the two are directly related)

(3)Overlap along flight lines (>=60%)and between flight (>=20%)lines is selected

Planning a flight

Overlap – since no film exists higher overlaps simply increase redundancy and thus can enhance accuracy – but obviously the processing time increase as overlaps increase

(4) Upload (store) – flight parameters are ready to go when you reach the job site

(5) Review flight plan (usually in Google Earth) to make sure no obstructions will limit your intended flight (ha-ha I am sure this will always work)

Planning a flight

(6) Select a takeoff location (perhaps may need to be changed in field)

In the field

(1) Weather check – small drones do not like big winds!!

(2) Inspect the unit based on vendor recommendations

(3) Put in fully charged batteries and make sure camera is ready per vendor recommendations

In the field

(4) Your drone goes through a series of pre-flight checks and any problems will be relayed to your lap top connected by radio to the drone

Federal Aviation Administration

Small UAS Certificate of Registration

CERTIFICATE HOLDER: **Raymond Hintz**

UAS CERTIFICATE NUMBER: **FA3LE4TCFA**

ISSUED:**02/02/2016** EXPIRES:**02/02/2019**

For U.S. citizens, permanent residents, and certain non-citizen U.S. corporations, this document constitutes a Certificate of Registration. For all others, this document represents a recognition of ownership.

For all holders, for all operations other than as a model aircraft under sec. 336 of Pub. L. 112-95, additional safety authority from FAA and economic authority from DOT may be required.

Safety guidelines for flying your unmanned aircraft:

Fly below 400 feet

Never fly near other aircraft

Keep your UAS within visual line of sight

Keep away from emergency responders

Never fly over stadiums, sports events or groups of people

Never fly under the influence of drugs or alcohol

Never fly within 5 miles of an airport without first contacting air traffic control and airport authorities

Remember these simple safety guidelines when flying your unmanned aircraft:

- Don't be careless or reckless with your UAS
- Fly below 400 feet and remain clear of obstacles
- Stay away from other aircraft at all times
- Keep your UAS within your sight
- Don't fly near airports, stadiums, or other people
- Don't fly under the influence of drugs or alcohol
- Keep away from emergency responders

For more information, visit: www.faa.gov/uas/model_aircraft

Previous photos are from approximately 120.1 m. above ground with a Sony DSC WX-220 camera which is 3.4 cm./ pixel

Camera image has 18.2 megapixels/image

Effective pixels are 4896 x 3672 = 17,978,112

Frame size is 6.17 x 4.55 mm

Which produces pixel size of 6.17/4896 = .00126 mm

Focal length is 4.55 mm. when flying

Ground dist = photo dist * flying hgt./focal length

Scale equation .00126 mm * (120.1 m / 4.55 mm) = .034 m = 3.4 cm!! Yeah!!!

Frame size is 6.17 x 4.55 mm

Focal length is 4.55 mm. when flying

Flying hgt is approximately 120 meters.

How much ground is covered?

By scale (flying hgt/focal length)

6.17 mm (120 m/4.55 mm) = 163 m

4.55 mm (120 m/4.55 mm) = 120 m

On an eBee the shorter distance is in the direction of flight

Old school photogrammetry

Along flight line

60% endlap (longitudinal in eBee default 70%)

Across flight lines

20% sidelap (latitudinal in eBee default 60%)

Old school thought was to minimize # of photos but keep some points on 3 photos along flight lines and make sure between flight lines no gaps exist

Photogrammetry old school

(1)Flying time (airplane) is expensive

(2) Film (especially from a 9 in. format metric camera) is expensive and also expensive to process

Drone Photogrammetry

(1)Flying time is cheap – battery life is your limit

(2) No film!! Storing jpegs is no big deal thanks to big harddrives

Evolution to Multi_ray Photogrammetry

(1)More photos add little expense

(2) If an image is on lots of photos it can be positioned more precisely than if only on 2-3 photos

(3)If an image is on a lot of photos, but in a couple photos the image is not clear (shadow, reflectance, etc.) it can still be positioned from the photos where it is clear

(4) Only issue is can processing time of many photos become a concern

Evolution to multi-ray Photogrammetry

(1)Higher overlaps between flight lines and photos along a line

(2) Possible cross flights (right angle to original flight lines)

(3) possible flight lines at angled line of sight – extremely useful to obtain sides of buildings

The fundamental least square routine that brings all exposures and all image points into one common coordinate system is called the bundle adjustment or aerotriangulation. It uses the principle of collinearity:

"A ground point, the nodal point of the lens, and its image location lie on a straight line"

Old school aerotriangulation

(1) **Unknown exposure stations (duh!)**

(2) **Manual measurement of image points**

(3) **Limited image points due to the slowness of manual measurement**

(4) **Ground control allows one to solve for all exposure (coordinates and 3 rotation angles) and unknown image station positions)**

Modern bundle adjustment

(1)Measured exposure station positions (by GPS) and angles (by IMU)

(2)Automated image matching of same point (pixel) on multiple photos – no human involved!!!

(3) Limited ground control (due to (1)) that is manually measured

Modern bundle adjustment

Why does automated image matching work?

(1)Due to known camera positions and orientations, and known focal length and image frame size, software can predict where image match points should be

(2) These pixel’s “ROY G. BIV” integer image returns are attempted to be matched. If initial guess does not match neighboring pixels are examined for a better match.

Modern bundle adjustment

Why does automated image matching work?

(3) Only excellent matches are used

(4) A preliminary bundle adjustment “refines” the initial GPS IMU positions of exposures – they get better

(5) With better exposure positions the matching algorithm works better

(6) Once matches are found, they are no longer match candidates so the search algorithm has fewer candidates to match on later examinations

When the bundle adjustment is complete all exposure stations and image points have been "best fit" by least squares to fit into one common coordinate system (UTM or state plane normally)

Lets look at some results from a 2 flight line job of 45 photos over a large field at the University of Maine under fairly lousy flying conditions (a little foggy as it was 50 degrees in February!!) From arriving at job site to leaving job site the exercise took 20 minutes!!!!!!

Summary

Project	farm
Processed	2016-02-04 14:03:04
Average Ground Sampling Distance (GSD)	3.42 cm / 1.34 in
Area Covered	0.174 km^2 / 17.4008 ha / 0.0672 sq. mi. / 43.0207 acres
Time for Initial Processing (without report)	06m:13s

Quality Check

Images	median of 68833 keypoints per image
Dataset	45 out of 45 images calibrated (100%), all images enabled
Camera Optimization	0.38% relative difference between initial and optimized internal camera parameters
Matching	median of 22490.8 matches per calibrated image
Georeferencing	yes, no 3D GCP

Preview

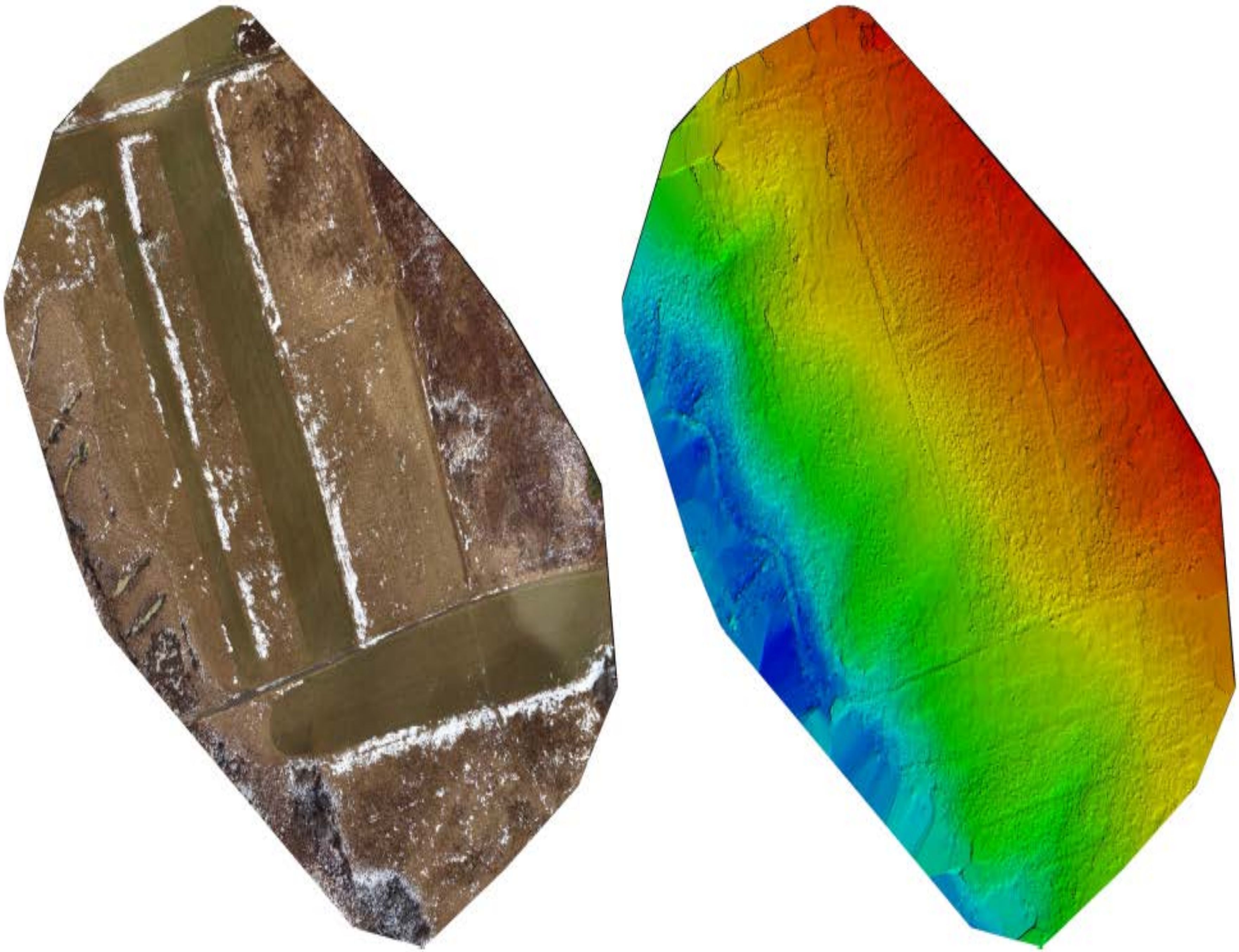


Figure 1: Orthomosaic and the corresponding sparse Digital Surface Model (DSM) before densification.

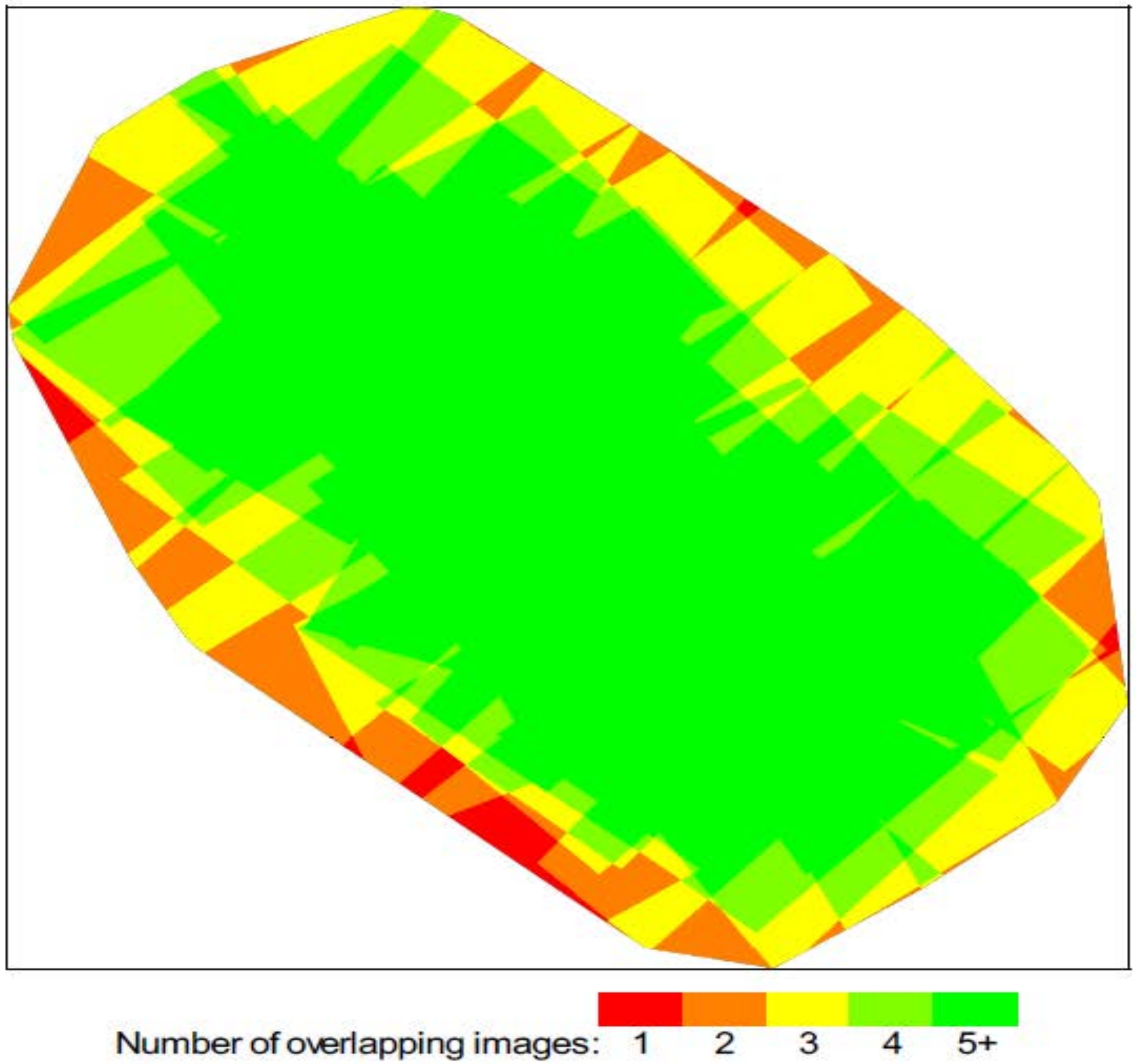


Figure 4: Number of overlapping images computed for each pixel of the orthomosaic.
areas indicate low overlap for which poor results may be generated. Green areas indicate an overlap of over 5 images for every pixel.
sults will be generated as long as the number of keypoint matches is also sufficient for these areas (see Figure 5 for keypoint matches).

Bundle Block Adjustment Details

Number of 2D Keypoint Observations for Bundle Block Adjustment	
Number of 3D Points for Bundle Block Adjustment	
Mean Reprojection Error [pixels]	

Internal Camera Parameters

DSC-WX220_4.4_4896x3672 (RGB). Sensor Dimensions: 6.170 [mm] x 4.627 [mm]

EXIF ID: DSC-WX220_4.4_4896x3672

	Focal Length	Principal Point x	Principal Point y	R1	R2	R3
Initial Values	3628.284 [pixel] 4.572 [mm]	2447.997 [pixel] 3.085 [mm]	1836.004 [pixel] 2.314 [mm]	0.012	-0.045	0.050
Optimized Values	3614.317 [pixel] 4.555 [mm]	2430.646 [pixel] 3.063 [mm]	1861.280 [pixel] 2.346 [mm]	-0.008	-0.003	-0.00

3D Points from 2D Keypoint Matches

	Number of 3D Points Observed
In 2 Images	311844
In 3 Images	64721
In 4 Images	19867
In 5 Images	8852
In 6 Images	4294
In 7 Images	2322
In 8 Images	564
In 9 Images	115

Absolute Geolocation Variance

Min Error [m]	Max Error [m]	Geolocation Error X [%]	Geolocation Error Y [%]	Geolocation Error Z [%]
-	-3.68	0.00	0.00	0.00
-3.68	-2.94	0.00	0.00	0.00
-2.94	-2.21	0.00	0.00	0.00
-2.21	-1.47	0.00	0.00	0.00
-1.47	-0.74	0.00	4.44	0.00
-0.74	-0.00	53.33	48.89	51.11
-0.00	0.74	46.67	40.00	48.89
0.74	1.47	0.00	6.67	0.00
1.47	2.21	0.00	0.00	0.00
2.21	2.94	0.00	0.00	0.00
2.94	3.68	0.00	0.00	0.00
3.68	-	0.00	0.00	0.00
Mean [m]		0.002984	0.006374	-0.002818
Sigma [m]		0.261153	0.453457	0.255087
RMS Error [m]		0.261170	0.453501	0.255102

Min Error and Max Error represent geolocation error intervals between -1.5 and 1.5 times the maximum accuracy of all the images. Columns X, Y, Z show the percentage of images with geolocation errors within the predefined error intervals. The geolocation error is the difference between the intial and computed ima positions. Note that the image geolocation errors do not correspond to the accuracy of the observed 3D points.

Now that you have fallen asleep looking at bundle adjustment statistics:

We have mathematical product that is the “control survey” of photogrammetry – now we can create products

(1)Point cloud densification – very detailed x,y,z on every unique image

(2) Orthophotomosaic – what a one photo of the entire area would look like except you are looking down at all points, not from a perspective of each individual exposure

Point Cloud – just a couple of point like more than 6 million!

Results

Number of Generated Tiles	1
Number of 3D Densified Points	6020544
Average Density (per m^3)	87.38

Point cloud – also contains the image information for each pixel/each xyz

Standard format in industry for point clouds (can be from Lidar, too is binary .las or a .laz which is .las which has been zipped)

Note it is so huge it has to be binary as text files take up huge space.

Note it contains the image of each x,y,z too!

Orthophoto

Based on initial flying height each 3.43 cm

Square is an image with a projection x,y that has been corrected for elevation (relief distortion)

Example – Two football fields at different elevations on one photo will have different lengths. They will be the same length (300 ft. goal to goal if a ground not grid coor. System) because they have been projected to a common elevation (usually the projection plane through the ellipsoid)

What follows

(1)Exposures in Map type look

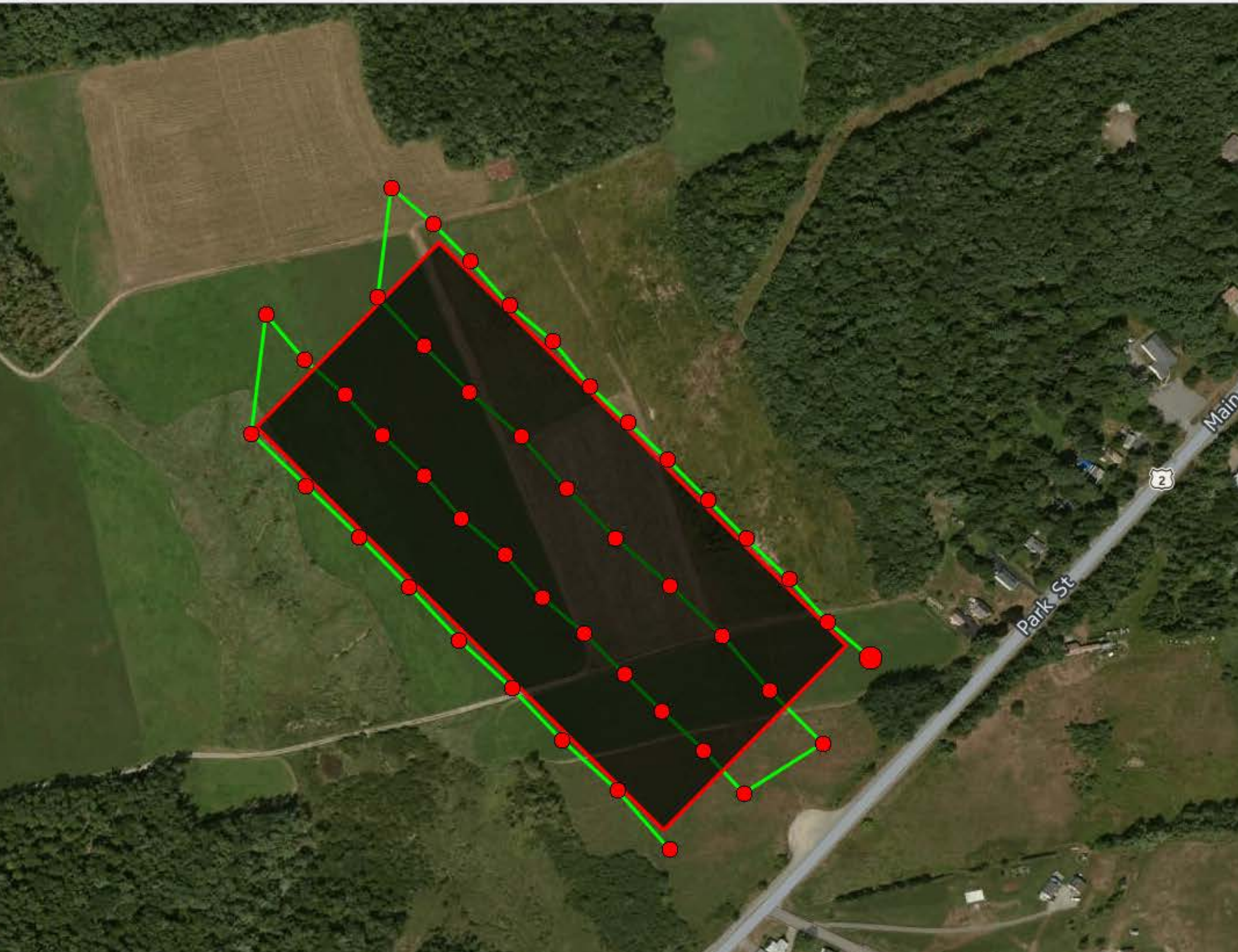
(2) Exposures in 3D type look

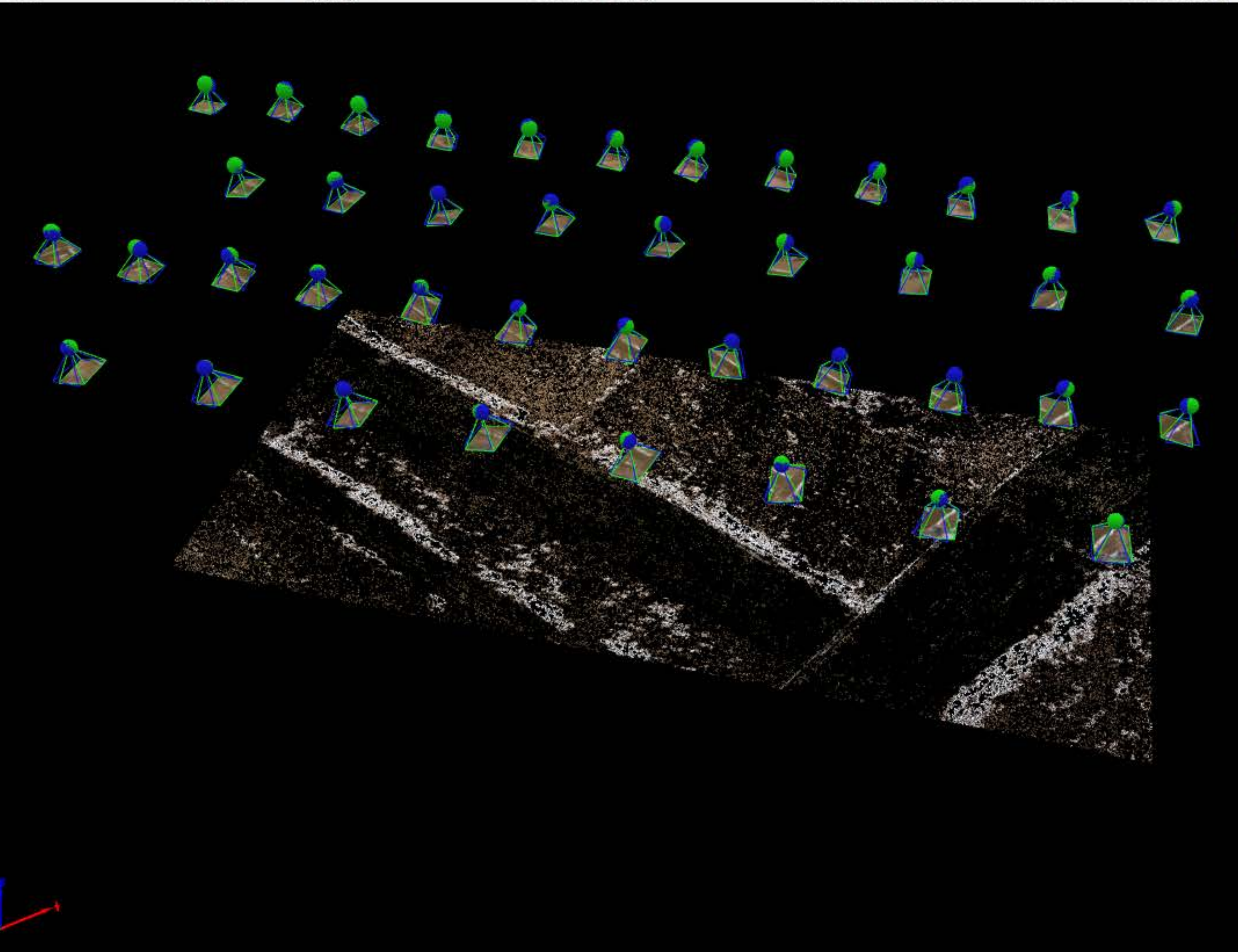
(3)Elevation model (DSM) color coded

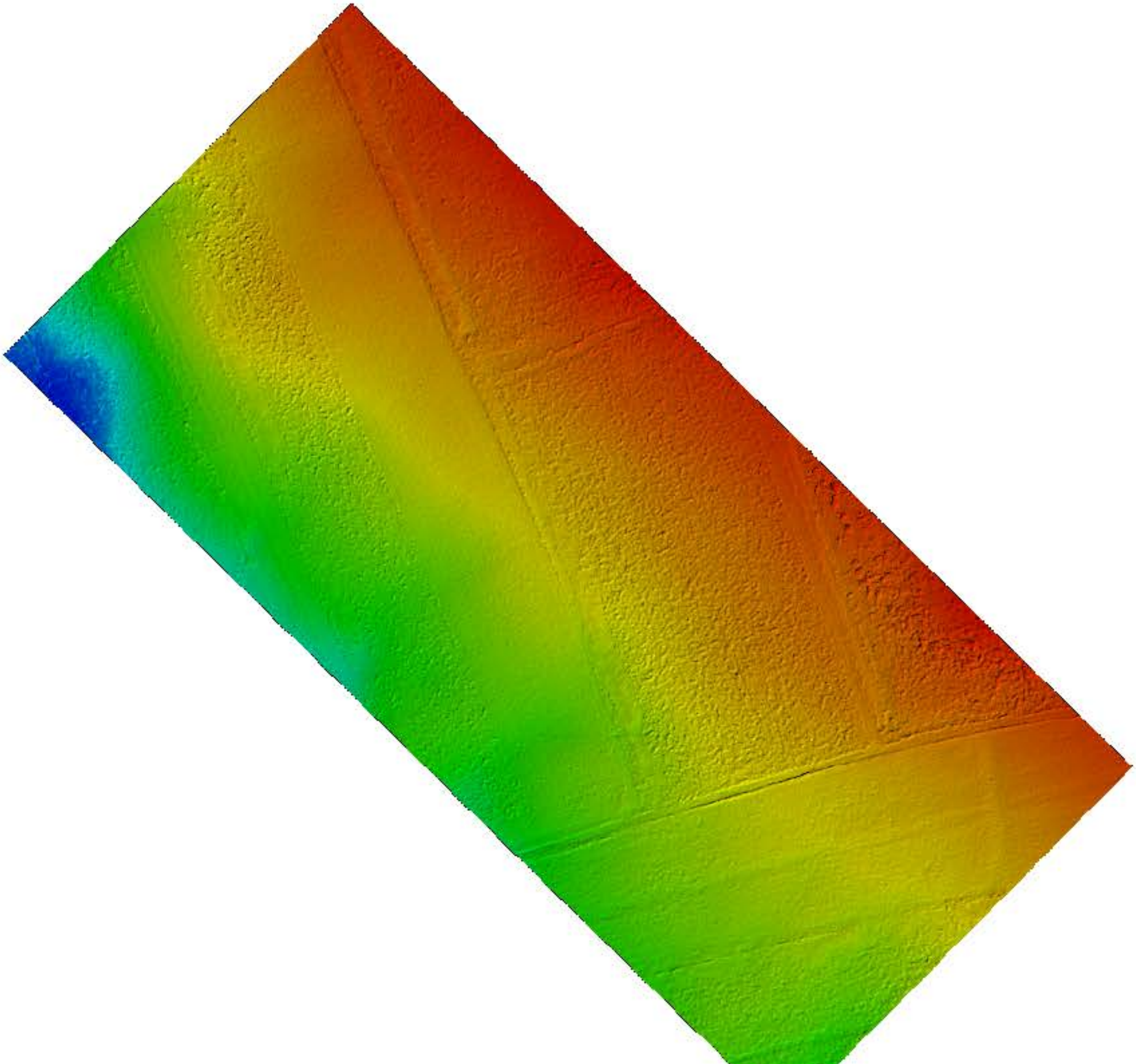
(4)Job on conventional map

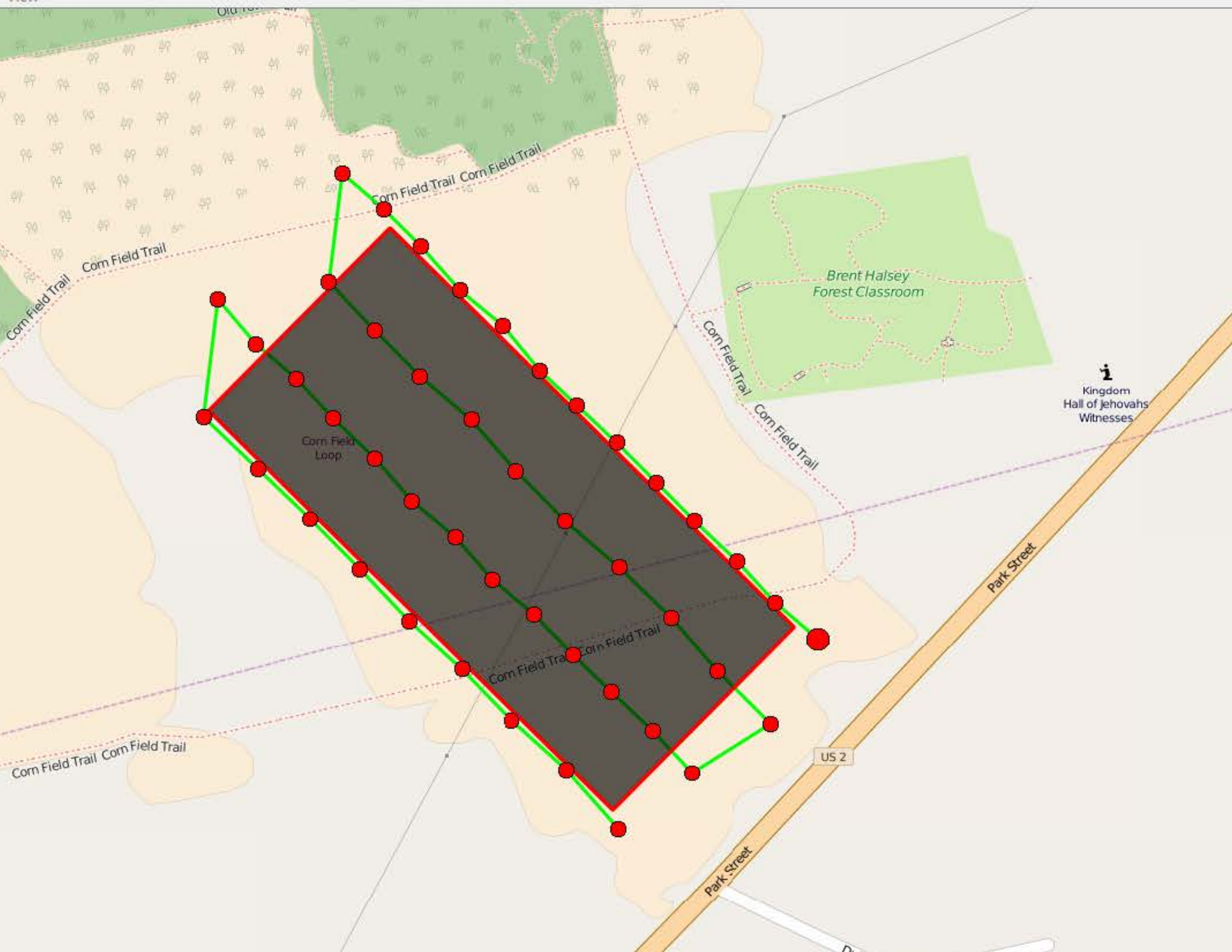
(5).las brought into other software (Fugroviewer) and 0.5 m. contours drawn

(note the contours need smoothing for production)

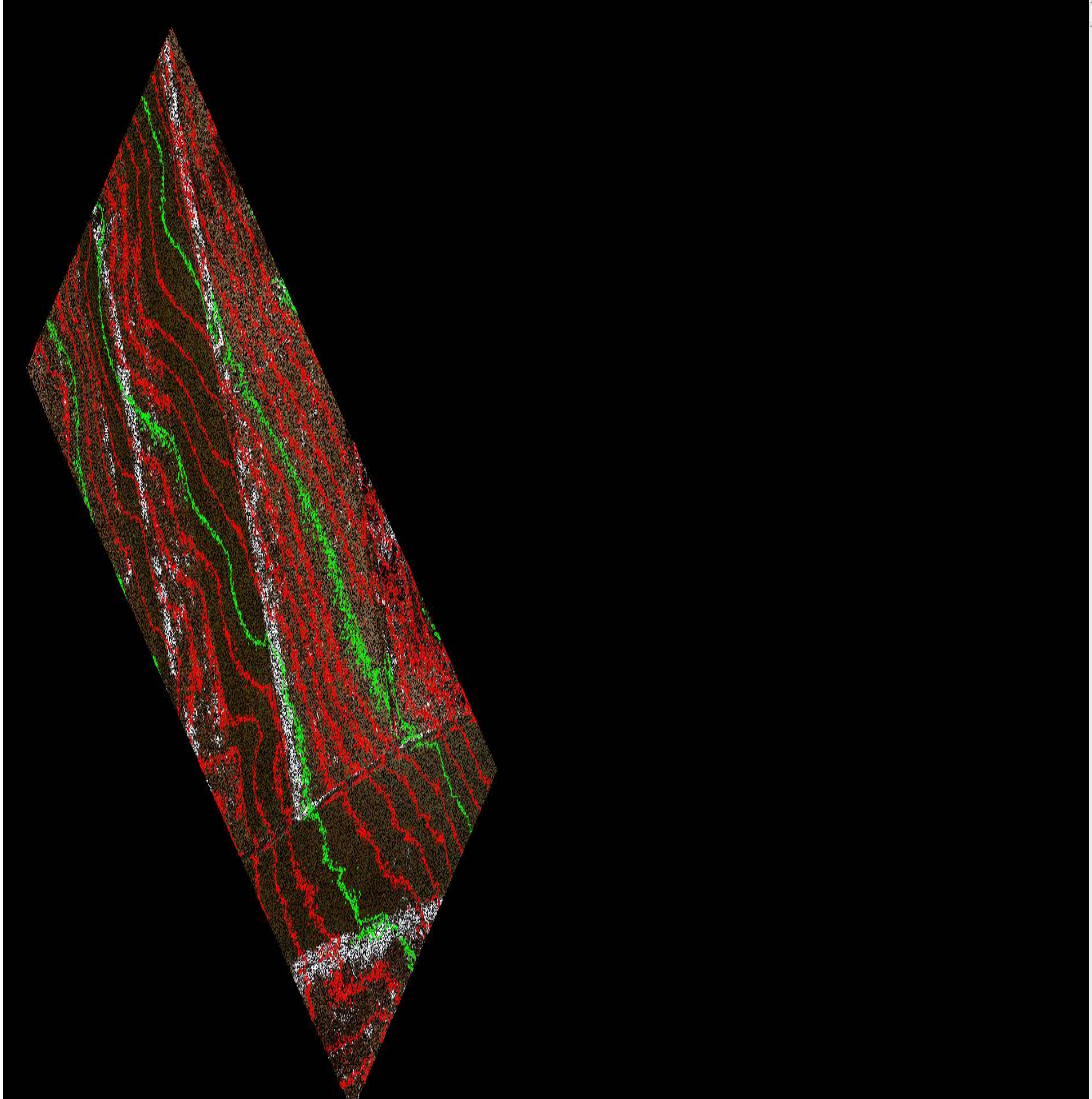

Main
2
Park St







Corn Field Trail
Corn Field Loop
Brent Halsey
Forest Classroom
Kingdom
Hall of Jehovahs
Witnesses
Park Street
US 2



Does this controversial in a licensure sense?

Check out

Here is an interesting article from a drone owner who is providing volume calculations but doesn't feel a survey license is necessary. I think this is a very slippery slope. I don't think our profession is based on our ability to accurately measure alone, but licensure dues help to ensure the public is protected in this area. Here is a case where a user thinks he knows better than the state board because he's a software developer and had done a lot of "quality control." He may be correct and his results may be accurate, but there is little doubt he is probably breaking a surveying law in some states.

I think we are going to all be battling this a lot more as the technology becomes more widely available and software easier to use. A joe-schmoe citizen with no education or training in photogrammetry or even ground control, has a $500 drone a whiz-bang software package starts providing a volume calculation (and eventually mapping) to the public.

I have very strong opinions about this automated photogrammetry software and its potential for misuse by uninformed drone owners who may over state it's capabilities. I think it poses a legitimate threat to public welfare.

http://www.lidarmag.com/content/view/11676/198/

Thoughts?

FAA things on 9-15-16 (could change quickly)

http://www.faa.gov/uas/ (general info)

https://registermyuas.faa.gov/ (register a UAV)

http://www.faa.gov/uas/getting_started/fly_for_work_business/becoming_a_pilot/

(become a UAS pilot)

http://www.faa.gov/training_testing/testing/acs/media/uas_acs.pdf (remote pilot standards)

FAA things on 9-15-16 (could change quickly)

http://www.faa.gov/training_testing/testing/test_guides/media/remote_pilot_ktg.pdf

(test guide)

http://www.faa.gov/regulations_policies/handbooks_manuals/aviation/media/remote_pilot_study_guide.pdf **(study guide)**

http://www.faa.gov/training_testing/testing/test_questions/media/uag_sample_exam.pdf

(sample test questions)

Do I need a regular airplane pilot's license?

No, but it is a faster process to become a licensed commercial UAS operator if you do.

https://www.faa.gov/uas/request_waiver/

(request waivers to the rules)

https://www.faa.gov/uas/getting_started/

(shows why a hobby UAS or an educator is easier to fly than a commercial operation)

Pilot Requirements:

- **Must be at least 16 years old**
- **Must pass an initial aeronautical knowledge test at an**
- **FAA-approved knowledge testing center+**
- **Must be vetted by the Transportation Safety Administration (TSA)**

+A person who already holds a pilot certificate issued under 14 CFR part 61 and has successfully completed a flight review within the previous 24 months can complete a part 107 online training course at www.faasafety.gov to satisfy this requirement.

Questions?

Maybe no answers!!