Case Study for sUAS Photogrammetric Accuracies

WHAT ARE THE ACCURACY EXPECTATIONS FROM UAS, NON-METRIC CAMERA BASED PHOTOGRAMMETRY INCLUDING GOPRO TYPE CAMERAS

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ABSTRACT

- Cardinal Systems, LLC is a software company specializing in the development of products for the photogrammetric and mapping industry. The Vr Mapping products support the use of imagery and (or) LiDAR/DSM/point cloud data as a base for feature extraction.

- Cardinal Systems worked with NASA during the Space Shuttle program more recently with imagery from the Mars Curiosity rover. This work involved the use of photogrammetry with small format cameras with non-standard camera angles. This work inspired several key software components to meet NASA’s tasks that are in use today with UAS imagery.

- We are interested in the level of accuracy that can be obtained from UAS based, low cost, non-metric cameras. The use of commercial cameras that were not designed for measurement purposes such as the GoPro was of special interest. Because of the payload requirements of small UASs the weight of the camera is more important than the measurement quality of the camera in this configuration.

INTRODUCTION

- The first set of results presented are from three UAS missions using one camera. The missions were flown with the same UAS from three flight heights. The camera used is the Phantom 2 Vision FC200 which has a field of view (FOV) of 140 degrees which is similar to a GoPro.
- The second set of results is from an Sony Alpha 6000 flown in a typical aerial configuration over a hillside in Arizona.
- Cardinal Systems did not fly these three missions they were flown by clients and associates with a long history in the photogrammetric industry. The experience of these photogrammetrists was the qualification for choosing these projects.

Phantom 2 Vision FC200

- The DJI Phantom 2 Vision FC200 camera produces 14MP, 4384x3288 pixel images and has a focal length of 5 millimeters. The FC200 uses a wide angle lens with a field of view (FOV) of 140 degrees at an aperture of f/2.8. This is similar to the wide-angle characteristics of the GoPro Hero lenses.

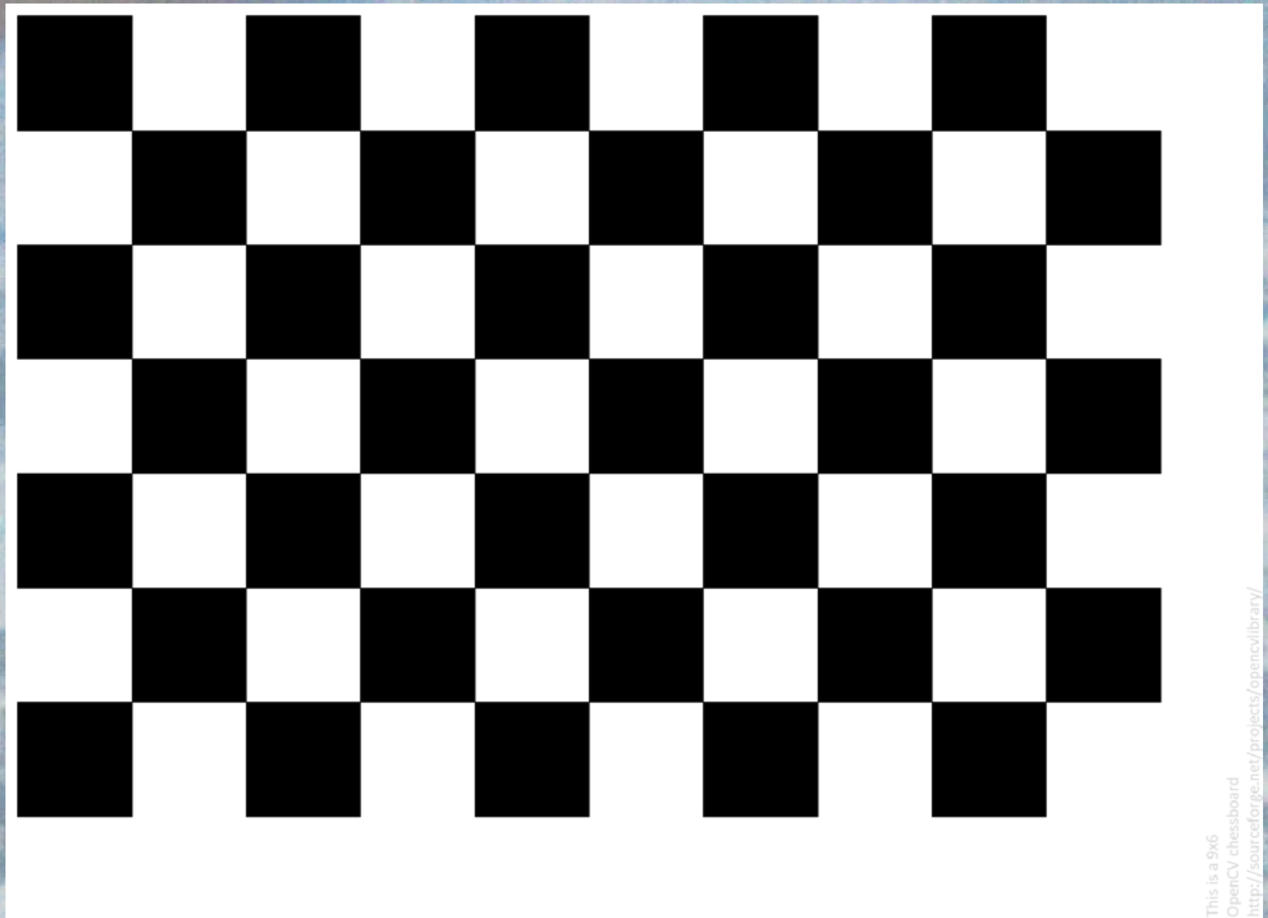
- This test consisted of three flight heights of 100, 200 and 300 feet above the ground. Considering the “fish-eye” characteristics of the lens, six bundle adjustment runs were performed with the software limiting the points used to a radial distance from the center of each image. These multiple runs were performed on the 100’ flying height imagery.

Phantom 2 Vision FC200 image from 200 feet

Camera Calibration program (VrCamCal)

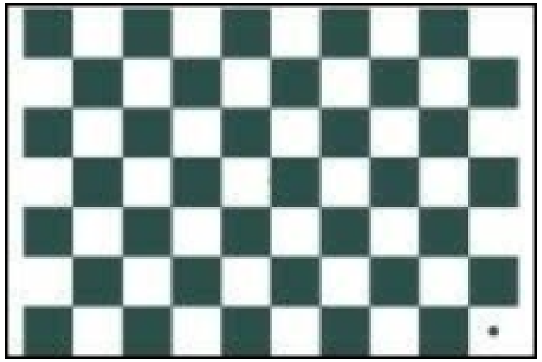
- As you well know, any lens used for mapping should be calibrated. We're not going to send these cameras to USGS so we wrote a camera calibration program. It had to be simple enough that anyone could use it. We don't have the luxury of a calibration room or the equipment they have at USGS. The method is not perfect (Bouguet's method using a checkerboard) but we've seen good results. Following are a few examples of the calibration of an almost fish-eye lens.

Bouguet's Method



Viewing Angles

- Photos should be taken from multiple angles or views. A total of nine views for each camera or calibration grid rotation should be taken as follows. Following are examples showing the nine views from the un-rotated orientation.

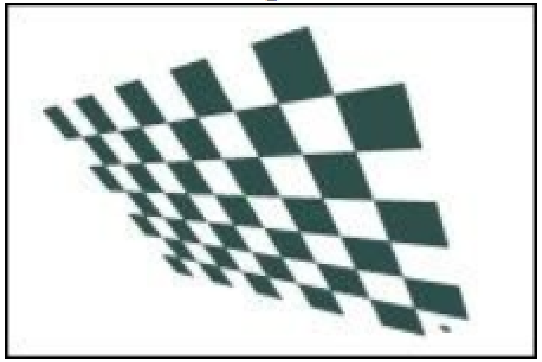


Nadir

Right

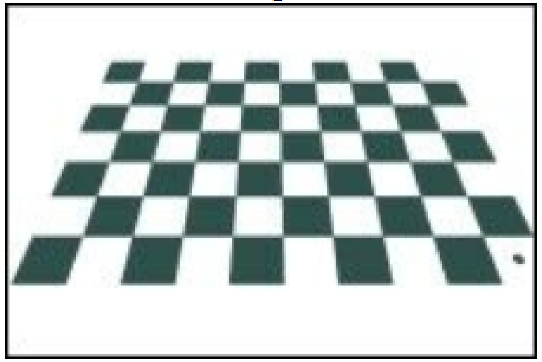
Left

Up

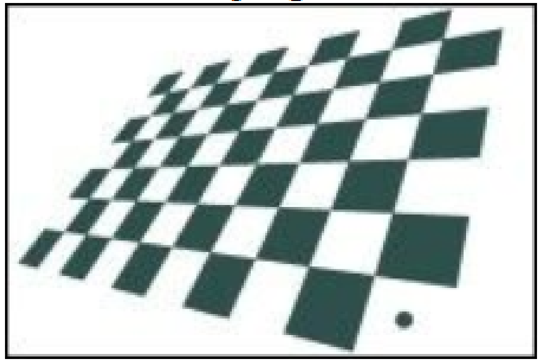


Up Right

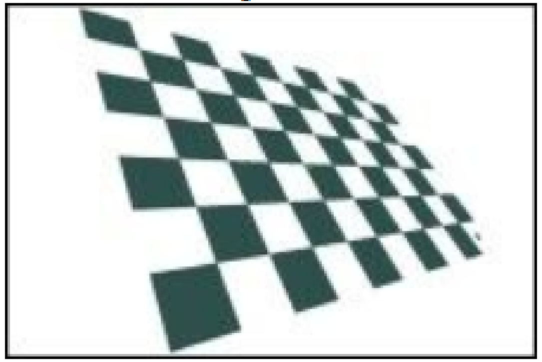
Up Left



Down

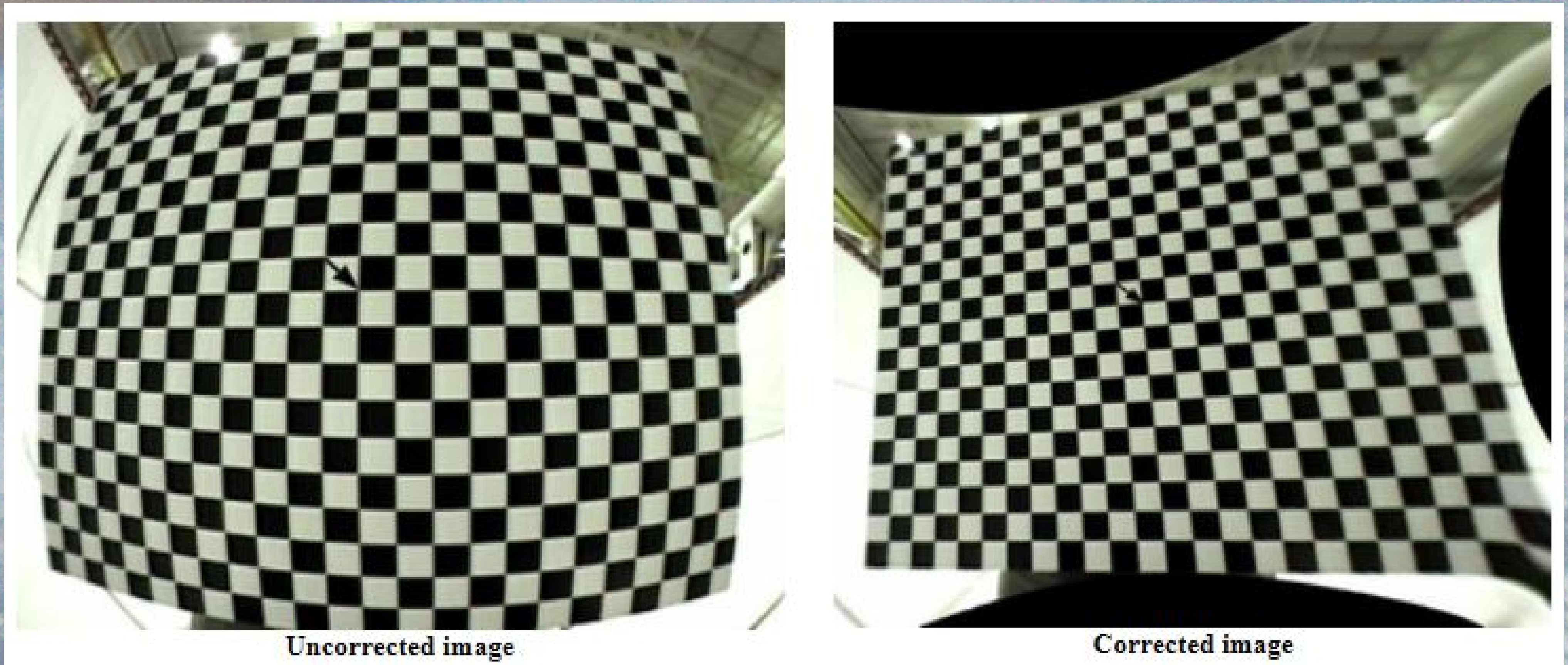


Down Right

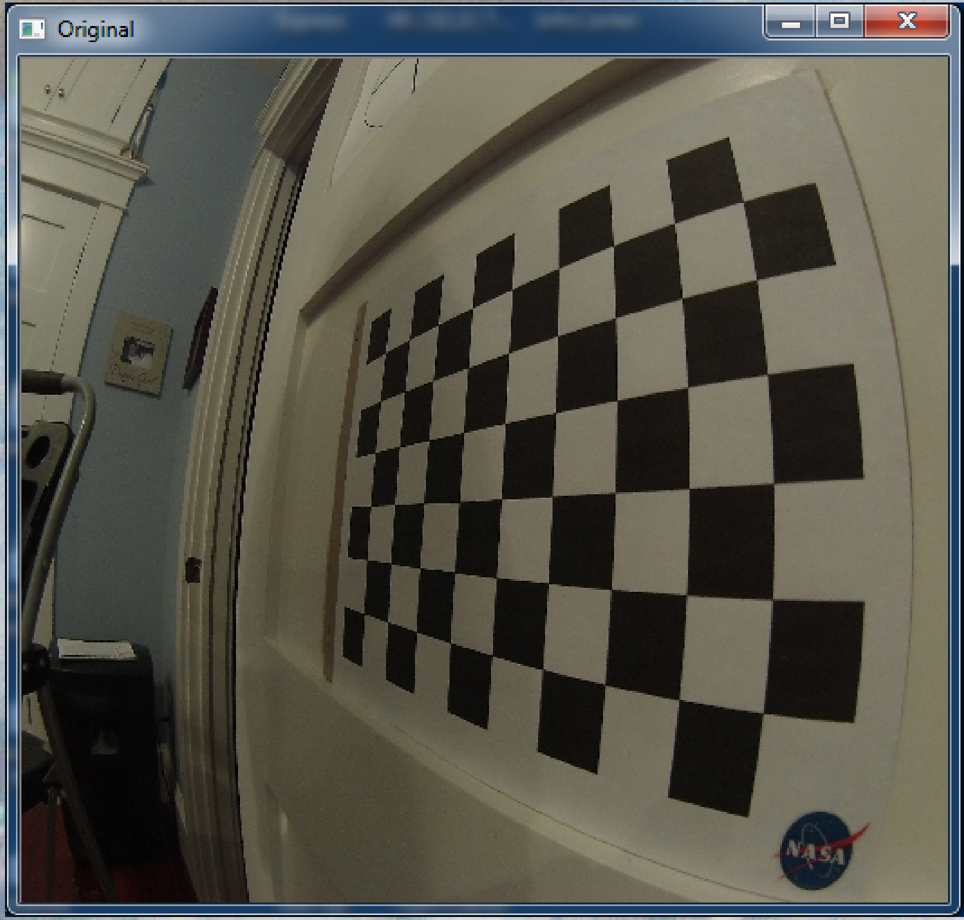


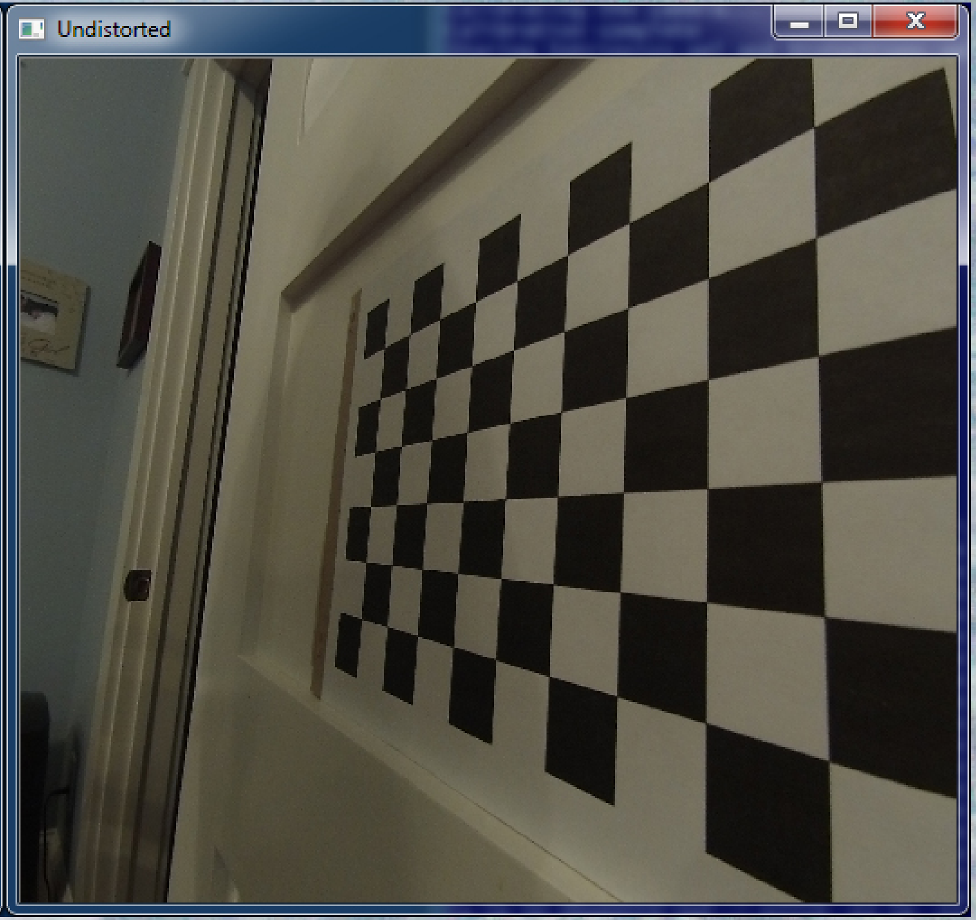
Down Left

Original and Calibrated

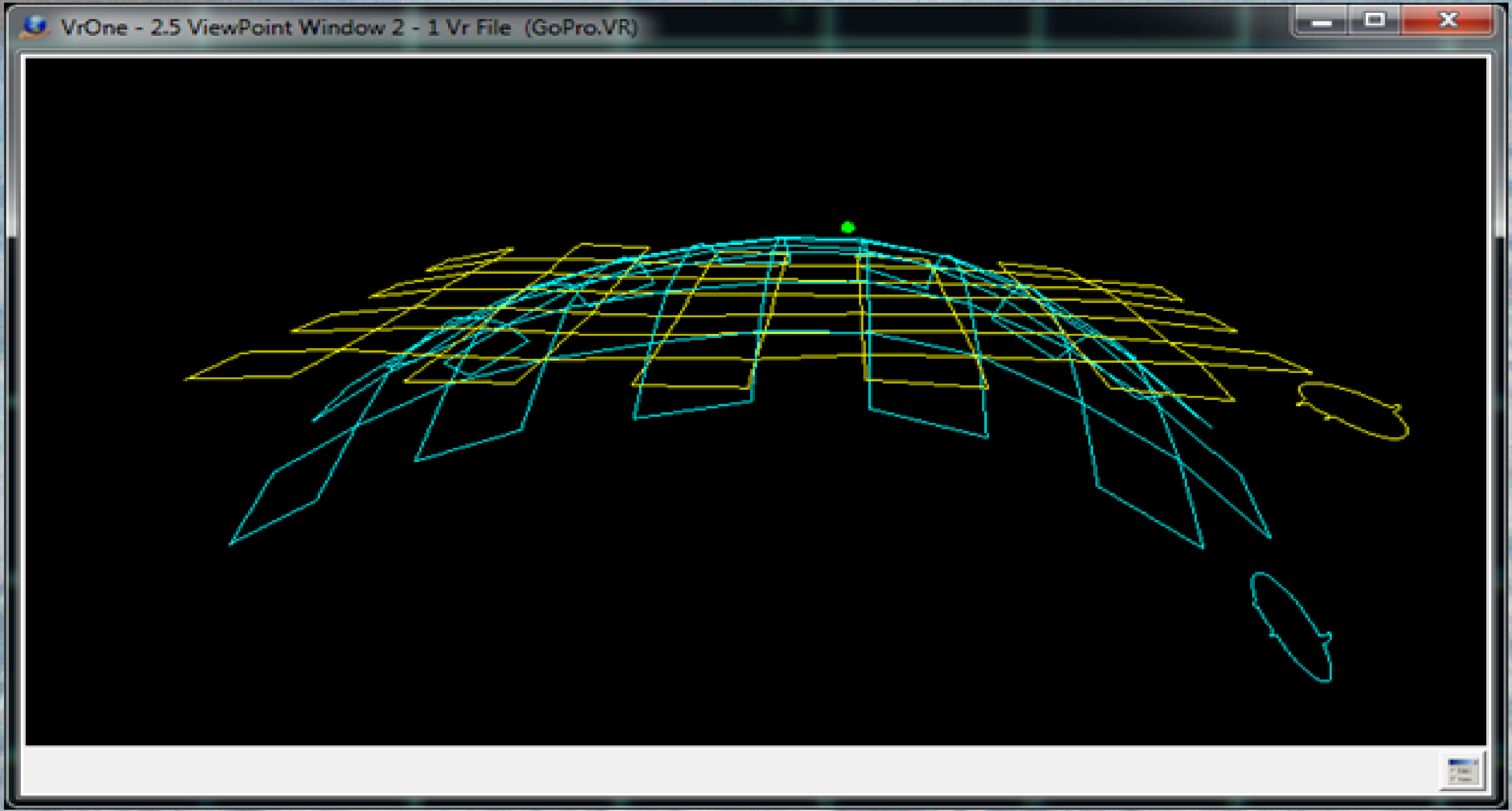


Original and Calibrated - GoPro





The screen shot below shows the difference between two stereo models from GoPro imagery with the blue uncalibrated solution and the yellow calibrated solution from VrCamCal.



A test from a FC200 with the original image on the left and the un-distorted image on the right

Flying height: 100 feet

Approximate pixel size at image nadir: 0.04 feet

Radius	RMSE	99% Error	Control RMSE (ground)			Control Max Error (ground)			Point Counts	
%	(pixel)	(pixel)	X	Y	Z	X	Y	Z	Control	Image
45	0.430	1.520	0.020	0.025	0.028	-0.050	0.073	-0.093	46	555
55	0.550	2.300	0.029	0.033	0.033	-0.127	0.114	-0.114	46	690
65	0.740	3.190	0.023	0.024	0.031	-0.069	0.056	-0.108	46	790
75	1.230	6.950	0.031	0.032	0.058	0.119	-0.104	0.267	46	841
85	2.160	13.000	0.040	0.032	0.090	0.144	0.078	0.351	46	853
95	2.310	15.080	0.050	0.039	0.106	0.263	0.153	0.442	46	854

Flying height: 200 feet

Approximate pixel size at image nadir: 0.08 feet

Radius	RMSE	99% Error	Control RMSE (ground)			Control Max Error (ground)			Point Counts	
%	(pixel)	(pixel)	X	Y	Z	X	Y	Z	Control	Image
50	0.440	1.980	0.034	0.026	0.051	0.076	-0.055	0.113	46	630

Vr Mapping Software

Flying height: 300 feet

Approximate pixel size at image nadir: 0.12 feet

Radius	RMSE	99% Error	Control RMSE (ground)			Control Max Error (ground)			Point Counts	
%	(pixel)	(pixel)	X	Y	Z	X	Y	z	Control	Image
50	0.320	1.030	0.041	0.029	0.061	-0.136	-0.106	0.135	46	430

Sony Alpha 6000, Flying height 250 feet

Approximate pixel size at image nadir: 0.02 feet

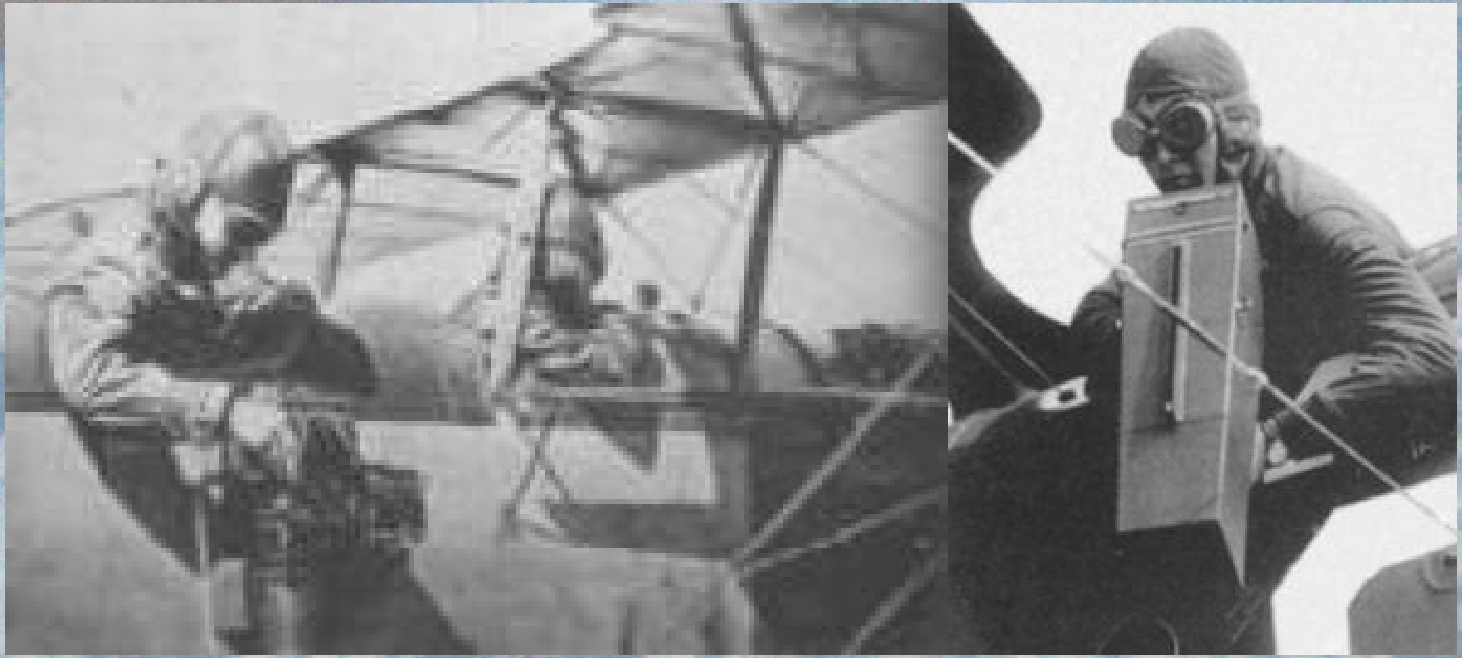
Radius	RMSE	99% Error	Control RMSE (ground)			Control Max Error (ground)			Point Counts	
%	(pixel)	(pixel)	X	Y	Z	X	Y	z	Control	Image
100	0.427	1.80	0.005	0.009	0.048	0.014	0.021	-0.130	14	44310

Vr Mapping Software

Comments

- This lens performed well in the center but the accuracy degrades sharply beyond 50% from the center to the image corners. The highest accuracy can be obtained by using approximately 40% of the image. Most of the control measurements for the 200 foot and 300 foot images were in the center 50% of the image radius.
- The control errors do not increase linearly with the flying height as would be expected, but rather in a sub-linear pattern. This could be because the error contribution from the ground control is constant and has more apparent influence on the lower flight data. In effect, making the results of the lower flights appear less accurate than they actually are.

IT’S STILL PHOTOGRAMMETRY



IT'S STILL PHOTOGRAMMETRY

- There have been many advances and changes in our field including the use of UASs (drones). Even with these changes it's still photogrammetry and it's frame photogrammetry. From our perspective, much has remained the same. However, there is some additional software that is needed to make the workflow better.

- There are several low cost, one-button solutions available but we're hearing that mapping people want more control over the process. At the end of these solutions you typically end up with a point cloud (Digital Surface Model) which is nice but it's like handing a client a billion LiDAR points. They are going to say "what am I to do with this". This is where mapping software takes over to produce a usable product.

IT'S STILL PHOTOGRAMMETRY

- Work from UAS photography is very similar to the tasks performed by traditional photogrammetry. Differences include imagery with more difficult geometries and cameras with higher radial distortions and more images due to the lower flying height.

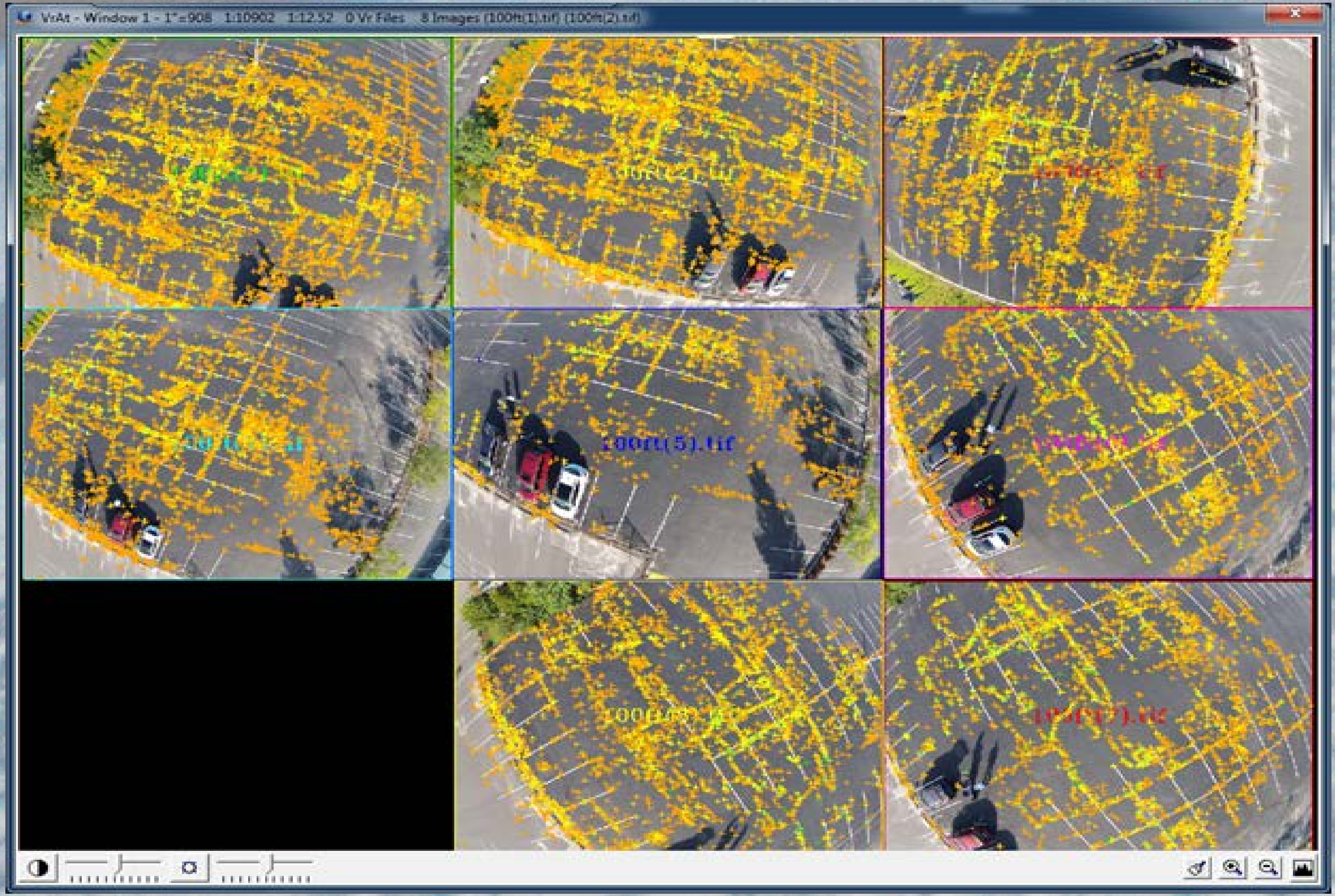
- Accuracy from photographs is dependent on several items including quality of the ground control and the quality of the camera lens. Camera calibration is an important step. Many triangulation bundle adjustments, including our own, generate a camera calibration but we feel the high oblique angles that a stand-alone solution provide better results which is why we added a stand-alone camera calibration program (VrCamCal). We are currently experimenting with the use of GoPro cameras to determine real-world accuracy expectations from this type of fish-eye lens.

Comments

- In regard to producing accurate measurements, conventional wisdom regarding UAS photography indicates that a realistic accuracy expectation is roughly two times the ground sampling distance. If we have a 2cm pixel on the ground we can expect 4cm accuracy with good control. We are currently testing real-world data to see if one pixel or sub-pixel accuracy can be obtained in x and y and one pixel accuracy can be obtained in z.

- Even though the software has been in production for many years in the areas of traditional aerial mapping and photogrammetry, in 2005 we began working with NASA and the software was used to map damaged areas on the Space Shuttle during mission from hand-held and robotic mounted cameras. It is also used for work on the International Space Station and was used to map rocket plume craters created when NASA's Curiosity rover landed on Mars. Out of this work came our latest additions to our triangulation software, VrAirTrig. This included an automatic tie application (VrAutoTie) and a revised bundle adjustment (VrBundle). Since the stability of unmanned aerial system (UAS) is higher than traditional aerial platforms, our current and new software works well with this type of imagery. Some information about the Mars work can be found at http://www.cardinalsystems1.net/#!mars-photogrammetry/c18in. More information on the Vr Aerial Triangulation program (VrAirTrig) can be found at http://www.cardinalsystems1.net/#!vrairtrig-vrautotie-vrbundle/c110q.

Below is a screen shot of some GoPro type images in a parking lot area with the results of the VR auto-tie shown. Notice the radial distortions from these raw images.



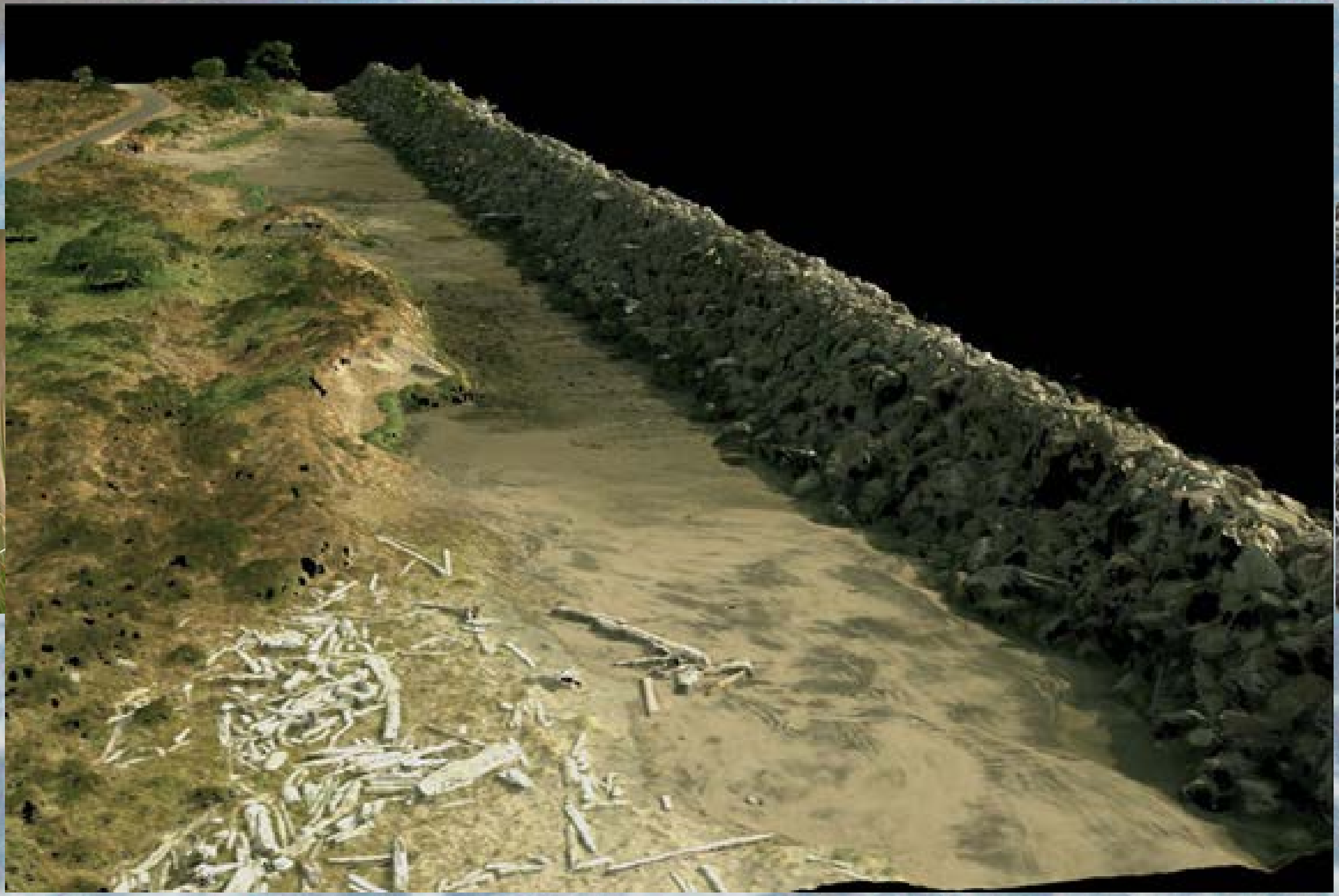
Thousands of models

- One of the problems with UAS imagery is that the UAS might hover when taking photos. It's possible to end up with thousands of models from several hundred photos since there is so much overlap. We have written a new, and very easy to use model orientation program that picks out the best models to set. This new program is called Vr Model Set (VrModSet).

- We also have a LiDAR module in which vector collection and editing is possible using point clouds from LiDAR or Digital Surface Models (DSM). This work is done using the same hardware as VrTwo and allows the work to be done in stereo 3D. If you are generating DSMs from imagery then you might be interested in VrLiDAR also.
- Below is a screen shot of a jetty area that is a Digital Surface Model (DSM) created from imagery. It's possible to collect and edit vector data from this in 3D stereo using our 3D Viewpoint module (http://www.vrmapping.net/help5/3dviewpoint.htm). This is from a customer in Oregon.

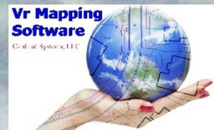
DSM

US Army Corps of Engineers dredging concerns for the habitat for the Streaked Horned Lark



Courtesy of David Smith & Associates

DSM – UltraCam UCE80



Conclusion

- We have spent quite a bit of time with UAS data lately. Writing a paper on mapping from a GoPro type camera. We picked this camera because it's the lowest cost, non-mapping camera we could think of. More on this later.

- Of the cameras we've processed UAS imagery from, the Sony Alpha 6000 is the most common. When we calibrated the 6000's lens the first time Mike was so impressed, he went out and bought one. It's now by his side all the time. These new mirror-less cameras are revolutionizing photography almost as much as when the first digital cameras came out. We have good results from the 6000. Be sure you use a fixed focal length lens. One customer is using the Sony Sonnar T* FE 35mm f/2.8 ZA lens and another is using the Voigtlander 15mm f/4.5 lens.

- While the results of these low cost cameras are good and we're able to calibrate the lenses fairly well, we think it's going to come down to image quality. These cameras are not on the same level as an UltraCam or DMC. The saving grace is that they are flying a lot closer to the ground.


QUESTIONS
Vr Mapping Software