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DMS-UAV Accuracy Assessment: AP20 with Nikon D800E

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Introduction

The Direct Mapping Solution for Unmanned Aerial Vehicles (DMS-UAV) is a complete and ready-to-integrate OEM solution for direct georeferencing on unmanned aerial platforms. Designed as a solution for systems integrators to create mapping payloads on UAVs of all types and sizes, DMS produces directly georeferenced products for any imaging sensor (digital camera, LiDAR, infra-red, multispectral imaging, even video). Additionally, DMS addresses the airframe's requirements for high-accuracy position and orientation for such tasks as precision RTK landing and Precision Orientation for Air Data Systems (ADS), Guidance and Control.

This paper presents the accuracy results using DMS to produce directly georeferenced orthorectified imagery from a test flight conducted by Applanix and GeoPixel Air on a manned platform over a test range north of Toronto, Ontario, Canada.

Configuration

The DMS configuration for the test as shown in figure 1 was as follows:

- The Trimble AP20 GNSS-Inertial System; embedded GNSS-Inertial OEM board set plus Inertial Measurement Unit (IMU)
- Nikon D800E (36MP; image size of 7360 columns by 4912 rows and a detector size of 4.9 microns) with a 50 mm AF-S Nikkor f/1.8G lens
- Aircraft: Cessna 182

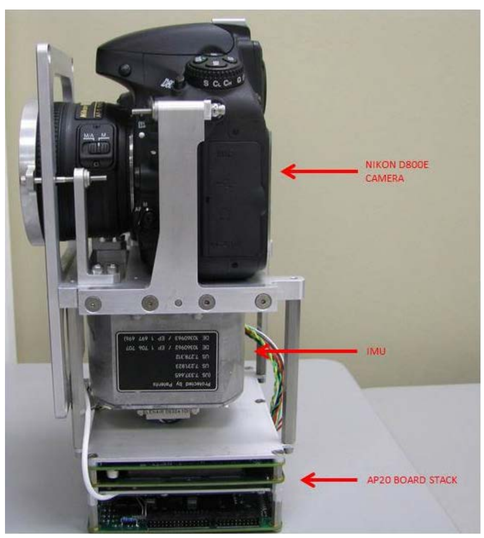


Figure 1: Applanix DMS-UAV

The Nikon D800E was focused and calibrated terrestrially using the Applanix camera calibration facility, and then integrated with the AP20 GNSS-Inertial system using a custom mount specifically designed for UAV applications. The mount is constructed in such a way as to maintain the stability of both the interior orientation and IMU bore-sight calibration over shock and vibration, thus turning the Nikon into a metric imaging solution.

Test Description

On September 27, 2013, Applanix carried out a test flight using the DMS installed in a Cessna 182 operated by GeoPixel Air. The goals of this test flight included:

- Evaluation of the quality and performance of the Nikon D800E camera with a 50 mm lens
- Assessment of the performance of DMS AP20 direct georeferencing system

The area mapped during the test was the Applanix Mount Albert test range in Ontario, Canada. Several ground control points are distributed within the test area. The test included 5 North-South lines flown at 4500 feet AGL, resulting in a 15cm GSD and 2 East-West lines flown at 3000 feet AGL, resulting in a 8 cm GSD.

A manned platform was used for the initial accuracy testing in order to provide a stable platform and eliminate the need to deal with regulations associated with flying unmanned vehicles.

Processing Description

POSPac MMS 6.1 was used to generate Exterior Orientation parameters for images collected during the test flight. The GNSS-Inertial data collected by the AP20 was post-processed in Single Base mode, using a base station located within the project area. This base station operates continuously, and its position was precisely determined by processing a number of 24-hour sessions using the Trimble CenterPoint RTX Post Processing service.

Test Results

A map view of the directly georeferenced orthorectified imagery is shown in Figure 2:

Figure 2: Orthophotos Displayed in Global Mapper

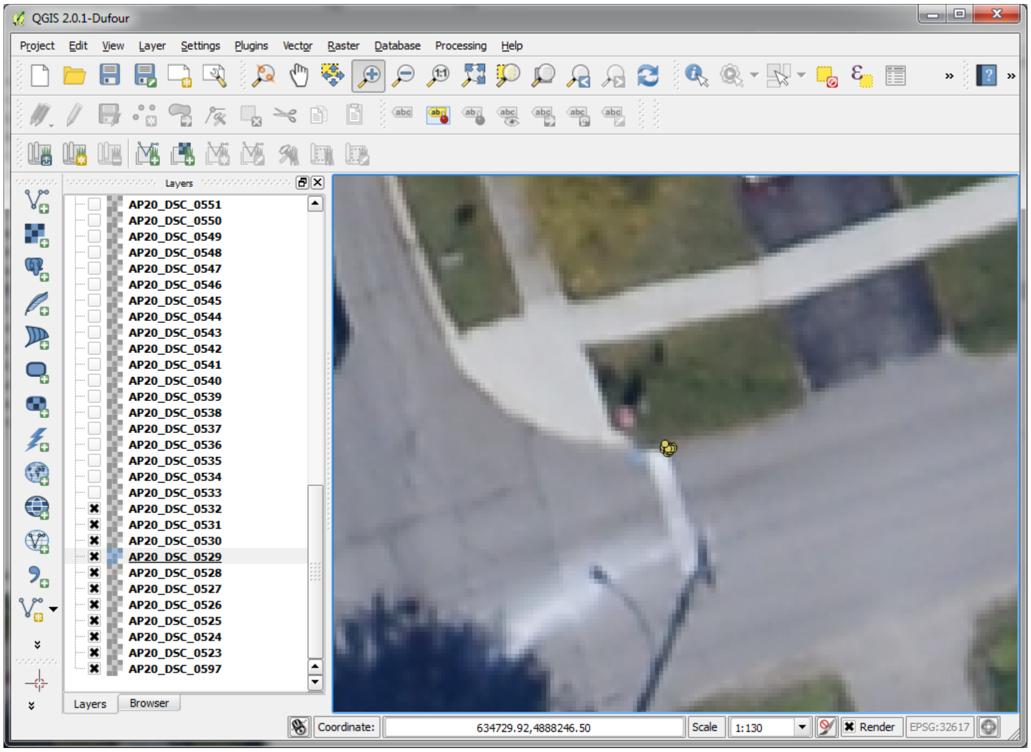
Image Accuracy Evaluation

Ortho-image Accuracy

The Inpho photogrammetric software package was used to develop ortho-images from the raw Nikon photos. The photos were ingested into an Inpho project, with camera calibration parameters defined by the Applanix terrestrial calibration and Exterior Orientation parameters generated from the GNSS-Inertial data by POSPac.

First, a Digital Surface Model (DSM) was self-extracted using Inpho MATCH-T DSM version 5.5. Using this DSM, the raw images were then orthorectified at a ground sample distance of 15 cm using Inpho OrthoMaster 5.5.

Because the number of available ground control points against which to evaluate absolute accuracy was relatively small, the accuracy of the ortho-images was instead evaluated by measuring the mis-registration of ground features between orthophotos. Using the Quantum GIS image viewer, each ground feature was measured in all available images. The figure below illustrates a typical distribution of measurements.



For each point, the mean position was computed from all images, and then the errors were computed by comparing against the mean position. Approximately 20 different ground features were used, resulting in approximately 170 total measurements. The computed accuracy values are summarized below. A more detailed list of results is presented in Table 1 below.

RMS Easting [m]	RMS Northing [m]	RMS Total [m]
0.10	0.10	0.14

Since the ground sample distance was 0.15 meters, this scales to pixels as follows:

RMS Easting [pixels]	RMS Northing [pixels]	RMS Total [pixels]
0.7	0.7	1.0

This level of accuracy is good enough to mosaic the images without noticeable mis-registration in the final mosaic.

Stereo Accuracy

Stereo accuracy was assessed using the Applanix Calibration and Quality Control application (CalQC) that is included with the POSPac Photogrammetry Tools module. This application has a 'Model QC' option that computes the estimated ground coordinates of each control point from each stereo-model, and then compares these estimated coordinates with the actual control point coordinates.

In order to perform the stereo accuracy assessment in CalQC, it was necessary to hold the camera calibration parameters, boresight angles, ground control point coordinates and exterior orientation parameters fixed, and then to measure the image location of each ground control point in each available image. This results in a photogrammetric bundle adjustment where none of the parameters are allowed to change; therefore, the post-adjustment statistics reflect the accuracy of the original, directly geo-referenced dataset.

From the Model QC output, summary statistics were gathered for each ground control point and were used to compile the overall accuracy values listed below. A more detailed list of results is provided in Table 2.

RMS Easting [m]	RMS Northing [m]	RMS Height [m]
0.22	0.15	0.60

Using a pixel resolution of 0.15 meters, this scales to pixels as follows:

RMS Easting [pixels]	RMS Northing [pixels]	RMS Height [pixels]
1.5	1.0	4.0

The height values are somewhat higher than those for Easting and Northing, but this is expected. Given the flying height and baseline distance between exposure stations, the convergence angle between stereo pairs is only about 9 degrees. In this case, the expected vertical error would be about 3.5x larger than the horizontal error due to the stereo geometry.

Table 1. Orthoimage Accuracy Measurements

Point ID	# of observations	Mean Easting [m]	Mean Northing [m]	RMS Easting [m]	RMS Northing [m]	RMS total [m]
1	8	635315.140	4888938.784	0.17	0.15	0.23
2	11	635477.405	4888370.821	0.07	0.07	0.10
3	12	635265.953	4888350.267	0.07	0.08	0.10
4	13	634866.556	4888845.146	0.16	0.11	0.19
5	21	634732.823	4888241.995	0.08	0.08	0.11
6	16	634313.871	4888491.361	0.10	0.14	0.17
7	12	634286.183	4887825.223	0.05	0.13	0.13
8	6	633636.486	4888457.149	0.08	0.09	0.12
9	13	634545.408	4888844.619	0.10	0.07	0.12
10	4	635586.394	4888461.011	0.03	0.09	0.10
11	10	635090.583	4887947.027	0.08	0.13	0.15
12	8	634836.348	4887755.128	0.09	0.08	0.12
13	6	634403.382	4887519.692	0.13	0.13	0.19

14	3	634014.828	4887463.468	0.07	0.05	0.09
15	6	634100.620	4888950.332	0.10	0.07	0.13
16	5	634095.857	4888184.983	0.11	0.06	0.12
17	10	634947.236	4887585.543	0.09	0.06	0.11
18	7	635274.021	4887638.547	0.13	0.09	0.16
Total	**171**			**0.10**	**0.10**	**0.14**

Table 2. Stereo Accuracy Measurements

Point ID	# of observations	RMS Easting [m]	RMS Northing [m]	RMS Height [m]
GCP00	7	0.23	0.17	0.39
GCP01	7	0.16	0.16	0.59
GCP04	10	0.29	0.13	0.58
GCP05	10	0.16	0.14	0.69
GCP07	9	0.11	0.13	0.54
GCP08	10	0.18	0.18	0.68
GCP09	6	0.32	0.19	0.72
GCP10	6	0.23	0.13	0.48
Total	**65**	**0.22**	**0.15**	**0.60**

Conclusion

Although this test was done on a manned platform (Cessna 172), it demonstrates the feasibility of using a DMS solution based upon a standard Nikon D800 camera to generate highly efficient, accurate and cost effective Directly Georeferenced map products from a payload small enough to fit into medium sized Unmanned Platforms. Accuracies were at the 1.0 pixel level RMS for the ortho products, and 1.5 pixels RMS horizontal and 4.0 pixels RMS vertical for stereo products (15 cm GSD).

Note: The accuracies demonstrated here will scale to lower flying heights and smaller GSD's until the lower limit of the GNSS position accuracy of 2 cm RMS is hit. At this point a relative photogrammetric adjustment will most likely be required to improve the overall accuracy further.