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Optimal Number of Ground Control Points for a UAV based Corridor Mapping

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ABSTRACT: Corridor mapping is a major use case in the field of engineering surveying. These surveys are conducted using survey grade equipment. Unmanned aerial vehicles (UAV) which are commercially available do not directly possess the capability to be a direct substitute for survey grade equipment. The data initially collected by the UAV must be corrected using ground control points (GCP). These ground control points are initially taken from survey grade instruments such as DGPS and RTK-GPS. In this study we have assessed the optimal number of ground control points to maintain survey grade accuracy throughout the corridor length using a UAV. Three iterations were conducted and results were concluded based on the errors obtained in X, Y and Z coordinates of each iteration.

KEYWORDS: UAV, Ground Control Points, Accuracy

I. INTRODUCTION

Unmanned aerial vehicles (UAV) have come a long way from military to commercial sector. Today UAV's are used in a number of commercial sectors to address problems such as reach, authenticity and longer lead time in data acquisition (Anuar Ahmad et.al. 2014 and Mauro Caprioli 2014). One such major sector is surveying applications. Traditional surveying practices are labour intensive which takes high manpower and a huge amount of lead time (Giribabu 2013). Many surveying firms are already using UAV's for applications such as mapping large parcels of land in turn key amount of time.

Corridor mapping is an operation where surveying is carried along the centerline of the corridor with a fixed width either side. All the features in the corridor are marked with X, Y and Z coordinates. Traditional surveying practices use instruments such as total station, auto level and DGPS (Nagi Zomrawi Mohammed 2013). The most accurate among the three being DGPS with an accuracy of <10cm. To replicate the same using only UAV's is not possible. As most of the UAV's are equipped with a commercial grade GPS of <2m accuracy. Hence each photo taken as well as the final output by the UAV and photogrammetric processing will have a maximum error of 2m (Udin 2014). This accuracy is not acceptable for engineering design and practices.

To rectify this problems Ground control points (GCP) are used. These are markings on the grounds which are made using survey grade instruments such as DGPS/ RTK GPS. We use these points during processing of the images to reduce the error in the final output to obtain survey grade accuracies. But the question of how many GCP's with respect to length of the corridor still remains. In this study we find the optimum number of GCP's based on errors for a particular length of the corridor.

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II. METHODOLOGY

Figure1 shows the workflow of the methodology adopted.

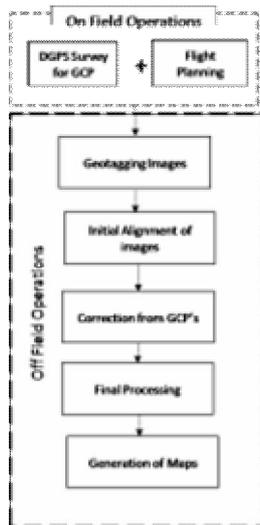


Figure 1: Methodology



Figure 2: Skylark Osprey UAV

ON FIELD OPERATION

The Skylark Osprey UAV (fig2) was used to perform the aerial survey. UAV specifications and study area is given in the table below

Table 1: UAV specifications and study area

Skylark Osprey UAV specifications		Study area(fig 3)
Wingspan	= 1.5 meters	Banashankari 6 th stage , Bengaluru
Payload	= 3 kgs	Lat : 12°53'16.68"N
Camera	= Sony Power shot SX230hs	Long: 77°30'47.37"E
Flight endurance	= 1 hour	Corridor dimensions = 600 X 60 meters



Figure 3: Study Area

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Before active data acquisition, an assessment of on field conditions such as preliminary visual survey of the site, Identification of potentially harmful features, check on prevailing weather conditions and implementing safety protocol.

Taking into account the above condition and factors altitude of flight was set at 130m above ground level to provide an expected Ground Sample Distance (GSD) of 4.2cm.

Ground Control Points (GCPs) collection being the most deciding factor for accurate results, we have considered DGPS survey for the acquisition of the geo-coordinates on field. The Base station was setup and total 9 GCPs were surveyed for corridor stretch of 650m. Over each GCP we have placed a marker (fig4).



Figure 4: DGPS



Figure 5: Flight planning

Flight planning for data acquisition is done by open source software Mission Planner (fig5). It is basically a ground control station for a drone and being used as a configuration utility or as a dynamic control supplement for your autonomous vehicle.

OFF FIELD PROCESSING

During the flight/data acquisition drone is recording a separate log file. This log file contains the geo-coordinates of the drone during the acquisition of data. Log file is read by Mission Planner and geo tags the images accordingly.

We need to perform the initial alignment of the images. Here, we have used a proprietary software Pix4D to perform initial alignment. Initial alignment is done to know whether the images were geo tagged and visualize the actual flight path taken. We get a Summary report after initial alignment which shows us previews of initial image position, overlap of images and information about internal camera parameters, Geo location details and Ground Sample Distance (Gsd).

After successful initial alignment of images, we now mark the GCP on the images. Here we perform 3 iterations considering different number of GCPs every time. We have considered the following number of GCPs for each iteration i.e. 9, 5 and 3. For each iteration we perform a final processing and generate the results. Comparison of RMSE error is performed on each axis i.e. XYZ and results are discussed. The various maps produced in the end were Orthomosaic, Digital Surface Model (DSM), Digital Terrain Model (DTM) and contour maps.

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III. RESULTS

Three combinations of GCP's were used for comparisons in three different trails. In trail1 all 9 GCP's were used in processing of the results. The obtained values were compared with the DGPS readings and the errors are tabulated in the table below. Similarly in trail 2 and trail 3 a total of 5 GCP's and 3 GCP's are used in the processing respectively. The respective errors are tabulated below.

Table 2: UAV specifications and study area

GCP	Trail 1			Trail 2			Trail 3		
	Error_X	Error_Y	Error_Z	Error_X	Error_Y	Error_Z	Error_X	Error_Y	Error_Z
1	-0.006	-0.037	-0.189	0.008	0.021	-0.096	0.006	0.032	0.146
2	-0.004	-0.007	-0.031	0.006	-0.009	0.065	-0.036	-0.023	0.203
3	-0.019	-0.021	-0.003	0.012	-0.036	0.123	0.025	0.068	0.03
4	-0.005	0.022	0.058	0.013	0.011	-0.102	-0.013	0.035	-0.036
5	-0.022	0.000	0.071	-0.022	0.068	-0.115	0.086	-0.065	-0.036
6	-0.02	0.006	0.146	0.063	0.025	0.036	-0.068	0.096	0.002
7	-0.036	-0.029	-0.001	0.018	0.029	0.168	-0.078	0.025	0.169
8	-0.044	-0.057	0.02	-0.041	-0.003	0.098	0.013	0.035	0.159
9	-0.093	-0.004	0.146	-0.007	0.035	0.024	0.002	-0.014	-0.065
Mean	-0.02766	-0.01411	0.02411	0.00555	0.01566	0.02233	-0.00700	0.02100	0.06355
RMSE	0.00882	0.00761	0.03199	0.00905	0.00933	0.03285	0.01569	0.01528	0.03291

■ Denotes GCP used for processing

IV. DISCUSSION

The major point to be discussed is that more the number of GCP's does not necessarily mean the processed data will be more accurate. This is due to the fact that there might be manual errors committed while performing the GCP correction step prior to processing. As each individual photo might contain disturbances such as over or under exposure, disturbances due to instantaneous pitch, yaw and roll values, camera triggering and autopilot errors

It has to be noted that in all the three trails the maximum error in X and Y (Table 3) direction is less than three times Ground sample distance (GSD = 4.24 cm) which is 12.72 cm. In the Z direction the maximum error is less than five times GSD which is 21.2 cm. Hence the errors are within the specified accuracy limit of the processing algorithm.

Table 3: Maximum error

Trail no	Max X error (in cms)	Max Y error (in cms)	Max Z error (in cms)
1	9.3	5.7	18.9
2	6.3	6.8	16.8
3	8.6	9.6	20.3

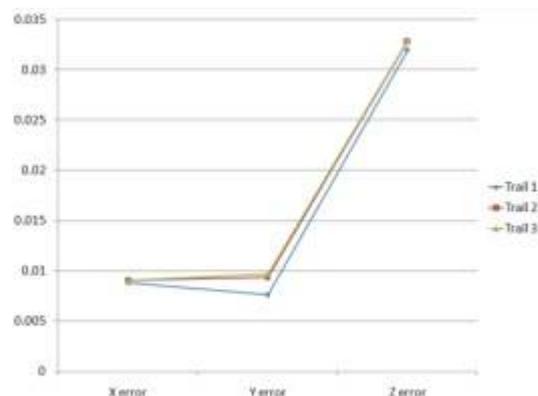


Figure 6: Error Plot

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From the results obtained it is evident that the X RMSE error increases from 8.8mm to 9.3mm to 15.6mm in trail 1, 2 and 3 respectively. Similarly the Y RMSE error increase from 7.6mm to 9.3mm to 15.2mm. In all three trails we find an increased variation in the Z values but the RMSE values of the three trails do not vary by a large deviation (Fig.6).

V. CONCLUSION

For the 600 meters of corridor selected we see little change in the error with reduction of number of GCP's. Given that three GCP's are the minimum amount of GCP's required to correct the initially aligned images we conclude three GCP's are sufficient to produce desired accuracy for a given stretch of 600 meters. Though increase in GCP's may increase the accuracy it is not a significant value. Also one must note that every GCP point will require a minimum of 45 minutes of setup time bearing in mind the whole UAV survey takes just 20 minutes for that length of corridor.

VI. FURTHER STUDIES

The same concept must be tested for longer length of corridor as three GCP's cannot sustain desired accuracies over lengthy stretches of a corridor. Also the change in accuracy with respect to varying GSD's must be tested out to obtain a clear idea of the optimal GSD and number of GCP's for longer corridors.

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