MAPPINGMATTERS

YOUR QUESTIONS ANSWERED

The layman's perspective on technical theory and practical applications of mapping and GIS

BY Qassim A. Abdullah, Ph.D., PLS, CP**

QUESTION:

Question: I have a few questions related to the use of the ASPRS Positional Accuracy Standards for Digital Geospatial Data of 2014:

1. If a project in which lidar and imagery were acquired for the same client under the same contract consists of two or more distinctly separate, non-contiguous blocks, can they or should they be combined when considering the recommended number of ground control points (GCPs) and checkpoints required for non-vegetated vertical accuracy (NVA) and vegetated vertical accuracy (VVA) testing?
2. Can you elaborate on accuracy thresholds in the current standard for surveyed ground control and checkpoints? Do you think it is practical on a regular basis to provide GCPs that are four times more accurate and checkpoints that are three times more accurate than the desired quality level for the aerial data?
3. In some cases, it is impossible or not practical to establish ground control in locations that are ideal for the even distribution of GCPs and checkpoints throughout a project. When it is not possible due to limited access or other issues, what do you suggest?
4. Would you elaborate on the minimum number of NVAs and VVAs for vertical verification?
5. Please discuss the use of standard deviation as a measure of the "accuracy" or "precision" evaluator for individual ground surveyed GCPs and checkpoints.

Jim Gillis, Survey Manager, *VeriDaaS Corporation*

Dr. Abdullah: Thanks for your questions, Jim. You bring up important topics that others in the industry have expressed concern about. I will address your questions in the order asked:

1. **Should you combine GCPs and checkpoints for non-contiguous areas?** That depends on the way the data were processed. For the photogrammetric processing of imagery, if an entire project area is processed as a single entity in one aerial triangulation block, and each of these subareas contains at least one ground control point, then I do not see why you can't use the minimum number of GCPs or checkpoints recommended by the standard for the project. This also applies to lidar data. If the calibration and boresighting of the data for the entire project area were performed in one session using a single set of calibration, then my previous suggestion for the imagery can be used. However, if each subarea of the project is processed individually, then a data accuracy assessment should be performed for each subarea as if it was a separate project. In the latter example, you would then combine the results from testing all subareas to achieve project-wide accuracy statistics.

> **"The RMSE value models random error and biases, while the standard deviation represents only random error and does not indicate the presence of biases in the data"**

2. **GCP and checkpoint accuracy thresholds:** As you referenced, the current edition of the standard calls for GCPs used for photogrammetric processing to be four times more accurate than the derived mapping product and for the accuracy of checkpoints to be three times more accurate than the tested product. It is worth mentioning here that the current standard does not provide guidance on the accuracy of ground control points used for Lidar data processing, but we do plan to add such a requirement to the coming revised edition. Anyhow, user experience tells us that these requirements are a little aggressive and can be difficult to meet—especially when dealing with products that require to meet an accuracy of 5cm or better. These accuracy thresholds were put in place to provide a reasonable product safety measure that was in line with the best practices and mapping technologies used at that time. However, since that standard was published, our processes and sensor technologies have become more refined, and the margin for error has diminished. Additionally, the demand for highly accurate products has increased. This has strained our surveying techniques in an attempt to meet

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this tight product accuracy requirement for the ground control network. For example, we started seeing more demand for lidar data that meet U.S. Geological Survey Quality Level 0 (QL0) accuracy of 5cm (as RMSEz). According to the current standard, you need checkpoints that are three times more accurate than the 5cm to verify the vertical accuracy of that product. That means the survey network of checkpoints need to achieve a vertical accuracy of 1.67cm. We all know that this tight vertical accuracy is difficult, if not impossible, to achieve using the popular RTK surveying techniques. To survey checkpoints with a vertical accuracy of 1.67cm, you need to use more expensive field surveying techniques that make the project extremely cost-prohibitive, especially for larger survey areas. To remedy the situation and address how processes and technologies that have evolved, ASPRS is revising the standard. Work is underway and, hopefully by the end of this year, ASPRS will publish a new standard that includes a less stringent requirement for GCP and checkpoint accuracy.

> **"the current edition of the standard calls for GCPs used for photogrammetric processing to be four times more accurate than the derived mapping product and for the accuracy of checkpoints to be three times more accurate than the tested product."**

3. **Even distribution of GCPs and checkpoints:** Being able to evenly distribute GCPs and checkpoints throughout a project area on a regular basis is a common and valid concern. Although the ASPRS standard and the National Standard for Spatial Data Accuracy guidelines call for an even distribution of the ground control network, it is widely acknowledged that this requirement cannot always be met for multiple reasons, including ground cover and site access restrictions. In the coming edition of the ASPRS standard, we will note that under these circumstances, the data provider, in consultation with the data user, will distribute the ground control network based on site circumstances to the best of their ability.
4. **The minimum number of checkpoints for NVA and VVA accuracy verification:** In a scientifically sound test, the size of the sample, which is the number of checkpoints in our case, needs to be large enough to represent the population, which is the geospatial data we are testing. The standard in Table C.1, provides recommendations for the number of checkpoints necessary to assess NVA and VVA. The recommended number of checkpoints is a function of the project size, and that number grows as the project area increases. As provided in that table, the minimum number of checkpoints for any project is 20 for NVA testing and 25 for NVA and VVA testing (20 for NVA and 5 for VVA). This is another area in which you will see a major change in the recommended number of checkpoints when the new edition of the standard is published.

> **"In a scientifically sound test, the size of the sample, which is the number of checkpoints in our case, needs to be large enough to represent the population, which is the geospatial data we are testing"**

5. **The use of standard deviation as a measure of the "accuracy" or "precision" evaluator for the individual ground surveyed GCPs and checkpoints:** When we authored the first edition of the standard in 2014, there were discussions on whether we should use the standard deviation instead of the root mean square error (RMSE). We ended up adopting the use of root-mean-square (RMS) instead for the reasons explained in the next few paragraphs. When the data is free of systematic error or biases and only random error exists in the data, the standard deviation and RMSE values are almost identical. However, using the RMSE has an advantage, and it provides a safeguard for the industry, especially when the data contains biases. The RMSE value models random error and biases, while the standard deviation represents only random error and does not indicate the presence of biases in the data. A technician who is evaluating product accuracy may not have the necessary statistical understanding of errors theory and may only be trained to watch for the accuracy threshold. For this technician, the same dataset in the presence of biases will present them with two accuracy numbers; for example, a standard deviation value of 5cm and an RMSE value 9cm. If the product needs to meet an accuracy of 5cm, looking at the standard deviation alone, the technician will pass the quality and certify the data as meeting the promised specifications. While if the technician is presented with RMSE only, they would declare that the data does not meet the specification. This is a broad explanation to clarify this question. If the technician has the necessary education and can evaluate the mean of the statistics, which in most cases reveals the presence of biases, the technician may realize that there are systematic errors, or biases, in the data that need to be dealt with despite the fact that the data accuracy represented by the standard deviation is within the project specifications. To illustrate the problem of using the standard deviation versus RMSE, Table 1 lists details of actual vertical accuracy assessment of a point cloud from a UAS using 28 checkpoints. The vertical accuracy threshold for the project was set to be 0.10 ft. as RMSEz.

   The results of the computations presented in the last few rows of Table 1 are highlighted in Table 2.

Table 1.

Point ID	Surveyed Elevation			UAS Elevation	Residual Values (ft.)	Delta Z after Z-bias Removed (ft.)
	Easting (ft.)	Northing (ft.)	Elevation (ft.)	Elevation (ft.)	Error in Elevation (ft.)	
CP_1	2447813.6658	320999.2773	1091.2897	1091.0405	0.2492	0.0033
CP_2	2447783.7307	321113.7985	1095.1525	1094.9447	0.2078	-0.0381
CP_3	2447759.1650	321215.2972	1098.3978	1098.1479	0.2499	0.0040
CP_4	2447733.0793	321308.6243	1101.5030	1101.2323	0.2707	0.0248
CP_5	2447700.7566	321419.0448	1105.1964	1104.9249	0.2715	0.0256
CP_6	2447674.8168	321511.8570	1108.2950	1108.0041	0.2909	0.0450
CP_7	2447653.6632	321604.4581	1111.2501	1110.8518	0.3983	0.1524
CP_8	2447626.2922	321705.3985	1114.6540	1114.3570	0.2970	0.0511
CP_9	2447596.3534	321793.1424	1117.6797	1117.3404	0.3393	0.0934
CP_10	2447571.4603	321890.3933	1120.9124	1120.8596	0.0528	-0.1931
CP_11	2447546.6611	321995.9759	1124.4512	1124.1878	0.2634	0.0175
CP_12	2447526.5566	322083.3588	1127.2359	1126.9793	0.2566	0.0107
CP_13	2447500.2614	322166.6011	1130.1904	1129.8961	0.2943	0.0484
CP_14	2447466.4229	322281.2289	1134.0343	1133.8363	0.1980	-0.0479
CP_15	2447308.6649	322248.5215	1138.2702	1138.0751	0.1951	-0.0508
CP_16	2447344.7171	322148.4501	1134.5498	1134.3433	0.2065	-0.0394
CP_17	2447365.3790	322069.0943	1131.7290	1131.6055	0.1235	-0.1224
CP_18	2447397.6980	321961.4341	1127.9513	1127.8022	0.1491	-0.0968
CP_19	2447432.4695	321852.6548	1124.1650	1124.0704	0.0946	-0.1513
CP_20	2447461.1104	321756.1124	1120.7587	1120.4909	0.2678	0.0219
CP_21	2447488.2891	321668.7552	1117.6552	1117.3064	0.3488	0.1029
CP_22	2447517.8379	321559.0553	1113.8186	1113.5437	0.2749	0.0290
CP_23	2447551.4267	321449.0224	1110.0430	1109.8008	0.2422	-0.0037
CP_24	2447574.2564	321367.1508	1107.0800	1106.8535	0.2265	-0.0194
CP_25	2447603.1840	321268.4371	1103.5923	1103.2865	0.3058	0.0599
CP_26	2447630.6428	321182.1303	1100.5619	1100.2992	0.2627	0.0168
CP_27	2447658.1476	321084.4832	1097.1436	1096.9267	0.2169	-0.0290
CP_28	2447691.2635	320973.0090	1093.2373	1092.9071	0.3302	0.0843
	Number of checkpoints				28	28
	Mean error				0.246	0.000
	Standard deviation (StDEV)				0.076	0.076
	Root mean square error ($RMSE_Z$)				0.257	0.075
	NSSDA vert accuracy at 95% accuracy level				0.504	0.147
	NSSDA vert accuracy at 95% accuracy level after Z-bias removal				0.147	

Table 2.

Number of Checkpoints	28	28
Mean error	0.246	0.000
Standard deviation (StDEV)	0.076	0.076
Root mean square error ($RMSE_Z$)	0.257	0.075
NSSDA vert accuracy at 95% accuracy level	0.504	0.147
NSSDA vert accuracy at 95% accuracy level after Z-bias removal	0.147	

"For the photogrammetric processing of imagery, if an entire project area is processed as a single entity in one aerial triangulation block, and each of these subareas contains at least one ground control point, then I do not see why you can't use the minimum number of GCPs or checkpoints recommended by the standard for the project."

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As you may notice, the computed standard deviation value of 0.076 ft. is well within the accuracy requirement for the project of 0.10 ft. A technician looking only at the standard deviation will qualify the data as meeting specifications. While looking at the RMSEz value, it clearly indicates that the data fails the accuracy test. Unlike the standard deviation value of 0.076 ft., the value of RMSEz = 0.257 ft. will trigger an alarm for the technician. If we look at the mean error of 0.246 ft., it indicates a bias in the data and most of the bias can be removed if we Z-bumped the data by 0.246 ft. Once the data are raised or lowered by the amount of the bias of 0.246 ft. and the test is repeated, the RMSE value comes down to 0.075 ft. as illustrated in the far right column of the table. Once we removed the bias from the data, the RMSE value becomes very close to the standard deviation value. This example highlights the importance of using RMSE when evaluating accuracy of geospatial data.

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