THE NEW STANDARD OF MAP ACCURACY

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Different nations and national agencies develop standards to govern and control the quality of certain products offered to the public by private or public entities. In the U.S., map standards were developed to define the required horizontal and vertical accuracy for a map as early as 1942 with the National Map Accuracy Standard (NMAS) by the U.S. Bureau of the Budget. The NMAS was published to fulfill the needs of the mapping community during a time that was characterized by small-scale paper maps produced by low-tech processes and technologies.

With the rapid progress in mapping technologies and techniques, however, the NMAS began to fall short by the 80s and 90s in addressing the growing needs of a new era of mapping activities. Such need opened the door for the American Society of Photogrammetry and Remote Sensing (ASPRS) to develop a new mapping standard that was more suitable for the more accurate, larger scale maps. That new ASPRS standard was published in the early 90s and is still used today.

A New Mapping Standard

Although, the current ASPRS standard addressed the needs of the mapping community during the 90s and early 2000s, it has now fallen behind on covering the growing needs of the mapping community. Today's mapping processes are very sophisticated and complicated and are characterized by the use of computers to perform most tasks. Very few maps are still produced on paper or other hardcopy media. In addition, the current state of technologies brought to the market a very accurate product that far exceeded the quality and accuracy of the mapping products that were produced just a few decades ago. Today's maps are:

- Produced from traditional sensors such as aerial cameras and non-traditional sensors such as LiDAR and IFSAR
- Produced using a fully digital workflow, starting with the digital acquisition and ending with the softcopy photogrammetric mensuration
- Produced in a hardcopy environment, and most maps are represented in a CAD package
- More accurate than old maps

These characteristics create a pressing need for a new mapping standard that is capable of addressing the quality and accuracy of mapping products. Based on this, the ASPRS through its Primary Data Acquisition Division (PDAD), tasked a committee of specialists and scientists to draft a new mapping standard that addresses today's users' needs.
In its second year of working on the standards, the committee is finalizing a draft that it will release soon to the public for feedback and comments. The new draft standard:

- Embraces products from the new sensors such as digital cameras, LiDAR and IFSAR
- References the horizontal map accuracy for digital orthos to the pixel size or the ground sampling distance (GSD) of the product and not to a map scale
- Addresses other accuracy aspects such as seamliness quality and LiDAR relative accuracy between flight lines
- Addresses large-scale and engineering maps
- Is based on metric units
- Follows the most common map scales used worldwide and uses the 1:xxxx scale measure instead of the 1"=xx'
- Introduces more stringent accuracy measures

Highlights of the Draft Standard

Horizontal Accuracy

The draft standard uses three horizontal accuracy classes, with class I being the highest. The standard differentiates digital ortho products from digital line maps (planimetric) due to the nature of the two products. For digital ortho products, the horizontal accuracy is calculated in reference to the GSD of the ortho product. Table 1 presents the proposed horizontal accuracy for the digital ortho products.

Using table 1, the accuracy figures for the most common ortho resolutions were calculated and presented in table 2. Table 2 also provides the user with a new measure to evaluate the quality of the mosaic seamlines.

As for the planimetric map, the standard adopted the map scale, as it is the natural way of representing a line map. Table 3 shows the horizontal accuracy measure for planimetric maps, while table 4 shows the accuracy figures for the most common planimetric map scale.

Vertical Accuracy

For the sake of vertical accuracy, the draft standard breaks the land cover into two categories: non- vegetated (NVA), and vegetated (VVA) terrain. The draft standard utilizes the root mean squares error (RMSE) as a measure for the vertical accuracy. Table 5 presents vertical accuracy figures for ten accuracy classes relevant to elevation technologies, including mobile mapping systems, unmanned aerial systems, airborne or satellite stereo imagery, LiDAR or IFSAR. Table 5 also introduces the relative accuracy between swaths.

Concluding Remarks

The new standard, once it is published, will provide a great service to the GIS and mapping community in the U.S. and worldwide. Many of the concepts presented in the draft are new to the community and many experts around the world are waiting for such aggressive but thorough measures on the map accuracy testing and verification to be published. The latter statement is especially true for the new technologies, such as digital camera, LiDAR and IFSAR, as there are no good guidelines to evaluate the new mapping products. Once the new standard is accepted and published, many of our production processes need to be evaluated and improved as the new standard brings more stringent accuracy measure for all GIS products.

Table 1. Horizontal Accuracy Standards for Orthophotos

Horizontal Data Accuracy Class	RMSEx and RMSEy	Orthophoto Mosaic Seamline Maximum Mismatch
I	Pixel size x 1.0	Pixel size x 2.0
II	Pixel size x 1.5	Pixel size x 3.0
III	Pixel size x 2.0	Pixel size x 4.0

[1] *Horizontal (radial) accuracy at the 95% confidence level = RMSEr x 1.7308*

Table 2. Horizontal Accuracy/Quality Examples for Digital Orthophotos

Orthophoto Pixel Size	Horizontal Data Accuracy Class	RMSEx or RMSEy (cm)	RMSEr (cm)	Orthophoto Mosaic Seamline Maximum Mismatch (cm)	Horizontal Accuracy at the 95% Confidence Level[1] (cm)
2.5-cm (~1 in)	I	2.5	3.5	5.0	6.1
	II	3.8	5.3	7.5	9.2
	III	5.0	7.1	10.0	12.2
5-cm (~2 in)	I	5.0	7.1	10.0	12.2
	II	7.5	10.6	15.0	18.4
	III	10.0	14.1	20.0	24.5
7.5-cm (~3 in)	I	7.5	10.6	15.0	18.4
	II	11.3	15.9	22.5	27.5
	II	15.0	21.2	30.0	36.7
15-cm (~6 in)	I	15.0	21.2	30.0	36.7
	II	22.5	31.8	45.0	55.1
	III	30.0	42.4	60.0	73.4
30-cm (~12 in)	I	30.0	42.4	60.0	73.4
	II	45.0	63.6	90.0	110.1
	III	60.0	84.8	120.0	146.8
60-cm (~24 in)	I	60.0	84.8	120.0	146.8
	II	90.0	127.0	180.0	220.3
	III	120.0	170.0	240.0	293.7
1-meter	I	100.0	141.0	200.0	244.7
	II	150.0	212.0	300.0	367.1
	III	200.0	283.0	400.0	489.5
2-meter	I	200.0	283.0	400.0	489.5
	I	300.0	424.0	600.0	734.3
	III	400.0	566.0	800.0	979.1
5-meter	I	500.0	707.0	1000.0	1224.0
	I	750.0	1061.0	1500.0	1836.0
	III	1000.0	1414.0	2000.0	2448.0
10-meter	I	1000.0	1414.0	2000.0	2448.0
	II	1500.0	2121.0	3000.0	3672.0
	III	2000.0	2828.0	4000.0	4895.0
	II	1500.0	2121.0	3000.0	3672.0
	III	2000.0	2828.0	4000.0	4895.0

Table 3. Horizontal Accuracy Standards for Digital Planimetric Data

Horizontal Data Accuracy Class	RMSEx and RMSEy (cm)
I	1.25% of Map Scale Factor (0.0125 x Map Scale Factor)
II	1.5 x Class I Accuracy (0.01875 x Map Scale Factor)
III	2.0 x Class I Accuracy (0.025 x Map Scale Factor)

Table 4. Horizontal Accuracy/Quality Examples for Digital Planimetric Data

Map Scale	Approximate Source GSD	Horizontal Data Imagery Class	RMSEx or Accuracy (cm)	RMSEr (cm)	Horizontal Accuracy at the 95% Confidence Level (cm)
1:100	1.25 cm	I	1.3	1.8	3.1
	II	1.9	2.7	4.6	
	III	2.5	3.5	6.1	
1:200	2.5 cm	I	2.5	3.5	6.1
	II	3.8	5.3	9.2	
	III	5.0	7.1	12.2	
1:250	3.125 cm	I	3.1	4.4	7.6
	II	4.7	6.6	11.5	
	III	6.3	8.8	15.3	
1:500	6.25 cm	I	6.3	8.8	15.3
	II	9.4	13.3	22.9	
	III	12.5	17.7	30.6	
1:1,000	12.5 cm	I	12.5	17.7	30.6
	II	18.8	26.5	45.9	
	III	25.0	35.4	61.2	
1:2,000	25 cm	I	25.0	35.4	61.2
	II	37.5	53.0	91.8	
	III	50.0	70.7	122.4	
1:2,500	31.25 cm	I	31.3	44.2	76.5
	II	46.9	66.3	114.7	
	III	62.5	88.4	153.0	
1:5,000	62.5 cm	I	62.5	88.4	153.0
	II	93.8	132.6	229.5	
	III	125.0	176.8	306.0	
1:10,000	1.25 m	I	125.0	176.8	306.0
	II	187.5	265.2	458.9	
	III	250.0	353.6	611.9	
1:25,000	3.125 m	I	312.5	441.9	764.9
	II	468.8	662.9	1147.4	
	III	625.0	883.9	1,529.8	
1:50,000	6.25 m	I	625.0	883.9	1,529.8
	II	937.5	1,325.8	2,294.7	
	III	1,250.0	1,767.8	3,059.6	
1:100,000	12.5 m	I	1,250.0	1,767.8	3,059.6
	II	1,875.0	2,651.6	4,589.4	
	III	2,500.0	3,535.5	6,119.2	
1:250,000	31.25 m	I	3,125.0	4,419.4	7,649.1
	II	4,687.5	6,629.1	11,473.6	
	III	6,250.0	8,838.8	15,298.1	

Table 5. Vertical Accuracy Standards for Digital Elevation Data

Vertical Data Accuracy Class	RMSEz in Non-Vegetated Terrain (cm)	Non-Vegetated Vertical Accuracy[2] (NVA) at 95% Confidence Level (cm)	Vegetated Vertical Accuracy[3] (VVA) at 95th Percentile (cm)	Lidar Relative Accuracy Swath-to-Swath in Non-Vegetated Terrain[4] (RMSDz/ Max Diff) (cm)
I	1.0	2.0	3.0	0.8/1.6
II	2.5	5.0	7.5	2.0/4.0
III	5.0	10.0	15.0	4.0/8.0
IV	10.0	20.0	30.0	8.0/16.0
V	12.5	25.0	37.5	10.0/20.0
VI	20.0	40.0	60.0	16.0/32.0
VII	33.3	66.7	100.0	26.7/53.3
VIII	66.7	133.3	200.0	53.3/106.6
IX	100.0	200.0	300.0	80.0/160.0
X	333.3	666.7	1000.0	266.6/533.4

[2] *Statistically, in non-vegetated terrain and elsewhere when elevation errors follow a normal distribution, 68.27% of errors are within one standard deviation (σ) of the mean error, 95.45% of errors are within 2σ of the mean error, and 99.73% of errors are within 3σ of the mean error. The formula 1.96 σ is used to approximate the maximum error either side of the mean that applies to 95% of the values. Standard deviations do not account for systematic errors in the dataset that remain in the mean error. Because the mean error rarely equals zero, this must be accounted for. Based on empirical results, if the mean error is small, the sample size sufficiently large and the data is normally distributed, 1.96 x RMSEz is often used as a simplified approximation to compute the NVA at a 95% confidence level. This approximation tends to overestimate the error range as the mean error increases. A precise estimate requires a more robust statistical computation based on the standard deviation and mean error. ASPRS encourages standard deviation, mean error, skew and RMSE to all be computed in error analyses to more fully evaluate the magnitude and distribution of the estimated error. While recognizing that the correct multiplier to approximate the NVA at the 95% confidence level is 1.96, ASPRS deliberately uses a 2.0 multiplier in Table 3 to simplify the memorization of the ASPRS NVA accuracy thresholds.*

[3] *VVA standards do not apply in heavily vegetated areas delineated with a low-confidence polygon (see Appendix C). Field surveys may be required to test vertical accuracies in heavily vegetated areas.*

[4] *For computing LiDAR relative accuracy swath to swath in non-vegetated terrain, elevation differences will not follow a truly normal distribution; elevation differences should be more tightly clustered, and the difference histogram should show elevated kurtosis.*