Mapping Matters

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

Your Questions Answered

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

Question: I noticed that the vertical accuracy is more stringent than the horizontal accuracy according to both ASPRS and NSSDA standards. For example, if I produce orthophoto products from 15 cm (6 in) digital imagery, the stated horizontal accuracy using the ASPRS standard is 30 cm (1 ft), while the expected vertical accuracy is 20 cm (0.67 ft). We always believed that the vertical accuracy of any mapping product is less stringent than the horizontal accuracy. Why is that?

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Dr. Abdullah: **PART III**: In Parts I (*PE&RS*, August 2010) and II (*PE&RS*, September 2010) of my answer, I addressed the issues that resulted in the contradictory accuracy figures that came into question. I explained that many of the map accuracy standards used today, particularly here in the United States, were derived from the use of film sensors and paper maps. I called on all concerned agencies and organizations in the United States to develop a new national standard that can be applied to modern geospatial data products. I also introduced some high level thoughts and ideas to generate discussions on how to create such a standard. The following summarizes the thoughts and ideas that I introduced earlier:

1. **The new standard should be useful on a national level**
2. **The new standard should be modular**
3. **The new standard should apply one of the following two measures to classify the accuracies of final products:**
   a) Accuracy according to the resolution of the final delivered products
   b) Accuracy according to national map classes
4. **The new standard should address aerial triangulation, sensor position, and orientation accuracies**

All current standards, except NSSDA, were published before lidar and IFSAR technologies were introduced to the mapping industry. As a result, we are lacking an accuracy standard that supports data produced from these technologies."

In this month's issue, I would like to introduce the final part of my answer (part III), which focuses on the importance of developing a standard that supports data derived from non-conventional modern mapping sensors such as lidar, IFSAR, and underwater topographic survey using bathymetric lidar and acoustic devices, such as active sonar (**SO**und **N**avigation **A**nd **R**anging). I will also offer recommendations on the statistical methodology and confidence level that I think the standard should endorse.

5. **The new standard should support data from non-imaging sensors, such as lidar and IFSAR**

All current standards, except NSSDA, were published before lidar and IFSAR technologies were introduced to the mapping industry. As a result, we are lacking an accuracy standard that supports data produced from these technologies. The standard should treats points-based-data differently from the data produced by imaging and photogrammetric sensors, which are produced using continuous terrain sampling methods. Moreover, two distinct aspects of lidar terrain surface data must first be measured before the standard can feasibly be used for points-based data. Each aspect described below, complements each other when they are used for evaluating lidar data:

a) **Lidar Data Accuracy:** Lidar Data Accuracy is represented by the absolute horizontal and vertical accuracy of the individual lidar points, which collectively form the surface or point-clouds (a term used to refer to the point-based terrain data collected with lidar).

The accuracy of lidar-based terrain surface should not be based on the absolute accuracy of the individual lidar point alone. An additional lidar dataset characteristic must also be considered in order to determine the correct accuracy. This additional characteristic, which is represented by the density of the lidar points in a dataset, will be discussed in the next section.

b) **Lidar Data Quality:** The quality of the lidar data equates to how well the lidar data represents the terrain undulation and continuity. No matter how accurate the individual lidar point is, without dense lidar data to represent terrain continuity, the data cannot be classified as accurate or of high quality. The following example will help simplify my point.

Example: A user requests that lidar data be used to map perms and ditches in rolling terrain. The perms and ditches are, on the average, about 1.0 meter wide and 0.60 meter deep. The data provider proposes a lidar dataset with the following specifications:

Horizontal accuracy: $RMSE_{XY}$ = 0.40 m
Vertical accuracy: $RMSE_{Z}$ = 0.10 m
Nominal post spacing of lidar points: 2.0 m

Using only this dataset, can the user map perms and ditches to match the lidar data accuracy stated by the vendor?

I hope we all agree that the answer to this question is no. In order to map the perms and ditches with sound terrain modeling accuracy, the user needs a denser lidar dataset (better quality) with a nominal post spacing of one meter or better, or a dataset that has been augmented with breaklines derived from another source, such as photogrammetry. Figures 1 to 3 clearly demonstrate the effects of lidar point density on the quality of terrain data, and eventually on the overall accuracy of the mapping products derived from a lidar dataset.

Figures 1 and 2 demonstrate, with some exaggeration, how a sparse lidar dataset affects terrain modeling. In Figure 2, the straight lines AB, BC, CD, and DE represent the shape of the terrain according to the Triangulated Irregular Network (TIN) surface constructed to represent the actual curve-shaped segments of the

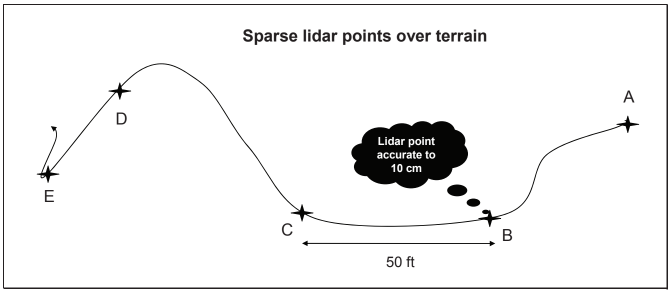

Figure 1. Terrain Modeling with Sparse Lidar Data.

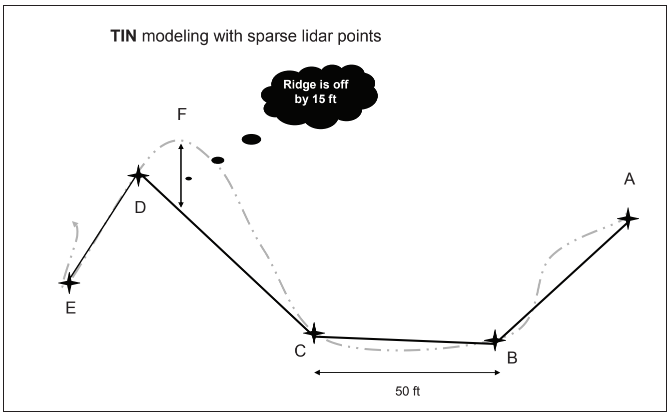

Figure 2. Effect of Sparse Lidar Data on Terrain Representation.

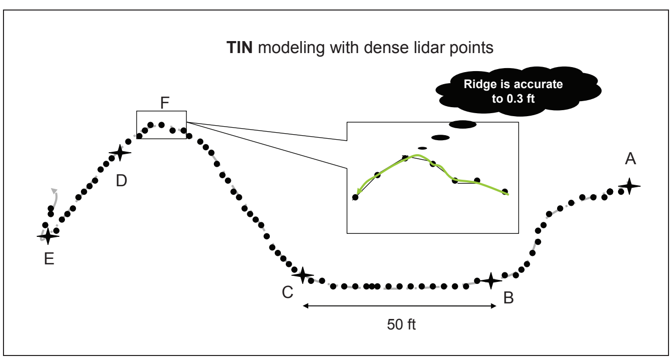

Figure 3. Terrain Modeling with Dense Lidar Data.

terrain between stations A, B, C, D and E (shown with dash lines). As depicted in Figure 2, if one tries to measure the elevation of the hill at point F, an error of 15 ft. may be introduced from using a lidar dataset with sparse points (every 50 ft. for this example). Figure 3 shows how a dense lidar dataset can prevent the elevation discrepancy illustrated in Figure 2.

The above discussions emphasize the importance of introducing a new concept to describe the accuracy of geospatial elevation data, such as lidar, that combines both the absolute accuracy of the individual lidar point and the density of the data or the post spacing. According to this concept, accurate lidar points do not necessarily result in a good quality lidar surface. Furthermore, a high resolution and high definition lidar surface does not necessarily result in high absolute accuracy unless data planning, acquisition, and processing are conducted to a high standard. In other words, the standard should provide different classes for the accuracy and quality measures. Users will also have the ability to select different accuracy and quality classes to match their specific needs and applications. The two measures can be described by the following:

a) **Classes According to Lidar Point Accuracy:**

1. **Engineering class-I grade lidar data accuracy,** for products with:
   Horizontal accuracy of $RMSE_X$ = $RMSE_Y$ = 20 cm or better
   Vertical accuracy of $RMSE_v$ = 5 cm or better
2. **Engineering class-II grade lidar data accuracy,** for products with:
   Horizontal accuracy of $RMSE_X$ = $RMSE_Y$ = 30 cm or better
   Vertical accuracy of $RMSE_v$ = 10 cm or better
3. **Planning class-I grade lidar data accuracy,** for products with:
   Horizontal accuracy of $RMSE_X$ = $RMSE_Y$ = 0.60 m or better
   Vertical accuracy of $RMSE_v$ = 20 cm or better
4. **Planning class-II grade lidar data accuracy,** for products with:
   Horizontal accuracy of $RMSE_X$ = $RMSE_Y$ = 0.75 m or better
   Vertical accuracy of $RMSE_v$ = 30 cm or better
5. **General purpose grade lidar data accuracy,** for products with:
   Horizontal accuracy of $RMSE_X$ = $RMSE_Y$ = 1.2 m or better
   Vertical accuracy of $RMSE_v$ = 0.50 m or better
6. **User defined Accuracy,** for products that do not fit into any of the previous five categories.

The above accuracy figures should only be guaranteed in open flat and rolling terrains.

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b) **Classes According to lidar Surface Definitions (quality):**

1. **Engineering class-I grade lidar data quality,** for a lidar surface with:
   a) Nominal post spacing of 0.30 m or less
2. **Engineering class-II grade lidar data quality,** for a lidar surface with:
   a) Nominal post spacing of 0.70 m or less
   b) To have optional break lines
3. **Planning class-I grade lidar data quality,** for a lidar surface with:
   a) Nominal post spacing of 1.0 m or less
   b) To have optional break lines
4. **Planning class-II grade lidar data quality,** for a lidar surface with:
   a) Nominal post spacing of 1.5 m or less
   b) To have optional break lines
5. **General purpose grade lidar data quality,** for a lidar surface with:
   a) Nominal post spacing of 2.0 m or less
   b) To have optional break lines
6. **User defined quality,** for products that do not fit into any of the previous five categories.

The above concept clearly describes the overall accuracy and quality of lidar or IFSAR data in a way that can be easily understood by both users and data providers. For example, if the user requests lidar data to meet **engineering class-I grade accuracy**

continued on page 1108

continued from page 1107

Table 1. Accuracy Figures at 95% Confidence Level According to Pixel Resolution		
GSD (m)	**RMSE$_{XorY}$ / RMSE$_z$** (m)	**Accuracy$_R$ / Accuracy$_z$** at 95% (m)
0.075	0.09 / 0.09	0.23 / 0.18
0.150	0.19 / 0.19	0.46 / 0.37
0.300	0.38 / 0.38	0.92 / 0.74
0.600	0.75 / 0.75	1.83 / 1.47
1.000	1.25 / 1.25	3.06 / 2.45

Table 2. Accuracy Figures at 95% Confidence Level According to National Map Classes		
Map Class	**RMSE$_{XorY}$ / RMSE$_z$** (m)	**Accuracy$_R$ / Accuracy$_z$** at 95% (m)
Engineering class-I	0.10 / 0.10	0.24/0.20
Engineering class-II	0.20 / 0.20	0.49/0.40
Planning class-I	0.30 / 0.30	0.73/0.59
Planning class-II	0.50 / 0.50	1.22/0.98
General purpose	0.75 / 0.75	1.84 / 1.47

and **engineering class-II grade quality,** the data provider must commit to the delivery of lidar surface according to the following specifications:

Horizontal Accuracy: $RMSE_X = RMSE_Y$ = 20 cm or better
Vertical accuracy of: $RMSE_v$ = 5 cm or better
Nominal post spacing: 0.70 m with optional breaklines, if requested by the user.

Additional details can be added to the standard, such as specifying accuracy and quality figures according to land use/land cover classes and bare-earth versus reflective surface.

6. **The new standards should be based on RMSE and 95% confidence level:** NSSDA provides good statistical testing guidelines, but lacks specifics with regard to the RMSE values needed to calculate given formulas. According to NSSDA, the following formulas test accuracy at a 95% confidence level, and when combined with proposed RMSE accuracy measures, they can be used to describe discrete accuracy figures at 95% (Tables 1 and 2) for digital mapping products, such as orthophotos products and 3-D vector maps:

Horizontal Accuracy:

$Accuracy_{XorY}$ at 95% = 2.4477 * $RMSE_x$ = 2.4477 * $RMSE_y$ ....(if $RMSE_x \neq RMSE_y$), ...(1)

or, $Accuracy_R$ at 95% = 1.7308 * $RMSE_R$ ....(if $RMSE_x = RMSE_y$) where,

$RMSE_R = 1.4142 * RMSE_x = 1.4142 * RMSE_y$

Vertical Accuracy:

$Accuracy_z$ = 1.96 *$RMSE_z$ ....(2)

The values in Tables 1 and 2 were derived using the horizontal and accuracy formulas 1 and 2, and the two concepts that I introduced in Part II of my answer regarding mapping products. Table 1, which refers to the final product GSD, may be more applicable for users of modern digital products, while Table 2 might be more applicable for those who are accustomed to using map scales rather than GSD. At this point, I would like to emphasize that although the proposed standard assigns similar RMSE figures to both the vertical and the horizontal mapping product accuracies, the accuracy figures derived at 95% confidence level differ slightly due to the nature of the one and two dimensional random variables.

"The accuracy of lidar-based terrain surface should not be based on the absolute accuracy of the individual lidar point alone. An additional lidar dataset characteristic must also be considered in order to determine the correct accuracy."

In closing, I would like to address all agencies and organizations that are currently involved or have previously been involved in defining and publishing map standards. Concerned users are looking for positive cooperation among expert geospatial organizations in hopes that they will consolidate their efforts to create a national geospatial data accuracy standard that satisfies the needs of all users, and will support current and future geospatial data collection and processing technology advancements. It is my sincere hope that all agencies who are currently publishing geospatial data standards and guidelines for their own use, stop their individual efforts and join forces (for the sake of everyone) to develop and publish this new standard by 2013.

Please send your question to Mapping_Matters@asprs.org and indicate whether you want your name to be blocked from publishing.

Answers for all questions that are not published in *PE&RS* can be found on line at www.asprs.org/Mapping Matters.

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