Mapping Matters

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**

I am in the process of estimating some horizontal accuracy potential for our lidar and am getting a lot of noise from our staff. They seem to think we can never be more accurate than 2 x GSD. So for a dataset with 1 meter posting they say it will never be better than 2 meters RMSE horizontally. However, when I do a survey and check points I come out at an RMSE of 1.6 feet, which is about $^1/_2$ the GSD. I found the graphic from your paper at ILMF last year which states that the horizontal accuracy of lidar can be estimated to be $^1/_2$ to $^1/_3$ the size of the pulse's foot print on the ground . I was wondering if you meant $^1/_2$ to $^1/_3$ the GSD or the beam width on the ground? Any help here would be appreciated.

Steve Kasten CP, PLS, VP Surveying and Photogrammetric Engineering
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Dr. Abdullah: The horizontal accuracy, according to manufacturer's specifications, should be better than what you state. My slides were correct in showing $^1/_2$ to $^1/_3$ of beam divergence width. However, the issue of the horizontal accuracy is very tricky. Estimating the horizontal accuracy based on point cloud post spacing, the common practice used by both vendors and clients, may lead to the wrong conclusion due to the coarse post spacing of the data. Some data providers rely on the manufacturer's specifications to label the horizontal accuracy of their lidar products. If we use horizontal accuracy as a function of post spacing, then the same dataset will have different accuracy at a different grid size, if you have to grid or resample the data. In addition, different data with different post spacing can be collected from the same flying altitude with the same accuracy by manipulating the pulse rate, FOV, aircraft speed, or scan speed. The lidar data accuracy is mainly affected by flying altitude, IMU/GPS data quality, atmosphere/troposphere effect on the laser ranging, etc. Post spacing is then a function of pulse rate, scanning rate, FOV, and aircraft altitude and speed and not the GPS/IMU which is the main contributor to the error budget of the lidar data.

"When manufacturers estimate the accuracy budget of their systems, they model the effect of the pointing errors of the IMU, the positioning errors of the ABGPS, the errors in range, errors in the encoder, etc. They do not consider the post spacing as criteria for their accuracy estimate."

When manufacturers estimate the accuracy budget of their systems, they model the effect of the pointing errors of the IMU, the positioning errors of the ABGPS, the errors in range, errors in the encoder, etc. They do not consider the post spacing as criteria for their accuracy estimate. In another words, in estimating lidar accuracy, manufacturers model a single laser pulse on the ground and not the point cloud. The rule of thumb I proposed considers the pulse geometry, which is a function of the laser aperture, and all parameters that effect accuracy and which are considered by the manufacturer estimate of error propagation. Considering the size (beam width, pulse foot print, etc.) of the pulse on the ground provides some reasonable measure for the horizontal accuracy estimation. The geometry of the beam divergence or pulse foot print is a function of flight parameters and therefore it can be utilized as an indicator for horizontal accuracy estimation. If we look at hard figures provided by the manufacturers of the Airborne Laser Scanner (ALS) according to the planning software, you get the following scenario:

"The geometry of the beam divergence or pulse foot print is a function of flight parameters and therefore it can be utilized as an indicator for horizontal accuracy estimation."

Scan FOV (full angle)	30.00	degrees
Nominal Flying Height Above Minimum Terrain Elevation	914.00	meters
Airspeed	120.00	knots
Max Cross Track Spacing (occurs @ nadir)	0.91	meters
Max Along Track Spacing (occurs @ FOV edge)	1.47	meters
Illuminated Footprint Diameter (@ 1.e^2 energy)	0.32	meters
Point Density (average)	2.38	pts/meter^2
Estimated Cross-Track Error	0.13	meters
Estimated Along-Track Error	0.13	meters

Here you notice that the illuminated footprint diameter is equal to 0.32 meters, while the maximum estimated error is about 0.13 meters (that's 40% of the footprint). The error magnitude is closer to $^1/_3$ to $^1/_2$ diameter criteria that I proposed and is by no means related to the post spacing. If we assume the nominal post spacing to be equal to the average post spacing or 1.19 meter, (0.91 + 1.47)/2, the estimated accuracy/error comes to only about 11% of the post spacing.

During follow up correspondences with Steve Kasten, I received the following message from him.

> *"I went out and performed a field survey of horizontal points I could see in the elevation dataset. According to the manufacturer planning software, the system was running with a beam width of 0.43 meters (1.41 feet). Also the estimated accuracy was 0.21 meters (0.67 feet) in across track and along track. I surveyed 42 identifiable features and came up with a RMSE in X of 1.76 feet and a RMSE Y of 1.84 feet. My product limit was 2 feet so I met the requirement, but this is larger than the values you outlined."*

"Estimating the horizontal accuracy based on point cloud post spacing, the common practice used by both vendors and clients, may lead to the wrong conclusion due to the coarse post spacing of the data."

In his study, Steve surveyed linear edges like the edges of tennis courts and parking lots and roads to avoid using discrete points. He also utilized the perceived intersection of two linear surfaces that appears clearly in the lidar elevation dataset. Checking horizontal accuracy is not a straightforward matter and people differ in their approaches to achieve it. I consider Steve's method of utilizing linear features in a scene as one of the most accurate strategies. However, his result does not agree with the manufacturer expected horizontal accuracy. As a matter of fact, it is about three times worse than the accuracy figure expected for the product according to the system specifications. Steve's findings agree with an accuracy figure that is equal to one-beam divergence width (one pulse foot print). As I prefer not to express accuracy in reference to point cloud post-spacing for the reasons I mentioned earlier, I am therefore not going to refer to his obtained accuracy in reference to the post spacing of the data set.

"Different data with different post spacing can be collected from the same flying altitude with the same accuracy by manipulating the pulse rate, FOV, aircraft speed, or scan speed."

The issue of post spacing is crucial to the determination of data quality. In the October 2010 "Mapping Matters" article, I explained extensively the confusion often happens in understanding the point cloud accuracy (the discrete 1lidar point accuracy) versus the terrain surface accuracy. Terrain surface accuracy is as closely associated with the point cloud quality as the terrain model accuracy. Determining the real shape of the terrain is a function of the post spacing and existence or nonexistence of break lines and not the discrete lidar point accuracy alone. You may have lidar data that is accurate to 9 cm but the resulting terrain model may not posses the same accuracy unless the point density is high enough to accurately shape the terrain with or without breaklines.

I hope this discussion opens the door for more dialogue. I would love to have readers' comments on reporting actual verification for lidar horizontal accuracy. I would also like to encourage comments on this topic and perhaps further explanation on Steve's conclusions from the lidar system manufacturers that are dominating today's world market.

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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