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: Does lidar data support the generation of accurate one-foot contours and if it does, how feasible is it to generate photogrammetric-quality one-foot contours?

Dr. Abdullah: During the past several years, a few data providers have delivered clients one-foot contours derived from lidar datasets. Most of these contracts were characterized by the following:

1) Contour accuracy and quality were assessed based on limited available ground control points, which makes it impossible to verify the acceptance criteria. Ground control points are essential to the discrete verification of the terrain surface accuracy. I am not aware of any project involving detailed field-surveyed profiles to verify the accuracy and quality of lidar-derived one-foot contours. This is understandable as tight project budgets in most cases prohibit such field investigation. This lack of verification has helped fuel the debate about whether lidar can support one-foot contour generation; there is, in fact, strong speculation among users as to whether lidar data will ever meet such criteria.

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2) Lidar data providers often are trapped by the conventional wisdom for modeling contours based on photogrammetric practices. Photogrammetric datasets combine highly accurate, manually collected breaklines with sparsely distributed, as-needed mass points. These breaklines and mass points never contradict each other as they are both collected from the same stereo pairs, by the same operator. This is not the case with lidar data, as it provides very dense mass points regardless of the terrain roughness or slope. What's more, lidar is often combined with photogrammetric breaklines that do not match in accuracy or distribution.

As a result, the lidar-derived contours in many cases do not meet certain cartographic quality standards. Accuracy can also be affected by this practice.

Recently, I acted as the principal investigator in a study designed to deal with the very same topic of contours modeling from lidar. The study provided insight into several outstanding questions surrounding the issue of one-foot contours generation from lidar, such as:

1) Will the error budget in the different components of the lidar system allow such accuracy?
2) If it does, then will the role of the breaklines be compromised considering the high density of the lidar points?
3) What type and density of breaklines are required to support one-foot contours generation from lidar data?

In order to accomplish comprehensive analysis and evaluation, a photogrammetrically-derived baseline terrain model was needed for evaluating the lidar-derived contours. Data for the investigation was acquired with Leica's ALS50-II MPiA lidar system and ADS40 digital imaging system over an established test field. The ground GPS station was located at the base airport which adjoins the project area. lidar data was collected from an altitude of 2,200 m, resulting in a post spacing of approximately 1.4 m. The ADS40 collection resulted in natural color imagery with Ground Sampling Distance (GSD) of 7.5 cm (or 3"). Such GSD is suitable to support photogrammetrically-derived one-foot contours that can be used in the evaluation of the lidar-derived contours.

With proper planning, the processed GPS resulted in low position dilution of precision, known as PDOP, (below 2) and high positional accuracy of 1-2 cm root mean square Error (RMSE). This accuracy is sufficient to support a one-foot contour deliverable. In addition, the ground control and flight plan for the digital imagery were designed to assure highly accurate photogrammetric mapping with an aerial triangulation vertical accuracy of 6 cm and stereo pairs with a vertical accuracy of 7 cm. Extra care and effort was employed in the collection of the ADS40-derived digital terrain model (DTM) since it would be used for evaluating the lidar dataset. This resulted in an extremely high definition DTM modeling every aspect of the terrain, making this data set suitable to use as a reference for the evaluation. The breaklines and mass points were merged together into a triangulated irregular network (TIN) model that was used to extract photogrammetrically-derived one-foot contours.

As for the lidar data modeling, different one-foot contour datasets were generated using the following bare-earth lidar data and breaklines:

- lidar points only,
- lidar points and breaklines from lidar stereo mates,
- lidar points and photogrammetric breaklines.

In order to verify the positional accuracy of the ADS40-derived DTM and the lidar surface, a surface subtraction was conducted between the ADS40-derived surface and the bare-earth lidar-derived surface. Elevation differences in open ground were found to be within the ±5 to ±7 cm range. In addition, a total of 65 points representing different terrain conditions were carefully selected around the study area to compare the lidar data to ADS40-derived surface. The result of the latter comparison is given in Table 1.

Table 1.

Comparison between lidar-derived surface and ADS40-derived surface	
RMSE (m)	0.089
Standard Deviation (m)	0.074
Mean (m)	-0.051
Normalized RMSE (m)	0.073

Finally, both surfaces were compared to the surveyed ground control, which also confirmed the two surfaces to be accurate to within a few centimeters as illustrated in Table 2.

Once the geometrical accuracy of both datasets was confirmed, thorough analysis on the quality of the derived one-foot contours was conducted. Here are some of the important findings useful in

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Table 2.

Vertical Accuracy of the Lidar and ADS40 Data Sets						
GCP ID	**Surveyed H**	**Lidar H**	**ADS40 H**	**Delta Lidar**	**Delta ADS40**	**Lidar - ADS40**
1805	142.94	142.92	142.87	-0.02	-0.07	0.05
1808	144.67	144.75	144.71	0.08	0.04	0.04
1810	147.37	147.34	147.40	-0.03	0.03	-0.06
1815	149.60	149.72	149.62	0.12	0.02	0.10
			RMSE (m)	0.07	0.04	0.07

answering the question of whether lidar data can support 1-foot contours:

- Contours generated from full density bare-earth lidar points show a rough finish and extraneous details that lack aesthetic and cartographic quality. In order to derive contours from lidar data with acceptable quality, a smart algorithm was designed to filter out unnecessary lidar points. Best results were reached by keeping lidar points at key terrain points. A second filter was applied in which the even contour elevation was used as criteria to filter out some of the remaining lidar points whose elevation are close to the elevation of the nearest contour. This approach discarded numerous lidar points from the modeled surface, delivering only contours of acceptable quality.
- Contours around flat ground and non-elevated roads show degraded quality and accuracy due to differences in the elevation of the lidar points and the lidar-derived breaklines. The black and white stereo mates created from lidar points and intensity do not show the same clarity and sharp definition associated with the imagery-based photogrammetric stereo pairs. A compiler can easily misinterpret the terrain elevation from lidar-derived stereo mates, resulting in breakline elevations that conflict with the actual bare-earth lidar point elevations in the range of ±5 to ±10 cm, causing unwanted drifting of the contours. As such, breaklines generated from lidar stereo mates should be used with caution, since they may lack the required accuracy in flat and low definition areas.
- Due to the density of lidar data, it is not necessary to collect breaklines throughout the entire project as was dictated by conventional photogrammetric practices. Breakline collection, when performed on an as-needed basis, is important for reducing cost and often improves the overall quality of the contours.
- Surface roughness or slope index maps may be used to indicate places where breaklines are absolutely needed; breaklines are only necessary in places where real breaks exist in the smoothness of the terrain. The common practice of collecting breaklines along all linear features, such as roads, is not necessary and may adversely affect the quality of the final contours. Figures 1 and 2 show the difference between the densities of full breaklines collection and slope-based collection.
- Establishing a buffer around breaklines where all lidar points are discarded from the dataset is necessary to obtain contours with acceptable quality. The buffer distance depends on terrain roughness, lidar point density, and contour interval.

Finally, the answer to the question is yes, one-foot contours can be reliably generated from dense lidar data to meet all mapping accuracy standards if all or some of the practices I emphasized earlier are considered.

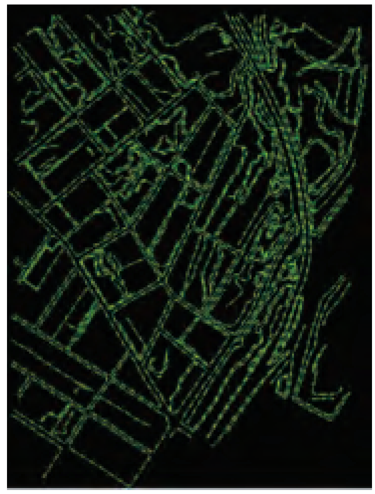

Figure 1. Fully Collected lidar-derived breaklines.

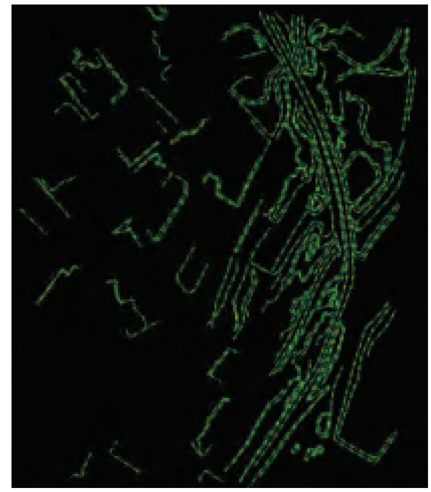

Figure 2. Slope-based breaklines.

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

***Dr. Abdullah is the Chief Scientist at Fugro EarthData, Inc, Frederick, MD.*

CORRECTION

Due to an error on the part of the publisher, the wrong question was published for the January 2009 Mapping Matters column. The question should have read:

Question: The use of 3D laser scanners (or ground-based lidar) has gained momentum over the last few years among the engineering and surveying communities. Could you please elaborate on the state of this technology and its benefits to public- and private-service agencies?

The material given in the answer in the January issue is correct.

We apologize for any inconvenience and hope that you will re-read the earlier article.