Spatial Data Accuracy Concepts

Earl F. Burkholder, PS, PE, F.ASCE
Global COGO, Inc. – Las Cruces, NM 88003

I am delighted to see geospatial accuracy being discussed in POB. For the most part, I believe that your editorial comments in the November 2019 issue are "spot on." You agreed with a previous reader who claimed that "in surveying there is no such thing as 'absolute' accuracy" and you expanded on the concept of "perfect being the enemy of good." You also invited additional comments.

For me, the fundamental question when discussing spatial data accuracy is "with respect to what?"

Background:

When considering the uncertainty of measurements and coordinates, the difference between accuracy and precision becomes relevant. That difference can be illustrated in Figure 1 by the pattern of bullet holes in a target. A close grouping of bullet holes is a measure of precision. The grouping may or may not be close to the bull's eye. Accuracy is often depicted by showing bullet holes scattered over the target. The mean location of the bullet holes could be quite accurate – but not effective for the serious hunter!

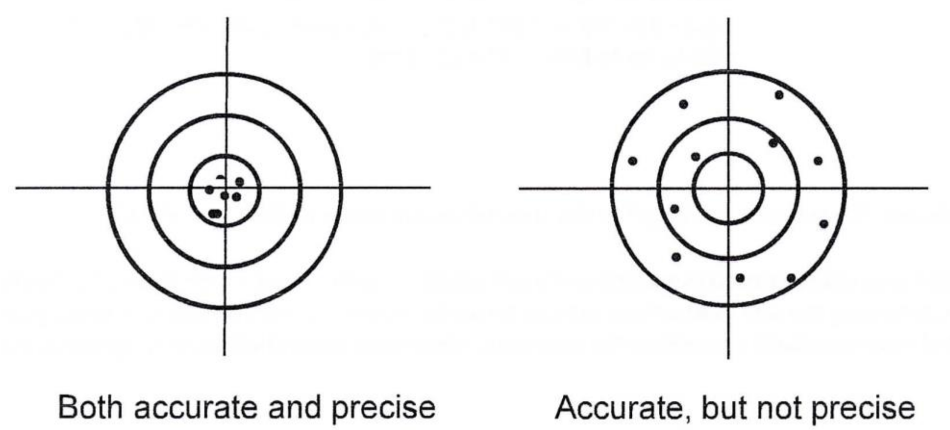

Figure 1. Difference Between Precise and Accurate Illustrated by a Bull's Eye Target

Perhaps a better illustration is a plot of the bell curve – Figure 2. In this case, the "narrowness" of the curve can be related to the precision of the measurements (data set A) while the location of the mean of the measurements (data set B) compared to the "actual" value is a measure of accuracy. Without violating the mathematical definition of either accuracy or precision, standard deviation is computed as the square root of the variance. Although the term standard deviation is used in each case, a convenient discriminator could be to answer the question, "with respect to what?" Figure 2 shows that one can be precisely wrong!

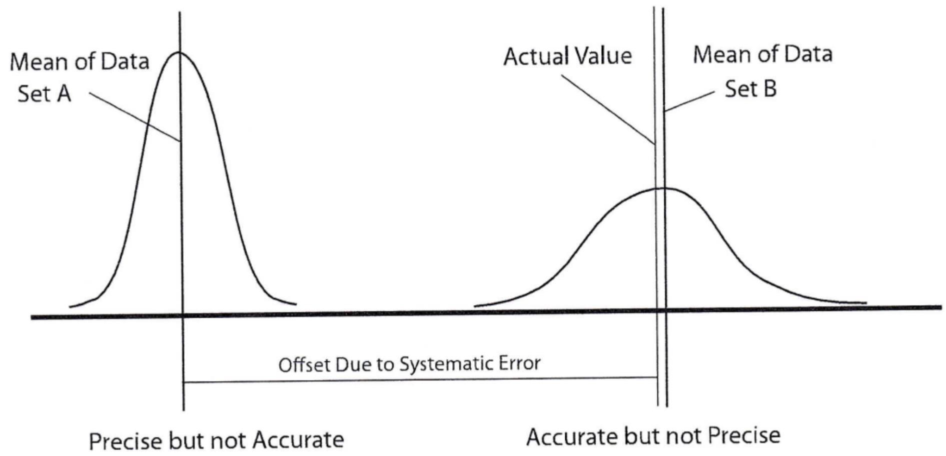

Figure 2. Difference Between Precise and Accurate Illustrated by Bell Curve Plots

- Precision relates to the repeatability of a measurement. Precision is computed as the standard deviation of a collection of measurements of the same quantity. Precision can be enhanced by refining the observations and reducing random error. But, as a previous reader noted, there is no such thing as 'absolute' accuracy because random error – often associated with precision - cannot be completely eliminated.

- Accuracy is related to the closeness of a value to the "truth." It is also called standard deviation and computed as the square root of the variance of a quantity. The presence of systematic error degrades the accuracy of a quantity. Good practice includes computing and applying corrections to remove systematic error – thereby improving accuracy. It is "sloppy" practice but, if unmodeled systematic error is lumped with random error, little harm is done so long as unmodeled systematic error is significantly smaller than the random error.

When looking at the standard deviation of a measurement, the presumption is "with respect to the mean of repeated measurements of the same quantity." When considering the standard deviation of a published quantity (coordinate, distance, azimuth, or height) the presumption is "with respect to the best estimate of the quantity." The best estimate is often obtained from a properly weighted least squares adjustment of a collection of repeated measurements containing redundant observations.

Applications:

A summary of the evolution of the terms "network accuracy" and "local accuracy" can be accessed at http://www.globalcogo.com/appendixE.pdf and is included as Appendix E in the 2nd Edition of "The 3-D Global Spatial Data Model (GSDM)" – Burkholder (2018). That summary starts by describing the 1947 National Map Accuracy Standards and includes a chronological listing of textbook discussions, federal agency specifications, and various professional society accuracy specifications. The summary concludes by looking at relative positional precision (RPP) as identified in the 2016 ALTA/NSPS Minimum Standards.

Acknowledging that "standard deviation" is used in the context of both precision and accuracy, the question "with respect to what" remains central to the discussions. Restating a previous point. . .

- In measurements, precision is computed as the "standard deviation with respect to the mean of the observed values."

- In computations, accuracy is computed as the "standard deviation with respect to the actual, known, or accepted value."

The remainder of this article deals with the standard deviation (accuracy) of a computed or published value. As described below, the spatial data user has several options available when computing accuracy. Choosing the most appropriate option is the responsibility of the user. Some choices are obvious while other choices have nuances associated with them. Attempting to retain full mathematical rigor of the definitions and attempting to be consistent, the following options were identified in Burkholder (1999).

http://www.globalcogo.com/accuracy.pdf

- Datum accuracy applies to a point (1D, 2D, 3D, or 4D) and describes the quality of a numerical value with respect to the published datum.

- Network accuracy describes the quality of a computed value (line, distance, direction) with respect to the existing network. Network accuracy can be computed using either:

    a. The full covariance matrix of each point or,
    b. Just the values on the main diagonal of each point covariance matrix.

- Local accuracy describes the relative position of one point with respect to any another named point using the full covariance matrix of each point and the correlations between the endpoints. If no correlation between endpoints exists, local accuracy is the same as network accuracy.

- P.O.B. accuracy describes the quality of a computed value assuming the standpoint has no error associated with it. In this case, the answer is specifically "with respect to the standpoint."

It was noted in Burkholder (1999) that these proposed designations were inconsistent with the 1997 draft FGDC specifications. The article closes with, "Acknowledging other accuracy names might be more appropriate, it is hoped the GSDM and proposed accuracy names will be considered and discussed carefully before final geospatial accuracy standards are promulgated." That ship sailed long ago. Given preparations for the 2022 datums, is it possible that another voyage is being planned?

Example:

The 2016 version of the "Minimum Standard Detail Requirements for ALTA/NSPS Land Title Surveys" (ALTA/NSPS 2016) includes a provision for Relative Positional Precision (RPP) that the relative position of a corner monument to any other property corner is to be reported at the 95% (2 sigma) confidence level. It also states that the RPP is to be estimated as the semimajor axis of the error ellipse representing the uncertainty due to random error as obtained from a properly weighted least squares adjustment. As summarized in Burkholder (2017) the problem is that "the error ellipse determined from a least squares adjustment provides an error estimate with respect to the control held by the user – not an adjacent (or any other) point in the survey. The intent is stated rather well and a properly weighted least squares adjustment is the 'gold standard' for survey adjustments."

Burkholder (2017) was presented at the Surveying & Geomatics Educator's Society (SaGES) Conference in Corvallis, Oregon, in July 2017. The paper contains a detailed example of a GPS network adjustment that includes the "new" EDMI calibration baseline installed by NGS at the New Mexico State University. The example uses the full covariance matrix of the adjustment and shows how both the network accuracy and local accuracy between all points on the baseline are computed. The solution uses standard matrix manipulation software and maintains full mathematical rigor throughout. Burkholder (2017) can be downloaded from . . .

http://www.globalcogo.com/EFB-SaGES-ALTA-NSPS.pdf

According to Mr. Gary Kent, Chair of the ALTA/NSPS Minimum Standards Committee, the committee is working on revisions for a subsequent version of the ALTA/NSPS Minimum Standards. Mr. Kent can be reached at gkent@schneidercorp.com.

Challenge:

The 3-D Global Spatial Data Model (GSDM) is a book (Burkholder 2008 and 2018) that describes both a functional model of geometrical equations for handling location computations anywhere within the birdcage of orbiting GNSS satellites and a stochastic model for computing error propagation and positional tolerances (standard deviations) when those observational data are available. The GSDM is based on the assumption of a single origin for 3-D data (Earth's center of mass) and uses solid geometry equations formalized by Descartes in 1637. The stochastic model is based on the standard error propagation equations found in any least squares textbook and has withstood a number of challenges in the technical literature. To date none of the GSDM concepts or procedures have been found to be deficient or defective. Details can be found in a link to an ASCE web site for Discussion/Closure of "Rigorous Estimations of Local Accuracy Revisited" by Soler/Han. A download of the pdf file is free.

https://ascelibrary.org/doi/full/10.1061/%28ASCE%29SU.1943-5428.0000274
(Accessed November 29, 2019)

Conclusion:

The issue of spatial data uncertainty is an important one that should not be ignored. Various disciplines (e.g., metrology, machine tooling, photogrammetry, navigation) routinely deal with spatial data uncertainty and the science of measurement is understood by many. Given the impact of the digital revolution and use of digital measurement systems, the surveying profession can no longer afford to ignore the consequences of dealing with 3-D digital spatial data. Meeting that challenge will require careful evaluation of fundamental concepts as applied to both spatial and geospatial data. I am convinced that the surveying profession has the talent if not the resolve to meet those challenges.

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Biographical Sketch – Earl F. Burkholder

Earl F. Burkholder, PS, PE, F.ASCE retired from teaching in the Surveying Engineering Program at New Mexico State University in 2010. Since then he devotes his energy to promoting “The 3-D Global Spatial Data Model (GSDM)” as a tool for handling 3-D digital spatial (and geospatial) data more efficiently. Prior experience includes degrees from the University of Michigan (BSCE 1973) and Purdue University (MSCE 1980), teaching 13 years at the Oregon Institute of Technology, 5 years in a corporate environment at Commonwealth Associates of Jackson, Michigan, and extensive consulting for the Southeastern Wisconsin Regional Planning Commission. His resume is posted at www.globalcogo.com/efbresume.pdf.