Call for "standardization" in modeling stochastic values for geospatial data: Timely or Premature?

Earl F. Burkholder, PS, PE, F.ASCE
Global COGO, Inc. – Las Cruces, NM 88003
September 22, 2014

Introduction:

The issue of spatial (especially geospatial) data accuracy is becoming increasingly relevant as more and more disciplines and users worldwide use 3-D digital spatial data and as they make important decisions based on the known (or unknown) quality of those data.

The global spatial data model (GSDM) [www.globalcogo.com/gsdmdefn.pdf] consists of a functional model (equations and geometry) and a stochastic model that is used to establish, track, and report the statistical characteristics standard deviation [www.globalcogo.com/accuracy.pdf] of any/all elements derived from the values stored in a BURKORD™ data base [www.globalcogo.com/burkord.html] .

The Goal:

The goal is for all users to be able to start with the same data (RINEX or otherwise) and to be able to compute network/local accuracy of a network of GPS points and get the same (or nearly so) estimates regardless of the "brand" software being used to perform the computations. Currently one can start with the same RINEX files and obtain very similar ΔX/ΔY/ΔZ baseline components regardless of the vendor software being used. A least squares adjustment of these baseline components determines the adjusted coordinates for the network. Currently, the estimates of network and local accuracies computed from the covariance matrix of the results of the adjustment appear to be dependent upon the brand of software being used to determine the covariance matrix of the baseline components (from the RINEX data). The GSDM provides a framework for such standardization.

Drivers:

This particular effort is driven by:

- A discussion [http://surveyorconnect.com/index.php] on the "Surveyor Connect" bulletin board in which users provide input with regard to how GPS data are used to estimate uncertainty (make sure you go to the top of the post) [http:surveyorconnect.com/php?mode=thread&id=280121#280391].

- Efforts by the author to get a handle on the issues of network accuracy and local accuracy [www.globalcogo.com/stddevlocalnetwork.pdf] for spatial data.

- A request [www.globalcogo.com/bigdata.html] from NOAA in March 2014 for information on how to exploit the commercial value of the vast spatial data holdings of the agency. I responded.

- A need to organize material to be included in a planned Second Edition of the book "The 3-D Global Spatial Data Model: Foundation of the Spatial Data Infrastructure" by the author and published by CRC Press in 2008.

Observations, opinions, and subsequent research:

1. The discussion on the Surveyor Connect bulletin board includes a number of excellent points and some obvious opinions. A discriminating reader chooses what to believe.
    a. I believe that open respectful discussion is healthy and aspire to contribute accordingly.
    b. The original post identified six different options. My comments are directed to option 5 in which the user has access to the baseline vector components and the associated baseline covariance matrix. The user should get the same answer for the vector components regardless of whether those baselines were computed from RINEX data, obtained from a given RTK controller, or assembled from a mixture of baseline data collected at different times by different brands of equipment. If that stipulation leads to the conclusion that this discussion is premature, so be it.
    c. Otherwise, I believe the procedures described in the following section can be used to put (or keep) many users on "the same page."

2. The first edition of the 3-D book (Burkholder 2008) contains a discussion of and examples of network and local accuracies – see chapters 11 and 12.
    a. Soler and Smith (2010) take exception to the material in the book in their article "Rigorous Estimation of Local Accuracy."
    b. In deference to their high level of technical insight, I was initially very worried that I had made an error, misinterpreted the concepts, or omitted important material from the book. But, the more I dug into it, the more I became convinced of the validity of the procedures as published in the 3-D book.
    c. According to accepted technical publication standards, I wrote a "Discussion" of their article pointing out what I felt was a mistake on their part. In such a case, the authors are given an opportunity to write a "Closure." My Discussion (Burkholder 2012) and their Closure (Soler and Smith 2012) are both published in the February 2012 issue of the ASCE Journal of Surveying Engineering.
    d. Still not satisfied with the Soler/Smith explanation, I wrote a separate "rebuttal" which ASCE declined to publish. Plan B included filing that rebuttal [www.globalglobalcogo.com/stddevlocalnetwork.pdf] with the U.S. Copyright Office and posting same on the Global COGO web site.
    e. The rebuttal confirms the validity of my work. It also shows that Soler/Smith and I get the "same" answer for all 3 examples – short, medium, and long lines.

3. But, that is not the end of the story. The last paragraph of the "rebuttal" states that additional work on network/local accuracy involves changing the tolerance imposed on the "anchor" point of the GPS network. The rebuttal paper holds the standard deviation of the anchor point at 0.010 meters in each X/Y/Z direction. Subsequent tests were conducted for tolerances of 0.002 meters, 1.0 meters, and 5.0 meters. The point of additional tests was to show that network accuracy "followed" the

degradation of tolerance at the anchor point while the "local" accuracy continued to be governed by the correlation (and the quality) of measurements between points.

   a. Subsequent tests verified that hypothesis but raised additional questions.
   b. Results of the Soler/Smith method do not agree with proven results when standard deviations of 1.0 m and 5.0 m are assigned to the anchor point.
   c. Using different brands of software to compute baseline components and associated covariance matrices provided even different results – not good!

4. I make mistakes when performing these tests and computations. I have therefore checked and re-checked my work and hope that any discrepancies others find will be reported back to me. In the best case, any discrepancies others find will not adversely affect tentative conclusions. We'll see.
   a. The additional work performed is reported [www.globalcogo.com/networklocal.html] on the Global COGO web site.
   b. The computational procedures are all "standard" and documented.
   c. Trimble results appear to be the most consistent.
   d. Thales and Topcon report baseline statistics as standard deviations and correlations whereas the Trimble baseline statistics are variances and covariances. I converted the standard deviations and correlations to variances and covariances in order to make the comparisons legitimate.
   e. Leica software is available in the surveying lab at NMSU. Attempts to compute baseline components and statistics from RINEX files have not been successful.
   f. From one vendor to another, the network/local accuracy trends remain consistent with the hypothesis, but the magnitudes of the computed accuracies are, I think, significantly different (and unrealistic?).
   g. Several vendors are looking at the results I've posted but, so far, feedback from the vendors has been minimal and guarded. What might it take for vendors to "buy in" to RINEX type consistency for stochastic results for spatial data?

5. Many issues being dealt with on the Surveyor Connect bulletin board (not just thread on RTK uncertainty) come under the GSDM umbrella in one way or another. That is particularly true for issues of map projections, grid/ground differences, basis of bearing, and many others. If NOAA, as a federal agency, could and would adopt a world-wide standard for digital spatial data and for spatial data accuracy it would eliminate many problems related to miscommunication among spatial data users. I hope to live a long time yet but I doubt such will happen in my life-time. But, that does not mean we should not try!

6. After sending the response to NOAA, I contacted CRC Press and suggested the time might be right for additional promotion of the 3-D book. Their response was to ask about preparing a Second Edition. The Author's Agreement has been signed. A Second Edition will contain information on least squares adjustment, an expansion of the network/local accuracy material, additional examples, and more arguments as to the benefits of the entire spatial data community using an integrated model for 3-D digital spatial data.

7. When an entire network is based upon vectors computed by the same brand software, the resulting network and local accuracies should be legitimate. Two GPS

network examples are posted on the Global COGO web site – one is based upon Trimble vectors and the other is based upon Topcon vectors. Both examples exhibit impressive results. A third example network on campus utilizing a mixture of brand vectors is still being computed and evaluated. That effort is currently frustrated due to making sure "apples" are being compared with "apples."

a. Trimble network link is http://www.globalcogo.com/nmsunet1.pdf
b. The Topcon network link is http://www.globalcogo.com/3DGPS.pdf

References:

Burkholder, E.F. 2012; Discussion of "Rigorous Estimation of Local Accuracies" by T. Soler and D. Smith, Journal of Surveying Engineering, Vol. 138, No. 1, pp 46-48.

Burkholder, E.F. 2008; "The 3-D Global Spatial Data Model: Foundation of the Spatial Data Infrastructure," CRC Press – Taylor & Francis Group, Boca Raton, London, New York.

Soler, T. and D. Smith 2012; Closure for "Rigorous Estimation of Local Accuracies" by T. Soler and D. Smith, Journal of Surveying Engineering, Vol. 138, No. 1, pp 48-50.

Soler, T. and D. Smith 2010, "Rigorous Estimation of Local Accuracy," ASCE Journal of Surveying Engineering, Vol. 136, No. 3, pp 120-125.