The Digital Future of Surveying

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This general interest article on the future of surveying should foster many related discussions. The credibility of this material relies heavily on basic mathematical principles (science), recognition of the impact of the digital revolution (technology), acknowledgement of past spatial data practices (history), and, ultimately, on a willingness of spatial data professionals to develop a shared vision for handling and using 3-D digital spatial data more efficiently (professionalism). The 3-D global spatial data model (GSDM) can be an important component of a vision for the digital future of surveying.

Acknowledgement of NSRS:

The focus of this article is application. It does not include high-level considerations such as inertial reference frames, relativity, gravity, or polar motion. Those issues are addressed by geodetic scientists and are embedded into the published control values of the National Spatial Reference System (NSRS) as provided by the National Geodetic Survey (NGS). With those NSRS values in hand, the GSDM provides the end user with powerful tools and efficient procedures for handling 3-D digital spatial data.

Science:

Spatial data are used in the context of the Earth-centered, Earth-fixed (ECEF) rectangular coordinate system, rules of solid geometry, and well-established error propagation procedures given by:

$$\Sigma_{yy} = J_{yx}\,\Sigma_{xx}\,J_{xy}^{t}.$$

Technology:

Sensors, computers, “unlimited” data storage capacity, and electronic signal processing are well-established as “givens” in the generation and use of digital spatial data.

History:

Various disciplines worldwide use spatial data – many spatial data are generic while others are geospatial, that is, referenced to the Earth. In the past, many analog spatial and geospatial data were developed, used, and stored as maps, pictures, or photographs. Typical storage media often included paper, glass, film, linen, or velum lying in a flat file somewhere. The need for specificity (1-D, 2-D, or 3-D) and quality (accuracy/precision) varied widely from precise geodesy and engineering applications, to monument-controlled cadastral and subdivision plats, to nautical charts for navigation, to maps for road trips, to topographic maps for resource inventory, and many other applications. Appropriate models ranged from flat-earth models for “local” projects, to spherical models for geography and navigation, to ellipsoidal models for geodesy and engineering surveying applications. Each spatial data application brings a “history” with it to the analog-digital transition. An obvious (and often legitimate) approach to digital adoption is to store “raw” data in an electronic file and to process those data using traditional models. Those methods and procedures need to be examined and accommodated in the evaluation of an integrated digital 3-D model that serves all spatial data users worldwide. The global spatial data model (GSDM) is a simple common standard worldwide model that can serve those needs efficiently.

Professionalism:

Developing a shared vision for spatial data disciplines and applications worldwide is viewed as an enormous undertaking and well beyond the scope of one person or organization. It is not possible here to consider all possibilities but, the following can contribute to on-going discussions:

Models:

A model is an abstraction that connects the real world with a representation of the same in the human mind. Of the infinite models available, the best model for any application is the simplest one that adequately represents the real world without sacrificing integrity. Spatial data models in the past have included the flat-Earth model, a spherical-Earth model, and the ellipsoidal-Earth model – the latter being somewhat more complex but needed to preserve the integrity of geometrical relationships for high-end applications. When working with 3-D digital spatial data, the GSDM is deemed appropriate for spatial data applications in all disciplines worldwide because:

- It is 3-D and it preserves geometrical integrity worldwide without distortion.
- It is already defined and uses simple, public domain, solid geometry equations.
- The stochastic component of the GSDM handles all levels of spatial data accuracy with aplomb.
- Local ground-level horizontal distances are computed directly without distortion.
- Geodetic (3-D) azimuths are easily computed as $\tan^{(-1)}(\Delta e/\Delta n)$. Convergence is handled routinely.
- Other "special use" systems can be defined and used sub-ordinate to the GSDM – meaning, local users can "do what they want" while preserving geometrical integrity and global compatibility. Caveat - there can be a difference between one-way and bi-directional transformations.

There are huge institutional and commercial obstacles to implementing the GSDM. But, progress can be (and is being) made in various arenas. The following comments describe challenges which, in my opinion, can be met. But, that will not happen instantaneously, and it may be that a paper, conference presentation, or a training session is not an appropriate time or place to lay out the issues for fellow professionals. But it needs to be done somewhere/sometime.

Feedback, especially on the following, is welcome:

ISO:

The International Standards Organization is the ultimate place for verifying the credibility and integrity of any/all procedures used by anyone/everyone worldwide in all disciplines. It will take a long time for the GSDM to become ISO certified as a spatial data model, but ISO certification needs to be pursued.

Military:

The U.S. Military is responsible to designing, building, and maintaining the U.S. global positioning system (GPS). They define the ECEF system in terms of the WGS84. Other international and scientific organizations independently observe, compute, and publish the ITRF. As I understand it, the two are compared daily and there is no statistical difference between them. Independent monitoring of those underlying "givens" is essential. There are many more details beyond this singular perspective.

But, the need for better understanding of spatial data is evidenced by a $200M study commissioned by the U.S. Army "to help. . . coordinate, integrate, and synchronize geospatial data standards and requirements." The deadline for completion of the study is February 11, 2023. The impact of such a study on how spatial data are used worldwide could be significant.

https://www.govconwire.com/2018/02/army-taps-general-dynamics-leidos-for-200m-geospatial-support-contract/

MITRE:

From the MITRE home page, https://www.mitre.org/, "The MITRE Corporation's mission-driven team is dedicated to solving problems for a safer world. We are a not-for-profit company that operates multiple federally funded research and development centers FFRDCs. We work across the whole of government, through our FFRDSs and public-private partnerships, to tackle problems that challenge our nation's safety, stability, and well-being. Our unique vantage point allows us to provide innovative, practical solutions in the defense and intelligence, aviation, civil systems, homeland security, judiciary, healthcare, and cybersecurity spheres."

Another web page describing additional MITRE capability is:

https://www.mitre.org/publications/project-stories/applying-design-thinking-to-boost-federal-agency-problem-solving

Following publication of "The 3-D Global Spatial Data Model" by CRC Press in 2008 - I was contacted by MITRE in 2009. They noted that they were studying the 3-D book and asked about the free prototype BURKORD™ software. That and a follow-up conversation was interesting, "guarded," and pretty much one-sided. There has been no response from MITRE to subsequent inquiries.

NOAA:

In March 2014 NOAA issued a Request for Information (RFI) for ideas and assistance in capturing the value of "silos" of digital spatial data for commercial purposes. The RFI and the Global COGO response are both available at http://www.globalcogo.com/BIGDATA.html

NGS:

The National Geodetic Survey (NGS) is well on their way to redefining the horizontal and vertical datums in the United States – to be completed in 2022. That is a large part of the activity included in the "Acknowledgement" at the beginning of this article. Even so, the GSDM represents an excellent opportunity to accommodate use of an integrated 3-D spatial data model. That opportunity is summarized in a poster presented at the 2016 Fall AGU Conference in San Francisco. The poster can be viewed at:

www.globalcogo.com/poster.pdf

As part of the 2022 datum update, NGS is also re-defining the state plane coordinate systems. Two NGS webinars on NGS March 8th and April 12th summarize the work being devoted to state plane coordinate systems. The comment is that, while various options are being considered – it appears that all of them involve the use of 2-D map projection models. Spatial data are 3-D.

https://www.ngs.noaa.gov/web/science_edu/webinar_series/2018-webinars.shtml .

Although 3-D might be a "fruitful field to be plowed," from a pragmatic perspective, NGS is doing what needs to be done. Even though huge benefits could be realized from using an integrated 3-D model, the NGS user community is probably not ready for the "sea change" associated with a 2-D to 3-D transition. The June 7th webinar (see link above) describes more of their high-level activities as described in the initial "acknowledgement."

NCEES:

The National Council of Examiners for Engineering and Surveying (NCEES) is the national organization that prepares and administers the licensing exams used by most state boards of licensure for surveyors and engineers. In response to a dramatic decline in the number of licensing applicants, the NCEES initiated a Forum on the Future of Surveying in January 2016. To find links to NCEES web pages, Google "NCEES future of surveying." Among others, the following link is helpful.

https://ncees.org/ncees-hosts-forum-strengthen-future-surveying-profession/

I had the opportunity to attend the first NCEES sponsored forum in January 2016. A link to associated comments is:

http://www.globalcogo.com/future.html

My issue with NCEES and some (but not all) state licensing boards is described in Item I.5 of the link above. For example, in 2016, the New Mexico Board of Licensure adopted defective Minimum Standards for describing basis-of-bearing. I have been trying ever since to get them to restore technical integrity to those standards. I have not yet been successful! My comment is that surveyors on the NM BOL are talented and dedicated. They strive to stand toe-to-toe with engineers but, in my opinion, are hampered by an attitude that "the authority of their position gives them the right to be wrong with impunity." It seems that the system of "checks and balances" needs attention. For additional insight on holding public officials accountable read "What the eye doesn't see" by Mona Hanna-Attisha, the story of lead in the Flint, Michigan water supply.

COGO:

The initial "Rules of Operation and Procedure" for COGO were first approved on August 4, 2008.

http://cogo.pro/

"The **Coalition of Geospatial Organizations** (COGO) is a **coalition** of 12 [sic 13] national professional societies, trade **associations**, and membership **organizations** in the **geospatial** field, representing more than 170,000 individual producers and users of **geospatial** data and technology." A unique feature of COGO is that all published policy statements must enjoy unanimous support of all organizations. Therefore, it is of historical significance that the "Report Card on the U.S. National Spatial Data Infrastructure" was published February 6, 2015. A link to a summary of the "report card" as presented at the 2015 ASPRS Rio Grande Chapter Annual Spring Meeting is:

http://www.globalcogo.com/COGO-report.pdf

A similar presentation was made in the fall 2015 to a joint meeting of the New Mexico American Planning Association and the New Mexico Branch of the American Society of Civil Engineers.

http://www.globalcogo.com/APA-ASCE-Spatial.pdf

In 2017, COGO made plans to prepare an update to the COGO Spatial Data Infrastructure Report Card. Given the previous report and existing conditions, it was suggested that fundamental issues should be investigated before compiling the update – that is, "Is the cart being placed before the horse?" See the "ReportCardTwo" link following. A link to a subsequent copy of an email exchange is also provided:

http://www.globalcogo.com/COGO-ReportCardTwo.pdf

http://www.globalcogo.com/EFB-COGO-EmailExchange2017.pdf

Incidentally, Global COGO, Inc. was incorporated in 1996 - well before emergence of the Coalition of Geospatial Organizations (COGO) - and the BURKORD™ trademark was issued June 1, 1999.

Spatial Data Accuracy:

Spatial data accuracy is often quoted in terms of standard deviations. That is the convention adopted for the GSDM. Many surveyors, engineers, photogrammetrists, and others use standard deviations routinely. However, the issue of network accuracy and local accuracy has generated some significant discussion – some of which is still on-going. A summary of network accuracy and local accuracy is included as Appendix E of the 2nd Edition of "The Global Spatial Data Model (also available on the Global COGO web site). An example of rigorous network accuracy and local accuracy as related to positioning standards as published jointly by the American Land Title Association and the National Society of Professional Surveyors (ALTA/NSPS) is included in a paper presented to the 2017 SaGES conference in Corvallis, OR:

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

Although beyond the experience of this author, the concepts of network accuracy and local accuracy are deemed applicable when establishing and monitoring movement of driverless vehicles. Given a consistent (essential) reference framework for both transmitter and sensor or data base;

Network accuracy provides information on "big picture" location.

Local accuracy provides information on relative (especially nearby) locations.

Network accuracy is essential for overall operation and navigation, but local accuracy is critical for precision targeting success or safety considerations – that is, collision avoidance.

Academia (SaGES):

The Surveying and Geomatics Educators Society (SaGES) promotes effective teaching/learning of surveying, mapping, geomatics, and other spatially-related education. SaGES is a forum where academia, industry, and government work together to exchange ideas, promote common causes, and provide opportunities to improve the teaching and learning of geomatics (paraphrased from an article in GPS World).

Before adopting formal Bylaws etc. in 2007, SaGES was known by various names relating to surveying education. Summer meetings were typically hosted by a university and held at 3- to 5-year intervals since 1937 (WWII being a "break"). SaGES now has a formal name and holds meetings every two years. The 2017 meeting was in Corvallis, Oregon, and the 2019 meeting is planned to be at Nicholas State University in Thibodaux, Louisiana.

I've spent 13 years teaching in the surveying program at Oregon Institute of Technology and 12 years teaching in the surveying engineering program at New Mexico State University. Yes, I have a bias for and many friends in surveying education. Given the existing talent pool and the challenges facing the surveying profession, I am convinced that surveying educators can provide a significant return on investment in surveying (geomatics) education. But I am also reminded (sometimes painfully) of the following:

> It takes money to solve problems
> Spending money does not solve problems
> People solve problems:
> (It takes both kinds – people who do things right and people who do the right thing.)

Many conflicting demands are placed on surveying faculty and some of them can be justified. Demands from university administration include research, publication, outreach, and related equipment/software acquisitions. Demands from practicing professionals include a certain amount of hand-holding and "teaching to the test." Demands from students (course offerings, prerequisites, deadlines, etc.) are legitimate in many cases. As a teacher, I've had many students say, "just show me which equation or software package to use." Yes, that can be part of the learning process, but education involves so much more. Maybe that comes under the auspices of mentorship. In that case, the learning process takes on a personal characteristic that goes beyond merely getting an answer – that is understanding the problem to be solved and taking pride in being able to understand and generate a solution.

Surveying educators will undoubtedly do some of the "heavy lifting" in pursuing a vision for the digital future of surveying. But, they need the unequivocal and unrelenting support of university administration (presidents, provosts, deans, and department heads), practicing professionals (boards of licensure, business owners, mentors, and agency bureaucrats), and industry (equipment suppliers, software vendors, and tax professionals). Oh yes, spouses must also be included somewhere. Without proper support, the best efforts of surveying educators will be fragmented, and faculty will become demoralized. As a recent professional put it, "surveying today is really exciting." We need more expressions of that excitement.

Where to start? Every person employed in or even interested in surveying has a contribution to make and a role to fill. It is not something that we can do in isolation, but we must find ways to work together and to help each other. What does it take to move forward? Everyone knows at least one thing that can or will make their efforts in surveying more satisfying. What is it for you?

This article and others are posted on a web page devoted to more "abstract" and high-level articles promoting a sea-change view of spatial data fundamentals. Glean from it what you will:

> http://www.tru3d.xyz