Innovation Proposal

Foundational 3-D Spatial Data Concepts for Civil Engineering Graduate Curricula

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The proposal is to include a spatial data component in the curriculum of each CE graduate student.

The civil engineering profession in the United States can realize huge benefits to the extent all CE graduate students are able to demonstrate a better understanding of spatial data concepts. Of several possible options (on-campus class, a web-based course, etc.), such knowledge can be evidenced by prior course work or by taking a formal course devoted to spatial data concepts.

This proposal is meant for Civil Engineering Department Chairs for consideration, discussion, refinement, recommendation, and adoption. A thoughtful response to the disruptive innovation fostered by the digital revolution is warranted and will, over time, enable ASCE members to be policy leaders in the use of 3-D digital spatial data as applied to civil infrastructure construction and renovations worldwide.

The digital revolution has exposed a gap between flat-Earth applications so familiar to many engineers and more sophisticated uses of 3-D digital spatial data. Solid geometry principles support extending the use of 2-D data to 3-D by adding the "Z" component – perfectly legitimate under flat-Earth assumptions. But civil engineering practice includes using spatial data referenced to the physical curved Earth. Those geospatial data are included in many geographic information system (GIS) databases by adding elevation for the third dimension. The problem (described in a poster at a recent AGU meeting) is that horizontal and vertical have separate disparate origins which complicates routine use of solid geometry equations. The geometrical integrity of spatial data used for surveying, mapping, location referencing, and monitoring the movement of driverless vehicles – whether airborne drones or land based vehicle navigation - depends on accommodation of Earth curvature, gravity, datums, coordinate systems, measurement systems, error propagation, and spatial data accuracy. These issues really should be included as part of the foundational knowledge of all civil engineering graduate students.

Case in point: Many talented students presented thoughtful research on a wide range of topics at the 2012 ASCE International Conference on Computing in Civil Engineering. Of the 81 papers presented, 15 of them had "3D" in the title but, in addition to a paper on "The 3-D Global Spatial Data Model," only one or two other papers seriously addressed "geo-referencing," focusing instead on flat-Earth assumptions. Those assumptions do not invalidate their research but demonstrate the need for graduate students (future professional leaders) to have a solid foundation in geospatial data concepts.

A broad statement is that the digital revolution has had an enormous impact on many facets of engineering practice and that CEs are uniquely positioned to provide leadership in the sea-change associated with efficient use of 3-D digital spatial data. Leadership in the policy arena is essential.

Gerard Mercator (1512-1594) gave the world the conformal map projection (used extensively by civil engineers, surveyors, and mappers) and René Descartes (1596-1650) formalized concepts of solid

geometry in his *Discourse on the Method* published in 1637. Geodesists such as Méchain (1744-1804), Delambre (1749-1822), Gauss (1777-1855), and modern contemporaries including those employed by the National Geodetic Survey (NGS) have refined geodetic measurements and computations for the benefit of humankind worldwide. Those accomplishments and applications are legendary.

Modern measurements are collected in a 3-D environment. Efficient use of those data can be enhanced by using an integrated 3-D spatial data model. The geodetic model and the map projection model for spatial data are both prefaced on horizontal and vertical datums. Horizontal is 2-D (latitude/longitude) and vertical is 1-D (elevation). Furthermore, those models require specific reductions of spatial data measurements to a mathematical surface (the ellipsoid or a mapping grid) as part of the computational process. To the extent that geometrical integrity is to be preserved, such processes can be complicated and onerous. Software has been written and is used to mitigate many of the associated challenges.

As opposed to "black box" solutions, a more professional approach is to implement a 3-D spatial data model that is both simpler and more appropriate. That involves stepping back and taking an abstract view of how 3-D spatial data are perceived and used. While stepping back can be a challenge for all spatial data disciplines, ASCE is uniquely positioned to provide leadership in the continuing revolution. A series of webinars can be designed to serve practicing professionals while the impact in the policy arena will be enhanced to the extent young professionals are well-grounded in spatial data concepts.

The 3-D global spatial data model (GSDM) is built on the 3-D Earth-centered Earth-fixed (ECEF) rectangular coordinate system (attributed to René Descartes) formalized by the United States DoD for the global positioning system (GPS). The origin is at Earth's center of mass and rules of solid geometry support computations in 3-D space. Many complex reductions needed in geodesy and cartography are avoided. That means end users can exploit characteristics of 3-D digital spatial data more efficiently.

The GSDM includes a functional model of geometrical relationships used to compute 3-D positions worldwide. The GSDM also includes a stochastic model that can handle error propagation throughout the computational process. Consequently, the end user has ready access to reliable estimates of spatial data accuracy of any derived quantity – coordinates, distances, angles, areas, volumes, and the like.

A book describing the GSDM was written by ASCE member Earl F. Burkholder and published by CRC Press in 2008. More recently, a 2nd Edition has been written and is scheduled for release by CRC Press in July 2017. For more information, see www.globalcogo.com/SecEd.html.

Progress in any human endeavor involves a combination of process and content. One analogy views it in terms of "doing the right thing versus doing it right." Regarding spatial data, professional organizations have done an excellent job with the "process" part. Without being critical of those accomplishments, realizing benefits from the digital revolution also relies on appropriate application of "content." The need for enlightened policy leadership for content is illustrated by three separate examples: first, one involving the National Council for Engineering & Surveying (NCEES), a second example draws from the 2016 Minimum Standard Detail Requirements for ALTA/NSPS Land Title Surveys, and a third example is related to the 2015 Report Card on the U.S. National Spatial Data Infrastructure. In each case, dedicated professionals are making decisions that have far-reaching impacts within the spatial data community. The point here being that the "content" of spatial data concepts deserves additional consideration in those discussions, deliberations, and decisions.

Alarmed by the declining number of persons taking the NCEES surveying licensing exams, NCEES hosted a form on "The Future of Surveying" in San Diego, CA in January 2016 - http://ncees.org/ncees-hosts-forum-strengthen-future-surveying-profession/. Eighteen different professional organizations were represented and the spirited discussions were quite productive. A follow-up meeting was held June 10 and 11, 2016 in Baton Rouge, LA. A collaborative bulletin board was established following the San Diego meeting for the exchange of information. Of many good ideas discussed on the bulletin board, the following link contains a portion of the discussion, highlighting the need for consideration of "content."

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

The previous link is a bit lengthy but closes on page 9 with a discussion relating to ALTA/NSPS Minimum Standards. The point being that the concept of "relative positional precision" is excellent but, in fact, not realized mathematically. Possible revision of the standard is being considered by NSPS. In the meantime, the "content" portion of the discrepancy is the basis of a proposed presentation to the Surveying and Geomatics Educators Society (SaGES) biennial conference in Corvallis, Oregon, July 30 to August 3, 2017.

http://www.globalcogo.com/SaGES-ALTA-NSPS-2017.pdf

Patterned after the ASCE Infrastructure Report Card, the Coalition of Geospatial Organizations (COGO – not Global COGO, Inc.) published a "Report Card on the U.S. National Spatial Data Infrastructure" in February 2015. That is an excellent document and, like the ASCE Report Card, is subject to updates.

http://www.cogo.pro/uploads/COGO-Report_Card_on_NSDI.pdf

A summary of that report as it impacts civil engineering and planning was presented to a joint meeting of APA and ASCE New Mexico Chapters on September 24, 2015.

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

A criticism of that report is that it is long on process (necessary) but short on content (needs attention).

An update to the COGO Spatial Data Infrastructure Report Card is being prepared and planned for publication in January 2018. While it appears that revision efforts are strongly "process" oriented, the aspiration is that "content" will be duly considered.

RECAP:

1. There is a large demand for technical professionals to be able to handle 3-D digital spatial data more efficiently.
2. ASCE can and should be involved because the use of spatial data is so fundamental to many civil engineering activities.
3. The challenge should be met on two fronts – webinars for practicing professionals and formal spatial data concepts for all CE graduate students (also desirable for undergrads).
4. Three examples are given in which "content" needs to achieve a better balance with "process."
5. The 2nd Edition of "The 3-D Global Spatial Data Model: Principles and Applications" focuses on spatial data "content" and is scheduled for release in July 2017.

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