

CORS, Gravity, Digital Twins, High-Definition (HD) Maps, and AI

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The term “artificial intelligence” (AI) is not new, but I don’t really know what AI is or even if AI is possible. Even so, AI is now manifest under labels such as ChatGPT, Bard, and Bing. These platforms enable one to ask a question and to receive a “legitimate” computer-generated answer within seconds. When using spatial data, AI relies on CORS and HD maps (surveying).

Although each item in the title above is worthy of a separate discussion, the intent in this article is to weave a surveying thread connecting all five topics. In a sentence – the continuously operating reference station (CORS) network is the geometrical foundation for the work of most surveyors, gravity is the challenge encountered when pushing the limits of flat-Earth surveying, the digital twins concept connects points/lines on the ground with their electronic representation, a high-definition map emphasizes geometrical integrity of the digital twin, and AI is a science fiction concept (at least I thought it was) that may impact surveying sooner than we might like. The thread is location and spatial data. The point is that measurements and using spatial data are a surveyor’s bread and butter. That is our area of expertise, and the contributions surveyors make to society are enormous. I am convinced that the geometry of points and lines on/near the Earth will be around forever, AI or no AI.

An article about getting the NMSU CORS¹ back online is included in the June 2022 issue of Benchmarks. Recently, the National Geodetic Survey (NGS), in cooperation with the National Park Service (NPS), established a new CORS near the Carlsbad Cavern. I and several other NM surveyors had the opportunity to participate in that installation on February 23 and 24, 2023. Lynda Bell, is the NGS Geodetic Advisor for NM and played a significant role in organizing the event. While this is a brief summary of the event, Lynda plans to develop a comprehensive description and release. The new station is called “CAVE” and fills a gap in existing CORS coverage of SE New Mexico. A map of the NGS CORS² network can be accessed via the internet. Starting with a map of the entire United States, one can zoom to any location desired – say southeast New Mexico. Information for stations shown on the map is accessed via embedded links. Although the CORS network is a fundamental resource for many spatial data users, most surveyors have a technical background which enables us to assist others in understanding the geometrical characteristics of the control network and using CORS data to the greatest advantage.

The impact of gravity is more abstract - bear with me. As one of the four fundamental forces of nature, gravity keeps everything together and we experience gravity locally by walking upright on a flat-Earth. But the Earth is not flat. Due to the digital revolution, local surveying practice has evolved from plane surveying to geodetic surveying which accommodates the curved Earth. The impact of gravity is complicated by the non-uniform distribution of mass within the Earth - meaning that the shape of an equipotential surface, although both curved and smooth, is irregular. Of infinitely many equipotential surfaces, the one closest to sea level is called the geoid and is used as the reference for elevation.

Let's put gravity in context by looking at extremes. Physicists at the CERN accelerator in Switzerland have refined the Standard Model of particle physics to accommodate observable phenomenon – i.e., fundamental physical forces. Ironically, although gravity is one of the four fundamental forces, it is not part of the Standard Model. A quote from the CERN³ website is:

“The Standard Model includes the electromagnetic, strong and weak forces and all their carrier particles, and explains well how these forces act on all of the matter particles. However, the most familiar force in our everyday lives, gravity, is not part of the Standard Model, as fitting gravity comfortably into this framework has proved to be a difficult challenge.”

Although gravity acts over “infinite” distances, the force of gravity is discounted in the CERN context described above. But we all experience the impact of gravity in daily life and deal with it as one cause of the difference between pseudo 3-D and true 3-D.

<http://www.globalcogo.com/true-versus-pseudo.pdf>⁴

On the other extreme, cosmologists assure us that the incredibly large force of gravity at the center of a galaxy is responsible for “black holes” from which nothing, not even light, can escape. Although current research confirms the existence of gravity waves (do an internet search on “gravity waves”), more data are needed to refine human understanding of the most obvious force – gravity. Given continuing refinement of a geoid model (a consequence of gravity), it stands to reason that the spatial data user community will be served better by using Earth's center of mass as a reference for vertical (true 3-D) than the geoid (pseudo 3-D).

I started my surveying career drawing survey plats on a drafting table using a T-square, parallel bar, and velum. Now everything is drafted on a computer and the digital equivalent of a carefully drawn plat is stored electronically as a combination of 0's and 1's. A digital twin can represent either local plane surveying (flat-Earth) products or, depending on software used, the true 3-D position of any/all points can be equivalently portrayed on a computer screen. In some cases, a digital twin of a horizontal survey plat is perfectly legitimate, but if or when contour lines are superimposed on a horizontal plat, the 3-D geometrical integrity may be compromised. The difference between pseudo 3-D and true 3-D is inconsequential in many existing applications and may not cause problems. Responsible professionals are equipped with the knowledge to handle those differences competently. But consequences of the ambiguity between pseudo 3-D and true 3-D can be a nuisance or, worse, cause real problems. Looking ahead, algorithms for controlling driverless vehicles must be understood, reliable, and efficient.

According to Wikipedia⁵ (article contains links to additional references):

“A **high-definition map (HD map)** is a highly accurate map used in autonomous driving, containing details not normally present on traditional maps. Such maps can be precise at a centimetre level.

HD maps are often captured using an array of sensors, such as LIDARs, radars, digital cameras, and GPS. HD maps can also be constructed using aerial imagery.

High-definition maps for self-driving cars usually include map elements such as road shape, road marking, traffic signs, and barriers. Maintaining high accuracy is one of the biggest challenges in building HD maps of real-world roads. With regard to accuracy, there are two main focus points that determine the quality of an HD map:

- Global accuracy (positioning of a feature on the surface of the Earth)
- Local accuracy (positioning of a feature in relation to road elements around it).

In areas with good GPS reception, it is possible to achieve a global accuracy of less than 3 cm deviation using satellite signals and correction data from base stations.

In GPS-denied areas, however, inaccuracy rises with distance traveled through the area, being largest in its middle. This means that the maximum GPS error can be expressed as a percentage of the distance traveled through a GPS-denied area: this value is less than 0.5%.”

Now, about AI: I recently became aware of ChatGPT capabilities through a virtual NMSU Training Center session titled, “The End of Student Writing? Teaching in the Age of Artificial Intelligence.” After the session, I signed up for a free trial of ChatGPT and asked several questions. The computer-generated responses were returned in less than a minute.

Question 1: How should surveyors and engineers address the challenges of working with 3D digital spatial data?

Answer: Surveyors and engineers should address the challenges of working with 3D digital spatial data by leveraging the latest technologies, such as 3D scanning and mapping, digital photogrammetry, and Geographic Information Systems (GIS). Additionally, they should make sure to understand the type and accuracy of the data they are working with, as well as the data’s accuracy requirements for their specific application.

Question 2: What is the difference between pseudo 3D and true 3D with references?

Answer: Pseudo 3D is a computer generated representation of a two dimensional surface while true 3D involves representing data in three dimensions, including depth and volume. References.^{6 and 7}

In my opinion, the convergence of abstraction/technology/policy/practice deserves careful consideration with regard to use of spatial/geospatial data. This article is also posted at www.tru3d.xyz⁸ and is intended to support other items appearing there.



CORS named "CAVE" located at Carlsbad Caverns, New Mexico



GNSS Antennae in Foreground and Solar Array in Background



Left to right: Earl F. Burkholder – (NMPS) Las Cruces, NM
 Todd Wagener – (NMSP) Roswell, NM
 Evans Ralston – (NMPS) Las Cruces, NM
 Andrea K. Goodbar – (WIPP Environmental Scientist) Carlsbad, NM



National Geodetic Survey (NGS) and National Park Service (NPS) personnel:
Left to right: Lynda Bell (NGS), Luca Kuziel (NPS), Erin Lynch (NPS), and Rod Horrocks (NPS)

Links to web references (go direct or copy and paste link as needed):

- 1 <http://www.globalcogo.com/A92.pdf>.
- 2 https://geodesy.noaa.gov/CORS_Map/
- 3 <https://home.cern/science/physics/>
- 4 <http://www.globalcogo.com/true-versus-pseudo.pdf>
- 5 https://en.wikipedia.org/wiki/High-definition_map
- 6 https://en.wikipedia.org/wiki/3D_modeling
- 7 <https://www.geospatialworld.net/blogs/true-3D-versus-pseudo-3d-mapping/>
- 8 <http://www.tru3d.xyz>