The Need for Time Standards in Geospatial Metadata

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SUMMARY

In the era of simple, high-accuracy and precision, GNSS enabled positioning, the expansion of time-dependent positioning has grown rapidly. Many countries have begun taking advantage of dynamic geometric reference frames that both acknowledge and depend on the utility of time being a component of position. The International Terrestrial Reference Frame annual updates and the World Geodetic System of 1984's various realization epochs, have accepted this reality for years through their reference data. However, the average practitioner of surveying and GIS has long been able to get away with assumptions of equivalence between common systems and indeed, many commercial software solutions fail to adequately acknowledge the necessity of proper temporal adjustment of data. As time has progressed since the advent of modern GNSS capabilities, the plates have continued their motion and drifted further from their locations of years ago. Surveyors have long kept pace with these subtle updates of the reference frames, but in the positioning industries at-large, maintaining positions to within one meter has often been considered an acceptable standard. As many of those frames began drifting beyond where the one-meter accuracy level, some as early as 20 years ago due to sudden tectonic events, many users collectively shrugged and persisted in the belief that such small differences remained unimportant.

As the international community develops new standards for plate-fixed work in various regions, many new reference frames, such as the currently under development North American Terrestrial Reference Frame of 2022, will be both geocentric and plate fixed at the moment of realization and then drift. The motion of the frame is to be acknowledged and built-in and any transformations of positions in the system will need to know when the data was captured to properly reflect accurate and precise position of the data and then needs to be maintained in perpetuity, along with the physical spatial position of the data. In modern geospatial referencing data formats, there are many parameters to maintain in metadata that are readable by both man and machine, but almost all concern the physical location, rather than the temporal location or reference. In many commonly used reference standards, there is indeed no way to properly reference time and as such, data inherently loses value as soon as it is separated from the creator unless great care of communication is taken. The need for modernized standards to fully acknowledge time across geospatial data formats is becoming more and more clear and the time we began to need those standards is already in the past.

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1. TIME IN GEOGRAPHY

Time is an essential and well understood component of geospatial metadata; it provides necessary information about when the data was collected or created. The attributes stored in geospatial data can change rapidly through time and the relevance and accuracy can be influenced by various factors such as seasonal variations, weather patterns, natural events, and human activities. Including temporal information in geospatial metadata can help users to better understand and analyze the data's characteristics and behavior. For instance, time-stamped geospatial data can provide insights into the dynamics of natural processes, such as changes in vegetation cover, water levels, or wildlife migration patterns. It can also help track human activities, such as land-use changes, transportation patterns, or urban development over time. Therefore, including accurate and detailed temporal information in geospatial metadata is critical for effective and informed decision-making in various domains, including environmental monitoring, disaster response, urban planning, and natural resource management. These uses are obvious and are easily understood. This portion of time is relates time as a coordinate of the data, when the data was collected.

2. TIME IN GEODETIC REFERENCES

All of this care for time is about the qualitative and quantitative data itself. The time reference of the spatial reference system that geographic data is located with is often relegated to the year included as a part of the name of the horizontal datum of the geodetic reference system. Typically, a horizontal datum is often named with its year of realization or standardization attached. Take for example the superseded survey datum of the United States “North American Datum of 1927” standardized in 1927 based on information collected previous to 1926. From 1927 until 1986, this was the standard for North America. (US Department of Commerce, 2018) The “1927” represents the year of standardization for this reference frame. A plate fixed system before the era of satellite-based surveying, it assumes that there is no deformation of the North American tectonic plates from the 1920s to the modern day. In these earlier days of modern geodesy, tectonic motion could be somewhat safely ignored due to the levels of accuracy and precision capable of being measured on a global scale. Positioning work on a given plate happened on that plate irrespective of the motion of other tectonic plates or the rest of the planet. In the latter portion of the 20th century, global positioning system technology began to unlock the possibility of performing highly accurate geodetic surveys around the globe. The first iteration of the North American Datum of 1983 (NAD83) was intended to be both plate-fixed and geocentric. In more recent times, that geocentricity was later determined to be lacking by about 2.2 meters to that of the World Geodetic System of 1984, created by the United States Defense Mapping Agency, a de facto global standard for positioning which was standardized in the same time period. Reference frames were largely handled as if they were fixed and unchanging in space whether through the span of years of NAD27 or the modern, rapidly evolving models of NAD83. Parallel to the development of plate fixed coordinate reference systems, international geocentric coordinate systems such as WGS84 and the International Terrestrial Reference Frames also evolved.

The science of geodetics, particularly the aspects that deal with determining precise and accurate positioning, have increasingly come to rely on space-based technology, beginning with the Global Positioning System, which has now expanded to be known as Global Navigation Satellite Systems as more nations bring their constellations of satellites online. This fundamental shift in positioning technology is in the process of turning traditional land surveying on its head. The extreme levels of accuracy and precision capable of being measured with these space-based technologies, has made possible advances in geodetics at a rate previously unattainable through earth-based techniques. Since its inception, NAD83 has been realized a number of times, from the original NAD83(1986) through other refinements at various reference epochs, known as HARN, FBN, NSRS2007, and 2011. Likewise, the International Terrestrial Reference Frame and World Geodetic Systems, have been evolving and steadily diverging from their modern plate fixed counterparts. With each of these, technology has evolved, new data was factored in, and the control of the systems became increasingly reliant on GNSS technology. Transformations between these refinements have not always been well understood outside or even inside the surveying community.

2.1 ASSUMPTIONS OF EQUIVALENCE

As survey authorities have continued to modernize and refine our reference datums and geometric networks, surveyors have kept pace with this through various reference systems established by requirements set forth in their national systems. GNSS devices and software most closely associated with the surveying and positioning work have a myriad of reference frames available acknowledging national systems, as well as WGS84 and the International Terrestrial Reference Frames. At times this has been imperfect due to assumptions of equivalence between systems. Within the International Association of Oil and Gas Producers' (IOGP) EPSG Parameter Dataset, there are over 210 Geodetic Datums that rely on GRS80 as the base ellipsoid. With 849 datums presently defined by the IOGP's database, almost a quarter of them use exactly the same dimensions of size and shape, simply realized against Earth's geocenter, or to a particular tectonic plate. Looking into the available transformation parameters to relate many of these national or international systems to each other, one quickly finds that the transformations are small, and all within a few meters of each other's geocenters. These small distances at the geocenter reflect in various magnitudes at the surface. A common assumption in many locales is that the local coordinate system using the GRS80 ellipsoid is functionally equivalent and considered coincident at the +/-1 meter accuracy level. A common transformation relating two geodetic reference systems is a three-parameter geocentric translation, with X, Y, and Z translations all equal to 0 meters. Since GRS80 based systems have been established, these zero shifts have been used to link these local reference systems to the global reference systems used within GNSS based positioning. Using the example of North America, the North American datum of 1983 is often related to WGS84 using a zero shift, identified as EPSG coordinate transformation 1188. Nomenclature around the North American Datum of 1983 and WGS84 are often vague and over generalized in commercial tools completely ignoring the epoch of realization, of which each of these geodetic coordinate reference systems have several, with varying relationships to each other dependent upon the epoch. EPSG transformation 1188 is defined as being accurate within two meters of each axis and being useful for military purposes; hardly suitable for survey work. These common assumptions of equivalence began with the advent of the GRS80 based systems and have remained persistent, likely due in no small part to solving an immediate problem for a user who does not understand the ramifications of the data manipulation they are performing.

2.2 TECTONIC MOTION AND DYNAMIC MODELS

The ability to run continuously operating reference stations has allowed survey authorities around the world to closely monitor tectonic motion and quantitatively assess both the motion and deformations of the very tectonic plates we aim to anchor our coordinate systems to. Indeed, anywhere in North America, through the use of Horizontal Time Dependent Positioning, published by the National Geodetic Survey of the United States can be used to model the velocities of positions anytime throughout the last 40 years and beyond. Likewise, survey authorities around the globe are publishing velocity-based models to accommodate motion through time of the surface of our planet. The everyday practitioner of geodetics now has access to a variety of time-based transformations, whether that be an eight parameter Helmert, a 15 parameter coordinate frame rotation or position vector rotation, or a hybridized system similar to Horizontal Time Dependent Positioning or any other of the grid file lookup-based transformations coming online around the world. Some of these grid-based methods also include adjustments for sudden dislocations between plates from earthquake events. Depending on where one is working there are a variety of distances and deformations in existing datum models that must be accounted for when accomplishing survey grade positioning.

3. SPATIOTEMPORAL DATA STORAGE

With dynamic models currently being developed and the data legacy of the almost 40 years since GPS changed the industry, there is a vast amount of data to reconcile, and still yet reams of new data yet to be produced or updated in the coming years. With the hundreds of spatial data formats available to the surveying and positioning industries, time is a newcomer. The Open Geospatial Consortium and International Organization for Standardization specification ISO19111, provides the necessary structure for recording time as a part of the reference frame or as a part of the coordinates as appropriate (Lott, 2018). Many legacy data types do not have a provision for time, either as a coordinate or as a part of a reference epoch. Some very commonly used formats entirely lack any ability for referencing time aside from a datum with an implied reference epoch. As such, surveyors and other practitioners of geographic data need to take care to record appropriate metadata with projects, to ensure the value of the data is not lost with the metadata as the epochs pass and the dynamics of the reference frame continue to have an effect on the locations we record. In a short few years, the vast majority of the planet will be covered by dynamic coordinate reference frames, and the need for temporal referencing, both in reference epoch and coordinate data will be crucial to maintain the high levels of accuracy and precision our new methods of survey control will require. To handle these new dynamic systems, modern formats such as Geodetic Gridded Data Exchange Format (GGXF) are being developed. GGXF is a fist of its kind standard to accommodate dynamic deformation grids and geoid models. No doubt additional standards will be developed.

4. CONCLUSIONS

Surveying is evolving rapidly both in the physical technology being used as well as the digital. The mass availability of satellite-based techniques combined with a move to dynamic reference frames is pushing surveyors to adapt in several ways at once. Dynamic coordinate references will only increase in usage in the coming years, the education and training required to successfully adopt these new technologies exists but itself is evolving. Surveyors who do not adapt to these new techniques or fail to adopt time-based practices for their spatial data management will be left behind. These changes have been a long time coming and would be easier to adapt current data to if time metadata had been more rigorously captured in the past. We still have an opportunity to learn and prepare before much of the world comes online with these new dynamic systems, it is never too late to move our work practices in a positive direction, the sooner we adopt new best practices on time metadata management, the better of future surveyors will be.

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BIOGRAPHICAL NOTES

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