USE OF CONSUMER GRADE 3D VISUALISATION TECHNOLOGIES IN ASSET MANAGEMENT

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ABSTRACT

Google Earth provides a free and easy-to-use platform for small-scale surveying and placement of virtual infrastructure for customer and quality assurance viewing purposes. Due to its design for small scale object presentation however, significant distortions of geometries occur of dimensions in excess of the size of a large building if careful measures are not taken. This paper investigates the challenges of maintaining spatial accuracy when utilizing standard Collada geometries to render objects across large distances for asset inspection purposes.

INTRODUCTION

With the rapid development of remote geospatial surveying technology in recent years, many exciting possibilities have emerged for managing electrical distribution assets across very large areas. Fugro ROAMES has used aerial LiDAR and camera technology to survey over 150 000 km of distribution lines across Queensland. At this scale of geospatial data capture, 3D visual inspection presents some unique challenges. A number of commercial-grade software packages are available for 3D data visualisation, some with added engineering features for asset management and design but they suffer from the need of licensing, and IT support. For most 3D visual asset inspection, the added functionality of commercial software isn't necessary, is often cumbersome and licensing for many users can be very expensive. Consumer grade software packages provide a platform for 3D data presentation at lower spatial accuracy with outsourced IT support for many users and lower cost. This paper investigates the spatial accuracy challenges of using Collada models in Google Earth, a free-to-use consumer software package, for serving 3D survey data to users.

At Fugro ROAMES, the strategy for using geospatial survey data for electrical asset management has been to do as much interpretation of data by automated procedures with only final stage visual validation requiring user input. This eliminated the need of common engineering functionality with its visual presentation of data and so Google Earth was chosen as the platform. As with almost all consumer-grade visualisation software, Google Earth is not optimized for large scale serving of accurate geospatial data but it was considered most preferential by Fugro ROAMES, mostly for its ease of many-user implementation. It is based on a geodetic (latitude/longitude) global coordinate system with a geoid height model representing the Earth's equipotential gravity surface undulation. Data may be served to google Earth in the form of Keyhole Mark-up Language (KML) files in the base-geodetic coordinates but also in packaged local Cartesian coordinate Collada files, origin-placed by KML wrappers.

Currently Fugro ROAMES serves its virtual world data in KML files which have been very reliable for accuracy but are limited by computer performance as the number of features on screen is increased. To address this challenge a study was performed to test the feasibility of serving large partitions of 3D feature data to customers using KML-wrapped Collada meshes. These features consisted primarily of power poles and trees growing nearby assets. It was discovered that when dealing with very large data sets spread over long distances, small relative distortions due to improper consideration of coordinate system transformations can drastically reduce spatial accuracy of features served. While these considerations were being investigated, evidence was uncovered showing a few important undocumented characteristics of the native Google Earth coordinate systems. These characteristics are identified in this paper and evaluated for design validity and strategies given for correction of resultant spatial distortion effects.

METHOD

The methods in this section are separated into the coordinate transforms used to generate 3D Collada meshes and methods used to measure distortions of these meshes when published in Google Earth.

Coordinate System Transforms

Prior to developing any sustainable method of serving 3D Collada models in Google Earth it was necessary to determine the necessary coordinate system conversions to be used in the generation of meshes from geodetic source data. As of the end of 2014 Fugro ROAMES has collected and kept most of its data in GDA94 (Geocentric Datum of Australia) Universal Transverse Mercator (UTM) coordinates. The conversions from UTM to geodetic (latitude/longitude) coordinates are repeatable and reversible without loss of precision. Once in geodetic coordinates, local Cartesian coordinate conversions with user-defined axis origins are then possible.

Important consideration must be made for the effect of Google Earth's geoid model to ensure correct alignment of any placed Collada meshes. Although it's not explicitly documented, Google Earth uses a local z-axis aligned with the perpendicular to the geoid in the relevant area. Normally since geoid undulations are so small over short distances this effect is negligible for Collada mesh placement but when meshes span several kilometres, lack of local z-axis alignment consideration causes vertical offsets of mesh features which can be seen clearly and hinder qualitative evaluation for asset management purposes.

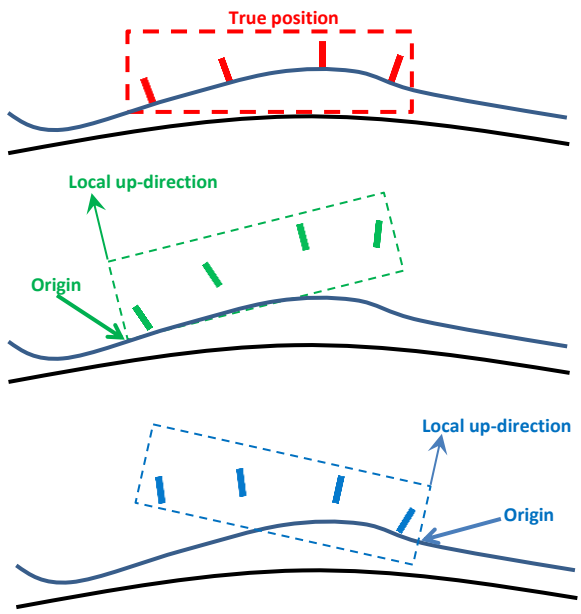

Figure 1 - Effect of origin placement on geoid surface

To account for geoid undulations at the respective mesh origins, all points contained in each mesh must be 3D rotated about their origin by an angle sufficient to cancel out the local geoid slope. The geoid model used in Google Earth is the EMG96 model which is included along with its call function in the Geographiclib package.

Measurement of Spatial Distortion

In order to verify the accuracy of served 3D Collada geometry in Google Earth a new novel approach had to be developed and applied. Since the Collada mesh layer in Google Earth is only interactive so far as allowing modification of KML-wrappers (scale, translation and rotation) of meshes, there is no accurate native method of measuring offsets between geodetic KML features and Collada features. The closest native solution is manually placing a mesh of known dimensions into Google Earth using the ruler tool to measure the visualization dimensions. To measure very small spatial offsets though this method is not sufficiently accurate.

The new method consisted of placing paired Collada meshes in Google Earth with a textured ruler to allow distance measurements with the naked eye. One mesh would have its origin at a known distance from the geometry origin while the other would have its origin coinciding with that of the geometry origin. The mesh with offset origin would have its KML position set to the same offset but in geodetic coordinates, effectively placing the two geometries at the same location. Transference of local Cartesian coordinates of the Collada mesh to global geodetic used in Google Earth can be easily done with Geographiclib tools, in this study performed in Matlab.

Any difference in position in the resultant paired geometries from this method would be the direct result of improper scaling of the coordinate transfer over the distance of the offset (see Figure 2).

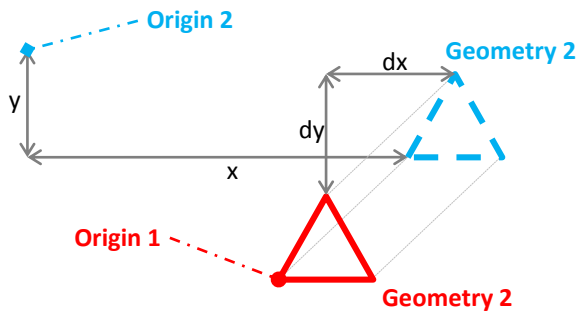

Figure 2 - Origin offset method of determining scaling errors

The aim was to isolate distortions in x, y and z directions so nine separate test structures were generated, one for each axis and latitude/longitude/altitude pairing, and placed at coastal areas at different latitudes and longitudes across the globe. Coastal areas were chosen because they had the least discrepancy between geoid heights and ground level heights, reducing the likelihood of possible additional scaling error. These models were also placed in triplets with each placed at increasing distance from their respective origin to test whether the scaling was linear with distance. Figure 3 below shows an example placed Collada pair that was used to measure spatial distortions.

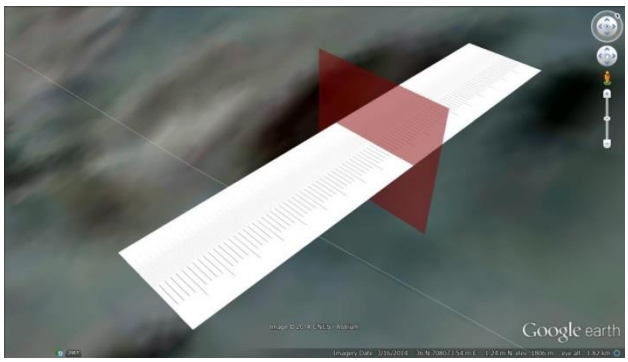

Figure 3 - Placed Collada geometry pair in Google

Earth for measuring spatial distortion

The results were recorded and mapped against corresponding latitudes, longitudes and altitudes of origin positions.

Scaling Function Determination

To be able to replicate position-dependent mesh scaling errors for correction, some form of analytical expression needed to be formulated to represent the observed effects. After evaluating which were the directions of most significant scaling error and the shape of these functions, two analytical expressions were formulated to best represent what was observed. The following is a detailed summary of how to use these two expressions and fit them to collected data.

The first is a sinusoidal fit with a wavelength of 180 degrees and a local minimum aligned at 0 degrees with an amplification parameter, A, plus a constant, C. The second is the same but with a near-one exponent applied to the sine function to allow for manual curvature modifications without changing the amplitude or function minimums and maximums.

$$\boldsymbol{f_1(\varphi) = A \cdot (\cos(2\varphi + 180) + 1) + C} \quad (1)$$

$$\boldsymbol{f_2(\varphi) = A \cdot (\cos^n(2\varphi + 180) + 1) + C} \quad (2)$$

With one sample position at the equator, both equations reduce to give the value of C, simply being the scaling factor recorded at the equator.

$$\boldsymbol{C_{1,2} = f_{1,2}(\varphi = 0)} \quad (3)$$

C will be the same value for either equation. A second sample point near one of the poles will allow for solving A.

$$\boldsymbol{\frac{f_1(\varphi=P)-C}{\cos(2P+180)+1} = A_1} \quad (4)$$

$$\boldsymbol{\frac{f_2(\varphi=P)-C}{\cos^n(2P+180)+1} = A_2} \quad (5)$$

where P is some latitude near 90 or -90 degrees. The A values for the two template functions will be different if n is not equal to 1. Note that for the second form, A is dependent on the choice of n so must be updated for any manual curvature adjustments made. If the second form is chosen, the value for n may be solved with a third sample point with an iterative solver. The following equation must be solved for n.

$$\boldsymbol{\frac{(f_2(\varphi=P)-C)\cdot(\cos^n(2T+180)+1)}{\cos^n(2P+180)+1} + f_2(\varphi = 0) = f_2(\varphi = T)} \quad (6)$$

where T is some latitude near 45 or -45 degrees. The scaling function should be used as follows to correct expected Google Earth distortions.

$$\boldsymbol{x_{new} = x_{old}/f_x} \quad (7)$$

$$\boldsymbol{y_{new} = y_{old}/f_y} \quad (8)$$

This should cancel out any scaling errors that Google Earth may induce by scaling the inputs by the inverse of what was observed.

RESULTS

Upon inspection of scaling effects at many places around the world using the nine test geometry pairs, it became apparent that any scaling in the z-direction is negligible and the scaling factors for both eastings and northings are functions of geodetic latitude only. Both of these were noted to be near-sinusoidal and fitted using the method outlined for function determination.

The function parameters for easting and northing scaling in Google Earth are provided in Table 1. The functions are also shown graphically in Figure 4.

	A	C	n
Northing	0.0050256	-0.0066925	0.998
Easting	0.0016798	0.0000020	1.01

Table 1 - Function fitting parameters for Google Earth scaling error

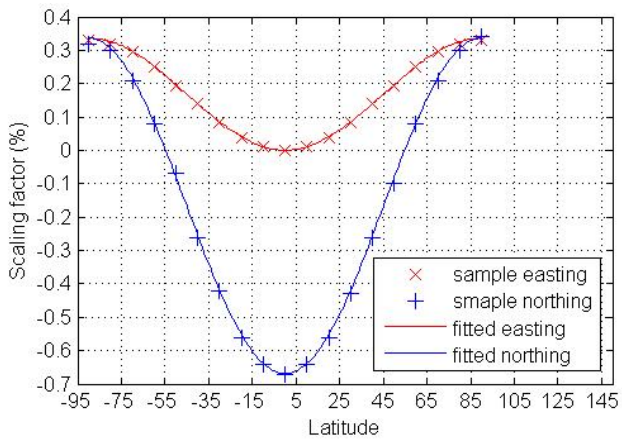

Figure 4 - Fitted scaling functions of easting and northing Collada mesh coordinates in Google Earth

Both the easting and northing observed scaling errors were sinusoidal with Latitude. The easting distortion was minimized at the equator at near-zero and maximized near the poles while the northing distortion was minimized at latitude of approximately 55 degrees with local maxima at both the equator and the poles, the pole maxima being the greater of these.

As best could be determined using the Google Earth user interface these results were not sensitive to absolute height, geoidal height or height above geoid.

DISCUSSION OF RESULTS

The sinusoidal functions used to represent Google Earth's scaling errors matched extremely well with the measured data points for both eastings and northings. Any discrepancies between the fitted curves and the measured data points were within the precision bounds of the measurements.
With a maximum axial distortion of under 0.7% in the northing-direction it's correct to assume that on isolated geometries, located near their origins of placement, the observed scaling changes do not need to be considered. This would be something like a single pole with all attachments or one collection of catenaries across a short span. For the purposes of electrical distribution asset visualization however this will rarely be the requirement. Since poles, cross-arms and conductors are geometrically simple and are spread over large distances it would often be desirable for rendering efficiency to merge geometries together into a smaller number of Collada meshes.

It would not be uncommon to see these kinds of geometries placed over 100m from their respective origins. Under the distortions observed in this paper a 100m distance from the mesh origin would translate into a 67cm offset near the equator. This is far greater than acceptable tolerances for most aerial asset inspections so the distortions must be countered at the generation stage of these meshes.

Investigations were made to determine the source of these distortions but were unsuccessful. The scale of the distortions is similar to that which would be observed if Google Earth was using a spherical model instead of an ellipsoid but shape of the fitted function is inconsistent with this. Also, if the source of the distortions is the ellipsoid model, Google Earth is using a model contrary to their documentation which claims a standard WGS84 (World Geodetic System 1984) ellipsoid. An ellipsoid model with a larger polar radius than equatorial could produce the distortions shown but this is the reverse of the reality of the Earth's shape.

CONCLUSIONS

Large scale usage of commercial software packages for the purposes of visual virtual asset inspection often becomes impractical due to licensing of many users. Consumer grade software offers a free service but without the reliability of the commercial packages so often some pre-emptive measures must be taken to make their usage viable.

Google Earth does have the capacity to be used for large scale deployment to visualize virtual electrical distribution assets but this paper shows that for practicality without the cost of accuracy some measures must be taken to account for spatial distortion errors. These errors, although insignificant over short distances scale with displacement from origin so any Collada mesh containing multiple poles will likely suffer the observed effects to an extent which compromises visual inspection quality.

The measurements taken in this paper and their associated analytical fits may be easily utilized in generation of Collada mesh geometry collections for presentation in Google Earth to cancel out the inherent spatial distortion that Google Earth suffers in its rendering of Collada meshes. Both scaling in northing and easting coordinates were found to be linear with distance from origin and sinusoidal with latitude. The fitted curves gave repeatable results within the error margins of the collected data. The maximum distortion observed in collecting the data was a 0.68% northing distortion near the equator which would likely be significant for any mesh consisting of more than one pole.

In addition to showing the challenges with using consumer grade software this paper demonstrates very well the potential problems associated with using closed source code products for presenting geospatial information. A far better alternative is to develop a purpose built platform or use open source platforms that allow proper access to their source code such as Cesium.