How to efficiently store and disseminate massive terrains?

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Abstract:

3D city models are being used in different applications like urban planning (Döllner et al., 2006; Kolbe et al., 2015b), 3D cadastre cadastre (Stoter et al., 2013), solar irradiation estimation (Biljecki et al., 2015;), energy demand estimation (Krüger and Kolbe, 2012), noise mapping (Stoter et al., 2008), population estimation (Biljecki et al., 2016b), etc. But so far, all these applications mostly revolve around buildings. Other features like terrain, vegetation, roads, water bodies, bridges, etc. are often ignored. The main focus in this research is on the terrain part of a 3D city model and particularly on its storage as a TIN in file based systems and DBMS. Storing and managing massive TINs is complexer than storing point clouds because it not only requires storing the TIN geometry but also the topology.

The 3D GIS standard CityGML (Groger et al., 2012) and its database implementation 3D City Database (Kolbe et al., 2015a) store TINs as OGC Simple Feature structure (OGC, 2011). But I argue that the Simple Feature structure is not efficient enough to store massive TINs. There are several problems, for instance: each triangle is stored independently as a linear with repeated vertex information; there is very little topological information stored (Fig. 1). As a result, the dataset becomes voluminous and cannot be analysed efficiently, which greatly hinders exchange, dissemination and applications.

I made some tests with the 3DTOP10NL (Kadaster, 2015) terrains for testing the storage requirements of TINs in CityGML. 3DTOP10NL terrain is a constrained TIN with more than 1 billion triangles. The 1 billion+ triangles of 3DTOP10NL terrains require around 700 GB of storage space with CityGML. Very large file size clearly prevents us from using the dataset. In practice, the CityGML LOD concept is limited to buildings. There is no widely-accepted LOD paradigm for terrains in 3D city modelling. CityGML is designed for the storage and exchange of 3D city models and not for visualizing them. This is owed to the large size and data redundancy in the CityGML datasets.

Keeping in mind all the associated problems in storing massive TINs in CityGML, I propose a framework for (a) developing a robust schema for the compact storage of terrains in CityGML and 3DCityDB(PostgreSQL) and (b) for visualizing and disseminating the CityGML terrains. I propose a CityGML ADE for handling very large TIN representation of terrains in CityGML. The ADE will cover all the four aspects of modelling a terrain in CityGML: geometry, semantics, texture and LOD. For geometry, we tested several TIN data structures like Simple Feature, Triangle, Triangle+ (with adjacency information) and Star (Kumar et al., 2015). We introduced triangle referencing scheme (Fig. 1) for the TIN vertices and triangles in the GML schema for the ADE. This resulted in around 25 times less storage than the current CityGML solution with 3DTOP10NL terrains.

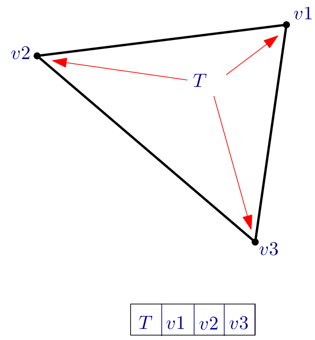

Fig. 1: Triangle data structure

Terrain datasets are massive, taking up gigabytes or terabytes. We plan to use Cesium 3D webglobe () for rendering these massive terrains (TINs) over web (Fig. 2). The Cesium terrain quantized mesh format is to be used for creating TIN tiles. An irregular mesh of triangles is pre-rendered for each of the tiles. It provides a better representation of terrains with less details in flat areas and more details for a steep terrain. To alleviate the bottlenecks associated with rendering massive CityGML terrains over web, we also aim to introduce the structures of tristrips (Speckmann and Snoeyink, 2001) and stars (Ledoux, 2015) in CityGML schema.

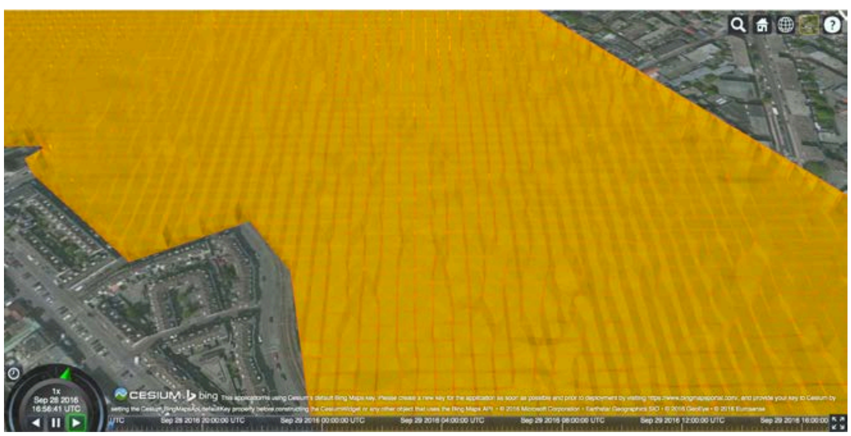

Fig. 2: TIN visualization over Cesium 3D webglobe

References:

Biljecki, F., Heuvelink, G. B., Ledoux, H., and Stoter, J. (2015). Propagation of positional error in 3D GIS: estimation of the solar irradiation of building roofs. *International Journal of Geographical Information Science*, 29(12):2269–2294.

Biljecki, F., Ohori, K. A., Ledoux, H., Peters, R., and Stoter, J. (2016b). Population estimation using a 3D city model: A multi-scale country-wide study in the netherlands. *PloS one*, 11(6):e0156808.

Döllner, J., Kolbe, T. H., Liecke, F., Sgouros, T., Teichmann, K., et al. (2006). The virtual 3D city model of berlin-managing, integrating, and communicating complex urban information. In: *Proceedings of the*

25th Urban Data Management Symposium UDMS, volume 2006, pages 15–17.

Groger, G., Kolbe, T. H., Nagel, C., and Häfele, K.-H. (2012). OGC City Geography Markup Language (CityGML) Encoding Standard version 2.0.0.

Kadaster (2015). 3DTOP10NL. http://arcg.is/1GKYy7E. (Last accessed: April 15, 2016).

Kolbe, T., König, G., Nagel, C., and Stadler, A. (2015a). 3D city database for CityGML. Institute for Geodesy and Geoinformation Science, Technische Universität Berlin, page v3.

Kolbe, T. H., Burger, B., and Cantzler, B. (2015b). CityGML goes to broadway. In *Photogrammetric Week,* volume 15, pages 343–356.

Krüger, A. and Kolbe, T. (2012). Building analysis for urban energy planning using key indicators on virtual 3d city models: the energy atlas of berlin. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 39(B2):145–150.

Kumar, K., Ledoux, H., and Stoter, J. (2016). Comparative analysis of data structures for storing massive TINs in a DBMS. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, XLI-B2:123–130.

Ledoux, H. (2015). Storing and analysing massive TINs in a DBMS with a star-based data structure. Technical Report 2015.01, 3D geoinformation, Delft University of Technology, Delft, the Netherlands.

OGC (2011). OpenGIS implementation specification for geographic information-simple feature access-part 1: Common architecture. OGC document version 06-103r4.

Speckmann, B. and Snoeyink, J. (2001). Easy triangle strips for tin terrain models. International journal of geographical information science, 15(4):379–386.

Stoter, J., De Kluijver, H., and Kurakula, V. (2008). 3D noise mapping in urban areas. *International Journal of Geographical Information Science*, 22(8):907–924.

Stoter, J., Ploeger, H., and van Oosterom, P. (2013). 3D cadastre in the netherlands: Developments and international applicability. Computers, Environment and Urban Systems, 40:56–67.