DELIVERING VALUE ADDED PRODUCTS FROM ELEVATION DATA

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Convergence in Geomatics: Challenges and Opportunities

ABSTRACT:

High density elevation data like Light Detection And Ranging (LiDAR) has been gaining popularity as the preferred high resolution digital surface model for 3D visualization, analysis and integration with other remotely sensed data. At Valtus we have been delivering elevation data in various formats for the oil and gas, environmental and infrastructure industries from our extensive online library encompassing Alberta and it surrounding provinces. The elevation data acquired by leading aerial providers has a high degree of accuracy and has been instrumental in our customers' spatial analysis and visualization needs. We have been using the online delivery mechanism of our spatial data store to allow users to securely search, clip to a given area of interest and download raw datasets (bare and full earth) in various formats and projections. Our customers have then taken these raw datasets and ingested them into different desktop applications for exploitation. However, our customer survey for improvements revealed that even though the datasets were being used in multiple GIS applications, the majority of the users only needed a handful of value added products like shaded relief and contours generated from these raw datasets. This usage trend has created an unnecessary burden on few geospatial experts not only in preparing the data for intake to different applications, but producing and disseminating these products to the non GIS users within their organizations. The major finding of the survey was, will it be possible to stream these value added products directly to the non GIS user's application instead of going through a multi-step workflow. Valtus has already developed very sophisticated and streamlined terrain processing modules that provide support for automatically creating different kinds of products, which include tiled point clouds, contours, elevation grids, shaded reliefs, intensity/data void images, accuracy analysis and evaluation reports and different metadata products.

The challenge was exposing the results of these processing modules without creating new applications and delivery protocols. In surveying the current state of terrain or 3D data delivery we could not find an accepted official or de facto standard that was supported by a significant number of GIS applications. In contrast imagery with its well defined/supported online delivery protocols like WMS is considered a utility service crucial to running a business since the data can be consumed in a variety of applications for analysis and interpretation directly. These short comings have forced us to use the mapping standards to stream elevation based value added products using fixed parameters and potentially extending them by means of style descriptors for parameterized rendering.

In this paper we will discuss the success and challenges of delivering value added products from elevation data using online streaming models and the impact of not having well established delivery standards for 3D terrain data.

1. INTRODUCTION

A digital terrain model or DTM is a digital representation of a ground surface. High accuracy terrain datasets are derived from either LiDAR or imagery based surface generation algorithms. The perspective offered by a third spatial dimension adds significant value to data analysis for a wide range of industries including oil and gas, agriculture, telecom and the military. Applications for the data include view shed calculations, flight planning, terrain analyses and line-of-sight analysis. There are also many by-products that can also be derived from raw terrain data. Some of the common ones are: shaded relief, 3-D perspective views, aspect maps, contour lines and line of sight profiles.

The days of only relying on global terrain datasets like GTOPO are quickly coming to an end. Users are demanding more accurate surface representations. As newly acquired imagery resolution increases, so does the demand for high resolution terrain data. Currently most satellite providers generate image products in the sub meter range and aerial sensor surveys are being done at a much higher resolution. All of this data creates a need for high accuracy, readily available terrain data to not only generate imagery based products like orthophotos, but also direct DTM based byproducts.

The volume and quality of DTMs has increased significantly over the last decade due to new methods for data acquisition (Interferometric synthetic aperture radar/airborne laser techniques), increasing availability of additional data sources useful for the DTM quality assessment and the introduction of 3D applications that use terrain like Google Earth and Virtual earth to the masses (Podobnikar T., 2009). The challenges for Valtus are to produce high accuracy, high density elevation data, as well as delivering the data efficiently to desktop applications through the established standards via the Internet.

In this paper we will discuss the different tools we have developed to efficiently process large volume terrain datasets and related value added products. We will also examine the different relevant standards that could be used to distribute the data and the current state of how Valtus delivers 3D data.

2. PROCESSING

Valtus has developed a suite of terrain processing tools that perform data management, product generation, analysis, 3D visualization, and metadata creation. In the development of the terrain processing tools several factors were taken into account.

- The large volume of point clouds
- The efficiencies of data processing in a production environment
- The archiving and management of the data
- The capability to generate output products in various format and projections
- The ability to create a product preview on-the-fly
- The efficiencies of product generation for real-time online delivery

The above goals were resolved by taking an approach that included the use of streaming processing, High Throughput Computing (HTC), and spatial database management techniques. Our processing workflow is illustrated in Figure 1. It consists of three groups of modules: data management, data processing, and product creation.
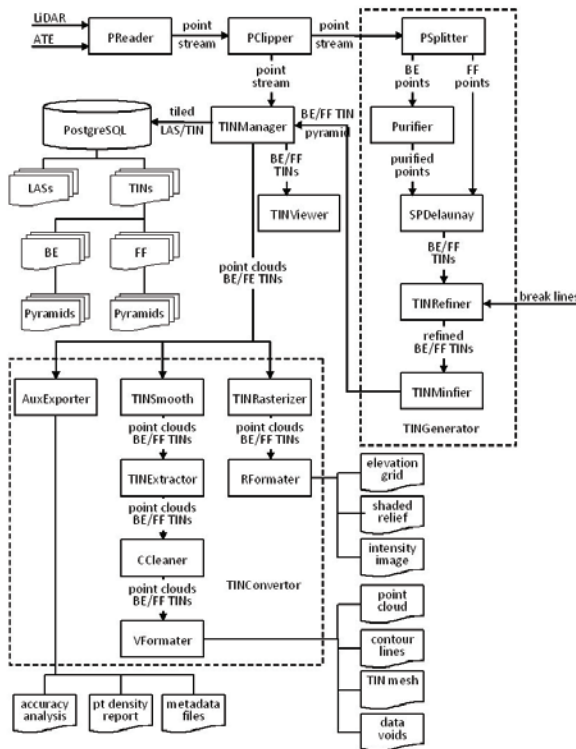

Figure 1. System modules and processing workflow

In the first phase of the development we covered the terrain processing workflow from classifying point clouds to product delivery only. Some pre-processing steps (e.g. flight planning, system calibration, strip adjustment) and advanced features such as automatic features extraction (houses, trees, power lines) and automatic full 3D scene reconstruction will be integrated in the follow-up phases.

2.1 Data Management

The various terrain data archiving and management requirements were handled by the development of a sophisticated data management system based on PostgreSQL with PostGIS spatial extension. One of the biggest challenges for terrain data management is that terrain data is essentially a kind of vector data in that the spatial locations of points have to be explicitly stored. This makes the data volume much larger than imagery and impractical to manage in a relational database. Therefore we use a strategy of managing raw data in tiles (disk files) and the metadata including the footprints of these tiles within a spatial database. This strategy not only makes it possible for storage and fast query of massive terrain data, but also prepares a solid ground for HTC and fast product delivery.

Three kinds of data need to be stored and managed in terrain processing: point clouds, surface meshes (Bare Earth (BE) and Full Feature (FF)), and data archives. ASPRS LAS format is used to store point clouds because:: 1) it is a binary file format with a file header so data access is relative fast; 2) it is capable of storing the raw x, y, z, and return values of a particular LIDAR data set and ancillary descriptive and numeric attributes. All points are stored in WGS84 Geographic coordinate system so it can be re-projected to various projections faster. Both BE and FF surfaces are modelled by Triangulated Irregular Network (TIN). A proprietary streaming TIN format was developed to store surface meshes in which vertices and triangles are intermixed, along with vertex finalization tags that indicates when all triangles referencing this vertex have already appeared in the stream. The streaming TIN format significantly reduces the memory footprint in product generation. This allows us to process multiple tiles in parallel to speed up product generation and make it possible to create on-the-fly product previews.

2.2 Data Processing

High density elevation data comes mainly from two sources: LiDAR and Automatic Terrain Extraction (ATE). The raw terrain data may be in different formats and projections. An extendable reader module was developed which accepts point clouds in various formats, performs re-projection, and pipes out point streams in WGS84 Geographic coordinate system.

The point stream is then clipped to preset tiles and sent to two destinations: TINManager that stores the tiled LAS files and creates data archives; TINGenerator that creates BE and FF surface meshes. Each tile is processed separately. HTC is utilized to process tiles in parallel at two levels: 1) Condor cluster is used to distribute tiles on large collections of distributed nodes; 2) multi-threading is used to process multiple tiles concurrently on each node. Various techniques are used to guarantee each tiled TIN is consistent with the global TIN.

In TINGenerator the point cloud is split into BE points and FF points based on point classification and return number. BE and FF TINs are created separately. BE points go through a Purifier module to remove high / low points automatically by analyzing the height of the points in relation to the surrounding area. A streaming 2D Delaunay triangulation is next performed which converts the purified point cloud into streaming TIN break lines, either hard (e.g. roads, streams, and shorelines indicating a significant break in slope) or soft (e.g. ridgelines on rolling hills separating watersheds). These break lines are then introduced to refine the TINs. Next, a full set of TIN pyramids will be created for both BE and FF TINs. Each TIN pyramid is

associated with a specified elevation error bound so we can pick the proper pyramid level to create products to match the required spatial resolution. Both BE and FF TIN meshes and their pyramids are stored as separate streaming TIN files. TINManager takes care of TIN archiving and storing the metadata into PostgreSQL database.

2.3 Product creation

Product creation is handled by the TINConvertor module which achieves large performance gains by partitioning output area into blocks, processing blocks concurrently using HTC, and then stitching blocks together for final products. Our terrain processing tools can generate different kinds of value added products in various formats and projections.

- Vector products
  - Point clouds
  - Contour lines
  - TIN meshes
  - Data voids
- Raster products
  - Elevation grids
  - Shaded relief image
  - Intensity image
- Auxiliary products
  - Accuracy analysis (against control points or existing elevation grids)
  - Point density reports
  - Metadata files

Our terrain processing tools can generate products in the formats (LAS, ASCII XYZ, ArcGrid, IMG, TIFF) that are easily ingested in other GIS applications. Most of these value added products are created directly from the point clouds or TINs, but some improvements have been made to generate better products. For example, contours created directly from TINs are often either noisy or jagged. Our contour generation tools was improved by running a Laplacian smoothing filter on the TIN before extraction and a contour cleaning algorithm after to generate contours that are much smoother and convey a consistent picture of the underlying topography. Our full feature elevation grid generator is able to accurately depict various features by analyzing point clouds, BE and FF TINs and different sources based on its feature type.

3. STANDARDS

There has been some work done in standardizing the classification level, accuracy, distribution, interchange format and other attributes of elevation data by different organizations (USGS 2007, NIMA 2000). Although these standards are useful as metadata or in quality control for DEMs generated by different organizations, they do not address the need for self describing datasets that are easy to consume by various software systems.

Most of the terrain data today is exchanged between systems using files in some kind of binary format or simple ASCII formats zipped for compression. The majority of online terrain data delivery is based on a workflow which can mostly be described as a clip, zip and ship. These systems allow the user to select an area of interest (AOI). The system then clips the datasets to the AOI, re-projects to the required CRS, reformats and compresses it for ease of download. The user is responsible for taking these compressed data sets and importing and reformatting it for each desktop application. This secondary step of preparing the elevation data for consumption in each desktop application is cumbersome and time consuming introducing another barrier for the usage of elevation data in multiple GIS applications. The lack of a simple to implement interoperable online data delivery specification for elevation data is a glaring shortcoming that is inhibiting the acceptance of terrain data in mainstream desktop applications. It has also resulted in applications being tied to vendor specific terrain data delivery systems. Imagery on the other hand can be used from multiple sources because of successful implementation of standards like Web Mapping Service.

Recently standards in the geospatial industry have come to maturity from the efforts of both the Open Geospatial Consortium (OGC) and the International Standards Organization (ISO). The use of common standards is the most efficient way to achieve interoperability of geospatial information (Beshah et al., 2008). Currently there is no defacto or accepted ISO/OGC standard specifically designed for online terrain data delivery. However, the following standards can be used to deliver terrain and related value added products to different applications. In this section we will discuss the pros and cons of using these standards for delivering the elevation data and its value added products.

3.1 OGC Web Map Service (WMS)

The Web Map Service is a specification that defines a simple interface for web based mapping applications to produce and consume a two-dimensional map of spatially referenced data dynamically from geographic information using standard image formats. The OGC WMS specification is the most successful OGC standard with more than 300 total and 52 officially compliant mixtures of open source and commercial implementations (OGC Implementation, 2010). WMS could be used to show portrayed data of not only imagery but also vector and terrain data. However, WMS is not well suited to 3D clients given that it does not provide enough control since the only manipulation a client can do through a standard request is to select the portrayal style to be applied to the rendering of the data.

3.2 OGC Web Coverage Service (WCS)

The Web Coverage Service (WCS) supports the exchange of raw geospatial data as "coverages" that are bound in space and time without the need to apply portrayal. Coverages can be a set of data points; a regular grid of points (or pixels); a set of segmented curves (e.g. road paths); a set of Thiessen polygons; or a TIN triangulated irregular network (OGC WCS, 2007). The WCS implementation specification defines the interfaces between web-based clients and servers for on-line access to multi-dimensional geospatial data in an interoperable way. There are not as many clients that consume WCS as are available for WMS and the few available are web clients used to allow users to select the area they are interested in and download data to be used in rich desktop applications (Beshah et al., 2008).

The main problem with using WCS to deliver terrain data is that there is no universally agreed upon way of describing the data that allows the client software to know that this is a three dimensional terrain data so it could render it as a base map and drape other data sources or layers on top of it. It is also not easy to do automated level of detail and field of view calculations in order to retrieve the right amount of data from the server.

3.3 OGC Web Terrain Service (WTS)

WTS is an OGC standard that produces 3D views of georeferenced data. It is a portrayal service similar to WMS that dynamically produces three dimensional visual representations of spatially referenced data from geographic information using standard image formats (GIF, PNG, JPEG, or other formats). This specification standardizes the way in which clients request 3D views and the way that servers describe their data holdings (OGC WTS, 2001). The specification for receiving a two-dimensional map has been a focus of OGC interoperability work for a long time and this specification tried to present an extension to the web mapping services effort by incorporating terrain elevation and three dimensional perspectives. According to the OGC implementation registration page there are currently 17 total and 0 officially compliant implementations for Web Terrain Server (OGC Implementation, 2010). However, a closer looks at the list provides a much more revealing story. Since there are only four products with different versions, that added up to the larger total count. Moreover, a survey of these products reveals that some of them have simply dropped support to the service since it is not even mentioned in their user manuals. There is also no clear indication if the client applications of these few vendors will work with the servers of another. Overall this standard seems to be abandoned with no active participation and being stuck in OGC Discussion Papers section since 2001 (OGC Standards, 2010).

4. SOLUTION

For several years Valtus has used the Internet to deliver orthophotos and satellite imagery to desktop clients. More recently the challenge has been to deliver our growing terrain data archive in an effective way for end users to consume. Valtus leverages its existing image processing and delivery infrastructure to provide value-added terrain products to customers. Service is provided from two distinct but complimentary systems a) direct streaming of geospatial data into desktop clients via established protocols and b) the Valtus online Spatial Data Store.

4.1 Direct Streaming: VIEWS

As part of Valtus' terrain production work flow, bare and full earth hill shade images are generated from the data and ingested into the Valtus data library in a similar manner as orthophotos. Once ingested the data can be served as layers to multiple desktop application clients such as ArcMap, MapInfo, uDig etc. and web clients via protocols such as WMS and ArcIMS. Figure 2 and 3 show some examples of these layers in a desktop application. The strengths of this delivery system are:

- Derived products are generated and stored centrally at Valtus thus saving GIS technicians the overhead of having to produce and distribute data
- New data or updates are automatically accessible by the customer as it becomes available, saving companies maintenance time and data processing lag time
- Data layers seamlessly support many EPSG and ESRI coordinate reference systems

Limitations are:
- User is restricted to the default rendering and therefore cannot change attributes like sun angle
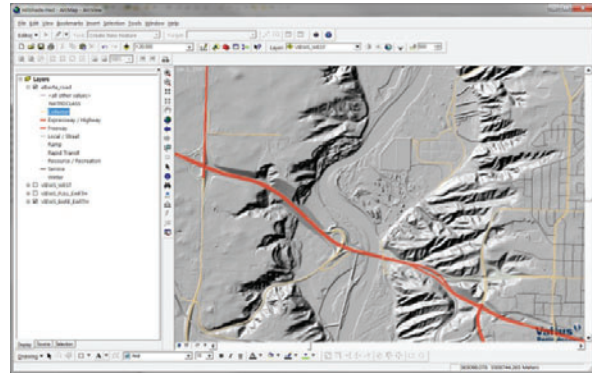
- Elevation data is lost

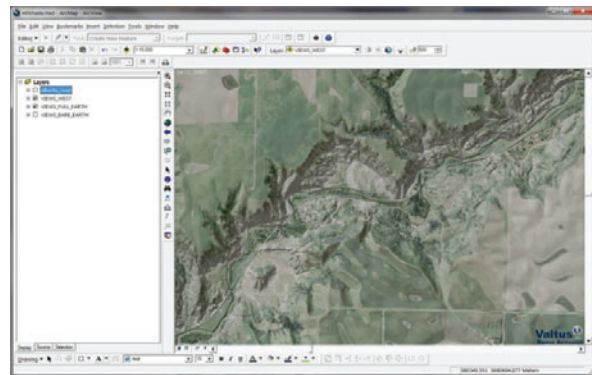Figure 2. Bare Earth Hillshade with Vector overlay

Figure 3. Full Earth Hillshade with Imagery overlay

4.2 Online Spatial Data Store

Valtus' Spatial Data Store is an online e-commerce website that allows users to order elevation data by selecting individual predefined tiles or by uploading an area of interest shapefile that is used to find and crop data. Several formats are available including ASCII XYZ, Surfer binary, ER Mapper binary and ESRI ArcGrid. The strengths of this delivery system are:

- Data is the actual terrain data therefore it has attributes that could be exploited by third party applications

Limitations are:
- Using the data is a multi-step process involving ordering, downloading and uploading to the application
- If data is updated or new data becomes available the user must order it again
- Distribution and awareness of the data in the organization is less effective

5. CONCLUSION AND OUTLOOK

As more of the terrain processing tools are developed and streamlined in our production environment they will become part of the Valtus delivery system. This will provide more output options including:

- More value added products such as contour maps
- More user output options such as projection, contour intervals and user defined sun angle as style descriptors
- Support for larger output files

We have shown that portrayal services like WMS and ArcXML are effective protocols for delivering value added raster based products such as shaded 3D relief and contour maps and that this meets the needs of some of our customers. However, these standards are insufficient and were not intended to support 3D data. If 3D geospatial data is to seamlessly integrate with non GIS users applications, the geospatial community needs to take the challenge and come up with a true 3D streaming specification that is easy to implement, remains consistent with 2D specifications and is supported by the community with reference implementations and vendor support. Current support for terrain models in both standards and GIS applications is lacking. Significant effort and collaboration between software and data vendors is required to give end users the same utility with 3-D data that they presently get from imagery.

6. REFERENCES

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