

OPEN STREAMING TERRAIN FOR MODELING AND SIMULATION

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ABSTRACT

In today's modeling and simulation market, there are many methods that can be used to create terrain databases for the various simulation applications. Some of these use more traditional terrain database generation processes, and some are new and innovative, utilizing the capabilities of cloud computing and geographic information systems. Each of these methods has advantages and disadvantages, and some are more suited for specific use cases than others. An emerging approach that VT MAK has developed is the ability to use open standards streaming terrain in real time virtual and constructive simulation.

In this paper, we discuss the concepts of streaming terrain for modeling and simulation, where applications can subscribe to web servers for geo-data in real time. We start with a discussion of the different types of terrain data and the advantages and disadvantages of each, covering the spectrum from traditional hand and tool modeled terrain databases, to direct from source geo-data, to streaming terrain from a server. We provide examples of each of these types of data, how it is created and used in simulation applications, and which use cases it is best suited to. We discuss the benefits of streaming terrain approaches to more traditional terrain database generation techniques, utilizing Open Geospatial Consortium (OGC) standards like web map service (WMS) and web feature service (WFS) for streaming elevation, imagery, and features. We discuss how the streaming terrain approach is different from other terrain approaches, like the Common Database (CDB).

The streaming terrain approach described in this paper offers a new flexibility to dealing with terrain data. Applications that can make use of streaming terrain provide a lot of flexibility when designing simulation exercises or events, where new sources of terrain data can be found and used directly as an alternative to the traditional terrain database generation approaches.

ABOUT THE AUTHORS

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INTRODUCTION

Open Streaming Terrain (OST) is a fairly new concept for modeling and simulation, and we believe has become a practical alternative to traditional terrain database generation techniques for certain applications. Open Streaming Terrain is where applications can subscribe to web servers using open standards based protocols, and receive geo-data in real time. This paper discusses different terrain database approaches and the advantages and disadvantages of each, covering the spectrum from traditional hand and tool modeled terrain databases; to direct from source geo-data; to Open Streaming Terrain from a server. Examples of each of these types of terrain data are provided, along with how each type is created and used in simulation applications, and which uses it is best suited to. We compare the cost and time savings of Open Streaming Terrain; utilizing Open Geospatial Consortium (OGC) standards like web map service (WMS) and web feature service (WFS) for streaming elevation, imagery, and features to more traditional terrain database generation techniques. We discuss how Open Streaming Terrain is different from other terrain server approaches, like the Common Database (CDB).

BACKGROUND

There are three fundamental stages for developing a terrain database for simulation that are used in all of these generation strategies. First, source geospatial data must be acquired for the project. Traditionally, this data has come from government organizations like the National Geospatial-Intelligence Agency (NGA) and the United States Geological Survey (USGS), which have been supplying geospatial data to the US simulation community for many years. As the utility of geospatial information has grown over the years, other markets that require similar types of data, are producing it. Much of this data is on line and readily accessible. It is our estimation that there are literally petabytes of geospatial data available on the internet for practically any part of the world, and more accurate data is being made available every

day. The second stage after acquiring the data is to refine it to match the requirements of the intended simulation exercise or event. There are many tools available for refining the source data, from geographic information systems (GIS) to terrain database generation systems. Much of this work requires terrain professionals to ensure the different data sets are correlated and of the right fidelity for the targeted simulation systems. Once the data is refined, the final and third stage is to construct the terrain databases for use in the simulation applications. The construction can be a two dimensional map - like terrains typically targeted for semi-automated forces (SAF) simulations or three dimensional worlds for visualization and advanced terrain reasoning in live, virtual, and constructive simulation applications.

Within those stages of terrain construction there are many different approaches that can be taken depending on the requirements of the simulations. These requirements will affect how the terrain database is constructed, both in terms of what source data is to be used and how it needs to be processed. Often, terrain correlation, where different simulation applications need to work together in the same area of the world, is a major requirement. In this case producing a consistent view of the world that satisfies the requirements and limitations of the different simulation applications may impose limits on the detail and/or density of the data. Lower fidelity source data may be selected so that different applications can inter-operate with each other. This may be done even if some of the targeted simulations can operate using higher fidelity data. Another requirement may be scale, where geographically large areas are necessary. In this case, some high fidelity data may be discarded to ensure that the terrain contains only the levels of detail that can be stored and processed by the simulation or image generation system being employed. Performance is often a requirement in itself. The terrain database must satisfy the run time and load time requirements of the simulation applications. Another requirement that can affect terrain database design is the desire to rapidly incorporate new data into a database. If the terrain covers an area of the world that is changing,

such as an area of rapid development, the desire to acquire new data quickly and enhance the terrain may influence the database generation process. Finally, cost may be a factor. To control the cost of the terrain database, one may want to leverage low cost, mass market sources and tools as much as possible.

The strategies for creating terrain databases for simulation include hand modeling of the terrain, where tools such as Autodesk's 3DS Max or Presagis' Creator are used to build 3D models of the terrain and its contents (Figure 1). These hand modeled terrains can be very high quality and very realistic, but very expensive to produce. Quality and detail are limited only by the artist's ability and production time available. These can be the most visually rich terrains, but require highly skilled artists to generate and are very time consuming to build. This approach allows fine control of the terrain content and the resulting run time performance. Hand modeled terrain databases are best suited for applications such as close combat operations, urban simulations, first person shooter applications, and architectural walk-throughs.



Figure 1: Hand Modeled Terrain

The next approach is to use database generation tools to automate some of the process (Figure 2). These tools use parametric algorithms to produce large areas of dense detail. Although significantly faster than hand modeling, this type of terrain can take weeks or months to produce, and changes often require rebuilding large portions of the terrain and many more hours or days of computer processing time. Examples of these tools are TerraSim's TerraTools, TrianGraphics' Trian3D Builder, and Presagis' TerraVista. These tools can ingest source data and apply processing rules to automate much of the refining process, with functions such as

generating cuts and fills for roads, extruding building models from building footprints, and even populating the building interiors with floor plans typical for specific building types. These tools also provide powerful functions to control the mapping from vector data to textured geometry for visualization, such as automatically applying road lines and crosswalks at intersections. Once the data is processed, the terrain data can be output in a variety of correlated simulation runtime formats, for both visualization and simulation. Optimizations for performance can also be integrated into the tool chain.

One of the disadvantages of these tools are that they are off line processes, so that it takes time to check the tools' output, make changes to the source data and rerun the tools to regenerate the terrain. The quality and detail of the terrain databases are defined by the terrain tool's capabilities and the choices made by expert users. Finally, large area terrain databases generated this way are static and require a large amount of disk space. This strategy is best suited for air crew flight training, large scale ground simulations, and large area operations.



Figure 2: Terrain from Terrain Database Generation Tool

The next terrain database approach to consider is sometimes called "Direct from Source", where geospatial source data is loaded directly into the simulation applications (Figure 3). Source data may include NGA products such as DTED and VMAP vector feature products, JPEG or GeoTiff raster data (images, elevation, raster maps), and GIS transmittal data, like Shapefiles. This can be a very rapid process and can allow simulation to be performed on new

areas very quickly. Loading terrains directly from source data can be very dynamic as new or updated source data can be loaded to augment existing source data that is already in use. This is very scalable for large areas and less expensive than previously discussed methods as no off-line processing or tools are required. Direct from source terrain databases can save thousands of dollars and tens to hundreds of man hours over the other methods. Applications that load source data directly can have performance issues though, as this data is not optimized for runtime applications. If the quality of the source data is poor the runtime performance may be poor also. Each application may internally process the source data differently, leading to correlation issues. This makes loading direct form source terrain data best suited for simulations that cover very large operational areas, such as theater level simulations, and where the benefits of rapid terrain creation outweigh the correlation issues.



Figure 3: Direct From Source Terrain

A special case of loading direct from source data is the use of GIS data directly in simulation applications. This has been done in the US Army's GIS-Enabled Modeling and Simulation (GEMS) [1] project, where ESRI's geodatabase is accessed directly by the models and behaviors in constructive simulation applications. This allows those simulations to use the same operational data as the command and control (C2) community use, providing correlation between the simulation and C2 domains. GEMS allows the enterprise GIS capabilities to be used to propagate dynamic data changes to the simulations during run time. Systems that use this architecture can also take advantage of the geospatial modeling capabilities of the GIS system to

offload terrain reasoning functions to the GIS. The GIS can perform terrain analysis, run cover and concealment models, and perform route planning and return these results to the simulation.

The remainder of this paper discusses the use of streaming geospatial data from servers to provide the terrain data for simulation and visualization applications. (Figure 4) This strategy can use GIS Servers or web-mapping services to provide a world of data at various quality levels. These servers can be on local networks or on the Internet. Examples include Microsoft Virtual Earth, ESRI's ArcGIS Online and ArcGIS Server/Data Appliance, OpenStreetMap, and many others. These servers can support open standard protocols, such as the Web Map Service (WMS) from the Open Geospatial Consortium. This strategy provides access to a vast amount of data that is growing every day, and which can be offloaded and warehoused locally where needed. Much of this data is free or very low cost, making this approach very economical. For instance, Landsat 7 imagery and Shuttle Radar Topography Mission (SRTM) elevation data coverage for the US are both available for free from USGS, without restrictions for commercial use. This data does suffer from some of the same limitations as the direct from source approach, however, including potential performance and quality issues. Because of the lower amount of detail in the terrain, Open Streaming Terrain is best suited for applications that are not close to the ground or require very large area coverage, such as global missions, moving map displays, air combat, large scale constructive simulations, theater level simulations, and applications that require fast turnaround prototyping without a high amount of detail.

Some of the other less than mainstream approaches to M&S terrain include the use of procedural geometry, where terrain geometry is generated "on demand" from high-level information like GIS feature data. Specialized products exist for generating micro terrain detail based on land use data, such as Blueberry3D from Bionatics. This technique provides geotypical detail to augment lower fidelity geospecific imagery and elevation data. In a SAF, procedural terrain can generate geometry only where it is needed, such as along a line of sight. Another dynamic terrain generation approach is the use of programmable shader technology, where much detail is generated in the visualization hardware, based on algorithm specific data in the terrain format.



Figure 4: Open Streaming Terrain

OPEN STREAMING TERRAIN

VT M&S performed an engineering study to determine the optimum approach to utilize the advantages of Open Streaming Terrain over more traditional terrain database generation techniques, while minimizing the disadvantages of this approach as much as possible. The biggest advantage we saw was the cost and time savings that Open Streaming Terrain could provide, especially utilizing Open Geospatial Consortium (OGC) standards like web map service (WMS) and web feature service (WFS) for streaming elevation, imagery, and features. By utilizing open standards, we could potentially access petabytes of geospatial data that is accessible on the Internet for practically any part of the world, with more accurate data being made available every day. And because these services are standards, much of the software to implement and use these standards is open source, which allows us to leverage the work of the geospatial community for future enhancements and improvements.

We first looked at the web map service (WMS) [2] standard for both its suitability to streaming terrain for M&S and the availability of geospatial data in WMS format. WMS provides an HTTP interface to raster data, but it is really geared toward the mapping community. WMS provides raster images as output, which can be displayed in a mapping application without further processing. A disadvantage, though, is that for every pan or zoom action, a new request to the map server has to be made. Queries can be made using bounding boxes of arbitrary size, and the returned image will always be rendered to the size and resolution specified in the query. This rendering process, though, makes WMS slower than other map services, making it less suitable for most realtime

M&S applications. The client can request the output type, and therefore the compression algorithm to be used. These include PNG, which is a lossless compression format, JPEG, which is lossy, and GeoTIFF, which is lossless.

The OSGeo WMS-C, or Web Map Service – Cached [3], standard addresses this issue by constraining the queries to cached or pre-generated fixed raster tiles that require no rendering before delivery. This standard implies fixed scale and zoom levels, but allows the client to use the data without further processing. The geospatial data is cached in a directory that contains map images of a specific format, extent and scale. Returning an image from the cache requires no rendering, so it takes the server much less time to deliver the images than the WMS service. Because maps are pre-rendered, the cartography can be tailored to the scale of the map, making it cleaner and more detailed than dynamically drawn maps, although the flexibility is less if multiple layers of data are combined in the cached images. This is less of an issue with M&S applications, since they tend to combine layers to improve query times, such as creating a single soil layer from multiple land use layers. WMS-C supports the same formats as WMS, but is less flexible in that the format returned must be the same as the format in which the data is stored on the server. This loss of flexibility is more than overcome by the increase in server access speed.

The Tile Map Service (TMS) standard [4], also from OSGeo, can eliminate the query entirely by providing a fixed tiling scheme for the Earth at fixed scales, so that geospatial data can be organized so that it is accessed directly using the indexing information of the tiling scheme. Access to these tiles is provided via a Representational State Transfer (REST) interface, starting with a root resource describing available layers, then map resources with a set of scales, then scales holding sets of tiles.

These map standards can provide a variety of geospatial data in various raster formats, which opens up a wide array of geospatial data sources. While they were originally developed for raster map data, they are commonly used for other raster data, such as elevation maps and imagery. They support standard formats such as PNG, JPEG, PPM, TIFF, and GeoTIFF. By accessing both elevation and orthorectified imagery data, terrain databases can be created by draping the imagery onto the elevation data.

There is a similar open standard for feature data, the OGC Web Feature Service (WFS), which utilizes the XML-based Geography Markup Language (GML)

for serving feature data. While feature data is important to many simulation applications, we have found that is not yet practical to access it from a server for M&S applications because of the time it takes to convert a large number of features from XML. In the meantime, there is support for streaming feature data using other widely used feature formats. For example, we can stream ESRI Shapefiles to our visualization application. The Shapefiles are used to locate features that are displayed in 3D, such as fences, roads and building models. Building footprints can also be extruded into textured 3D geometry, and tree locations can be mapped to shader-based SpeedTree models.

There are many sources of geospatial data that can be accessed using these open standards. These include traditional GIS sites, like ESRI On-Line, federal, state and local government sites, commercial satellite imagery providers (Harris, DigitalGlobe, etc.), and many others. As an example the VR-TheWorld Online server contains over 4 terabytes of data, including 90-meter elevation data with bathymetry, and 15-meter color-corrected and pre-tiled imagery, for the entire globe. This data can be used by different simulation applications, and can be accessed either from a local server or through an online site, allowing very rapid simulation anywhere in the world. There are hundreds of public OGC compliant WMS servers that can be used as potential open streaming terrain servers. For example [5] lists 994 public WMS servers.

COMPARISON TO OTHER APPROACHES

Open Streaming Terrain is different from other terrain server approaches because it is based on open standards that are in widespread use in the geospatial community. Source data that is available from anywhere on the Internet that supports the OGC and OSGeo standards can be used in this approach. This is not true of other standard terrain database approaches. For instance, Goggle Earth does not provide all of the data needed for M&S applications. While Goggle Earth has imagery that covers the world, it does not provide elevation to go along with it. Their licensing agreement does not allow the use of their imagery outside of Google based web applications. Microsoft Earth does provide elevation along with the imagery, but has restrictive licensing requirements.

The Common Database Specification [6], created by SOCOM and managed by CAE and Presagis, focuses on defining a terrain format that meets the needs of Mission Rehearsal and Training applications. The CDB approach, through a very detailed specification, constrains the use of several defacto-standard

formats. The result is a very predictable structure that applications developers can write “runtime publishers” to consume and use the data. Like all well-conceived database designs, this approach has some very practical advantages.

CDB is one of many format based approaches that address a segment of the general terrain problem. Some of the other approaches to standardizing terrain formats for M&S include SEDRIS (DMSO/MSCO), NPSI (US Navy), TPSG (US Air Force), and SE CORE MDB (US Army PEO STRI).

Open Streaming Terrain, on the other hand, doesn't focus on the database format per se, but rather focuses on open standards based internet protocols widely in use by a growing commercial industry to distribute terrain data over the Internet, with hundreds of potential open source terrain servers available.

Whoever made the famous quote “the beautiful thing about standards, is that there are some many of them” was, we think, trying to dispel the notion that the next terrain database standard would solve all the simulation problems. As it turns out, each new standard, if successful, adds complexity to the general modeling and simulation problem.

CONCLUSIONS

As described in this paper, Open Streaming Terrain is just one of many different approaches that can be used to provide geospatial data to simulation applications. Open Streaming Terrain is however a very powerful solution when a terrain is needed quickly for any place around the world. As in all engineering decisions, the tradeoffs of the different approaches must be taken into account when choosing which method to use for a specific exercise or event. Visual quality, the degree of correlation, and the need for specific geographic features are all factors that must be considered. While other methods may provide higher quality, direct from source and streaming web mapping data are both catching up to the more expensive traditional terrain database generation approaches. Technology is advancing rapidly to allow much of the functions that are done in a terrain database generation system to now be done in real time, leading to improved terrain quality and performance, and eliminating the need for optimized runtime formats that cover only a small part of the Earth. As the M&S community moves away from simulation specific standards, we can take advantage of the investments being made in the broader geospatial marketplace.

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