Cloud Terrain Generation and Visualization Using Open Geospatial Standards

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ABSTRACT

The Joint Training Data Services (JTDS) is a web-based set of services that provide Modeling and Simulation (M&S) ready data and scenario development tools to the DoD Enterprise to support Joint and Service theater level constructive & virtual training. JTDS provides persistent web access to an Order of Battle Service and a Terrain Generation Service (TGS) that leverage unique data repositories and tools to generate training scenario initialization files. Historically, the terrain generation service proved difficult to maintain and extend given its closed architecture, stove pipe terrain generation capabilities and stagnant source data collection. Given the lessons learned from the legacy terrain generation service, a technology update and refresh was undertaken to create an updated terrain generation service that supports open source formats, accessibility through an easy to use web interface, and dynamic terrain during runtime. The new terrain generation service heavily utilizes open simulation data standards and geospatial web mapping interfaces to share and distribute simulation products and geospatial data. The open source Common Database (CDB) structure is used as the underlying source data format based on its ability to promote sharing, reuse and utility by storing geospatial and simulation data sets in non-proprietary formats structured to facilitate rapid access, rendering and visualization. Open Geospatial Consortium (OGC) web standards are used to maximize connectivity to the CDB by enabling most geospatial tools to natively visualize and navigate the Terrain Repository. This paper will share the lessons learned and architectural updates of the new terrain generation service.

ABOUT THE AUTHORS

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INTRODUCTION

The Joint Training Data Services (JTDS) is a web-based set of services that provide Modeling and Simulation (M&S) ready data and scenario development tools to the DoD Enterprise to support Joint and Service theater level constructive training. JTDS provides persistent web access to an Order of Battle Service and a Terrain Generation Service (TGS) that leverage unique data repositories and tools to generate training scenario initialization files. In the last twelve months 480+ users of JTDS have logged on over 20,000 times and generated and downloaded thousands of files to include order of battle and terrain files to support Joint & Service training events. Historically, the terrain generation service proved difficult to maintain and extend given its closed architecture, stovepipe terrain generation capabilities and stagnant source data collection. Given the lessons learned from the legacy terrain generation service, a technology update and refresh was undertaken to create an updated terrain generation service that supports open source formats, accessibility through an easy to use web interface, and dynamic terrain during runtime. The new terrain generation service heavily utilizes open simulation data standards and geospatial web mapping interfaces to share and distribute simulation products and geospatial data. The Common Database (CDB) is used as the underlying source data format based on its ability to promote sharing, reuse and utility by storing geospatial and simulation data sets in non-proprietary formats structured in fashion to facilitate rapid access, rendering and visualization. Open Geospatial Consortium (OGC) web standards are used to maximize connectivity to the CDB by enabling most geospatial tools to natively visualize and navigate the JTDS Terrain Repository.

BACKGROUND

The mission of the Joint Staff J7 is to support the Chairman of the Joints Chiefs of Staff (CJCS) and the Joint Warfighter though joint force development in order to advance the operational effectiveness of the current and future joint force. The Deputy Director, Joint Training (DDJT) mission statement is: “Develops and delivers a continuum of individual, staff, and collective joint training in order to enhance the operational effectiveness of the current and future joint force.” Joint Training requires terrain database creation and enhancement to meet training objectives. The Terrain Services Team enables trained, ready, and adaptable Joint Forces by providing realistic terrain to support M&S for training events.

The Joint Training Terrain Services Team supports Joint Exercises and Service training by building M&S ready terrain, and currently must support 13 simulation specific data formats. Resources are limited and demand for terrain databases are high, so the JTDS Terrain Generation Service (TGS) provides “off the shelf” M&S ready terrain databases for Service Joint Conflict and Tactical Simulation (JCATS) and Joint Theater Level Simulation (JTLS) users. The current Terrain Generation Service, which will be referred to as the Legacy Terrain Generation Service (L-TGS), was used 306 times in 2013 to generate terrain databases for DoD enterprise users.

The Joint Training Data Services (JTDS) is a set of web-based exercise scenario initialization tools developed to support the needs of the DoD Modeling & Simulation Training Community. JTDS is composed of two services; the JTDS Legacy Terrain Generation Services (L-TGS) and the Order of Battle Services (OBS). These tools rapidly build scenario terrain and force structure initialization files, thereby saving money and time by accelerating exercise preparation. JTDS increases the quality of data used to support events by providing consistent M&S-ready data sets derived from the best available source data. JTDS provides an online web service, available 24/7 via the Government NIPR and SIPR computer networks. Mining of the content for L-TGS is from authoritative sources (e.g. National Geospatial Agency (NGA), Army Geospatial Center (AGC), etc.), and the content is made M&S-ready via various manual enhancements and correlation actions.

Legacy Terrain Generation Service (L-TGS)

Robinson et al (2002) describe the conceptual approach for the Legacy Terrain Generation system. Robinson et al. also describes the need for a rapid web enabled database development system while recognizing the challenges of creating such a system with a lack of clear, comprehensive data standards, enterprise software approaches and properly conflated source data.

L-TGS required a technology refresh for various reasons. The L-TGS repository design does not support 3D models, raster material definitions or high-resolution color satellite imagery (support is limited to Controlled Image Base (CIB)). The design of L-TGS limits support for many open, standard GIS formats as well as NGA-specific data formats. The L-TGS was not designed to incorporate the data enhancements and highly detailed models required to support Joint Training events & Service customers. The L-TGS does not support data sharing, discovery and dynamic terrain requirements for the Joint Live Virtual Constructive (JLVC) 2020 program being developed for the Joint Staff. The current system was built to support specific use cases. L-TGS export format supports earlier versions of JTLS & JCATS only. It does not support other JLVC simulations or planned JLVC 2020 services.

Current Joint Staff development efforts are focused on the Joint Live Virtual and Constructive (JLVC) 2020 to address several issues identified by the Joint Staff and the M&S industry as a whole. The JLVC 2020 is the new M&S training enabler of the Joint Staff replacing JLVC & other Joint M&S systems. JLVC 2020 is a multi-year development effort with an interim capability in FY16. It provides Cloud-Enabled Modular Services (CEMS) designed to scale as M&S needs grow, exploit cloud based technology and operate as a modular service forming a composable simulation environment.

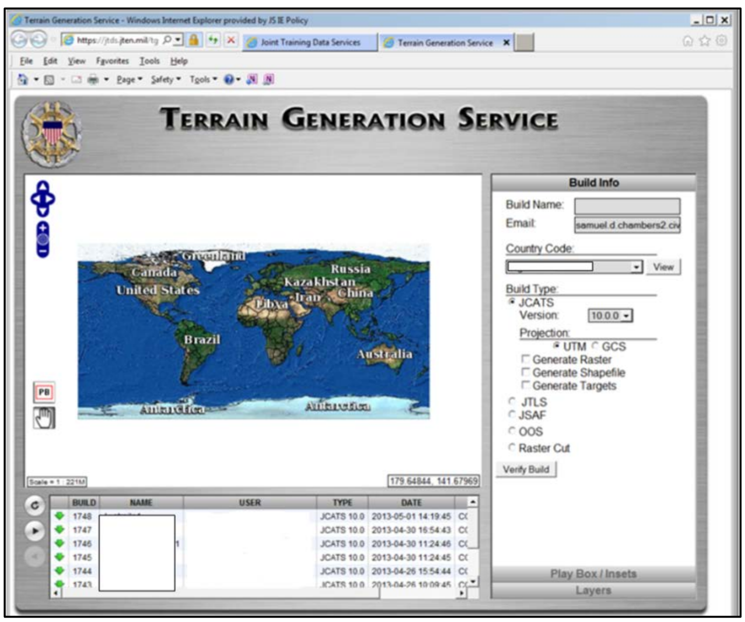

Figure 1: Legacy Terrain Generation Service Website

L-TGS was designed and implemented in 2008 as a web portal and simple database generation system (DBGS) that allows end users to request terrain database products to be produced on demand based on geospatial data loaded into the system. Figure 1 illustrates the web interface of the L-TGS. Users navigate the geospatial source data contained within the system with limited ability to visualize the actual content. Users only see a bounding box denoting the geographic extents of the underlying datasets contained within the system. As the user navigates the system to the area of interest, the user defines a bounding box and insets of the desired terrain products. The L-TGS generates the requested terrain products on-demand and notifies the user when the product is available for download. The user can request JCATS and JTLS terrain builds from the selected geospatial source data by the underlying DBGS.

The L-TGS strengths are the ability to provide M&S ready simulation databases from a web portal, the ability for the user to define the parameters of the terrain databases (playbox, data required, projection and simulation format), and cost savings by building an M&S repository once and providing it to the DoD Enterprise for reuse.

While the L-TGS system contained numerous strengths and performed admirably over the last 7 years of use, the system has several flaws as well. The L-TGS is difficult to maintain due to a disjointed architecture and lack of an intermediary data model. The underlying DBGS is a series of widgets composed of utilities, scripts and translators that compile terrain databases in an assembly line fashion. If one of these components failed, the terrain build failed with no indication of the cause of the failure. Extending the L-TGS to support new terrain formats or updates is difficult as the underlying widgets are not available as a library or Application Plugin Interface (API) within the architecture. Each terrain format's creation process is a stove-pipe solution that is unique and closed. The application can be difficult to use because the nature of the source data was not apparent and it was unclear to the user which source features were being selected. The L-TGS was plagued with stagnant source data. The system stored source data in numerous Geographic Information System (GIS) formats such as Vector Product Format (VPF), Controlled Image Base (CIB), and Digital Terrain Elevation Data (DTED). Unfortunately, the source data used by the system was "hardcoded" within the various widgets that composed the DBGS making it extremely difficult to add new source data to the system. Furthermore, given the multitude of GIS formats composing the underlying source data, many unique data translators were required to construct an ad hoc, undocumented data model that was supplied to the terrain generation capability.

The legacy TGS provides numerous lessons that were applied in the design and implementation of the new TGS. The new TGS is designed to allow source data updates in a simple manner, maximum connectivity to the source data repository, a user interface that allows the user to visualize their actual source data, a defined source data model and extensible/maintainable DBGS.

COMMON TERRAIN GENERATION SERVICE (C-TGS)

The Common Terrain Generation Service (C-TGS) will provide increased capability over the legacy TGS. The C-TGS vision addresses the historical weaknesses of the legacy TGS by leveraging OGC geospatial standards, enabling incremental data updates, improving user connectivity and data available, and designing the architecture as a Services Orientated Architecture (SOA).

The Common Terrain Generation Service (C-TGS) development began in 2013 and saw initial deployment in the fall of 2014. C-TGS operates as a service available within the Joint Staff J7's Joint Training Data Services JTDS on the NIPR network (NIPRNet). Within the C-TGS architecture, several services operate in the NIPRNet subnet as series of connected servers composing a "cloud" capability. The C-TGS collectively represents a Services Orientated Architecture (SOA) with four (4) major components: Visualization and Dissemination Service, Geospatial Discovery Service, Common Database, and Content Creation Service.

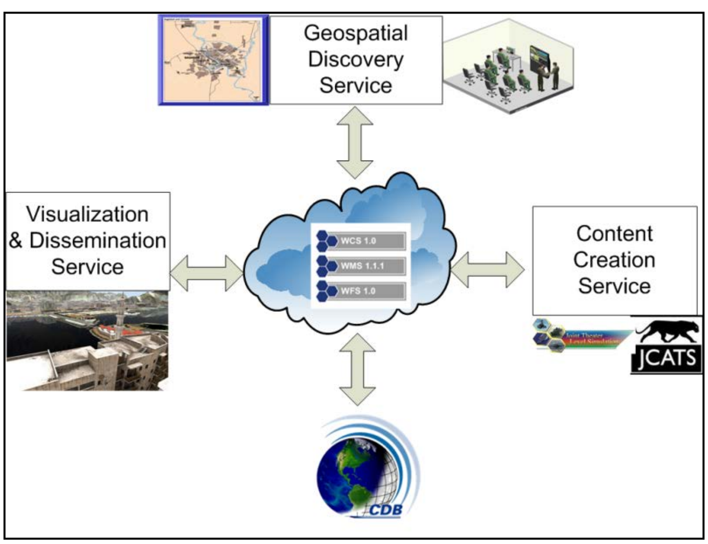

Figure 2: C-TGS Top Level Architecture

The C-TGS SOA utilizes OGC web standards for interfaces and events between services. C-TGS services discover communicate, process, and distribute geospatial data using Web Mapping Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS) and Web Processing Service (WPS). Disseminating, discovering, and visualizing raster content, such as high-resolution color satellite imagery, utilizes WMS. Disseminating, discovering, and visualizing vector content, such as road centerlines as part of the transportation network, utilizes WFS. WCS provides a mechanism to denote simple metadata regarding the underlying terrain holdings. WPS is the mechanism to task other services to perform actions, such as the Content Creation Service.

The Visualization and Dissemination Service (VDS) is the web interface where users of C-TGS interact with other services available within the architecture. The design principle surrounding the VDS is to assure that the end user of the C-TGS requires no specialized terrain database building knowledge or experience. The VDS is a simple user interface where operators visualize all of the underlying terrain holdings by simple zoom and pan commands within the interface. A key philosophy of the VDS is "What You See is What You Get" (WYSIWYG). WYSIWYG systems display content in a form as close as possible to how the final product will look. In the case of the VDS, the resolution of imagery, vectors, elevation, materials, and 3D models displayed are rendered from the same source data used to build the requested terrain database product. As a user zooms or pans within the website, the VDS automatically determines the appropriate level of detail and types of feature content to visualize and display to the user. The user manually types in geo-coordinates, or pans and zooms to locate and establish their desired area of interest (AOI). Once the user establishes an AOI, the user determines what terrain product they need to have generated. To minimize development and maximize OGC technologies, OpenLayers serves as the base map-rendering engine to display geospatial content with the VDS. Figure 3 illustrates the VDS user interface.

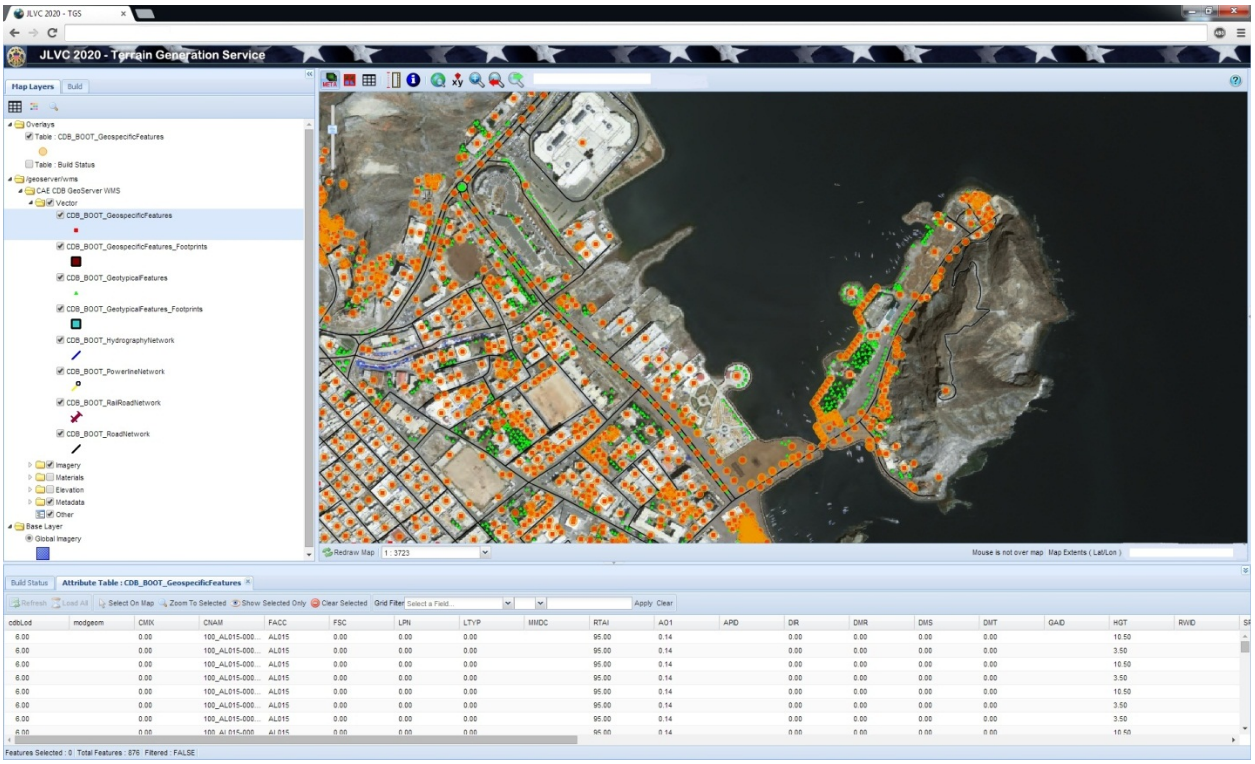

Figure 3: VDS User Interface

The Geospatial Discovery Service (GDS) is responsible for serving geospatial content to the VDS, Content Creation Service (CCS) and other OGC compliant clients from the underlying terrain repository. GDS receives service requests for geospatial content and discovery from the VDS, CCS or other OGC compliant clients. Each service request for GDS yields an action to locate the appropriate geospatial content and deliver it to the requesting client. In the simplest sense, a client asks GDS for a type of data (e.g. road network) in a given geographic extent (e.g. 32 North, West 87 to 33 North, West 86), which is located and transmitted to the client using the appropriate OGC web standard (i.e. WMS, WFC, WCS). GeoServer is the foundation technology composing GDS. An extension to GeoServer leveraging the CDB API serves as the mechanism to read/write CDB content within the application.

GDS in many ways acts as a "universal adapter" to the underlying geospatial repository. Within the GEOINT (GEOspatial INTelligence) community and closely-related GIS (Geographic Information System) tool market, OGC Web Standards are widely adopted. Most, if not all, relevant GIS tools support OGC Web Standards. A brief list of GIS tools that support OGC Web Standards includes, but certainly are not limited to, ESRI® ArcMap, Google Earth®, Quantum GIS®, Intergraph GeoMedia®, and Geospatial Data Abstraction Library (GDAL).

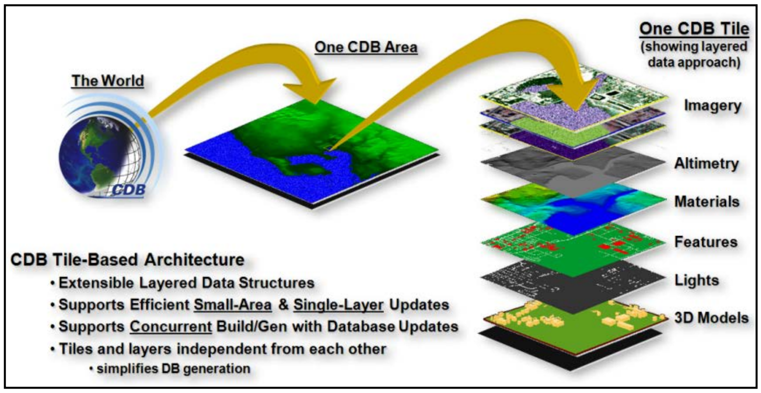

Figure 4: CDB Structure

The underlying geospatial repository of C-TGS is the Common DataBase (CDB). Figure 4 depicts the conceptual structure of CDB. CDB is a non-proprietary terrain database format developed for USSOCOM as an IG-agnostic terrain database format capable of incremental updates and runtime publishing. The rationale of selecting CDB as the underlying terrain database format include USSOCOM's massive existing CDB holdings, the ability to support a world-wide database, improved correlation due to a singular terrain representation, ability to create on-the-fly database updates in a rapid manner, vendor agnostic terrain representation, and ability to support legacy terrain systems by offline publishing. Leveraging USSOCOM's CDB holdings gives the C-TGS immediate capabilities to produce medium resolution JCATS and JTLS databases for most, if not all, significant areas of the world.

Connecting OGC Web Services to an open, simulation-optimized terrain database repository, such as CDB, results in high-end performance for serving and rendering geospatial content, the ability to dynamically modify terrain and support for all levels of simulation. Wiesner et al. (2011) describe the various methods of building a simulation to include manual (hand modeled), parametric (DBGS tools), "direct from source," and Open Streaming Terrain (OST) creation methodologies. Wiesner et al. accurately describe the requirements to achieve high-end performance using OGC Web Standards. Pre-tiled and rendered source data is a critical component to achieve high-end performance when using OGC Web Standards. While OGC Web Standards do contain approaches for pre-tiling and rendering the underlying source data, the approaches are limited with respect to revision control (i.e. changes to the underlying dataset) and format translation. Given that the GDS serves a single CDB representation, any client connected to the GDS can update the CDB and have their updates instantaneously broadcasted by the GDS. In more simple language, a high-end simulation system using CDB can dynamically update the terrain (such as a bomb crater) and have that dynamically updated terrain instantly served by the Geospatial Discovery Service to any OGC compliant system, such as ESRI® ArcMap or a mobile web page. The underlying architecture and framework of the C-TGS provide a mechanism to move high-end simulation to the point where data sharing, crowd-sourcing, and dynamic terrain are in-sync with GIS tools and simulation system edits of the terrain repository.

The connection of high-end simulation systems to OGC compliant software systems is a powerful advancement that offers many exciting opportunities. The connection of simulation systems to desktop or even mobile enabled OGC compliant software system produces the ability for soldiers in the field to dynamically update their training systems with enhancements and updates that more accurately and precisely depict their operational training needs and observations.

The Content Creation Service (CCS) is responsible for off-line compilation of terrain database formats from content supplied by the GDS. The CCS leverages Presagis Terra Vista 13 as a commercial off-the-shelf (COTS) technology to build various terrain formats. In the case of C-TGS, Terra Vista provides a capability to produce Joint Conflict and Tactical Simulation (JCATS), Joint Theatre Level Simulation (JTLS) and CDB. Other formats are under consideration for future integration. The creation of a Web Processing Service (WPS) task occurs when the end user selects an area of interest from the VDS. The CCS listens for WPS tasks within the SOA and reacts to any tasks found. When the CCS completes the terrain database build based on the WPS task, the VDS prompts the user to download their terrain database.

Development of the C-TGS provides several lessons learned. Utilizing open standards, such as OGC web standards and CDB, greatly reduced the development time required to create a high-end, robust visualization and distribution system of geospatial content on the cloud. Many open source software solutions natively support open standards and such solutions were leveraged to achieve an initial operating capability in much shorter time than if the base technologies had been developed organically.

SUMMARY

Current terrain processes to support Joint and Service training requires supporting thirteen (13) simulation specific formats with limited resources and ever-increasing demands by the warfighter. To help meet this challenge, terrain development processes must shift from the current paradigm where every simulation uses a different format, source data is duplicated and fraught with miscorrelation, and producing simulation formats is labor-intensive process. The recently developed JTDS Common Terrain Generation Service creates a cloud-based service that is an “always on” and “always available” service to support the warfighter. The Common Terrain Generation Service is an extensible service-orientated architecture providing an enterprise-level capability to search, discover, and retrieve M&S terrain data through a simple-to-use web portal. The Common Terrain Generation Service standardized data structure based on industry standard Open Geospatial Consortium (OGC) approved formats served by OGC Web Services normalize terrain data across the Force Development simulations. The Common Terrain Generation Service establishes an architecture and data repository to meet the requirements of harmonized terrain that enables distributed, dynamic synthetic environments between multiple simulation systems.

DISCLAIMER

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