Aerial Imagery Unraveled

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ABSTRACT

Using satellite and airborne aerial imagery in simulation systems entails labor intensive imagery preparation. Making aerial imagery suitable for use as draped imagery in a terrain database often requires orthorectification, pan sharpening, color balancing, mosaicking, tiling, cloud removal, and shadow reduction or elimination. Ensuring correlation between the aerial imagery and vector feature data requires significant manual labor, including adding and aligning features to match the imagery, recoloring imagery pixels when a feature is not wanted, and resolving the disparities resulting from source collection differences. Moreover, if any type of material-based simulation model is required, material classification is requisite, which can be tedious even with the best automated tools. Most aircraft simulation system database builders view this labor intensive imagery preparation as unaffordable and unnecessary. But, ground-based simulation system database builders cannot dismiss these preparation steps. Aerial imagery artifacts are not easily overlooked when, in the visual system, the trainee sees “driving on tops of cars on the road”, or “walking on the tops of the trees on the ground”. When higher resolution imagery is used, the negative artifacts are more distracting. The Synthetic Environment (SE) Core program has developed a unique set of imagery processing tools and techniques to address these imagery artifacts and processing deficiencies. This paper unravels the complexities of using aerial imagery in ground-based virtual and gaming simulation systems and explores the affordability of using synthetically generated imagery alternatives and automated material classified techniques. These tools and techniques, when applied, result in highly correlated, artifact-free Controlled Image Base (CIB) imagery, full color aerial imagery, ground surface imagery, ground surface material masks, and material classified sensor maps. This paper describes how these techniques are applied, highlights the results of the improved simulation scene quality, and details the exceptional fidelity achievable in the material representations.

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INTRODUCTION

Modern advances in orbital space flight and reconnaissance sensor technologies has led to the increased availability of commercial and Government satellite aerial imagery sources, such as Google Earth™, DigitalGlobe™, GeoEye™, and the Unites States Geological Survey (USGS). This widespread availability of high-resolution raster data provides a direct benefit to modeling and simulation (M&S) developers, especially in the development of terrain databases. The widespread availability of these sources, means that developers have options (alternative coverages, multispectral, times-of-year, resolutions, etc.) when choosing to use satellite aerial imagery for geospatial information extraction via Geographic Information Systems (GIS) or for direct implementation as a ground texture within a simulation environment or image generator (IG).

While these high-resolution sources provide many benefits to the M&S community, high licensing fees, DoD security classifications, and unwanted imaging artifacts can provide barriers to their widespread utilization. Commercial high-resolution satellite imagery can prove costly to small programs or organizations looking to implement the latest and greatest imagery coverage, especially in large quantities for today's large scale terrain databases. The U.S. Government provides an alternative by offering freely available or highly discounted unclassified imagery products; however, these products are often dated due to the bottleneck of the imagery preparations and declassification process. Additionally, once sufficient satellite imagery is obtained, it can be fraught with imaging artifacts such as cloud-cover, seasonal representations, and cultural features like vehicles, crowds and shadows, which are undesirable in the simulation. These artifacts prohibit true homogeneous imagery coverage and can result in additional costly clean-up through image processing tools and services.

In response to these impediments, the U.S. Army Synthetic Environment Core (SE Core) program has developed a multi-solution approach to preparing aerial imagery for use in terrain database production. This paper provides a summary of the SE Core aerial imagery production requirements, reviews the challenges in preparing aerial imagery for use in simulation databases, describes an approach to unravel the complexities of using aerial imagery in modeling and simulation applications, provides lessons learned, and ends with a discussion on the path forward.

IMAGERY REQUIREMENTS

In Modeling and Simulation (M&S), aerial imagery is used in two very distinct ways: 1) as a visual reference for vector editing in the feature population process, and 2) as aerial imagery used within the dataset of a terrain database delivery. SE Core develops correlated geospatial terrain databases for U.S. Army simulators, simulations and training systems. These training systems primarily support the execution of combined arms and joint training at homestation and deployed locations. SE Core's correlated terrain database production is to enable interoperability and facilitate fair fight in the U.S. Army's Integrated Training Environment (ITE). Aerial imagery used in vector editing is critical to ensure correlation of the imagery and feature data within a terrain database, and the use of this correlated aerial imagery in the delivered terrain database is critical to ensure correlation between training systems.

Aerial Imagery in Vector Editing

In the database production process aerial imagery provides the basis for feature correlation. Aerial imagery is collected from approved imagery sources for the required geographic extents and is used as the reference layer to clean, align and digitize all vector features. The aerial imagery is selected based on the most current date, minimum obliquity (closeness to nadir), minimum cloud cover, best color, and highest resolution. If the imagery is not orthorectified, it will be orthorectified; if it is in an unwanted reference frame, it is re-projected; if the available monochrome imagery is higher resolution than the available color imagery, it is pan sharpened. For vector editing multiple overlapping images are collected to ensure complete coverage to account for gaps, clouds, and unwanted shadows. Once collected and selected, the imagery is split into tiles and hosted on an imagery server.

The Vector Editing aerial imagery quality and resolution requirements are derived based on the ability of the Geospatial Information System (GIS) analyst to extract a feature of a minimum size based on a content specification. The resolution must be suitable for the GIS analyst to see the details necessary for feature alignment and extraction. When creating high detail geographic areas such as Military Operations on Urban Terrain (MOUT), maneuver and gunnery ranges, one meter or better aerial imagery resolution is required. In less significant geo-typical non-training areas, no worse than five meter aerial imagery is required. In all cases, the analyst requires multiple overlapping images to assist in the identification of obscured features.

Aerial Imagery in Training Systems Datasets

Aerial imagery is also prepared and included in the database production products. Aerial imagery is used in the image generator databases as draped textures, in the sensor simulation as material maps, in the Plan View Display (PVD) as full color aerial imagery, and in the Mission Command (MC) simulations as operational aerial imagery. For example, Aviation Combined Arms Tactical Trainer (AVCATT) requires the delivery of CIB black and white aerial imagery. Modular Universal Simulation Environment (MUSE) Night Vision Image Generator (NVIG) requires full color aerial imagery draped on the terrain skin. Virtual Battlespace 3 (VBS3)™ requires full color ground surface aerial imagery draped on the terrain skin and a correlated ground surface material mask. Enhanced fidelity sensor simulation requires correlated sensor material maps.

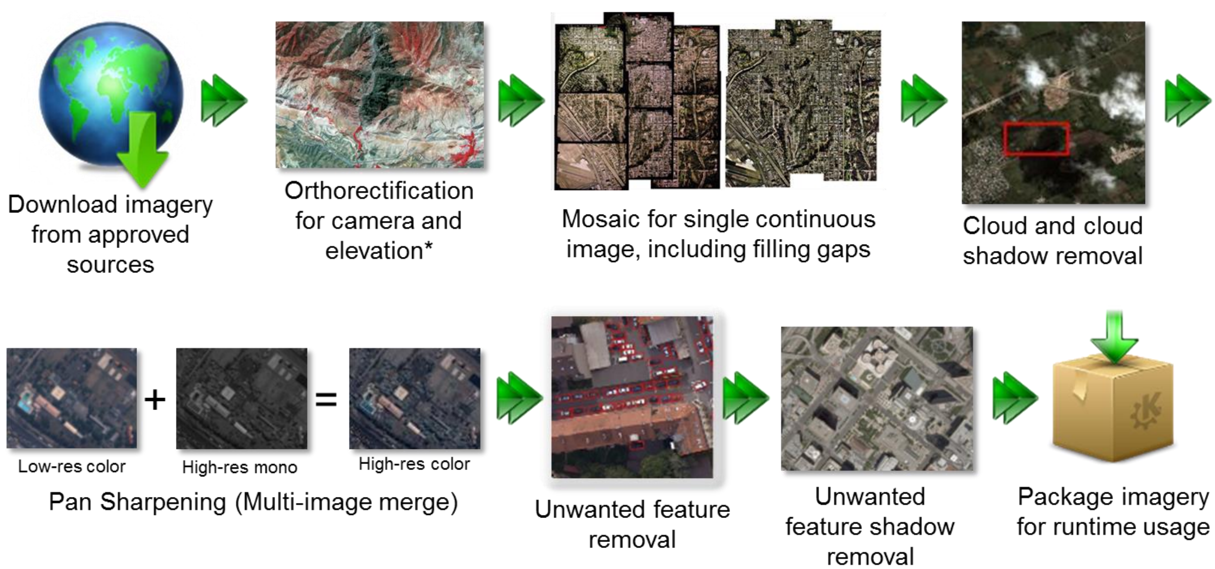

Figure 1. Real Aerial Imagery Preparation Process

Similar to the aerial imagery preparation for vector editing, the targeted product aerial imagery must also be collected and prepared; however, using aerial imagery as draped imagery requires additional image preparation steps, illustrated in Figure 1, including color balancing, removing shadows, cleaning vehicles from transportation features, and classifying materials for ground surface masks and sensor material maps.

Our training systems' aerial imagery dataset requirements are determined by the U.S. Army National Simulation Center (NSC) and the SE Core Confederates (customers). These requirements include full color aerial imagery at one meter resolution, CIB imagery at one meter resolution. Full color ground surface aerial imagery at one meter resolution with correlated ground surface material mask is required. The aerial imagery must be non-overlapping, cleaned, tiled and one hundred percent area coverage without holes or gaps.

Background Search for Imagery Solutions

The application of aerial imagery as a draped photographic texture to terrain databases has been a capability of Image Generators (IGs) for many years. As early as 1998, Economy *et al*. posited that traditional self-repeating texture patterns did not produce the same degree of realism as that of real-world imagery when applied to a terrain representation. Their research described an early technique for applying extensive aerial imagery photo-texturing to a terrain database. In their research they identify the large costs associated with high-resolution aerial imagery, thus only utilize this data for high interest areas (Economy, Ellis, & Ferduson, 1988).

In recognizing a capability gap for satellite imagery at the time, Aplin *et al*. proposed a technique for integrating simulated satellite sensor imagery with digital vector data. The resulting hybrid dataset was used to classify land cover on a per-parcel basis in the United Kingdom (Aplin, Atkinson, & Curran, 1999).

Isaacson, recognizing system data storage limitations of real-world imagery, proposes a hybrid terrain texture solution that integrates high-resolution imagery into a synthetic imagery backdrop on the terrain (Isaacson, 2007). In this process, a real-world imagery dataset is obtained. A compositing engine then inserts synthetic texture images at multiple resolutions into a continuous whole-earth texture grid as indicated by a land coverage model. Finally, the compositing engine integrates the real-world imagery insets into the background synthetic imagery coverage.

Several commercial software applications directly related to this research area exist. CAE™ has implemented a Motif Compositing tool within the Common Database (CDB) terrain architecture. Motif Compositing utilizes latitude, longitude, altitude and geopolitical boundaries as inputs to algorithms and rulesets that can be used to populate the particulars of the visual scene in real time and make it look more realistic without burdening the database unnecessarily (Croft, 2009). Presagis™ has teamed with ITspatial™ to develop an extension to Esri's ArcView in order to create photo-realistic textures in a 3D environment from GIS data utilizing Creator Pro™ and the Vega Prime™ visualization engine (Unrau & Richards, n.d.). TerraSim™ has developed the tool MaterialMAP2, which creates surface material maps and attribution from aerial imagery. These material maps can then be integrated directly into simulation environments to determine mobility and routing, runtime visual effects, and sensor representation (TerraSim Inc, 2016).

IMAGERY USE CHALLENGES

The challenges of preparing aerial imagery include meeting the quality and coverage requirements, managing the large datasets, material classifying the imagery for sensor usage, removing negative aerial imagery artifacts for ground training systems usage, correlating the elevation and feature data to the imagery data, and filling in the gaps of missing imagery data.

Variations in Imagery Coverage and Quality

The availability and quality of aerial imagery varies based on the location within the world, depending on local, regional, national and international interests, both governmental and commercial. Moreover, availability and quality varies based on the seasons and regional weather – for example snow cover or cloud cover. In the continental United States (U.S.) the coverage is excellent and requires minimal preparation processing. Alaska and Hawaii are average coverage, but with multiple sources and reasonable work acceptable results can be achieved, as illustrated in Figure 2. However, outside of the U.S., in locations of interest to international security, the aerial imagery often lacks coverage and quality, requiring extreme techniques to make acceptable.

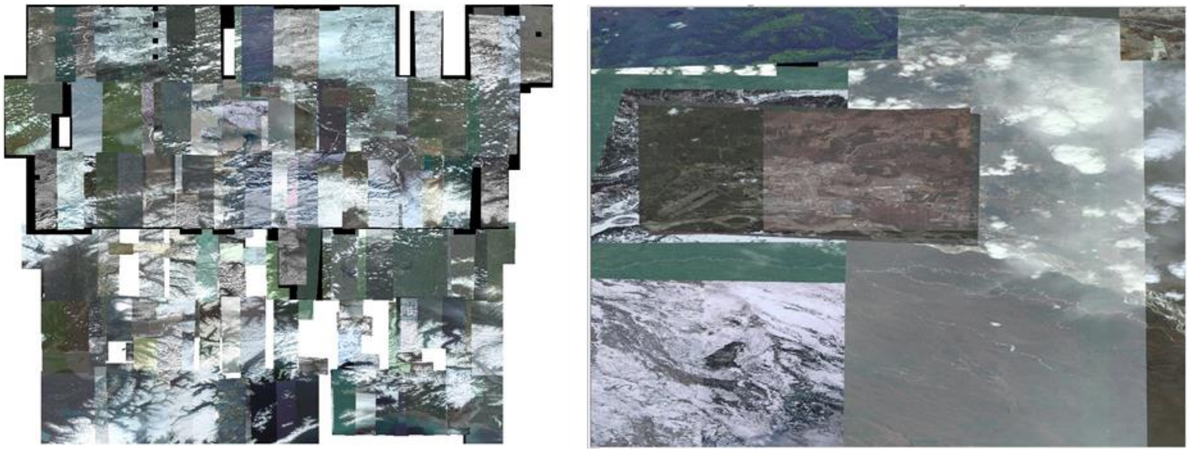

Figure 2. Example of Real Aerial Imagery Variations

Imagery Dataset Size

As terrain databases increase in size (larger geographic extents) and imagery improves in resolution the volume of data correspondingly grows. Adding to the increasing geographic extents and improving image resolution is the availability of multiple imagery sources and the multiple years of imagery available. The volume of data balloons and the manpower to select the best imagery becomes cost prohibitive. As depicted in Figure 3, the problem we now face is the increasing manpower cost. We are reaching the practical limits on what a human-guided system can achieve.

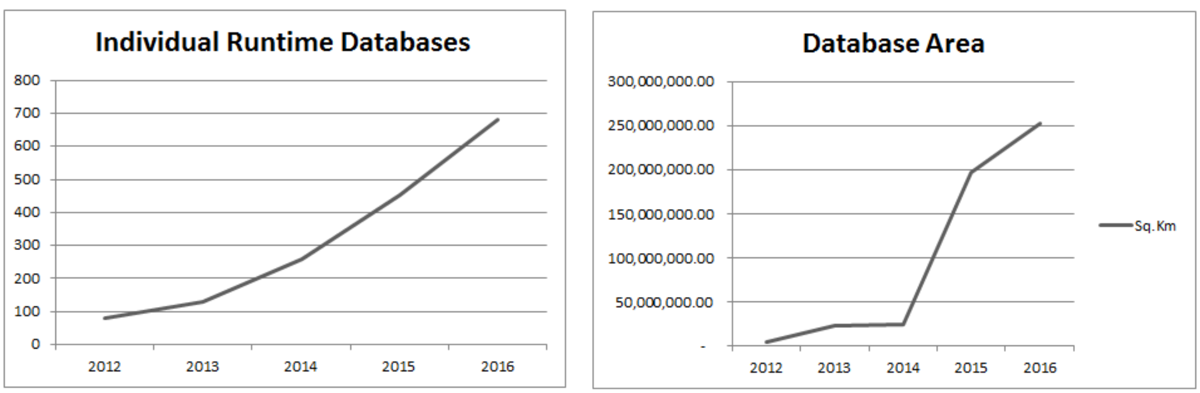

Figure 3. SE Core Database Production Growth

One of the most important roles the GIS analyst plays in imagery preparation is the visual inspection of the raw data. The amount of time it takes an analyst to inspect data is spread over a large geographical area. Large database extents combined with high resolution imagery essentially causes the affordable time per "texel" to approach zero. Often the raw image data is a mix of many formats, content conventions, and map projections. There is simply too much data for the GIS analyst to sort through, reformat, re-project and reorganize. Large amounts of data become difficult to manage without establishing data categorization, normalization and traceability conventions. One of the most time consuming problems is managing the raw imagery source data and the derived data products that are spread over a distributed computing environment. When the data is so large that it "bursts" out of the classical storage constraints (limited server and single-location network storage), the GIS analyst begins to lose track of the raw imagery data; resulting in unwanted errors or omissions. The increase in terrain database geographical size and imagery resolution results in exponential growth in computational resource requirements to prepare the imagery for use in M&S.

Imagery Material Classification

Material classification is critical for training systems that include simulated high fidelity physics-based sensor simulations. These training systems are dependent upon correlated material maps to render realistic electro-optical sensor simulations. Multispectral imagery, when available, can be used for material classification. The use of these multispectral imagery datasets still present challenges to the GIS analyst when mapping the spectral response of each pixel associated with natural terrain surface features and man-made materials. Effort is required by the GIS analyst to group and associate individual pixels, based on the object shape and spectral similarity characteristics. Of particular consideration is the level of material classification detail which needs to be consistent with the expected classification for the image generator or scene graph software.

Imagery Artifact Removal

Typically the fixed and rotary wing training systems can accept aerial imagery with minimal artifact removal. Most aircraft simulation system database producers view the labor intensive imagery preparation processes as unnecessary. Often these training systems see the world from fundamentally the same view as the orbital space flight and reconnaissance sensor.

Unfortunately, ground based simulation system database producers cannot dismiss these aerial imagery preparation steps. As illustrated in Figure 4 and 5, the aerial imagery artifacts are not easily overlooked when, in the visual system, the trainee sees “driving on tops of cars on the road”, or “building rooftops and aerial imagery shadows on the ground”. Moreover, the higher the resolution of the ground imagery, the more distracting negative artifacts will be to the trainee.

Figure 4. VBS IG Using Real Aerial Imagery

Figure 5. Google Earth Real Aerial Imagery

Correlation of Imagery Data to Elevation and Feature Data

Geospatial data reference frame differences continue to hinder the GIS analyst’s ability to rapidly process data. The vector and elevation data is often in a different spatial reference frame than the aerial imagery. The location of the features in the context of the imagery is important, often these spatial reference differences manifest themselves as misalignment of imagery data layers relative to the vector feature data layers. The correlation of the terrain, elevation, feature and imagery data, is essential for the terrain database to appear properly,

Supplementing Real Aerial Imagery

Aerial imagery of locations outside the continental United States and Western Europe are more limited and often contain imagery gaps and coverage holes with undesirable seasonal variations. Automated tools and processing techniques are required to affordably fill these gaps in the aerial imagery. In addition, support for “notional” locations such as Missionland requires additional innovation in aerial imagery creation (Lemmers, & Gerretsen, 2012). In response to these challenges the analyst is faced with the need to support both real and simulated imagery preparation.

UNRAVELING THE COMPLEXITIES

The GIS analyst is faced with the time consuming problems associated with aerial imagery cleaning and preparation. Temporal artifacts such as time of year and time of day, weather color distortions, and shadows can be mitigated using commercial software tools when applied to small area datasets. Most current commercial tools require significant user interaction for the preparation of aerial imagery. Admittedly, scripting can be applied to provide automation of repeated imagery manipulation functions; but unfortunately, these tools are very limited in scalability. Tool limitations combined with the exponential increase of aerial imagery volume necessitate investigation of automated techniques to reduce the aerial imagery preparation time. To address these challenges in preparing aerial imagery for use in terrain database production, we have developed a multi-solution approach composed of automating the real aerial imagery processing functions and added a simulated aerial imagery generation capability.

Real Aerial Imagery Preparation

To address the challenges of processing real aerial imagery we have focused on reducing human viewing time, provided tools for managing the variety and volume of data, focused the user interface on simplifying the task, and expanded the distributed computing resources to reduce processing time.

Reducing Human Imagery Inspection

To reduce the rising costs of data preparation, automation of the imagery inspection is necessary. When imagery quality is low and data processing is required, the focus must shift towards the detection of the anomalies that the current commercial tools cannot reasonably handle in their present form. The intent of the semi-automated anomaly detection functions is to focus the attention of the GIS analyst to the imagery that requires specific human action.

Managing the Varieties of Data

The categorization of the data based on its intended interpretation and value to the user (panchromatic, color, multi-spectral, etc.) is another area that benefits from automation to effectively focus the GIS analyst on the aerial imagery data exceptions. Data categorization though the use of established patterns in the data (number of bands, metadata, etc.) help users focus on the datasets that do not fit known patterns.

Managing the Volume of Data

It is not unusual for the GIS analyst to be faced with handling datasets that require the active management of hundreds of thousands of files. Intensive human-in-the-loop solutions are just not feasible. Managing the process flow and having GIS analysts in the loop to only address the aerial imagery data exceptions is critical in the automation of aerial imagery preparation.

Reducing Processing Time

Historically, the available software tools use serial processing on a multi-process capable workstation. However, the need to process large datasets in a reasonable amount of time requires additional resources through the use of multi-machine processing software applications. Some commercial software tools are already evolving in this direction, but it is more than just multi-machine processing. It is planning a network infrastructure to provide scalable processing, high-throughput fault tolerant networks, high-speed, high-volume distributed data storage, and full failover recovery techniques.

Consolidate Tools and Focused User Interaction

Increased data demands require a user interface that optimizes the human interaction and avoids unnecessary hand editing. Intermediate datasets are often larger than the final data products, so the consolidation of tools eliminates the persistence of large intermediate datasets, thus alleviating some data storage issues. Integrating tools that would have normally been chained also minimizes the number of steps that the human-in-the-loop needs to supervise and validate, thus relieving the “attention” bottleneck that the large data problem induces.

SE Core has developed a real imagery processing tool that addresses these architectural challenges. The software provides automated functions of map projection, determines resolution layer stacking, image accumulation, grayscale colorization, pan sharpening and blending. It also detects invalid pixels and tile seams resulting from re-projection and warping operations, and replaces the “bad” pixels with secondary sources or clones neighbor pixels. Most importantly, the software is scalable to operate in a distributed workstation processing environment in a server/client configuration, where the file servers and client workstations are configured into a boss and worker configuration.

Simulated Aerial Imagery Generation

Merely processing available real aerial imagery has proven an incomplete solution. Holes and gaps in real aerial imagery need to be filled. Negative artifacts like cloud cover and cloud shadows need to be removed and snow cover, multiple seasons must be eliminated to support ground-based simulation systems. Systems that require material classified data must be produced affordably. When asked to produce a database of a notional training area, we were given the task of creating aerial imagery for the non-real-world location. A method was needed to "fill the gap" in available aerial imagery.

SE Core Simulated Imagery

It was determined that to provide an acceptable draped aerial imagery solution for ground surface textures in ground-based training systems; SE Core would either expend significant schedule and labor resources on removing negative artifacts from real aerial imagery for every database produced. Alternatively, SE Core could develop an automated method to synthesize aerial imagery from the vector feature data, artifact free. Clearly, our database production process could benefit from an automated solution to address the challenges of processing aerial imagery to support ground-based training systems and notional training locations. This capability also helps fill in the gaps from real aerial imagery.

As illustrated in Figure 6, the SE Core simulated imagery processing tool provides import of either standard feature and elevation dataset or OpenFlight® databases. The simulated imagery software automates the painting of simulated aerial imagery based on a defined set of painting rules. The simulated imagery processing tool paints 2D and 3D features with realistic colors and geo-typical textures onto an image canvas that represents the base view of each scene element (painted orthorectified).

The simulated imagery processing tool is based on the use of rasterized geometry features and the progressive enhancement of those features though the use of elevation data derived terrain topography combined with the application of organic and rule-based geo-representative textures (both RGB and materials).

The nature of the enhanced feature data produced can be controlled through user defined rules so that aspects of the real world may be separated based on the simulation application (e.g., bare earth without foliage or 3D contents for ground applications, fully populated images for high-altitude flight application, images with and without shadows).

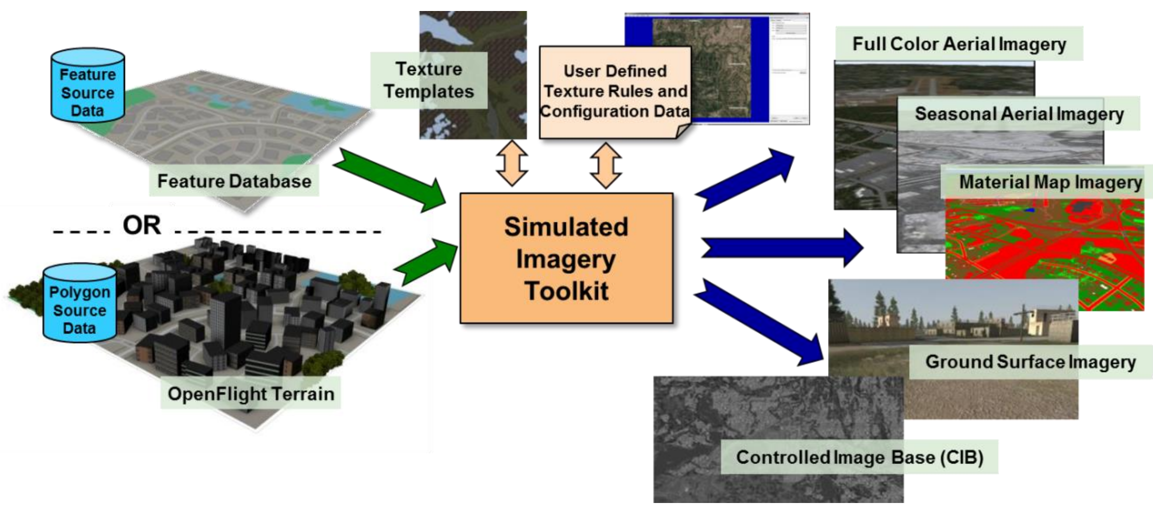

Figure 6. - SE Core Simulated Imagery Process

Improve Aerial Imagery Representation

Figure 7 illustrates the depiction of real aerial imagery when the aerial imagery clean up preparation steps are not fully applied. When used for the ground surface simulation and training applications the simulated convoy vehicle entities would appear as though driving on top of the undesirable clouds instead of driving on the underlying transportation network. The use of simulated aerial imagery shown in Figure 8 illustrates the significant improvement of aerial image quality when the imagery is derived from the vector feature data; resulting in aerial imagery that is free of the undesired real aerial imagery artifacts.

Figure 7. NVIG IG Using Real Aerial Imagery

Figure 8. NVIG IG Using Simulated Aerial Imagery

Similarly, the simulated sensor representation when real aerial imagery is applied as shown in Figure 9 and includes undesirable cloud artifacts. However, the simulated draped imagery in Figure 10 is artifact free.

Figure 9. NVIG Sensor Simulation Using Real Aerial Imagery

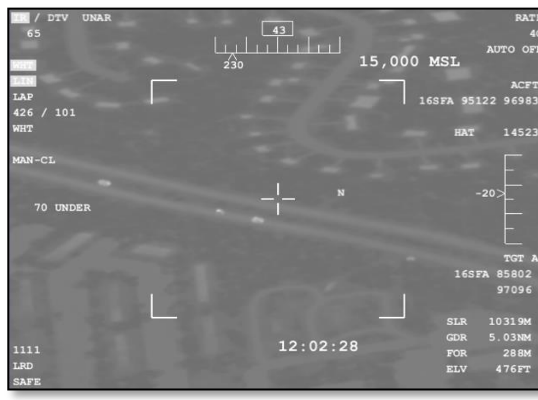

Figure 10. NVIG IG Sensor Simulation Using Simulated Aerial Imagery

Material Classification Derived from Vector Data

The simulated imagery processing tool is capable of generating material encoded imagery as depicted in Figure 12. This material synthesis is generated based on the feature classification used to generate the simulated full color aerial imagery shown in Figure 11. Of particular interest to the simulation and training system use case is the image data types and output configurations are guaranteed to be correlated because they are derived from consistent source data and image generation rules. This guarantees consistency in material and color assignments, thus eliminating the need to correct for data capture and seasonal differences normally found in real-world captured datasets.

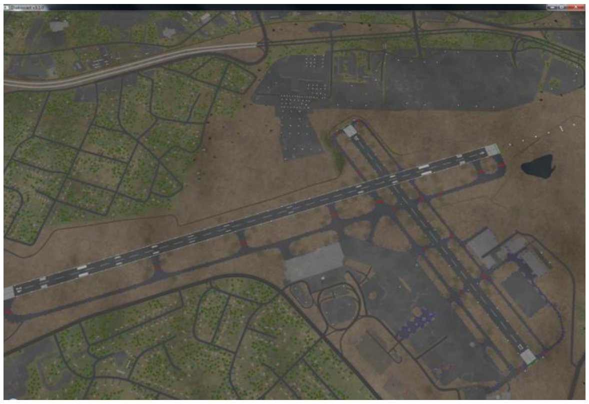

Figure 11. Simulated Terrain Surface Imagery

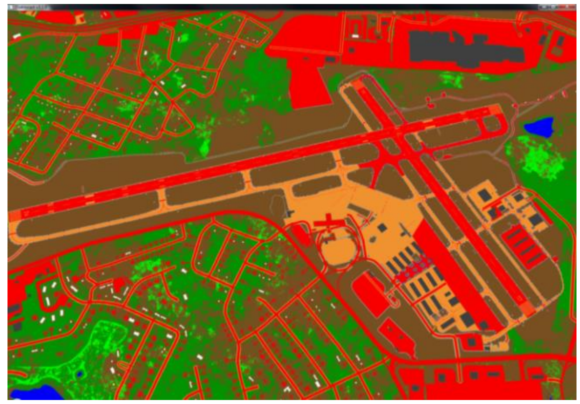

Figure 12. Correlated Material Map Imagery

Ground Surface Aerial Imagery and Material Mask

The simulated imagery processing tool provides for the generation of the ground surface imagery, as depicted in Figure 14. This imagery represents only the ground surface features that exist under the placed 3D features. Figure 13 illustrates the unwanted shadows, building rooftops on the ground and unwanted parked vehicles. These figures provide a comparison between a real aerial imagery and simulated aerial imagery used in a VBS3 terrain database. Additionally, VBS3 requires a ground surface material mask to provide the definition for the generation of procedural feature generation and the calculation of mobility. Using the correlated material map generation as part of the Simulated Imagery Processing tool the ground surface material mask is automatically generated and fully correlated to the 3D features.

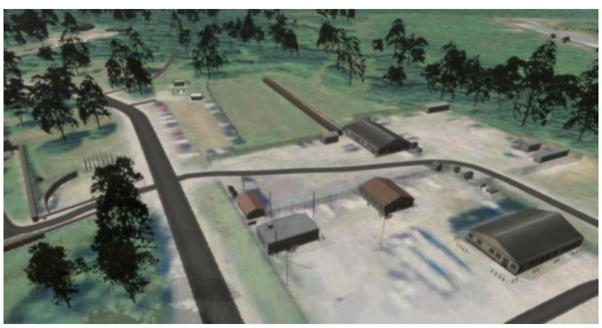

Figure 13. VBS Terrain using Real Aerial Imagery

Figure 14. VBS Terrain using Simulated Imagery

LESSONS LEARNED

Supporting the production of hundreds of terrain database deliveries and processing thousands of square kilometers of terrain and imagery has resulted in a need to develop automated techniques to replace the analyst in the loop activities. Using a recent SE Core database development activity as an example, it is not uncommon for the volume of raw aerial imagery data to be in excess of one million files for a single database. This clearly exceeds the analyst's ability to manually inspect, select and apply the suitable imagery data. To generate large area runtime databases in a timely manner, the data management must be standardized and automated, a fault tolerant computing infrastructure and advanced processing techniques must be in place and cybersecurity constraints must be accommodated.

Implement Data Management Standards

First and foremost, the volume of data required visualizing and discarding low value data sets, as well as the conversion of non-standard data to a common form for later use. What was noticed is there are two sides to this problem, the first one that it is impractical for a human to inspect all the data one piece at the time, and secondly, most of the existing tools (COTS or otherwise) struggle when manipulating such large data sets. Streamlined ways of processing the source data for inspection are critical (e.g. timely generation and visualization of thumbnails) so that current data visualization tools could help the users perform a quick inspection and organization of the real source images. A high-level view of the images is useful in detecting patterns. Then actions can be taken to convert the detected patterns to a standard data representation through automated techniques.

Automate the Process

This is perhaps the most difficult and important evolution of the current image preparation processes needed in the industry today. The large volume of data has made it impossible for users to directly and explicitly address anomalies in the data (e.g. invalid pixels that are not properly tagged). There are simply too many files to deal with, and the human-in-the-loop processes had to evolve to the point where the analysts can identify the problems but not actively solve them. Instead, a solid backing of software heuristics that can reasonably approximate "what the human would have done" is required so that these heuristics may be applied to full datasets with minimal inspection. From a software development point of view, it is a never ending problem that is constantly evolving to address new categories of anomalies. In many ways these solutions are starting to converge on Artificial Intelligence like solutions, not unlike the rest of the "big data" problems that are arising world-wide due to the ever increasing amount of data to process.

Establish Fault Tolerant Environment

Image processing is infamously computationally intensive, and with large datasets this quickly and directly translates into "calendar time". Managing the "calendar time" challenges becomes paramount as it directly affects the ability to not only meet data production deadlines, but also software development iteration and debug needs. The two main lessons in this regard were 1) provide parallel processing for the image processing algorithms and, 2) build a robust and failure tolerant infrastructure. This infrastructure must support the "calendar" related activities such as cybersecurity driven periodic system updates, the inevitable reboots, power interruptions and many other unplanned operational interruptions that exist in the work place. It became increasingly necessary to be able to spread the processing load across as many machines as possible in a way that the individual imagery datasets could be independently produced, as well as recovered and re-tried in the case of failures and interruptions. No machine could be assumed that once assigned a piece of work it would be performed. It had to be monitored for completion and failure, reassigned and re-tried until a predictable "terminal" condition was reached before considering each individual work package complete. Even the monitoring itself had to be fault tolerant, which required a persistent processing state for the dataset and the use of system services to "wake up" and resume after system failures.

Accommodate Cyber Security Design Constraints

This was the biggest lesson of them all. Since dealing with large volume image datasets quickly evolved into a multi-process, multi-machine shared data and processing solution, accounting for the cybersecurity constrains while designing a "network-wide" distributed system proved to be an unexpectedly cumbersome challenge. There may be a thousand different way to design and implement these kinds of systems, but a very thorough understanding of the constraints that cybersecurity imposes on the software dramatically reduces those options. If one designs solutions without a thorough understanding of what is allowable in secure environments, one is doomed to a near endless trial and error cycle that will do nothing more than consume time and resources. Know your cyber-security constraints first. Design nothing until you do, or you'll be doing it over and over again.

PATH FORWARD FOR IMAGERY TECHNOLOGY

The current geospatial data technology trends indicate a significant increase in the quality and availability of aerial imagery that will be widely available in the near future. These emerging commercial geospatial data trends can be observed today by witnessing the advancements in companies such as DigitalGlobe and VRICON™ in partnership that will offer automated generation of high quality and accurate imagery (i.e., 0.50 meter imagery with a spatial 3D accuracy of 3 meters absolute) products designed for commercial and military geospatial data applications.

In addition, emerging commercial data providers such as UrtheCast are beginning to offer very high quality real aerial imagery and real time earth observation streaming video to subscriber (UrtheCast Inc, 2016). Currently the

UrtheCast Company operates a wide variety of remote sensing camera systems onboard the International Space Station with future plans to deploy multiple satellite constellations in earth orbit. The availability of these innovative real-time commercial remote sensing systems combined the rapid deployment of the imagery coupled to user friendly automated cloud based processing system will clearly lead to readily available defect free aerial imagery.

The SE Core program has successfully integrated the real imagery processing tool and the simulated imagery processing tool as part of the Standard/Rapid Terrain Database Generation Capability (STDGC). Furthermore, the planned software enhancements include customer directed improvements such as the inclusion of a standard material list data dictionary and the representation of realistic organic terrain and natural and manmade feature representation. Additional development activities will include the capability to automatically import a real-world/simulated aerial imagery hybrid to improve representation with enhanced feature classification.

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