

Analyzing Point Cloud Data in ERDAS IMAGINE

Using Spatial Modeler Operators to Produce Bare Earth Models from Point Clouds

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Introduction

In addition to a rich set of operators for analyzing raster data, the Spatial Modeler (available in ERDAS IMAGINE, GeoMedia and other product lines by Hexagon's Geospatial division) also offers point cloud tools. When creating point clouds, even the best sensors and photogrammetry techniques tend to collect unwanted features. Producing a bare earth model from point cloud data can be challenging, as unwanted features in a point cloud can interfere with its intended use.

Powerful new tools available in the Spatial Modeler enable users to tailor their point cloud data through editing, classification, filtering, and surfacing. The data can be used in its native LAS format or as a gridded raster. The point classification and remote sensing operators allow for data to be manipulated in a fashion tailored to the customer's application. Once processed, the edited data can be used in many applications, including high-accuracy orthorectification.

The case study in this paper will demonstrate how the Texas Department of Transportation (TXDOT) removed unwanted features in their elevation source with spatial model operators to create accurate orthorectified images.

ERDAS IMAGINE – A Product Overview

Overview

ERDAS IMAGINE supports advanced point cloud processing and visualization through the operators available in the Spatial Modeler. Point cloud classification and RGB encoding operators allow for visual enhancement of point cloud data. Advanced editing tools like class selection and subset enable users to filter unnecessary data out of the point clouds and keep only the ground data and the bare earth model as a result.

The Spatial Modeler also includes operators that not only streamline the workflow process but also add additional functionality for a more accurate bare earth extraction. For example, rasterizing the point cloud data is now an option within the Spatial Modeler. When a point cloud dataset is rasterized, it becomes a surface file on which remote sensing applications can be used to further enhance a bare earth solution for additional downstream processes. With ERDAS IMAGINE, users have access to remote sensing functionality developed over decades that accompanies a multitude of point and raster operators in a spatial modeling environment.

Features

- Point cloud operators in a spatial modeling environment
- Graphical dataflow construction
- Ability to preview spatial model results
- Additional point cloud tools available in the ERDAS IMAGINE ribbon interface
- Point classification, selection, and subset
- Point cloud rasterization and surfacing
- Ability to string together multiple operators for point cloud and raster processing
- Point cloud workflow and operation batching

Benefits

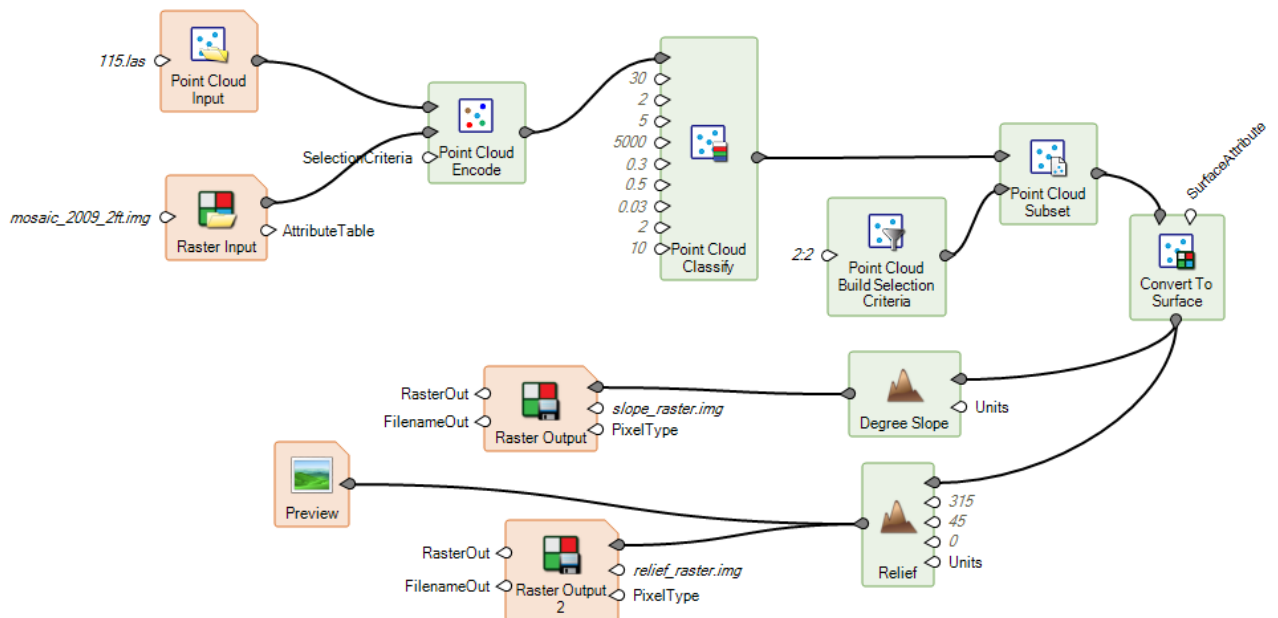
- Spatial models allow for streamlined repeat-pass processing of cloud point data
- Spatial modeling offers operations that extend the use of point clouds into remote sensing
- Point cloud rasterization feature increases functionality in remote sensing applications
- Spatial models are standardized for simple sharing
- Point cloud files can be used in their native LAS format
- Batching and distribution allows indefinite repetition of a single build
- Automate several manual steps into a single process

Architecture

The Spatial Modeler supports a variety of inputs and outputs. Inputs including but not limited to point cloud, raster, and vector files can be introduced into the models. These models can subsequently produce any number of different outputs.

The setup and design of the Spatial Modeler environment is modular, which allows users to add or remove operators as needed. A model can be tested in increments, as more operators can be appended with every satisfactory result. This process is both more streamlined and more flexible.

Merging all the operators together creates a string of processes that can be batched to run on multiple files. In the figure below is a Spatial Model that comprises several consolidated individual operators. Only the input needs to be defined within this black box architecture, which saves time and reduces human error.



Texas Department of Transportation – A Case Study

Overview of Texas Department of Transportation

The Texas Department of Transportation (TXDOT) is responsible for ensuring the quality and upkeep of the roadway infrastructure in the state of Texas. The TXDOT requires accurate orthorectification of their imagery, which often includes limiting unwanted features in their elevation source.

Trees, man-made objects, and other such features positioned close to the roads often show up in surface models and greatly influence the accuracy of the orthorectification by causing smearing, ghosting, or misregistration. The workflows described in this paper demonstrate how Spatial Modeler can eliminate these unwanted features from point clouds for a more precise orthorectification.

Current Bare Earth Model Solution

Orthorectification of imagery can be most difficult when the bare earth Digital Terrain Model (DTM) is not accurate. Standard automated terrain extraction engines produce point clouds or Digital Surface Models (DSM). The difference between DSM and DTM is that the surface model includes non-terrain features, such as trees and buildings, that are not present in a bare earth terrain model. In other words, DSMs require manual editing strategies to produce an accurate DTM. Having the appropriate tools available to string these operations together in a point cloud environment adds the functionality of a modeling environment and increases productivity immensely.

With automated terrain extraction also come inherent errors in the elevation output due to factors similar to those that affect DSM generation. These errors can be manually corrected but at the expense of effort and time. Minimizing this editing procedure saves time and yields a higher return on investment. Semi-Global Matching (SGM) algorithms from photogrammetry are one option for high accuracy point cloud creation, but they still require editing much like lidar point clouds do. This editing can be largely minimized. Part of the editing procedure requires some processing to create value-added products that aid in the removal of the extraneous features. By allowing for workflow and batching it, the point cloud tools and operators available in the Spatial Modeler create an ROI.

TXDOT is already a Hexagon Geospatial software solutions customer who makes use of the following geospatial software solutions:

- ImageStation Automatic Triangulation (ISAT) – for triangulation
- ImageStation OrthoPro (ISOP) – to orthorectify and mosaic their imagery
- ImageStation Automatic Elevations (ISAE without SGM) – to create their DTMs
- ImageStation DTM Collection (ISDC) – for generating a DTM

The workflow that TXDOT currently uses for a typical orthophotography project involves running ISAE without SGM to generate a surface. This surface consists of a grid of elevation points in a MicroStation design file. Using ISDC, they generate a DTM and use this preliminary surface in ISOP to create preliminary orthophotos. They then return to MicroStation, load the design file with the elevation points, and attach the orthophotography as reference images. Often the orthophoto requires a close inspection (particularly in areas with buildings) to check for distortions that the DTM might have caused in the orthorectified imagery. Contours are sometimes created to help pinpoint areas where ISAE has erroneously placed elevation points on rooftops or treetops. The inspection typically requires a lot of edits to the elevation points in order to produce a useable surface.



Once the edits are completed, the generation of a new DTM is required along with the creation of a revised orthophoto. The orthophoto must be inspected once again to ensure that all the surface-induced distortions have indeed been removed. When working in an area with a lot of buildings, it is sometimes necessary to forego using ISAE altogether and instead use ISDC to collect elevation points using the stereo viewing environment. This method is time consuming. However, depending on the complexity of the area, it may be more time efficient than manually editing the ISAE generated surface.

With the addition of the new SGM algorithm now available in the ImageStation Automatic Elevations - Extended and IMAGINE Photogrammetry software, it is possible to reduce the editing time. However, no photogrammetrically-derived nor lidar-derived point cloud generation will be free of unwanted features. These generations will therefore almost always require editing. With the methods described in this paper, we hope to minimize these manual efforts.

Problem Description – Streamlined Point Cloud Editing

The TXDOT uses Hexagon Geospatial's products in the interest of creating accurate orthorectified imagery. To that end, accurate point cloud collection and editing is a key component. A raster DTM can be created from this edited point cloud essentially by rasterizing the points into a surface and interpolating any missing points to create a seamless raster grid file. With an accurate DTM (i.e. one void of extraneous features) the orthophotography can be registered much more accurately, avoiding improper overlap from the rectification process. The elevation source for these orthophotos can be a raster DTM or point cloud. The inaccuracies that result in road shift, smearing, and ghosting can be avoided by using these streamlined operators to fine tune the point cloud so that little or no manual editing is necessary.

Adding the SGM algorithm to this workflow further increases the accuracy of the point cloud file. The SGM output coupled with the new spatial modeling capabilities helps smooth out the wrinkles in point cloud data, which enables the TXDOT to create more accurate DTMs. With this increased accuracy also comes quicker orthophoto generation, resulting in not only a better product but also a higher ROI.

Workflows Used to Create Bare Earth DTMs

Creating an accurate Bare Earth model is complicated when so many factors can influence where points are detected, regardless of whether they are collected from a lidar sensor or photogrammetrically-derived using an algorithm like SGM. The workflows described below employ the techniques necessary to automate the removal of features and turn DSMs into DTMs. Each workflow model can be used individually or combined to create a single black box procedure. Furthermore, the black box can be batched and distributed across multiple nodes for a streamlined push-button approach.

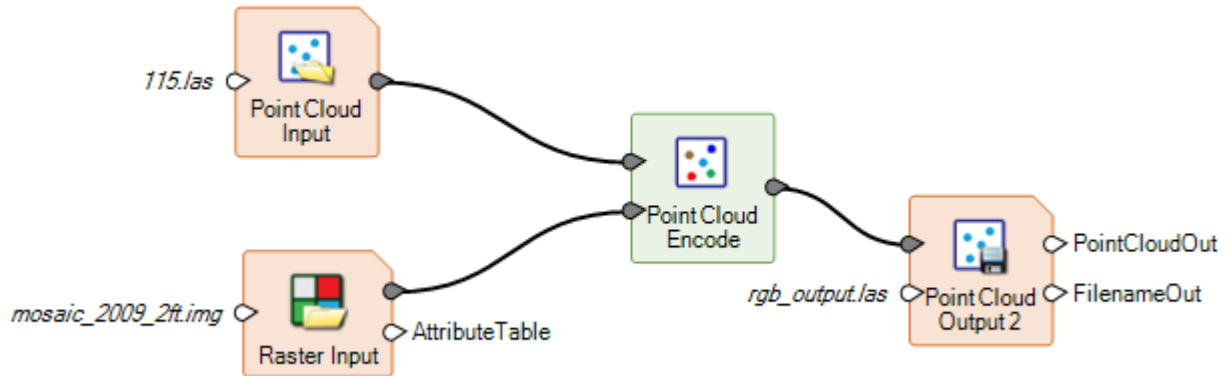
Workflow 1 – RGB Encode the Point Cloud

Problem Description

Point clouds generated from Lidar sources do not contain the RGB values that imagery does. Adding these RGB values allows for a more photorealistic view of the point cloud. Classifying points is both easier and more relatable to the human eye when the points are in true color.

RGB values can be added to a Lidar source or any point cloud that does not have already have an RGB value assigned to each point by using the "RGB encode" operator. This initial workflow is not always necessary when the point cloud file originates from SGM generation in the ISAE-Extended or IMAGINE AutoDTM software.

Workflow Diagrams



Product / Functional View

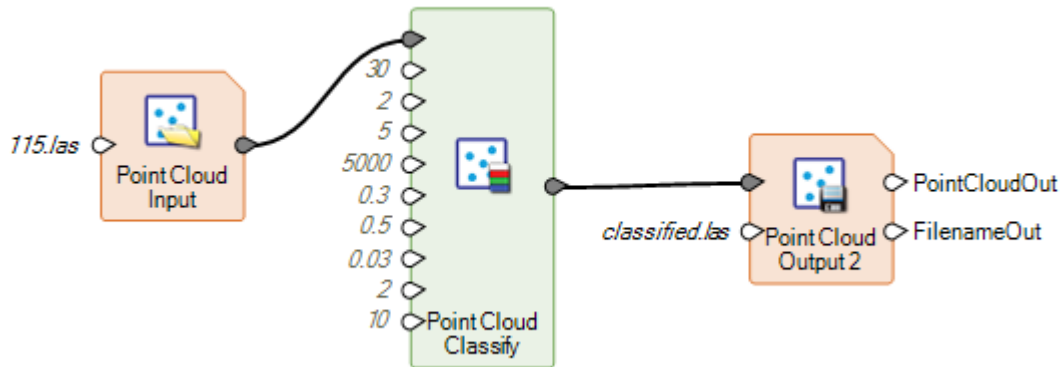
This RGB encode model requires two input sources: 1) the point cloud you wish to encode and 2) the source of the RGB encoding. The source can be any multispectral or panchromatic orthorectified image. It is important that both sources are in the same projection to ensure good encoding quality. If their input types match, each workflow can be appended to another. Combining separate workflows into one unit allows for seamless batch processing of multiple functions on multiple input files.

Workflow 2 – Classify the Point Cloud

Problem Description

Using the “Point Cloud Classify” operator in the Spatial Modeler, you can account for features (such as buildings and vegetation) above the bare earth surface and classify them based on certain building and vegetation criteria. The result facilitates the eventual removal or reworking of features for the creation of a bare earth DTM.

Workflow Diagram



Product / Functional View

This operator requires point cloud input, which may or may not be RGB encoded. The process begins with attaching it to the classifier and opening the configure operator dialog. In the configuration dialog, changes can be made to object and vegetation parameters based on your area on interest. Once finished, the output can be sent to a point cloud. If their input types match, each workflow can be appended to another. Combining separate workflows into one unit allows for seamless batch processing of multiple functions on multiple input files.

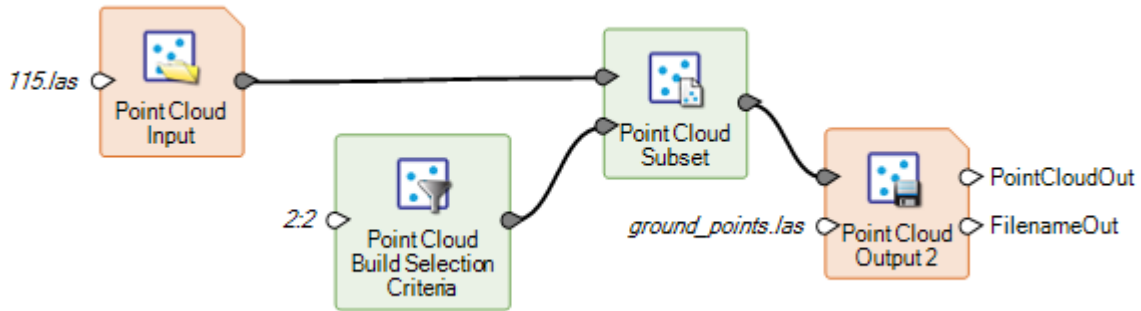
Workflow 3 – Select and Subset the Point Classes

Problem Description

A properly classified point cloud facilitates the disengagement of features that interfere with the average ground elevation. Using the “Point Cloud Build Selection Criteria” operator in the Spatial Modeler, specific points can be selected and only those points will be included in the output to the refined point cloud. This selection operator is best used in conjunction with the “Point Cloud Subset” operator and has many options available to filter or crop out points that you wish to include or exclude. In this workflow, only the points classified as ground are included, as anything else may negatively influence the orthorectification. This selectivity eliminates problems with terrain relief displacement at or near features like building edges or vegetation. The areas that once included these features will be assigned null data values. The orthorectification engine will simply overlook these areas, rather than produce a distorted result.

These operators successfully create a simple and automated approach to eliminating extraneous features, a task that would have otherwise required time-consuming and potentially error-prone manual editing.

Workflow Diagram



Product / Functional View

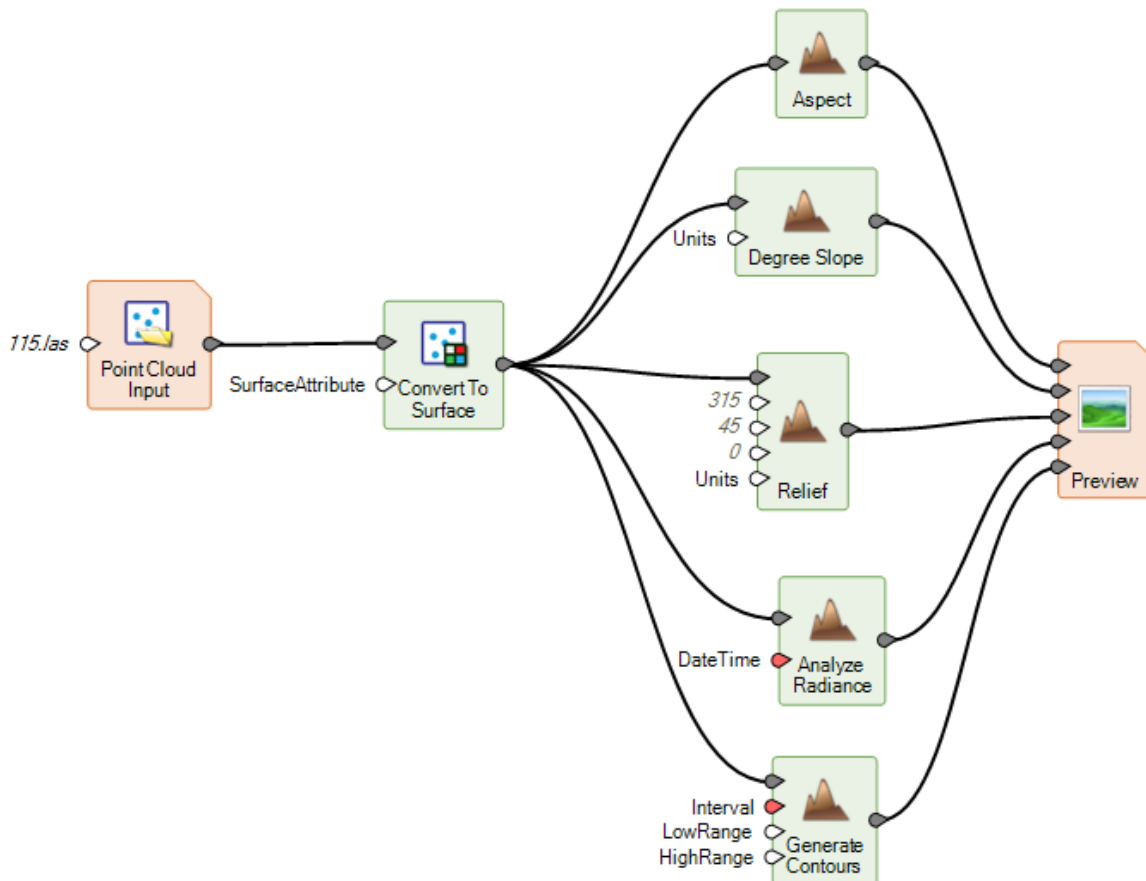
This operator requires point cloud input, which may or may not be RGB encoded. The process begins with attaching it to the classifier and opening the configure operator dialog. In the configuration dialog, changes can be made to object and vegetation parameters based on your area on interest. Once finished, the output can be sent to a point cloud. If the input types are all LAS files, each workflow can be appended to another. Combining separate workflows into one unit allows for seamless batch processing of multiple functions on multiple input files.

Workflow 4 – Rasterize and Perform Topographic Analysis

Problem Description

Working exclusively with LAS files as both the input and output type means that only point cloud operators are needed for analysis. Rasterized (or voxelized) LAS files are fitted with all the capabilities that have been created for raster files over the decades of IMAGINE Professional development. With all the remote sensing functionality at your disposal, the possibilities for value-added products are virtually limitless. This final workflow shows how the spatial modeling environment allows for the voxelization of the point clouds so that topographic raster outputs can be created for additional analysis.

Workflow Diagrams

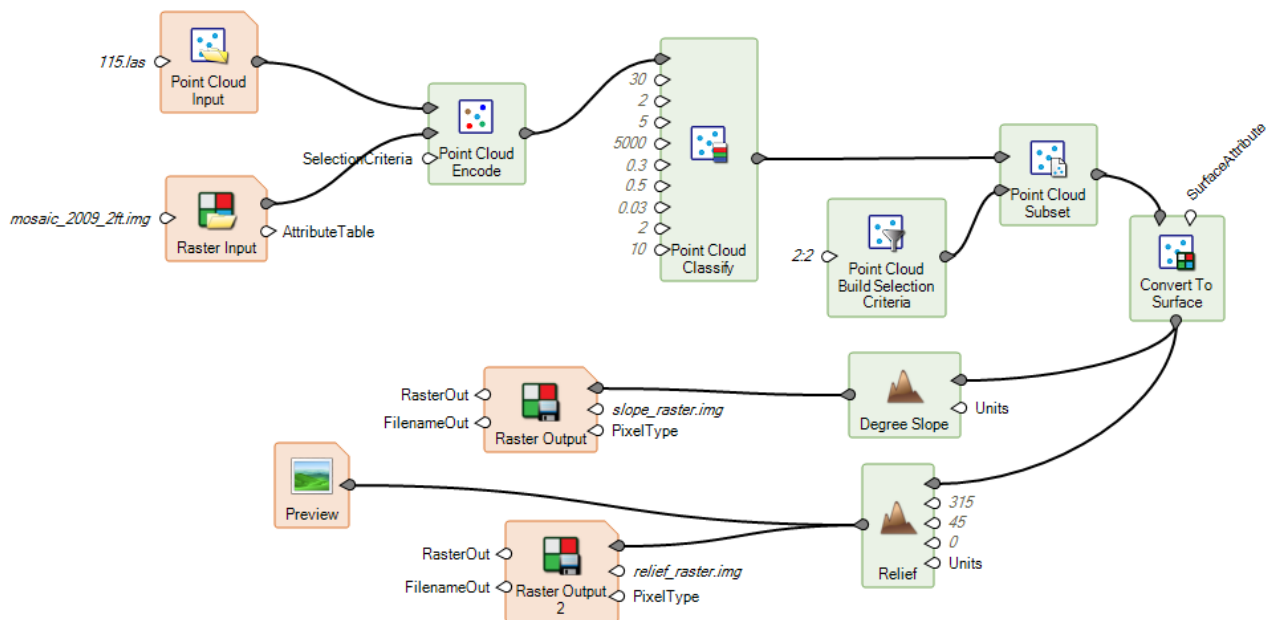


Product / Functional View

Here is an example of the possible outputs that the Topographic Analysis tools can produce. Note that rasterizing the point cloud input is required first. Once the point cloud is rasterized, it is possible to simply output to a raster file and stop there. This example shows all the additional processes that can be performed. The “Convert to Surface” operator creates a gridded surface much like a typical greyscale raster DEM. All the functionalities of a raster DEM become available in this format. The need to go beyond the point cloud to refine a surface model is not typically necessary, as the resulting “Point Cloud Classify” and “Point Cloud Build Selection Criteria” operators fulfill the editing requirements. However, some orthorectification software does require a gridded elevation surface. In this case, the point cloud to raster operator would be the final step. It is also possible to use the Topographic Analysis tools in place of the “Point Cloud Build Selection Criteria” filtering tools discussed and used in this example. Whether the output is a raster or a point cloud, the outcome does eventually lead to a bare earth DSM.

Solution Architecture

The final solution to the problem of creating an accurate bare earth model can be stitched together in one seamless model, as shown below. This process is as simple as opening each model, even if they are saved in separate files, copying the models, and pasting them onto a template where they can be joined together as one cohesive element. The output from one model simply becomes the input to the next model. The models essentially function as a single, complete start to end solution. Not only does this all-in-one model require the designation of only one input file, but it also has the ability to run in batch mode. This mode of operation requires a folder of input files that have each been labeled by an automated output naming convention. Also possible is the distribution of input processing simultaneously across multiple processors.



Data

The following data was used during testing of the Spatial Modeler environment:

- Subset portion of the 5800 DMC II 140 frames
- ISAT Project files provided by TXDOT for point cloud generation
- Orthorectified imagery from project for RGB encoding of LAS files
- Individual Spatial Models for each workflow
- Combined Spatial Models into one for streamlined workflow



Results

This document provides some guidance on how to use point cloud operators in the ERDAS IMAGINE Spatial Modeler. Beyond the scope of this document, these operators could be combined with remote sensing and other operators that exist in the Spatial Modeler. Stringing operators together and batch processing the model on multiple files, while also taking advantage of multiple processors, can dramatically increase productivity.


Coupling the point cloud operators now available in the Spatial Modeler environment of ERDAS IMAGINE with the Remote Sensing capabilities that already exist greatly improves the bare earth output from point clouds. The methodology in this paper can be used with Lidar point cloud data or photogrammetrically-derived point cloud data. Both point cloud types can benefit from the new functionality found in the spatial modeler and, if desired, create a black box approach to editing DSMs.


With these new operators in place the TXDOT is able to reduce processing time and improve their orthorectification results. By eliminating objects and vegetation from their point clouds, they are able to produce accurate orthorectified imagery, especially along the interstate roads where they are most concerned about orthorectification quality. Furthermore, once the model is created, new datasets can be fed to the model at any time and processed when system resource are available. This black box approach allows the data to be processed during non-business hours, which increasing productivity during working hours.



Contact us

For more information, please contact us at:

 marketing.us.gsp@hexagon.com

 +1 877 463 7327

 <https://go.hexagongeospatial.com/contact-us-today>

About Hexagon

Hexagon is a global leader in sensor, software and autonomous solutions. We are putting data to work to boost efficiency, productivity, and quality across industrial, manufacturing, infrastructure, safety, and mobility applications.

Our technologies are shaping urban and production ecosystems to become increasingly connected and autonomous — ensuring a scalable, sustainable future.

Hexagon's Geospatial division creates solutions that deliver a 5D smart digital reality with insight into what was, what is, what could be, what should be, and ultimately, what will be.

Hexagon (Nasdaq Stockholm: HEXA B) has approximately 20,000 employees in 50 countries and net sales of approximately 4.3bn USD. Learn more at hexagon.com and follow us @HexagonAB.

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