Cloud Point Data Processing

Understanding software components of data registration, editing, modeling and viewing through Cyclone and AutoCAD

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CVEN 5396; May 02, 2017

1. Introduction to Point Cloud Data

HDS and LiDAR data live in a 3D space typically defined by an orthogonal grid system, or more conveniently a suitable GCS. Elaborate surface modeling techniques give life to discrete, perplexing point cloud datasets. Even sparsely dense point clouds demand optimal data processing and rendering capabilities. Therefore, it is often the associated surface models that are desired and implemented into geospatial engineering workflows and software platforms.   Heavily rooted in the Mathematical niche of Numerical Analysis, the transformation of point cloud data to a relatable and reliable entity is complex and intricate process.

2. Methods, Software, and Data

We will be using the point cloud software Cyclone for all data registration, processing, cleaning, modeling, sub-cloud formation and object/surface generation. After sufficient results, we will then import data components into AutoCAD Civil 3D. The utilization of two very different platforms will magnify both strengths and limitations of the software in the context of point cloud data.

Point cloud datasets were collected by a Faro scanner and expressed as FLS file formats. The project site is centered about the Administration Building of UCDenver location within Auraria campus in downtown Denver, Colorado. We will be incorporating data from a total of 12 collection sites, each housing up to 20 million data points. Included in project information is a JPEG image of each scan world as well as a schematic sketch of the project vicinity as seen to the right. Components to identify in the diagram are the location of targets, scanners as well as adjacent feature objects such as nearby buildings, walkways, and major roadways

(Speer Blvd.). Familiarity of the project site is essential for any data scanning assignment. Collection was performed March 4th, 2017.
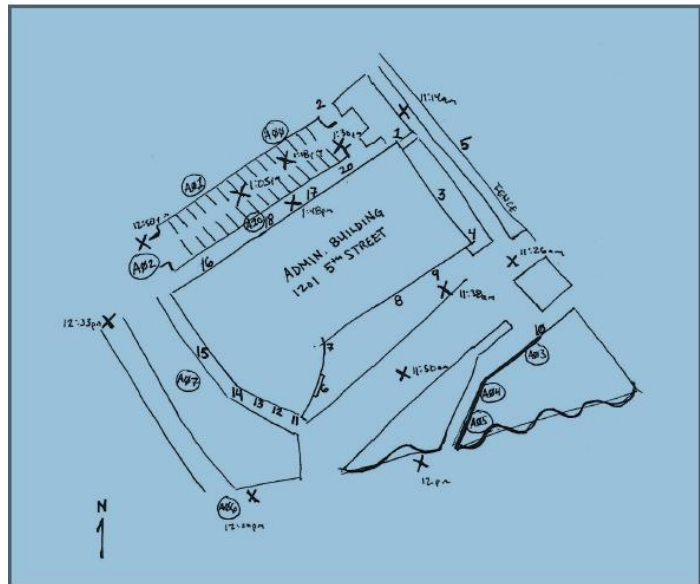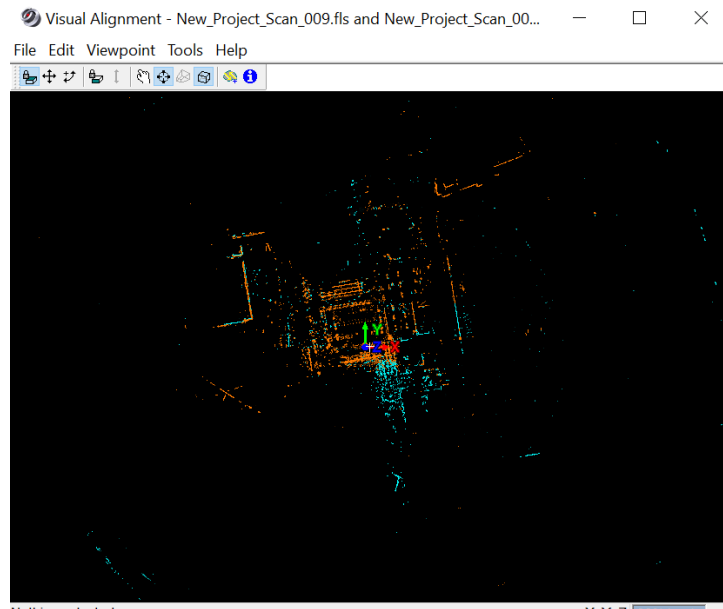
3. Point Cloud Registration

A batch import of individual FLS data files populated our project database with 12 scan worlds. Unfortunately, spherical targets were not automatically detected upon import. Also, be aware of the lack of georeferenced control points; data is without a linked position to an absolute location on earth, although we do know it's whereabouts.

Point cloud registration is essential for any multi-station scanning project. It acts as the foundation for suitable data preparation and model design. If executed properly, cloud point registration creates a complete functioning point cloud network by aligning all data accurately in the project space. Although there are many registration methods offered by the software, we will undergo

manual registration through the dual pairing of scan station data. As there are 12 collection sites total, there exist 78 (11+10+…+1) possible piecewise sets, although only a handful will need to be integrated.

3.1.   Manual Registration via Visual Alignment

First, create a new registration and import all scan world. Under visual alignment, manually sync point cloud data of the two selected sets. It is important to access all Euclidian direction combinations during manual registration. A toggled elevation view allows users to determine proper assignment within the Z plane. Essentially, the desired outcome is a tightly constrained unified network of point clouds where each individual scan world is linked to the overall system. One scan world will be selected as the *home scan world* acting as a static control reference for the whole network of data. Throughout the registration process, be mindful of the following,


- Continually *optimize cloud registration* as well as scan world pairings.

- Adjust the home scan world to one that is well established within the working network.

- You will likely have parings that are either not aligned or are aligned but "underconstrained" (need more links or improve alignment).

- It is important to consider both group error (how well the alignment syncs with the overall network) and error (how well the two data sets align with each other).

- If scan station(s) are causing high errors, consider removing them from the registration.

- View intem results (a model space) of your current, working registration.

After tedious and timely manipulation, an adequate registration was established with minimal error. It incorporated all 12 scan worlds and included a total of 26 dual-pairing alignments. Now we must freeze the registration and launch a new model space displaying our universal scan world.

| Constraint ID	ScanWorld	ScanWorld	Type	St...	Wei...	Error	Error Vector	Group Error
Cloud/Mesh 49	New_Project_Scan_005.fls	New_Project_Scan_007.fls	Cloud: Cloud/Mes...	On	1.0000	0.216 m	aligned [0.048 m]	0.217 m
Cloud/Mesh 52	New_Project_Scan_006.fls	New_Project_Scan_007.fls	Cloud: Cloud/Mes...	On	1.0000	0.179 m	aligned [0.026 m]	0.179 m
Cloud/Mesh 77	New_Project_Scan_006.fls	New_Project_Scan_005.fls	Cloud: Cloud/Mes...	On	1.0000	0.172 m	aligned [0.016 m]	0.172 m
Cloud/Mesh 3	New_Project_Scan_001.fls	New_Project_Scan_004.fls	Cloud: Cloud/Mes...	On	1.0000	0.142 m	aligned [0.027 m]	0.142 m
Cloud/Mesh 51	New_Project_Scan_006.fls	New_Project_Scan_008.fls	Cloud: Cloud/Mes...	On	1.0000	0.102 m	aligned [0.028 m]	0.102 m
Cloud/Mesh 53	New_Project_Scan_005.fls	New_Project_Scan_008.fls	Cloud: Cloud/Mes...	On	1.0000	0.101 m	aligned [0.043 m]	0.100 m
Cloud/Mesh 74	New_Project_Scan_007.fls	New_Project_Scan_000.fls	Cloud: Cloud/Mes...	On	1.0000	0.089 m	aligned [0.033 m]	0.088 m
Cloud/Mesh 8	New_Project_Scan_002.fls	New_Project_Scan_004.fls	Cloud: Cloud/Mes...	On	1.0000	0.079 m	aligned [0.016 m]	0.080 m
Cloud/Mesh 57	New_Project_Scan_001.fls	New_Project_Scan_002.fls	Cloud: Cloud/Mes...	On	1.0000	0.074 m	aligned [0.010 m]	0.075 m
Cloud/Mesh 43	New_Project_Scan_003.fls	New_Project_Scan_004.fls	Cloud: Cloud/Mes...	On	1.0000	0.060 m	aligned [0.020 m]	0.060 m
Cloud/Mesh 67	New_Project_Scan_006.fls	New_Project_Scan_011.fls	Cloud: Cloud/Mes...	On	1.0000	0.050 m	aligned [0.014 m]	0.050 m
Cloud/Mesh 42	New_Project_Scan_002.fls	New_Project_Scan_003.fls	Cloud: Cloud/Mes...	On	1.0000	0.046 m	aligned [0.009 m]	0.046 m
Cloud/Mesh 76	New_Project_Scan_001.fls	New_Project_Scan_003.fls	Cloud: Cloud/Mes...	On	1.0000	0.045 m	aligned [0.013 m]	0.045 m
Cloud/Mesh 75	New_Project_Scan_008.fls	New_Project_Scan_000.fls	Cloud: Cloud/Mes...	On	1.0000	0.035 m	aligned [0.018 m]	0.035 m
Cloud/Mesh 66	New_Project_Scan_001.fls	New_Project_Scan_010.fls	Cloud: Cloud/Mes...	On	1.0000	0.033 m	aligned [0.031 m]	0.033 m
Cloud/Mesh 48	New_Project_Scan_007.fls	New_Project_Scan_008.fls	Cloud: Cloud/Mes...	On	1.0000	0.031 m	aligned [0.012 m]	0.032 m
Cloud/Mesh 69	New_Project_Scan_006.fls	New_Project_Scan_010.fls	Cloud: Cloud/Mes...	On	1.0000	0.031 m	aligned [0.011 m]	0.029 m
Cloud/Mesh 73	New_Project_Scan_009.fls	New_Project_Scan_000.fls	Cloud: Cloud/Mes...	On	1.0000	0.028 m	aligned [0.024 m]	0.028 m
Cloud/Mesh 78	New_Project_Scan_009.fls	New_Project_Scan_005.fls	Cloud: Cloud/Mes...	On	1.0000	0.024 m	aligned [0.015 m]	0.027 m
Cloud/Mesh 44	New_Project_Scan_004.fls	New_Project_Scan_006.fls	Cloud: Cloud/Mes...	On	1.0000	0.025 m	aligned [0.036 m]	0.025 m
Cloud/Mesh 72	New_Project_Scan_010.fls	New_Project_Scan_000.fls	Cloud: Cloud/Mes...	On	1.0000	0.023 m	aligned [0.025 m]	0.023 m
Cloud/Mesh 65	New_Project_Scan_010.fls	New_Project_Scan_009.fls	Cloud: Cloud/Mes...	On	1.0000	0.024 m	aligned [0.012 m]	0.021 m
Cloud/Mesh 71	New_Project_Scan_007.fls	New_Project_Scan_011.fls	Cloud: Cloud/Mes...	On	1.0000	0.020 m	aligned [0.012 m]	0.020 m
Cloud/Mesh 68	New_Project_Scan_008.fls	New_Project_Scan_011.fls	Cloud: Cloud/Mes...	On	1.0000	0.017 m	aligned [0.011 m]	0.020 m
Cloud/Mesh 64	New_Project_Scan_011.fls	New_Project_Scan_010.fls	Cloud: Cloud/Mes...	On	1.0000	0.015 m	aligned [0.012 m]	0.016 m
Cloud/Mesh 70	New_Project_Scan_009.fls	New_Project_Scan_011.fls	Cloud: Cloud/Mes...	On	1.0000	0.010 m	aligned [0.013 m]	0.000 m

4. Data Cleaning Techniques

All point cloud data includes some factor of "noise"; unwanted false data commonly caused by intense sunlight, atmospheric moisture, pollution, or highly reflective nearby objects. The existence of problematic data points causes overall point cloud would be consumed with error would not be deemed as creditable. Just from initial glance, original registration model space contains two distinct radius clouds of noise surround our project site.
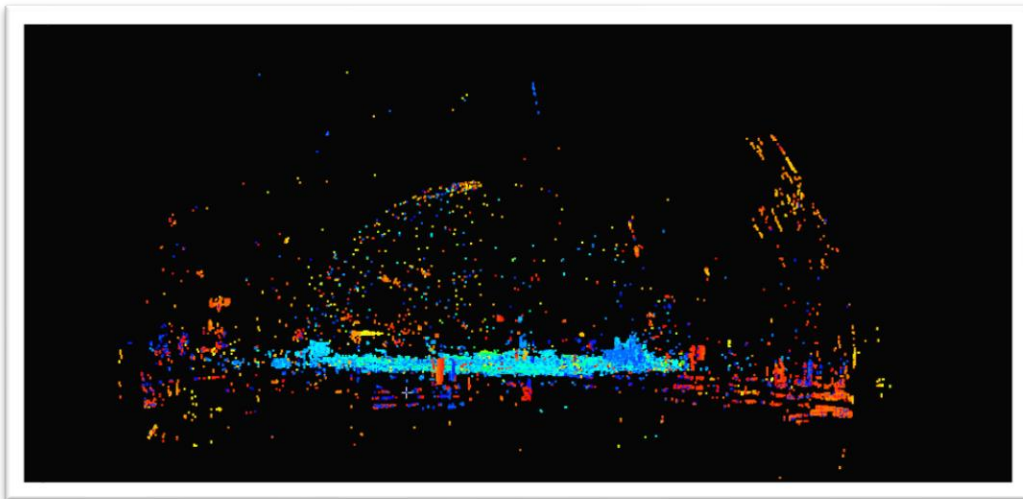
4.1.   Limit Box

One way to quickly segregate objects from the entirety of the point cloud is via limit box. This creates a new model space session while making data viewing manageable as workspace is less congested. Methods of limit box formation include both cursor and fencing. The extents can be adjusted after creation. This function should be considered when point cloud data is vast with many objects of interest. Although not directly related to data cleaning, by creating a quick limit box, we are able to evaluate the quality of our registration; does ground data and building vertices align naturally? A limited box view of the Admin Building seen here can facilitate strategical and thorough data cleaning.
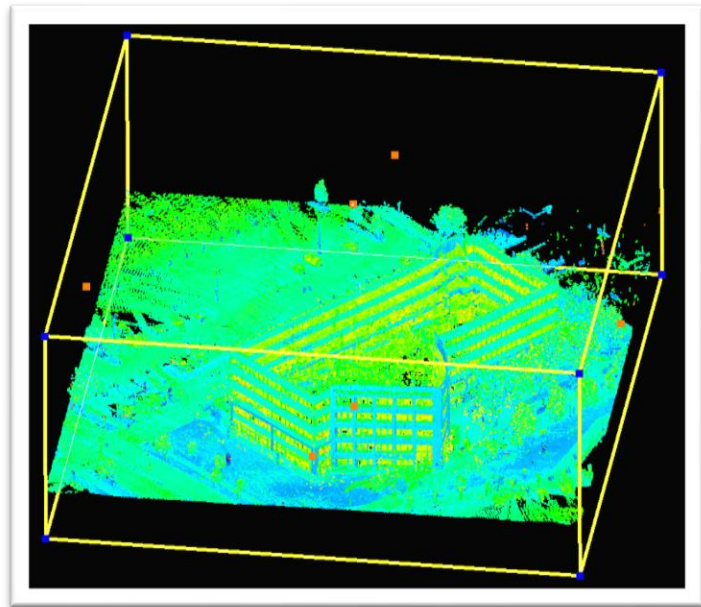
4.2.   Fencing

Perhaps most frequently used, fencing allows users to quickly bulk select data of interest or of noise to delete. Boundaries are created via rectangle, circular or free-formed polygon. We can either delete data inside or outside the established fence or launch a new model space from the selection. Fencing data is often the finalizing cleaning step, after convenient "cleaning-friendly" views have been established. We will discuss these conveniences next.
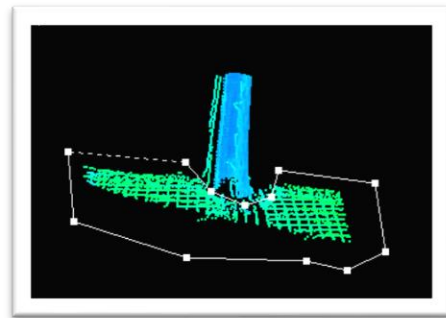

4.3.   Active Reference Plane and Cut Plane

Initial reference plane placement usually defaults to the scanner position. Orientation of the object thereafter is completely user-defined. Panning and adjusting Z values were utilized most for this project, however. By adjusting parameters such as grid spacing, line weight and color we can create a welcoming data viewing environment.

As the name suggests, reference planes are often coupled with other objects to establish a spatial orientation of reference. Cut plane views are often generated by defining a positive and negative distance (thickness) from the reference plane, creating a cross-section view of point cloud information. This method was used to eliminate surface data from the Admin Building and vegetation sub-clouds.
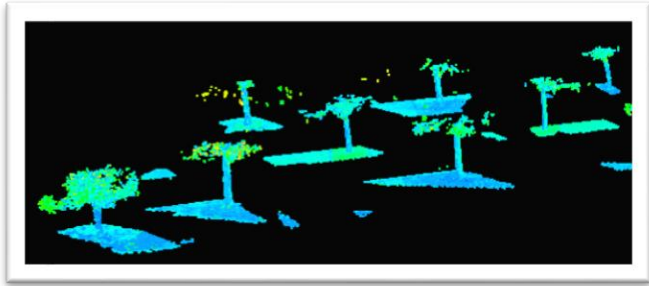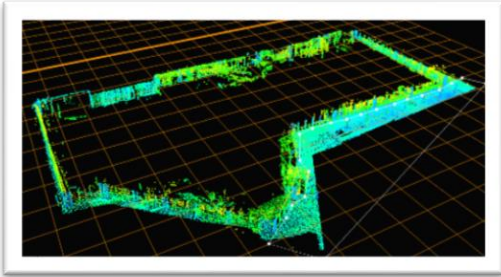
As seen below, implementing limit box, fencing, reference and cut plane data cleaning techniques resulted in two distinct sub-clouds of the Admin Building and vegetation.
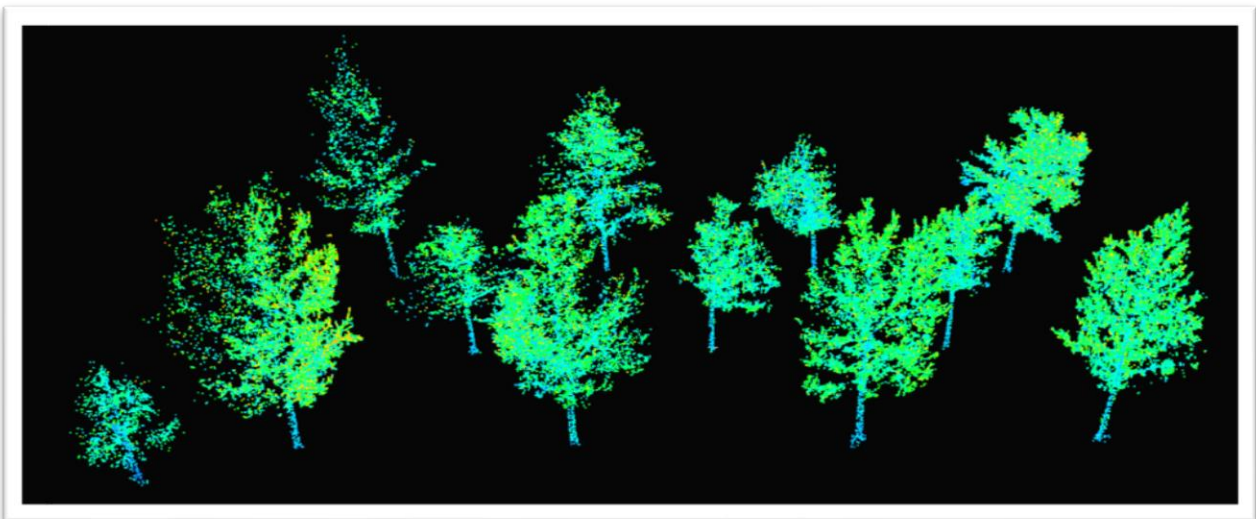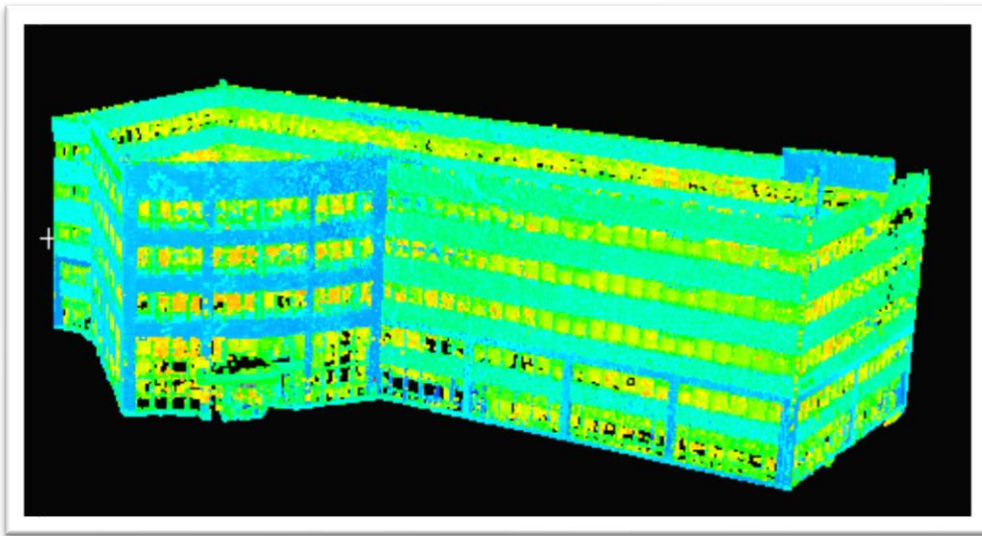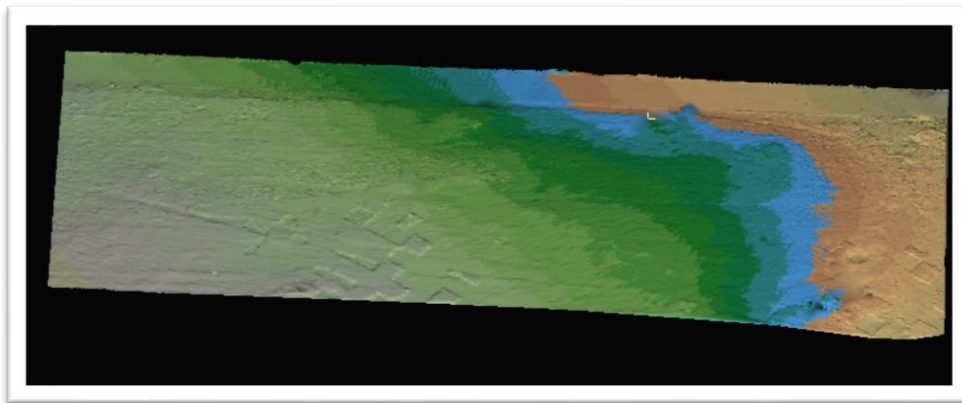
5. Surface Modeling

5.1.   Region Grow

Cyclone offers a wide scope of surface models based off of point cloud data. Before surface objects can be accurately generated, it is essential to first establish surface definition parameters; computationally answering the question of what makes a grouping of points a surface? Region grow via smooth surface is a tool that helps segregates a surface from other nearby objects. We will execute this command for ground data just north of the Admin Building. Also, it is advised to unify all point clouds before computing region grow. Consider assigning future surfaces to separate layers. This will simplify data viewing and eventually exportation.

5.2.   Creating Mesh Surface

A mesh model, a 3-D representation of discrete point cloud data, is just one of many surface creation types available in Cyclone. We will apply a 3D triangularization of the data subset defined by the region grow function to produce a TIN surface mesh. Using a wire-frame view, we can identify areas where we may need to edit data as linking parameters have been over utilized ("stretched too far"). If holes appear close to the parameter, consider simply deleting that area. Otherwise, use Cyclones
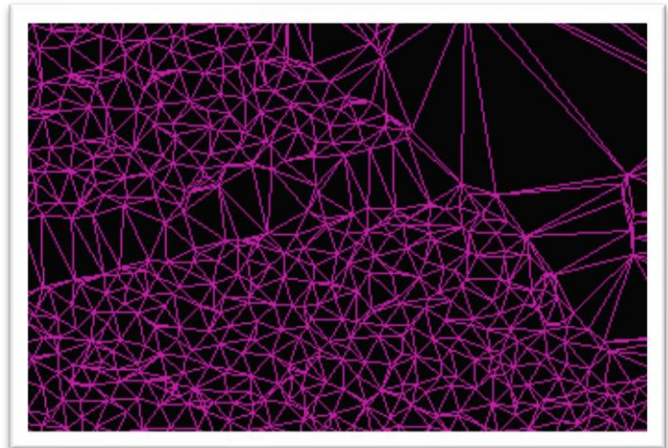

built-in function to fill voids in mesh surface. Another stylized view option displays a topographic map; displaying elevation based on specified color ramp. Run the optimize mesh tool before continuing.

5.3.   Generating Contours

Another valuable GIS surface compatible with Cyclone is expressed as contours. Although it represents topographic data, the resulting output is not a 3D surface model. We will latter see that contour data exports hold a polyline geometry. When generating contours from a mesh, be mindful of interval assignment as this will directly affect computation runtime.
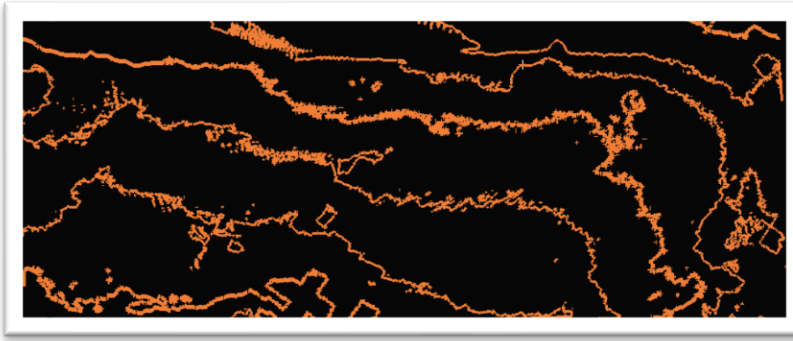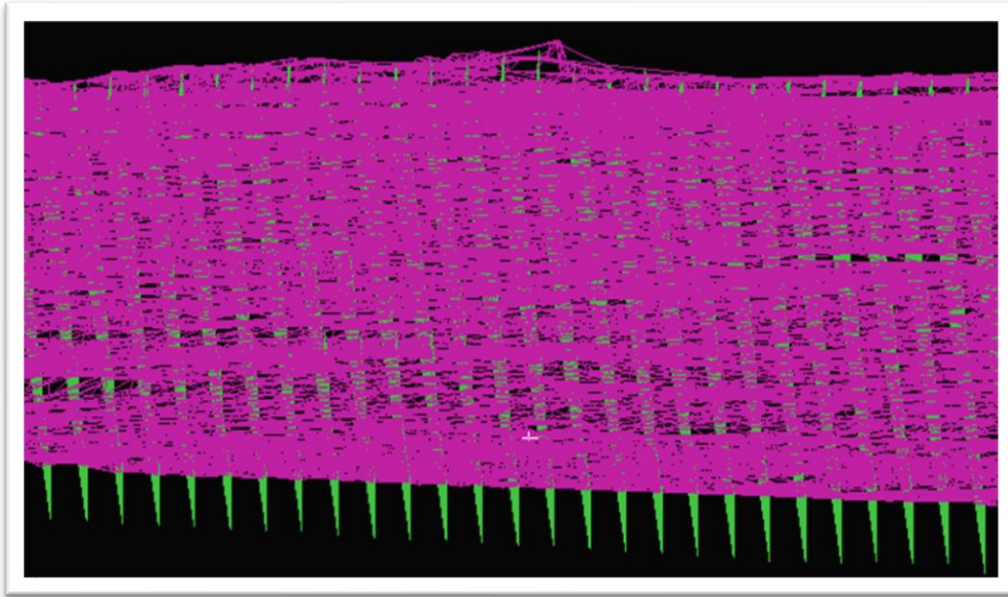
5.4.   Surface Analysis

Analyzing surface statistics permits a numerically driven understanding of generated surfaces, allowing us to further assess creditability. Let's observe how much a surface model deviates among itself. A surface with no deviation is of course completely planar. Such analysis is achieved by comparing a reference plane to the surface of intersest. We can view a summary table of deviation information. Note that not all change in height (delta) values are present as our generated mesh (Z1) doesn't cover as much "space" as the reference (Z2). This is no surprise considering that the TIN surface is only an approximate model. Heavy outliers in the delta field could indicate possible errors in the surface model, depending on true elevation. Although there were no obvious outliers, there were a significant number of null Z1 values; voids in the mesh are either caused by lack of data or poor region grow results.

Measure Surface Deviation Results —				
Origin Reference Plane" - "TIN 1" (mesh)				
X	Y	Z1	Z2	Delta
15.573	-10.950	1615.076	1614.848	-0.228
15.573	-10.645	1615.090	1614.848	-0.241
15.573	-10.340	1615.081	1614.848	-0.233
15.573	-10.035	1615.066	1614.848	-0.218
15.573	-9.730	1615.063	1614.848	-0.215
15.573	-9.426	1615.077	1614.848	-0.228
15.573	-9.121	1615.065	1614.848	-0.217
15.573	-8.816	1615.088	1614.848	-0.239
15.573	-8.511	1615.107	1614.848	-0.259
15.573	-8.206	1615.116	1614.848	-0.268
15.573	-7.902	1615.128	1614.848	-0.280
15.573	-7.597	1615.133	1614.848	-0.285
15.573	-7.292	1615.138	1614.848	-0.289
15.573	-6.987	1615.140	1614.848	-0.291
15.573	-6.682	1615.140	1614.848	-0.291
15.573	-6.378	1615.147	1614.848	-0.298
15.573	-6.073	1615.151	1614.848	-0.303
15.573	-5.768	1615.164	1614.848	-0.315

Similarly, we can look at volumes above or below the reference plane. This differs from the previously discussed deviation results given that the function's domain is more continuous. Visually inspect mesh volume results below. Other common measurement tools within a model space include distance, surface area and mesh to points deviation (how well approximate surface model fits with raw source data by calculating linear distances).

In addition to the topographic ground surface sub-cloud, a small section of ROW was segregating using discussed surface creation techniques. The red/orange coloring likely represents a roadway pot-hole as these colors indicate a lower elevation.
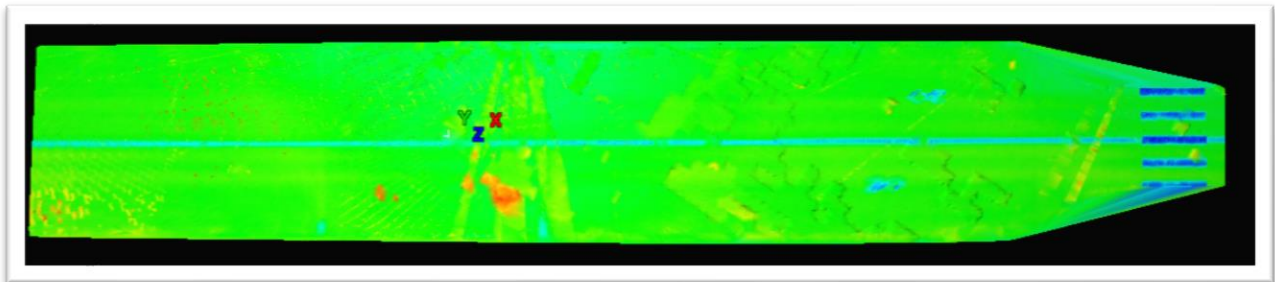

6. Implementation of Data into AutoCAD Civil 3D

6.1.   Export Data from Cyclone

Within an active model space, numerous different format options exist for data/object export. It is likely that we will need to perform a reduction in point cloud data as file sizes are extremely large. It is doubtful that CAD will be able to display all point data within a model space regardless. The following objects and surfaces were exported.

AutoCAD 2D DXF R12 Format (*.dxf)
AutoCAD DXF R12 Format (*.dxf)
Binary Point Clouds - PTG Format (*.ptg)
Binary Point Clouds - PTZ Format (*.ptz)
COE Format (*.coe)
E57 Scan Format (*.e57)
Intergraph SDNF 3.0 (*.sdf;*.sdnf)
LandXML (*.xml)
Ortho Image - Tagged Image File Format (*.tif)
Text - All ASCII Files
Text - Mesh Format (*.msh)
Text - PTS Format (*.pts)
Text - PTX Format (*.ptx)
Text - SIMA Format (*.sim)
Text - SURVEY Format (*.svy)
Text - TXT Format (*.txt)
Text - XYZ Format (*.xyz)
Text - PTS Format (*.pts)

- Admin Bldg → PTS
- Vegetation →PTX
- Region Grow Surface → XML / PTS
- ROW → XML / PTS
- Contours --> DXF
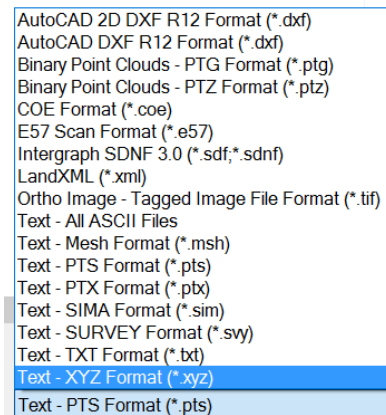
6.2.   File Import into CAD and Style Editing

6.2.1.   Vegetation Data
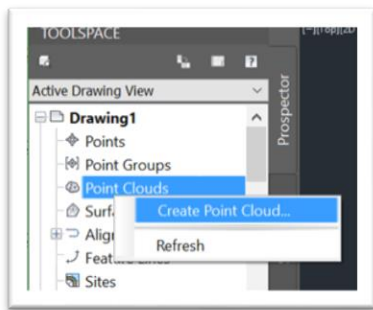
AutoCAD Civil 3D is compatible with commonly used surface models formats, yet importation methods greatly depend on the file type. First create a point cloud object within the toolspace by either importing a raw point cloud file (PTS, PTX, LAS, etc.) or by selecting a previously constructed ISD point cloud database. Choose the point cloud display style (elevation, classification, single color, etc.) during import or within model space drawing via style properties. A critical C3D function hot-key to remember when engaging with any 3D object is "3dorbit" as this will allow you to freely rotate the object.


6.2.2.   Admin Building Point Cloud

Again, create a point cloud object via PTS import. Be aware that the file size is over one gigabyte and initial import may be very slow. (The DXF file version for the same point cloud was three gigs!)   One noteworthy observation is that the number of points displayed is less than 4% of total points housed in database (31 million). The lack of display rendering capabilities for large point cloud data is a prominent limitation of CAD software.
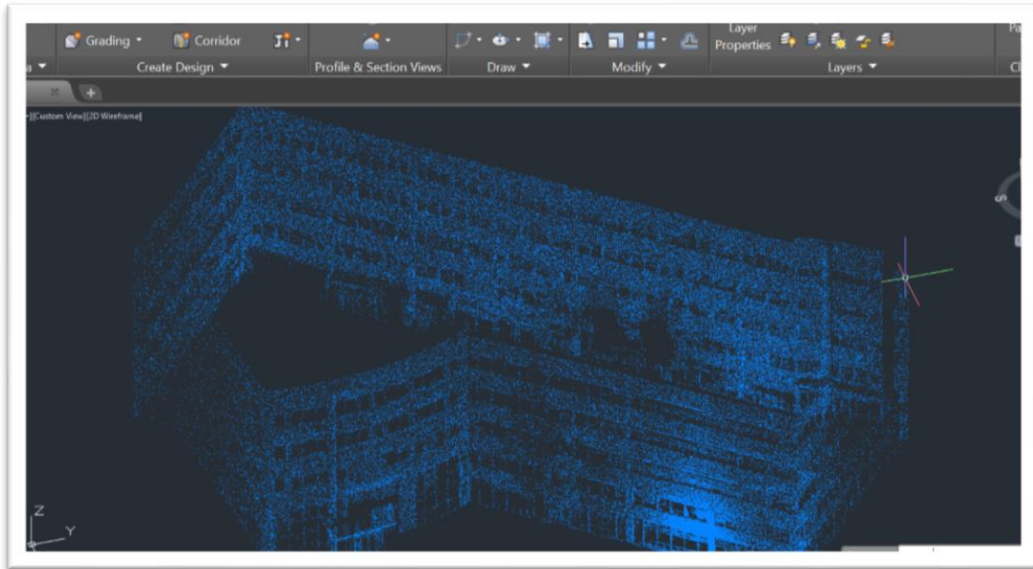
6.2.3. ROW Surface

AutoCAD C3D is much more user-friendly toward Land XML files. We can simply import ROW.xml rather than navigating through an installation wizard and storing point cloud data in an exterior database. The software will immediately recognize the MESH TIN as an object. Adjust display view styles as desired; here we see the familiar wire frame option. An alternative approach if a pre-established mesh surface is not availble would be to create a point cloud data set by importing the significant ROW.pts. Then create a C3D surface object from these points.
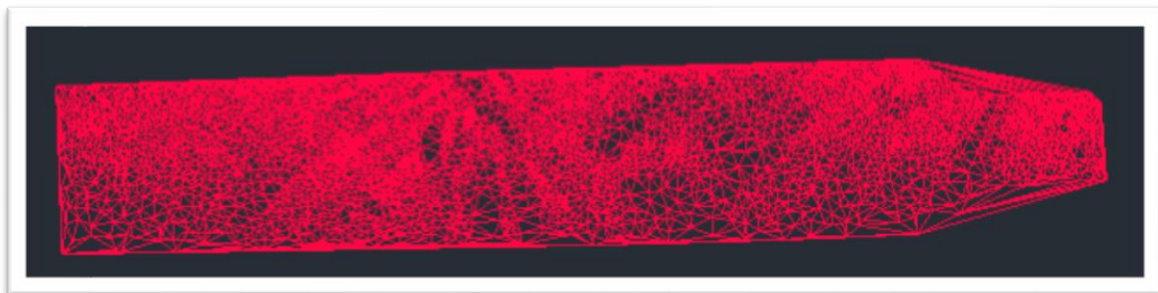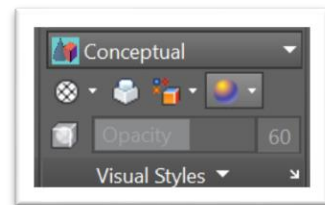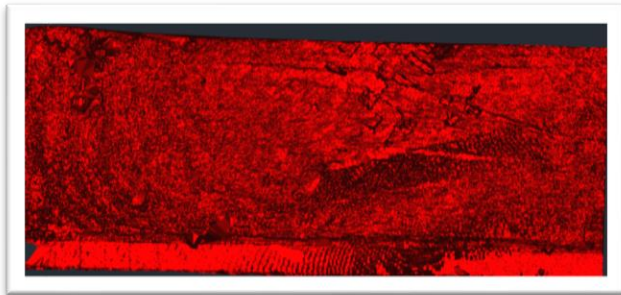
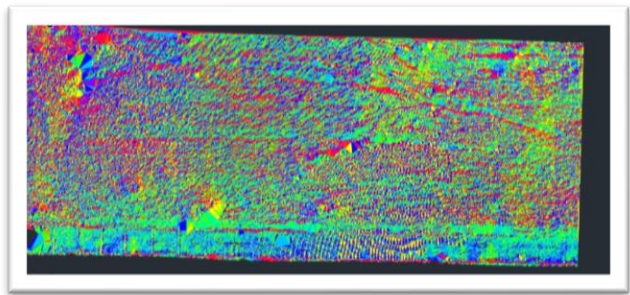### 6.2.4. Ground Surface and Style Editing

One strength of working with 3D objects in C3D is ability to activate different data components for easily switchable display options. The ground surface XML is declared as an object during import.   See three varying display styles expressed simply by turning off and on different data components.
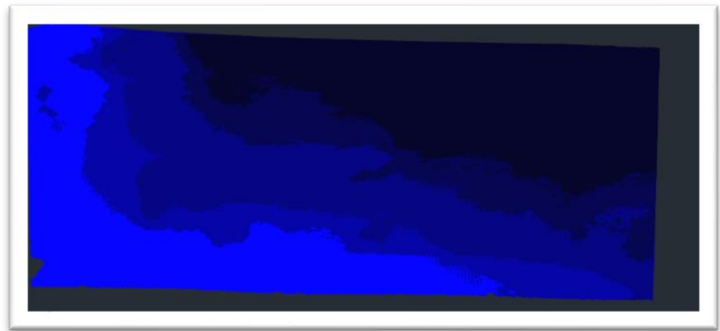

Elevation

Slopes

Directions (8 hydro flow directions)

6.2.5. Contours

Out of all export file types seen in this project, Contours.dxf will be the most interoperable with the software as it is already in an official CAD format and contour data will be encoded as C3D object; 3D polyline. Therefore, we can edit the polyline as need. Being able to import DXF formatted data is extremely convenient compared to PTZ/PTS.
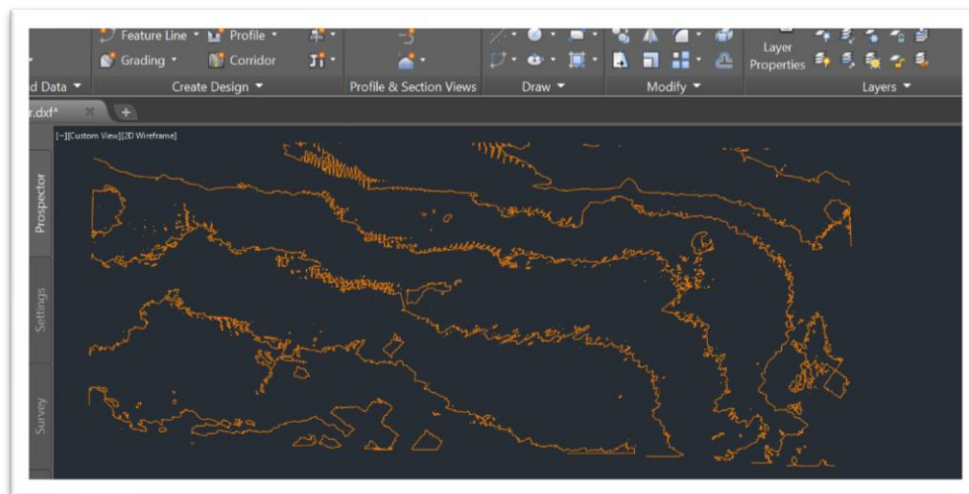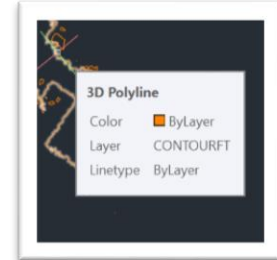
7. Conclusions

This project showed us the strengths as well as limitations of point cloud processing software, Cyclone. Data editing and display rendering abilities stand out noticeably. We first preformed manual registration to align all scan stations. Next, we cleaned data via fencing, limit box and cut plane/reference plane methods. Surfaces models created included mesh and contours. Lastly, we exported data to appropriate formats and imported them into CAD. AutoCAD C3D can apply various styles to imported objects/data, but has limited operability overall compared to Cyclone.