

CES226806

Using Point Clouds and Large Datasets in InfraWorks

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Learning Objectives

- Learn how to import and manage large data sets, including point clouds, into InfraWorks
- Discover how to use feature extraction to identify vertical features within an InfraWorks model
- Learn to style and configure the extracted vertical features to highlight the most-important features of the model
- See the process used to create a storyboard fly-through to present to stakeholders

Description

Point clouds can be a wealth of information for modeling and design projects, and the large data sets of point clouds can provide amazingly detailed models when viewed in InfraWorks software. But managing these data sets and importing the point clouds can be a challenge. And then, once you have the point cloud imported, what's next? In this session, we will show how to create a model from scratch and how to import large point clouds and data sets. We'll demonstrate a simple but effective method to manage large collections of point clouds when bringing them into InfraWorks, and then show how to use the point clouds to extract vertical features such as transformers, poles, and street furniture. This method can be employed for a variety of items, and then the features can be styled to reflect the goals for your 3D model. We will also walk through the process of creating a storyboard and a fly-through that will impress your stakeholders and provide detailed information in a visually informative model.

Speaker(s)

Stephen Brockwell founded Brockwell IT Consulting to provide independent business and technical leadership for the Geospatial community. His leadership at Autodesk, where he was a Senior Business Development Manager and Director of Product Management, provided the path for advanced GIS initiatives. Before joining Autodesk, Stephen was on the team for SHL VISION* Solutions, developers of the first all-relational GIS based on Oracle. Qwest Communications and First Energy, among others, still use the underlying technology he developed. Recently, Stephen has been involved in enterprise-level projects for Nevada Energy and First Energy; field mobility projects for City of Alexandria and Welland Hydro; and product development for Autodesk. With his experience in the Geospatial industry including government and private sector, Stephen has been a regular instructor at Autodesk University. He is committed to efficient, low-cost solutions to implement GIS technology for infrastructure design.

Richard Horrocks focuses on supporting large, enterprise utility customers and government customers, providing both software and solution support as well as consultative problem solving. Richard has extensive experience in the analysis and development of spatial data and GIS. Richard has a dynamic, multi-disciplinary, customer-focused approach to technology and infrastructure, with many years of experience in varying working environments. He is highly versatile and able to engage in any type of task, technology or technology usage, with extensive experience in the North America and Latin-America markets.

Introduction

Point cloud data is becoming more widely available, less expensive, and more accurate. The processing platforms—affordable high-end laptops, relatively inexpensive desktops, and virtualized platforms with Nvidia grid technology and GPU processing capabilities mean that using the data is within the reach of the serious engineer and the student. The tools to give structure to point clouds are numerous and functionally rich. Many tools are available as open source. And we have the ability to turn points into meaningful data such as ground surfaces, measurement surfaces, and as a source for automated feature extraction.

The City of Kingston, Ontario, Canada is working with us and our partner, Cyclomedia, to improve engineering business processes using city-wide panoramic imagery and mobile Lidar data that is accurate, precise, and photogrammetrically matched so that the Lidar data gives a very high-quality visual rendering of the street-level city scape.

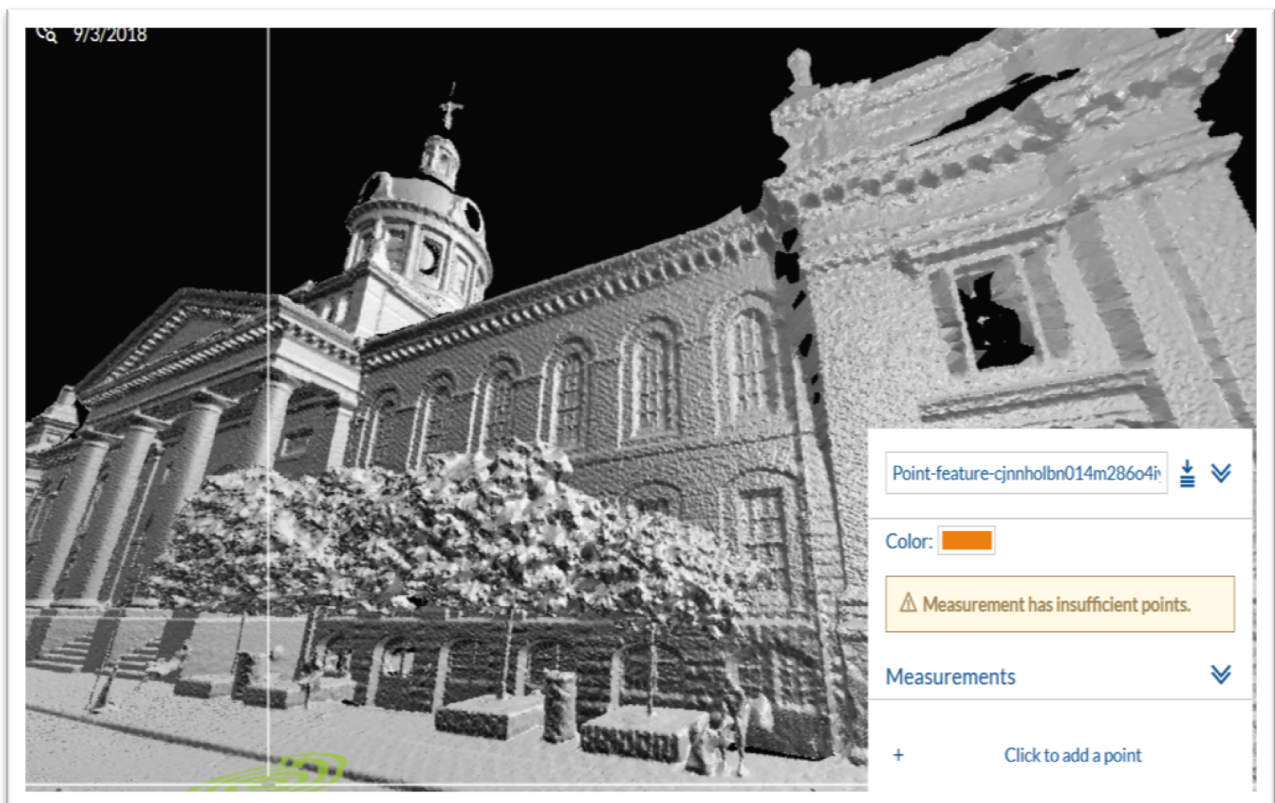


Figure 1 - Measurement Surface for Kingston City Hall

Scanner Specifications

The mobile scanner used is a Velodyne HDL-32E with the following specifications:

- 32 separate beams
- Average point density recording @ 40 km/hr:

- 2500 points/m² on the ground
- 1900 points/m² on wall at 10 m distance
- 1500 points/m² on ceiling at 4.5 m distance
- 700.000 points/sec
- 70 meter data range
- File size:
 - 255 - 375 MB / km @ 40 km/hr
 - 170 - 250 MB / km @ 60 km/hr
 - 127 – 157 MB / km @ 80 km/hr
- Position accuracy:
 - Absolute: avg standard deviation 10 cm
 - Relative: < 2 cm

Noise Concerns on Sunny Days

In the image below, there is a higher than expected degree of apparent noise in the point cloud.



Figure 2 - Noise Resulting from Very Bright Sunlight

Based on analysis of the pattern of the noise and the dispersion angle compared to the angle of the shadows of poles and trees, it is likely that the noise results from air-borne particulate matter

directly in the path between the sensor and the sun. The scan was conducted on a very bright day.

When working with this data in large, merged datasets, this noise appears to cause issues with ground surface detection in InfraWorks. From a visual perspective, the noise interferes with the clarity of the area under study.

Eliminating the noise became one of the most important activities on our project. Initially, we tried to use Recap but found that the noise-reduction tools (based on intensity measures) were not the best choice for this particular kind of noise, which happened to be across the spectrum in intensity.

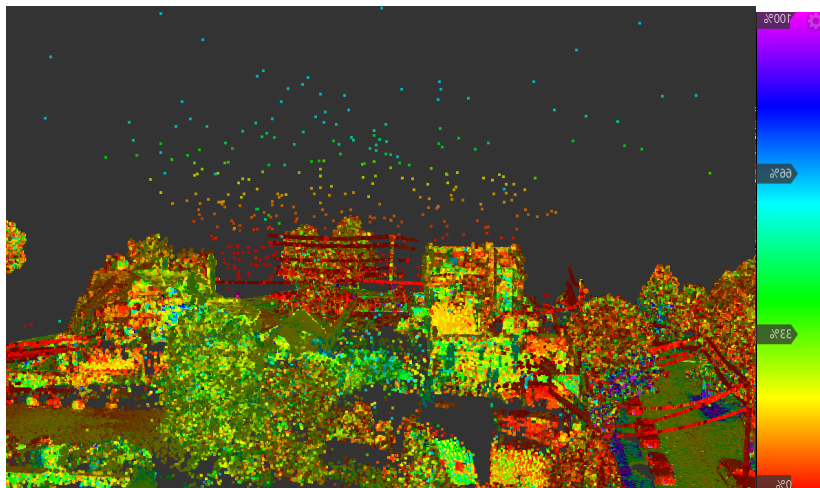


Figure 3 - Intensity of Noise is Variable

The panoramic image, shown below, confirms that sunlight was very bright and above the horizon at an angle that supports this hypothesis.



Figure 4 - Panoramic Image Showing Solar Angle and Brightness

Tools for working with Point Clouds

We investigated several alternatives to eliminate the noise in detail.

1. PDAL (Point Data Abstraction Library)—an open source command line tool
2. Cloud Compare—an open source GUI platform for point cloud editing analysis
3. 3DReshaper—a licensed tool for point cloud processing
4. Recap—the Autodesk tool for aggregating, editing and visualizing point cloud data and preparing it for use with Autodesk products.

PDAL

The Point Data Abstraction Library (PDAL) is an open source command line tool for processing point cloud data. It has an extensible architecture, a very easy-to-use mechanism for pipeline processing large volumes of data through multiple stages of readers, filters, and writers.

The pipeline command accepts a simply formatted JSON file that includes

1. The file to read
2. The list of processes to run on the data (translate, project, filter, merge)
3. The file to write

Our use of PDAL is illustrated schematically below.



The JSON file for the pipeline command contains the following specifications for the pipeline:

```

noise4.json
1  {
2    "pipeline": [
3      "filtered_7623_97963.laz",
4      {
5        "type": "filters.outlier",
6        "method": "radius",
7        "radius": 0.1,
8        "min_k": 4
9      },
10     {
11       "type": "filters.range",
12       "limits": "Classification![7:7]"
13     },
14     "pdc_r_filtered_7623_97963.las"
15   ]
16 }

```

The input file (by default using readers.las)

Statistical outlier filter based on a small radius of 10cm in which no more than 4 other points live.

Filter the noise elements.

Save the result to this uncompressed .las file.

The command is run with the simple command line:

```
D:\Kingston>pdal pipeline noise4.json
```

Instructions on the installation of PDAL can be found at <http://pdal.io>.

CloudCompare

Cloud Compare is another open source tool that provides extensive point cloud processing tools in a visual environment with a reasonably easy-to-use viewer.

Unlike several other tools, you can simply open files of supported types.

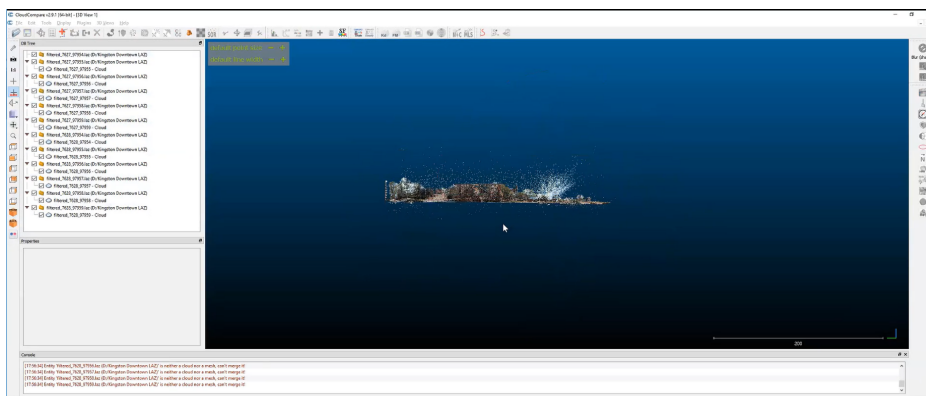


Figure 5 - CloudCompare Loading Multiple LAZ Files—Noise is Clearly Visible

Once the files are loaded, it's easy to merge them. Note that merging is a good idea when reducing noise, since noise on the boundary of multiple scans can depend on points in adjacent scans.

One potential deficiency with CloudCompare—to nominally improve performance and minimize loss of precision in the computations—is the use of offsets which must be applied to all files and then reapplied when saving.

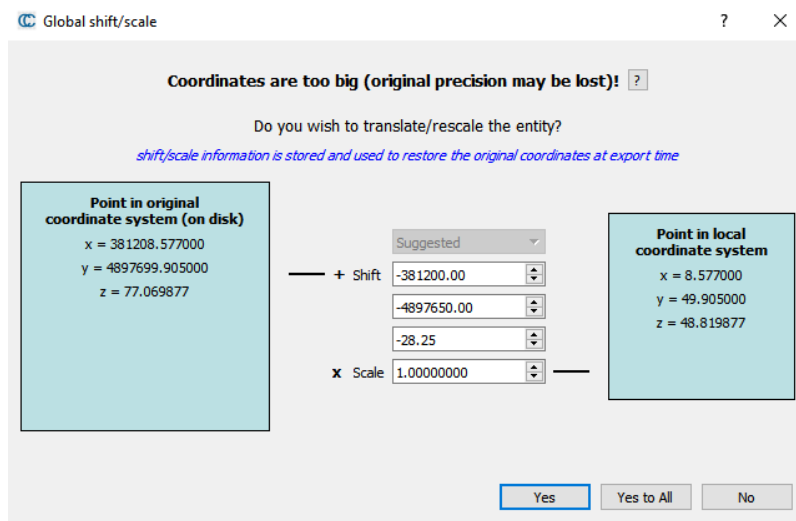
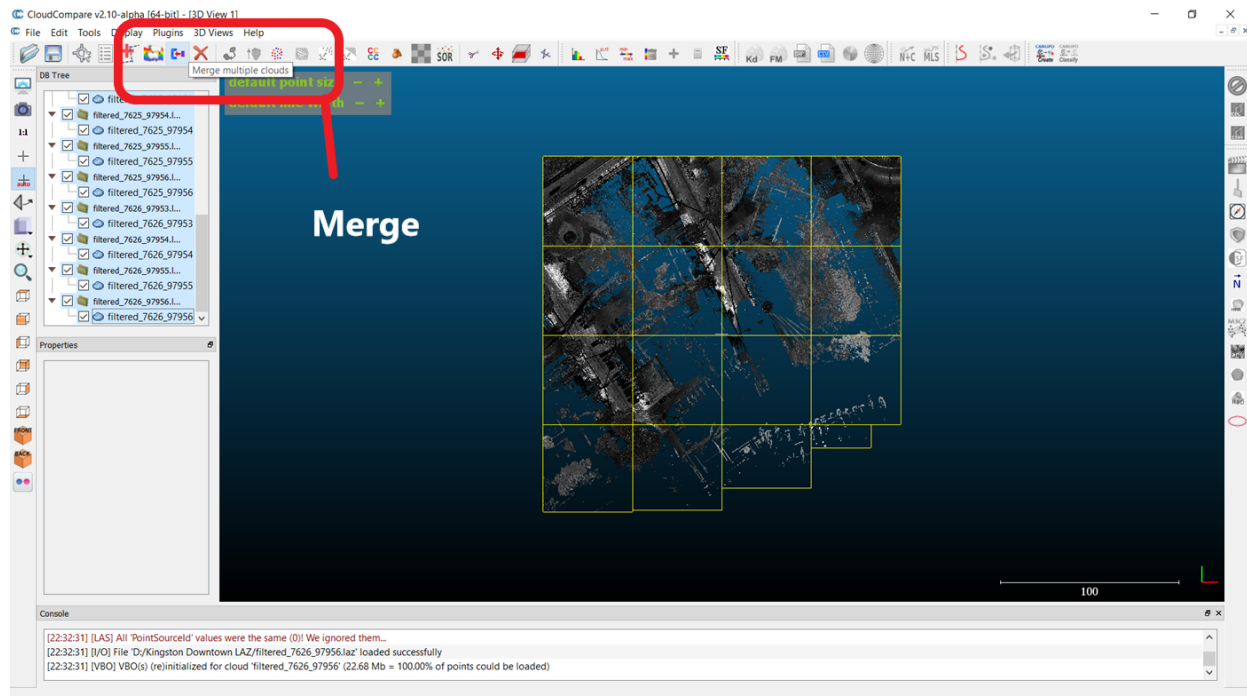
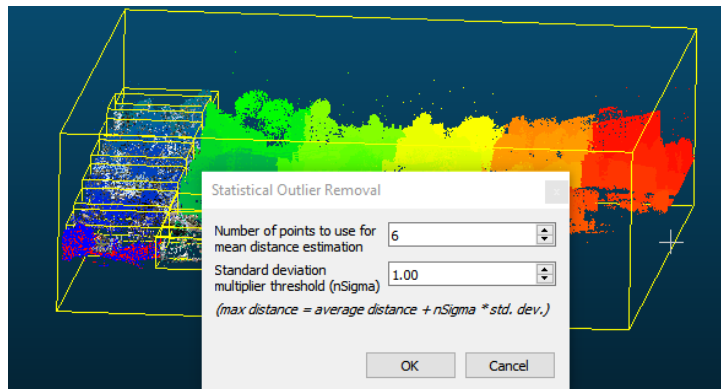


Figure 6 - Coordinate Shift Preserves Precision



CloudCompare also provides easy-to-use tools for noise reduction and sampling. Visualizing the specifics of the noise depends on styling the point cloud to view the Noise data by its classification value (7).

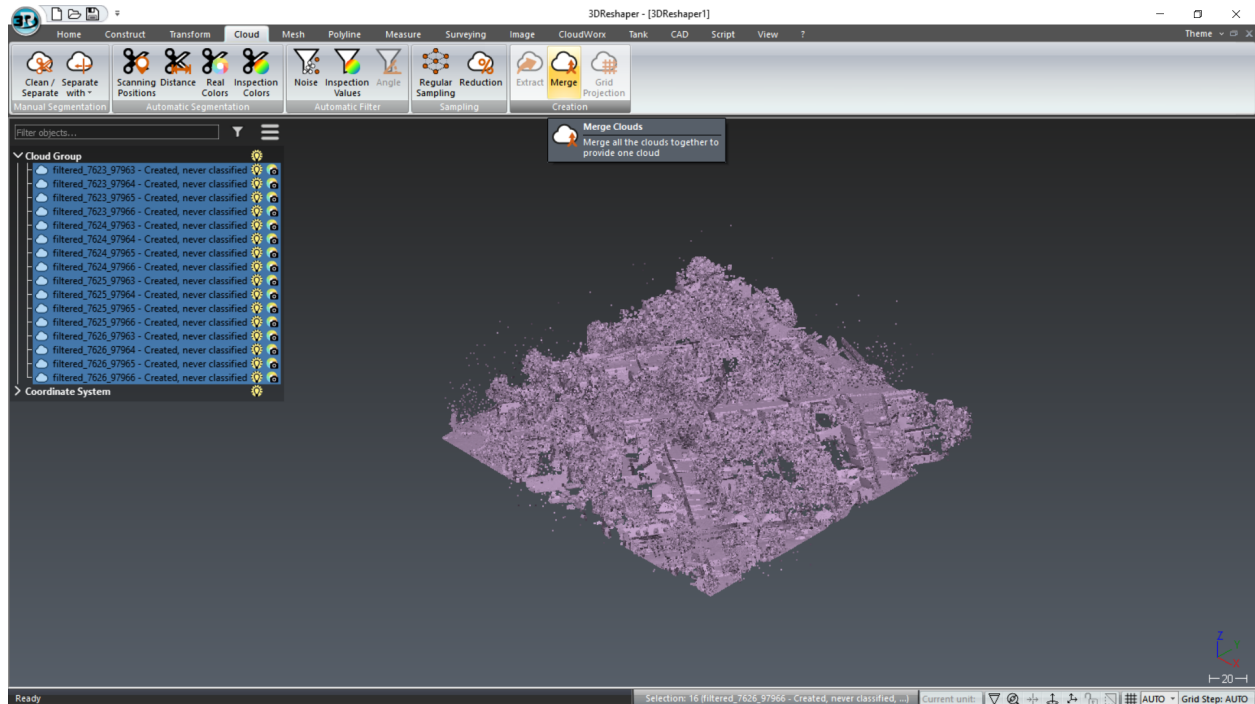


Once the file is merged, noise-reduced, and sampled for performance, it can be easily saved using the File menu.

3DReshaper

3DReshaper is a GUI tool from Hexagon used commonly with Leica scans. For this project, we investigated only its ability to merge point clouds, reduce noise, resample the result, and export it.

Using the main 3D file menu, you can import multiple files into a project.



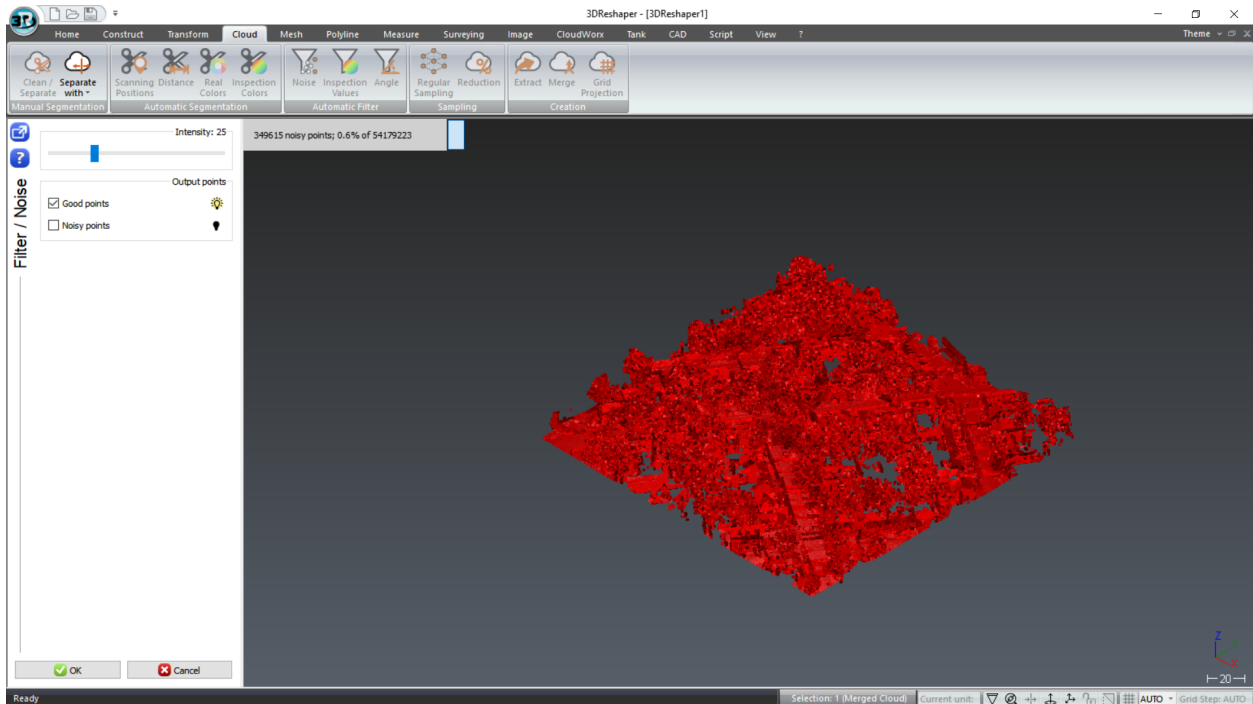
Once the files are loaded, the result can be easily merged—this operation is the fastest available. Once the files are loaded in memory, merge is instantaneous.

The noise reduction process is easy to use, but it doesn't expose the parameters. It uses an intensity parameter—a slider from 0 to 100. In our case, an intensity of 25% appears to clear all the visible aerial and below-grade noise, while eliminating only approximately 0.6% of the points.

One advantage of 3DReshaper for noise reduction is the ease with which it allows users to visualize the Noisy Points and Good Points for comparison.

Once the merged scan has been processed, including a variety of options for resampling, including resampling to a specific file size (i.e. point count), the resulting point cloud can be exported using the main 3D file menu.

Note—in all cases, it is possible to preserve the noise data once it has been classified as such. It will be appropriately ignored by downstream products.



Autodesk Recap

With all the tools above, Autodesk Recap must be used to prepare the lidar data for use in Autodesk products.

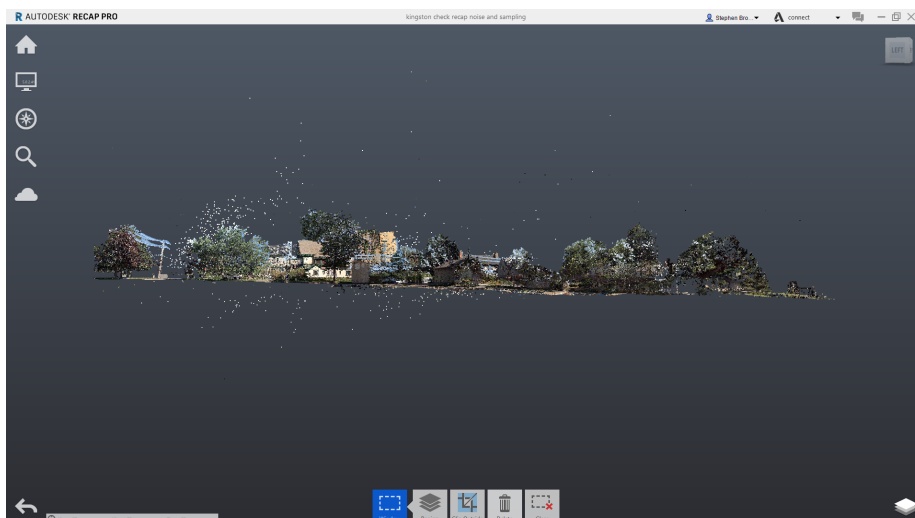


Figure 7 - Recap Desktop UI

With Recap, the following process works well for non-structured scans (this means scans which are non-stationary, ground based, with survey control).



Figure 8 - Recap Import Process

Note that Recap has intensity-based input filters and decimation capabilities based on a cube volume. The decimation was not used in this case, since there was somewhat better control when choosing specific resampling techniques in other tools.

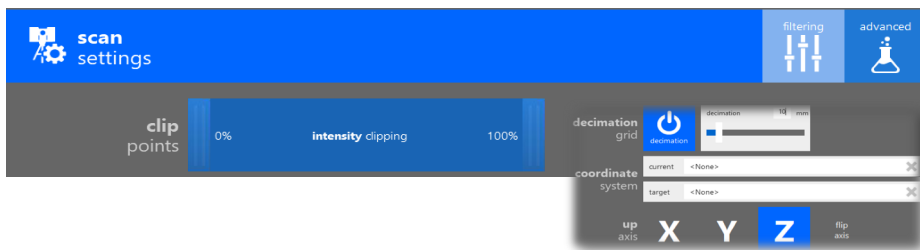


Figure 9 - Recap Import Settings

While the other tools had the ability to provide ESPG coordinate system information, we specified it at this stage.

It should be said that Recap has exceptional visualization performance. Recap also provides very easy to use tools for manually cleaning noise and partitioning the cloud. In fact, we were able to manually able to clean most of the noise—as well as cars and pedestrians—by simply selecting specific regions and deleting the points. This is useful for individual projects, but not practical for large-scale processing.

A video of using Recap to perform these operations is available as part of our additional resources.

Note that the command line DECAP tool provides most of the options available in the UI for importing scans from LAZ files and writing the appropriate RCP project and support files.

One major advantage to the use of Recap—the resulting projects are visualized within InfraWorks, AutoCAD, and AutoCAD Civil3D are almost instantaneous thanks to the Recap indexing model.

Finally, on the top-level menu, it is possible to create a unified scan in a single RCS file for easier sharing.

Now that the merged, cleaned, resampled point cloud file is ready, it can be easily used in Autodesk InfraWorks.

From an InfraWorks perspective, the entire point cloud project is treated as a single unit—even if you use Recap to create a multiple-scan project, InfraWorks will treat all points in the project as a single scan.

Working with Point Clouds in InfraWorks

The workflow for using point cloud data with InfraWorks is very straight-forward:



Two other aspects of the use of InfraWorks that we will explain in detail in our class:

1. Visualization—visualizing the resulting classification.
2. Export—exporting the resulting processed point cloud and its derivatives:
 - a. Export classified data
 - b. Export classified point cloud
 - c. Export surface

Adding Point Cloud Data

Open an existing model, or, create a new model in the main window of InfraWorks. Using the Data Sources panel, add a new Point Cloud and select the cleaned, processed file for your project.

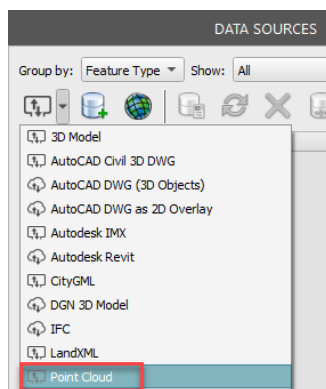
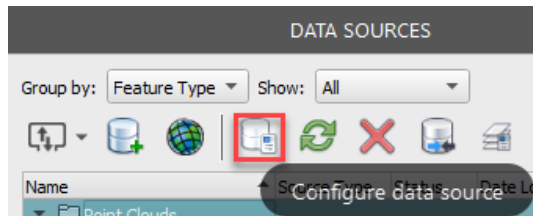
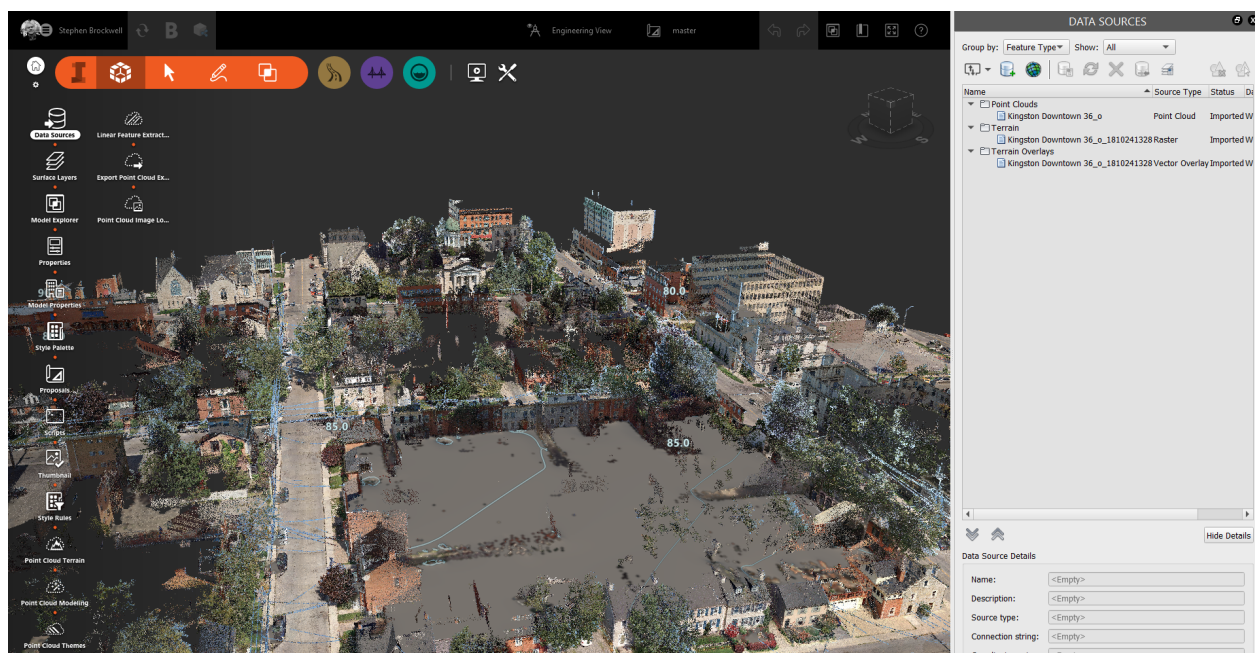


Figure 10 - Point Cloud Feature Type In Data Sources

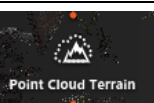

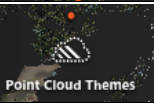
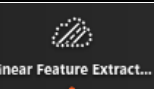
If the coordinate system has been assigned in Recap, you will only need to Configure the data source and refresh the result.




Press the **Close & Refresh** button to view the resulting project.



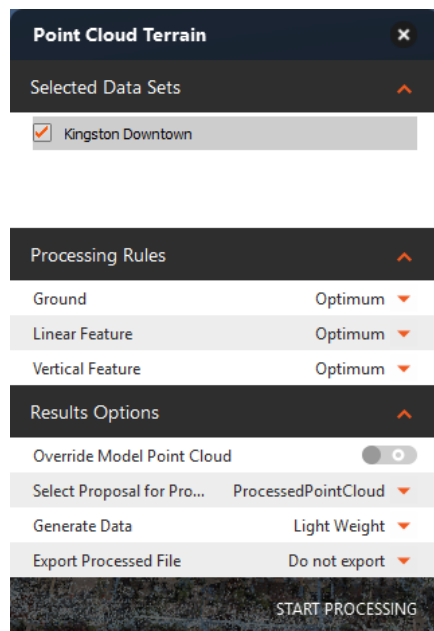
Now use the appropriate tools to classify, visualize, and extract features.

	<p>Create point cloud terrain—this process prepares the ground surface model and classifies points to identify candidate features.</p>
	<p>This tool allows the user to verify classification results. This is explained in detail in the videos provided in our class.</p>
	<p>This tool allows the user to view the various different point cloud styles and visualize classifications, RGB, and other properties.</p>
	<p>This tool provides an extensive, guided workflow for extracting real 3D models for streets including centerline, curb, and other features.</p>

	This tool allows the products of the point cloud process to be exported for use in downstream products, particularly AutoCAD Civil3D.
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Point Cloud Surface Generation

The surface generation tool displays the following dialog to collect parameters for generating the surface. For the most part, default values are used.

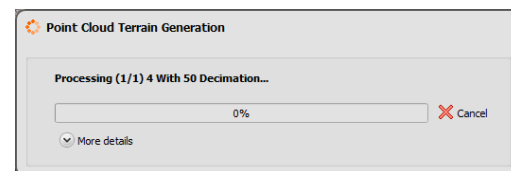


The dialog box is titled "Point Cloud Terrain" and contains the following sections:

- Selected Data Sets:** A list with one item, "Kingston Downtown", which is checked.
- Processing Rules:** A list of three rules, each with a dropdown menu set to "Optimum":
 - Ground
 - Linear Feature
 - Vertical Feature
- Results Options:** A section with several options:
 - Override Model Point Cloud:** A toggle switch that is currently turned off.
 - Select Proposal for Pro...:** A dropdown menu set to "ProcessedPointCloud".
 - Generate Data:** A dropdown menu set to "Light Weight".
 - Export Processed File:** A dropdown menu set to "Do not export".
- START PROCESSING:** A button at the bottom right of the dialog.

One setting worth noting: the Override Model Point Cloud setting allows the user to optionally retain the original point cloud and add the classified point cloud to a new proposal. Otherwise, the existing point cloud is substantially modified.

A progress dialog is displayed while the terrain is processed. Note that this process can take a long time with large point clouds. We provide some guidance on performance in our class.



The progress dialog is titled "Point Cloud Terrain Generation" and shows the progress of the processing. It includes a progress bar that is currently at 0%, a "Cancel" button, and a "More details" link.

Figure 11 - Point Cloud Terrain Properties

Feature Extraction—Point Cloud Modeling

InfraWorks provides an extensive step-by-step workflow for verifying InfraWorks suggestions and overriding the specific features, or deleting erroneous inferences that are not useful features.

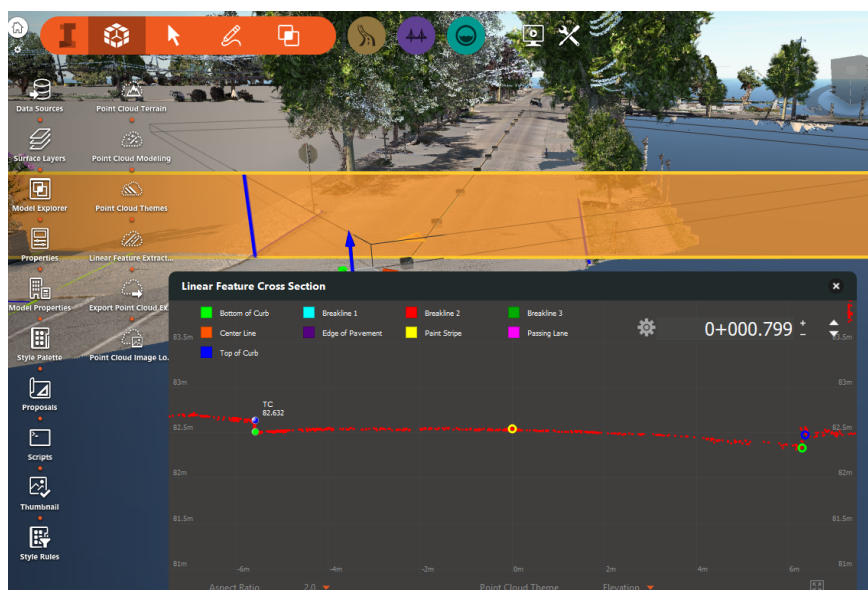


Figure 12 - Overview of Point Cloud Modeling Process

The user navigates from feature to feature and visualizes the underlying point cloud used to infer the feature. The user can rotate, scale and modify the type of the classified feature.

Linear Extraction

The linear extraction process allows users to create curbs, centerlines and other linear features in an automated or semi-automated fashion. Once the line is created, the user can step through the profiles of the surface at chosen intervals for the linear feature to specify elevations, curbs and other related properties.



Exporting Results

There are several ways to export InfraWorks classified features, point clouds, and surfaces.

1. Ground Grid Point Only—Generates a RCS file from the generated surface terrain.
2. Shape file – Can be converted to any format and GIS analysis can be run on them. They include the elevation information.
3. RCS file – a processed point cloud file can be uploaded in Civil 3D and from there be converted into a TIN surface.
4. CSV file – this is a plain text file that includes the values for X,Y and Z and can be imported as survey data to be consume by the Civil 3D tools.
5. Without the need to export the features, you can load the InfraWorks model directly from the SQLite file. With this method you can access the Transverse lines (not only the points) but your elevation is not displayed.

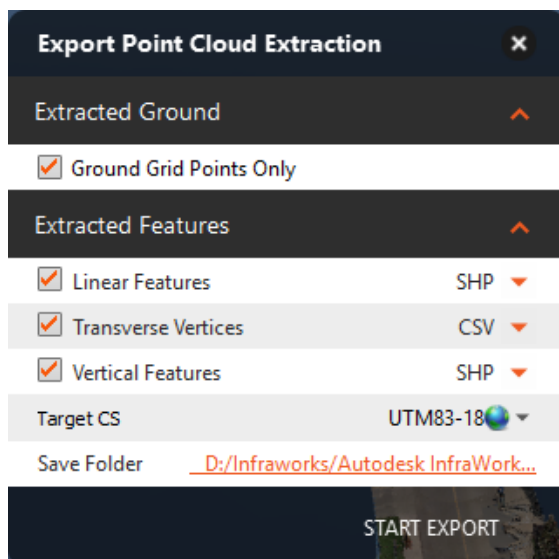


Figure 13 - Export Point Cloud Extraction

Conclusion

The Kingston project is a challenging city-wide data collection activity. The total storage required for the point cloud data exceeds 2TB including both .laz and .rcp files. As we observed, there were noise issues due to the bright sunlight during the scans. Reducing this is an ongoing challenge.

Noise Reduction

We found that there are good tools available for precise calibration of noise reduction. Of the tools we tested, PDAL was best for large-scale processing (although there remains some work to ensure output format RGB consistency).

The 3DReshaper and CloudCompare tools were very useful in determining the parameters for noise reduction and resampling.

Resampling

Depending on your hardware, resampling of large files may be useful to improve performance. In some situations, when analyzing the best process, it may be useful to test several resampling rates to get the right balance between performance and surface and feature extraction quality.

Hardware and Performance

Use the best hardware you can afford. Our 32 GB memory desktop platform with a high-end 6 core, 12 thread Intel processor was more than twice as fast as our reasonably high-performance 16 GB 4 core, 8 thread laptops. Both platforms had SSD storage. The SSD storage on the desktop used high-end Samsung 960 disks.

Workflow

InfraWorks does a good job of providing a strong user-experience of navigating extracted data. While substantial user interaction is required, this tool can substantially reduce the cost of field surveying data or collecting it from existing maps or aerial scans.

Collection Alternatives

Point cloud data requires substantial investment in knowledge and training to use effectively at the scale of a city. There are a few important reasons to consider collecting it at this scale:

1. It is an excellent photo-realistic source of accurate, precise data at a moment in time that can be used for planning, design, visualization, situational awareness, and, within a collection cycle (annual, quarterly), as a source of change detection.
2. The resulting data can be used for realistic visualization in most GIS and CAD applications with certain reservations.
3. The InfraWorks surface generation results are excellent—ground surface quality is generally very high. Cars and pedestrians seldom cause unwanted artefacts.
4. Measurements performed on the generated surfaces are often within 2 cm from ground-verified measurements, even at long distances. While this is not survey grade, it is almost certainly adequate for many design processes.
5. The feature extraction capabilities are improving rapidly. In our experience, the linear extraction capabilities of InfraWorks are excellent. While a complete inventory of assets

may not be possible using this data, on a case-by-case basis, these tools can be used to statistically verify the quality of existing inventories by overlaying GIS feature sources and comparing them to classified results.

Fundamentally, the cost of collecting this data (which is surprisingly low) must be compared to the cost of collecting alternatives such as aerial photography, oblique imagery (which may lack precise elevation data), or aerial lidar, and ground-based localized scans which generally must be stitched together for large-scale projects.

The noise concerns we had are not typical—other customer scans taken under different conditions do not have excessive noise. While we believe this is due to bright sunlight, this has not been confirmed with certainty.