CES502661

Leveraging Entwine LiDAR Datasets Within Civil 3D & Recap Pro

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Learning Objectives

- Find LiDAR data for your area of work or even business development quickly.
- Clean & generate a consumable point cloud within Civil 3d in minutes.
- Make better informed proposals before a contract is created.
- Have a more refined understanding of grading constraints early in your project lifecycle.

Description

In this session we will explore Entwine Point Tiles (as of June 2022 there are over 42.5 Trillion points), and how to consume them inside of Civil 3D as a surface (via point cloud) in mere minutes. As large point cloud datasets become ubiquitous in the AEC community, open-source libraries and software dedicated to manipulating these datasets are valuable tools for those in the geospatial community and civil engineers. Entwine is a free online cloud repository that anyone can access, and with this technical instruction go from zero (knowledge) to office hero in mere minutes!

Speaker

Justin Ehart is the Engineering BIM Manager with Ware Malcomb, based out of their Denver Colorado office. With an education in architecture, he has spent the last twenty-eight (28) years in architecture, civil engineering, and land surveying; specializing in large scale single family residential design & surveying. His current focus is on the development of BIM (bridging the disconnect within the AEC industry), the automation of Civil 3d through Infraworks/Dynamo/Python integration, and creating a custom content browser for Revit via an IFC website. He is an expert user of Civil 3d, Revit, Navisworks, AutoCAD, and InfraWorks while becoming eerily proficient in Recap Pro in a short amount of time. His varied range of expertise and knowledge has identified him as a technical expert on large data projects and custom integrations.

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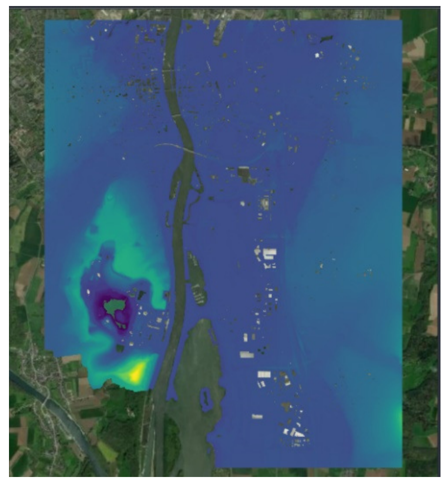
What is Entwine?

Entwine is a data organization library for massive point clouds, designed to conquer datasets of trillions of points as well as desktop-scale point clouds. Entwine can index anything that is PDAL-readable, and can read/write to a variety of sources like S3 or Dropbox. Builds are completely lossless, so no points, metadata, or precision will be discarded even for terabyte-scale datasets. There might be a new term listed above you might not know, PDAL. This begs the next question, "What is PDAL?" We are going to use a few abbreviations so lets create a small glossary of terms and examples:

Glossary of additional terms:

PDAL: *Point Data Abstraction Library is a C/C++ open source library and applications for translating and processing point cloud data. It is not limited to LiDAR data only, although the focus and impetus for many of the tools in this library have their origins steeped in LiDAR data. Evolved out of the development of database storage and access capabilities for a U.S. Army Corps of Engineers project. Read more about PDAL here https://pdal.io/en/stable/*



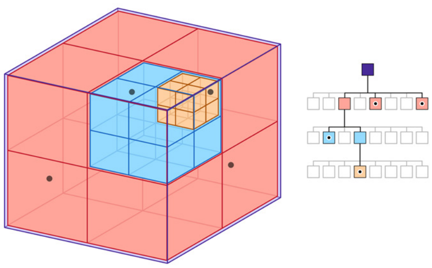
PDAL generated data example.

LiDAR generated data example.

LIDAR: *Light Detection and Ranging, is a method for determining ranges (variable distance) by targeting an object or surface with a laser and measuring the time for the reflected light to return to the device. It can be used to make digital 3-D representations of areas on the Earth's surface and ocean bottom of the intertidal and near coastal zone by varying the wavelength of light. It has terrestrial, airborne and mobile applications.*

3DEP: *The goal of the USGS 3D Elevation Program is to collect elevation data in the form of LiDAR data over the conterminous United States, Hawaii, and the U.S. territories, with data acquired over an 8-year period. The first resource is a public access organization provided in Entwine Point Tiles format, which a lossless, full-density, streamable octree based on LASzip (LAZ) encoding.*

3DEP generated data example.



Octree distrubution example.

OCTREE: *An octree is a tree data structure in which each internal node has exactly eight children. Octrees are most often used to partition a three-dimensional space by recursively subdividing it into eight octants. Octrees are the three-dimensional analog of quadtrees. Octrees are often used in 3D graphics and 3D game engines.*

USGS Source Data Products

Source data products include lidar point clouds, source (original) resolution DEMs from which the 3DEP standard DEM datasets were produced, and additional data types produced from IfSAR collections.

- **Lidar point cloud:** This collected data is the foundational data for 3DEP in the conterminous U.S., and contain the original three-dimensional information from which the DEM products are derived. Most of the data collected in 2014 and later meet 3DEP specifications for quality level 2 nominal pulse spacing and vertical accuracy, and data collected prior to 2014 often do not meet the quality level 2 specification. Distinctions in nominal pulse spacing are provided in the lidar point cloud status graphics and in the download platform; however, other qualities such as vertical accuracy must be examined to determine if the data meet particular 3DEP quality level specifications.

- **Source resolution DEMs:** Data collected this way are the original bare earth DEMs derived from lidar point cloud source. Source DEM's processed by the USGS after January 2015 are provided where the original DEM horizontal resolution or projection differ from the 3DEP standard DEM datasets.

- **IfSAR orthorectified radar intensity image (ORI):** These rasters (resolutions vary), available only in Alaska, are radar reflectance intensity recordings detected by the IfSAR sensor.

- **IfSAR digital surface model (DSM):** These 5 meter rasters, available only in Alaska, are the initial IfSAR product. DSMs provide elevation values of landscape features on the earth's surface. This topographic product contains the height of the highest surface on the ground including vegetation, man-made structures, and bare earth.

- **IfSAR digital terrain model (DTM):** provide elevation values of the underlying terrain of the earth's surface. This topographic product reflects the height of bare earth where the elevations of vegetation and man-made features have been removed. The USGS Earth Resources Observation and Science (EROS) Center distributes IFSAR Alaska products in Georeferenced Tagged Image File Format (GeoTIFF). The pixel values for the grayscale images represent elevation numbers. EarthExplorer can be used to search, preview, and download IFSAR Alaska data. The collection is located under the Digital Elevation category.

Standard DEMs

Standard DEMs represent the topographic surface of the earth and contain flattened water surfaces. Each DEM dataset is identified by its horizontal resolution and is produced to a consistent set of specifications. Standard DEMs are characterized either as project-based or seamless. Project-based DEMs are available for the full areal extents of projects when produced from light detection and ranging (lidar), or as one-degree blocks with overedge when produced from IfSAR. Seamless DEMs are produced by blending only the highest quality project data into a continuous terrain surface for the U.S. These data are distributed in tiles that can be merged to support analysis across large geographic areas.

Project-based:

1 meter: *This dataset was introduced in 2015 with limited coverage of the U.S., but will be expanding as new DEMs from 3DEP quality level 2 or better lidar data are acquired. Horizontal coordinates are referenced to the Universal Transverse Mercator projection*.

1/9 arc-second: *This dataset covers about 25 percent of the conterminous U.S. and is produced from 3-meter or higher resolution DEMs acquired by the USGS prior to January 2015. Horizontal coordinates are referenced to geographic coordinates (longitude, latitude). The 1/9 arc-second dataset will no longer be updated with newly acquired DEMs; however, it will continue to be distributed.*

5 meter: *This dataset is comprised of 5-meter IfSAR-derived DEMs (3DEP quality level 5) over Alaska only. Horizontal coordinates are referenced to Albers Equal Area Conical projection.*

Seamless:

1/3 arc-second: *This is the highest resolution seamless DEM dataset for the U.S. with full coverage of the 48 conterminous states, Hawaii, and U.S. territories. Alaska coverage is partially available now and is being expanded to statewide coverage as part of the Alaska Mapping Initiative. Ground spacing is approximately 10 meters north/south, but variable east/west due to convergence of meridians with latitude.*

1 arc-second: *This is a lower resolution seamless dataset providing complete coverage over the conterminous U.S. and partial coverage of Alaska. Most of Canada and Mexico are also covered* *by the 1 arc-second dataset. Ground spacing is approximately 30 meters north/south, but variable east/west depending on latitude.*

2 arc-second: *This seamless dataset is the lowest resolution seamless dataset available and covers only Alaska. Although ground spacing is approximately 60 meters north-south, east-west spacing can vary from 35 meters in southern Alaska to 20 meters on the North Shore.*

The 3DEP Bare Earth DEM Dynamic Service and Viewer

The 3DEP Bare Earth Digital Elevation Model (DEM) dynamic service allows users to explore multiple-resolutions of 3DEP data available in the National Map. In addition, Open Geospatial Consortium (OGC) Web Map Service (WMS) and Web Coverage Service (WCS) interfaces are enabled to support interoperability across systems.

The DEM viewer creates multi-resolution visualizations DEMs on-the-fly generated dynamically from the USGS 3D Elevation Program elevation data. Users may explore a variety of representations including: aspect; contours; tinted hillshade; hillshade; hillshade stretched; multi-directional hillshade and slope maps.

About Surfaces [(via Civil 3D Support and Learning)]

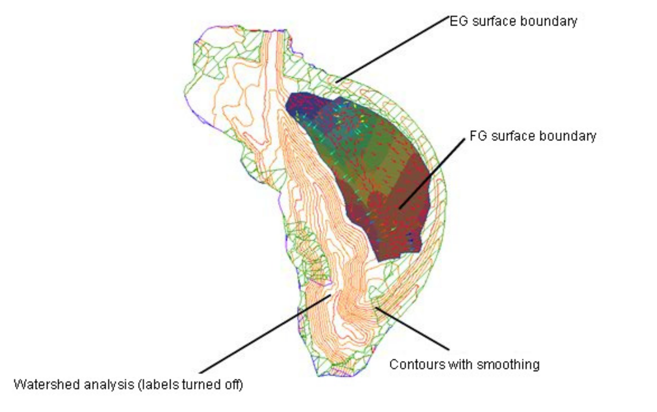
A surface is a three-dimensional geometric representation of an area of land, or, in the case of volume surfaces, is a difference or composite between two surface areas.

Surfaces are made up of triangles or grids, which are created when Autodesk Civil 3D connects the points that make up the surface data.

To use a surface in your drawing, you can create an empty surface and then add data to it. You can also import existing files containing surface information, such as LandXML, TIN , or DEM files.

Points or contours are usually a primary part of the original surface information and are supplemented with breaklines and boundaries.

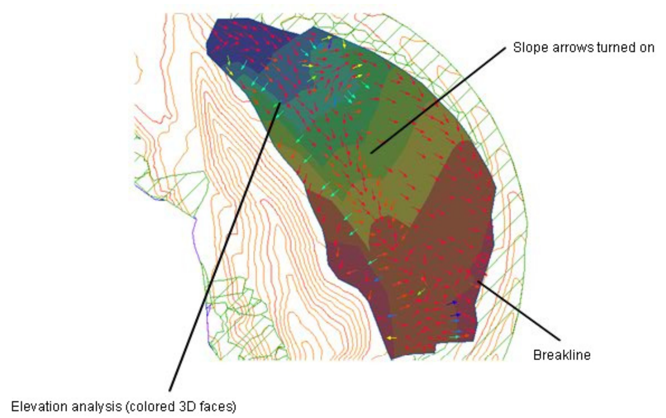
Boundaries define the visible area of a surface. Only the area within the boundary is included in calculations, such as for total area and volume. You can also define masks to hide or show parts of a surface for editing or presentation purposes, while still including that area in calculations.



Surface displaying boundaries, contours & elevation Analysis. Image provided via AutoDesk Civil 3D help topic

Breaklines are used on TIN surfaces to define linear features that triangles cannot cross, such as retaining walls or streams. Breaklines affect triangulation of the surface.

You can define different sets of contours, for example, for different intervals. Smoothing is provided for the surface object as a whole, which gives better results than simply smoothing the contours. In Autodesk Civil 3D, the build process for surfaces is incremental. Whenever data is added or corrected, the surface is updated. Each surface has a definition list. This list contains all the operations performed on the surface. By turning the operations on and off, you can return a surface to a previous state or modify it to support different types of analysis.



Surface displaying slope arrows elevation analysis.
Image provided via AutoDesk Civil 3D help

To Create a Surface from Point Cloud Data (via Civil 3D Support and Learning)

You can create a TIN surface from points within RCS format point cloud scan files and RCP format point cloud project files created with Autodesk® ReCap™.

You can use the Create Surface from Point Cloud command to create a surface from several point clouds, selecting only the areas that you want to include and filtering out non-ground points so they are not included in the resulting surface. When using this command, you can select entire point clouds or areas of point clouds to include in the surface. You can select areas of point clouds by using window selections, by defining polygon areas, or by selecting existing closed polylines in the drawing.

If the quantity of points in all the selected point cloud areas exceeds two million points, then the areas are subdivided for faster point cloud processing.

1. Attach one or more RCS point cloud scans or RCP point cloud projects to the drawing. For more information, see About Working With Point Clouds and To Attach a Point Cloud to a Drawing.
2. Click Home tab Create Ground Data panel Surfaces drop-down Create Surface From Point Cloud Find.
3. Select a point cloud, or use one of the command line selection options to select an area of one or more point clouds. The Create TIN Surface from Point Cloud wizard is displayed.
4. On the General page, specify the surface creation details.
5. On the Point Cloud Selection page, refine the selection of the point clouds and point cloud areas.
6. On the Non-Ground Point Filtering page, specify options for filtering out non-ground points.
7. Click Create Surface.

Edit Point Clouds [(via ReCap Support and Learning)]

Editing point cloud data into more advanced or focused displays is available in ReCap and ReCap Pro for desktop. With these tools, you can manipulate your point cloud to extract data and collaborate more efficiently across the project.

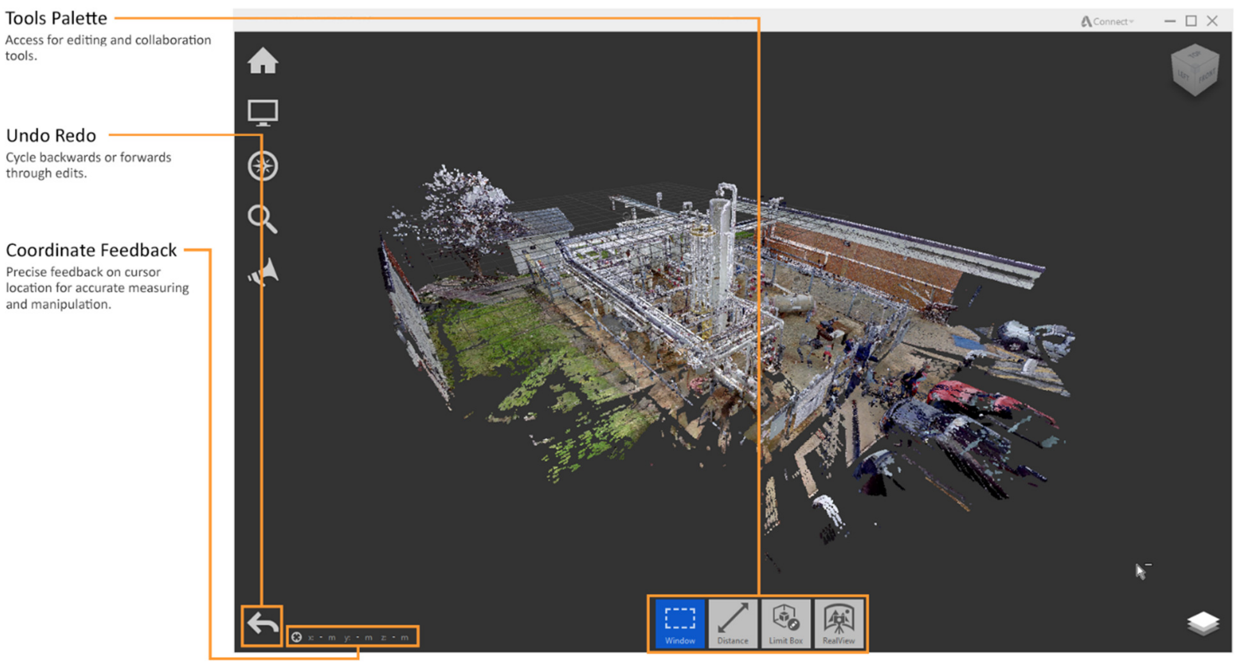


Image provided via AutoDesk ReCap Pro help topic

Selection is the fundamental action at the root of all point cloud modification. A number of tools and options are available to make selection easier, as outlined in this section. Selections allow you to assign Scan Regions, specify extraneous objects such as people or cars for deletion, or outline areas that you want to clip. Because the selection area often extends beyond the areas you specify, you can use the Limit Box to act as a selection boundary and focus your work within a smaller subset of data.

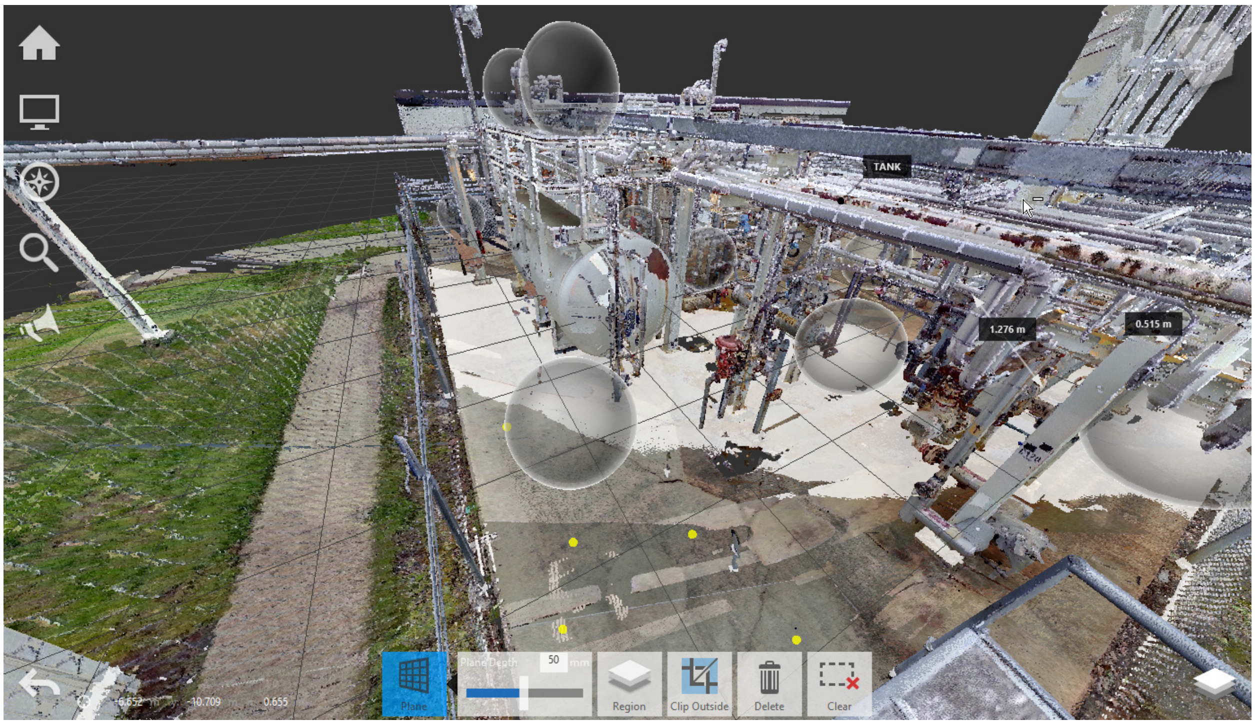


Image provided via AutoDesk ReCap Pro help topic

About Clipping and Deleting Points (via ReCap Support and Learning)

Clipping provides a way to hide extraneous portions of the point cloud without permanently removing the points. For example, you can use clipping to trim away people and vehicles picked up in the laser scan. In the following illustration, multiple clipping areas were used to remove the boat stands holding up the boat.

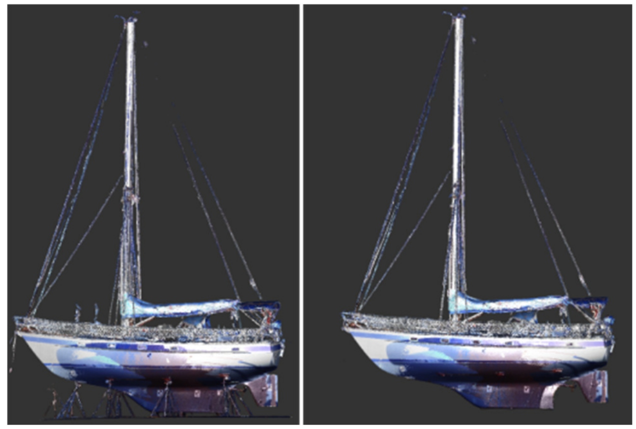


Image provided via AutoDesk ReCap Pro help topic

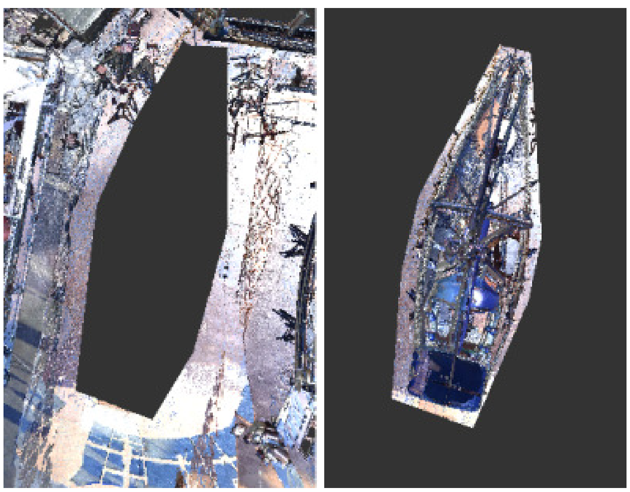


Image provided via AutoDesk ReCap Pro help topic

Creating a Scan Region, the clipping action originates with accurate selection. Once a selection has been made, you can specify whether points are clipped inside or outside the clipping boundary, depending on whether you want to remove something from the scene or isolate it.

Remove clip boundaries to restore display of the clipped points. In point clouds with more than one clip boundary, you can choose to remove all boundaries, or step back chronologically to remove boundaries one at a time.

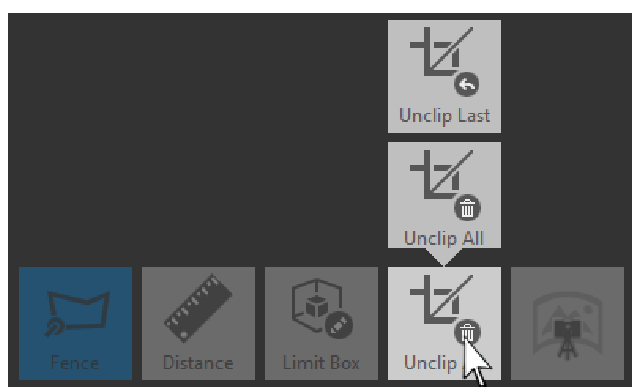


Image provided via AutoDesk ReCap Pro help topic

You can also permanently remove points from the scan file by directly selecting them or by deleted a Scan Region with cleaned points. This is a good way to clean up extraneous points that are outside the area of interest. If you need to restore points that you did not want to remove, click the Undo button or Ctrl+ **Z** immediately after the Delete operation.

Of Note: *Be cautious when deleting points. Deletion permanently removes the points from the scan file. They can only be restored by using Undo immediately after you delete them or else you will have to restore all points collectively deleted from the project!*

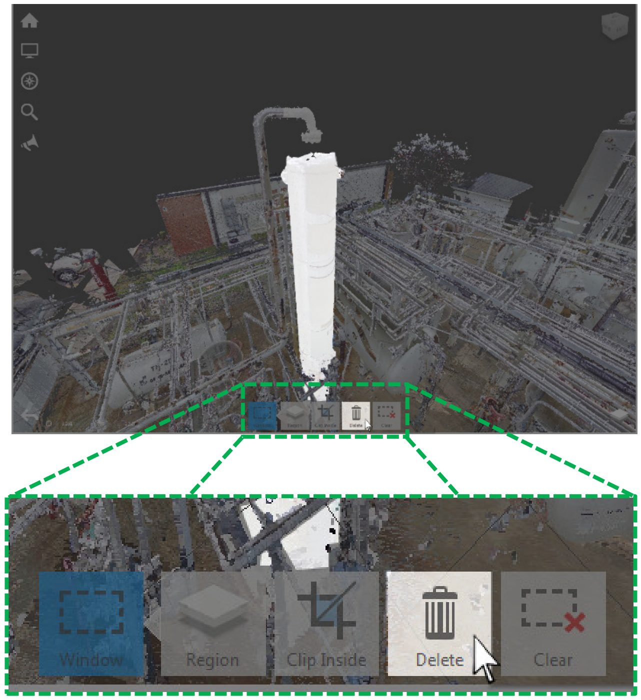
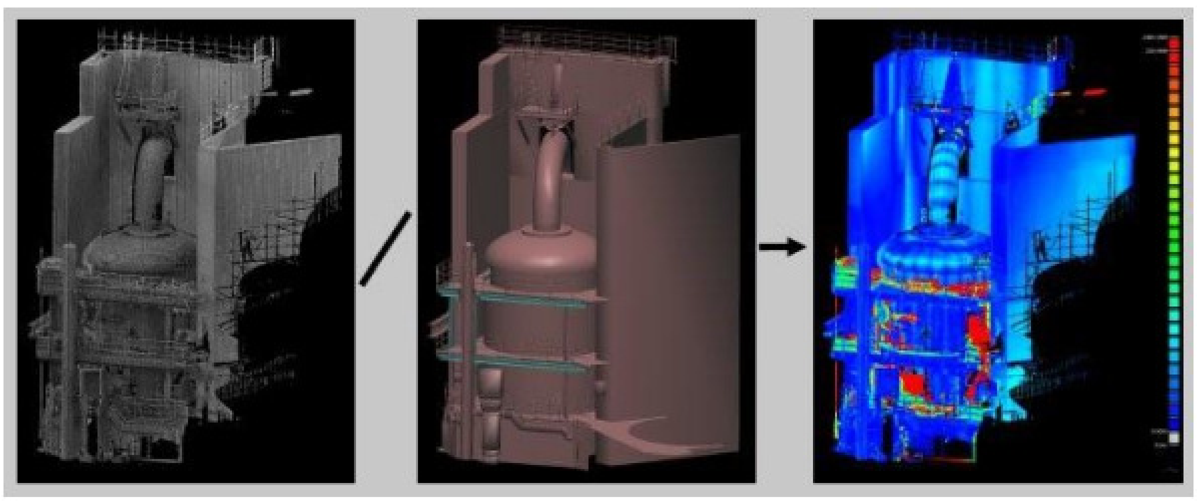


Image provided via AutoDesk ReCap Pro help topic

Cloud Compare [(via Cloudcompare.org User Manual)]

History:

CloudCompare is a 3D point cloud (and triangular mesh) editing and processing software. Originally, it has been designed to perform direct comparison between dense 3D point clouds. It relies on a specific octree structure that enables great performances1 when performing this kind of task. Moreover, as most point clouds were acquired by terrestrial laser scanners, CloudCompare was meant to deal with huge point clouds on a standard laptop - typically more than 10 million points (in 2005!). Soon after, comparison between a point cloud and a triangular mesh has been supported (see below). Afterwards, many other point cloud processing algorithms have followed (registration, resampling, color/normal vectors/scalar fields management, statistics computation, sensor management, interactive or automatic segmentation, etc.) as well as display enhancement tools (custom color ramps, color & normal vectors handling, calibrated pictures handling, OpenGL shaders, plugins, etc.).



(1) for instance it took about 10 s. to compute the distances of 3 million points to a 14.000 triangles mesh on a laptop with dual-core processor

Philosophy: Point cloud vs Mesh

Regarding its particular history, CloudCompare considers almost all 3D entities as point clouds. Typically, a triangular mesh is only a point cloud (the mesh vertices) with an associated topology (triplets of 'connected' points corresponding to each triangle). This explains that meshes have always either a point cloud named 'vertices' as sibling or parent (depending on the way they have been loaded or generated). And while CloudCompare will let the user apply some tools directly on a mesh structure (i.e. triangles), some tools can only be applied to the mesh vertices. It may be a bit disturbing at first, but we don't want the user to ignore this: **CloudCompare is mainly a point cloud processing software.**

Of course, as CloudCompare is meant to do change detection (e.g. subsidence monitoring) and as a triangular mesh is a very common way to represent a reference shape (e.g. a building), it is very useful and it couldn't be ignored. Nevertheless it remains a "secondary" entity, especially as CloudCompare is able to compare two point clouds directly, without the need to generate an intermediary mesh.

The main reasons for this are:

- meshes are generally very hard to generate properly on real-life scenes, especially when scanned with a laser scanner (noise, variable density, etc.)
- and as ALS/TLS point clouds are generally very dense (and accurate), we already have all the information we need

Scalar Fields

Among all 'features' that can be associated to a point cloud (colors, normals, etc.) one has a particular place in CloudCompare: the *scalar field*.

A scalar field is simply a set of values (one per point - e.g. the distance of each point to another entity). As each value is associated to a point (or vertex) it is possible to display those values as colors (with custom color ramps) or to apply filters on them (smooth, gradient, etc.), some basic math operations (exp, log, power of 2 or 3, cos, sin, tan, etc.) and of course to segment the cloud relatively to those values (thresholding, local statistical filtering, etc.).

CloudCompare can handle multiple scalar fields on the same cloud. It is even possible to apply simple arithmetic operations (-,+,/,*) between two scalar fields of a same cloud.

Scalar Fields > Filter by Value

This tool is accessible via the '**Edit** > **Scalar fields** > **Filter by value**' menu. Filters the points of the selected cloud based on their associated scalar value. A new cloud (or mesh) is created with the points falling inside the specified range.

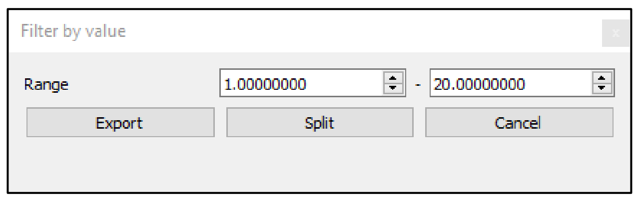


Image by author via Cloud Compare software

Subsample

This tool is accessible via the '**Edit** > **Subsample**' menu. Subsamples a point cloud (i.e. decreases the number of points). Several subsampling methods are available (random, spatial and octree-based).

Of Note:

- for each input cloud, a new subsampled cloud is created (the original one is simply deactivated)
- a subsampled cloud is a subset of the input cloud (the original points are not displaced)
- thanks to this, a subsampled cloud keeps the features of its source cloud (scalar fields, colors, normals, etc.)

Procedure:

Select one or several clouds then launch the tool.

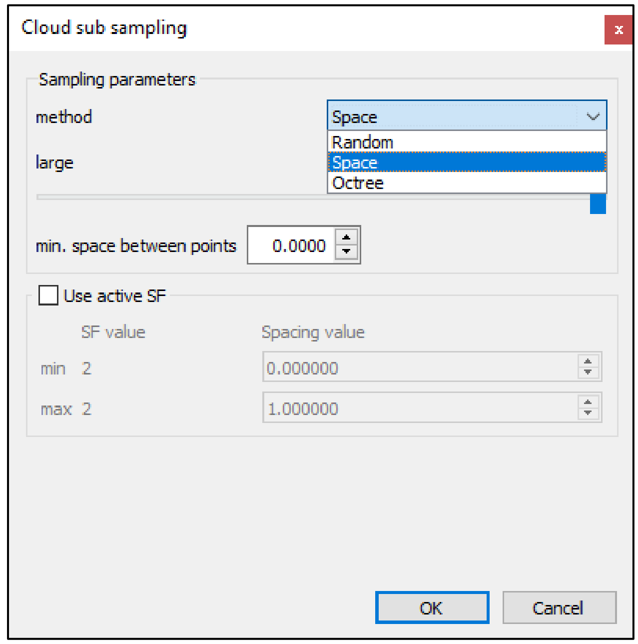


Image by author via Cloud Compare software

In '**Random**' mode, CloudCompare will simply pick the specified number of points in a random manner. Use the slider to reduce the number of points in the point cloud by sliding to the left. I like to move it close to the middle.

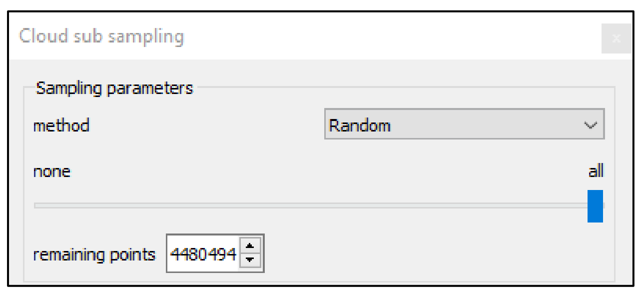


Image by author via Cloud Compare software

In '**Spatial/Space**' mode, the user must set a minimal distance between two points. CloudCompare will then pick points from the original cloud so that no point in the output cloud is closer to another point than the specified value. The bigger this value is, the less point will be kept.

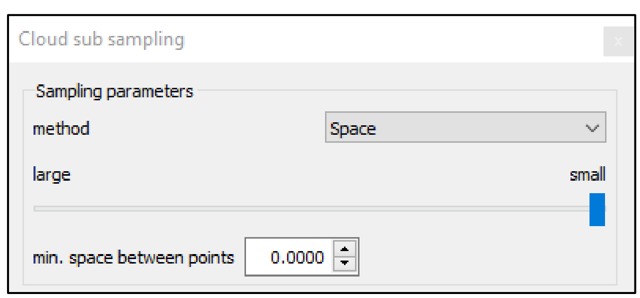
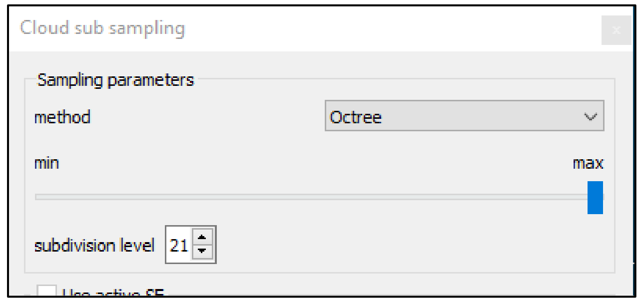


Image by author via Cloud Compare software



The '**Octree**' mode lets you select a level of subdivision of the octree at which the cloud will be 'simplified'. In each cell of the octree, the nearest point to the octree cell center is kept.

Of Note:

- the higher the level is, the smaller the cells are (so the more points you'll keep)
- the maximum octree level is 10 in the 32 bits version of CloudCompare, and 21 in the 64 bits version.
- the tool differs from the 'Octree > Resample' method. The Resample tool computes the center of gravity of the points falling in each cell (i.e. the created cloud is not a subset of the original cloud)

This document is only suplimentary to accompany the powerpoint presentation. Please refer to the recorded presentation for the actual workflow. Thanks… jde

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