STONEX

Cube-3d

3D Software

User Manual

STONEX

Contents

1. Software introduction

Cube-3d is a mapping and aerial image processing software solution. It lets you build professional 3D models from 2D images and geospatial data, captured using drones or other vessels and devices. Cube-3d offers photogrammetric processing (building geometry, geo-referencing, dense reconstruction) as well as 3D modelling and analysis of both Cube-3d-generated photogrammetric point clouds and third-party source data (las, LiDAR, CAD, etc). Create your own orthophotos (DOF), digital surface models (DSM) or calculate volumes and manage stockpiles in a fast and easy manner. An integrated reports wizard will help you put all that work together in a compact and presentable way.

Type of accessible data differs from project to project as should workflow. Two most popular use cases:

1. Drone flight & Mission Planner + Cube-3d Processing + Cube-3d Modelling and Analysis

Capture your own images (along with EXIF, GNSS, GPS RTK, etc. data for geo-referencing) and import them to Cube-3d for photogrammetric processing. Set parameters for bundle adjustment, orientation (geo-referencing) and reconstruction. The result will be a metric, geo-referenced, realistically coloured 3D point cloud that serves as a basis for all further calculation, modelling and analysis. Learn more about project preparation or jump to **License details.**

2. Cube-3d Modelling and Analysis

Just finished with Processing? Importing third-party data, such as las point clouds, photogrammetric point clouds from other sources, LiDAR, etc. without having your own data for photogrammetric processing? No problem. This part lets you build, manipulate and customize point clouds, DSMs, DEMs, orthophotos, calculate volumes and profiles, contour lines, generate reports and export data in various formats for further CAD or any other use. Go to Modelling & Analysis.

This manual will help you get the most out of Cube-3d to achieve high-accuracy, survey-grade results in a professional and high-tech approach. Naturally, being a team of surveying professionals, we made sure that Cube-3d also supports data acquired with classical measuring methods and devices.

1.1. System requirements

Cube-3d runs on Windows 64-bit operating system. Processing runs on CPU, graphical interface runs on GPU. For best performance and speed make sure you have enough RAM (16GB+). See below for further specification requirements.

Minimum system requirements:

Windows 7, 8, 10; 64 bit

I5/i7

16 GB RAM

Nvidia GTX760

SSD 128 GB + HDD 500 GB

Recommended system requirements:

Windows 10; 64 bit

i7: https://ark.intel.com/products/88967/Intel-Core-i7-6700HQ-Processor-6M-Cache-up-to-3_50-GHz

16 - 32 GB RAM

Nvidia GTX960 or better

SSD 256 GB + HDD 1 TB

Advanced Professional Use (large datasets, full-frame cameras):

Windows 10; 64 bit

i9: https://ark.intel.com/products/123613/Intel-Core-i9-7900X-X-series-Processor-13_75M-Cache-up-to-4_30-GHz

64 - 128 GB RAM

Nvidia GTX960 or better

SSD 512 GB + HDD 1 TB

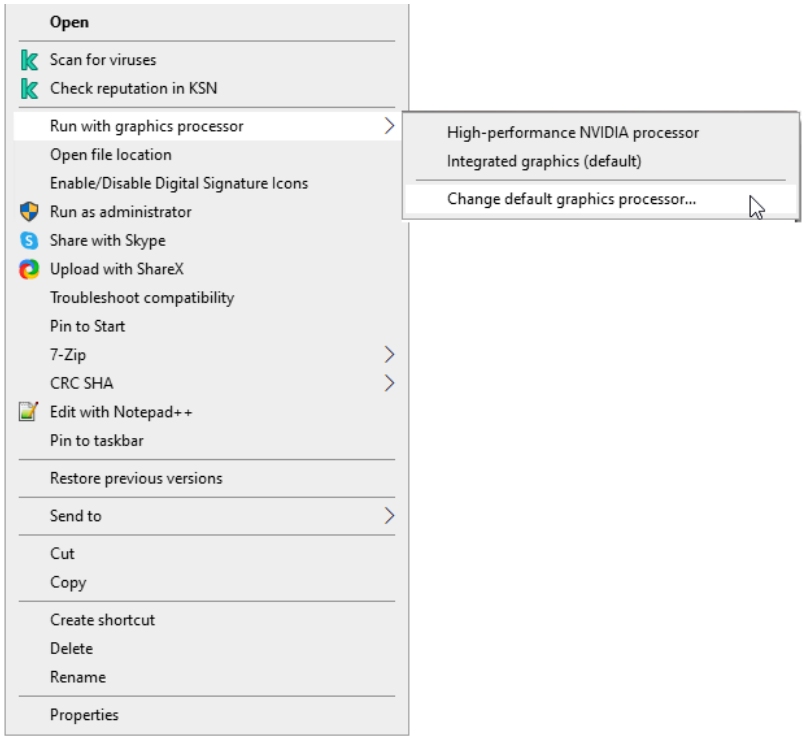
1.2. Graphic card usage

Using notebook PC: Power plan should be set to high performance

In case of additional graphics card: Dedicate the use of graphics card to Cube-3d.

Right click on ***Cube-3d shortcut*** -> ***Run with graphics processors*** -> ***Change default graphics processor…***

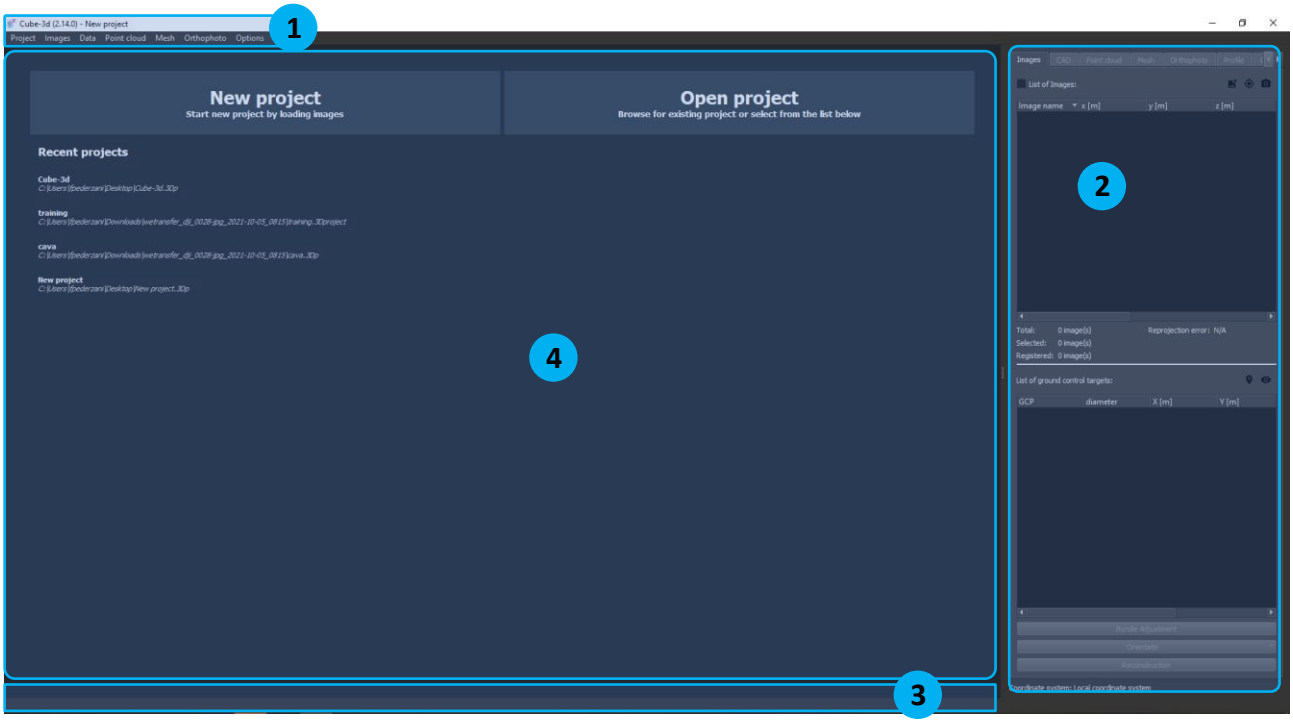
When card's control panel pops up, go to ***Manage 3D settings*** -> ***Program settings***. Check if Cube-3d is on the list of selected Program to customise. If not, click ***Add*** button and find ***Cube-3d***. Click ***Add Selected Program*** and close *Control panel*.



2. GUI *(Graphical User Interface)* walkthrough

2.1. Welcome screen

Opening Cube-3d brings us to a welcome screen with a couple of options to start our project; ***New project***, ***Open*** an existing project, or select from ***recent projects*** list. Other buttons remain disabled as no data is loaded in the app.

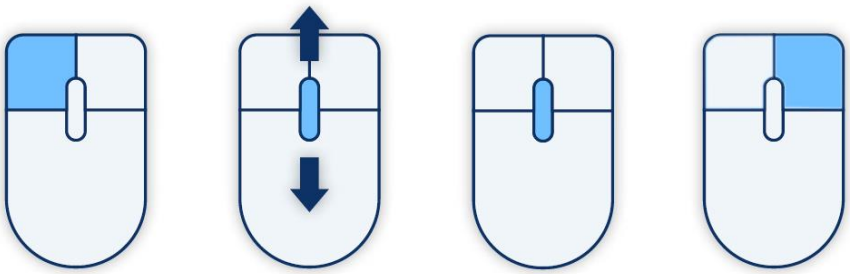


Graphical user interface of Cube-3d consists of four fundamental sections with tools, advanced options, guidelines and information for data processing:

1. **Toolbar** is the upper left part that provides us with all main options
2. **Working Panel** is located on the right side containing seven tabs, each giving us basic and advanced tab related tools. Tabs unlock as we move through processing to point cloud, modelling, Orthophoto, etc. Some menus, as well as some functions are locked due to either lack of data or because we tried to skip some of the processes.
3. **Live Command Window** is located on the lower left part, providing us with live results of running functions: coordinates of marker's position, computed distances, etc.
4. **Viewer** is the central board for viewing images, and all of 2D or 3D data.

2.2. Viewer and live command window

Main Viewer screen and Live Command line provide and interactive graphical and numerical interfaces for you to control and work with models, results, pick points, monitor coordinates as you explore your 2D or 3D material. The easiest way to handle models in Cube-3d is using a mouse and its four operations. Left mouse click is, just like any other app, used for selecting (starting polygon selection). When selecting polygon, use left mouse button to determine its points and right mouse click to finish your selection. To rotate models, click and hold left mouse button. To zoom in or out use the scroll wheel. If you need to shift the selected angle of view at selected zoom, click scroller and use it like pan function. When viewing Orthophotos or Profiles use scroller to zoom and pan.



3D Rotate Vertical Navigation

Scroll Wheel to Zoom in or Out

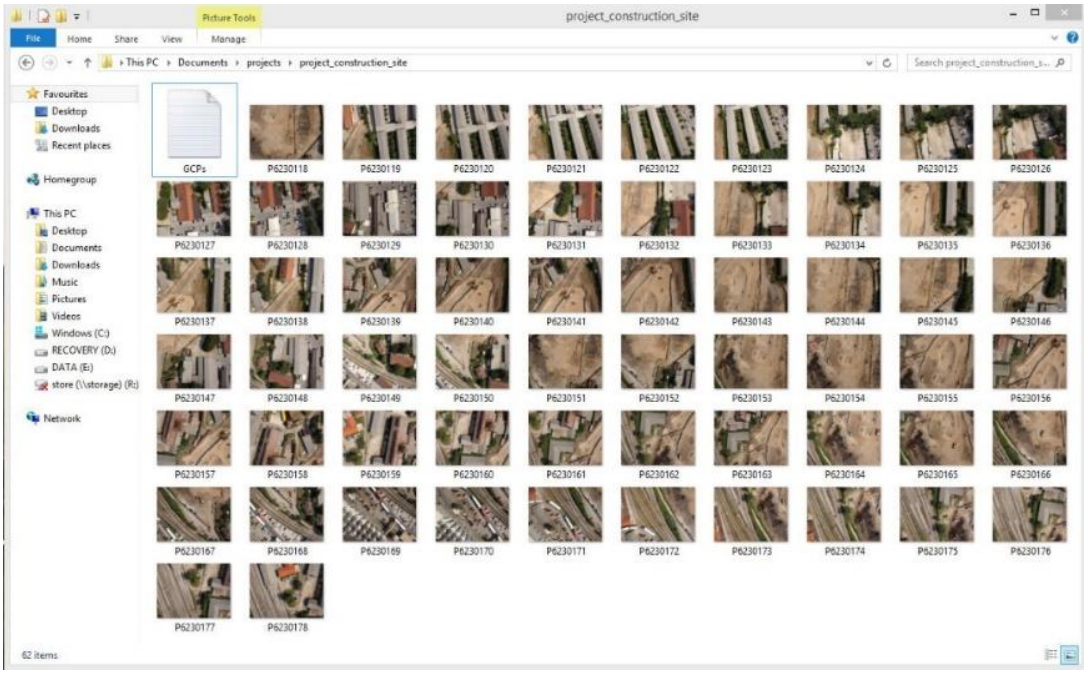
Pan Function

Confirming Closing selection

3. Preparation

Prepare your project folder on your disk and copy your images of selected project from SD card into the folder. If your UAV supports telemetry, use that data. Depending on your UAV model, telemetry data are ascribed to images, or recorded into *.csv file.

The .csv file must also be added alongside images and consists of further data: enabled, index, longitude, latitude, altitude, date, time, yaw, pitch, roll, x Sigma, y Sigma, z Sigma, p Sigma, blur, and file name. Organization of data must be known but is to be specified as you wish. See below an example of generic telemetry file (use this option if your UAV type is not listed). It is recommended you save your ground control point coordinates (GCPs) .txt file into the same folder as your image files. GCP file should be organized in the following way: point name, x coordinate, y coordinate, z coordinate – space delimited. Be advised, it is highly recommended to make some map of GCP/validation points locations especially when large datasets are in use.



Example of GCP coordinate file:

```
2000    461826.497    101890.277    299.055
2002    461890.872    101944.218    306.204
2003    461912.476    101975.102    298.454
2004    461918.598    102038.315    298.804
2005    461924.782    102083.948    298.882
2006    461889.252    102029.085    297.492
2007    461862.244    101990.371    294.797
2008    461863.334    102042.424    294.880
2009    461828.060    102028.207    300.632
2010    461796.036    101953.868    299.634
```

Example of csv telemetry file:

```
1  Enabled;Index;Longitude;Latitude;Altitude;Date Time;Yaw;Pitch;Roll;xSigma;ySigma;zSigma;pSigma;Blur;FileName
2  1;0001;13.9583636602449;45.8337773528361;271.29;05.12.2015
   11:14:39.874;146.75;3.31;1.62;0.00731778655059028;0.00550090901579003;0.0127800625976558;0.0157206870078887;0.0045;F:\5.12.2015\120m_70\DCIM\100MSDCF\DSC00001.JPG
3  1;0002;13.9584470721282;45.8336518897466;271.253;05.12.2015
   11:14:40.674;162.75;3.37;1.68;0.00731368580129062;0.00549727205075 39;0.0127718440328717;0.0157108242940974;0.00565;F:\5.12.2015\120m_70\DCIM\100MSDCF\DSC00002.JPG
4  1;0003;13.9584784645431;45.8335148563475;271.744;05.12.2015
   11:14:41.474;177.56;3.31;1.62;0.00730547739713155;0.00549181208709839;0.0127569588852516;0.0156929920665245;0.00392;F:\5.12.2015\120m_70\DCIM\100MSDCF\DSC00003.JPG
5  1;0004;13.9584659361907;45.8333702699896;272.749;05.12.2015
   11:14:42.314;188.4;3.31;1.74;0.00702281994643178;0.00547722557505166;0.0123923363414652;0.015260733927305;0.00532;F:\5.12.2015\120m_70\DCIM\100MSDCF\DSC00004.JPG
6  1;0005;13.9584281045896;45.8332299296499;274.225;05.12.2015
   11:14:43.154;192.07;3.31;1.74;0.00479061582680139;0.00540462764674866;0.00847230783199005;0.011132834320154;0.00585;F:\5.12.2015\120m_70\DCIM\100MSDCF\DSC00005.JPG
7  1;0006;13.958391200951;45.833105293 4532;275.878;05.12.2015
   11:14:43.914;190.53;3.31;1.80;0.00478539444560216;0.00540185153442 78;0.00847289796940811;0.011129690022 6376;0.00417;F:\5.12.2015\120m_70\DCIM\100MSDCF\DSC00006.JPG
8  1;0007;13.958362663814;45.8329738996776;277.428;05.12.2015
   11:14:44.714;185.58;3.37;1.74;0.00477912125813941;0.00539444158370447;0.00846108740056501;0.0111144050672989;0.00617;F:\5.12.2015\120m_70\DCIM\100MSDCF\DSC00007.JPG
9  1;0008;13.958354030887;45.8328480387836;278.474;05.12.2015
   11:14:45.474;179.71;3.37;1.62;0.00477387304912;0.00538794951720968;0.0084504437753292;0.0111009008643443;0.00556;F:\5.12.2015\120m_70\DCIM\100MSDCF\DSC00008.JPG
```

Example of .csv generic telemetry log file:

Standard log file for telemetry import:

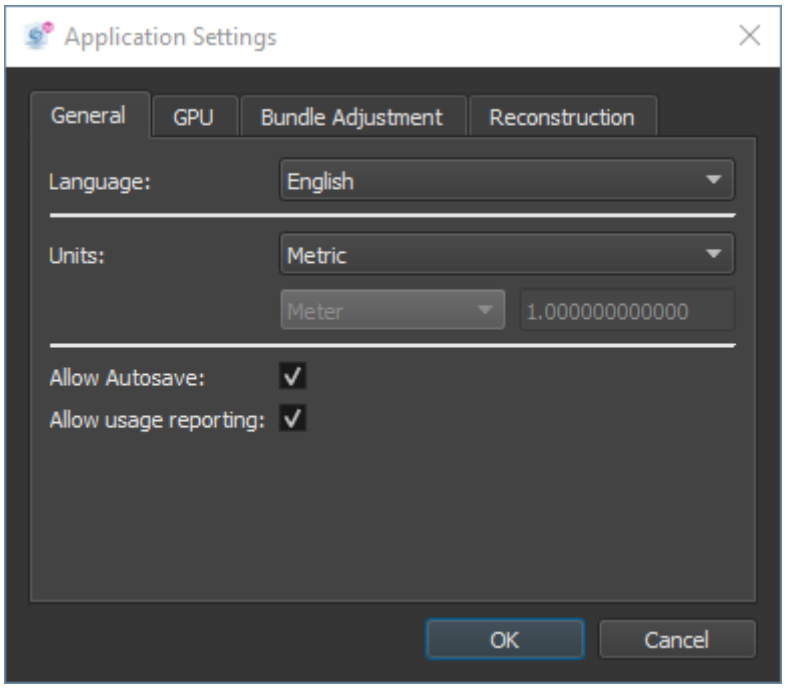
File type: *.csv

Delimiter: semicolon [;]

Image name/ID	Longitude	Latitude	Altitude	Yaw	Pitch	Roll
DSC01762.JPG	34.841698	119.183754	230	146.75	3.31	1.62
DSC01763.JPG	34.841301	119.183754	229	162.75	3.37	1.68
DSC01764.JPG	34.840881	119.183762	230	177.56	3.31	1.62
DSC01765.JPG	34.840485	119.183754	230	188.4	3.31	1.74
DSC01766.JPG	34.840088	119.183762	229	192.07	3.31	1.74
DSC01767.JPG	34.839672	119.183754	230	190.53	3.31	1.80
DSC01768.JPG	34.839275	119.183762	229	185.58	3.37	1.74
DSC01769.JPG	34.838879	119.183762	230	179.71	3.37	1.62
DSC01770.JPG	34.838463	119.183762	230	172.85	3.31	1.68
DSC01771.JPG	34.838066	119.183762	229	166.39	3.31	1.74
DSC01772.JPG	34.83765	119.183762	230	161.6	3.31	1.85
DSC01773.JPG	34.837254	119.183769	229	159.01	3.37	1.85
DSC01774.JPG	34.836838	119.183769	230	157.79	3.42	1.85
DSC01775.JPG	34.836437	119.183769	229	157.45	3.37	1.85
DSC01776.JPG	34.83604	119.183769	230	157.43	3.37	1.85
DSC01777.JPG	34.835625	119.183769	230	157.88	3.37	1.85
DSC01778.JPG	34.835228	119.183777	230	157.48	3.37	1.85
DSC01779.JPG	34.834812	119.183769	230	156.64	3.37	1.85
DSC01780.JPG	34.834415	119.183769	229	155.85	3.37	1.85
DSC01781.JPG	34.834019	119.183777	230	154.99	3.37	1.85
DSC01782.JPG	34.833618	119.183777	230	155.07	3.37	1.80

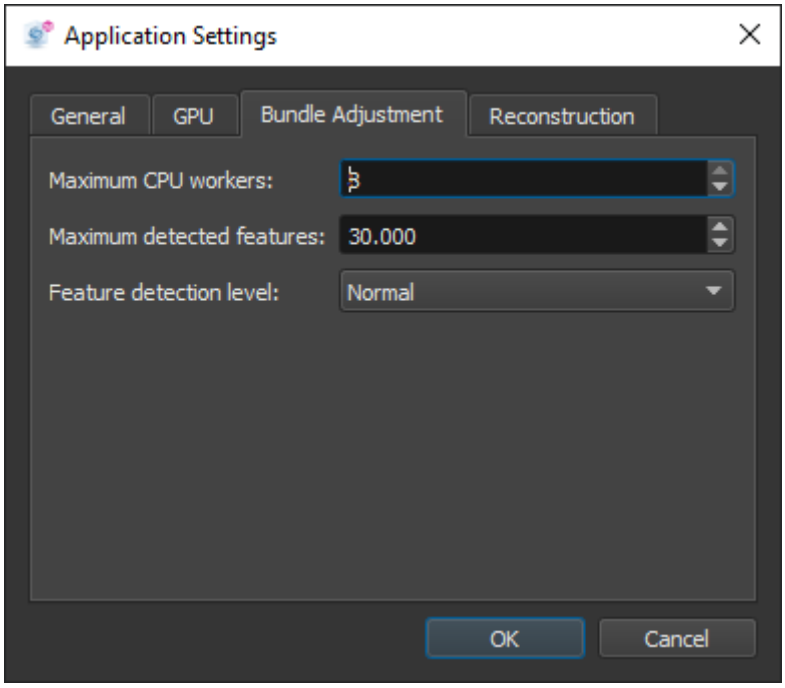
3.1. Option settings

Start ***Cube-3d*** and set language. Click ***Options -> Application settings*** and select language and units- You have to restart application to assign applied changes.



When imperial units are selected, you can further assign weather you want **International foot** or **US survey foot**. You can select **Other.** On the right, where by default is set 1.000000000000, type value of 1unit in meters.

Next, click **Bundle Adjustment**.



There you can assign:

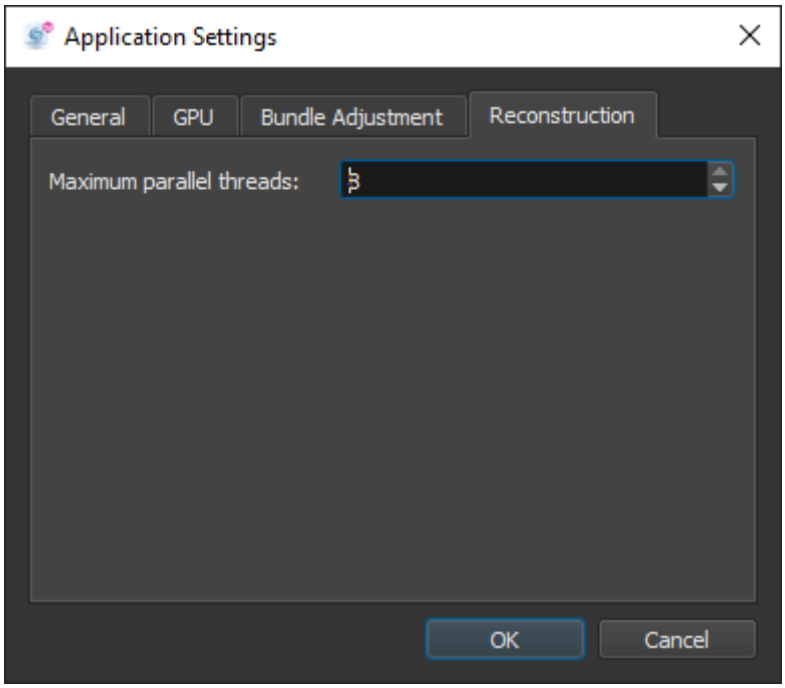
Number of Maximum parallel threads depend on your computer CPU type. For default value Cube-3d checks number of available threads and directs them all. Decreasing threads is an option when RAM is insufficient to avoid plausible comp crash. It is imperative to keep sufficient level of RAM and processor. For example: if you have a good i7 processor with 4 cores – 8 threads and just 8GB of RAM we would advise you to lower the threads number to 4. This will avoid memory leaks during the processing.

Number of Maximum detected features, default number is 40.000;

Features correspond to so called tie points on each image further used for "sawing" them to strings and strings to block.

Feature detection level defines robustness of the matching step. Level of detection is inversely proportional to reliability and smoothness of detected points – features. Level of detection is also proportional to time of computation. Levels rise from *Normal*, *High* to *Ultra*.

Click **Reconstruction** to set **Number of maximum parallel threads**, where default value is 8. When all preferred values are assigned, click Ok to assign selected measures.



To save the changes for Language and Units you have to restart application to assign applied changes.

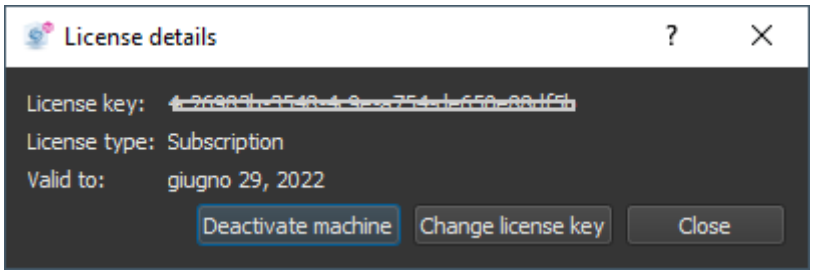
Changes of Bundle adjustment and Reconstruction settings are confirmed with selecting OK button - You don't need to restart application.

Note, that, if selected language is other than English, furtherly named command buttons and functionalities will be translated to selected language and will therefore defer from presented screenshots.

3.2. License details

All cube-3d licenses are floating licenses. Just go under **Help** -> **License** and click on **Deactivate machine**. This will allow you to use the same license on another machine.

In case you have a new code, click on **Change license key.**


License details
License key:
License type: Subscription
Valid to: giugno 29, 2022
Deactivate machine
Change license key
Close

4. Processing

Aerotriangulation, Geo-referencing and Reconstruction

This part of Cube-3d empowers you to import your own dataset(s) containing images and geospatial data to generate metric, geo-referenced point clouds that serve as a basis for further modelling and analysis. When using unmanned or manned aircraft for the resulting data are overlapping aerial images along with image positions (exif gps, rTK, PPK, etc.) and/or GCPs to further improve geospatial orientation of the model. Therefore, it is advised to utilise flight mission planning software/app compatible with your UAV (pixhawk, GS Pro DJI, etc.). Flight path needs to be planned as to achieve image overlap that is paramount to successful matching and alignment of the images. Recommended overlap is 70% or more (For terrain with higher terrain difference increase it up to 80%).

Another important parameter of mission planning is setting the right flying height. Its value depends on desired ground pixel size, resolution of used camera, and terrain characteristics. If your platform supports telemetry data, this is where it comes into play. Use it. To further improve geo-locating and referencing your project/model it is recommended to use ground control points. They need to be distributed across the surveyed site properly as to provide adequate spatial reference (minimum 3 GCPs, recommended 9 GCPs per every 500m x 500m area/segment). GCPs can be measured manually using GNSS devices (or any other device with GPS/GNSS capabilities) and can be in the form of natural/manmade features (building corners, rocks, manholes, shafts, etc.) or in the form of ground control targets. You can find the video description for all the procedure in the following video:

To recap: Place GCPs → Plan flight mission + UAV flight (capture images and positions) → Import to Cube-3d.

4.1. Setting flying height

To achieve great results, make sure you start with the correct settings right at the beginning. Higher overlap means more images and more images means longer processing time. The minimum overlap between images is 65% (front and side overlap). However in some cases (wide-angle cameras, high vegetation, uneven terrain, etc) it is safer to increase these values to 80%. Below are instructions on how to best prepare and set up your flight mission to get the best possible orthophoto with minimum processing time. In case you would like to calculate volumes, as well, additional side images will have to be captured – see the instructions for Volume calculations.

Standard settings for any drone, any camera:

- Camera angle nadir direction (vertically downward) - 90° angle
- Flying height from 40 - 150 m AGL (above ground level) - Usually 80 m
- Front Overlap (overlap in the flying way) 80%, Side overlap 75%.

Most drones automatically geotag the images based on drone GPS (usual accuracy 1,5 m) and you can orientate the model in Cube-3d based on that telemetry data. If you would like to achieve survey-grade accuracy (up to 4 cm), don't forget to set up GCPs before the flight and measure them with survey-grade RTK GNSS. In case you have a drone with RTK GPS with 1 cm accuracy you can use that data to orientate the model accurately without employing any GCPs.

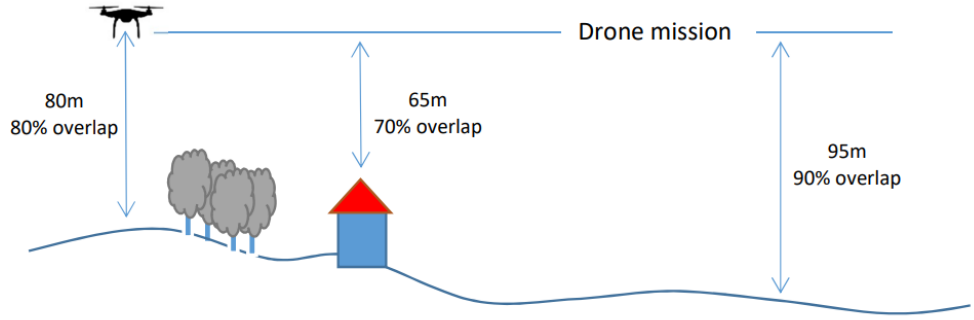
Note: We always recommend using GCPs if the type of terrain allows for the placement. Cube-3d supports all combinations of geo-referencing data, including or excluding GPS inputs in the processing stage is also supported. Check the instructions hot set them correctly: GCP Setup

Tips and Tricks:

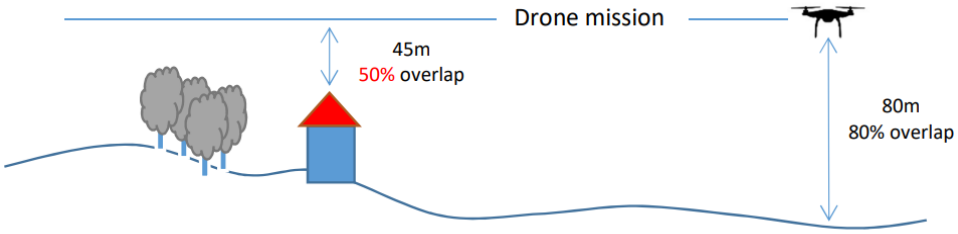
1. Start your mission from the highest point in relation to the terrain you are about to map. Most drones (DJI Phantom 4, Yuneec, DJI drones) fly missions in a single plane and don't automatically adjust their flying height to

the terrain characteristics. This can result in an insufficient image overlap (less then 60%) when capturing higher terrain points, high buildings, high trees, etc. in case you start the mission from lower positions.

a. Best practice: Drone mission 80m 80% overlap 65m 70% overlap 95m 90% overlap



b. Wrong starting point:



2. Lower flying height with better ground pixel resolution (GSD) does not always mean better results. In areas with high density of buildings, flying too low can result in the following:

a. High buildings will not be ortho-projected in the digital orthophoto.

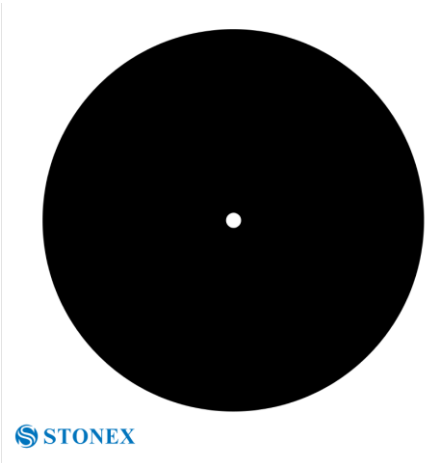
b. Image stitching can be less than perfect if they are directly over a building.

To eliminate the over-the-building image stitching we advise you to have the whole building on a single image. First, perform your mission at 80 m AGL, then manually trigger a few nadir images from a higher AGL (120 m above the object, for example) to get the whole object in one image. That enables you to recalculate the area with - or/and around - the building.

4.2. GCP setting up

Ground control points orientate the model and improve the accuracy of calculated model. Minimum required number of GCPs to orientate the model is 3, however it is highly recommended you always use more than required. We advise you to set up a minimum of 10 GCPs per 10 acres (most common area size that can be mapped with a Drone on a single battery).

Use Stonex Auto-detectable targets as your GCPs, place them down on the ground before the flight and measure them with a survey-grade GPS (GNSS) or a total station.



Use the advanced automatic orientation in Cube-3d.

Note: in case you are not using Cube-3d ground control target template you can measure any characteristic point in the area of interest, such as manholes, curbs, road markings, etc. That still enables you to do the orientation in Cube-3d but in this case semi-automatic.

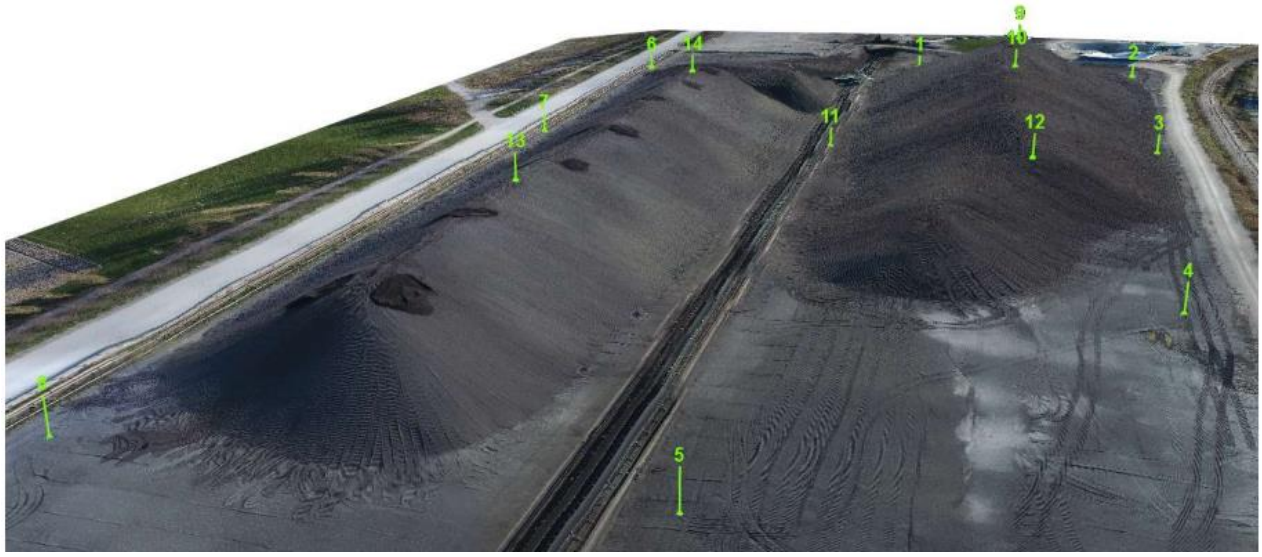
Accuracy of the end model depends on:

- Camera type
- Flying height (image resolution)
- Number of GCPs and correct setup

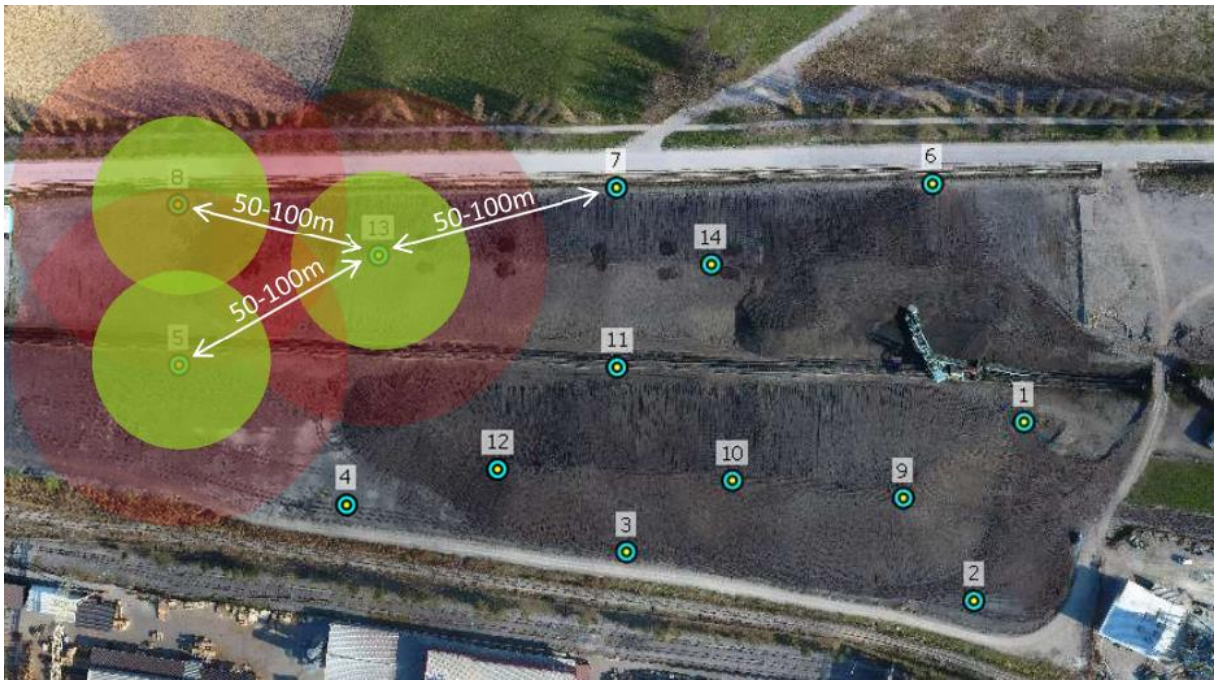
Best practice GCP setup

Square areas GCPs should be spread across the whole area as uniformly as possible and should not be placed to close to the border of the area of interest.

In case of uneven (or rugged) terrain it is highly recommended to place GCPs on both lowest and highest points of your area of interest.



To achieve survey-grade accuracy, place your GCPs 50-100 m apart. Higher density of GCPs also means higher accuracy of end results.

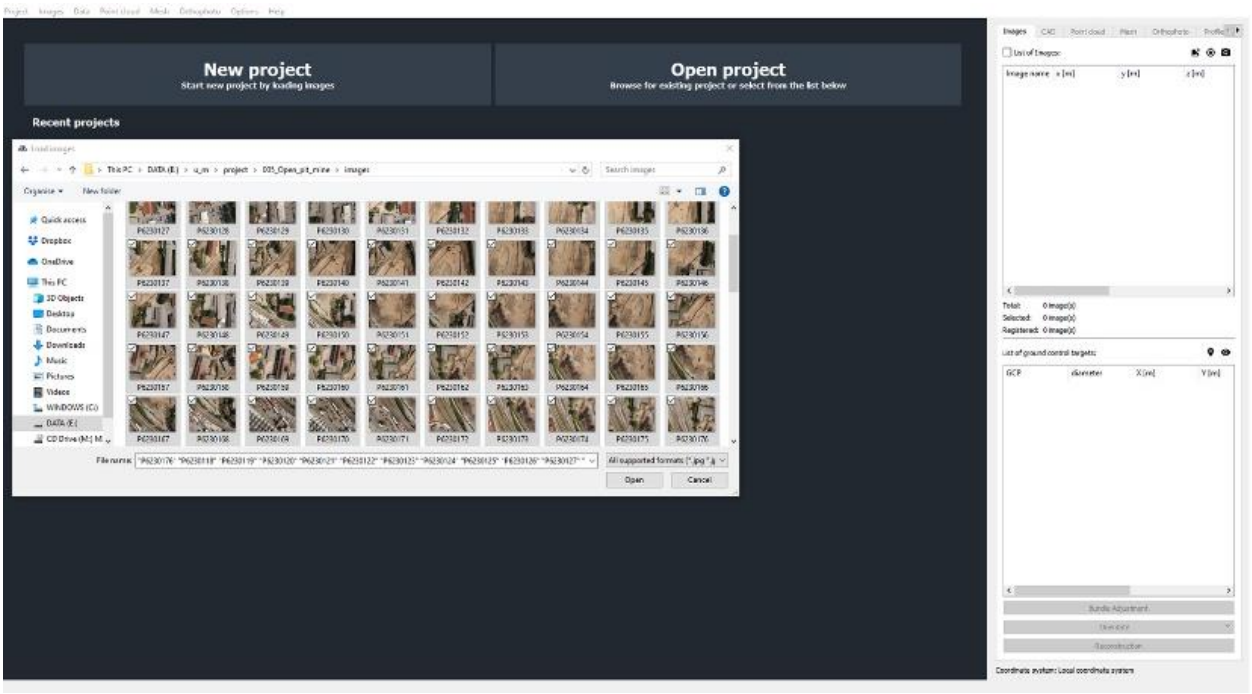


Road/Railway example of GCP setup

To achieve survey-grade accuracy (up to 4 cm) we advise to set up GCPS in pairs every 50 – 100 m – one to the left and one to the right of the object of interest (road, railway, river bank, etc). This will provide you with a stable and consistent accuracy across the whole area – around the pairs as well as between them.

4.3. Load images

Start Cube-3d, select ***New project*** button in *Viewer* and select project images in your folder. Same can be done through *Toolbar's* ***Images*** - > ***Load images***.



When images are loaded, *Telemetry importer* window pops up. For DJI drones, Yuneec drones and all other drones who are writing GPS position of the images during the flight use EXIF data.

For drones with the separate log file use one of following options:

C-astral Bramor -> *.csv

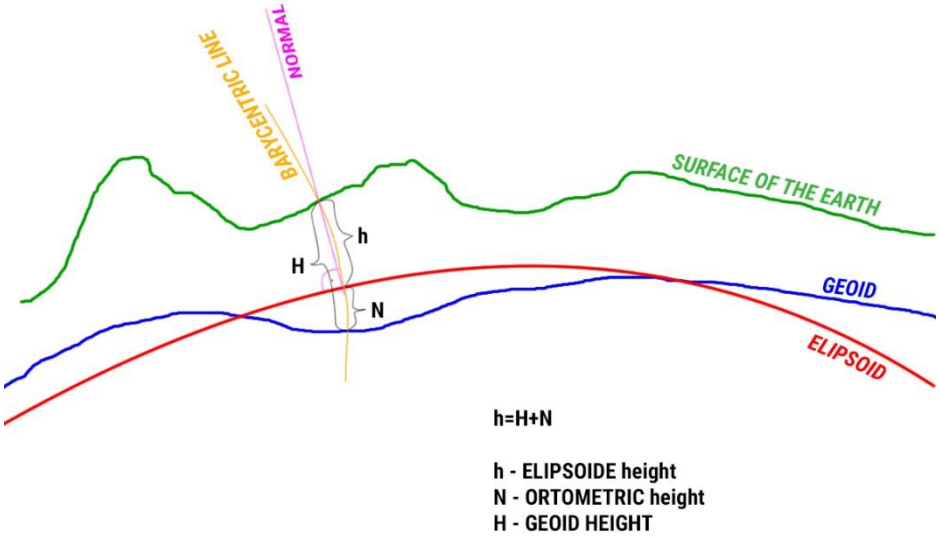
MaVinci Sirius Pro -> *.csv Exif data (DJI Phantom 4, Inspire 1, eBee, Falcon 8,..)

Other -> *.csv

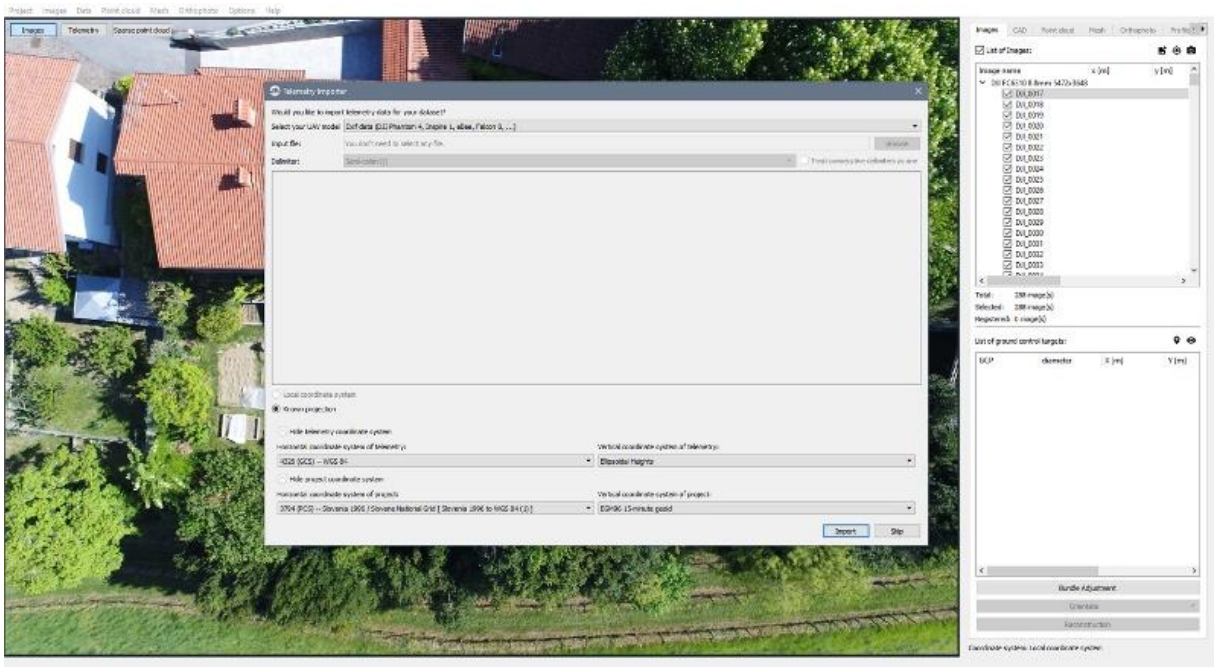
Below select coordinate system of telemety data and one of project. As origin and base of measurements for horizontal and vertical position defere you need to define coordinate system of imported and further computed data.

Horizontal coordinates are composed of 2 parameters measured on spherical or ellipsoid approximation of Earth, its horizontal datum. Data of most known horizontal datums are incorporated in Cube-3d. Click more, type name of country and select preferred system.

Vertical coordinate is composed of 1 parameter that refers to Earths gravitation field, its vertical datum. Cube-3d currently includes ellipsoid heights, EGM 15 minue geoid.

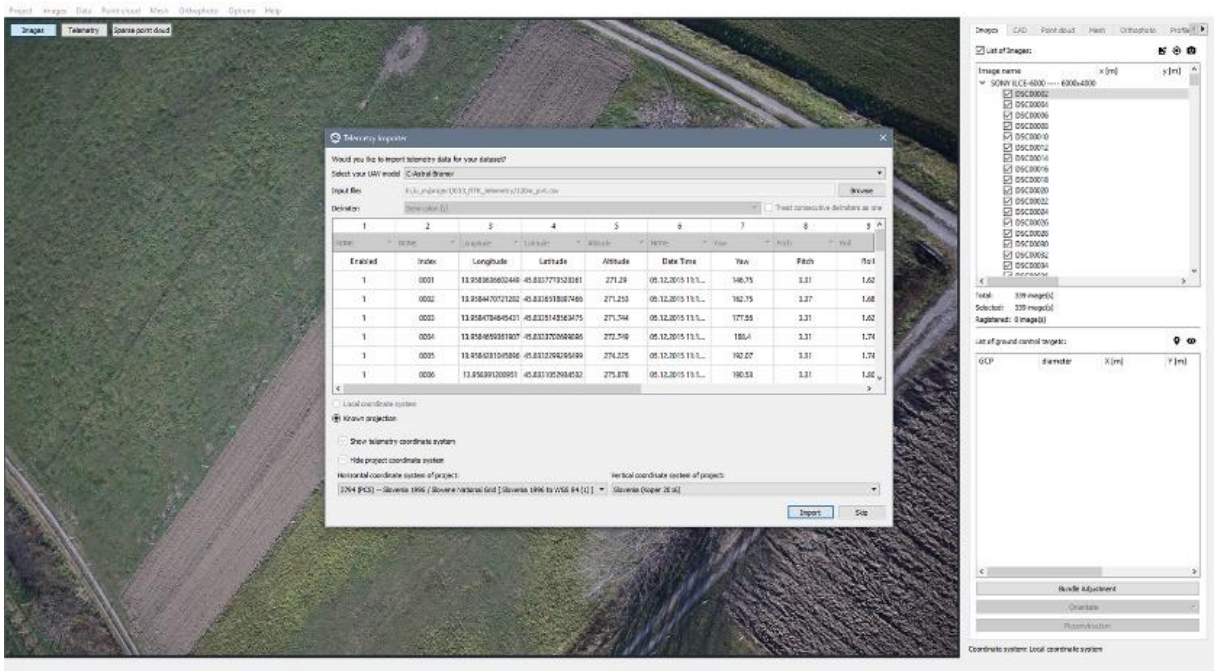


If your preferred vertical datum isn't included in Cube-3d, select *Enter geoid height above WGS84 ellipsoid* and type value.

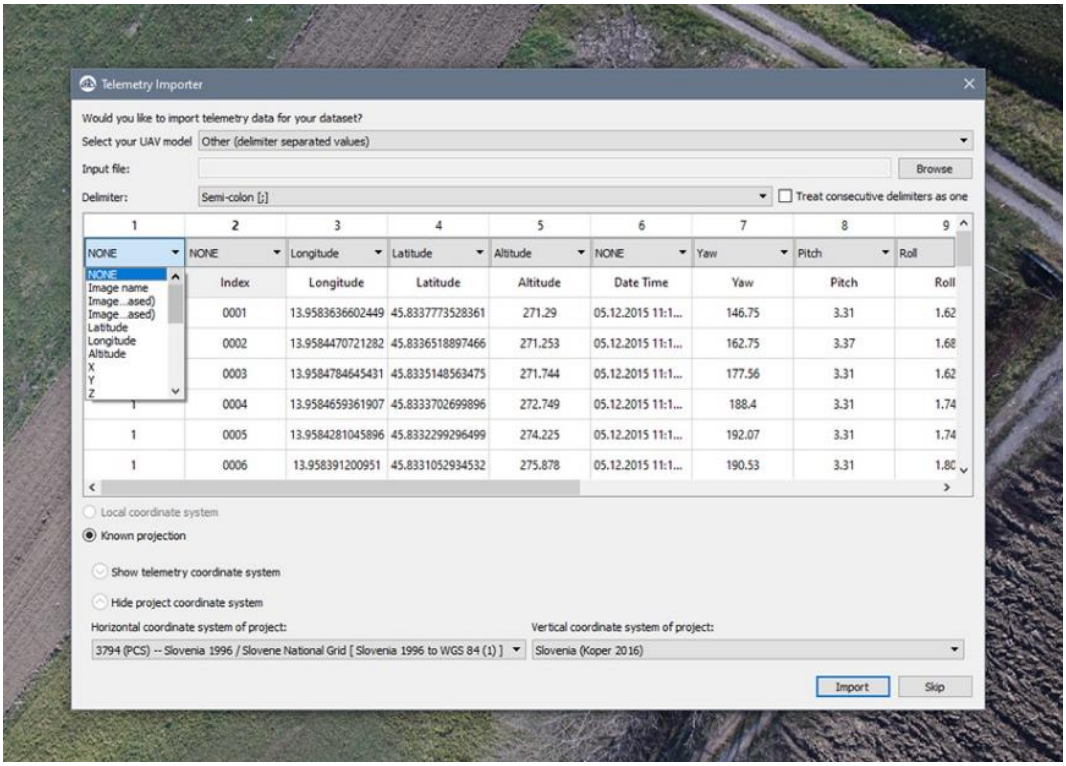


4.3.1. Telemetry

Telemetry data is attribute data to your images. They hold information about external orientation of images in the moment of exposure (their position). As the next process is matching and stitching the images together, adding telemetry data at this stage significantly speeds up the process of *Bundle adjustment*.



In case you are not using DJI drones the most universal is ''**Other**'' option. First you must set the data delimiter. Click where Semi-column [;] is displayed and select delimiter sign. Now you must assign attributes of your log file to each column. Click on a tab on top of each column, where none is displayed. Scroll the list and click on desired attribute, to assign each column to specified attribute.



See below for example of how log file should look like.

Standard log file for telemetry import:

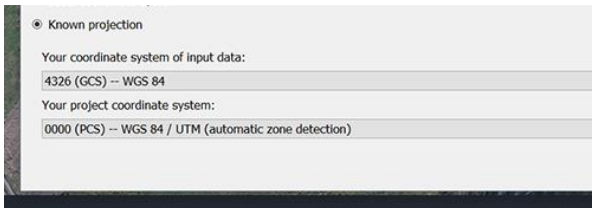
File type: *.csv

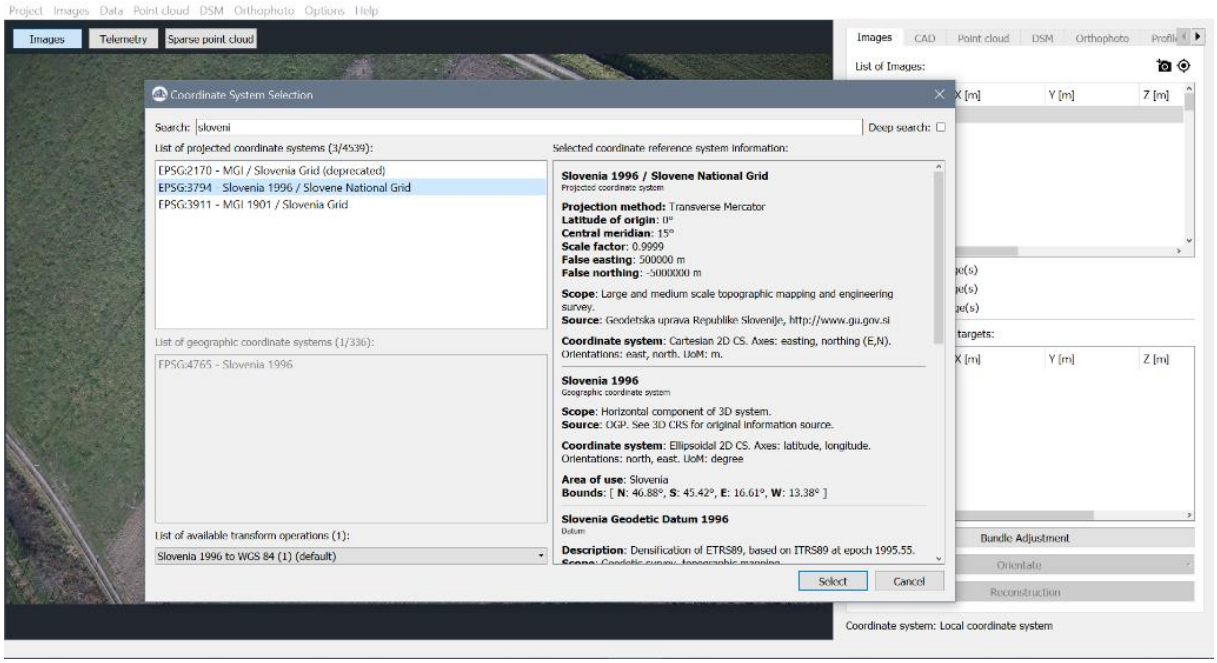
Delimiter: semicolon [;]

Image name/ID	Longitude	Latitude	Altitude	Yaw	Pitch	Roll
DSC01762.JPG	34.841698	119.183754	230	146.75	3.31	1.62
DSC01763.JPG	34.841301	119.183754	229	162.75	3.37	1.68
DSC01764.JPG	34.840881	119.183762	230	177.56	3.31	1.62
DSC01765.JPG	34.840485	119.183754	230	188.4	3.31	1.74
DSC01766.JPG	34.840088	119.183762	229	192.07	3.31	1.74
DSC01767.JPG	34.839672	119.183754	230	190.53	3.31	1.80
DSC01768.JPG	34.839275	119.183762	229	185.58	3.37	1.74
DSC01769.JPG	34.838879	119.183762	230	179.71	3.37	1.62
DSC01770.JPG	34.838463	119.183762	230	172.85	3.31	1.68
DSC01771.JPG	34.838066	119.183762	229	166.39	3.31	1.74
DSC01772.JPG	34.83765	119.183762	230	161.6	3.31	1.85
DSC01773.JPG	34.837254	119.183769	229	159.01	3.37	1.85
DSC01774.JPG	34.836838	119.183769	230	157.79	3.42	1.85
DSC01775.JPG	34.836437	119.183769	229	157.45	3.37	1.85
DSC01776.JPG	34.83604	119.183769	230	157.43	3.37	1.85
DSC01777.JPG	34.835625	119.183769	230	157.88	3.37	1.85
DSC01778.JPG	34.835228	119.183777	230	157.48	3.37	1.85
DSC01779.JPG	34.834812	119.183769	230	156.64	3.37	1.85
DSC01780.JPG	34.834415	119.183769	229	155.85	3.37	1.85
DSC01781.JPG	34.834019	119.183777	230	154.99	3.37	1.85
DSC01782.JPG	34.833618	119.183777	230	155.07	3.37	1.80

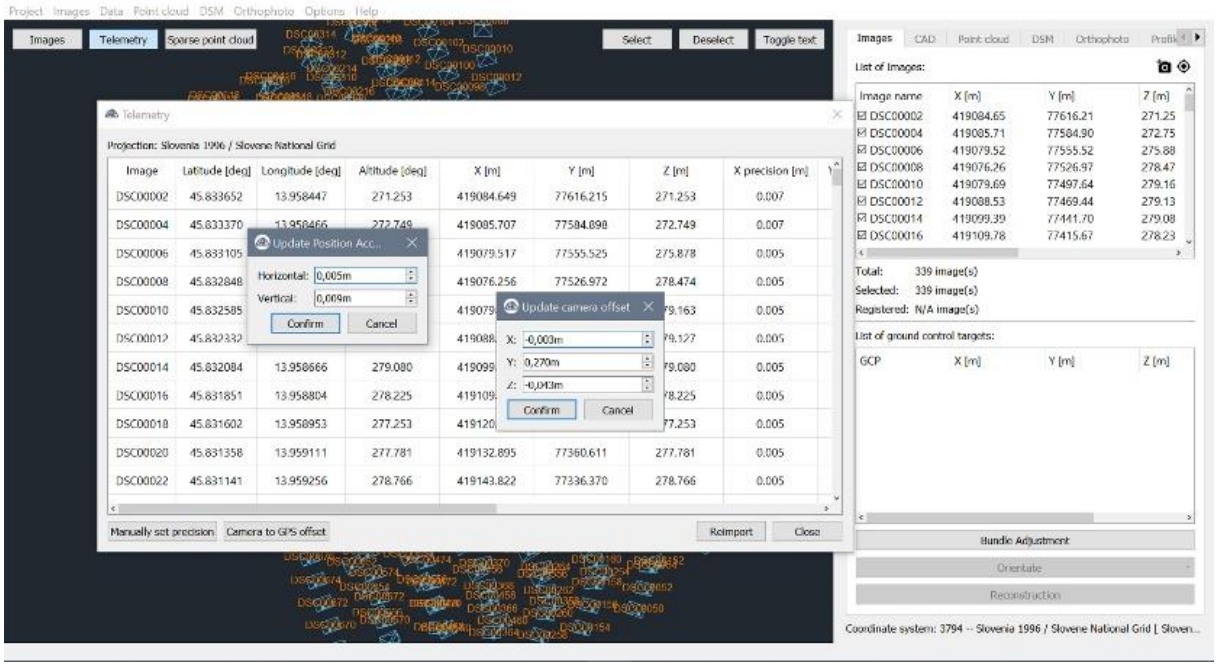
Further chose coordinate systems. In most of the projects the ''**Your coordinate system of telemetry data**'' is WGS 84 – and this is also the default value in Cube-3d. In case your drone is writing the telemetry data in any other coordinate system feel free to change it.

Second, select **project coordinate system**, the system you want your data to be computed in. Please be aware to select the ––right project coordinate system, because afterwards you cannot change it! History of last selected systems are seen in the pop-up menu or click more to select desired one.





In the Coordinate system Selection window, select desired system. You can either write its name, or name of the country into search window or scroll down the list to find desired one. Click desired system and click **Select**. If you would like to know more about items in Selection window, go to chapter *4.3.2*. When desired system is selected click OK.



Telemetry window pops up, presenting imported data and its transformation to project coordinate system with their accuracy. You can **manually set precision** and determine **Camera to GCP offset.** If you imported wrong log file, click **Reimport,** to reimport telemetry data or/and close. Camera positions are displayed in the *Viewer* after the data has been imported and processed. In the upper left side of the *Viewer,* you will see three buttons, ***Images***, ***Telemetry*** and **Sparse point cloud** to observe data in preferred mode. By this stage, Sparce point cloud isn't available. When in ***telemetry*** mode, three buttons appear in the upper right side.

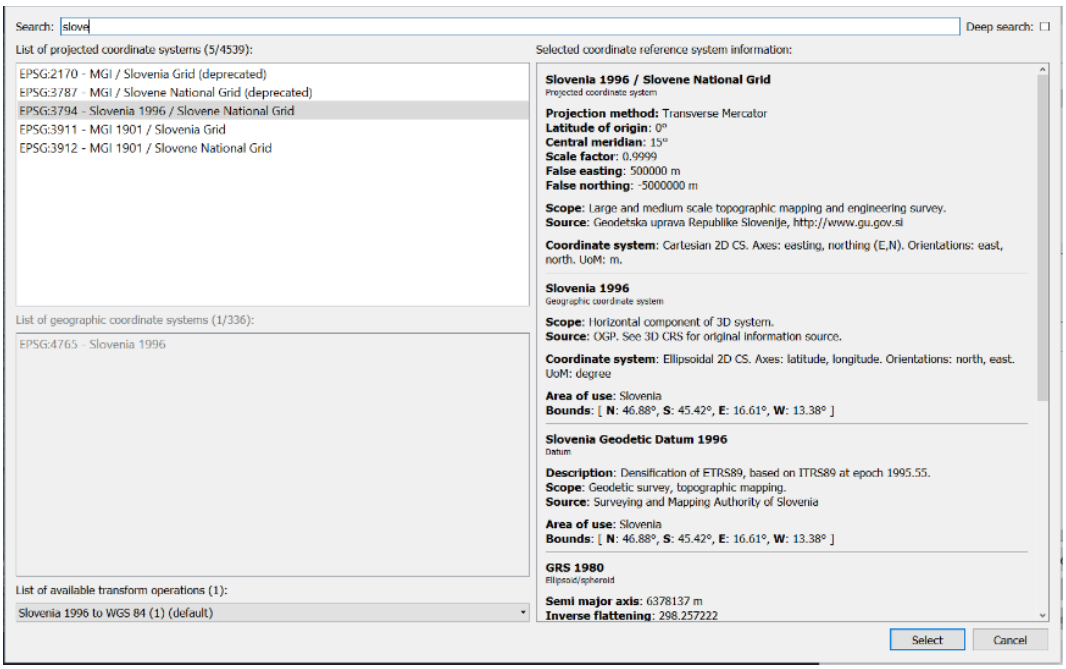
Third button ***toggle text*** is for *display* of image names. By default, all imported images are selected – number of selected images from available is shown in the working panel. Use ***Deselect*** button to exclude any number of images from bundle adjustment. Use the *left mouse button* to *draw* polygon surrounding desired cameras. *Close polygon* and confirm selection with the *right mouse button*. Deselected images will change colour from blue to grey and on the list of images in working panel, deselected images will be unhooked. If you wish to include some of the deselected ones, click **Select** button to reselect them, or hook them on the list of images. That has intrinsic value in two cases:

- When a data set of more than 1000 images is being processed probably more effective way would be to process them by parts;
- You can easily deselect images which are not important for your project and would just increase the processing time for the project – panoramic images, images during the drone lift to the exact height, …

4.3.2. Advanced explanation about coordinate systems

When importing image telemetry data or ground control points, you need to select data coordinate system and project coordinate system. When you are assigning preferred project coordinate system, as described in *4.3.1* you may be interested in data displayed along selected coordinate systems.

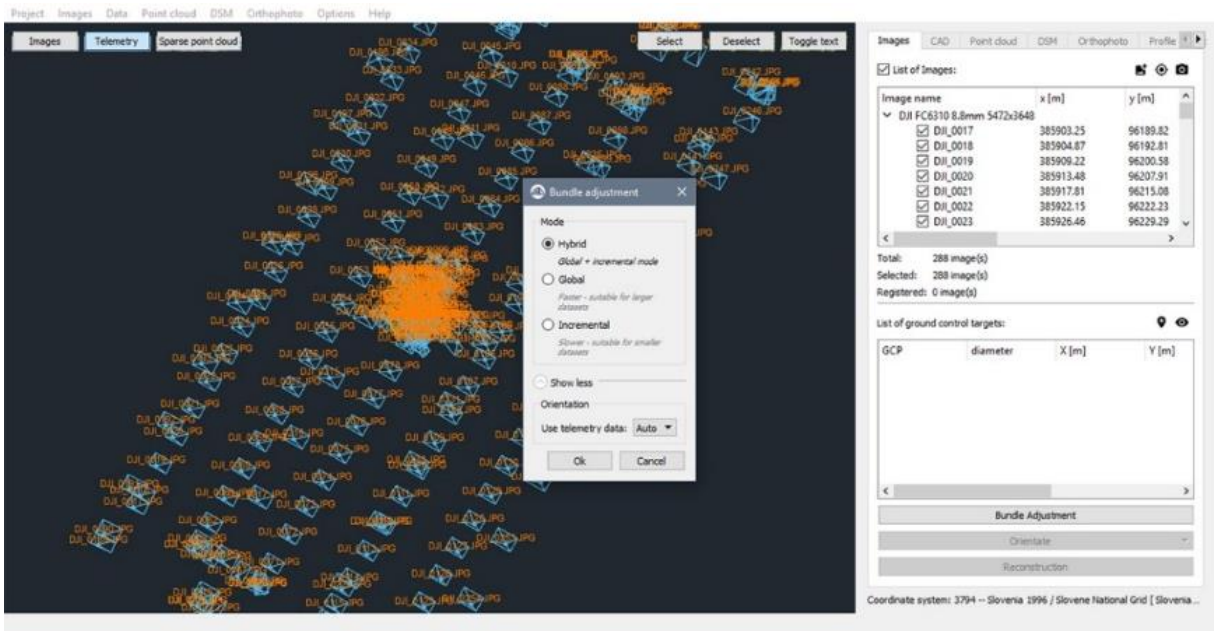
In the upper left window, **list of available projected coordinate systems** appears. You can either scroll down the list or type name of the country or coordinate system in search menu. In the right window, observe **information** about **selected coordinate system**. Bottom left window presents a list of geographic coordinate systems found due to search menu. List of available transformation operations that refer to selected system appears below. In the right window you can inspect coordinate system metadata. In case of several systems for one country, it might be handy to select the right one.



4.4. Bundle adjustment

If you have camera calibration parameters, click  and load camera parameters. Such data significantly improves the speed of the process of bundle adjustment and should be imported if available. For most popular drones (DJI Phantom 4, 4 PRO, Mavic, ...) the predefined parameters are already integrated in the software and you don't need to import it additionally. In case you are using other cameras, we advise you to calibrate your camera on your fist project and use those parameters for future projects. Check out chapter: *4.3.4.3 Export camera calibration* for detailed instructions.

Above ***Bundle Adjustment*** button ***number of all images*** is presented as a **number of used images**. Press ***Bundle Adjustment*** to calculate parameters of camera orientations.



You need to select the Mode of adjustment:

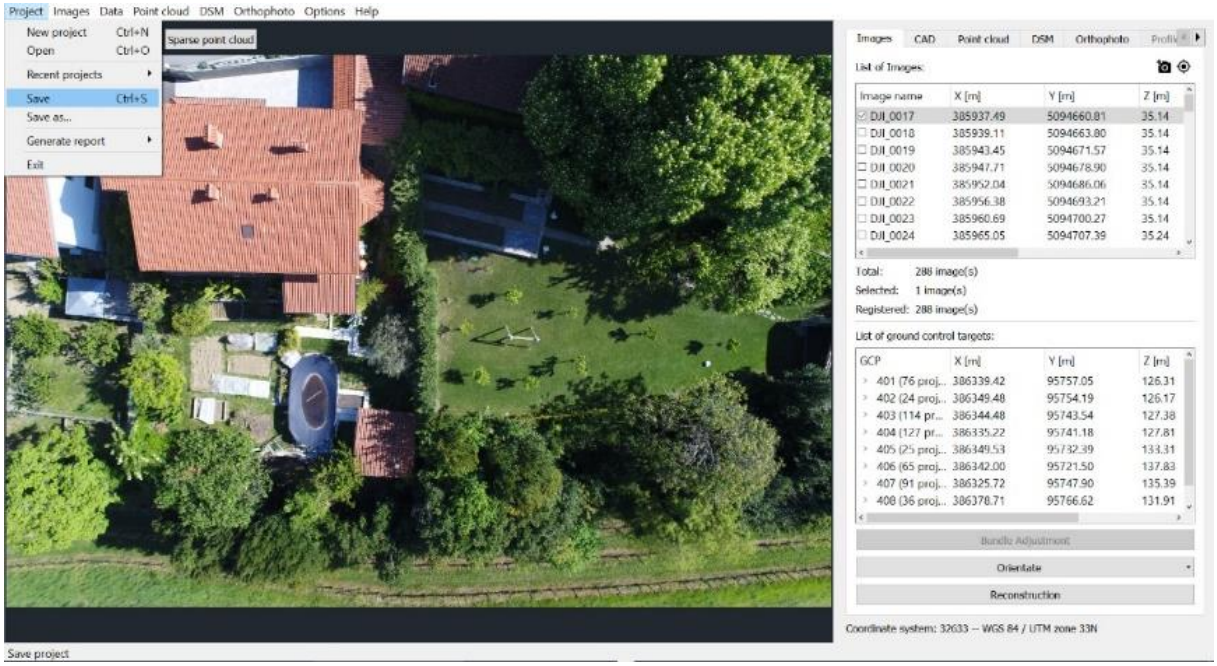
- ***Global*** is faster method suitable for larger datasets – use it for default setting. In case you will not be satisfied with the number of matched images repeat the Bundle Adjustment calculation with Incremental approach.
- ***Incremental*** is slower but more stable – suitable for project where image texture or overlap isn't the best: High vegetation, bad overlap between images, blurry images… We advise you to use incremental approach for data sets up to 500 images (because of the processing time…)
- ***Hybrid*** is combination of global and incremental mode. It gives the best result using characteristics of both modes, but is also the slowest.

Click ***Show more***, to select weather you wish, to orientate model using telemetry, while bundle adjusting. By default, ***Auto*** is selected, that means when telemetry data is available it is used in process of bundle adjustment. There are two more options ***Yes*** that insists on computing orientation or ***No***. Use of telemetry georeferenced your project and fastens process of bundle adjustment. Click ***OK***, and type your flying height – use the same value as you set into the planning software (for example: DJI GS PRO, Mission planner, Microdrone Cockpit, …). If you are flying at different heights: 60m high with first battery, and 80m with the second battery, and you wish to compute entire dataset in one take, you have to select the higher value, meaning 80m.

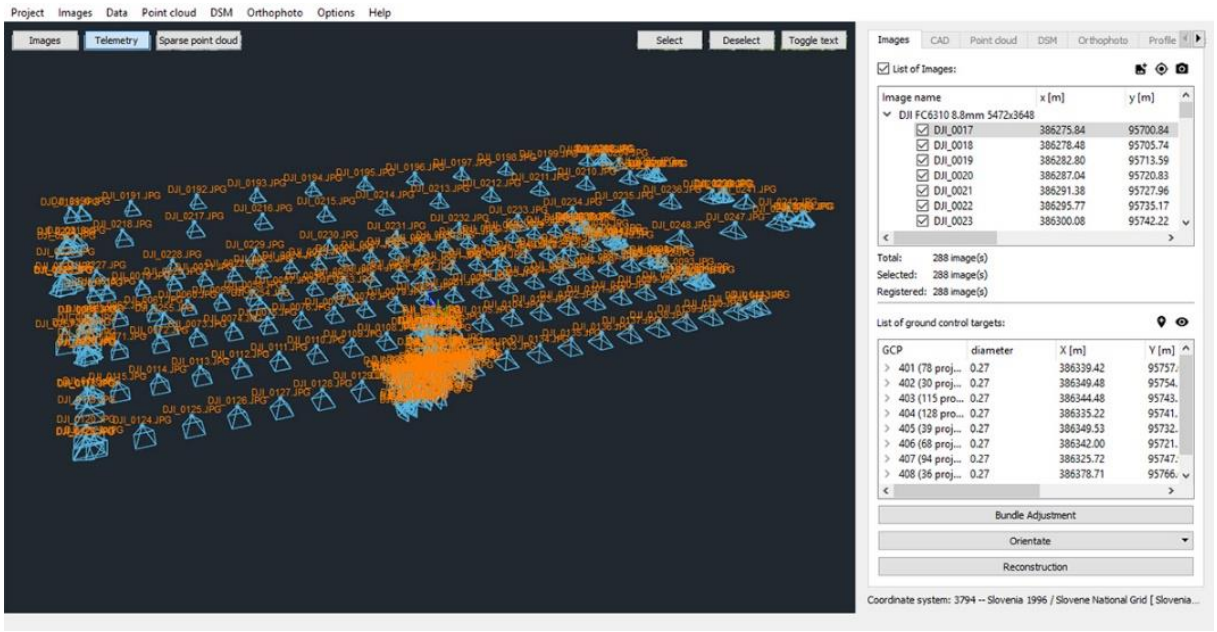
Click ***OK*** to start Bundle adjustment. The processing time could be between a couple of minutes and up to several hours. It depends on the number of images and your CPU specifications (number of cores…)

Note: Try to save your project after every operation (Bundle Adjustment, Orientation and Reconstruction). It can be done through *Toolbar* ***Project > Save project***. The latest version also has ***autosave***, which makes that for you.

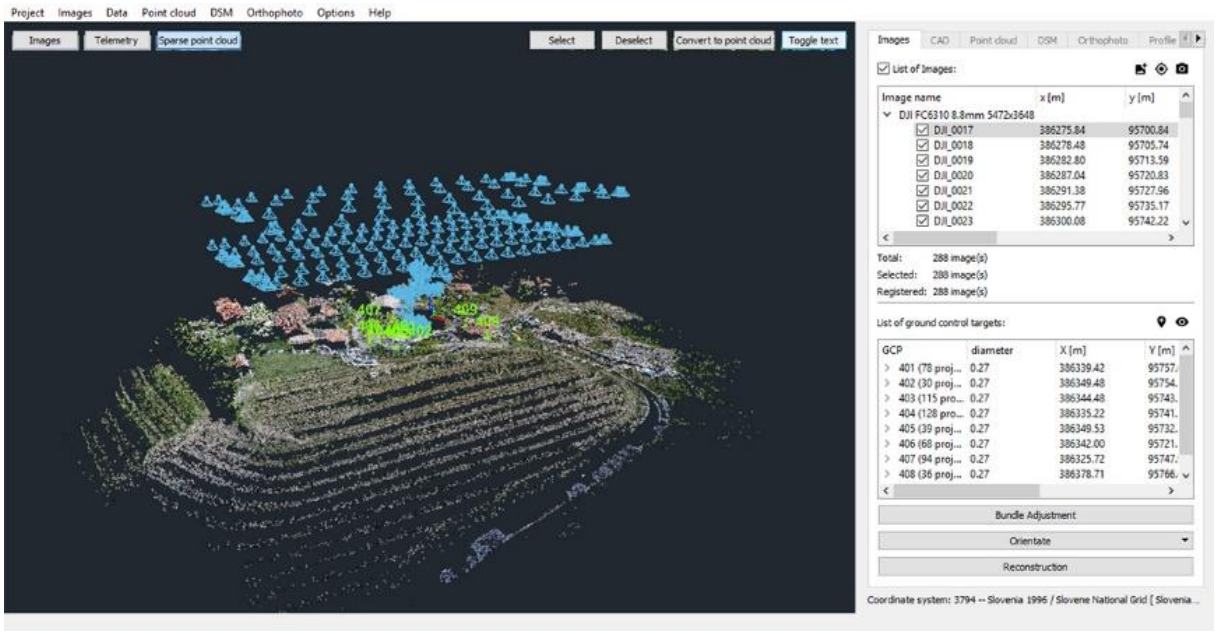
All images must be imported from a single folder to be processed as one project. Some of the drones start to write images in a second folder after 1000 created images and start once again with the image name 001.jpg (Phantom 4 Pro). In this case rename the images in second folder and copy all in one folder.



Once project is bundle adjusted, you can observe several function in the viewer. As before, you can watch ***images***, or click ***telemetry***, to observe location and orientation (external orientation) of images. ***Toggle text***, to view or not image names.



Click ***sparse point cloud*** to observe sparse point cloud beneath telemetry data. There, you can ***toggle text***, ***select*** or ***deselect*** desired camera positions or click ***convert to point cloud*** that shifts your position in the working panel from Images to point cloud.



4.4.1. Bundle Adjustment troubleshooting

If bundle adjusted set of images is beneath your expectations, here are some guidance, that might help.

In case, that matches were found on only half of the selected images *(probably due to insufficient overlap, bad texture on images, high vegetation, images of water areas that are blurry) you may get better results by:*

recomputed Bundle Adjustment using *Incremental* mode. If results aren't better, proceed;

go to 3Dproject folder, and inside the folder with images manually delete folder named "Features". Then increase *Number of maximum detected features* to 80.000 in Cube-3d -> Options. Results should be better.

If the results are still insufficient: repeat the step 2. and increase also *Feature detection level* from *Normal* too *High* or *Ultra*.

After computation, set all changed parameters back to default, because made changes increase processing time and are unnecessary for standard datasets.

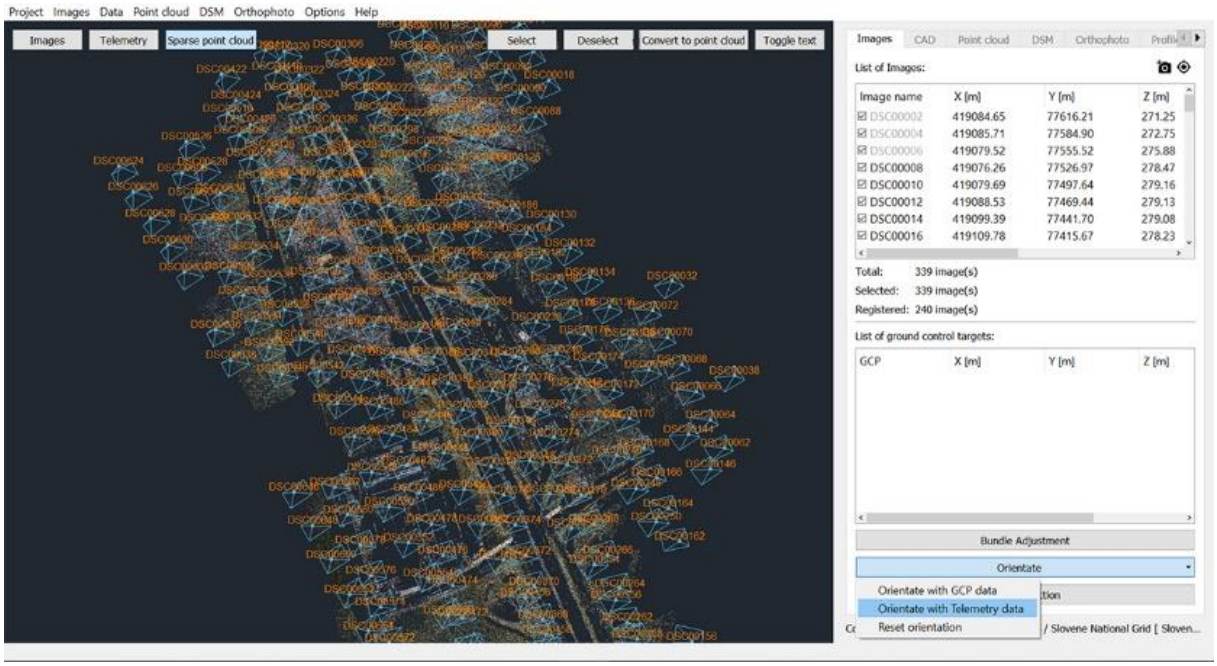
Default values of *Number of maximum detection features* is 40.000. *Feature detection level* is, by default set to *Normal*.

4.5. Orientation (geo-referencing)

To geo-reference a project, proceed with **Orientation**. Three options are available depending on your data type.

4.5.1. Orientate with telemetry data

In case of available and imported telemetry data, you can orientate images using just telemetry recordings, although it is recommended to use GCPs to achieve better accuracy. Remember, in the process of *Bundle adjustment* you selected weather you wish to orientate images or not.

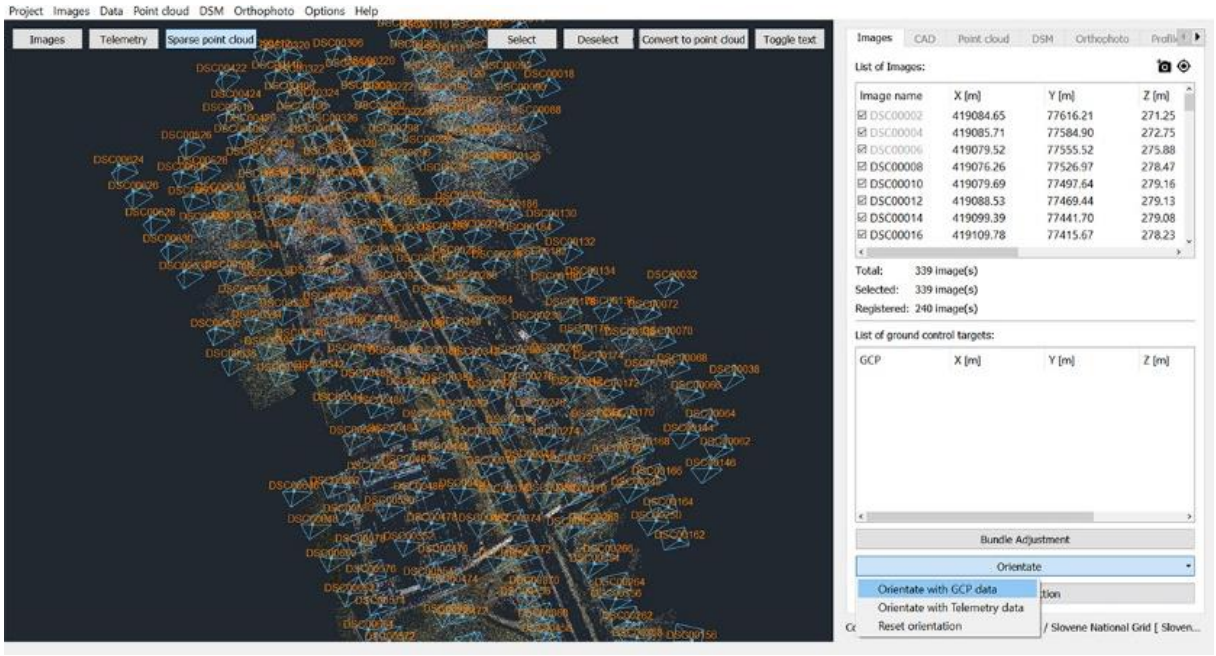


To proceed, click **Orientate with telemetry data** and follow the pop-up wizard. First you inspect location of images in assigned coordinate system. Some rows might be seen in grey colour as image's telemetry has error. To proceed, click **Next**.

Orientation summary window presents residuals of adjusted camera positions on all three axis and its spatial value. Click **Finish** to complete orientation. If some images have errors in telemetry, they appear as unregistered in the **List of images** in **Working panel**.

4.5.2. Orientate with GCP

In most cases, especially when telemetry data cannot be measured, or it isn't accurate enough (most UAVs caries GPS antenna with 1.5m accuracy), block of images is orientated using ground control points (GCPs). Position of GCPs are measured using GNSS services or by total stations.

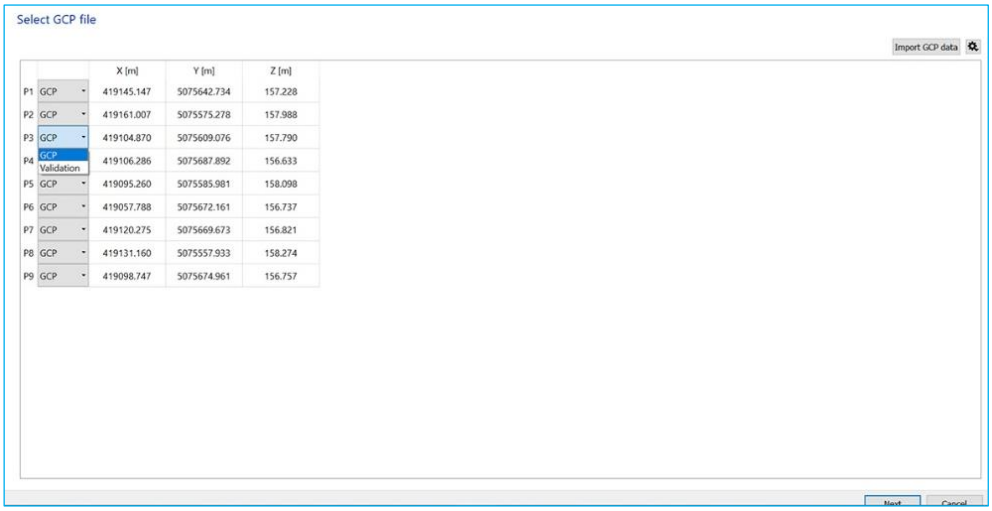


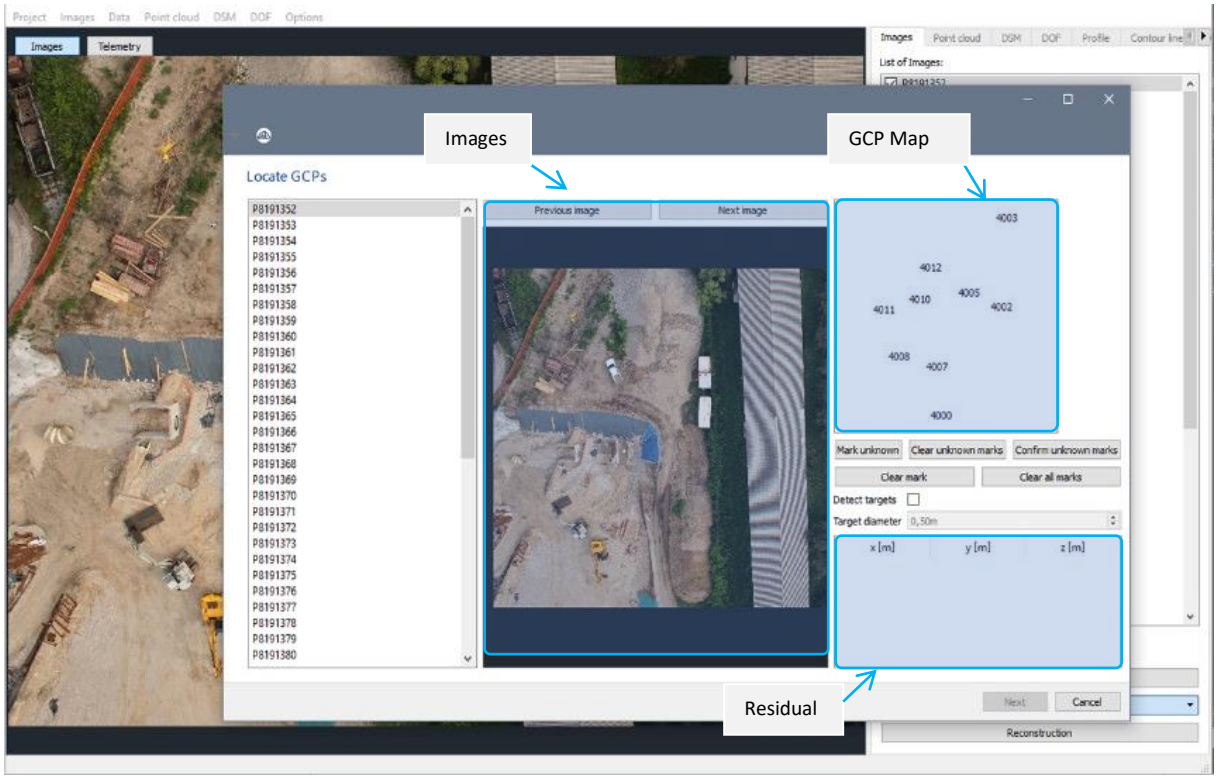
To proceed, click ***Orientate with GCP*** and follow the Orientation pop-up wizard: First, **select *ground control points*** (*.txt) file and click ***next***. Continue by defining the purpose of GCP. Click on a tab after points name and select whether it is ground control (GCP) or validation point:

- GCP - its reference coordinates are used in the orientation adjustment,
- Validation point – excluded from orientation adjustment and used for quality assessment at the end of the process.

Further select GCP's coordinate system and also project coordinate system in which computed results and data will be transformed. Usually, the GCP coordinate system is the same as project coordinate system which was defined after importing the images with telemetry.

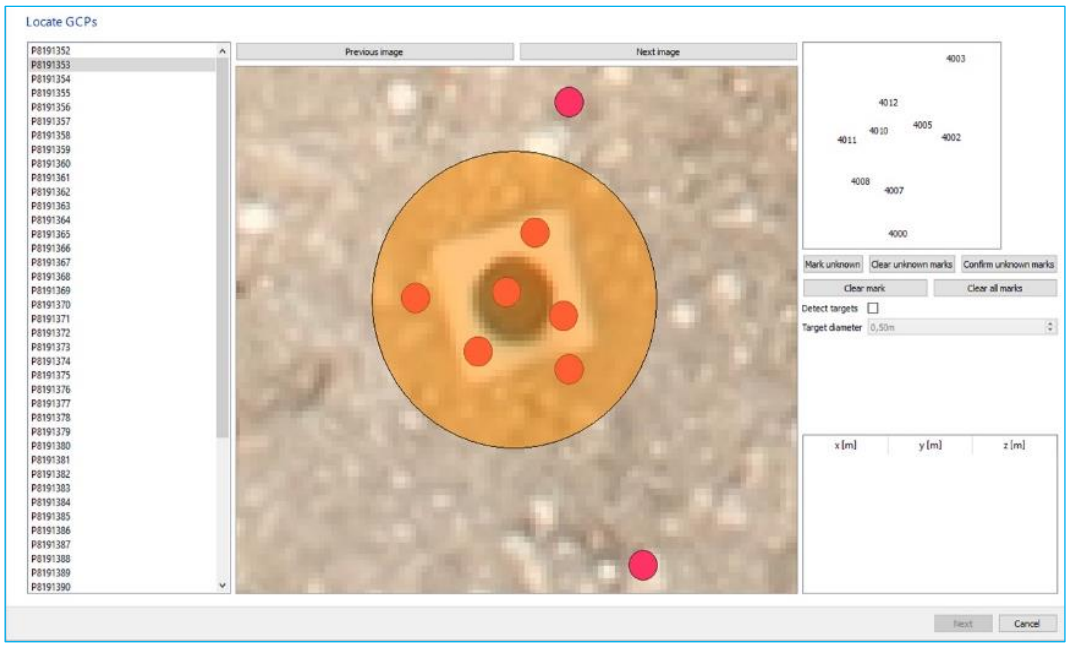
In case you select the wrong coordinate system by importing the images into project, be reminded that you cannot change project coordinate system in this step. If you would like to correct this you need to start from the beginning (New project, …) or use the second option – select: Local coordinate system. Further information about coordinate systems can be found in chapter *Bundle Adjustment troubleshooting.*



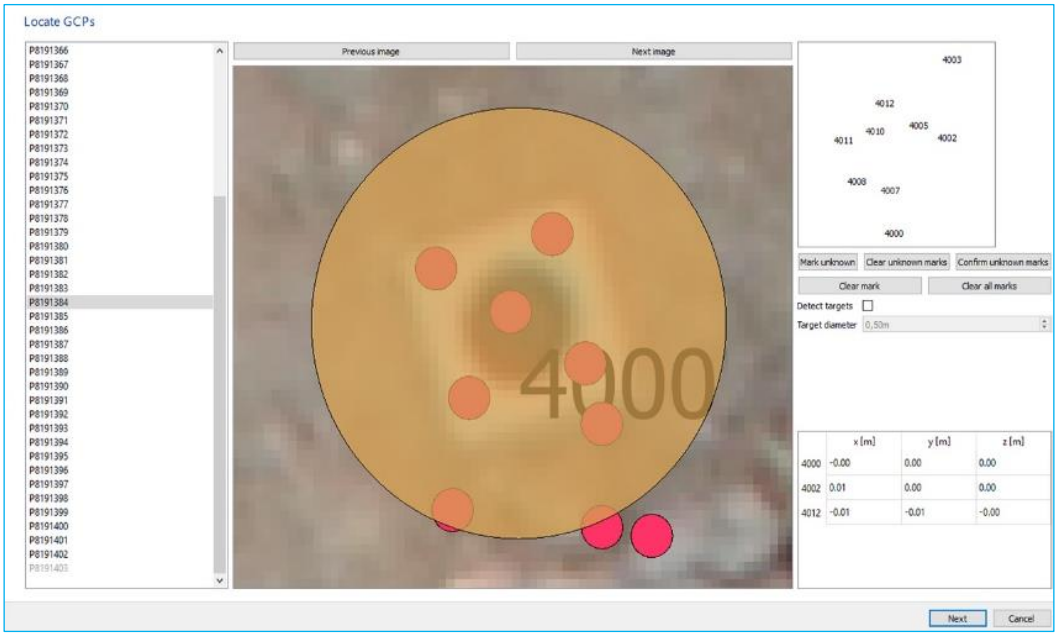


4.5.3. Automatic orientation

On the left of the pop-up window, **select image** with GCP. Use mouse scroller to zoom in or out. For automatic orientation a minimum of 3 GCPs need to be manually marked. **Mark** GCP with a **right mouse click**. Marked position is coloured in orange and ascribed a ''?'' as its name is not defined.



Continue by **selecting additional two** GCPs from other segments of your project area. When you select the third ground control point the automatic recognition for all other GCPs will start. Three marked GCPs remain orange coloured while automatically found GCPs are now coloured green and the names of all GCPs are identified.

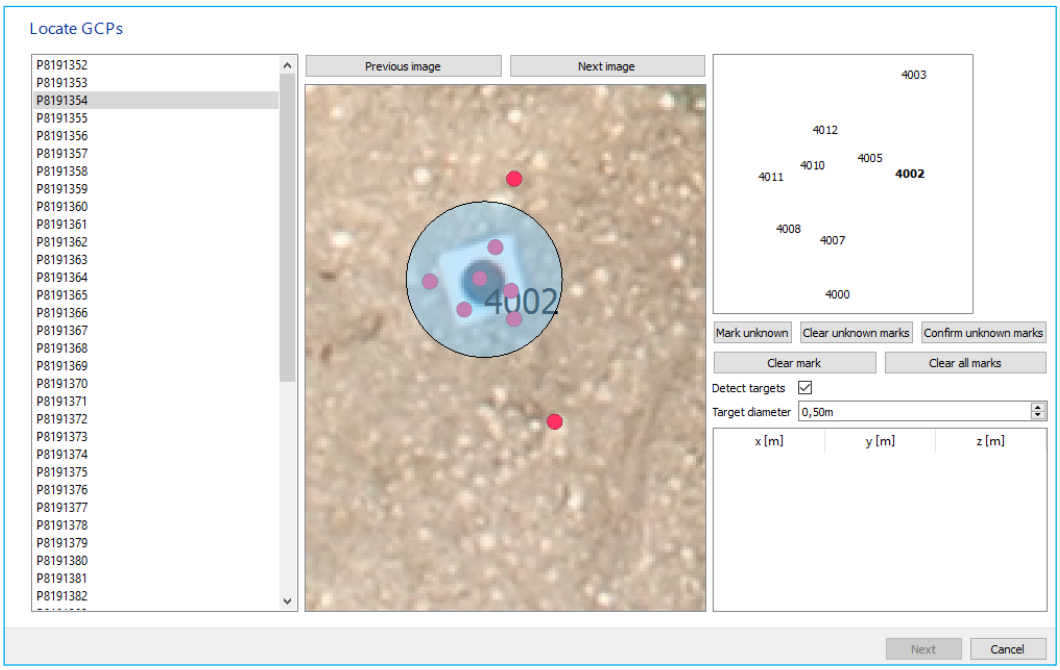


If you mismark the position of the ground control point, click *Clear all marks* button and reselect. Otherwise, click *Confirm unknown marks***.** A useful tool for checking the appropriation of GCPs are their *residuals*. If displacements of selected points are high, you should check if you forgot to survey one of them (their position is missing in the file). Described method of Automatic orientation as furtherly described Troubleshooting with orientation in chapter *Troubleshooting with orientation*.

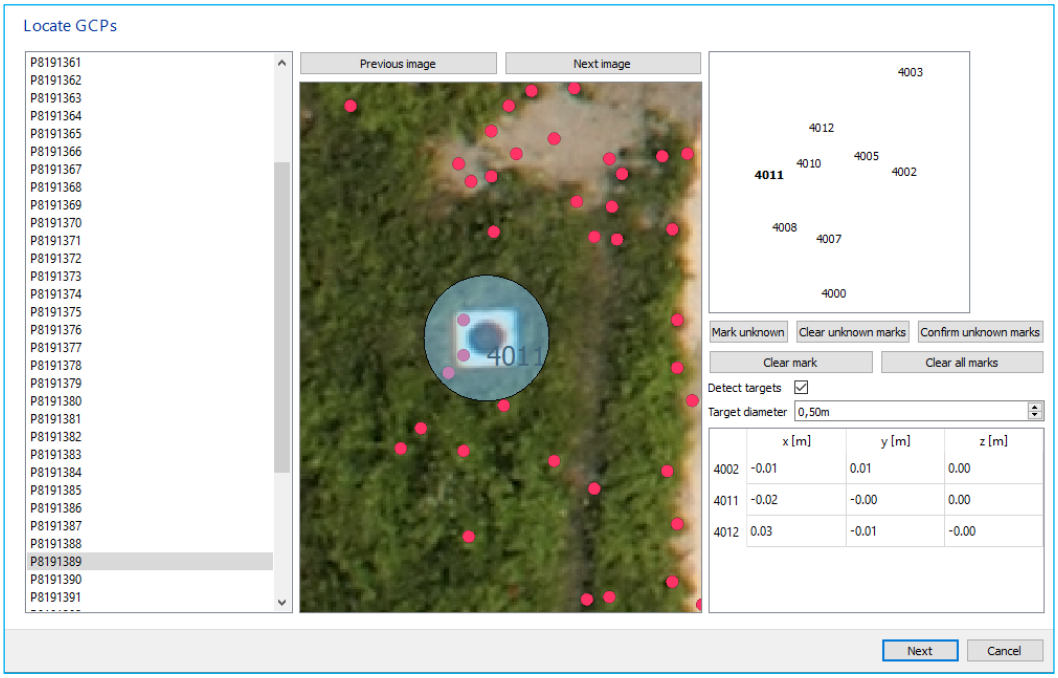
4.5.4. Semiautomatic orientation

Use GCP Map and select first the name of the ground control point on GCP map with **left mouse click** (for example 2009) and **mark** its position **on image** with **left mouse click.** Marked position is coloured blue, and its id appears.

If you mismark the position, click *Clear mark* button and reselect. *Clear all marks* button clears all selected markers.



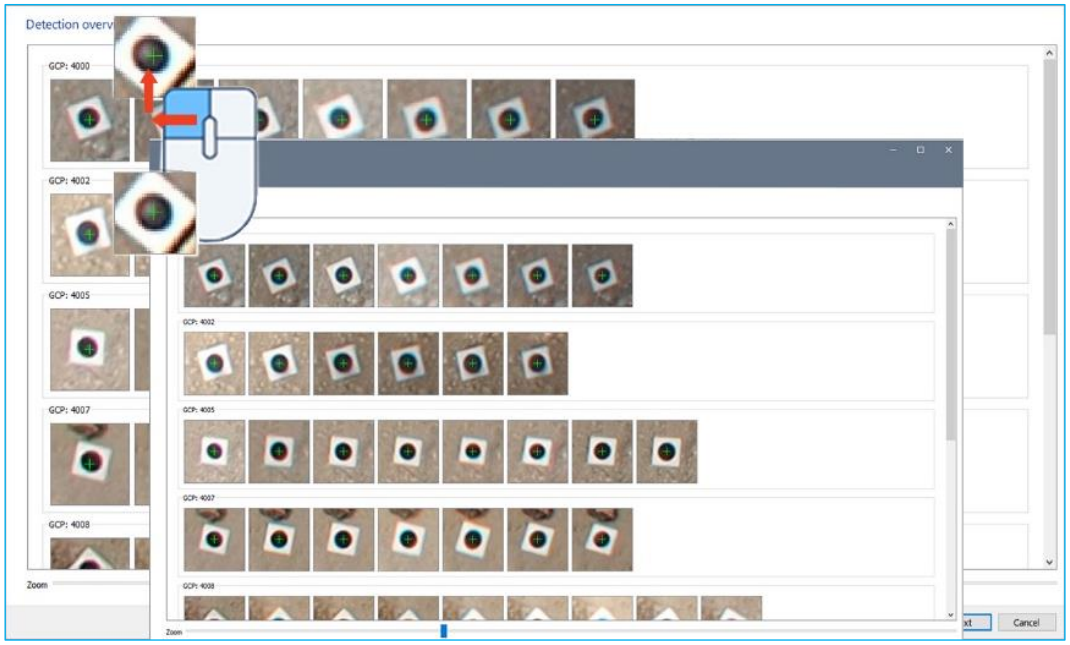
Select two more GCPs with a left mouse click (same as above). When you select the third ground control point the automatic recognition for all other GCPs will start. GCP are now coloured green and the names of all GCPs identified.



In the lower right corner appears the **residuals** of marked points. Residuals should be within 1m. Check if the automatic positions are calculated correctly - GCPs need to be coloured green. If not, correct them with manual selection. First, select the name of GCP on GCP map, then show the exact position of GCP map on an image. Use left mouse click.

In case you are using **STONEX GCP targets** (black dot on white plate) be sure to select the ''Detect targets'' and set the correct diameter for the black dot. The default value for diameter is 0,27m (standard Cube-3d target). In case you are using some detail points for orientation as **manholes, road marks, building corners**... deselect ''Detect targets'' click ***next*** to **continue with orientation**.

In the next step, we can see automatic recognition of ground control points (in case of Cube-3d targets). If the GCP is not recognised on a specific image, it is eliminated and coloured red. If you want to include this GCP into orientation, just double click the image and the red overlay will disappear. Several images can be marked or unmarked by ticking them in their upper left corner, where unticked square appears. Use Ctrl + a shortcut to select all target windows at once. You can also correct/realign the automatic measurement - left mouse click and move the centre of GCP to the green cross. Same approach can be used to correct the positions of GCPs that have been automatically detected but not measured perfectly because of the bad conditions during data acquisition.



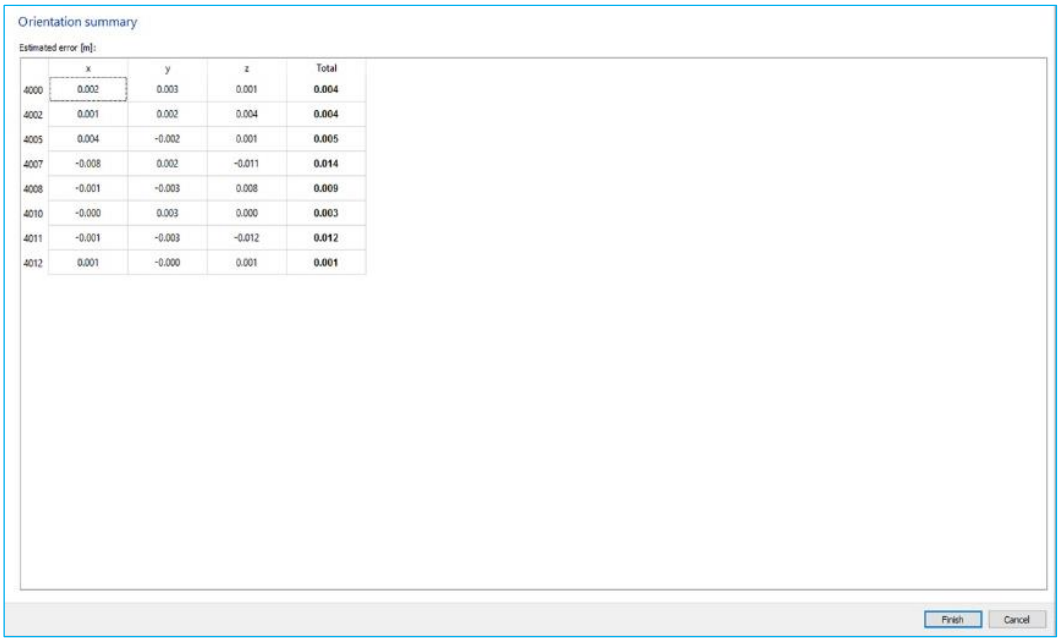
Faster approach for centring target is provided by the right mouse click. Put the mouse in the centre of the target and right mouse click for centration. Use mouse wheel or slide bar below to zoom in or out, which works for all target windows to realign easier.

If you are using the same dataset in numerous computations/projects it can be useful to **export GCP image positions** of centred targets. Click **tooth wheel button** in the upper right corner and click **export**. In case if you calculate the same project again next time you don't need to select and correct the GCP targets once again but just import the saved file and go to next step.

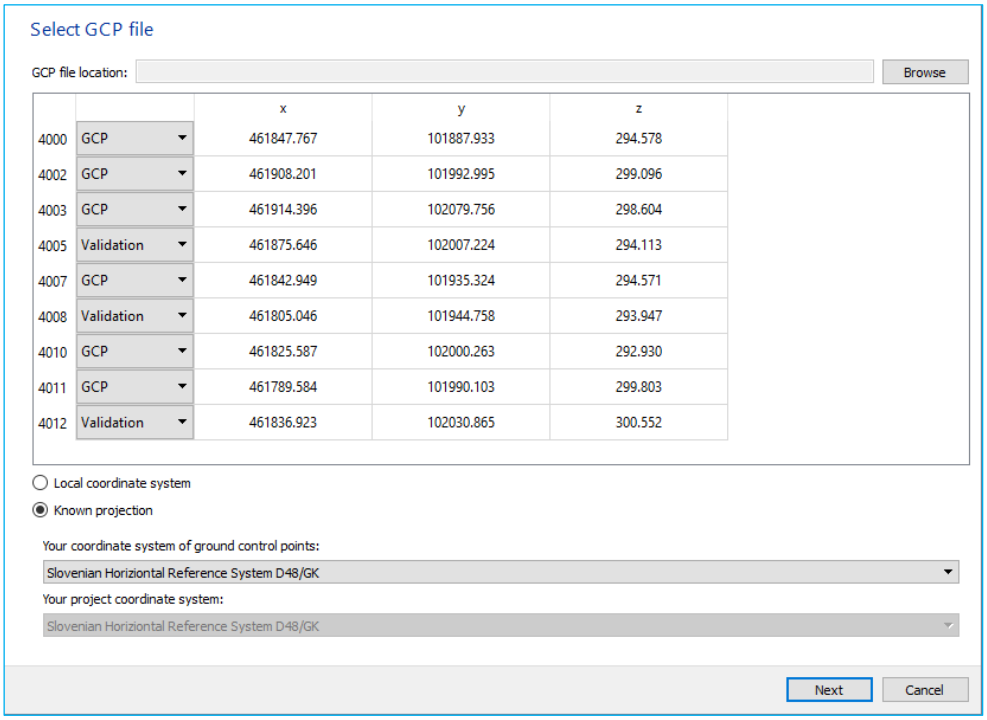
Click ***Next***, to observe orientation's accuracy.

Orientation summary displays GCP errors – a sum of photogrammetric measurements and total station /GPS measurements. **Check GCPs accuracy** by **observing** their **residuals**. If residuals show high displacements of certain GCPs, go and recheck them. Click ***back*** button on the upper left corner and repeat the marking process. Click ***Finish*** when satisfied.

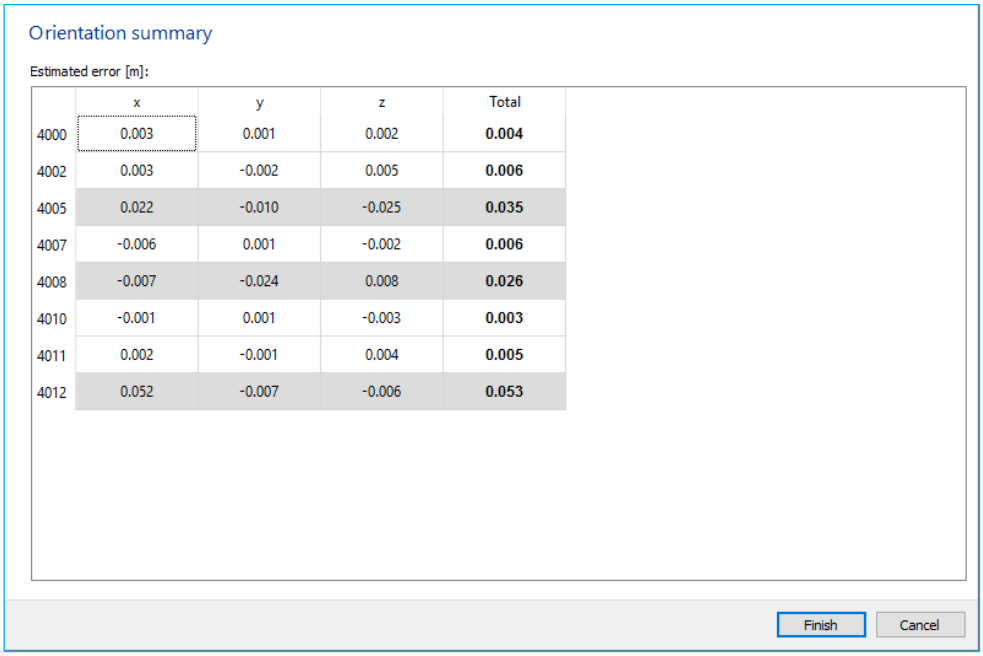
Save project.



To check for independent accuracy quality, GCPs can be marked as Validation points that provide independent values to compare against GCP values. Points defined as Validation points get coloured grey.



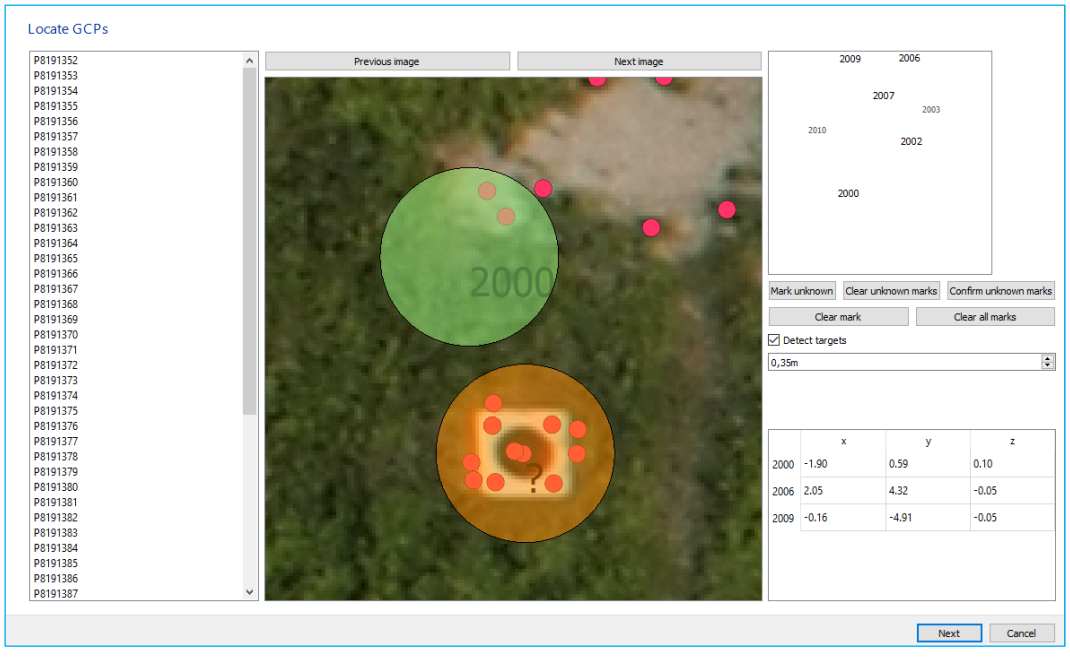
Approach the orientation automatically or semi-automatically, as previously described.



In the *orientation summary*, you can observe adjusted accuracy presented with residuals. As four points are used as control points, orientation is computed based only on selected GCPs. As described above, residuals need to be low. Impact of their size can be observed on residuals of control points. In case of high values markings need to be corrected.

4.5.5. Troubleshooting with orientation

In case if automatically selected point markers mismatch - residuals show large coordinate differences, that exceed 1m limitation for presentable final centring, as presented below - you should click ***clear all marks*** and proceed semiautomatic orientation, as described above. Keep in mind that selected points need to be observed – have observed coordinates written in ****.txt***. If at the beginning of the orientation, at least one of selected markers is declared as control point, residuals will show misplacements.



If you would like to continue with the standard workflow, continue with the *Reconstruction*.

4.5.6. Orientation of unknown dataset

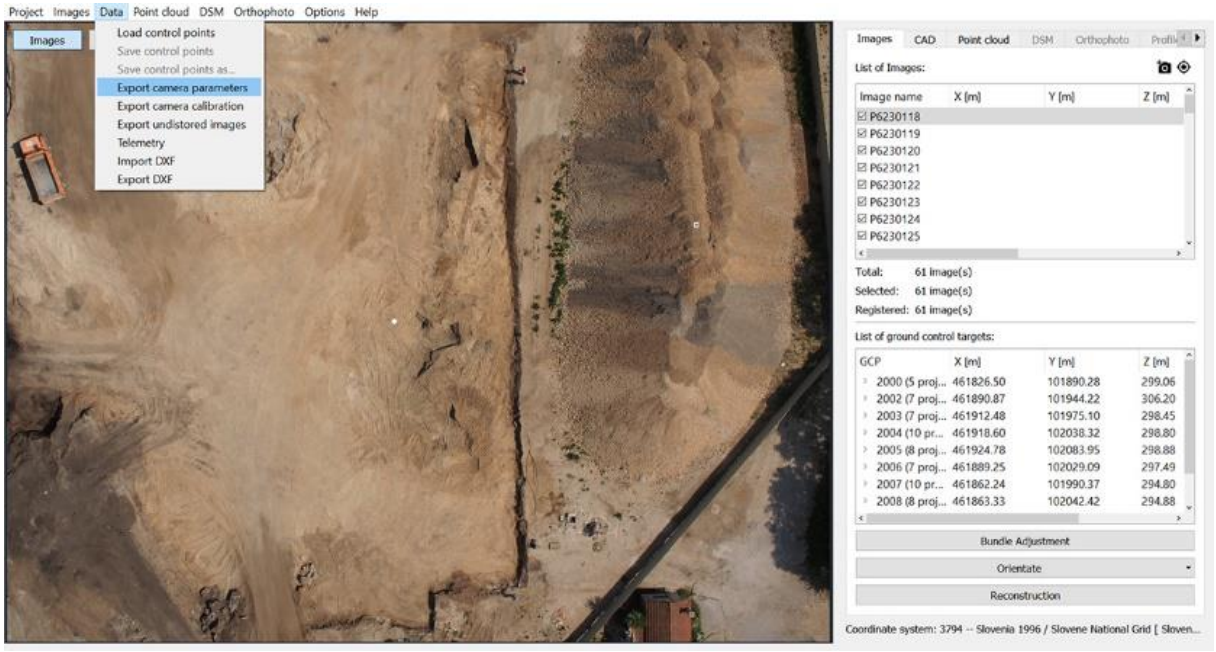
Sometimes you need to process dataset of one of your co-workers. You weren't present during field work and you do not have any map of positions of GCPs. There are several ways to proceed:

- *Use Automatic orientation* method
- Select all GCPs as validation points and use *Semiautomatic orientation* method for GCPs you are shore of its position. Observe residuals from the list, and if for some GCP values are high, select it from the list or click on it in the map and click ***clear mark***. It is time consuming process especially when processing large datasets. It is highly recommended to make and archive some map of GCP / validation point locations.

4.6. Advanced functionalities

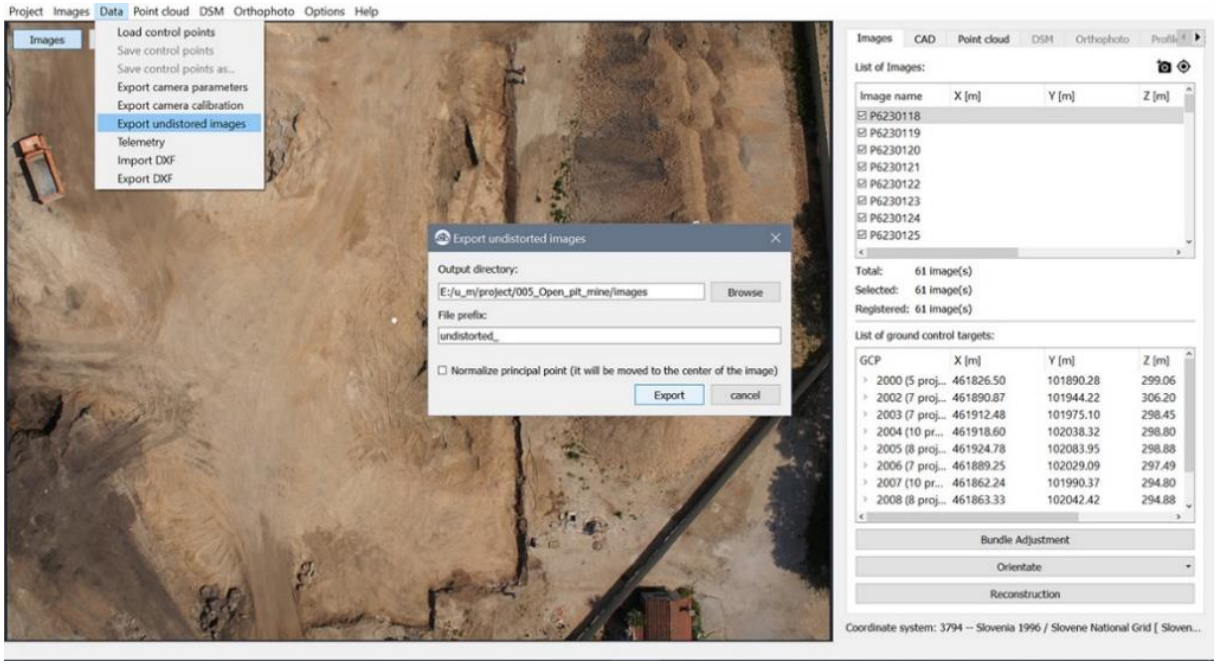
4.6.1. Export camera parameters and undistorted images

If you would like to import results of Bundle Adjustment in any other photogrammetric software, you need to export camera parameters and undistorted images. Click **Data**, chose **export camera parameters**. Type preferred name of exported document or chose predetermined one and confirm.



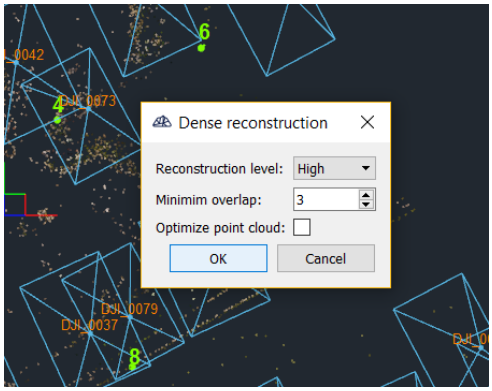
4.6.2. Export undistorted images

Click **Data** and chose **export undistorted images**. In the popup window assign path of directory and type in its name.



4.7. Reconstruction

When you are finished with orientation wizard the main window will appear. Next step is Reconstruction of dense point cloud. On image you can find the default values for Reconstruction step which offers you the most effective calculation (time VS results).



Click OK to start reconstruction.

Continuing each reconstruction parameter is described for more information. ***Reconstruction level*** – there are 4 levels of reconstruction:

- Low,
- Medium,
- High,
- Extreme.

Minimal overlap - how many overlapping images to include in the point cloud reconstruction? The higher the overlap the higher the reliability of reconstructed point position. Minimum possible overleap is 2 (edges of surveyed area), the rate of its maximum depends on the set of images. **Default number is 3** and fits 99% of situations.

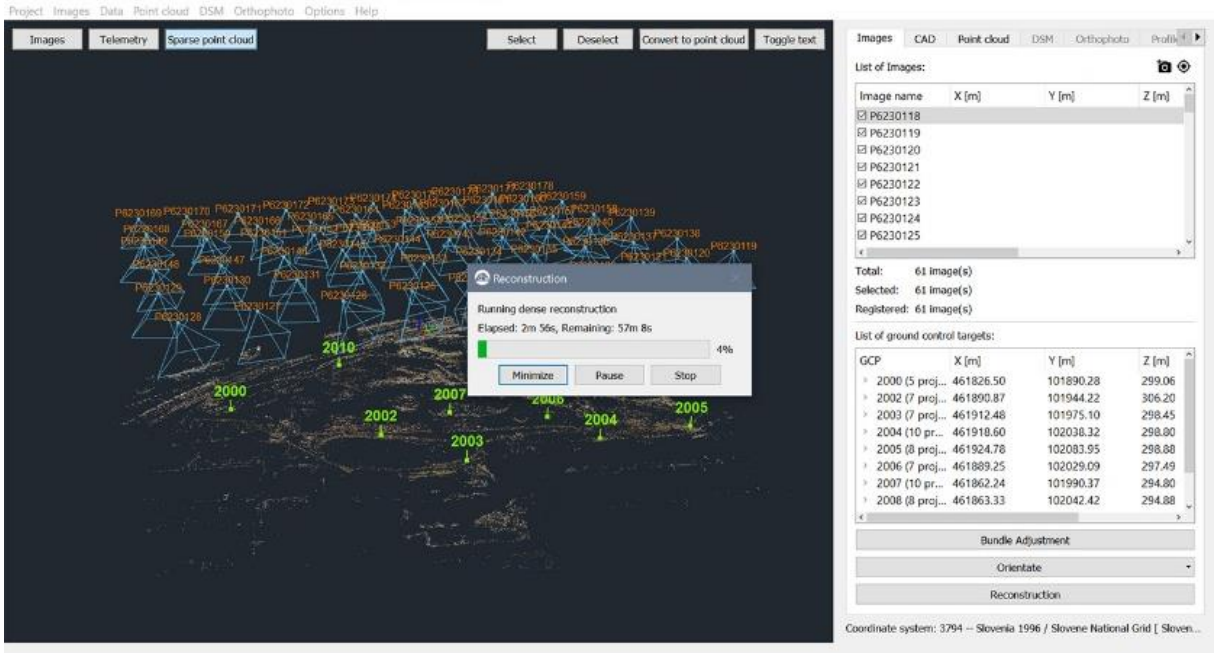
Optimise point cloud – in case of areas with good texture (open pit mines, garbage damps, rural areas, high vegetation areas…) there is no need to use the Optimize point cloud option – it would just increase the processing time. In case of areas with bad texture, such as asphalt areas, roads, vast parking grounds it is reasonable to use optimization option. Be aware that the use of optimisation:

- doubles the amount of time necessary for computation.
- is extremely RAM consuming process. It could happen pretty fast that you won't own sufficient level of RAM.
- Is recommended when you process data is set at **up to 500** images per project.

Areas with good texture are ideal for computation **without the use of optimization**:

- **set up by default**
- two times faster than with optimization
- works also for big data sets. Up to 5000 images

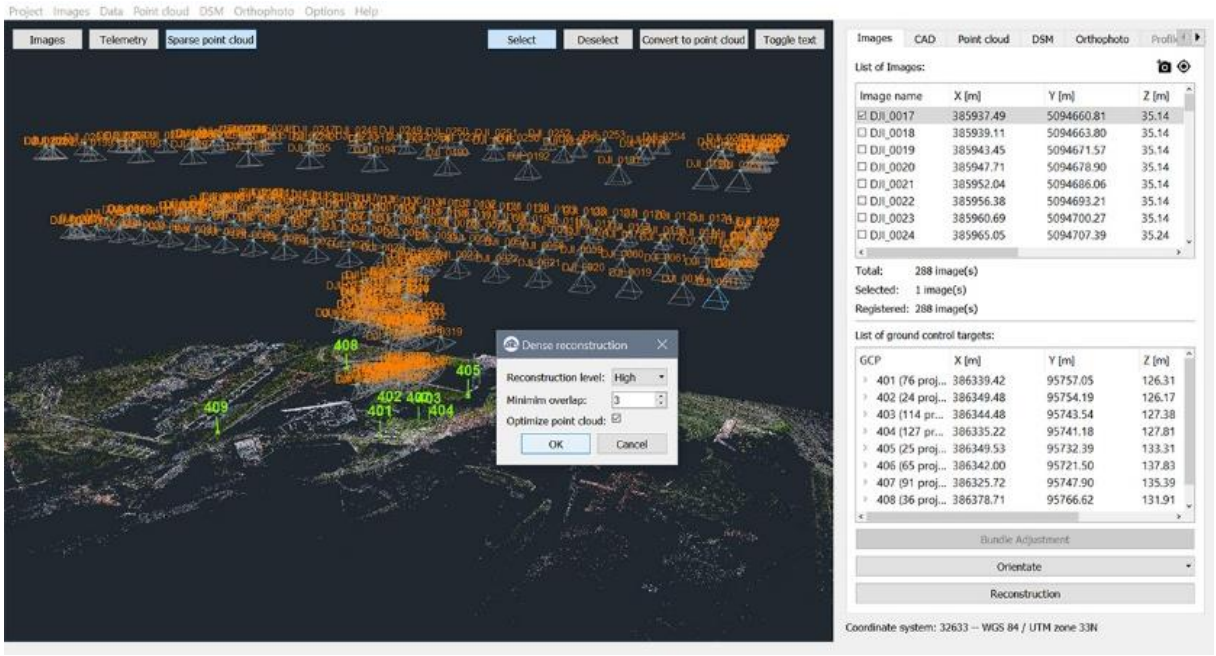
As the reconstruction is in progress, the *Point cloud* tab unlocks in *Working panel*. In the *Viewer*, the progress bar displays the stage of completed processing. The predicted processing time is realistic after 7% of the process is computed.



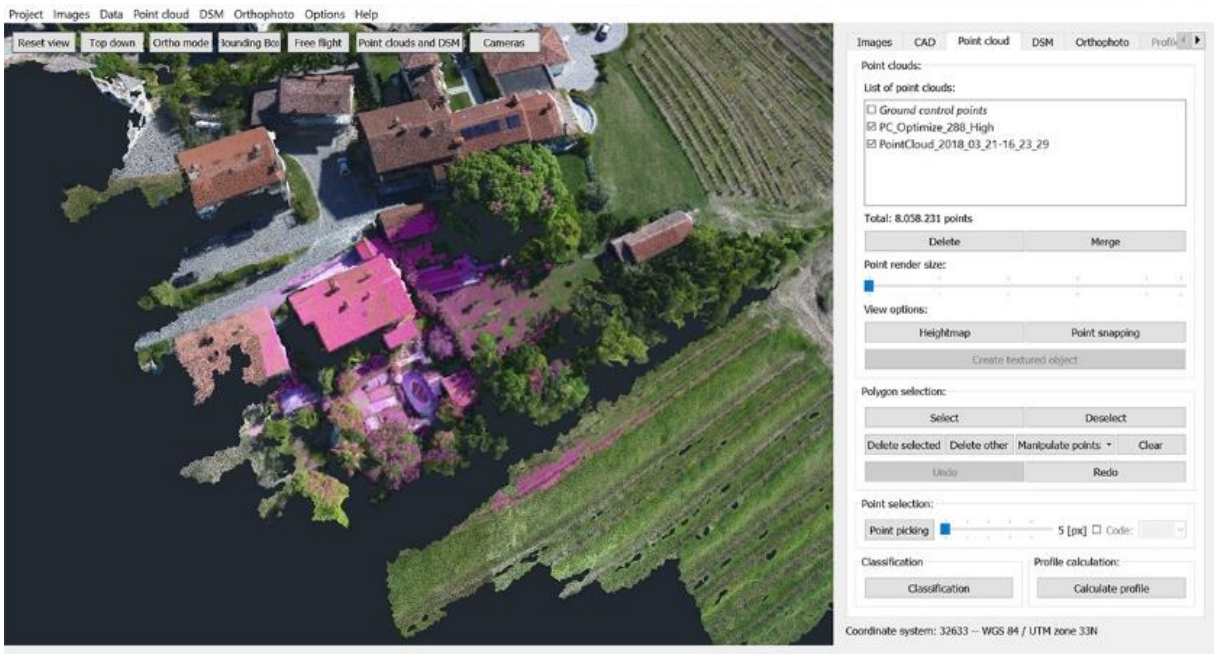
Reconstruction advances

As described in Option settings desired images can be chosen to reconstruct point cloud from. When all images are being orientated, point cloud can be reconstructed from only one selected image. Although you chose only one image, app runs reconstruction with all of overlapping images, with same detail of surface. Select preferred images and run **reconstruction**. You can use select or deselect button or manually deselect images from the image list. Further assign desired level of reconstruction, number of overlapping images and possibility of optimization.

This function allows you to process the dense reconstruction for one project in two pairs (1st half and 2nd half) or calculate the dense reconstruction with a different level – for example: centered area with Extreme level, less important area on High or Medium level.

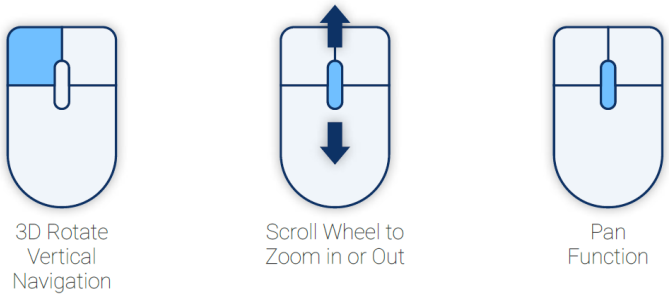


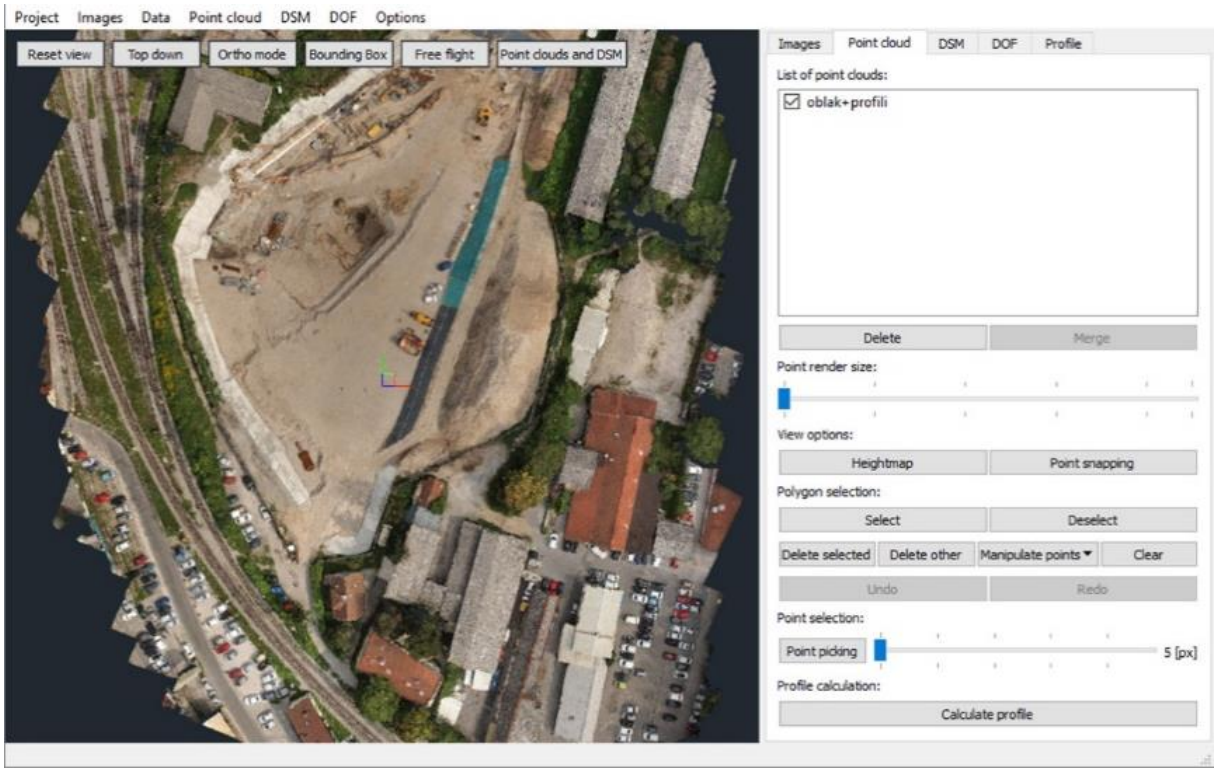
To see the effect, we selected point cloud (coloured purple) reconstructed from one selected image with its overlapping images selected amongst point cloud reconstructed from entire batch of images. Although selected image was from the first row of images, about 700.000 points were reconstructed.



5. Point cloud manipulation

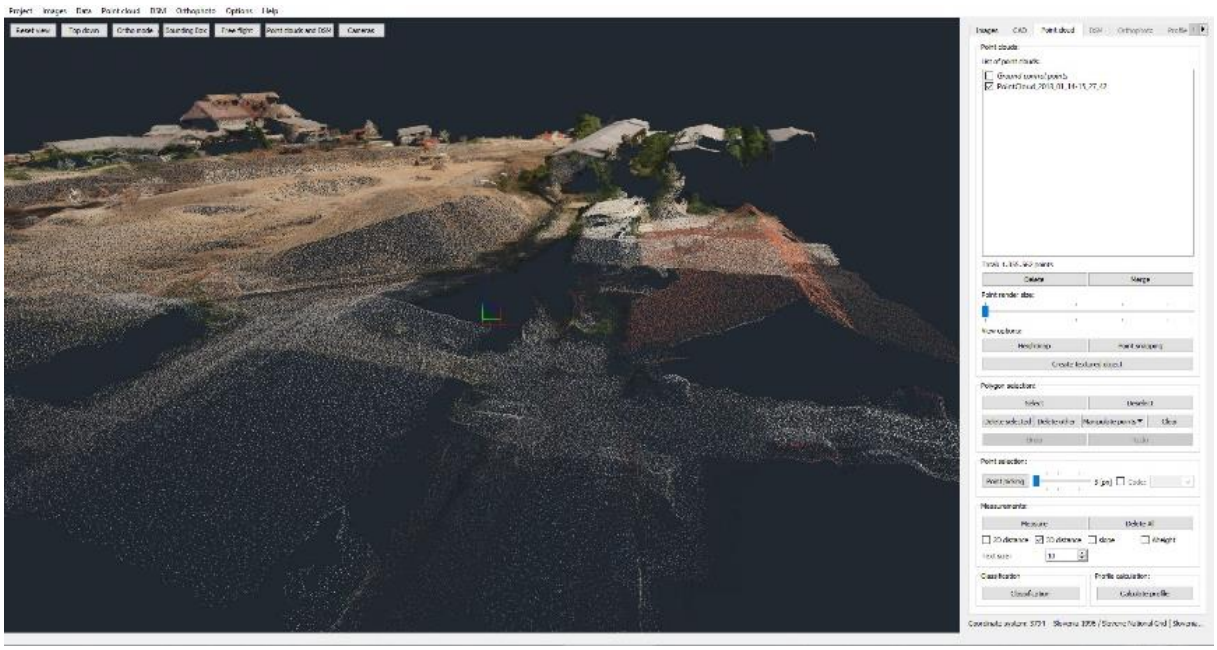
The calculated point cloud will appear in Point Cloud tab. To manipulate the point cloud: use **left mouse click** to rate point cloud, **scroll** to zoom in or out, click and hold the **mouse scroller** to pan the model.



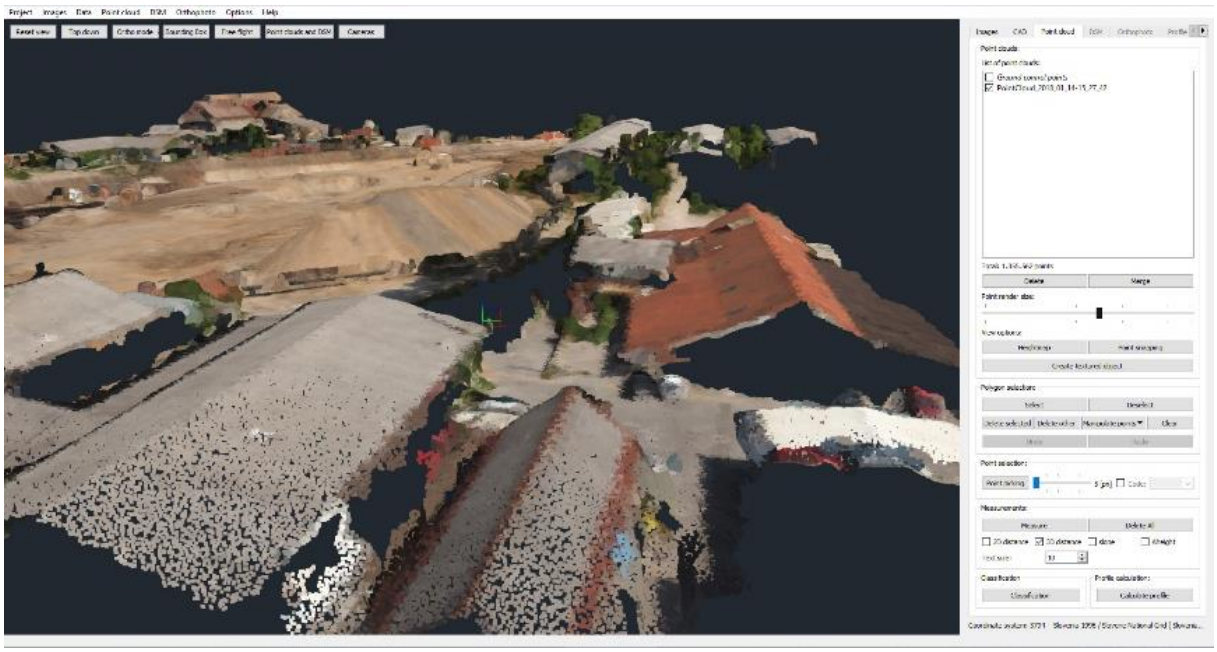


Point Cloud includes points from surface, buildings, vegetation and other objects. To generate a digital Orthophoto those obstructions need to be eliminated (select and delete) as to get a clear digital terrain model that serves as a basis for Orthophoto generation.

5.1. Point rendering

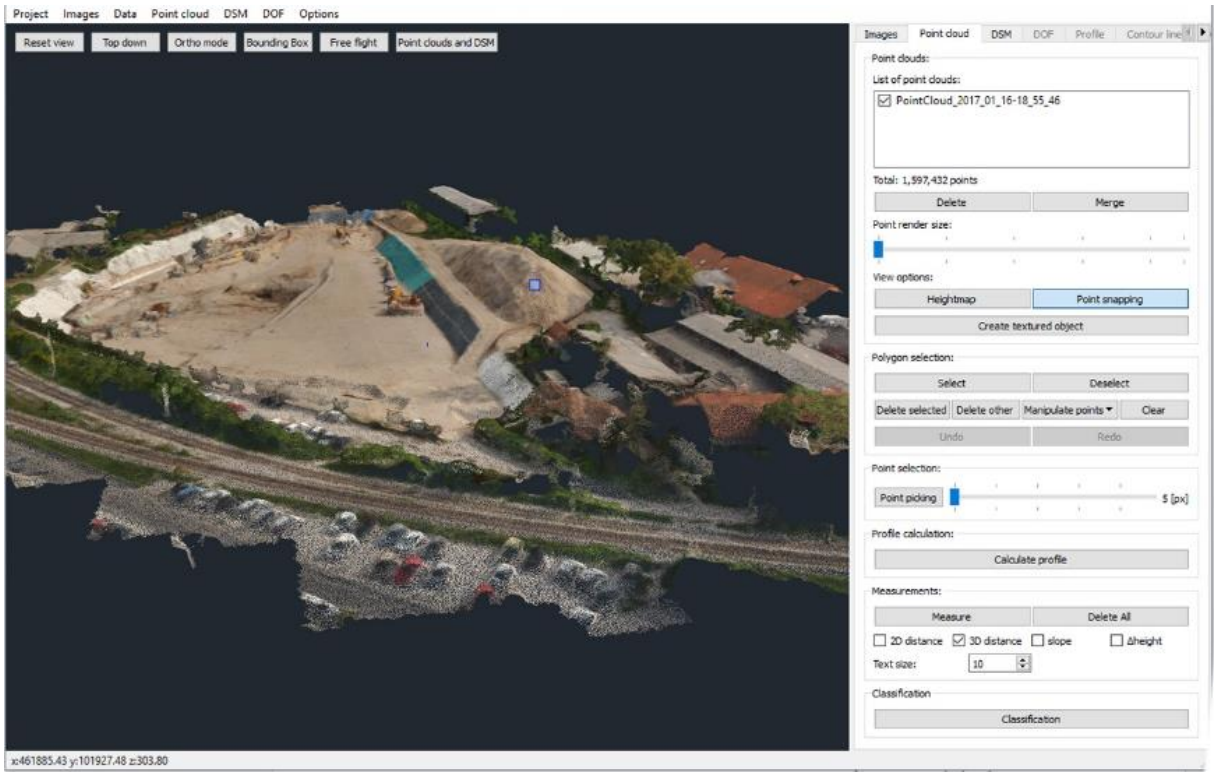


Use the ***Point render size*** **bar** to increase or decrease the points of Point Cloud.



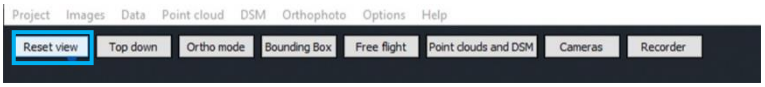
5.2. Point snapping

Use the **Point snapping** tool to inspect the 3D coordinates of the point cloud. The x, y, z values are presented in the live command window (lower right corner).

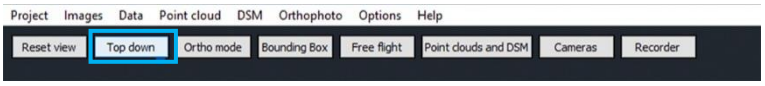


5.3. Cube-3d viewer

Use **Reset view** to set the default view.

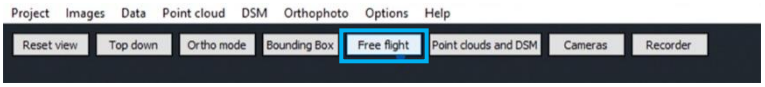


If you would like to view PC or DSM from nadir projection, click ***Top down*** button. Model can now be rotated only around z-axis. The button is on as long as you do not switch it OFF.

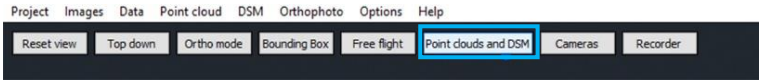


If you would like to view the point cloud in orthogonal projection, you need to click ***Ortho mode*** button. Enabling the function results in the button colouring blue. To rotate around all axes, disable the Orto mode by selecting the function one more time.

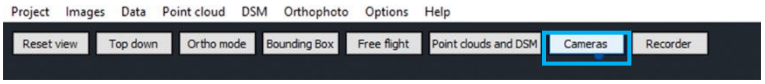
If you would like to capture short movies from your 3D model with an external software, you can use **Free flight** function and smoothly fly around 3D model and objects. Use: **left mouse click + keyboard**. **A** to move left, **D** to move right, **W** to move forward, **S** to move backward, **F** to zoom in, **R** to zoom out, **V** to zoom in centre. **Scroll** to set vertical angle of view. To speed up the flaying press +, to reduce speed press -.



IF you wish to see PC and DSM at the same time, click ***Point cloud & DSM*** button. You can use this function in CAD tab, Point Cloud tab or DSM tab. This is a useful tool when you are working with Point Picking function.



If you wish to see positions of cameras above the point cloud – reconstructed terrain, click **Cameras**. You can use this function in CAD, Point Cloud or DSM tab.



Bounding Box – It is a useful tool for two reasons.

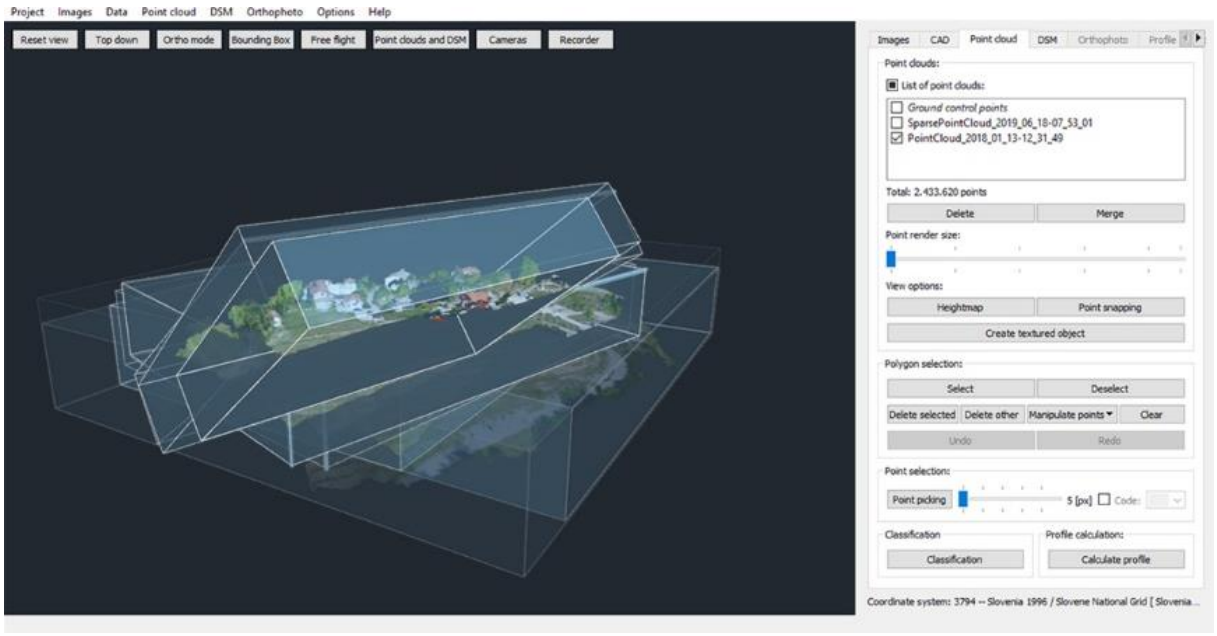
First, move sections freely left, right, up or down and the tool lets you easily inspect the data inside the box whilst ignoring everything outside your box selection.

Second, sliding 2 opposite Bounding Box panes together gives you a 3D profile of the surface model.

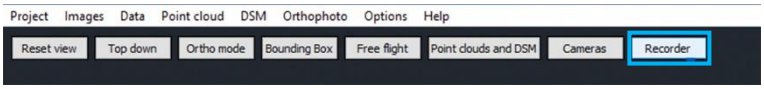
Third, click and drag on any of the rims of Bounding Box and rotate bounding box around point cloud centre. To move through the 3D model press CTRL and left-click on the Bounding Box pane and you will be able to slide it in any direction and explore all the sections on the fly. Turning on the Height map displays the height differences even more clearly.

Use Bounding box in either point cloud tab or DSM tab.

It is possible to inspect the differences between several point clouds or surfaces, of course. For example, loading two-point clouds from the same area but measured at a different time and using Bounding Box will clearly show the difference. Apply different colours to surfaces for even more impressive results.



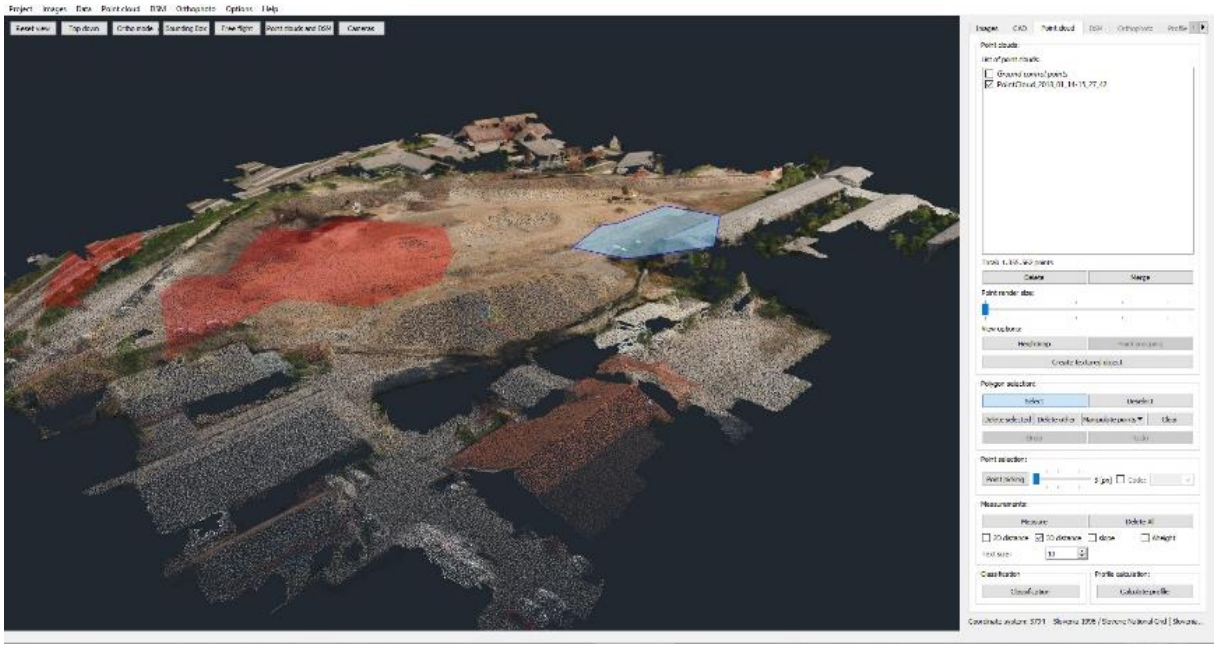
IF you wish to record desired parts of computed project and highlight significant details, click ***Recorder*** button. You can use this function in CAD tab, Point Cloud tab or DSM tab. This is a useful tool when you need to make quick presentation of project and made calculations.



5.4. Point selection

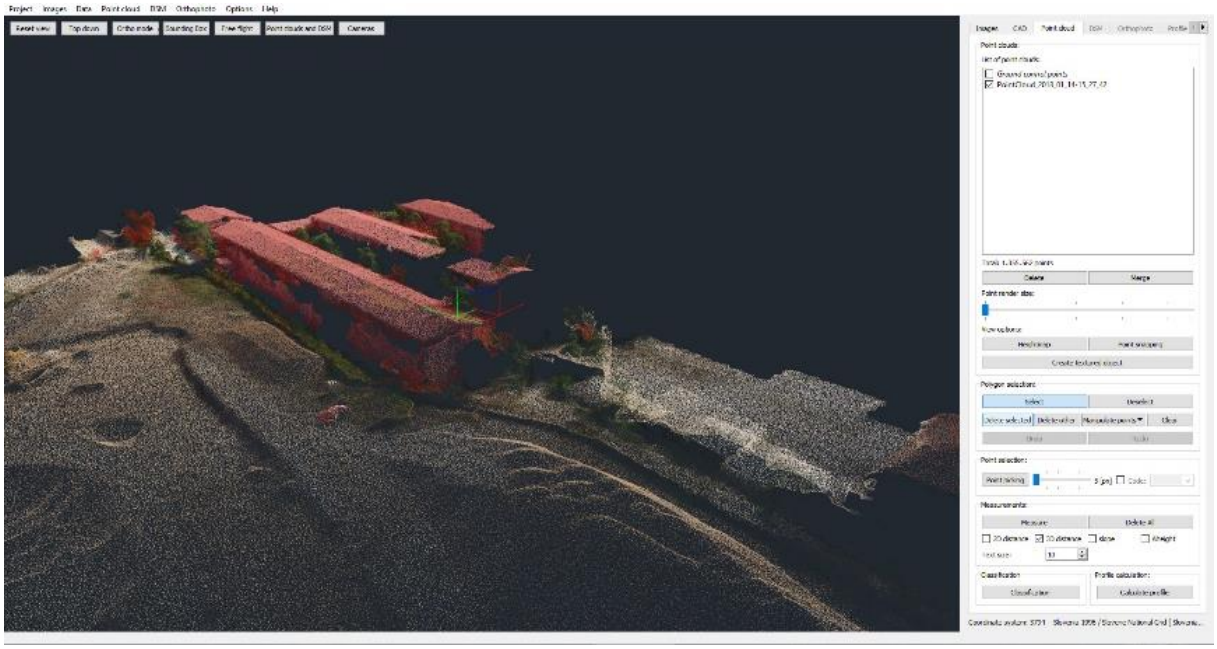
Click ***Select*** button and draw polygon around surveyed area using **left mouse click**. Finish the selection with **right mouse click.** Selected points will be coloured.

Use the Deselection function to ignore interested points from selection. Left mouse click to select, with right mouse click to finish selection. Use ESC on keyboard to cancel selection or click clear button.



5.5. Deleting points

To delete points, you need to select them first.



Delete selected points either by clicking ***Delete selected*** button or use delete button on keyboard.

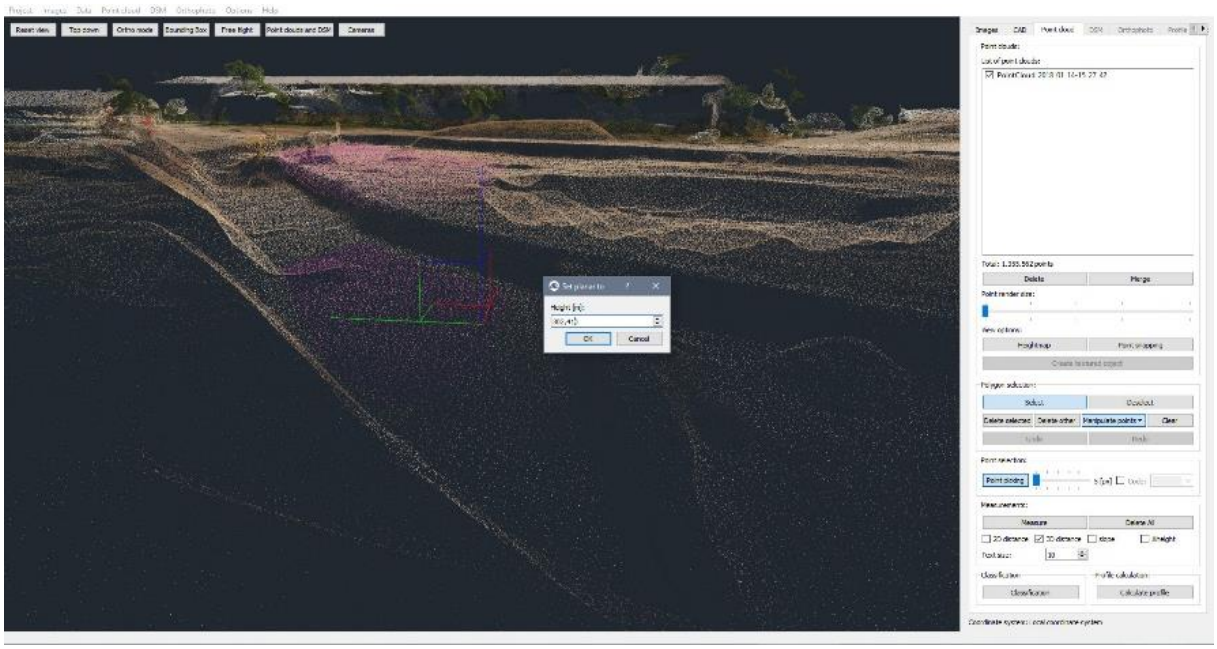
Use ***Delete other*** function to delete everything that is not selected.

Use **Undo** or **Redo** function in case you change your mind.

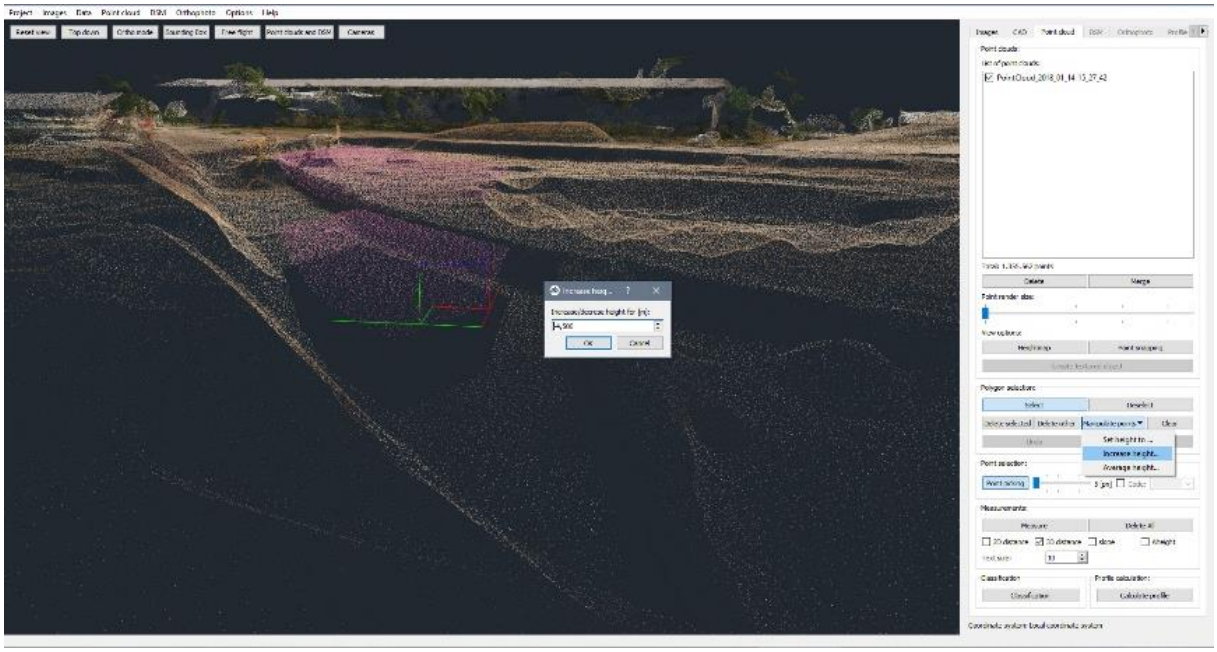
5.6. Manipulate points

Popup ***Manipulate points*** enables you to *set height*, *increase height* or *compute average height* of selected area.

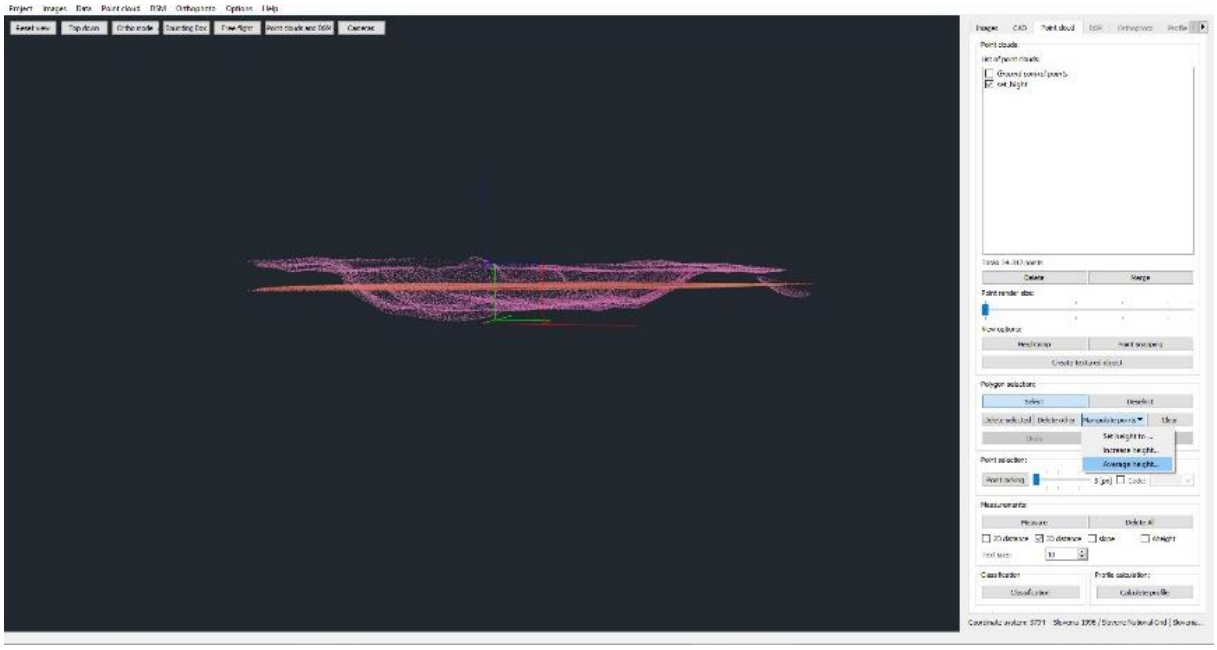
Select desired area and click ***set height***. ***Type*** desired new ***height*** and click ***OK***. The selected points are moved accordingly.



In case you would like to lower or raise the selected points use increase height function and type the desired value. For example, if you would like to lower the selected points for 0.5 meters type -0.5 m. If you would like to raise the selected point to specific value, type for example 1.5m and click OK.



You can also compute the average height of selected points. Firstly, select the area of interest, go to Manipulate points and click Average height.



5.7. Calculating profile

It is often required, especially on construction sites, to present profiles. Open Point cloud tab and click ***Calculate profile***. Set the parameters in the pop-up:

Consider point within distance *0.15* by default – distance of buffer zone for snapping longitudinal profile to PC,

Approximate segment length *0.15* by default – approximate stationary distance of longitudinal profile,

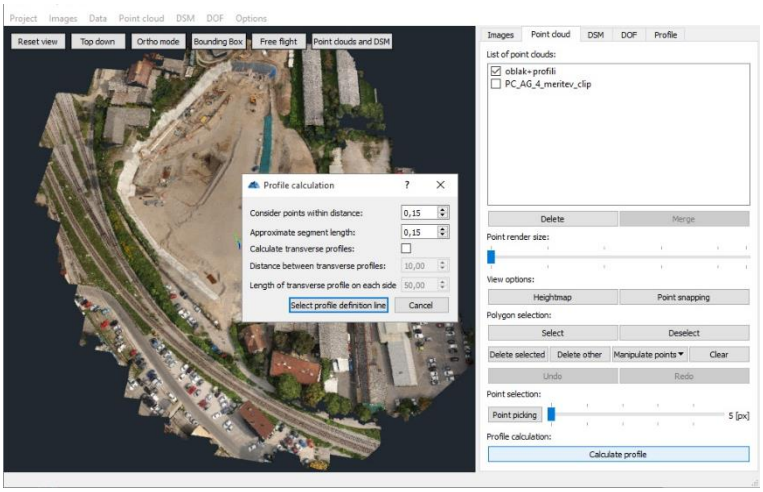
Calculate transverse profiles *disabled* by default – to set computation of transverse profiles,

Distance between transverse profiles *10* by default – stationary distance on longitudinal profile to compute transverse profiles,

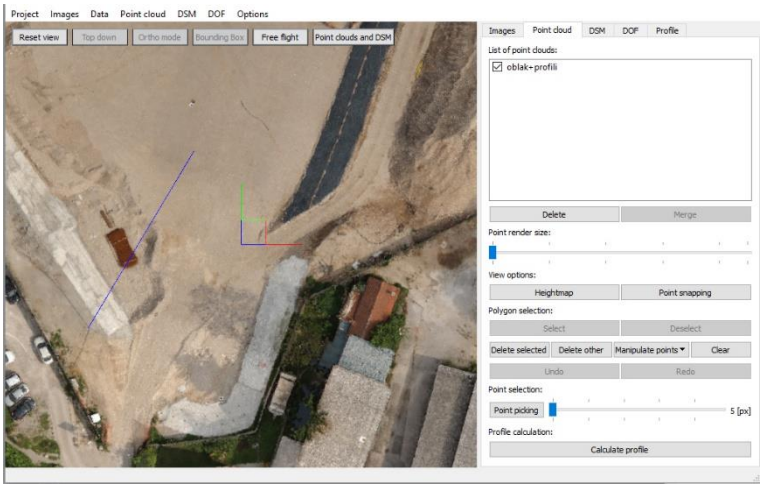
Length of transverse profile on each side *10* by default – width of either flank of transverse profile.

Longitudinal profile

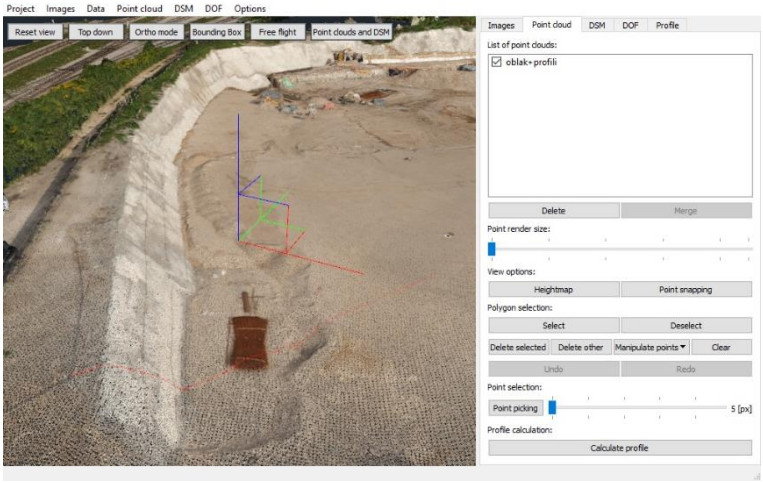
To compute longitudinal profile, ***Calculate transverse profiles*** must be ***disabled***. Click ***Select profile definition line*** to define profile.



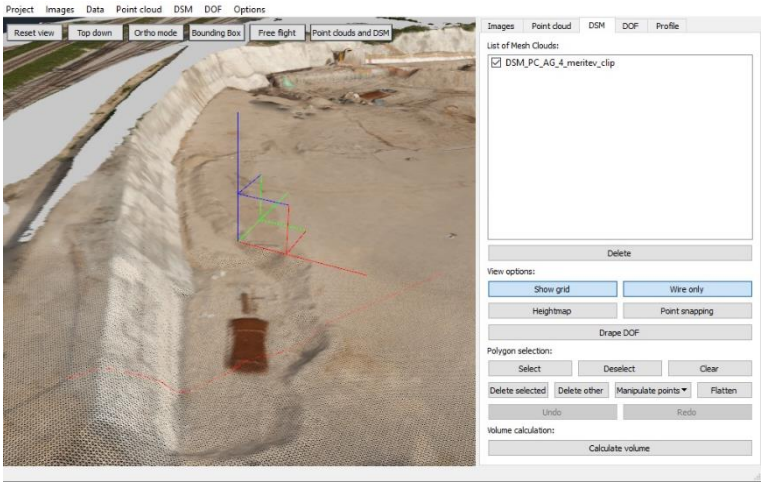
Left clicking the mouse, **draw polygon**, that defines longitudinal profile, ending it with a right mouse click.



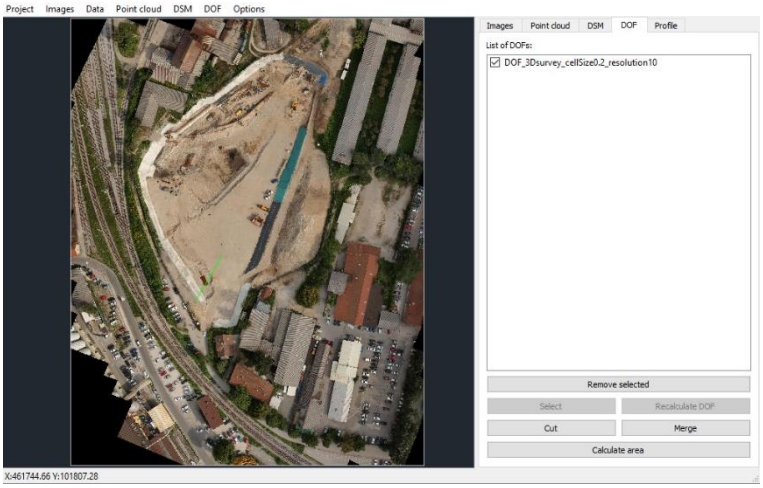
Calculated profile is displayed on the Point cloud in both 2D and 3D.



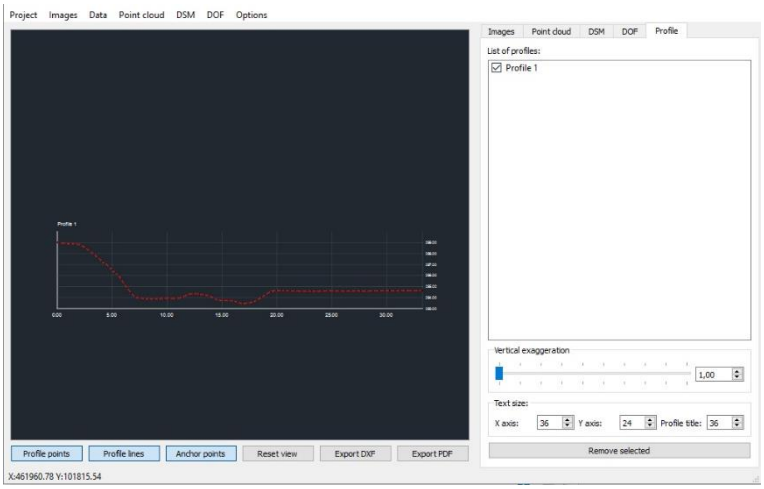
Calculated profile, presented on DSM, Wire only



You can observe defined profile presented on DOF, and open Profile



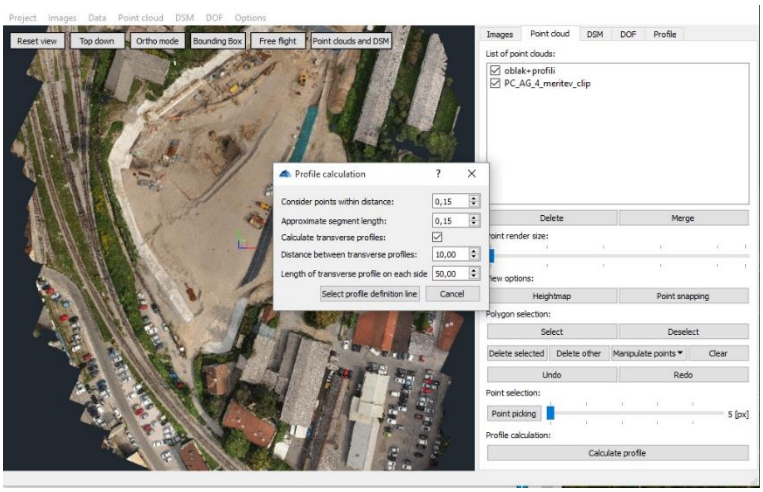
Computed longitudinal profile is displayed in the working panel.



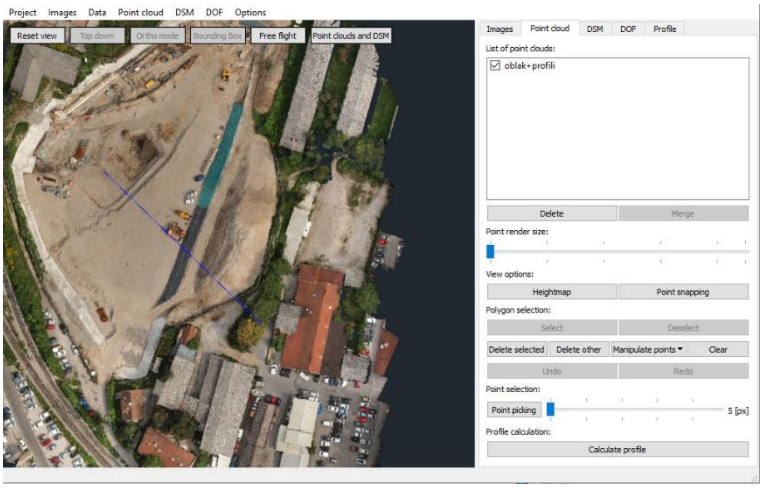
Save project.

Transverse profiles

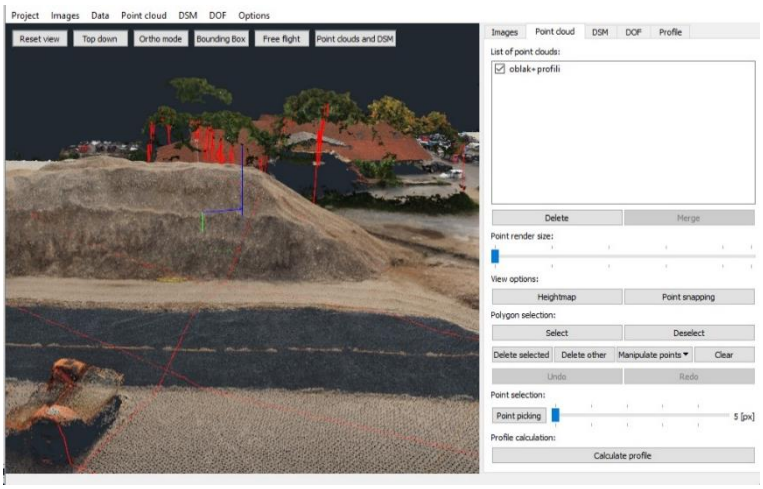
To compute transverse profile, ***calculate transverse profiles*** must be ***enabled***. Click ***Select profile definition line*** to define profile.



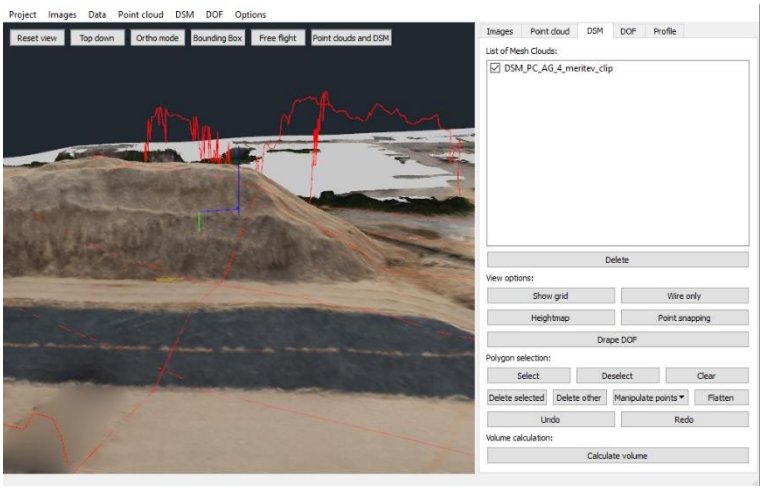
Left clicking the mouse, **draw polygon**, that defines longitudinal profile, ending it with a right mouse click.



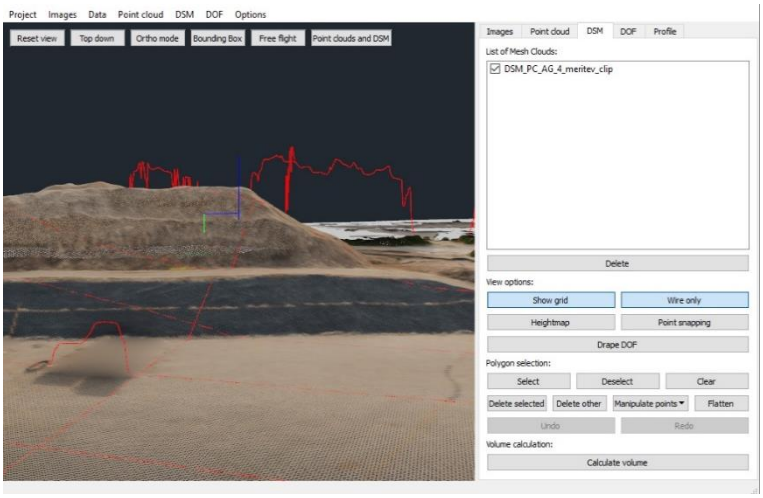
After right click, transversal profiles are drawn on top of longitudinal profile. As we used raw point cloud without removing obstructions, transverse profiles include objects and tree canopies.



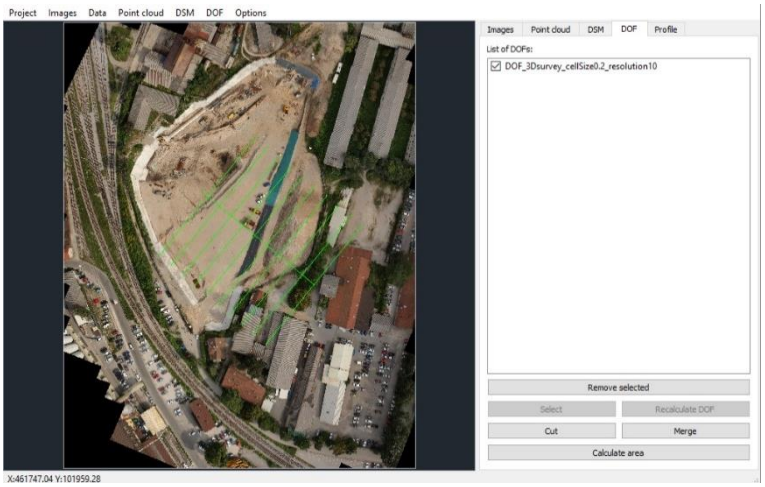
The same profile presented on top of DTM shows the shape of deleted objects on which transverse profiles lay on.



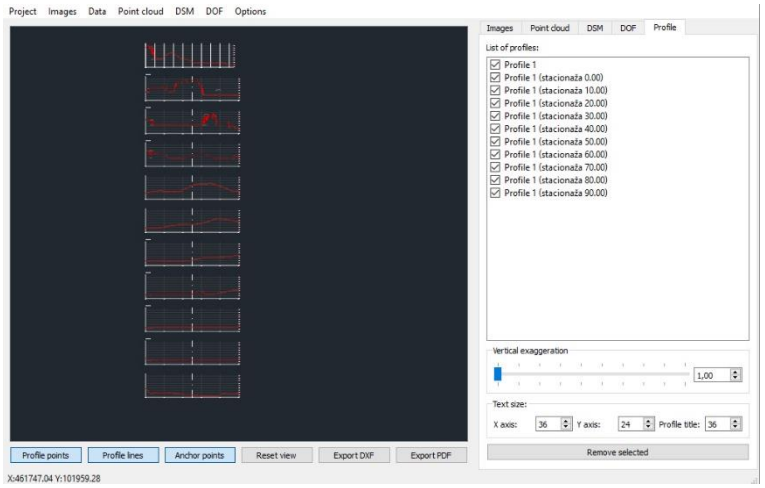
Calculated profile, presented on DTM, Wire only**.**

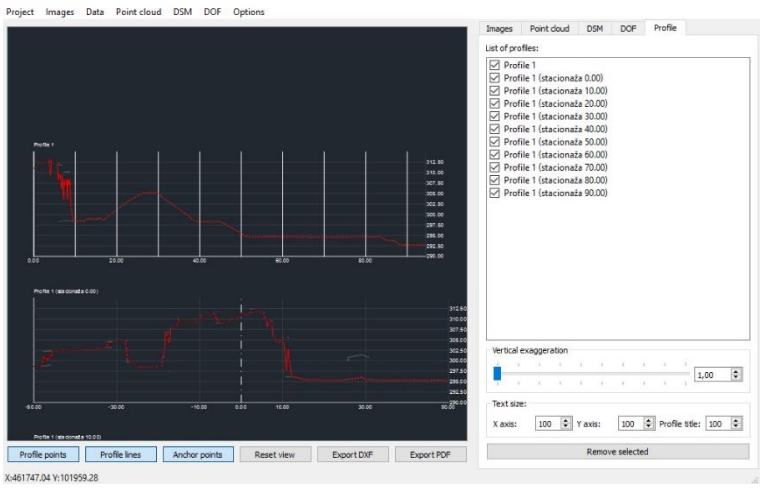


You can observe defined profile presented on DOF, and open Profile.

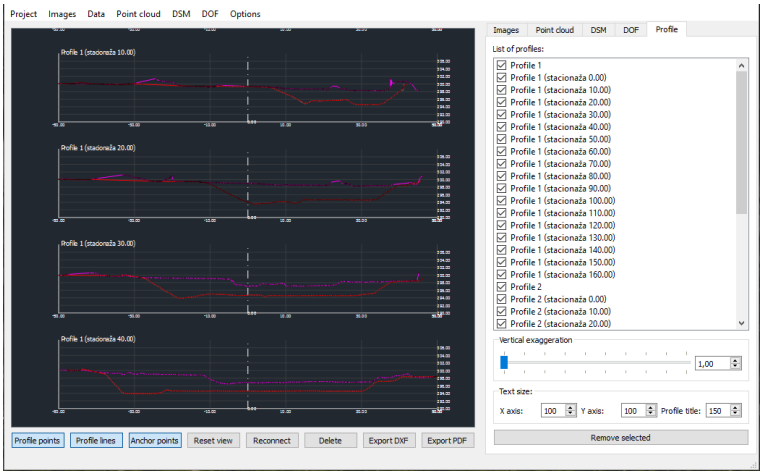


Transverse profiles are displayed below longitudinal profile, as displayed on the list in the ***Working panel***. If you wish to view desired profile, you can zoom to it or click it on the list.



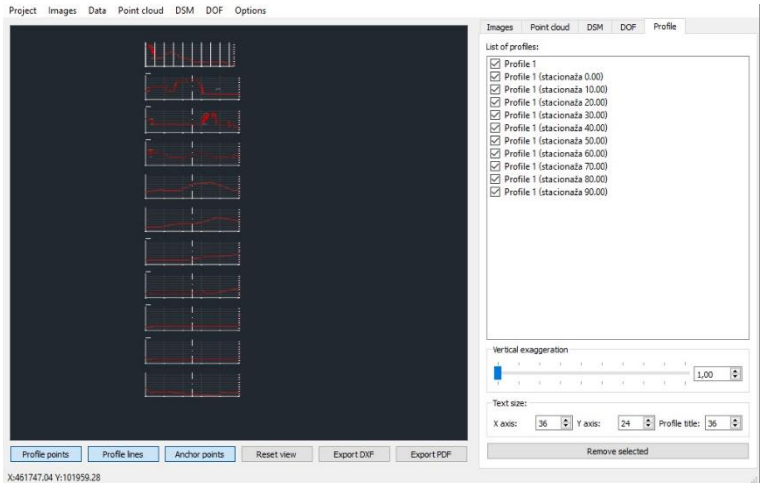


Using point clouds of two temporal measurements of construction site, you can observe reshaping of terrain, as presented below. Transverse profile shows two profile points, which present two measurements.

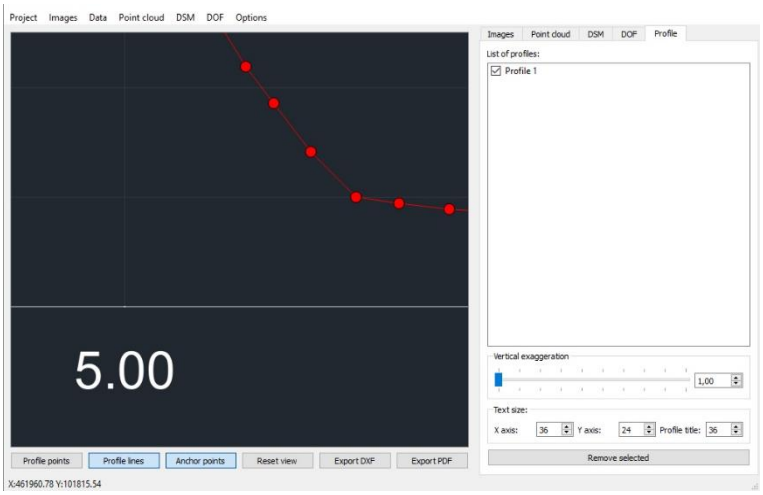


Profile manipulation

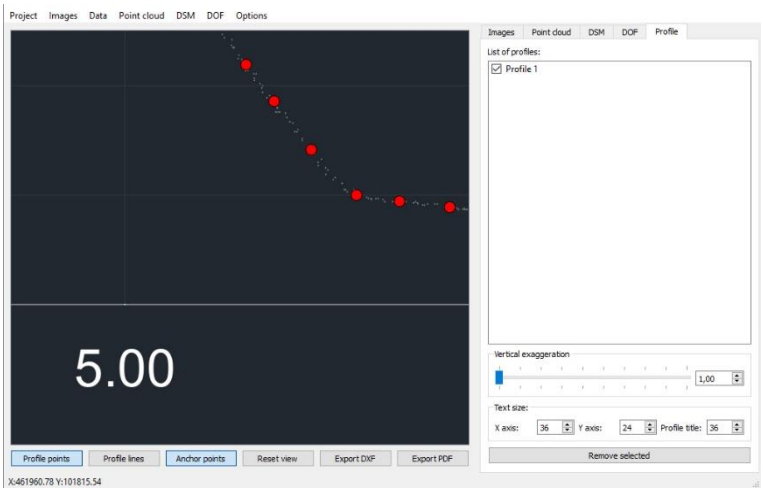
Profile manipulation buttons/tools are displayed on the bottom of the profile window.



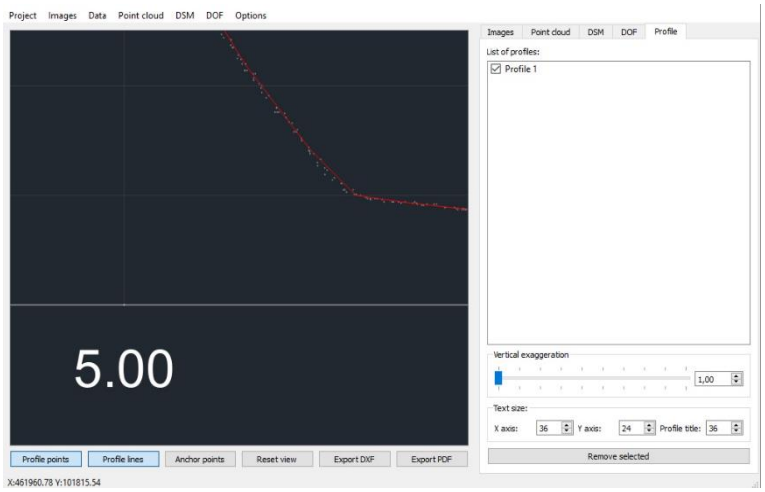
- ***Profile points*** show point cloud points detected in buffer zone.



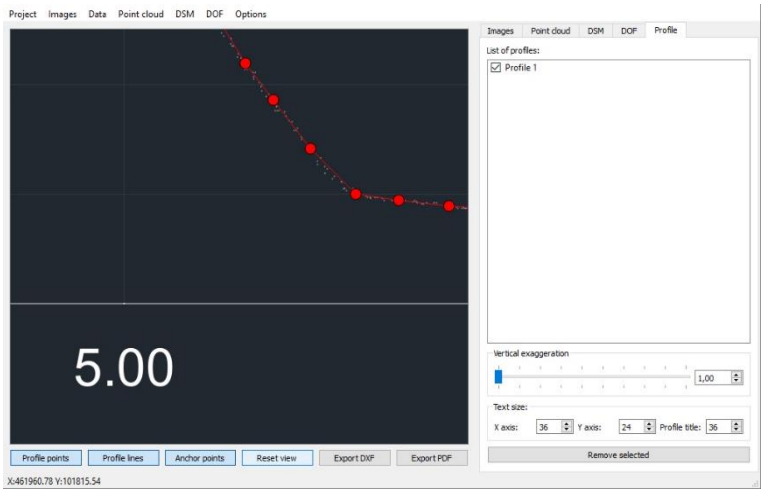
- ***Profile lines*** show lines that define profile.



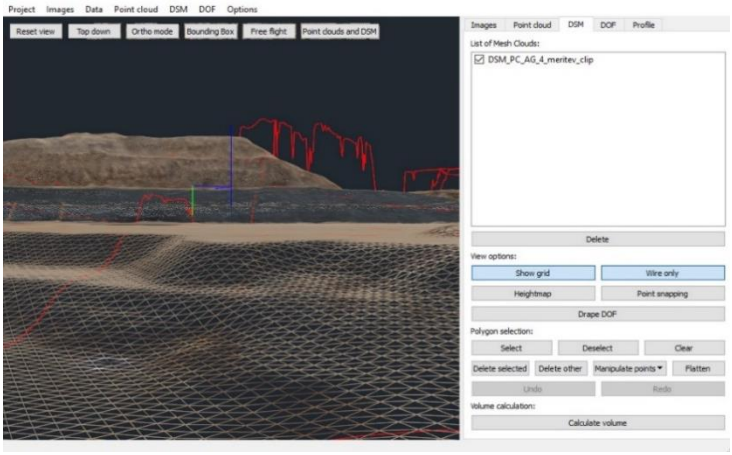
- ***Anchor points*** show interpolated point that define profile line.



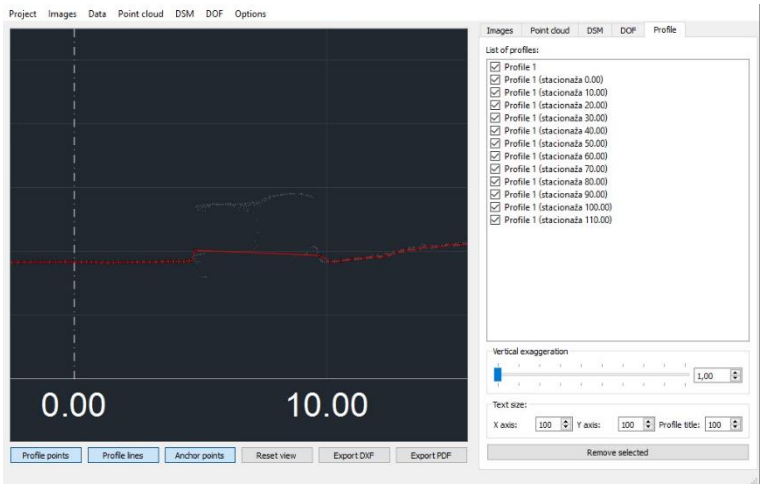
- ***Reset view*** returns the view to all profiles.



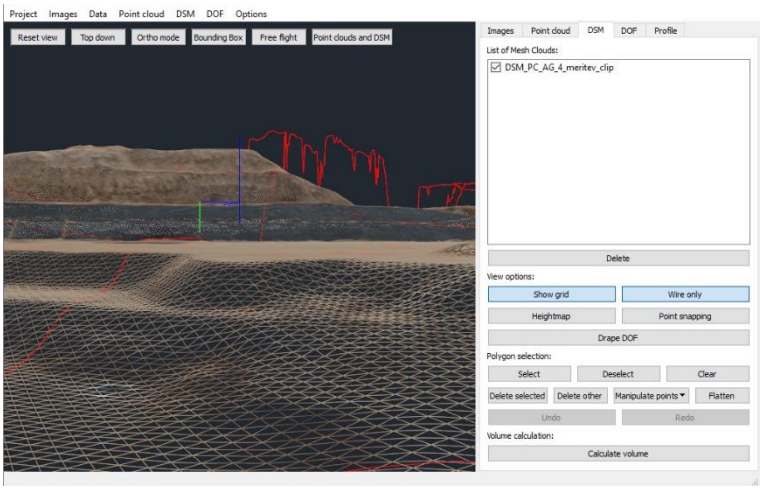
- ***Reconnect***, reconnects profile line between two selected anchor points. When you have a bump or undeleted object on top of the terrain, or if you would like to reshape it. Here we have transversal profile computed across construction machinery.



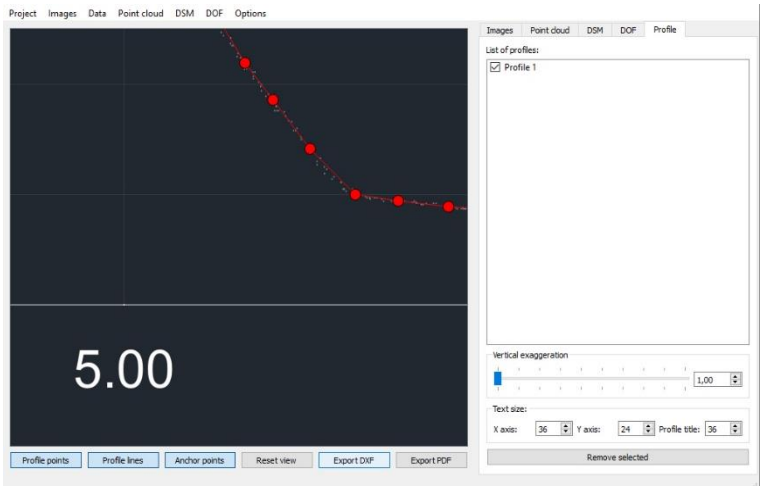
To shape it to preferable curve or level, zoom to transversal profile and click two external points that present the desired shape. Click ***Reconnect*** button and the transversal profile will be reshaped. As you see, points that define transverse profile remain present as profile points - the new shape is displayed below them.



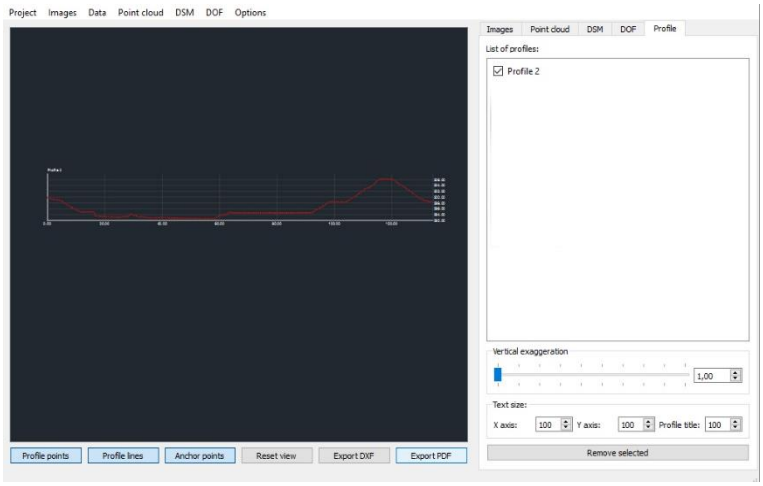
Present new shape of transversal profile on top of wire only model. New shape is now suitable to shape of the DTM.



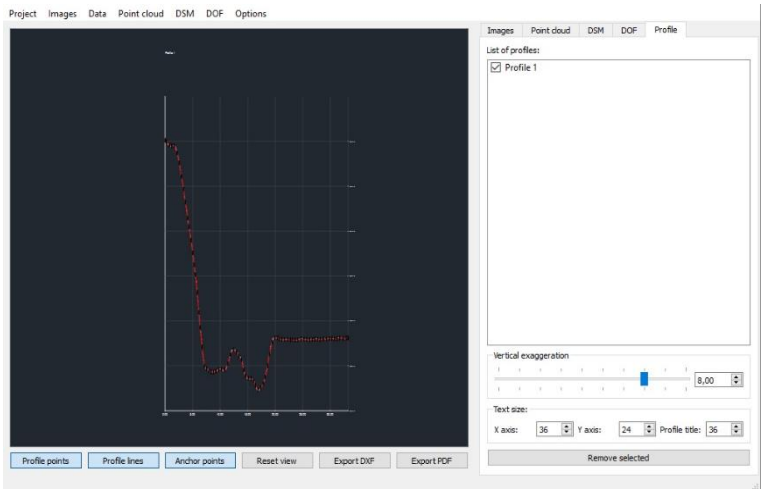
- ***Delete*** deletes selected anchor point and automatically reconnects neighbouring points.
- ***Export DXF***, exports longitudinal profile to desired dxf file.



- ***Export PDF,*** exports what you see in the window to pdf file.



- ***Vertical exaggeration*** slide bar allows you to extend vertical scale of profile.

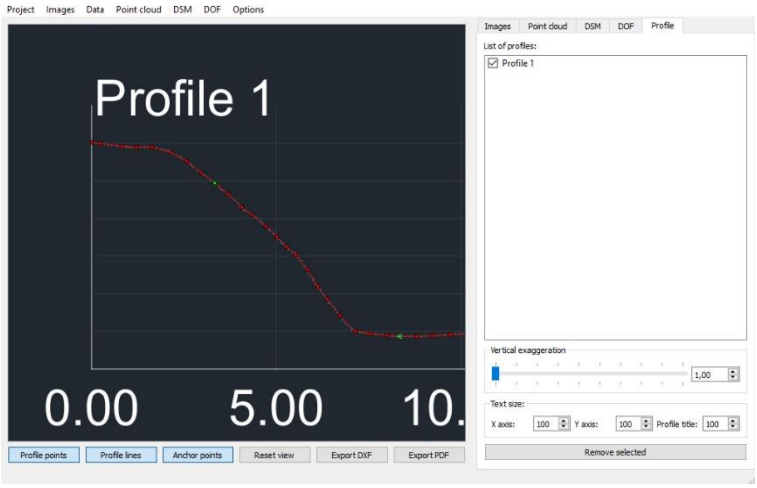


- Text size

  Profile title, allows you to change scale of profile title.

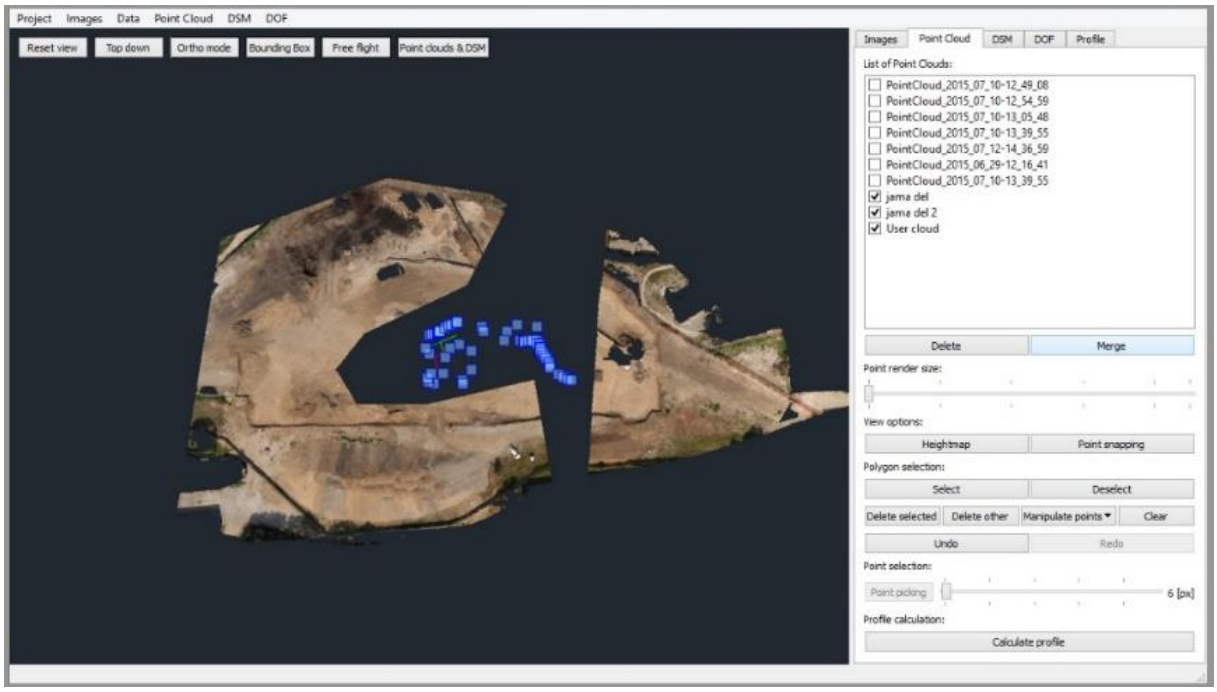
  Y – Axis, allows you to change scale on longitudinal axis.

X – Axis, allows you to change scale on vertical axis.

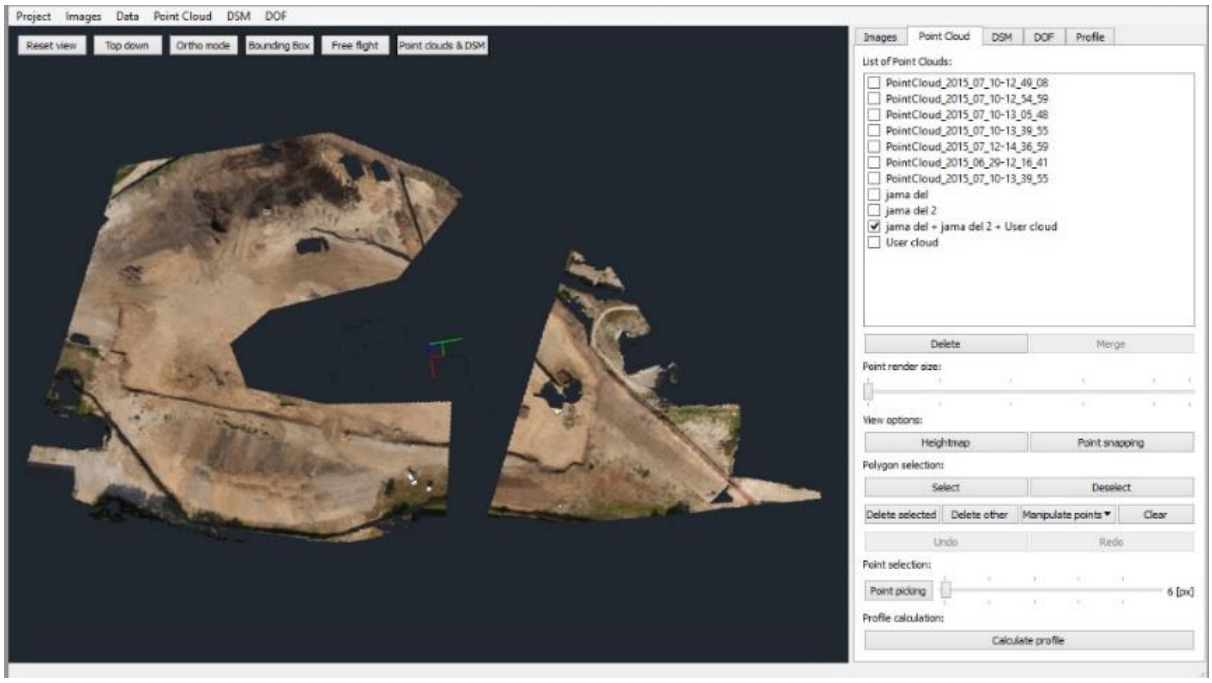


5.8. Point cloud merge

If you have different point clouds you can merge them to a new point cloud. Both point clouds need to be selected. Click ***Merge*** button to merge them into one.



New PC appears



5.9. Height map

When processing Point clouds or DSMs, data can be viewed in hypsometric scale. When viewing desired data, click on ***Height map*** button to display digital elevation model with accompanying scale and colour legend. Use double mouse click on preferred colour of the legend, to change it

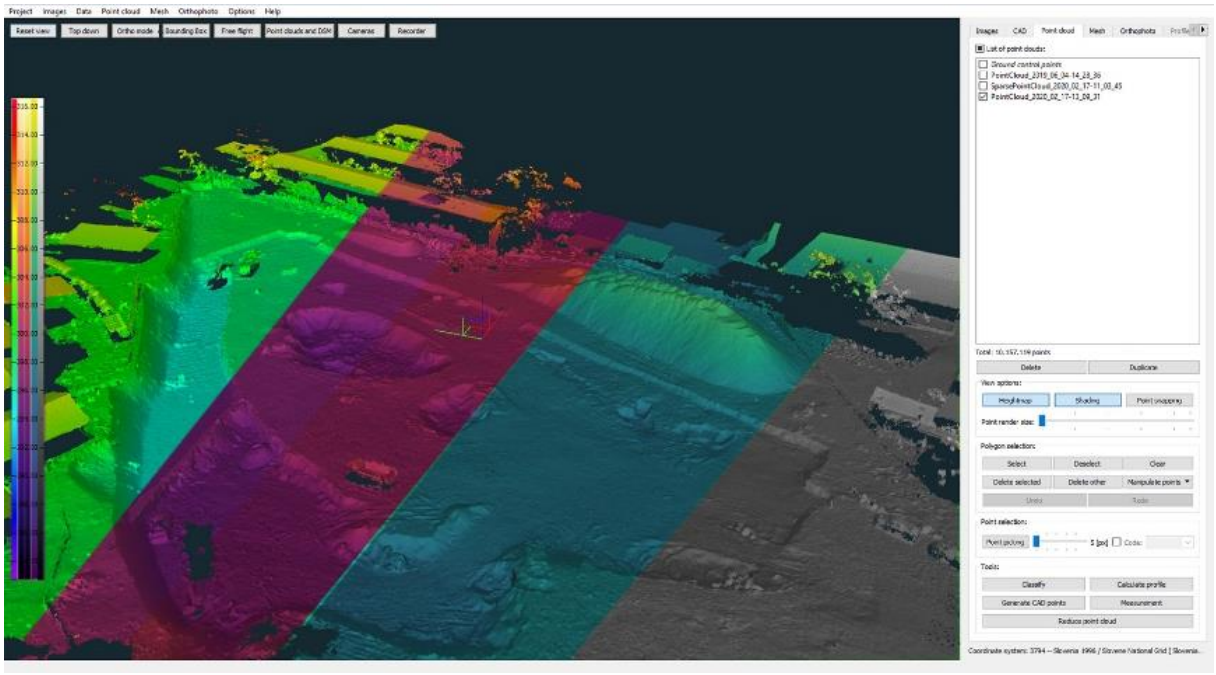
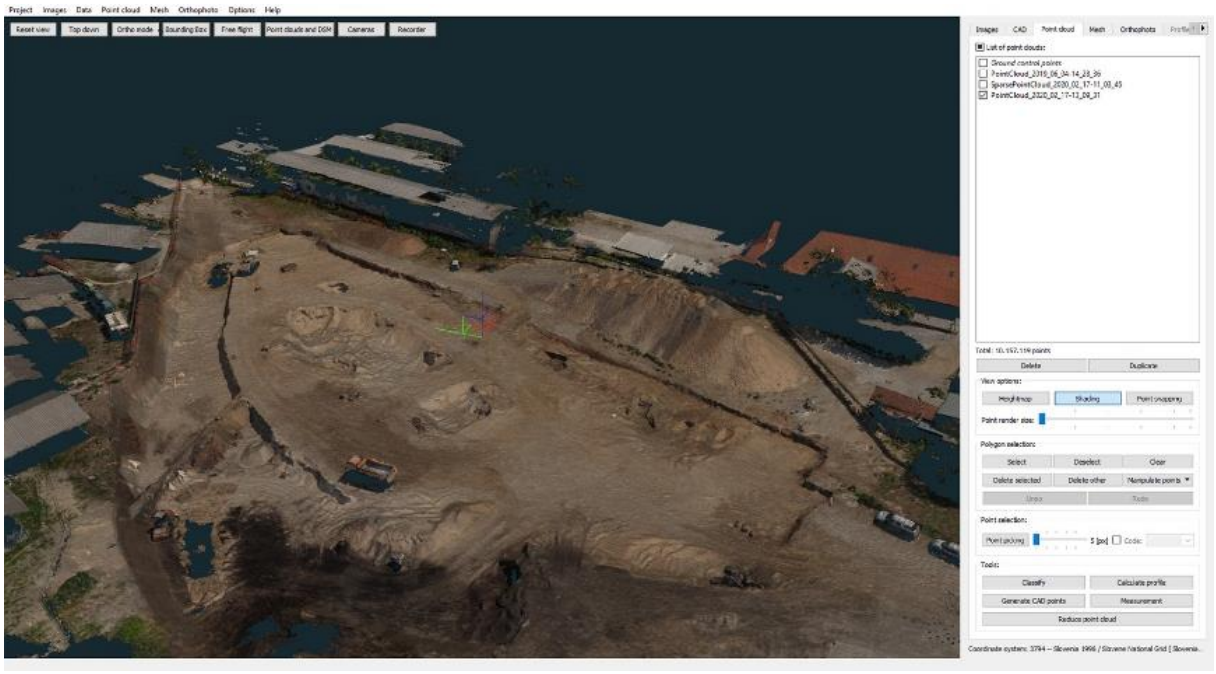


Image show height maps in possible hypsometric ranges.

5.10. Shading

For better perception of spatial characteristics, point clouds, and meshes can be shaded Click on ***Shading*** button to display shades on point cloud points.



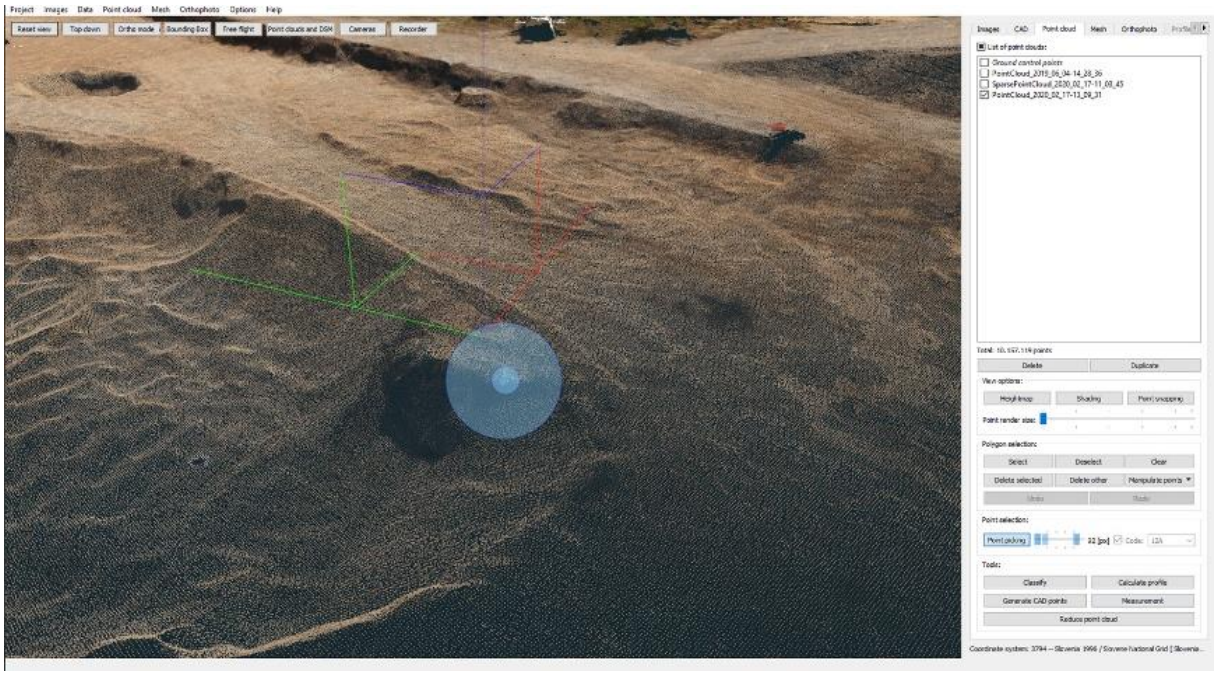
5.11. Delete

Tick point cloud data that you would like to delete from application and click ***delete*** button.

5.12. Point picking

Point picking is a function for point selection in order to compute point. Click ***Point picking*** button and ***slide bar*** to set circle radius. Tick code, if you wish to pin code to new point. Type or select code from the list. Set marker to desired position. **Left mouse click** creates a new point. Its position is computed based on neighbouring points (those covered with the marker circle). Point has appended code.

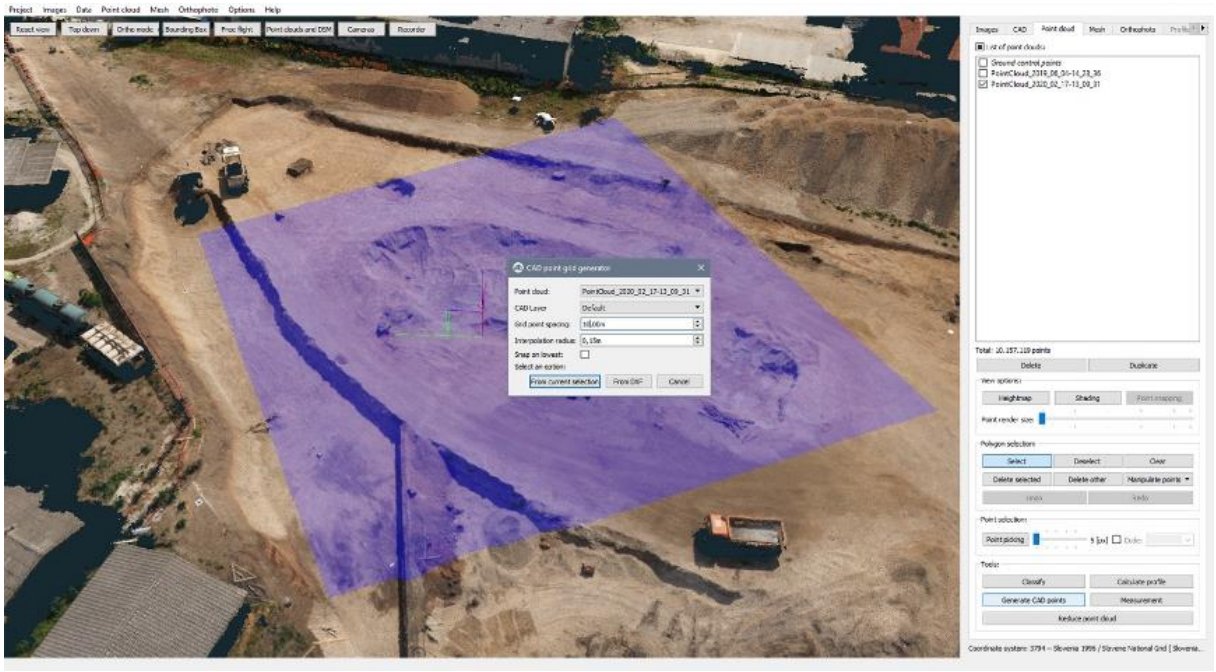
Picture shows three samples of circle radius and their appearance on PC.



5.13. Generate CAD points

Use CAD point generator and automatically extract points in regular grid of desired size, with CAD capabilities. You have 2 options, select desired area or use CAD function and draw closed polygon for selection. Here, we guide you through first option.

Select desired area of point cloud, and click Generate CAD points function.



Set parameters:

Point cloud, selected one by default

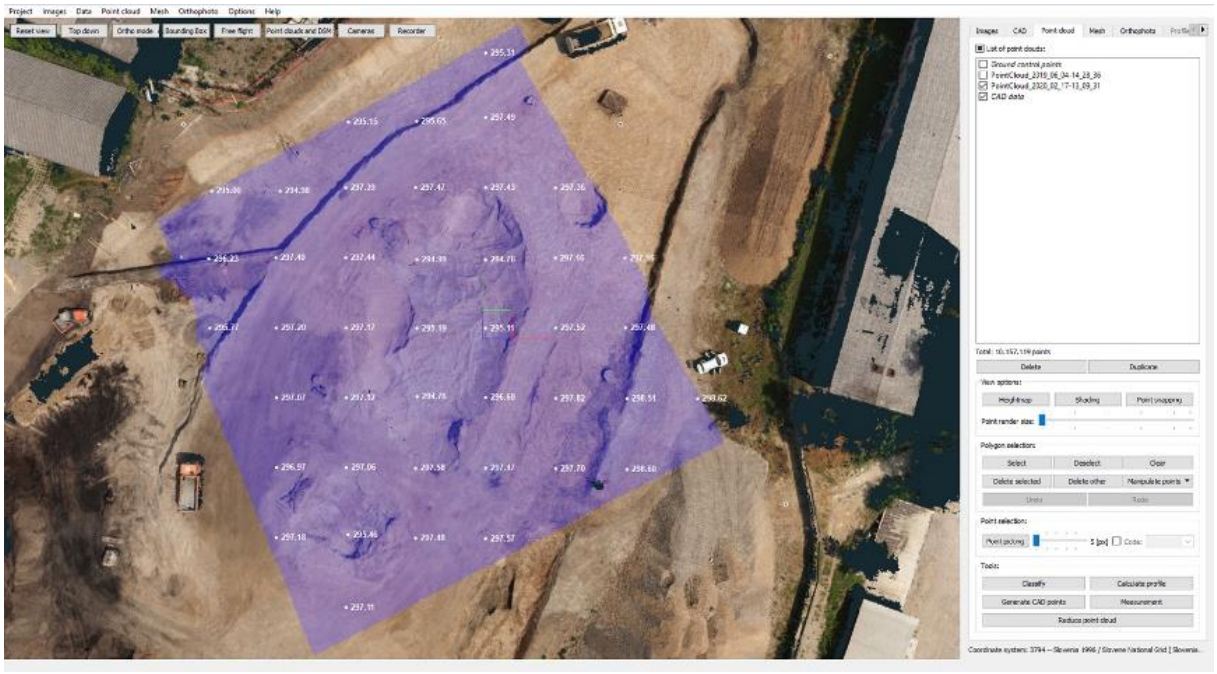
CAD layer, default

Grid point spacing, default 5m

Interpolation radius, default 0,15m

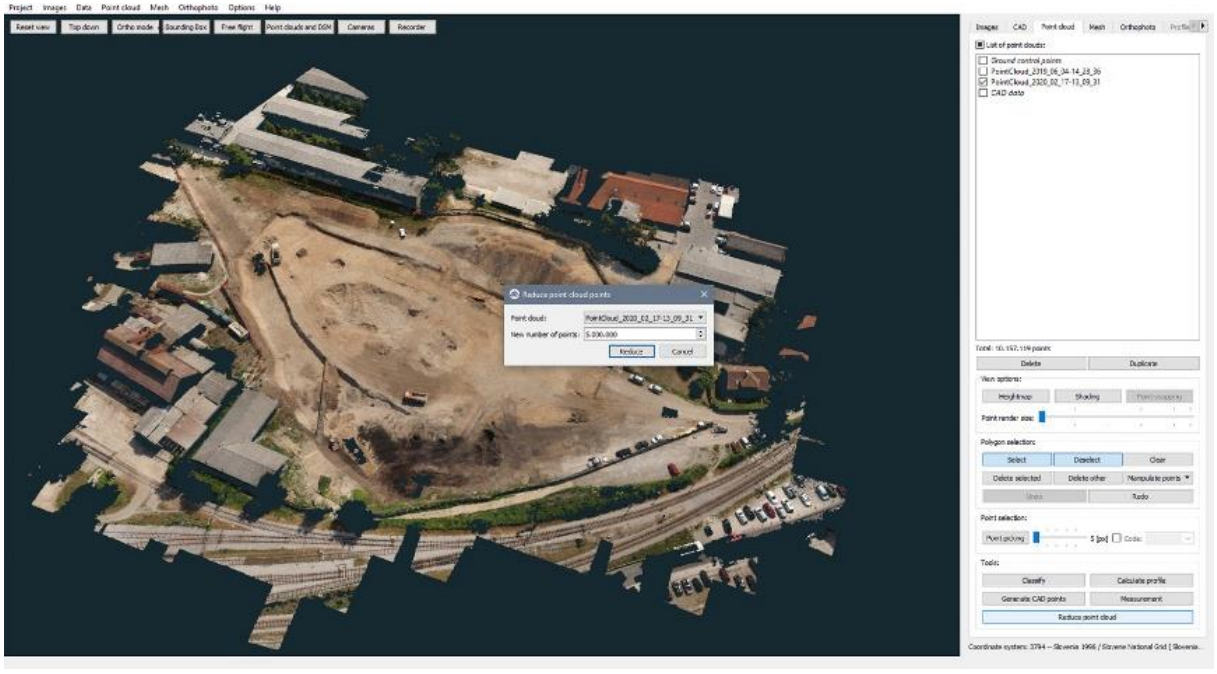
Possibility of extracting only lowest points

Confirm by selecting desired option of selection. In our case ***From current selection***. Generated CAD points with displayed height are presented.

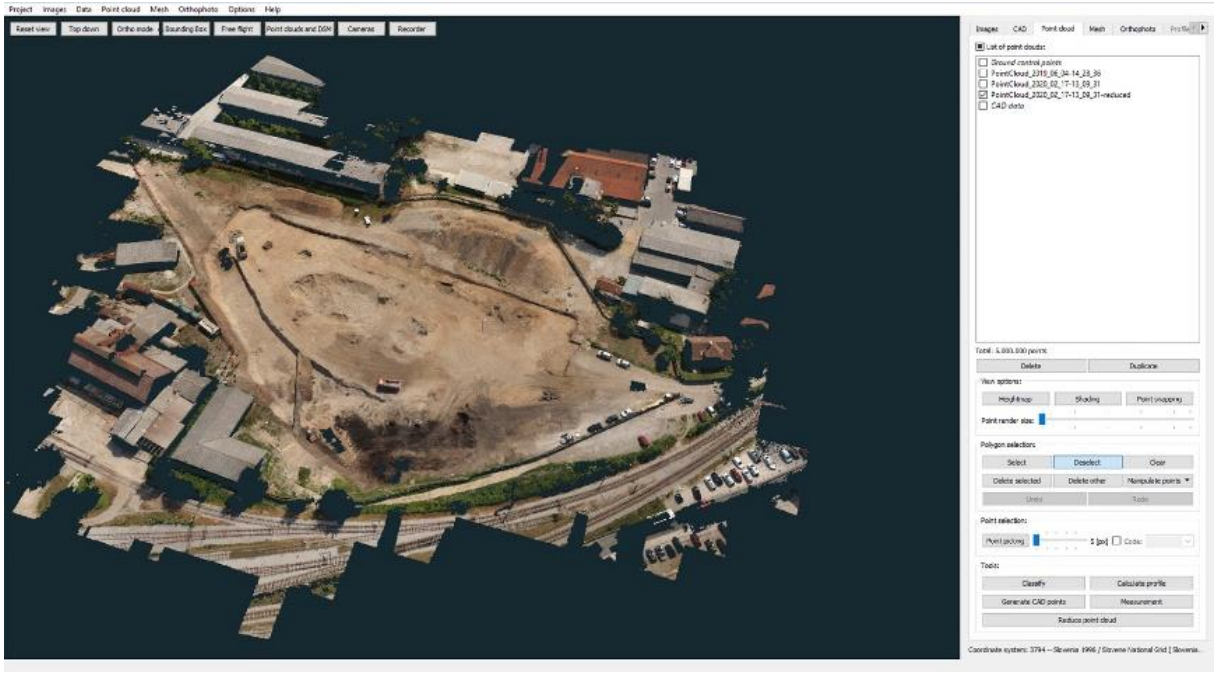


5.14. Reducing point clouds

Want to reduce point cloud points, but don't want to process reconstruction again. Use ***Reduce point clouds*** function.



Define desired point cloud, and set desired number of point cloud points. Typed value, that has to be lower than original point cloud. New point cloud appears with "-reduced" in the name.



5.15. Saving point clouds

Save project. You can export PC to – Select from dropdown list ***Point cloud*** -> ***Save as***:

*.*ply* – default Stanford mesh file

*.las *.laz – laser and LiDAR files

*.zlas – LiDAR ESRI file

*.*koo* – file of coordinates,

*.*txt* – text file.

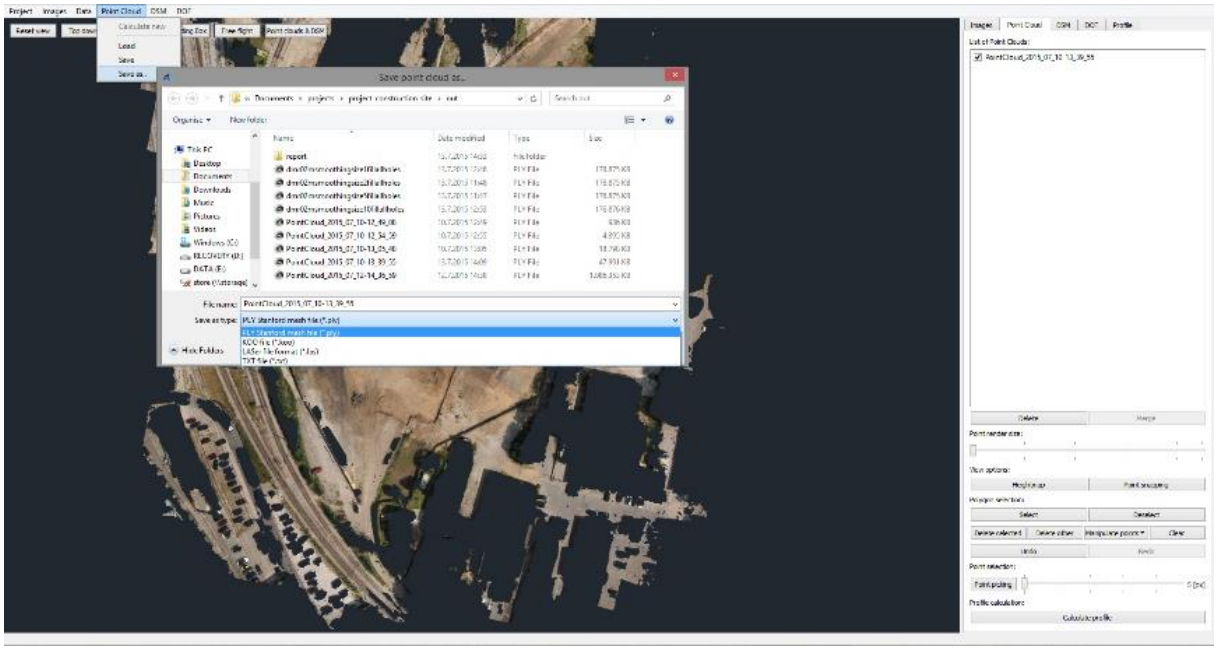
*.xyz – text file

*.csv *.dsv – delimiter-separated values format

*.pts – PTS format

*.*cl3* – TOPCON LC3 format

*.*e57* – ASTM E57 format



5.16. Classification

Click ***Classification*** button to classify terrain points. In the pop up window, you can adjust:

terrain elevation –maximal sudden elevation change in terrain

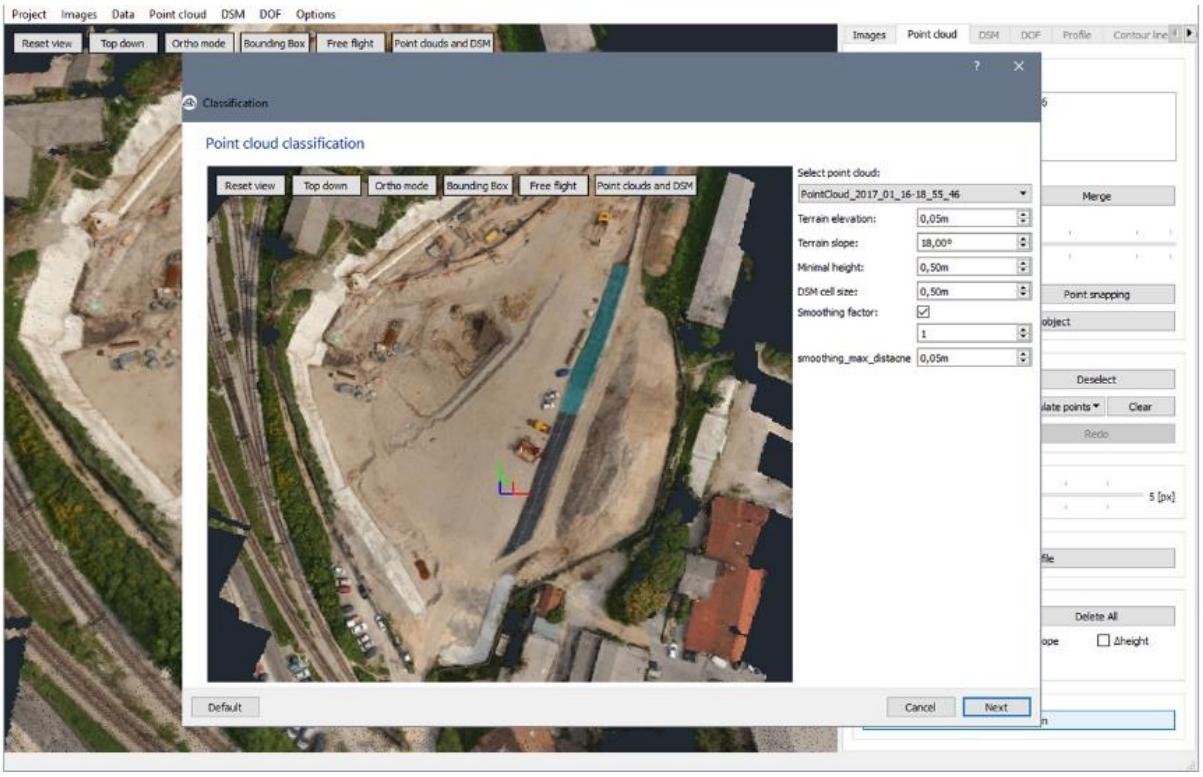
terrain slope –maximal angle between horizon and slope in degrees,

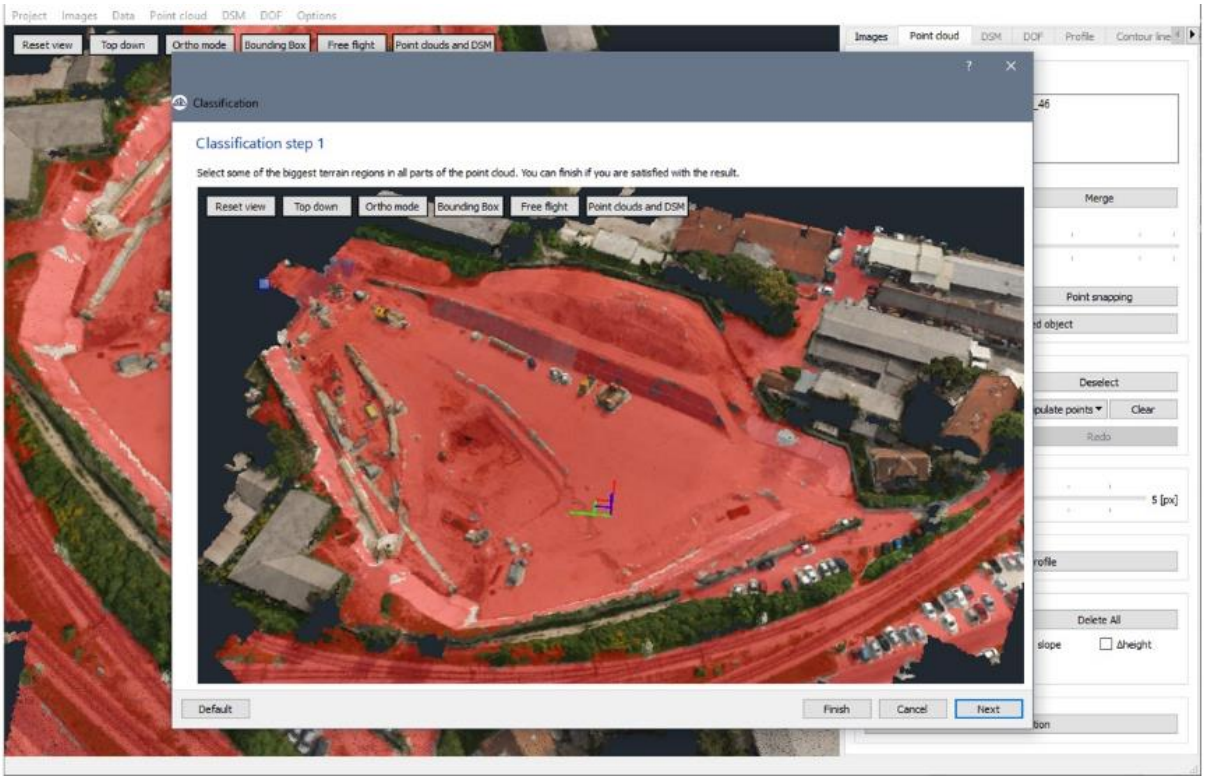
minimal height – minimal height of objects to be deleted,

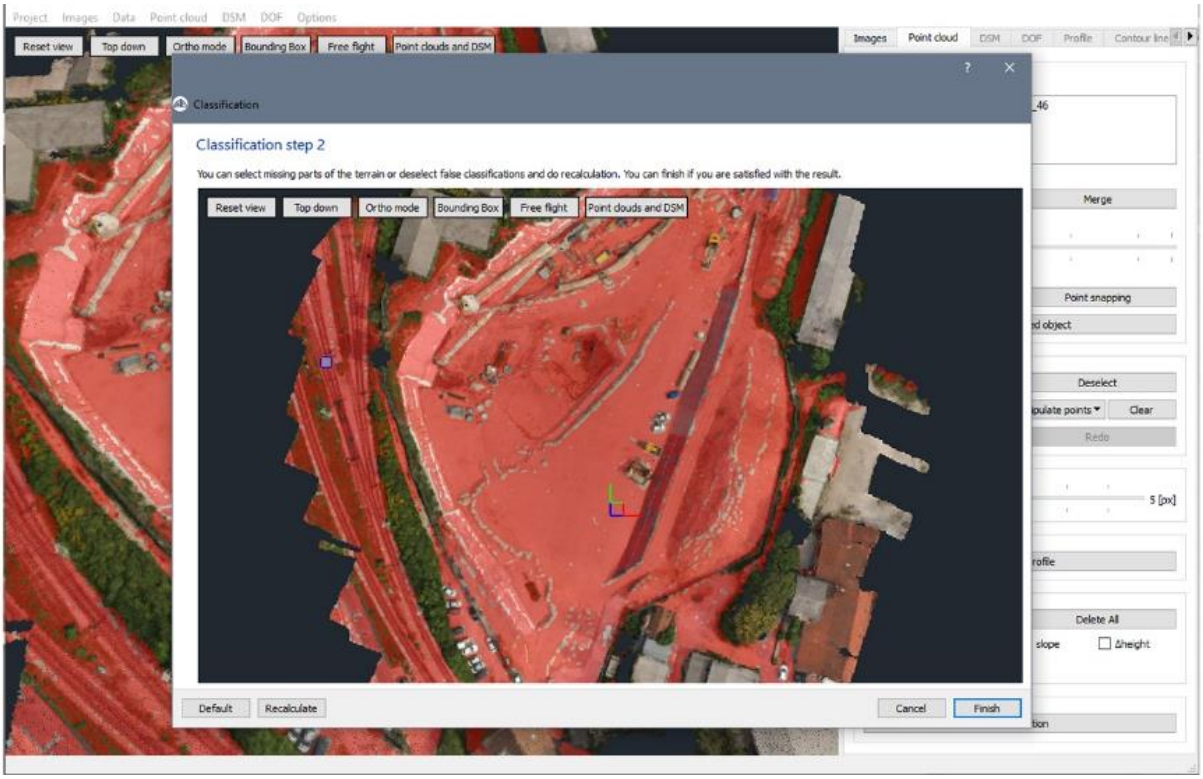
DSM cell size - cell size of previously computed DSM,

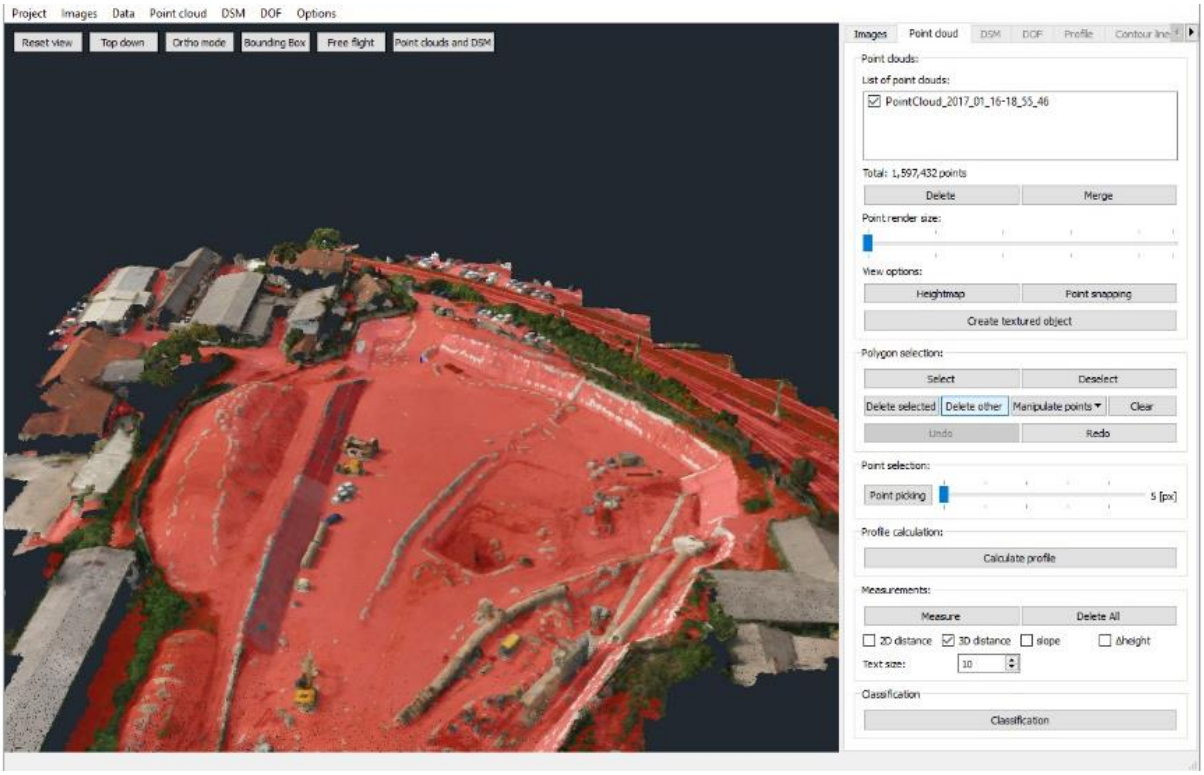
smoothing factor – proportionate to smoothness of classified terrain

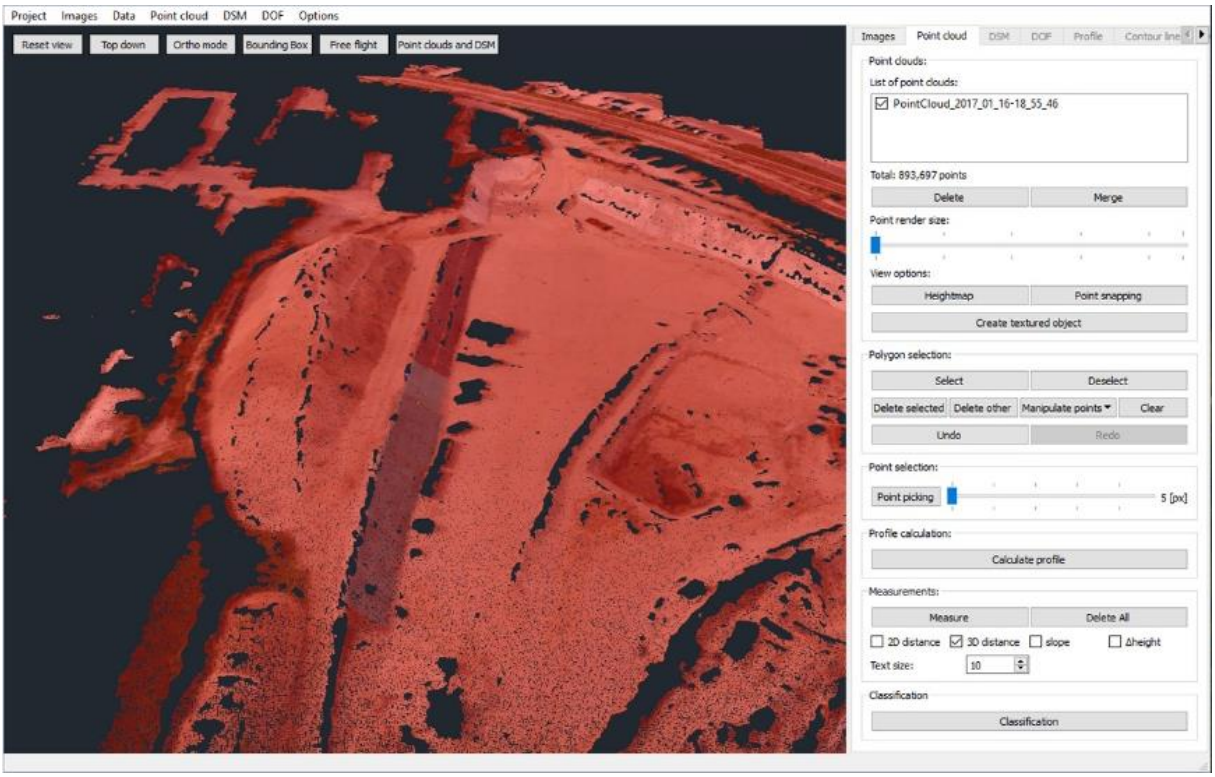
smoothing maximum size – maximal size of influential area.


Project Images Data Point cloud DSM DOF Options
Reset view Top down Ortho mode Bounding Box Free flight Point clouds and DSM
Images Point cloud DSM DOF Profile Contour line
Classification
Point cloud classification
Reset view Top down Ortho mode Bounding Box Free flight Point clouds and DSM
Select point cloud:
PointCloud_2017_01_16-18_55_46
Terrain elevation: 0,05m
Terrain slope: 18,00°
Minimal height: 0,50m
DSM cell size: 0,50m
Smoothing factor:
1
smoothing_max_distacne 0,05m
Merge
Point snapping
Deselect
Clear
Redo
5 [px]
Delete All
Δheight
Default
Cancel
Next


Project Images Data Point cloud DSM DOF Options
Reset view Top down Ortho mode Bounding Box Free flight Point clouds and DSM
Images Point cloud DSM DOF Profile Contour line
Classification
Classification step 1
Select some of the biggest terrain regions in all parts of the point cloud. You can finish if you are satisfied with the result.
Reset view Top down Ortho mode Bounding Box Free flight Point clouds and DSM
Merge
Point snapping
Deselect
Clear
Redo
5 [px]
Delete All
Δheight
Default
Finish
Cancel
Next


Project Images Data Point cloud DSM DOF Options
Reset view
Top down
Ortho mode
Bounding Box
Free flight
Point clouds and DSM
Images
Point cloud
DSM
DOF
Profile
Contour line
Classification
Classification step 2
You can select missing parts of the terrain or deselect false classifications and do recalculation. You can finish if you are satisfied with the result.
Merge
Point snapping
Deselect
Clear
Redo
Delete All
Default
Recalculate
Cancel
Finish


Project Images Data Point cloud DSM DOF Options
Reset view
Top down
Ortho mode
Bounding Box
Free flight
Point clouds and DSM
Images
Point cloud
DSM
DOF
Profile
Contour line
Point clouds:
List of point clouds:
PointCloud_2017_01_16-18_55_46
Total: 1,597,432 points
Delete
Merge
Point render size:
View options:
Heightmap
Point snapping
Create textured object
Polygon selection:
Select
Deselect
Delete selected
Delete other
Manipulate points
Clear
Undo
Redo
Point selection:
Point picking
5 [px]
Profile calculation:
Calculate profile
Measurements:
Measure
Delete All
2D distance
3D distance
slope
Δheight
Text size:
10
Classification
Classification


Project
Images
Data
Point cloud
DSM
DOF
Options
Reset view
Top down
Ortho mode
Bounding Box
Free flight
Point clouds and DSM
Images
Point cloud
DSM
DOF
Profile
Contour line
Point clouds:
List of point clouds:
PointCloud_2017_01_16-18_55_46
Total: 893,697 points
Delete
Merge
Point render size:
View options:
Heightmap
Point snapping
Create textured object
Polygon selection:
Select
Deselect
Delete selected
Delete other
Manipulate points
Clear
Undo
Redo
Point selection:
Point picking
5 [px]
Profile calculation:
Calculate profile
Measurements:
Measure
Delete All
2D distance
3D distance
slope
Δheight
Text size:
10
Classification
Classification

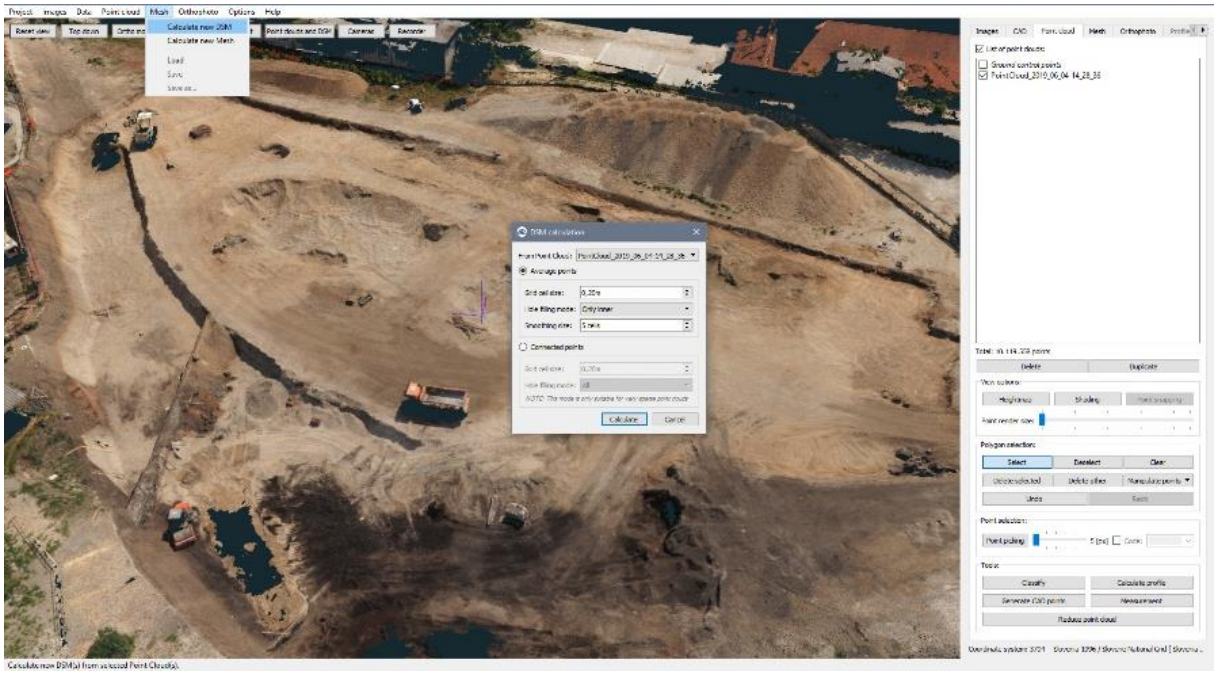
6. Mesh manipulation

Point clouds can be presented as 2 types of meshes:

- DSM, made from points in regular grid, that don't present overhanging surfaces
- full 3D mesh, made from points in irregular grid, that present overhanging surfaces

6.1. Calculate digital surface model

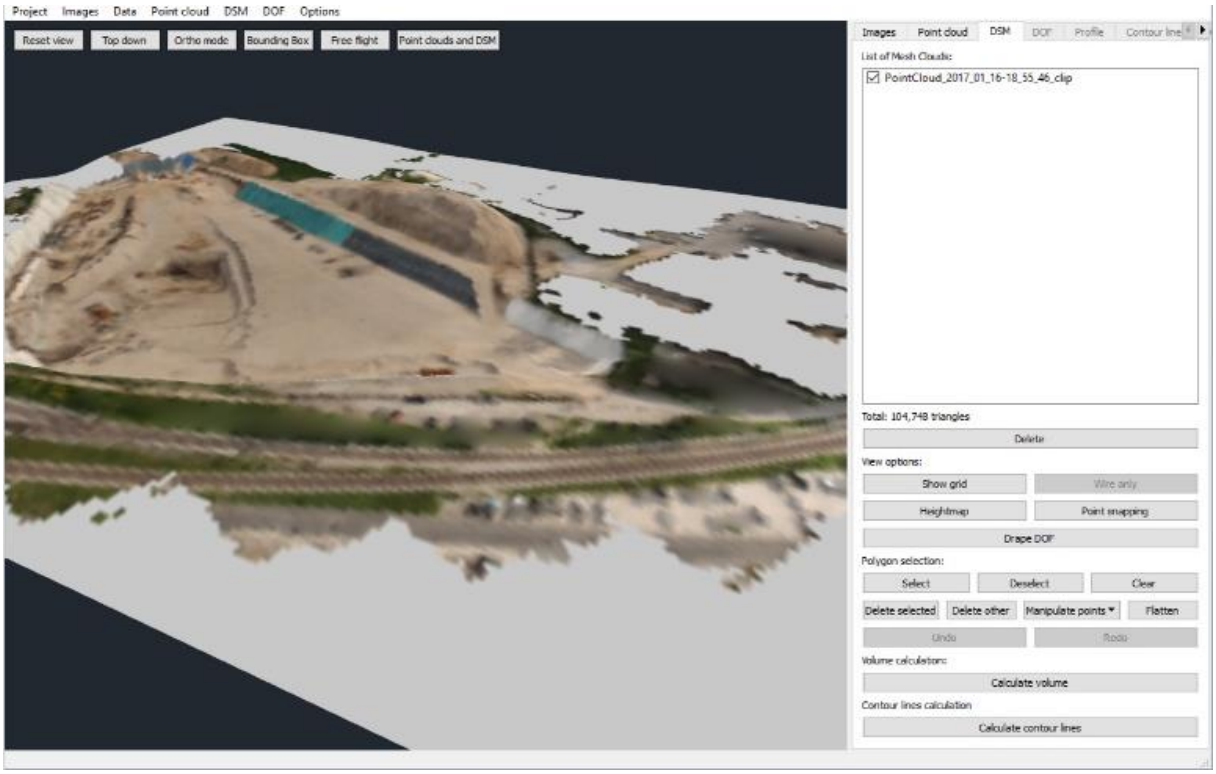
Select from dropdown list ***Mesh*** -> ***Calculate new DSM*** and set parameters.



For Orthophoto production the default parameters are:

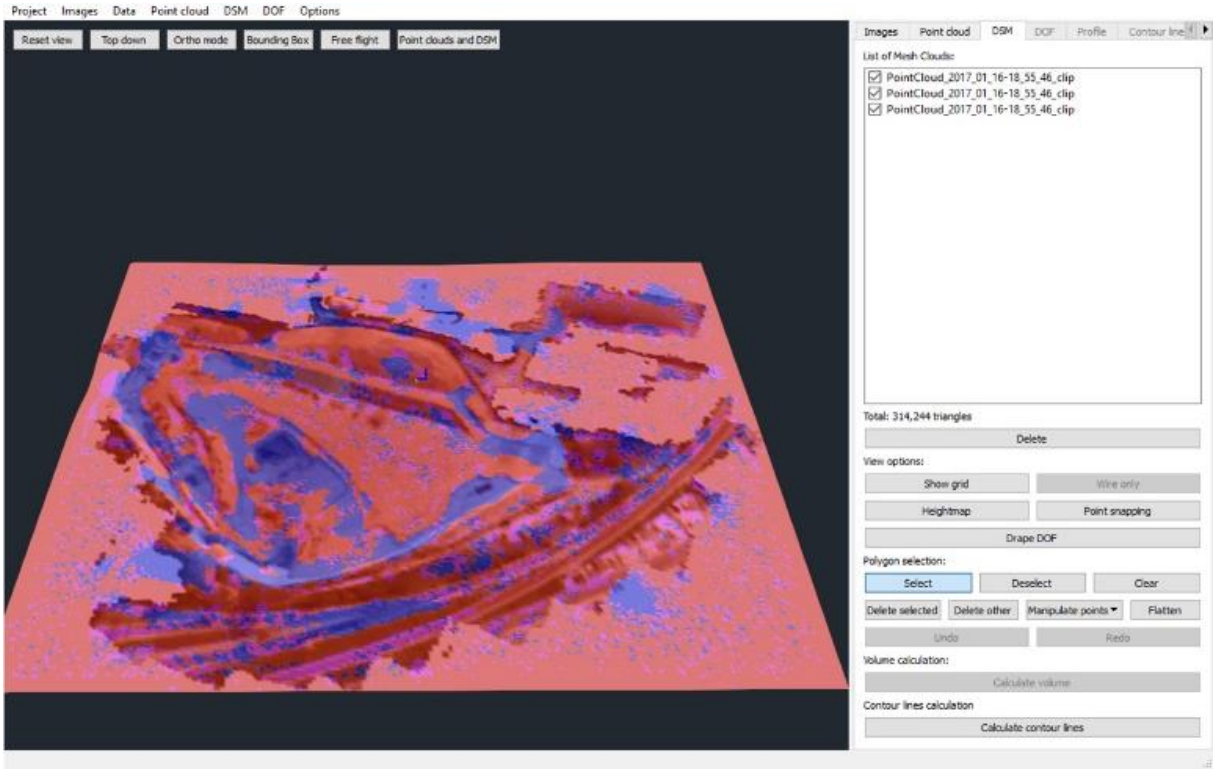
- From Point cloud: DSM
- Grid cell size: 1.0m
- Hole filling mode: All
- Smoothing size: 3 cells

The lowest grid cell to be set is 20 cm and gives the highest detail.



Comparison of three DSMs shows that higher ***smoothing size*** gives smoothest surface. Selected models present the effect of three *smoothing sizes*:

- 10 cells (red) – the smoothest
- 5 cells (purple) – semi-smooth
- 1 cells (blue) – the least smooth.



To export computed Meshes, you need to do it on at a time. First view just the one, you wish to save. Select from dropdown list ***Mesh*** -> ***Save as***:

**.ply* – default Stanford mesh file

*.dxf – DXF drawing exchange format

*.txt – text file

**.koo* – file of coordinates,

**.xyz – text file,*

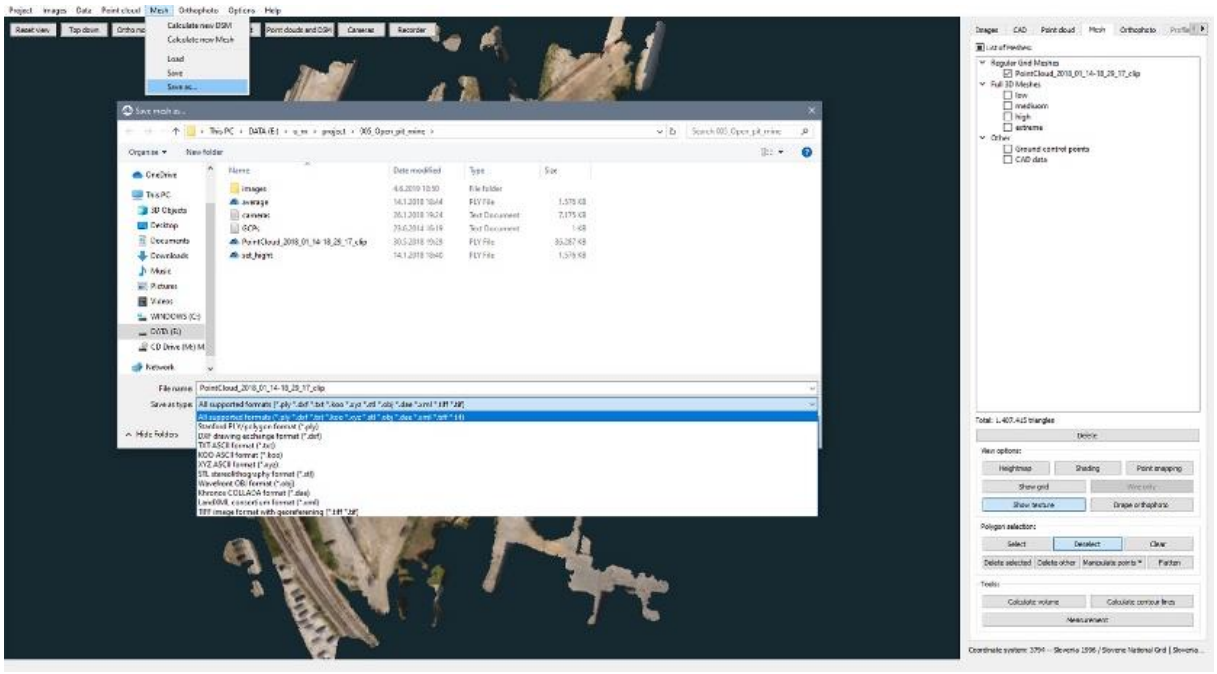
*.stl – stereolithography format,

*.obj – Wawefront OBJ format,

*.dae – Khronos COLLADA format,

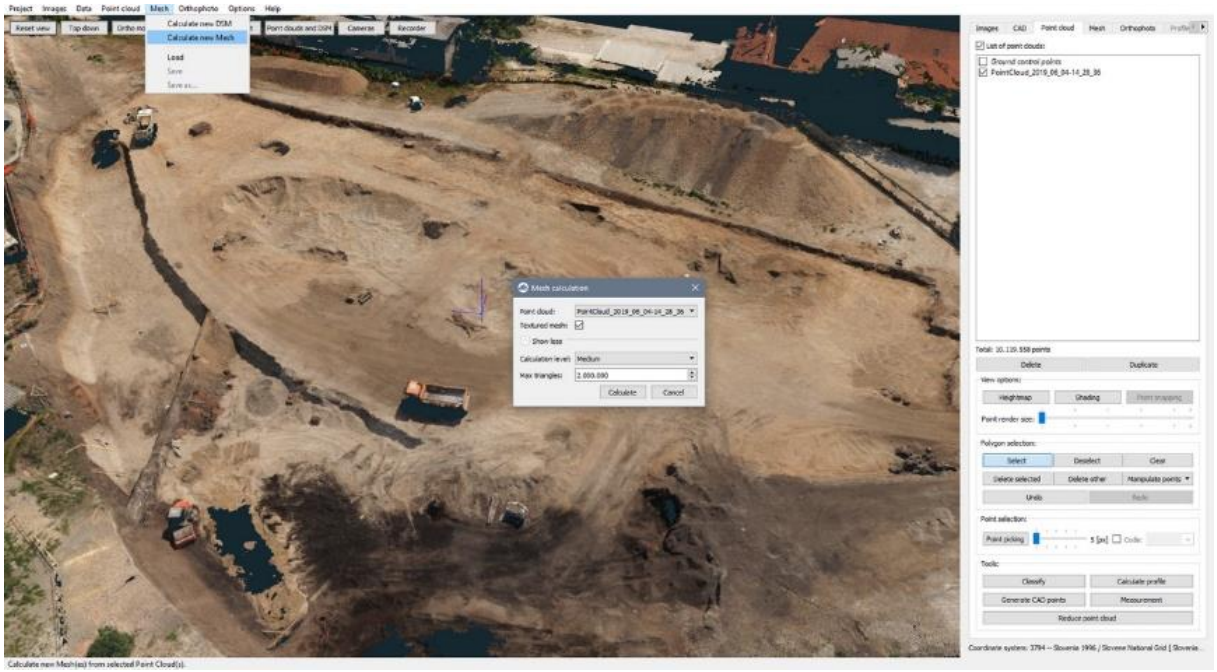
*.xml – landXML construction format,

*.tiff *.tif – TIFF image format with georeferencing (only for DSMs)



6.2. Calculate texturized full 3D mesh

Select from dropdown list ***Mesh***-> ***Calculate new Mesh*** and set parameters.

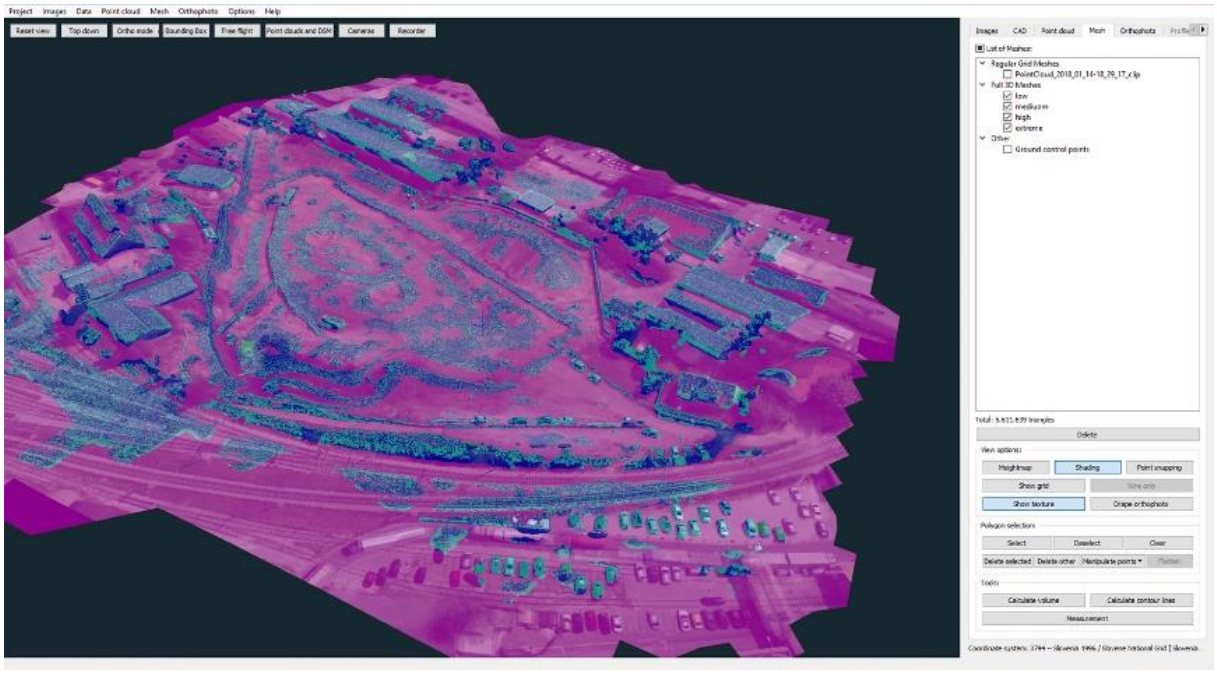


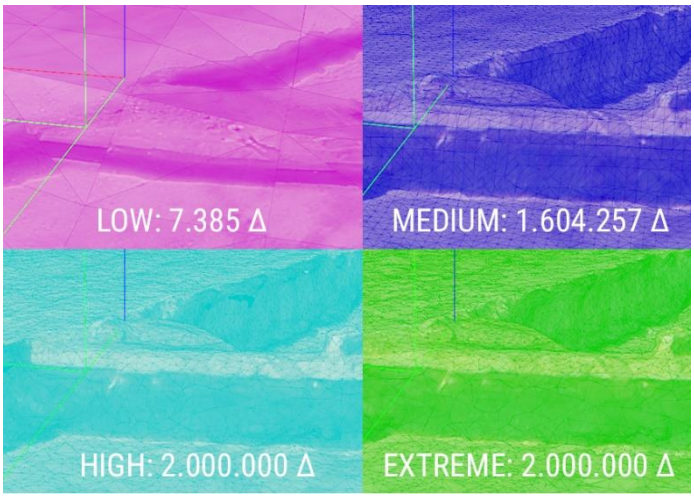
Most commonly used, default parameters are:

- Textured mesh: on
- Calculation level: Medium
- Maximal number of triangles: 2.000.000
- The highest number of triangles can be set to 10.000.000, and allows you to make most completed 3d mesh.

Comparison of four Meshes shows that higher ***Calculation level*** gives completed – most detailed surface at the same maximal number of triangles. Selected models present the effect of four *calculation levels*:

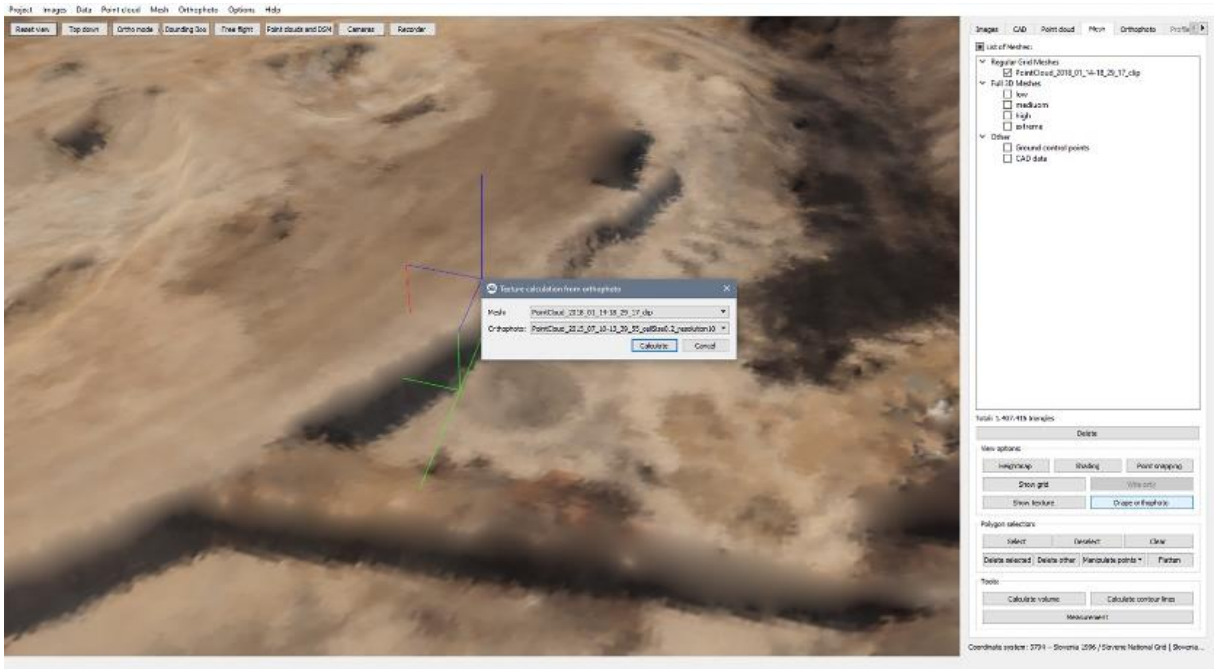
- low (purple) – the smoothest surface without edges
- medium (blue) – smoothest approximation of edges
- high (turquoise) – half smoothed edges
- extreme (green) – sharp edges with barely smoothed surfaces



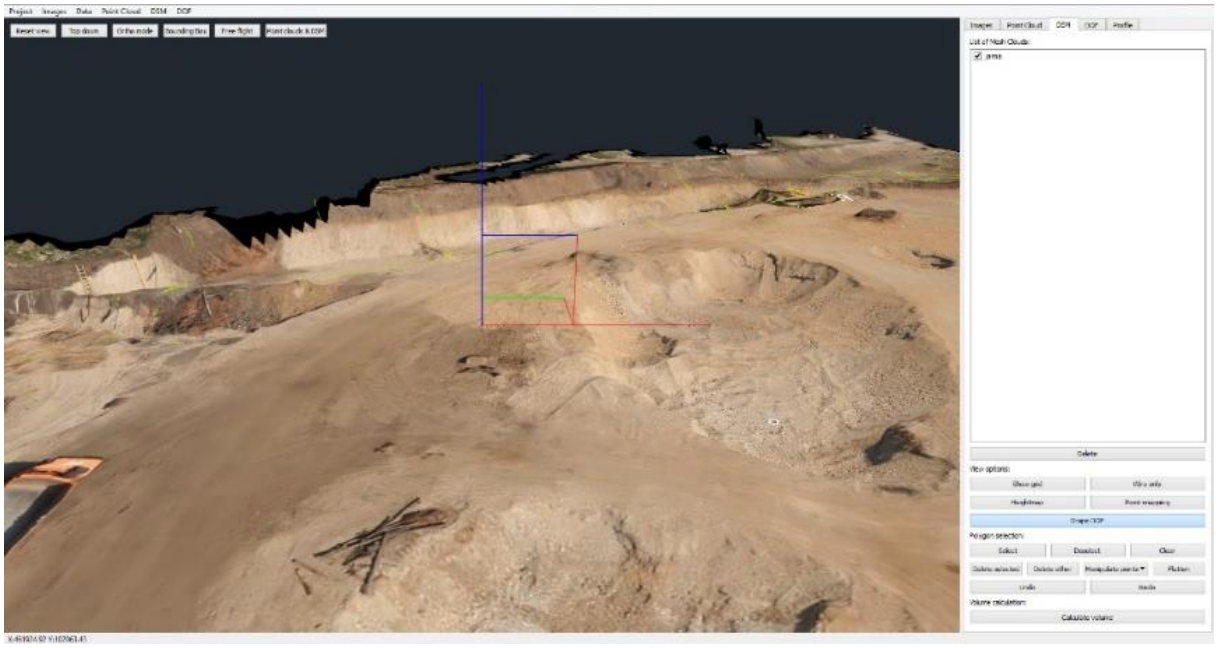


6.3. Draping digital orthophoto

For better visualization and spatial presentation, multiple Orthophotos can be plastered on top of multiple DSMs. Go to Mesh tab and select function Drape Orthophoto.



Set preferred combination of orthophoto and DSM. Remember, only DSM can be used for draping.



As orthophoto is plastered on top of regular grid mesh, function ***Show texture*** becomes activated.

6.4. Show texture

Viewing of plastering of true or traditional orthophoto on top of full 3D or regular grid mesh can be memory consuming.

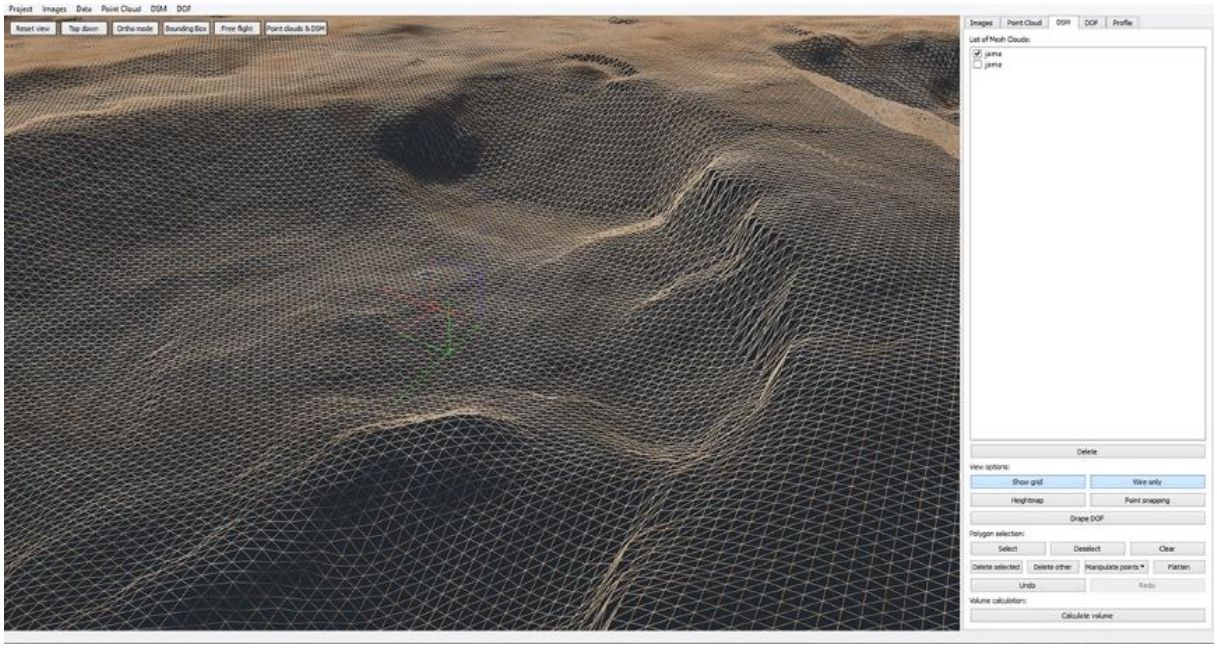
Use ***Show texture*** function to manage texture-viewing ability.

6.5. Show grid

If you want to see wire surface of undraped DSM, click ***Show grid*** button

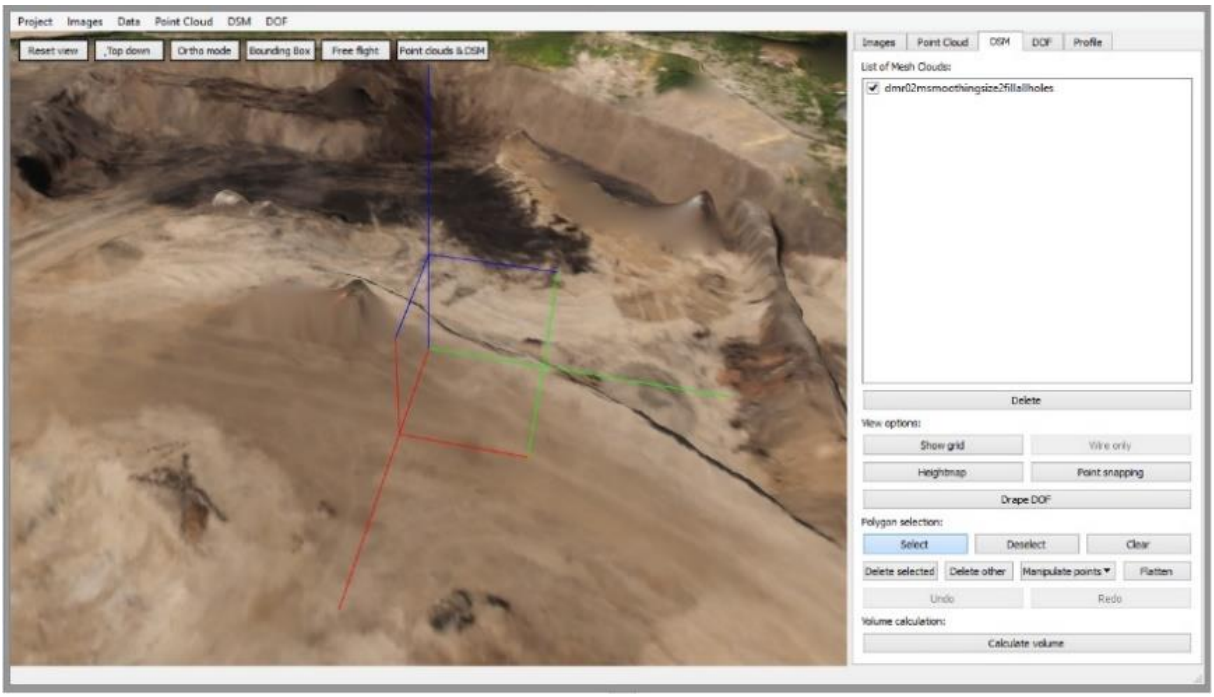
6.6. Wire only

If you want to see wire of undraped DSM, click ***Wire only*** button.

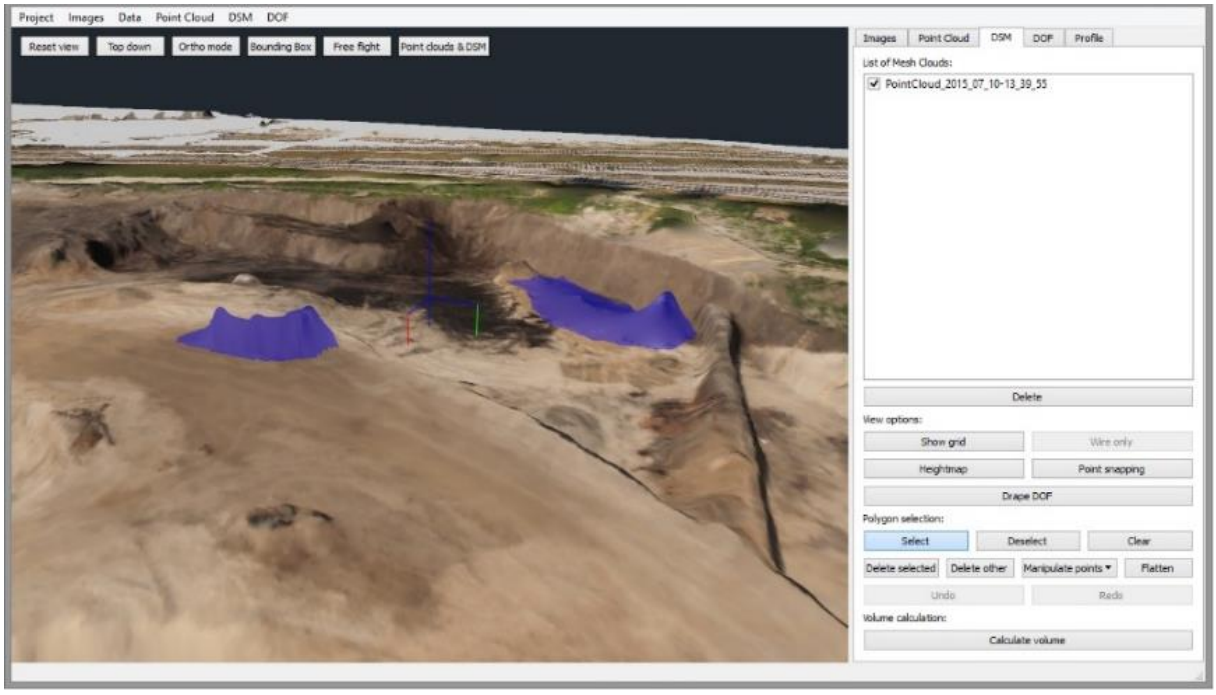


6.7. Flatten

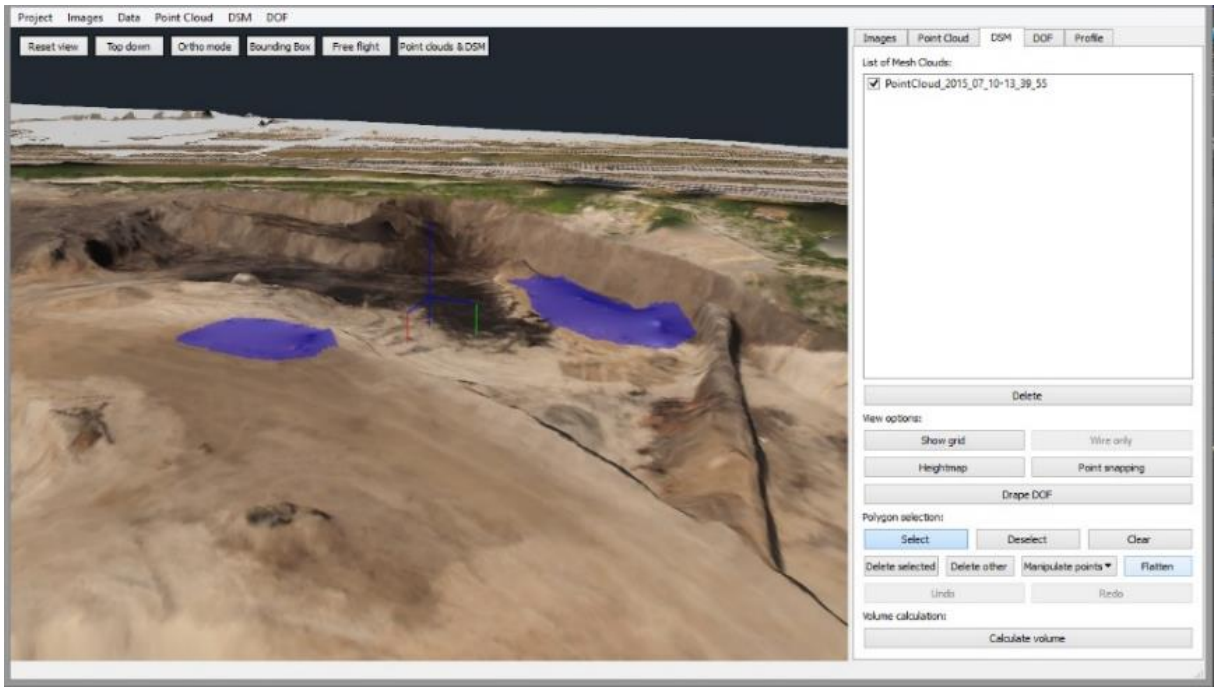
Check for any objects that you would like to filter out of the model.



First **select** recognised masses extended to surrounding area with preferable height. To eliminate masses, use function ***Flatten***.



After *Flatten*:



6.8. Volume calculation

Volume calculation based on interpolated surface: Calculate volume of material for single measurement - appropriate for the calculation of dredged material.

How?

Calculate or **load point cloud** of selected area -> Click ***Mesh*** -> **Calculate New** DMS and set calculation parameters as shown in Option settings_.Now you have two options for selecting area of interest:

Manual selection using select function for single use,

Click ***Select*** button and select area for Volume calculation with left mouse click. To finish selection, click right mouse click.

To calculate the volume on the selected area, click ***Calculate volume***.

For initial surface, use default value *Interpolate surface*

For final surface, select: calculated DSM

Click ***From current selection*** to calculate volume of selected area.

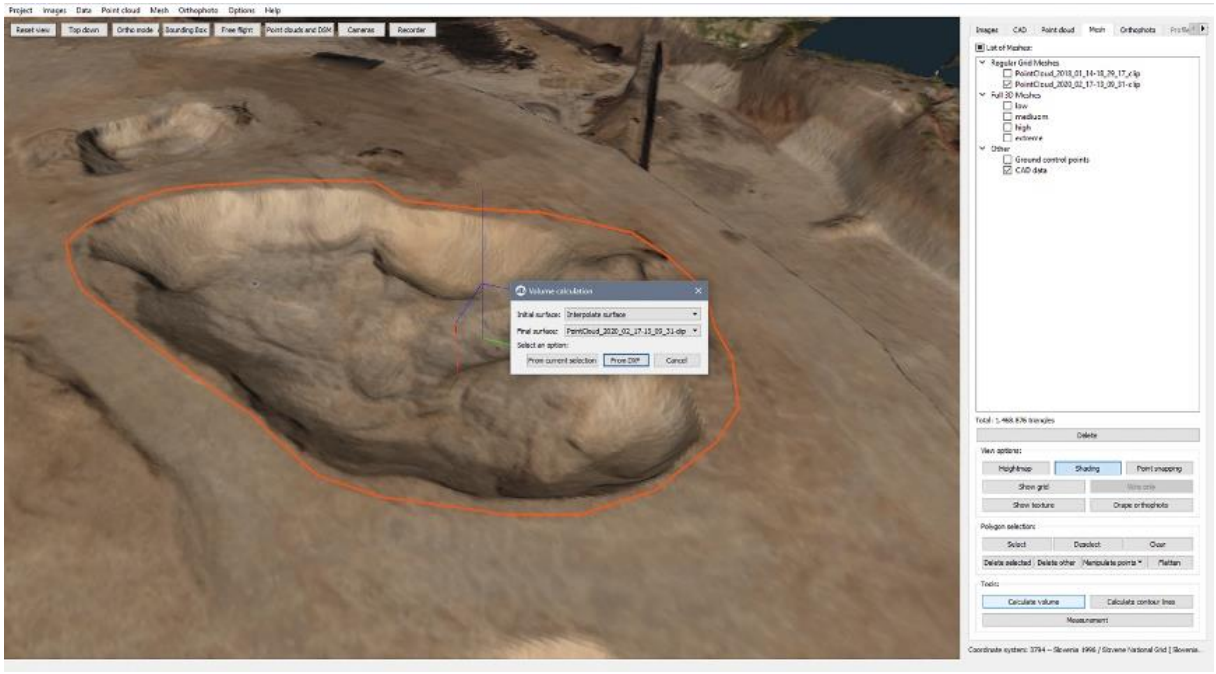
dxf boundary using CAD functionality for repeated or detailed use,

To calculate the volume on the area, defined by dxf boundary, click ***Calculate volume***.

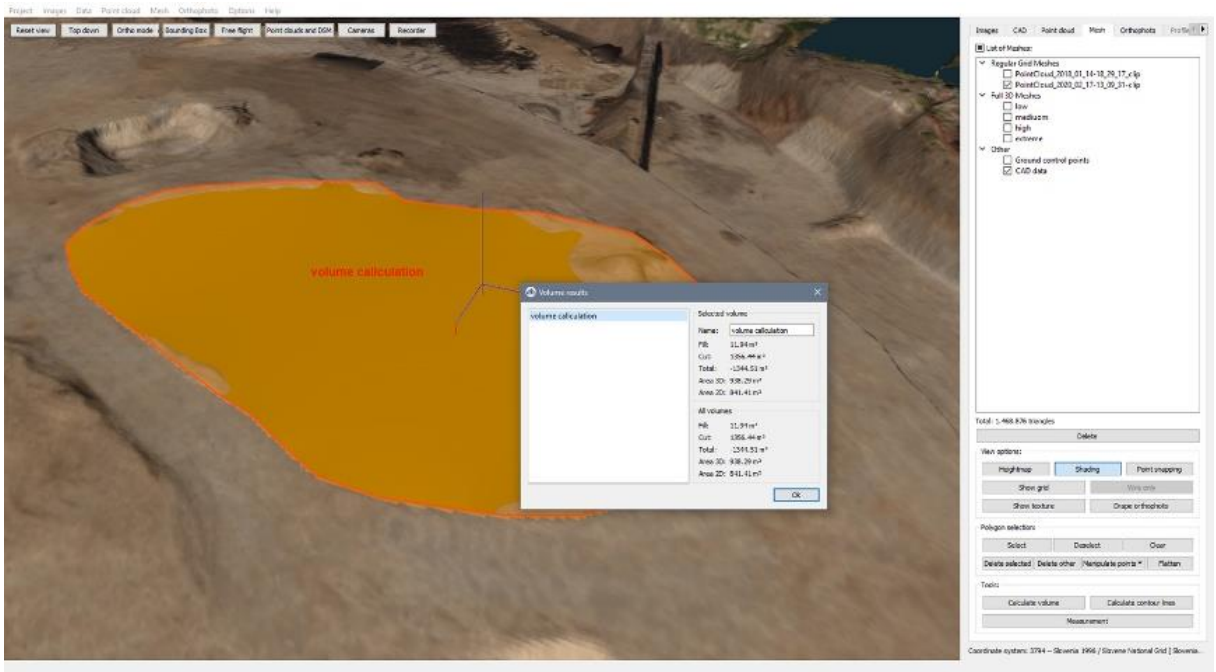
For initial surface, use default value *Interpolate surface*

For final surface, select: calculated DSM

Click ***From DXF*** and open desired file.



When *Calculate volume* is in process, the initial surface will be generated first, based on points closer to the edges of selections! Volume is calculated as subtraction of two surfaces.



Displayed results present values for both current volume selection and a total sum of all volumes, consisting of:

Fill – volume of needed mass to fill holes beneath mean surface.

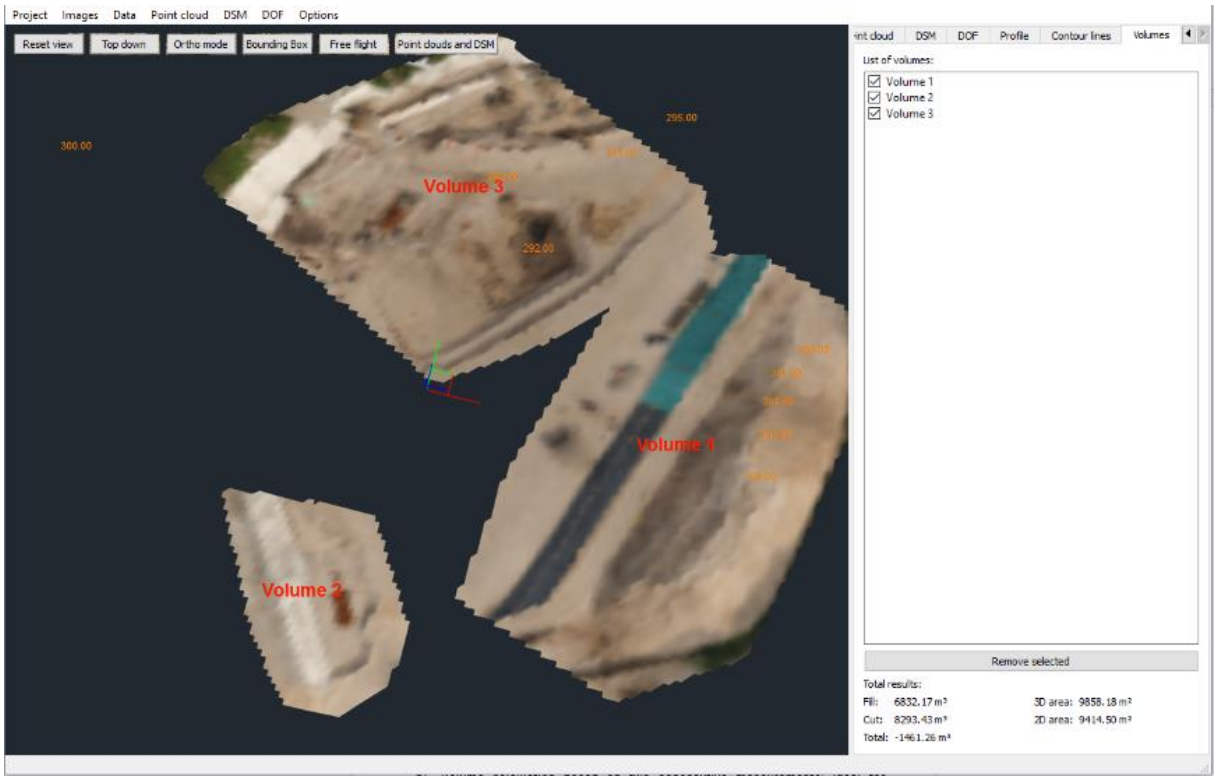
Cut – volume of mass above mean surface

Total – sum of filled and cut volume

Are 3D – three-dimensional area of selected surface

Area 2D – horizontal area of selected surface

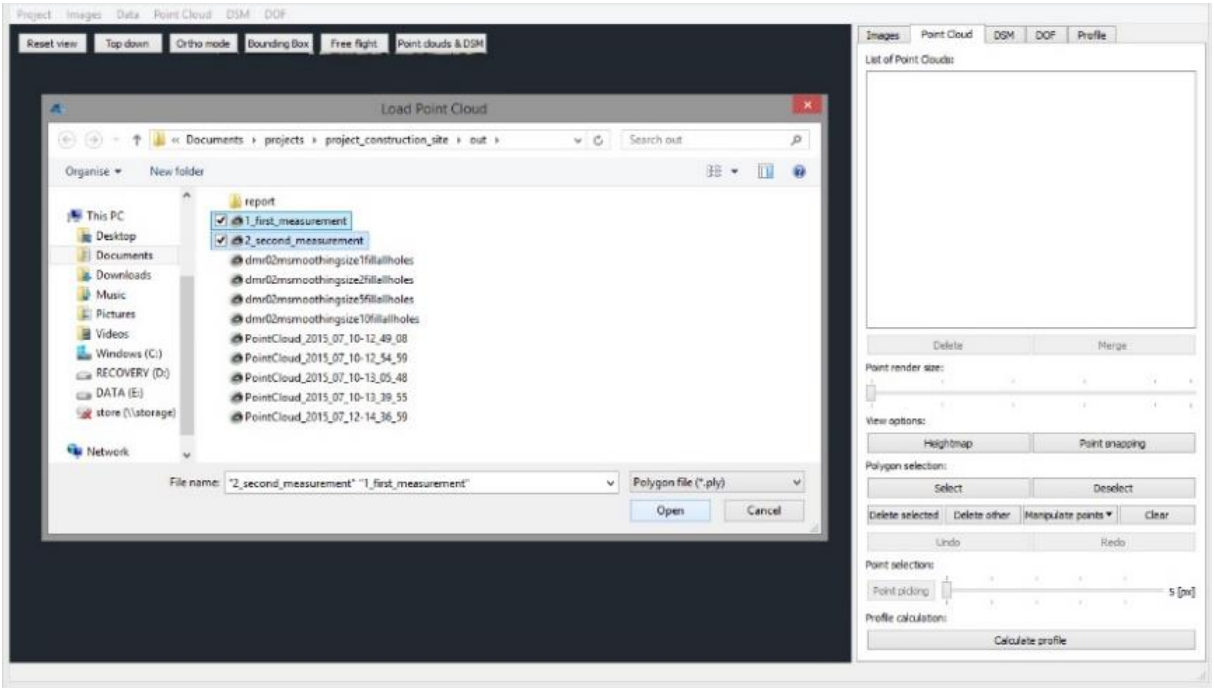
Select ***Volume*** from the *Working panel* to observe all calculated volumes. Areas of volume calculation are presented as cuts from ***draped DSM,*** each with its own title. If ***Contour lines*** are visible, their cuts are also presented. You can ***select***, deselect and ***remove selected*** volumes.



Volume calculation based on two consecutive measurements: Ideal for monitoring on construction site. Measure the volume difference between two consecutive measurements.

How?

Calculate or **load two point clouds** the area you would like to calculate -> Click ***DSM*** -> ***Calculate New*** and set DSM calculation parameters as shown on the image below.



Now you have two options for selecting area of interest:

Manual selection using select function for single use,

Click ***Select*** button and select area for Volume calculation with left mouse click. To finish selection, click right mouse click.

To calculate the volume on the selected area, click ***Calculate volume***.

For initial surface, select starting surface

For final surface, select final surface

Click ***From current selection*** to calculate volume of selected area.

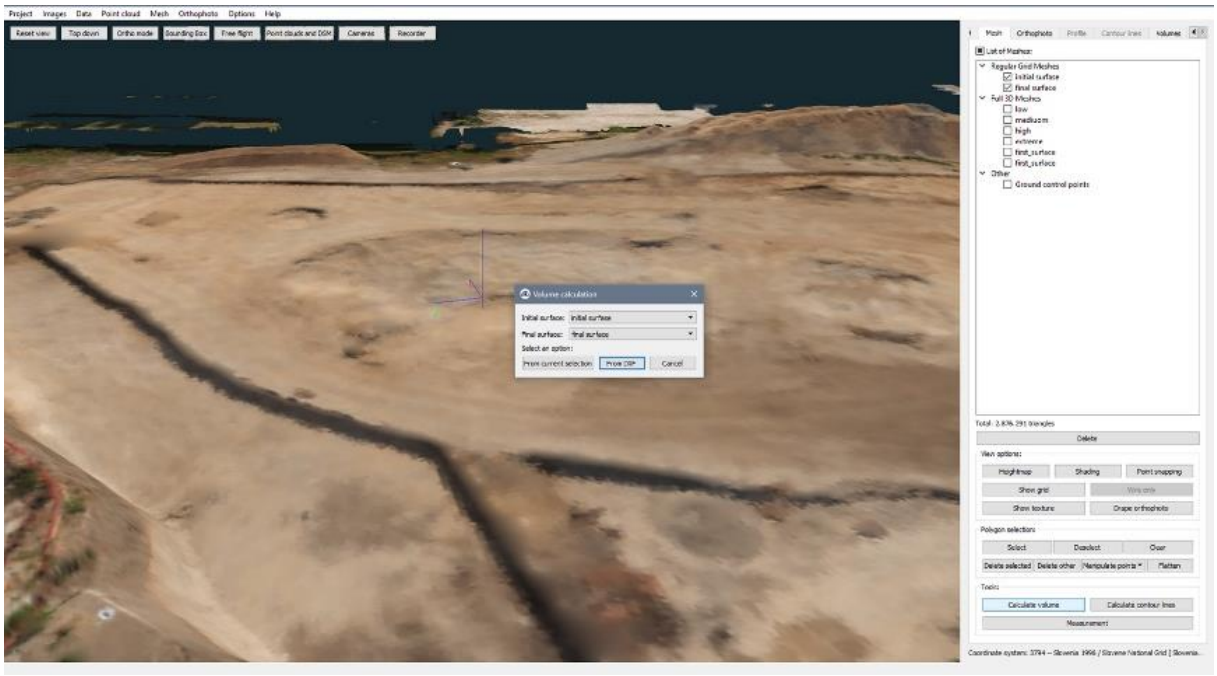
dxf boundary using CAD functionality for repeated or detailed use,

To calculate the volume on the area, defined by dxf boundary, click ***Calculate volume***.

For initial surface, select starting surface

For final surface, select final surface

Click ***From DXF*** and open desired file.



Displayed results present values for both current volume selection and a total sum of all volumes, consisting of:

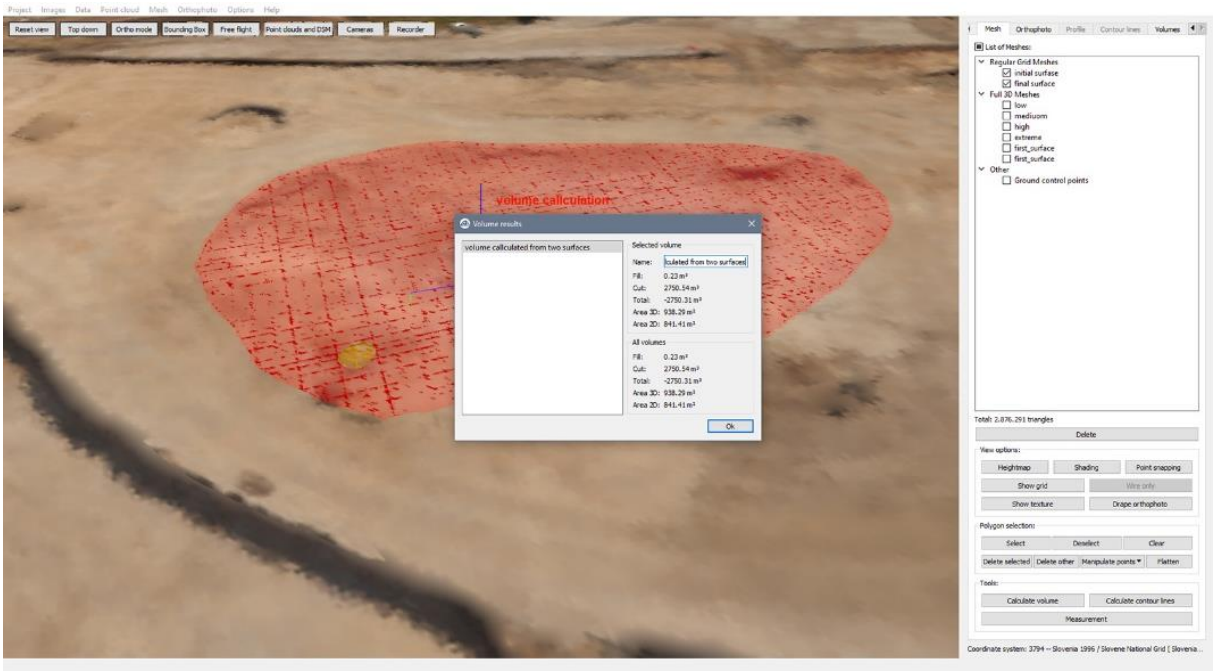
Fill – volume of needed mass to fill holes beneath mean surface.

Cut – volume of mass above mean surface

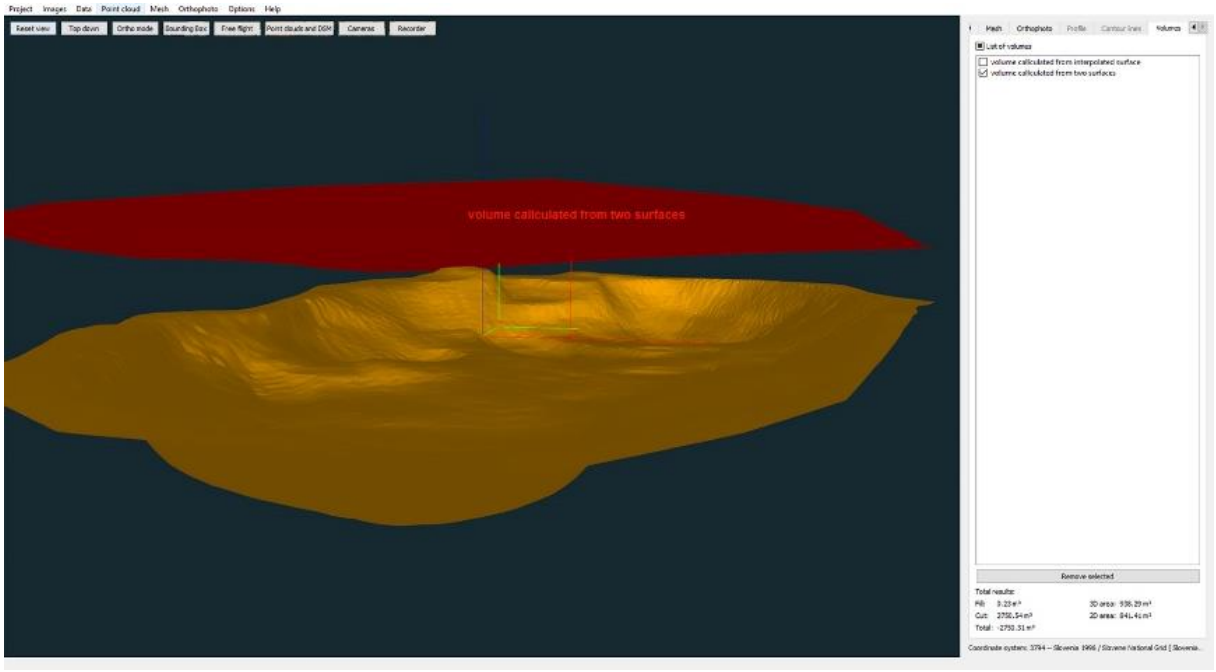
Total – sum of filled and cut volume

Area 3D – three-dimensional area of selected surface

Area 2D – horizontal area of selected surface

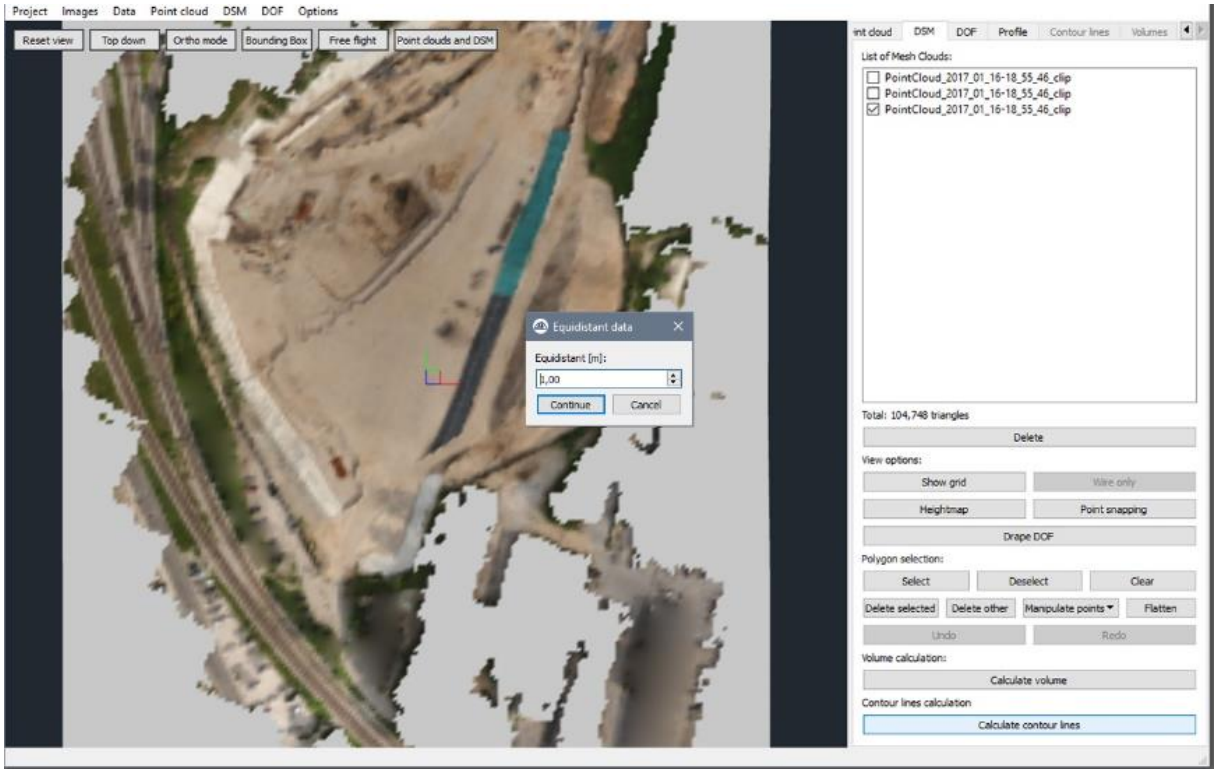


Use ***Remove selected*** button to delete selected volume.

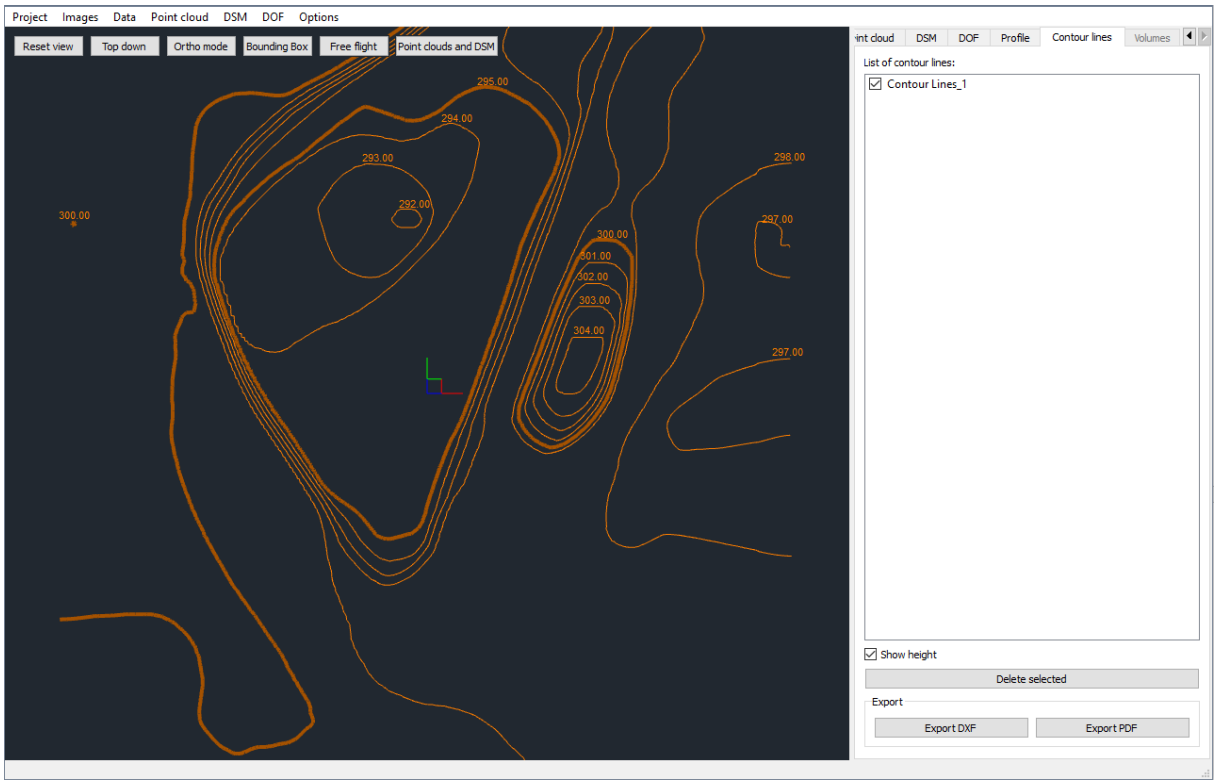


6.9. Calculate contour lines

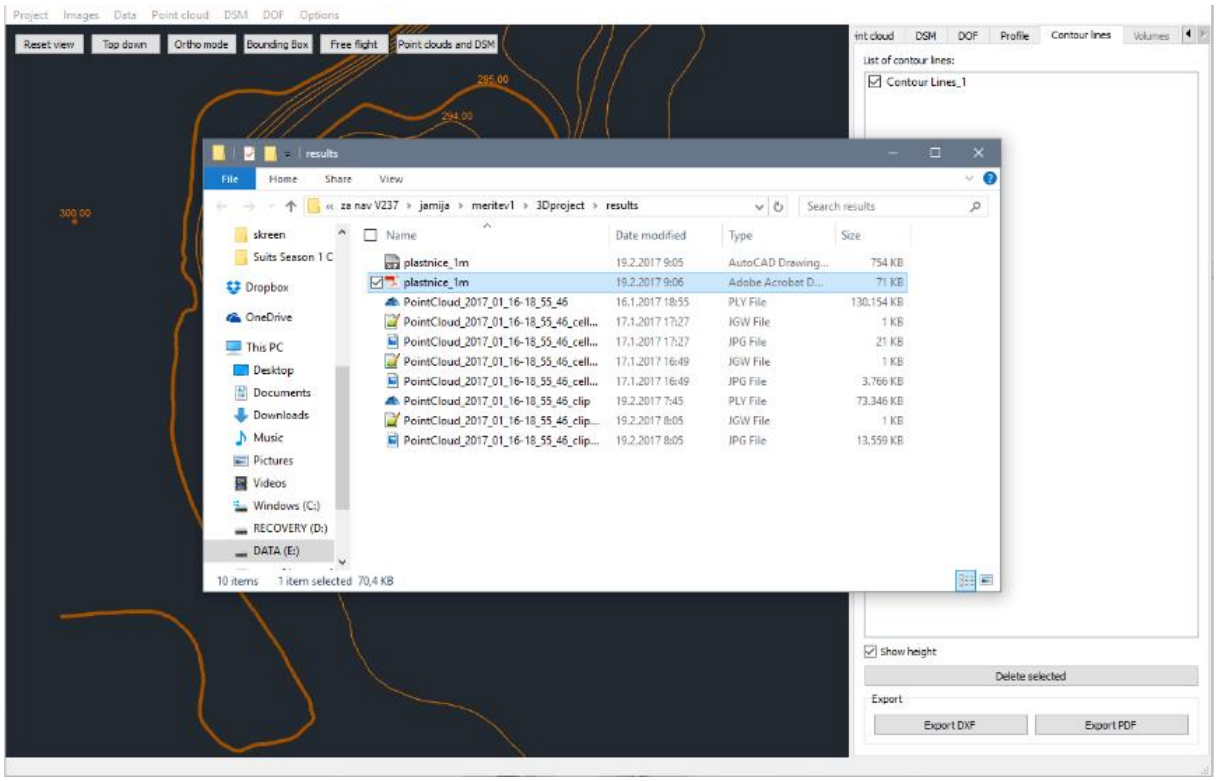
Click button ***Calculate Contour lines***. Select desired equidistance in a pop-up window.



Calculated contour lines are displayed on the DSM. To export, go to ***Contour lines*** tab in *Working panel*.



Contour lines' height can be displayed by checking ***Show height*** box. To ***export*** contour lines, choose between *.***DXF** and *.***PDF** data types. A new window, titled *Save contour lines as DXF* or *Save contour lines as PDF,* pops up. Enter desired file name and click ***save.*** New window with exported file path pops up.



6.10. Delete

Tick Mesh data, you would like to delete from application and click ***delete*** button.

7. Digital orthophoto

Cube-3d offers computation of two types of orthophoto:

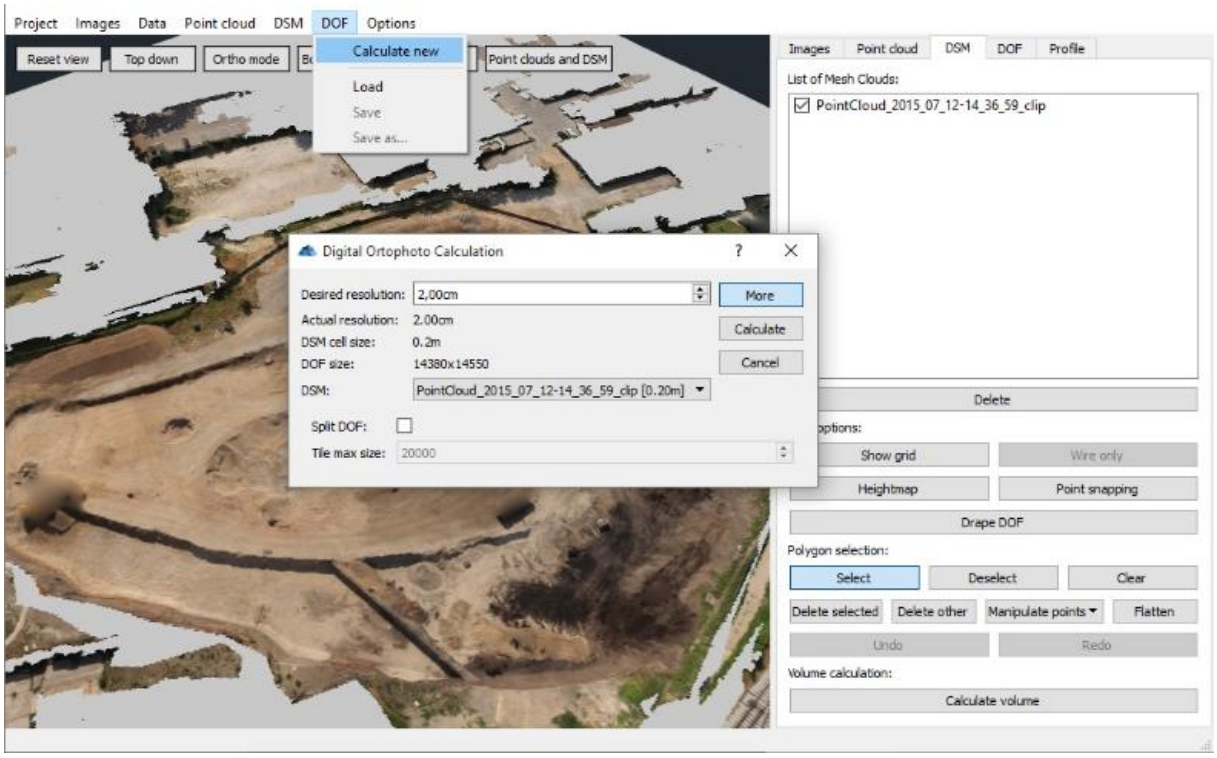
- original orthophoto based on regularly gridded mesh
- true orthophoto based on irregularly gridded full 3D mesh

7.1. True Digital orthophoto calculation

Select from dropdown list ***Orthophoto*** -> ***Calculate new***.

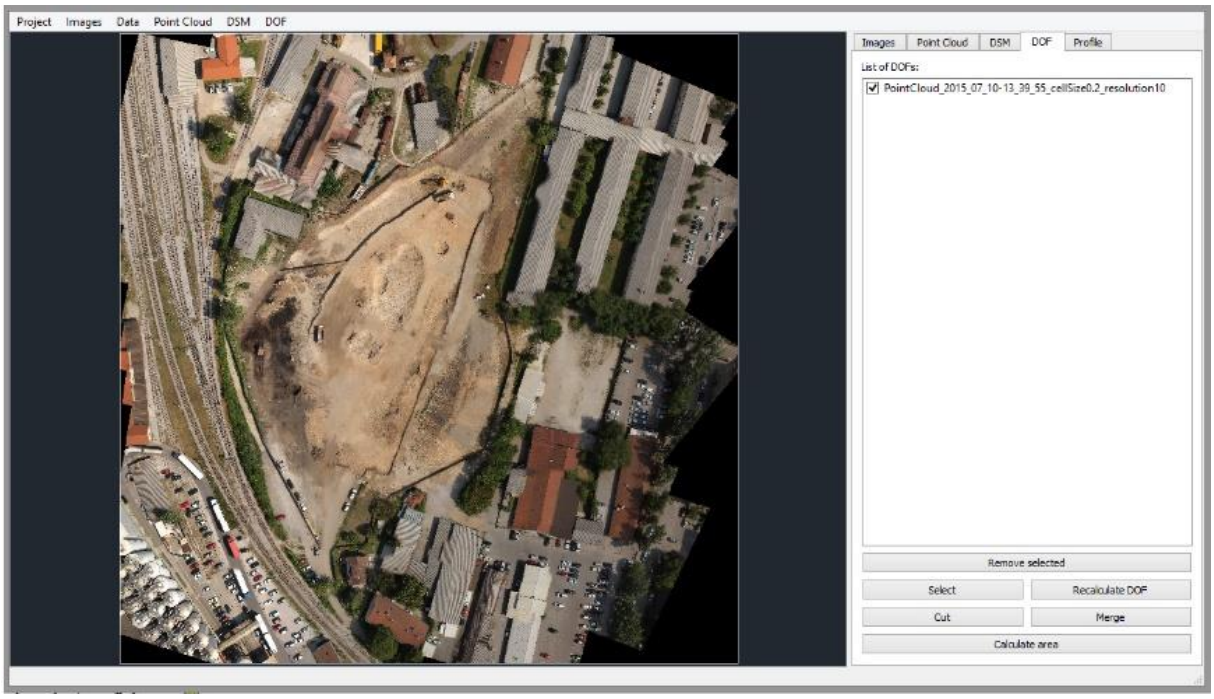
7.2. Digital orthophoto calculation

Select from dropdown list ***Orthophoto*** -> ***Calculate new***.



Set parameters in a ***Digital Orthophoto Calculation*** pop-up. First, set ***Desired resolution.*** As entered value may not be possible to compute, ***Actual resolution*** is presented below to inform you about the closest available result. It is an outcome of entered desired resolution and DSM cell size based on selected ***DSM***. Click ***more*** to check the *split DOF* box. Default *Tile maximum size* is set to 20.000, meaning DOF will be split if it exceeds 20.000 pixels. When set, click ***Calculate***.

Resolution parameter depends on flight height and size of grid cells. For example: If we set resolution parameter on 50 and use DSM grid size 1.00m this mean 50 pixels on 1.00 meter -> end result pixel size will be 1 cm (Orthophoto with resolution of 1 centimetre).

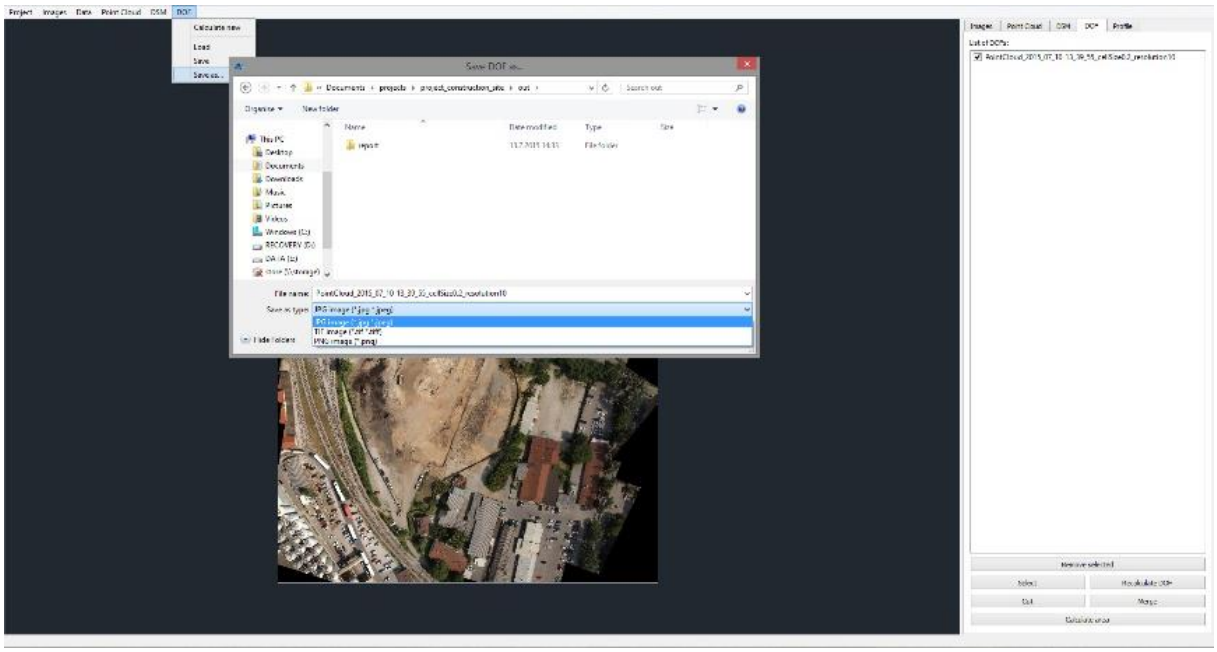


Save project. You can export computed DOF to – Select from dropdown list ***DOF*** -> ***Save as*:**

**.jpg *.jpeg + *.jgw*

**.tif *.tiff + *.tfw*

**.png + *.pgw*



In addition to image file is appointed **text file** (*.jgw, *.tfw or *.pgw) that contains DOF geolocation and pixel size.

7.3. Digital orthophoto corrections

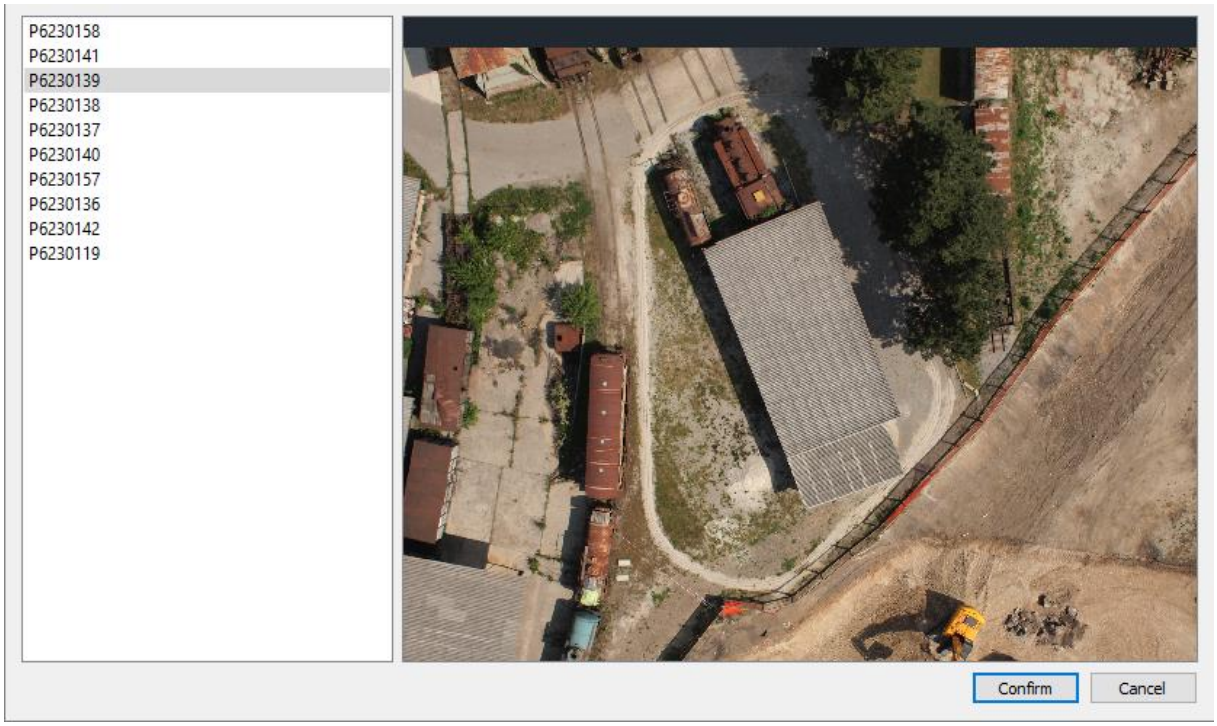
To calculate digital Orthophoto follow steps from 1 to 11 (page 2- 21). If you are not satisfied with results, you can use correction tools to improve them. Because of low flight altitude, often artefacts on roofs of the houses will appear. You can easily correct them with Recalculation DOF tool.

Note: Simply loading your Orthophoto into Cube-3d is not enough for Recalculate DOF function. To be able to recalculate, one needs to go through the whole process for DOF calculation.

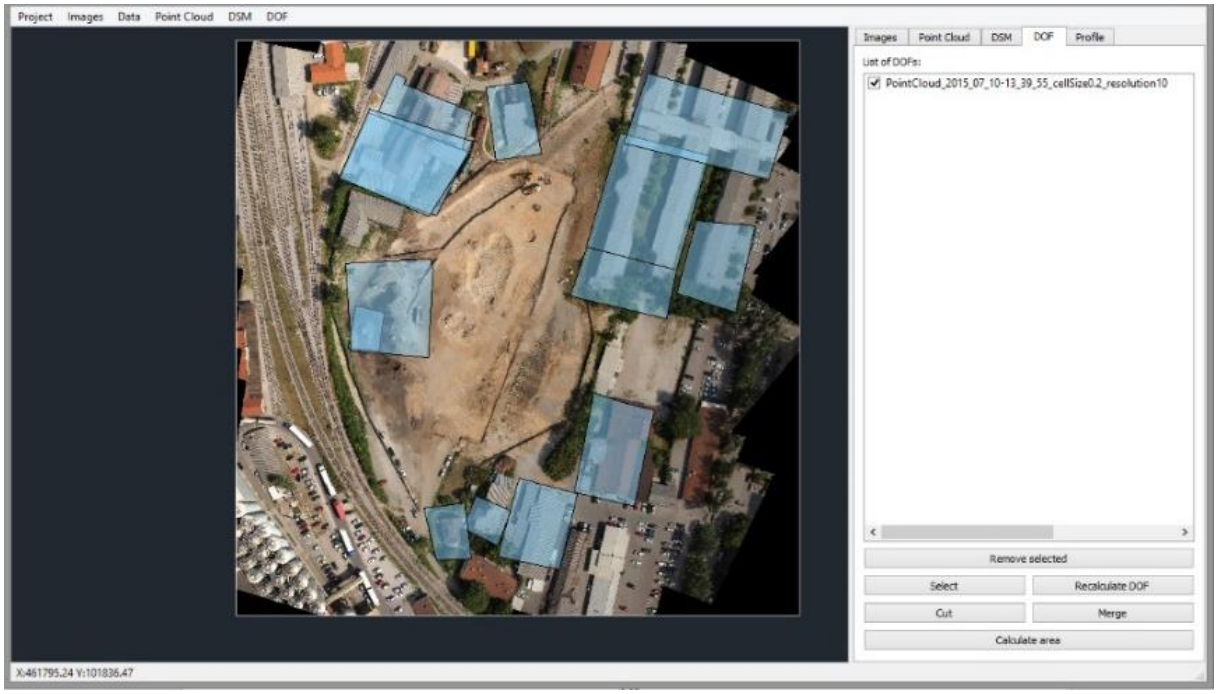
How?

When your Orthophoto is calculated, select the areas you would like to recalculate. Use ***Select*** button and select preferred images.

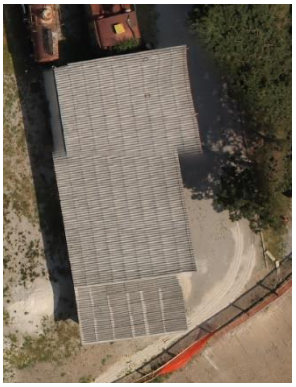
Wizard for image selection, with images of selected area will appear – **select** the **image** you would like to use for recalculation and click ***Confirm***.



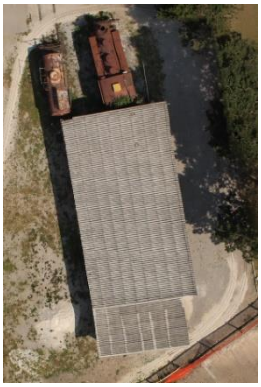
In case of additional artefacts repeat the same process to select all the areas. When you are finished with selecting click ***Recalculate DOF*** button.



Results:



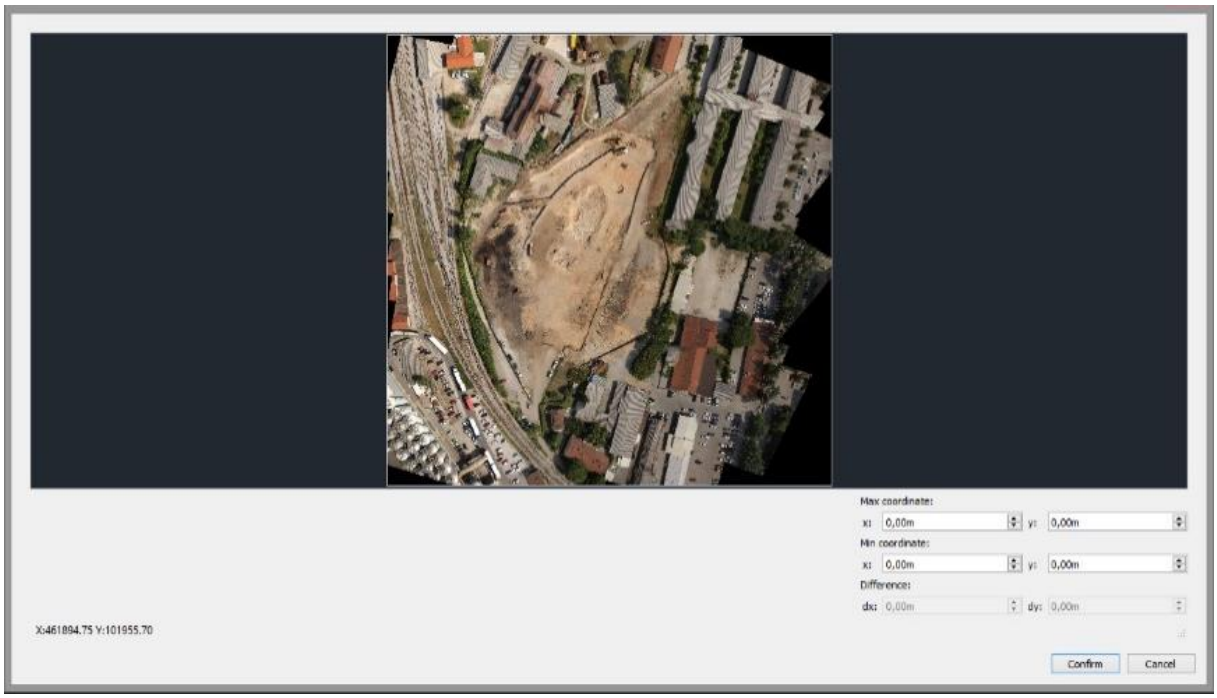
Before



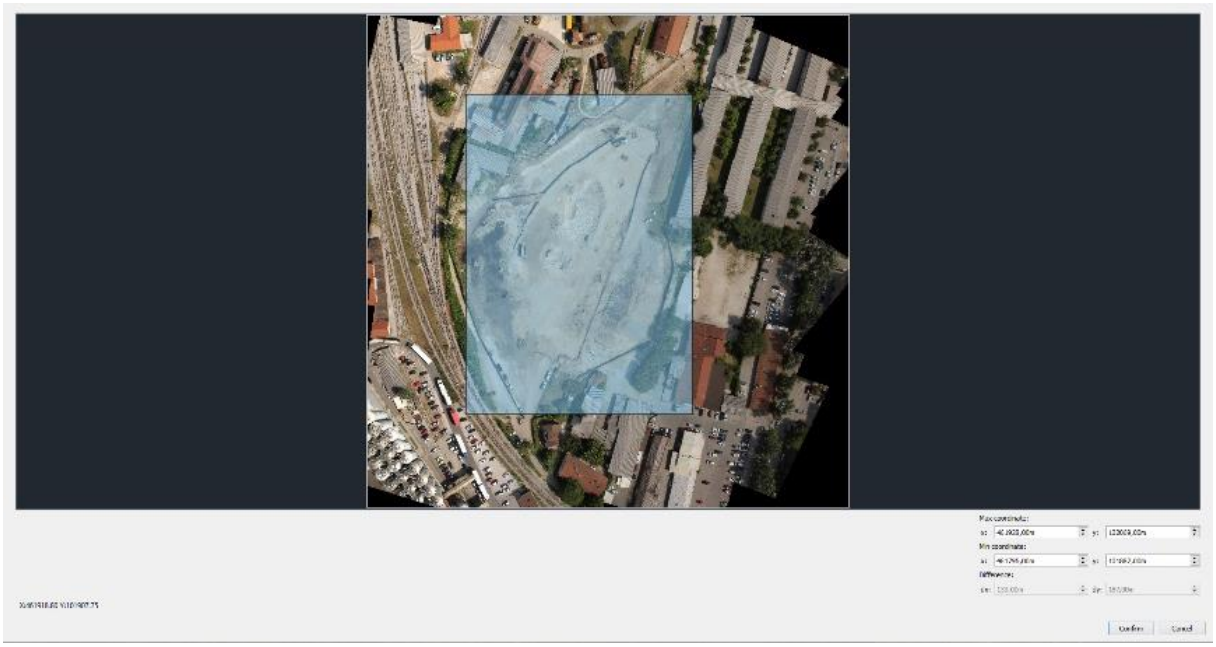
After

7.4. Cut orthophoto

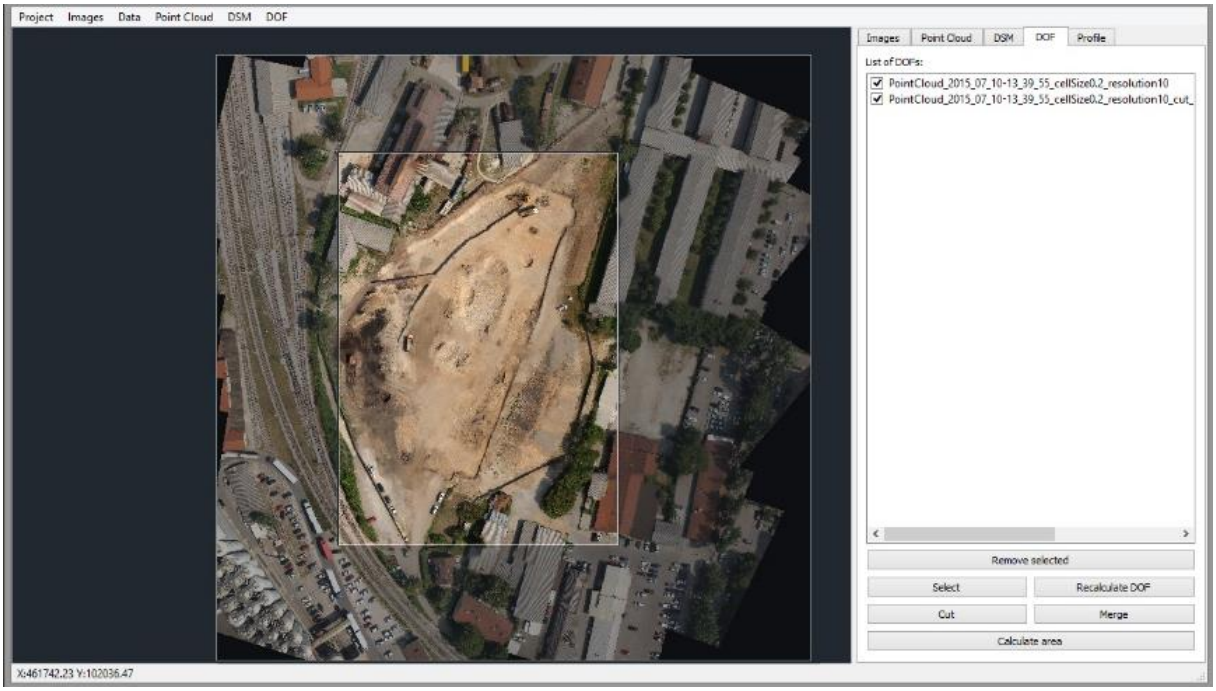
You can also cut certain area out of the DOF and save it as another DOF. Click Cut.



Select desired area. Left mouse click to start drawing rectangle and drag mouse to select rectangle over desired area. You can observe coordinate values in left bottom corner and coordinate range of selected rectangle.



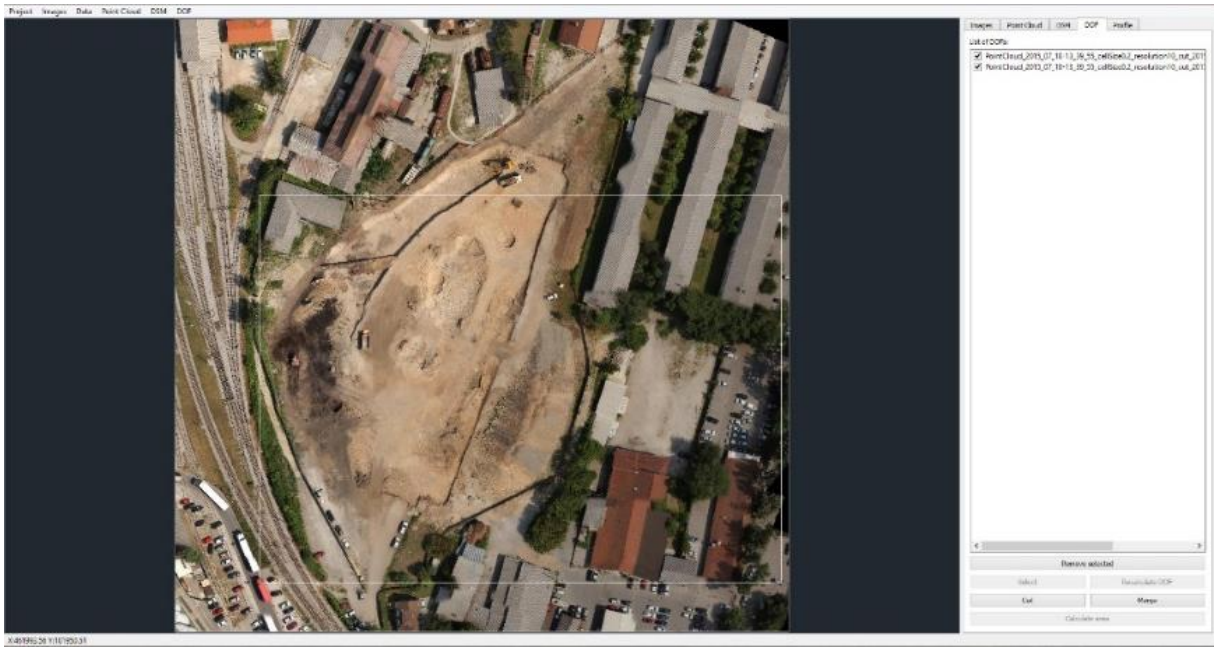
When area of interest is selected, click **confirm** to calculate DOF cut.



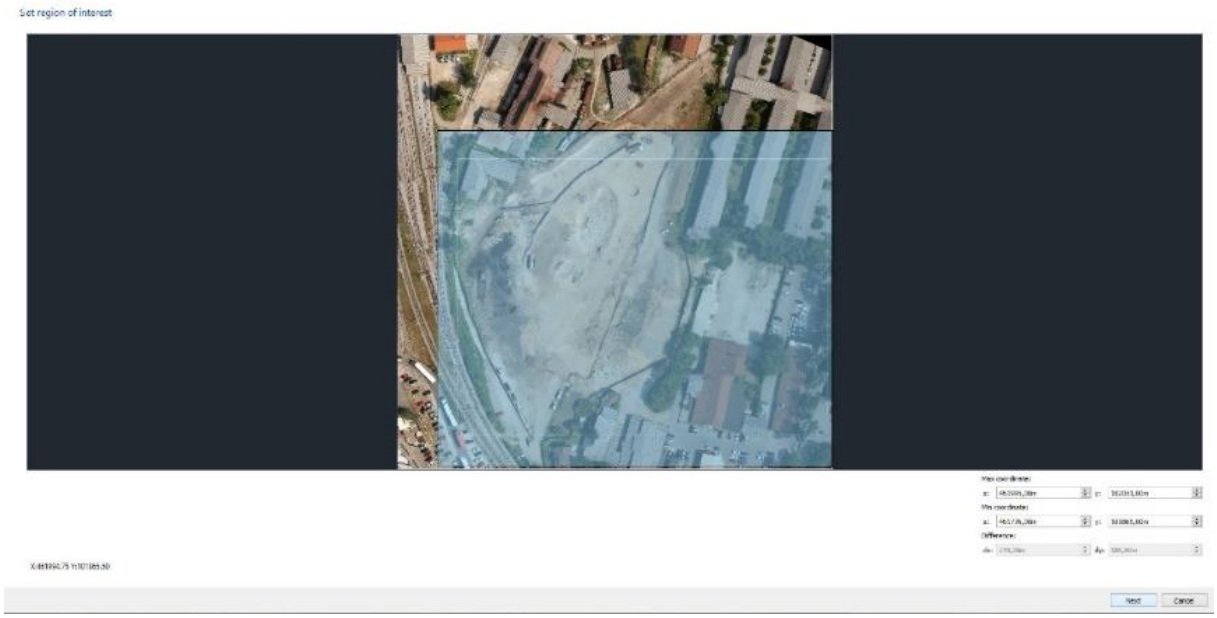
7.5. Merge orthophoto

Merge DOF is a function that merges two DOFs that don't need to overlap or even converge.

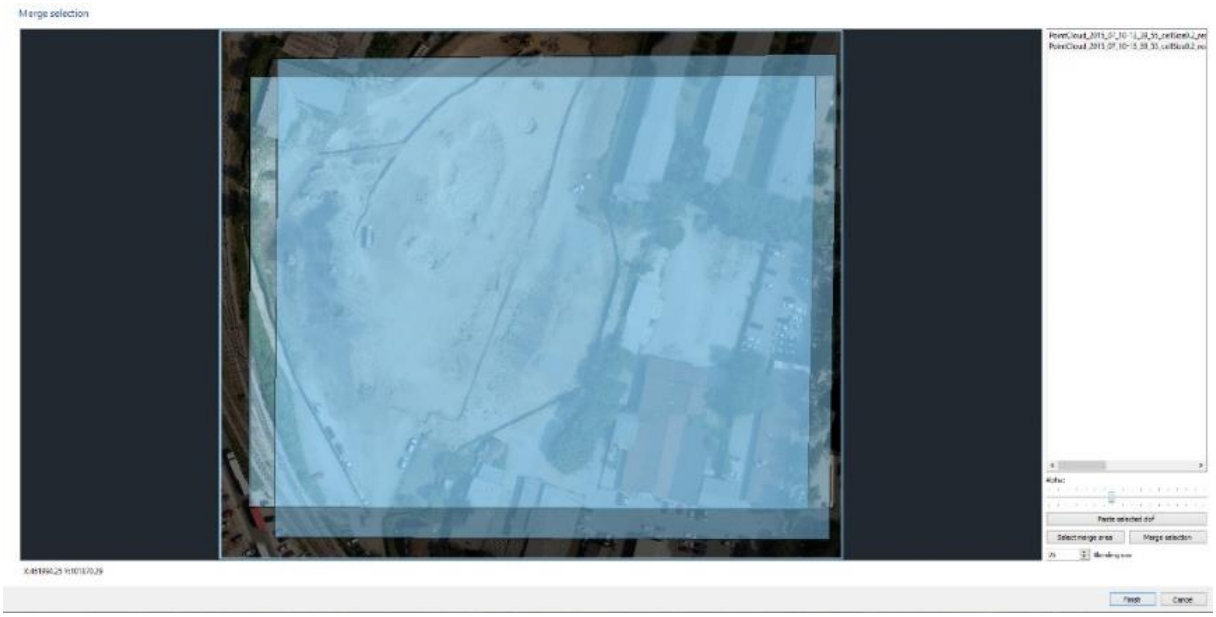
Load or select desired DOFs and click **Merge**.



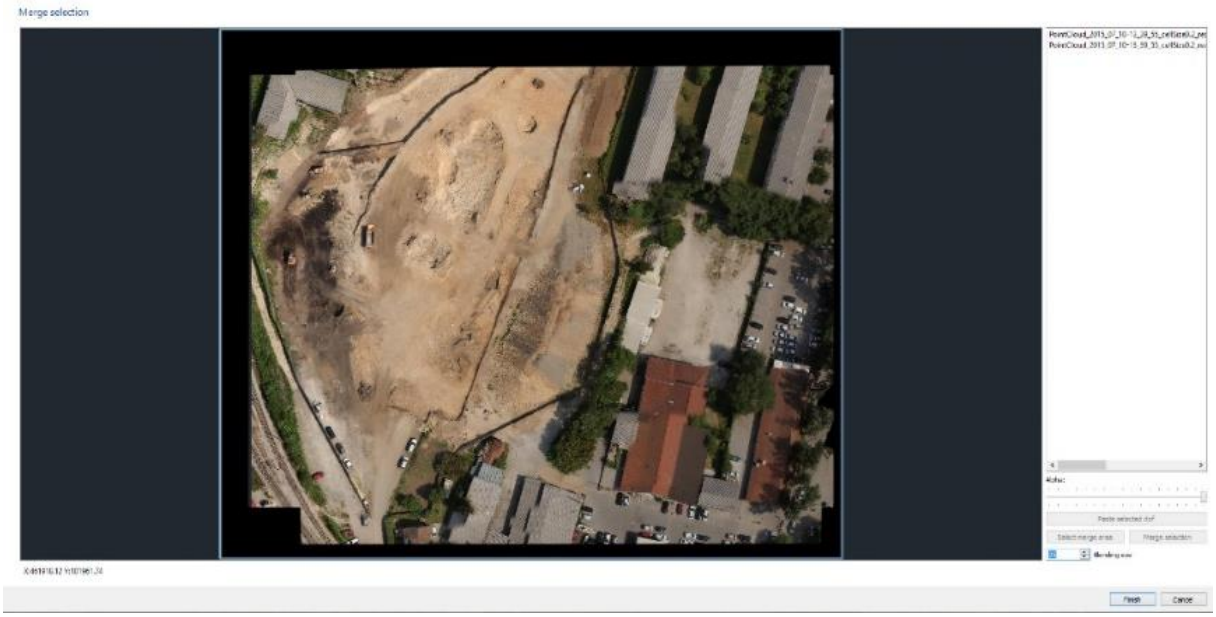
In a pop-up window, **select** area you want to merge. Left click on one end and set the rectangle across interested area. Click **Next**.



When you click on desired part on the right side, it pops on area of a new DOF. Another click shows what actually is on new DOF. You can select specific area of DOF part to be merged. Click ***Paste selected DOF*** button to paste part on new DOF. Clicking next DOF part on your list gives you an option to set its transparency by adjusting **Alpha**. **Select** desired area on the second part - adjusting alpha shows merging boundaries. ***Blending size*** allows you to smooth edges between overlapping parts. When all parts are pasted, **click Finish**.



When merging ends, new (merged) DOF is displayed.

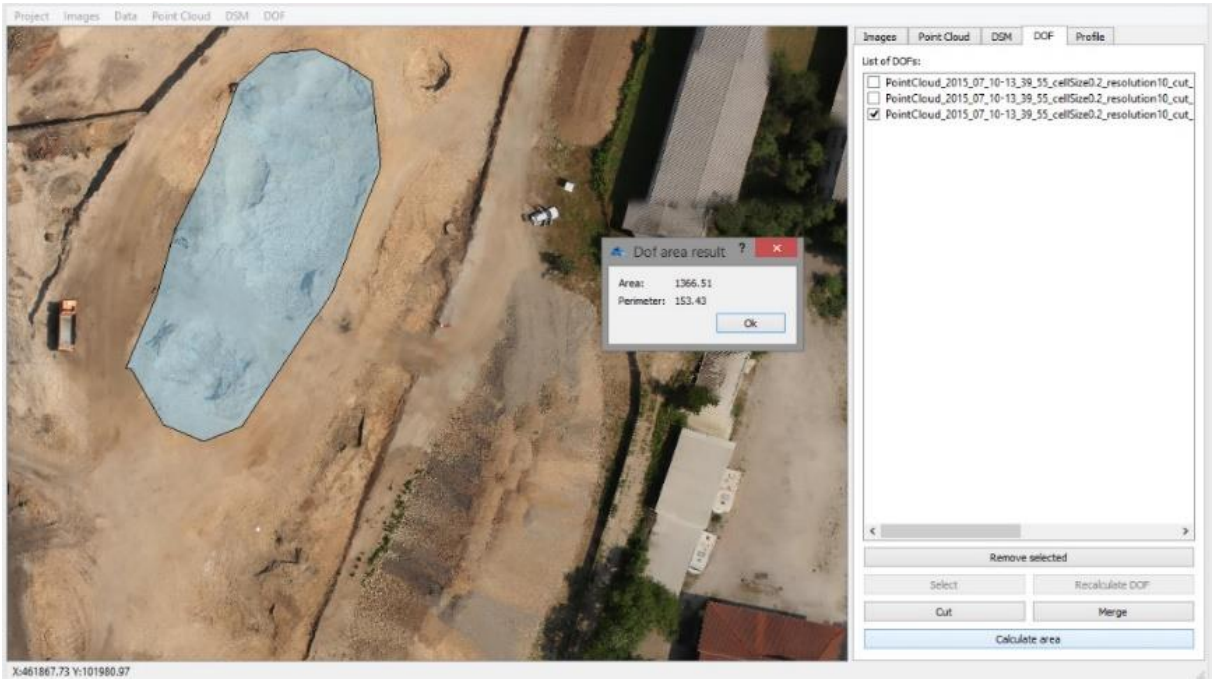


7.6. Calculate area

Click ***Calculate area*** button to compute area on DOF. Select area with polygon using left mouse click to determine points and right one to close it. DOF Area result, will popup:

Area – planimetric area of selected region,

Perimeter – circumference of selected region or length of polygon



7.7. Delete

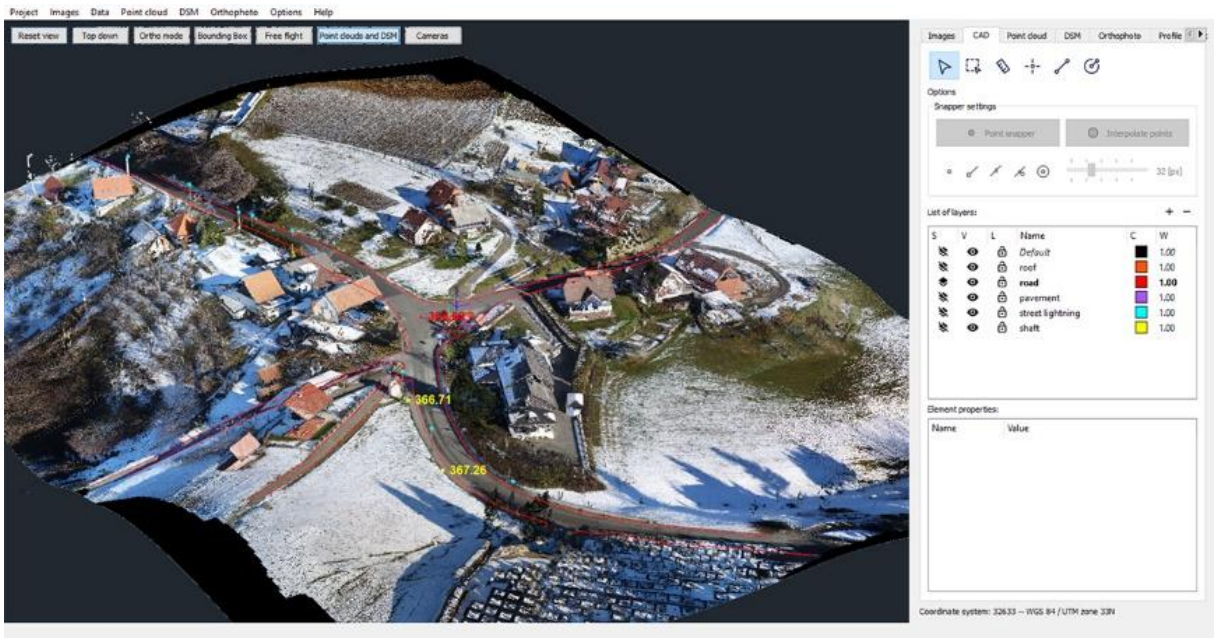
Tick DOF data, you would like to delete from application and click ***delete button***.

8. CAD Functionalities

There comes a need, when you wish to draw on your point cloud. Draw objects entities that could further be used in Computer aided design (CAD) programs. In **working panel** tab **CAD**. At the top is a working panel tool bar, with **edit tool**, **selecting tool**, **draw line tool** and **draw circle tool**. You can check all layers in the **layer list** on **working panel**. Each layer has its attributes (whether it's **selected**, **visible** or **locked), name**, **colour** and **line weight**.

8.1. Preparing layers

As all CAD applications tent to use layers, it is useful, if you first make new layers, assign their colour and line width. Click **+** to make new layer. To change name, double click it. Pres enter to confirm. Double click on colour square, to change the colour. Change line weight by double clicking on number. Type new weight. Those layers that are visible, have a scheme in the second row, as oppose to nonvisible ones . At the time, only one layer can be selected, in the second row is visible, as oppose to all the others . Third row shows whether layer is **locked** or **unlocked** . To change any of layers attributes, click on unwanted scheme in desired row of layer.



8.2. Select tool

Use **select** tool to select multiple drawn CAD objects. By selecting from left to right, you can select different points.

when you draw selection from **right to left**, all objects, of which parts were inside selection are selected;

when you draw selection from **left to right**, you will select only those objects, of which all parts are being selected.

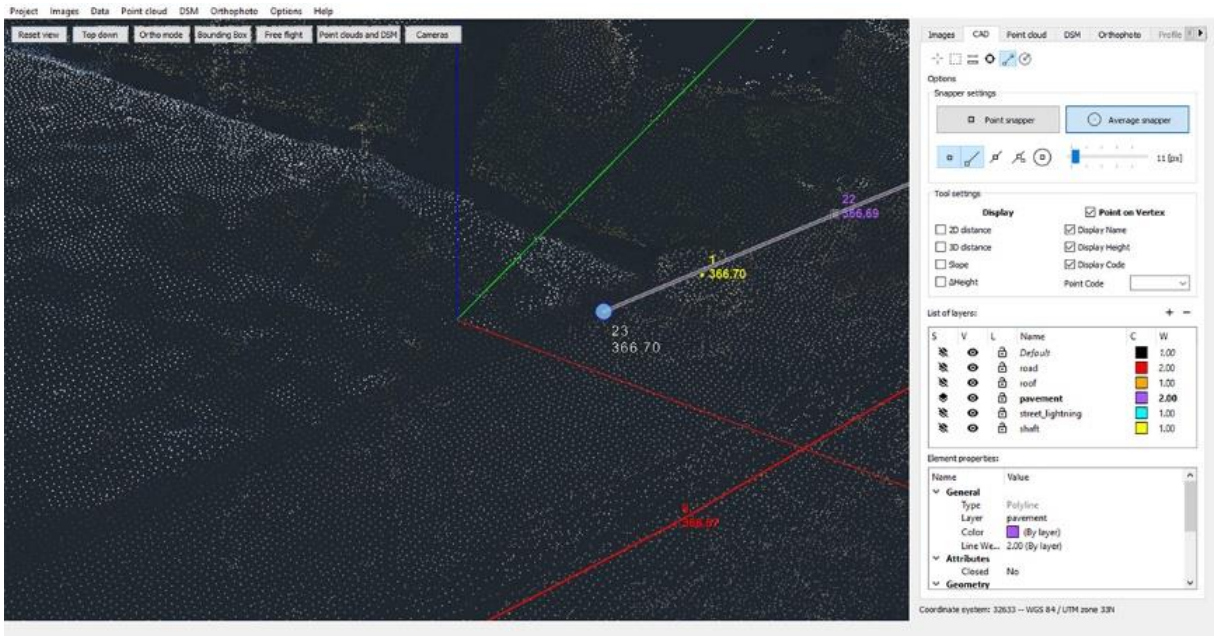
8.3. Draw point

To draw set the desired layer and select **draw point** tool . Go to **snapper settings** and **tool settings** to select type of snapping and display settings. If you want to snap directly on point cloud point, select **point snapper**. This option supports also snapping on endpoints, midpoints and on or near existing lines. Each point can have displayed name, height and code. Size of displayed text and code value can be specified.

8.4. Draw line

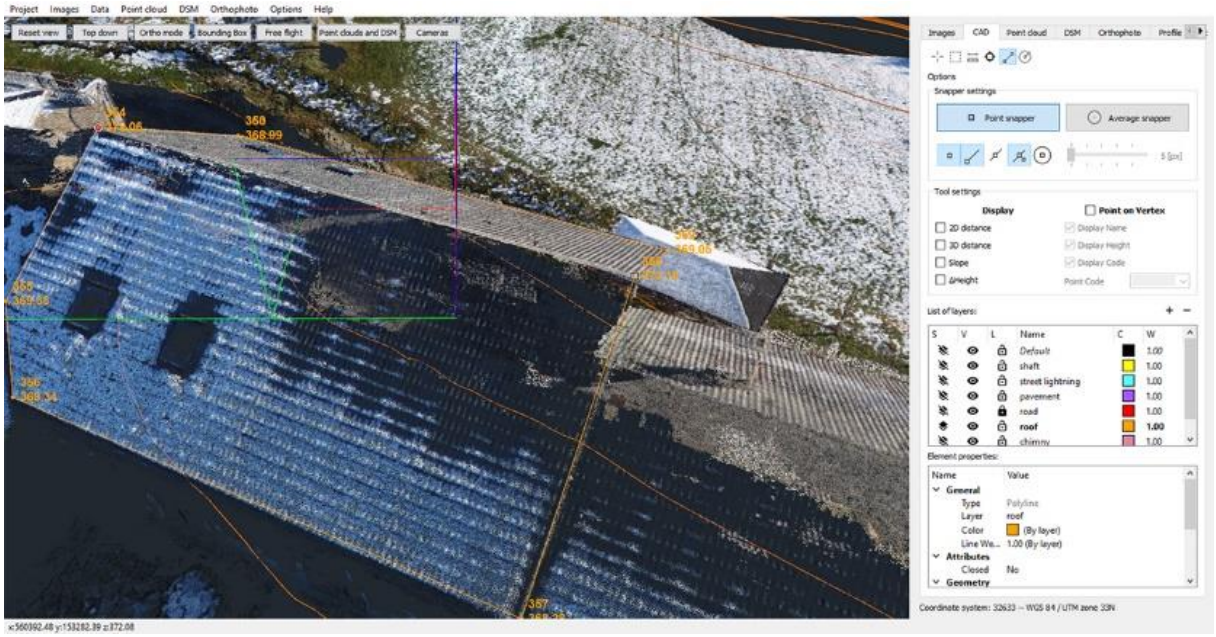
To draw set the desired layer and select **draw line** tool . Second, click on **snapper settings** to select type of snapping and **measurements display**. If you want to snap directly on point cloud point, select **point snapper**. This option supports also snapping on endpoints, midpoints and on or near existing lines.

2nd option is to draw the line by creating new points – this option is useful in case you don't have a certain point cloud point to draw on – in this case **interpolate points** and select desired radius of **point snapper** to define the average height (at least one point of the point cloud needs to be in the blue circle) of the new point which will be created in the centre of the mouse cross.



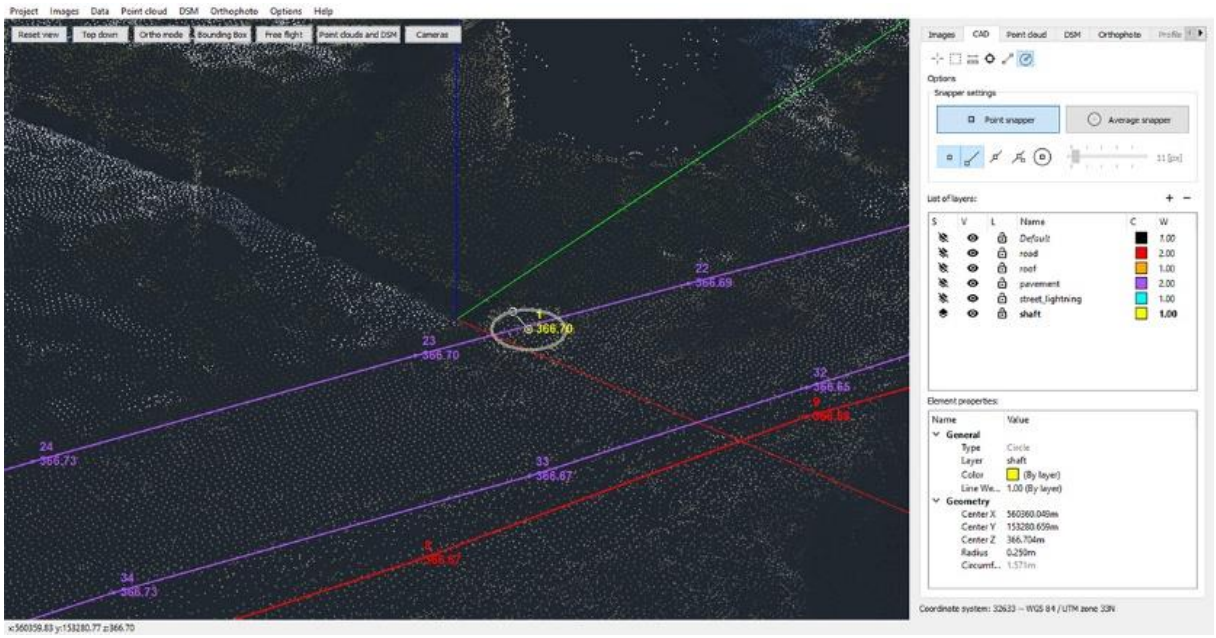
Start drawing lines, using *left mouse click*. If you mis-clicked use *backspace*, to delete last point. Abort drawing at any point with **escape** button. End drawing polygon of lines using *right mouse click*.

If you want to end drawing polygon on already drawn point, select to **use element snapper** an approach desired point with your cursor. As snapper is active, already drawn element/elements will mark. Click at desired point with left mouse click and continue to draw. You can change **snapper settings** while drawing CAD objects.



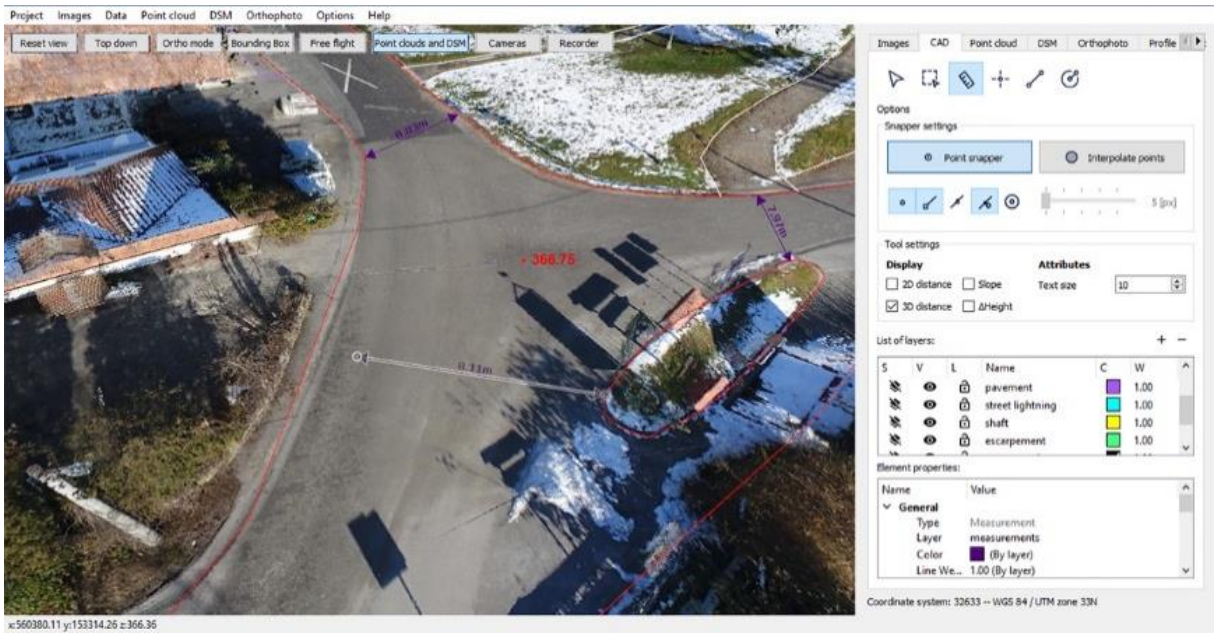
8.5. Draw circle

To draw a circle, select **draw circle** tool and desired layer. Select type of snapping, and snapping zone. Left click circles base point, drag mouse to assign diameter, confirm with left mouse click. Use right *mouse click* as well as escape button to abort drawing.



8.6. Measure tool

To measure set the desired layer and select **measure** tool . Second, click on **snapper settings** to select type of snapping. If you want to snap directly on point cloud point, select **point snapper**. This option supports also snapping on endpoints, midpoints and on or near existing lines. Left mouse click on the first end of measurement and then on second. Click **esc** to escape or continue measuring.

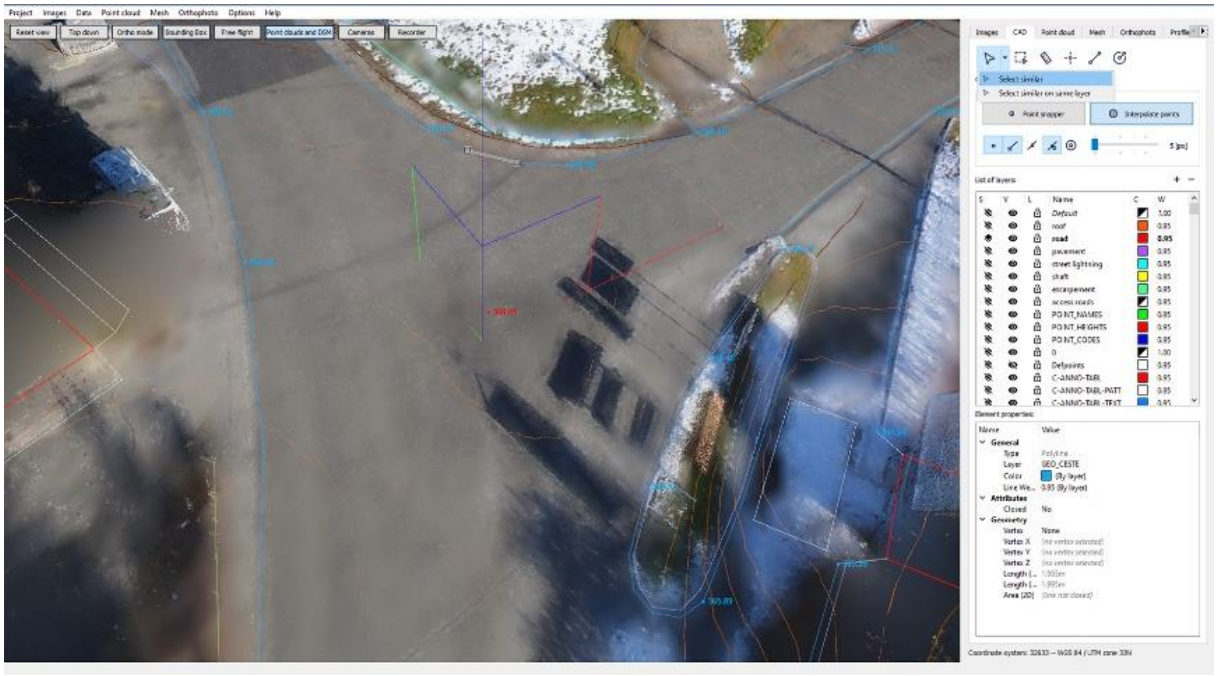


8.7. Edit tool

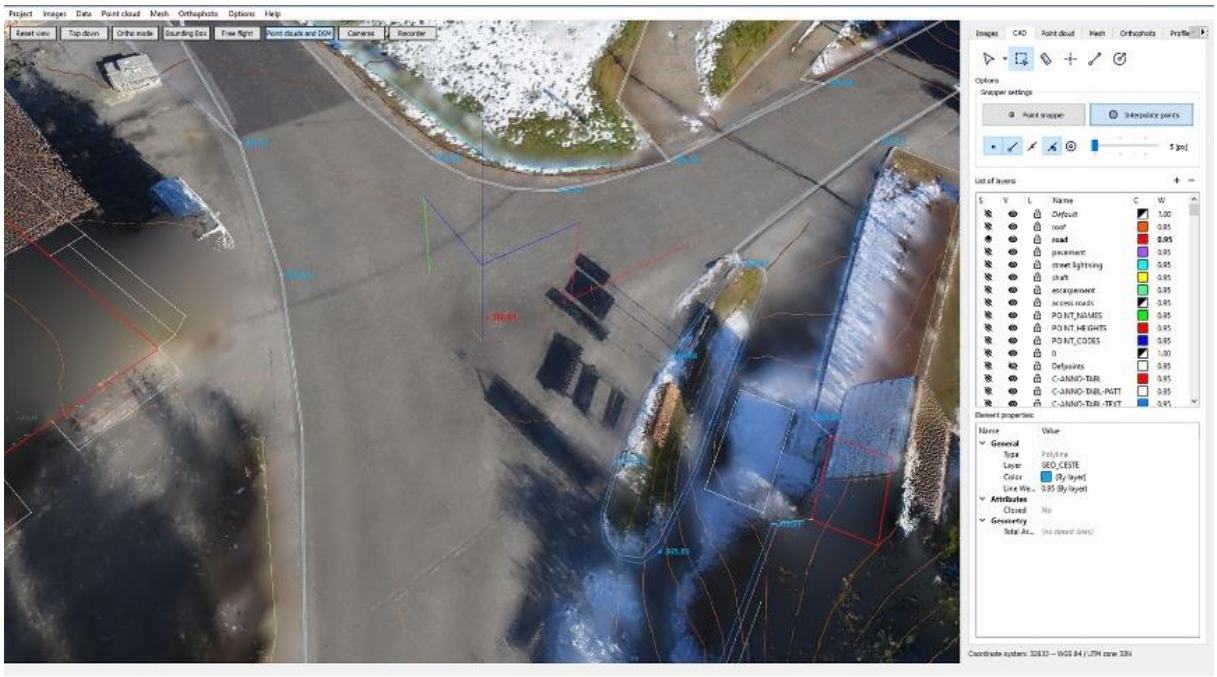
To edit drowning, select **edit** tool and get close to desired objects. When marked, select it with *left mouse* click. You can move, redraw or delete selected points or objects. Click on the drop down button of **edit** tool and click on:

select similar to select same CAD object drawn on all layers

select similar on same layer to select all CAD objects on layer of selected object

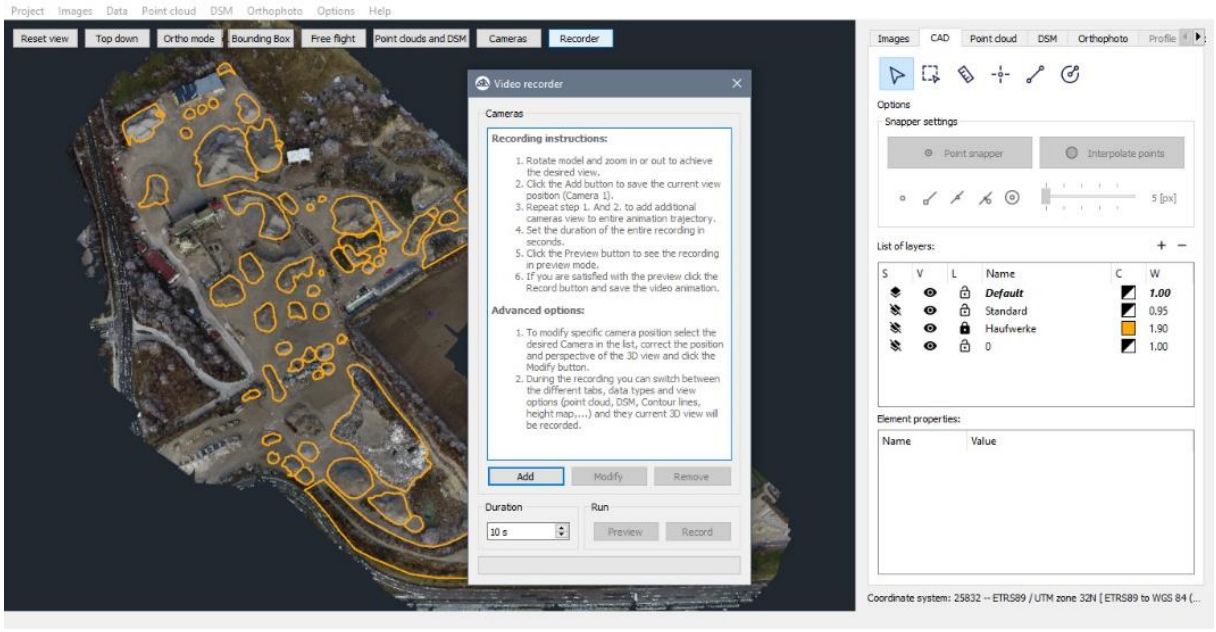


All data of selected object or layer are displayed in **Element properties** window of **working panel**. There you can change its **colour**, **line type** or **layer** by clicking on desired attribute and change it from available possibilities.

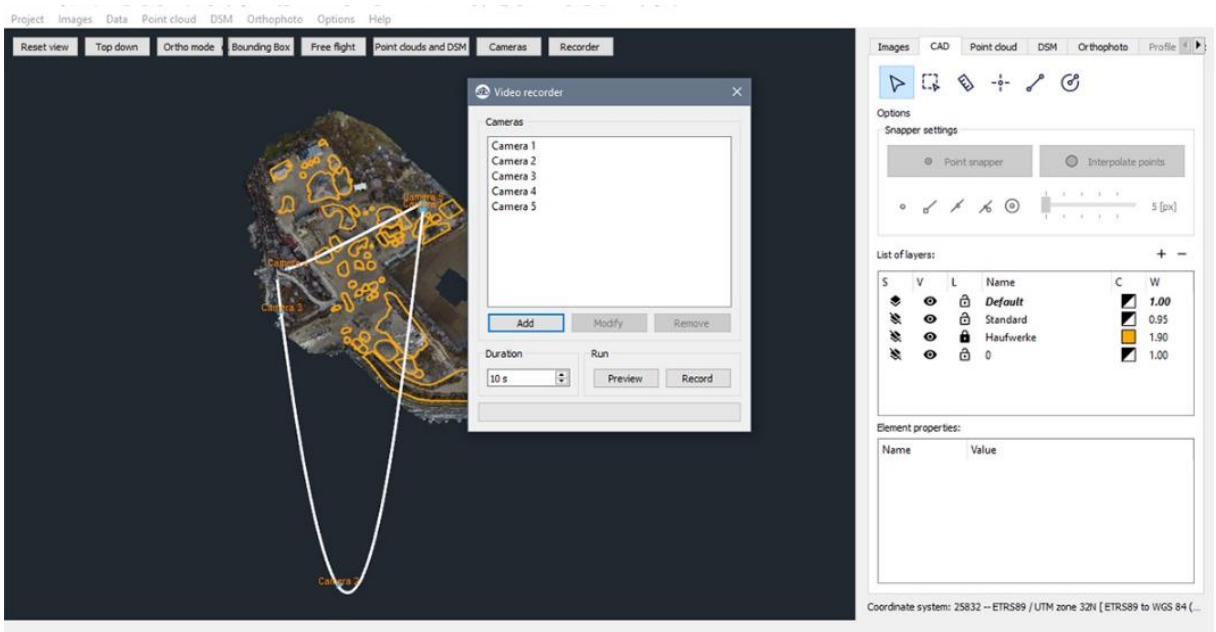


9. Recorder function

Sometimes you wish to make video presentation of point cloud and measurements made on it. Click ***Recordings*** button in the viewer. A Video recorder with instructions pops up.

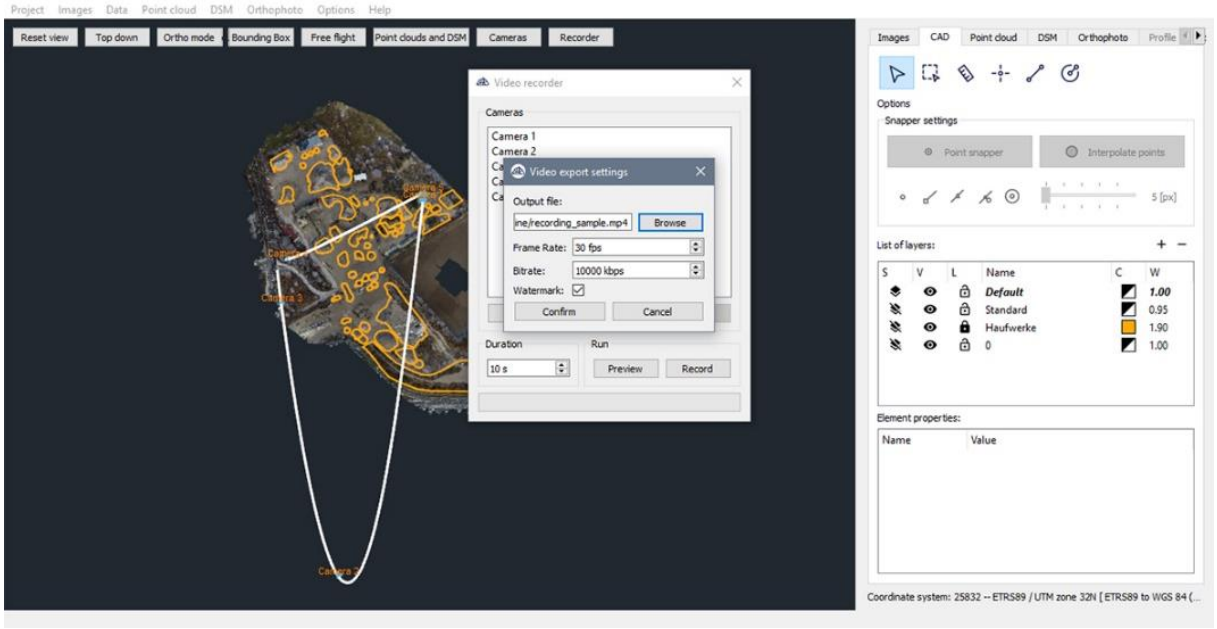


As described, you need to rotate/move/zoom to desired start point and click ***Add*** button to create first recording camera. Proceed throe entire area, creating new cameras to capture desired details. A recording trajectory appears between selected camera positions. Define desired time of recording duration.

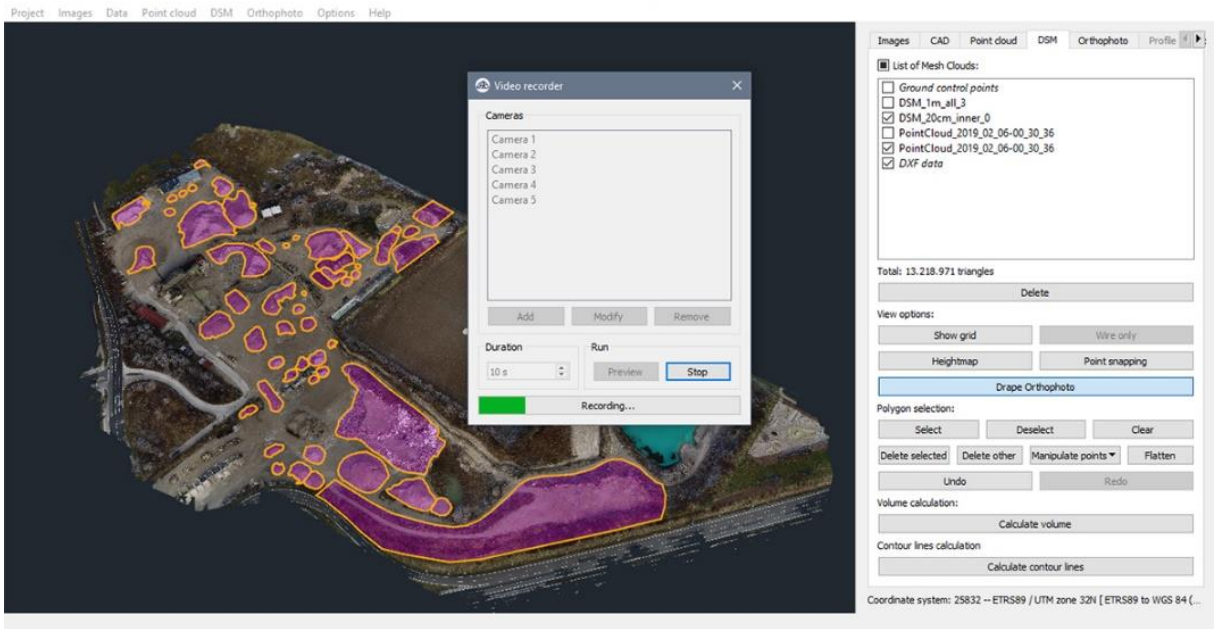


Click ***preview*** to preview flight and it's duration. By clicking on a camera from list, you can remove or modify it. When you click modify, cameras position is moved to current viewpoint. Add new ones if pleased. Remember, you will display types of data and measurements once you record. Once you created desired path of needed duration, click ***Record***.

Video export setting window pops up, where you need to set the path and name of saved recording in mp4 format. Adjust Frame rate and bitrate if desired. Select weather you want watermark in the recording. Once set, click ***Confirm*** to start recording.



As recording is following desired path, change displayed data by switching between ***CAD***, ***Point Cloud***, ***DSM***, ***Profile***, ***Contour lines*** and ***Volumes*** from Working panel. Switch between Viewing options to achieve desired effect. Once you are viewing point cloud, you can also display it with dsm. When you are viewing dsm, you can display it with point cloud as well as drape orthophoto on it. When switching viewed data, observe recording bar, so, that all data is displayed in desired proportions of time! Once the recording has completed, close Video recording window.

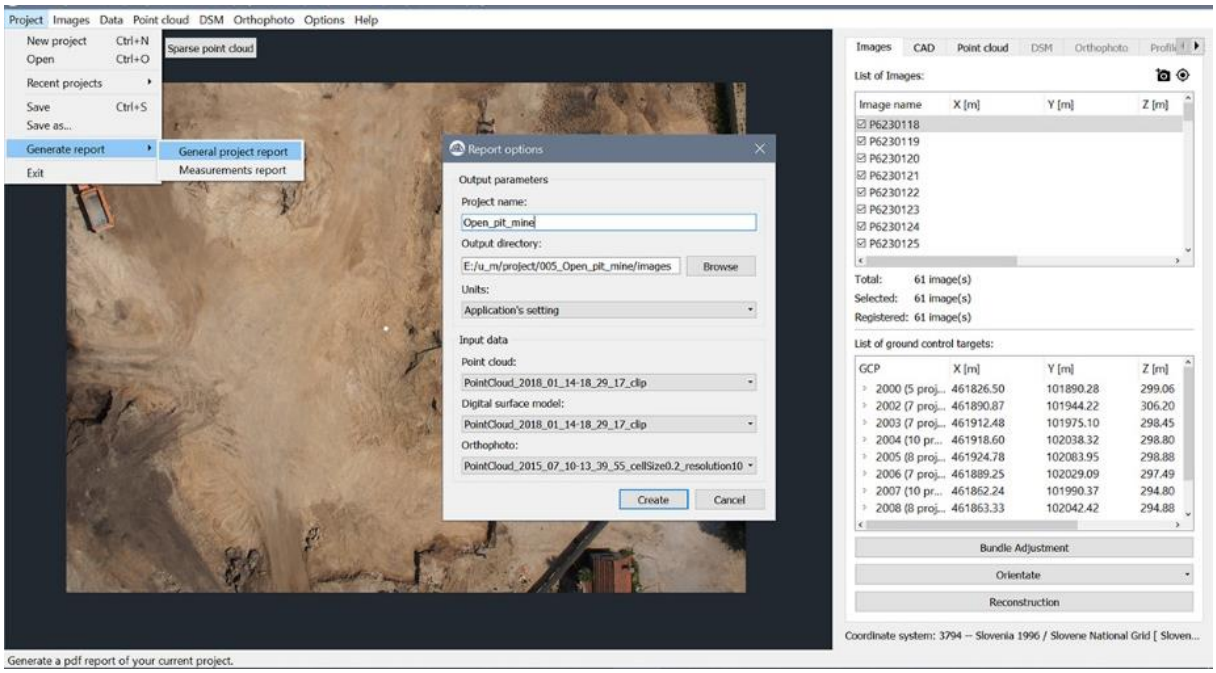


10. Reports

Generating a general project report and/or measurements report, is basically in a few clicks and the report is done. General report contains information about imported/processed images, geo-referencing, camera positions, flight characteristics, calculated accuracy, GCP positions, orthophotos, DSMs, error summary. With measurements report you get the ability to include all your calculated data, profile lines details, volume and stockpile measurements, and contour lines.

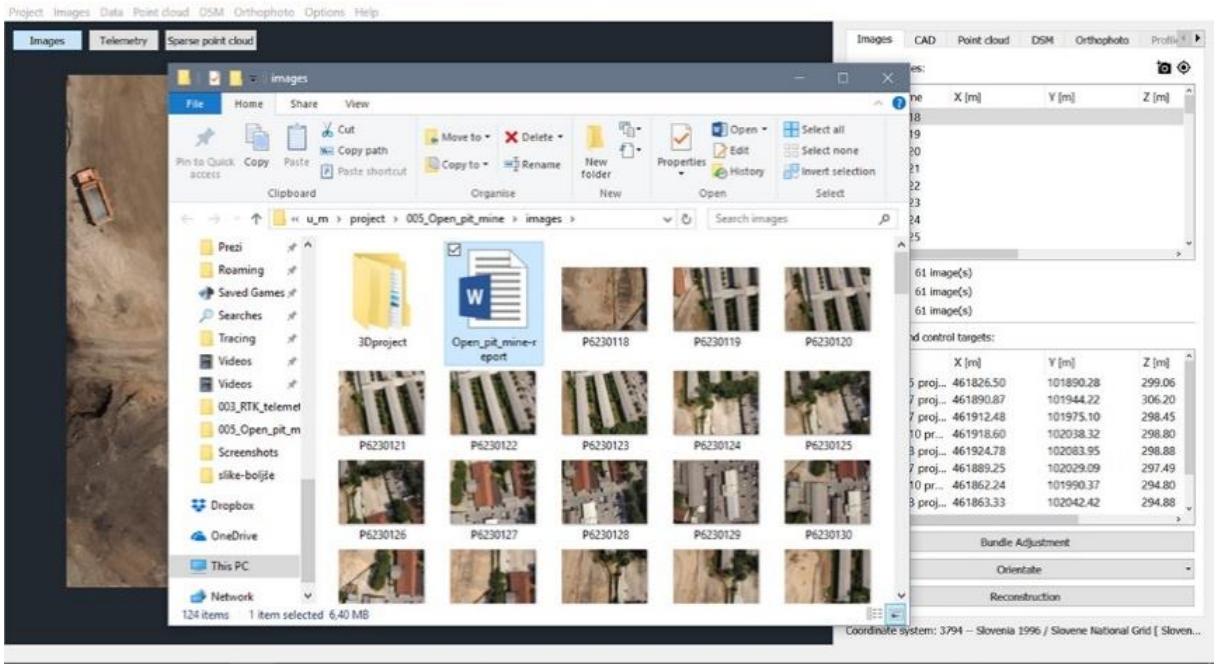
10.1. General report

To create a general report, click ***Project*** - > ***Generate report*** - > ***General report***.



Enter the document's name and select the data you want included in the report. If not, Cube-3d automatically selects top listed data from all working panel tabs.

After the report is generated, the folder with report file path pops up for you to verify the information. It is created in *.docx file which makes it easily customizable. Simply save it as pdf in your text editor if needed.



Here is a quick overview of a general project report.

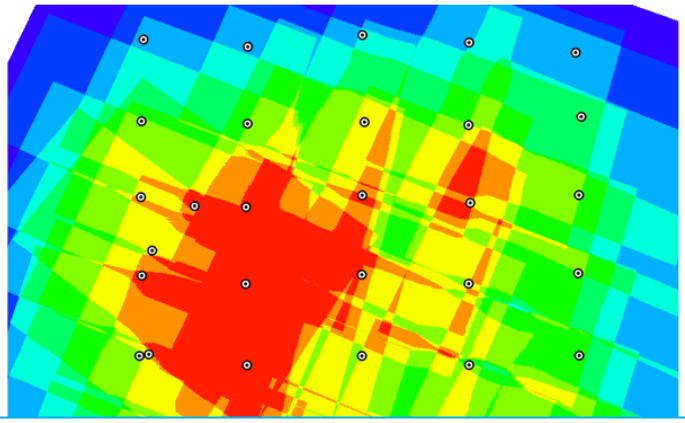
Project:	Meritve_1
Date of capturing images:	2014-08-19

Camera model	Resolution	Focal length	Sensor size	Pixel size
OLYMPUS IMAGING CORP. E-P2	4032 × 3024	17mm	17.3 × 13.0 mm	4.291µm

Orthophoto size:	203m × 258m	**Pixel resolution:**	0.022m

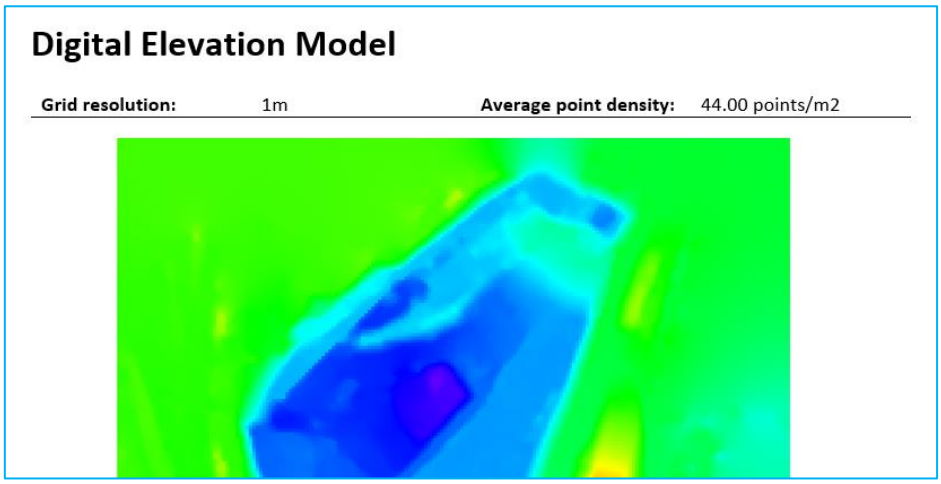
Survey Data

Number of images:	52	**Number of registered images:**	51
Flying altitude:	90.7m	**Number of key points per images / average:**	3265
Ground resolution:	0.0220m	**Georeferencing:**	Yes



Ground Control Points

Point ID	Coordinates X	Y	Z	Errors [m] X	Y	Z	3D	Number of projections
4000	461847.767	101887.933	294.578	0.002	0.002	-0.001	0.004	7
4002	461908.201	101992.995	299.096	0.002	-0.001	0.010	0.010	6
4003	461914.396	102079.756	298.604	-	-	-	-	0
4005	461875.646	102007.224	294.113	0.004	0.002	0.002	0.005	8
4007	461842.949	101935.324	294.571	-0.007	0.004	-0.002	0.008	7
4008	461805.046	101944.758	293.947	0.002	-0.006	-0.002	0.007	9
4010	461825.587	102000.263	292.930	-0.005	0.001	-0.000	0.005	11
4011	461789.584	101990.103	299.803	-0.000	0.001	-0.002	0.002	8
4012	461836.923	102030.865	300.552	0.004	-0.003	-0.001	0.005	7

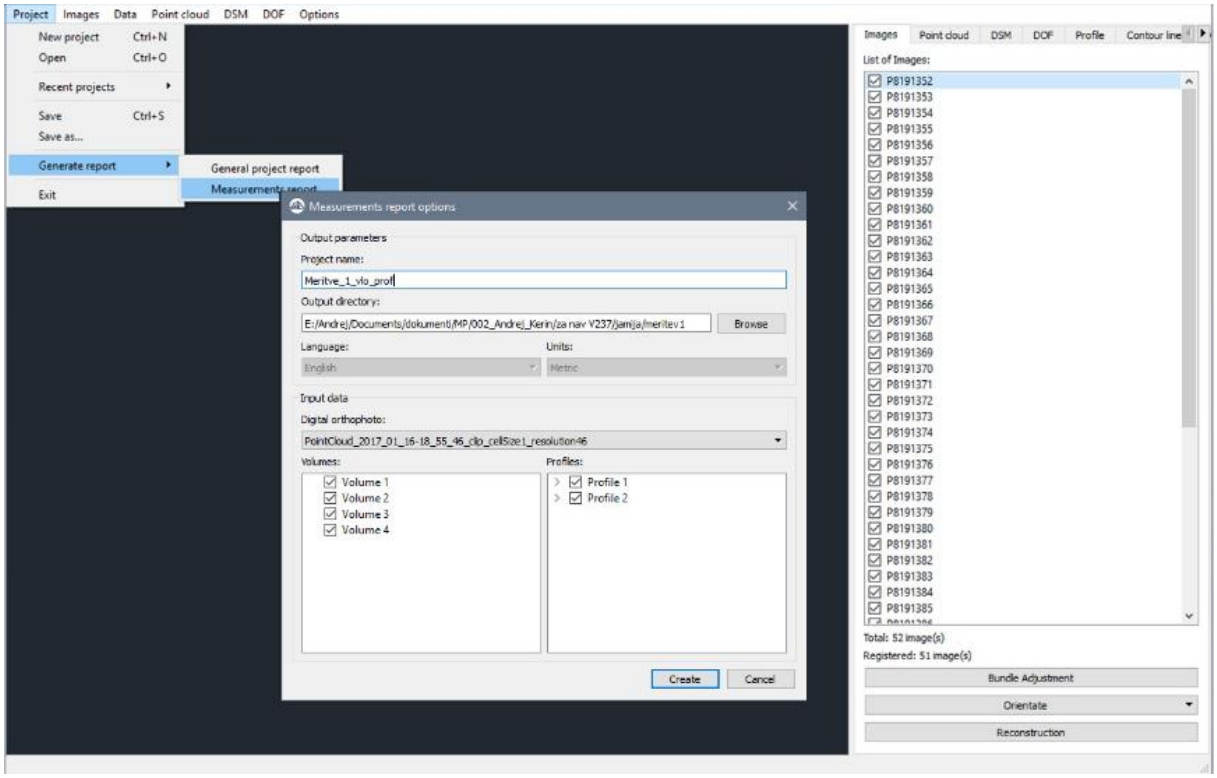


Processing Parameters

Bundle adjustment statistics	
Images	52
Registered images	51
Number of ground control points	9
3D tie points	39678
RMS reprojection error	0.616427

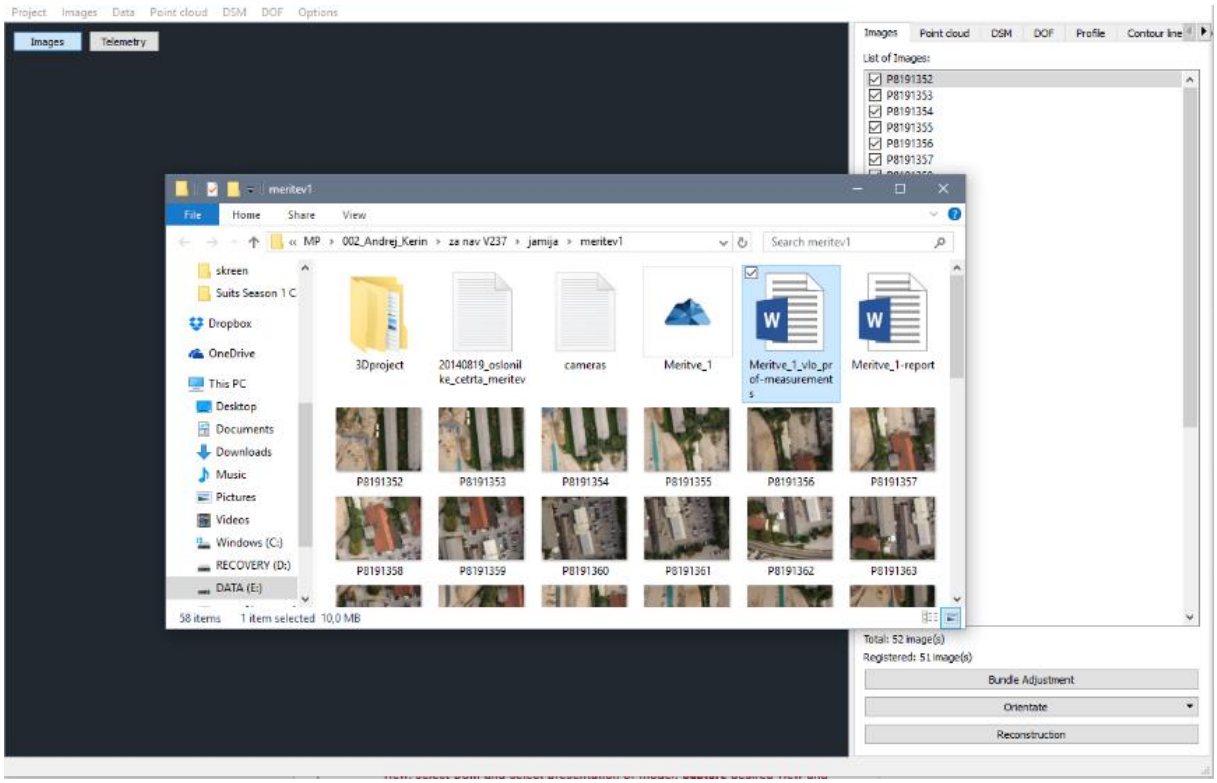
10.2. Measurement report

To create Measurements report, click ***Project*** - > ***Generate report*** - > ***Measurements report***.



Enter the document's name and select the data you want to have included in the report. If not, Cube-3d automatically selects top listed data from all working panel tabs.

After the report is generated, the folder with report file path pops up for you to verify the information. It is created in *.docx file which makes it easily customizable. Simply save it as pdf in your text editor if needed.



Here below is a quick overview of a measurements report.

Volume

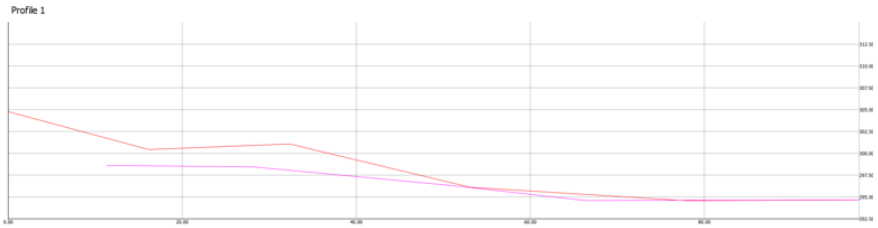
Name:	Volume 1		
Fill:	6660.52 m^3	**2D area:**	4117.00 m^2
Cut:	659.18 m^3	**3D area:**	4356.65 m^2
Highest point:	304.29 m	**Lowest point:**	294.57 m

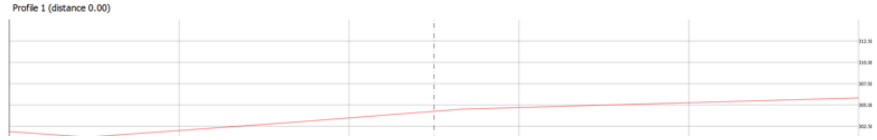
Profile line with transverse lines

Profile names:	Profile 1, Profile 2		
Lowest point:	293.763 m	**Length of profile:**	97.799 m
Highest point:	305.154 m	**XZ scale:**	1:1

Longitudal profiles - 2D break point coordinates	**X**	**Y**
T1 (Profile 1)	461886.625	101875.562
T2 (Profile 1)	461853.000	101942.453
T3 (Profile 1)	461842.062	101962.609
T1 (Profile 2)	461886.625	101875.562
T2 (Profile 2)	461853.000	101942.453
T3 (Profile 2)	461842.062	101962.609

Transverse profiles - 2D break point coordinates	**Start X**	**Start Y**	**End X**	**End Y**
Profile 1 (distance 0.00)	461841.969	101853.102	461931.281	101898.023
Profile 1 (distance 10.00)	461837.469	101862.039	461926.781	101906.961
Profile 2 (distance 10.00)	461837.469	101862.039	461926.781	101906.961
Profile 1 (distance 20.00)	461832.969	101870.969	461922.281	101915.891
Profile 1 (distance 30.00)	461828.500	101879.906	461917.812	101924.828
Profile 2 (distance 30.00)	461828.500	101879.906	461917.812	101924.828
Profile 1 (distance 40.00)	461824.000	101888.836	461913.312	101933.758
Profile 1 (distance 60.00)	461815.000	101906.703	461904.312	101951.625





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