Co-funded by the European Union

MODULE 07

TRAINING PROGRAMME

PHOTOGRAMMETRY

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1. Objectives of the module

This module allows first to understand what photogrammetry is, then to see the techniques to achieve automatic or manual flights of drones for this activity and finally to process the images to obtain 3D models and exploit them.

Basic level module for the use of drones in construction, considering that all the knowledge set out here is essential.

2. Principes of photogrammetry

2.1 History of photogrammetry

This old method was invented in France (Facade of the Hotel des Invalides for Aimé Laussedat in 1849), and is based on the principle of correlation of images acquired from different points of view which allows the automatic recognition of homologous points.

Photogrammetry was industrialized between the two world wars, thanks to the development of aerial photographs which made it possible to produce much more accurate maps of entire areas or countries.

This work, very tedious, requires a considerable computing power. It is therefore quite logical that professional applications have only been democratized in the last few years, as the supercomputers formerly dedicated to this type of operation are much less suitable than modern office computers which now incorporate the necessary computing power.

← 3D model from Google Maps obtained by hotogrammetry

(Lyon, France)

Figure 2-1 google maps model (Google)

Drones facilitating the acquisition of aerial photos or facades further accelerate the development of photogrammetry.

2.2 What is photogrammetry?

Photogrammetry is "All the techniques used to determine the shape, dimensions and position in space of an object from photographs" (translated from the Larousse dictionary). The 3D model thus created is an exact copy of the original objects (if dimensional information is given), but on a computer screen.

Figure 2-2 example of 3D model (https://numerisation3d.construction)

If humans can see in 3 dimensions, it is because they have two eyes. Being able to see an object simultaneously from two points of view gives us a three-dimensional appreciation of it. This principle, called stereoscopy, is used in photogrammetry.

There are several invariant points belonging to a surface (whatever the movements of the surface in space, these points always have the same coordinates in the object frame) and several points of view whose 3D position in space is not known (successive positions of the camera) but which "target" these points belonging to the surface. Several "points of view" (successive camera positions) generate lines of sight passing through the points identified on the surface.

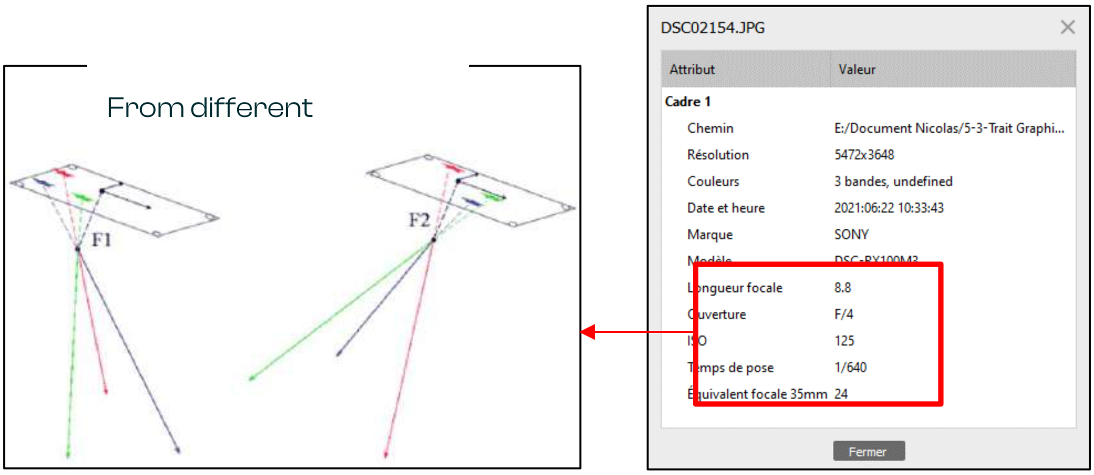


Figure 2-3 independent photos of the same object (techno-science.net)

By successive iterations of the coefficients of the equations of the lines (ad hoc software) we can calculate the coordinates X, Y Z of each point in the object frame.

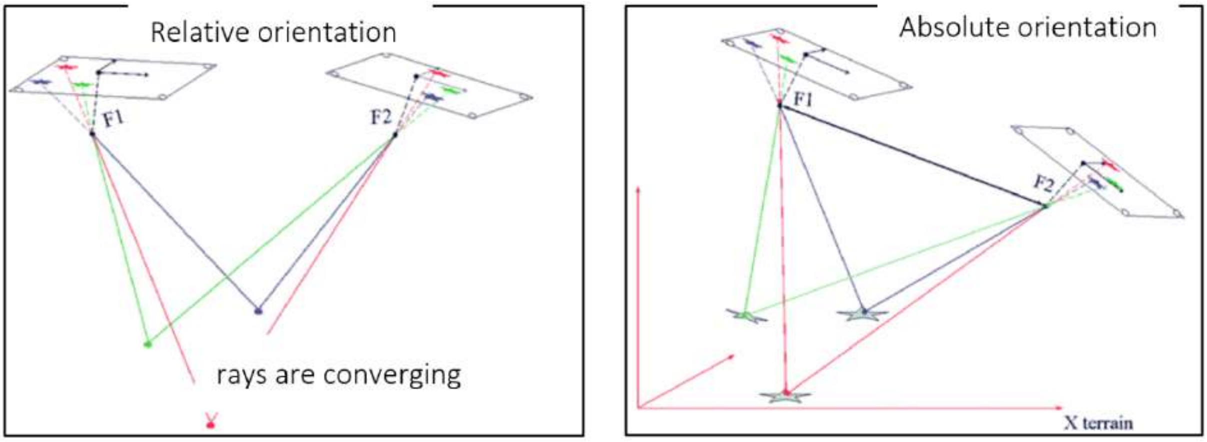


Figure 2-4 relative and absolute orientation of photos by the software

Indeed, image correlation consists in the automatic recognition of homologous pixels on a defined surface. The objective is then to determine the relative orientation of the images (photos) from these points identified as homologous between these images.

Image analysis algorithms replace human vision by associating to any point of an image A, a homologous point in an image B. At this stage, the computer algorithmically proceeds to a stereoscopic reading of the scene to determine the relative positions of each point. The multiplication of the process to a large number of points of view makes the calculation of the position of each pixel more reliable by dividing the error while increasing the extent of the 3D modelling. At this stage, we obtain a 3D model homothetic to the real objects photographed. To obtain a digital copy of the real size of the objects, it is necessary to give the software indications of measurements: Either indications of distance between different points (after measurements on the ground or by adding a ruler or a sight on the photos), or coordinates of topographic reference points on the objects and on the photos.

3. Photogrammetric shots

3.1 General principles

The following criteria must be met when taking pictures:

- Constant focal length of the lens, no zoom for the same series of photos processed together
- Constant brightness of the photos: To avoid black shadows, it is better to shoot on a cloudy, but not too dark, day (and without rain). Alternating sun/clouds are bad, on sunny days it will be necessary to add photos in the shadow areas.
- sharpness: To avoid motion blur, do not shoot on a high wind day, no more than 30 kph windspeed, depending of your drone's stability. Particularly, when shooting buildings, facades, or in sharp mountains, the wind turbulences can shake the drone and give more motion blur.
- precision: use the best definition of the image sensor, 15 MP (mega pixel) is the minimum
- Constant distance to the ground, facade or building, even in circular flight
- Constant tilt of the camera for the flight, the group of images processed together
- 70% minimum **overlap** of the photos between them in all directions, 80% is better, otherwise impossible to process

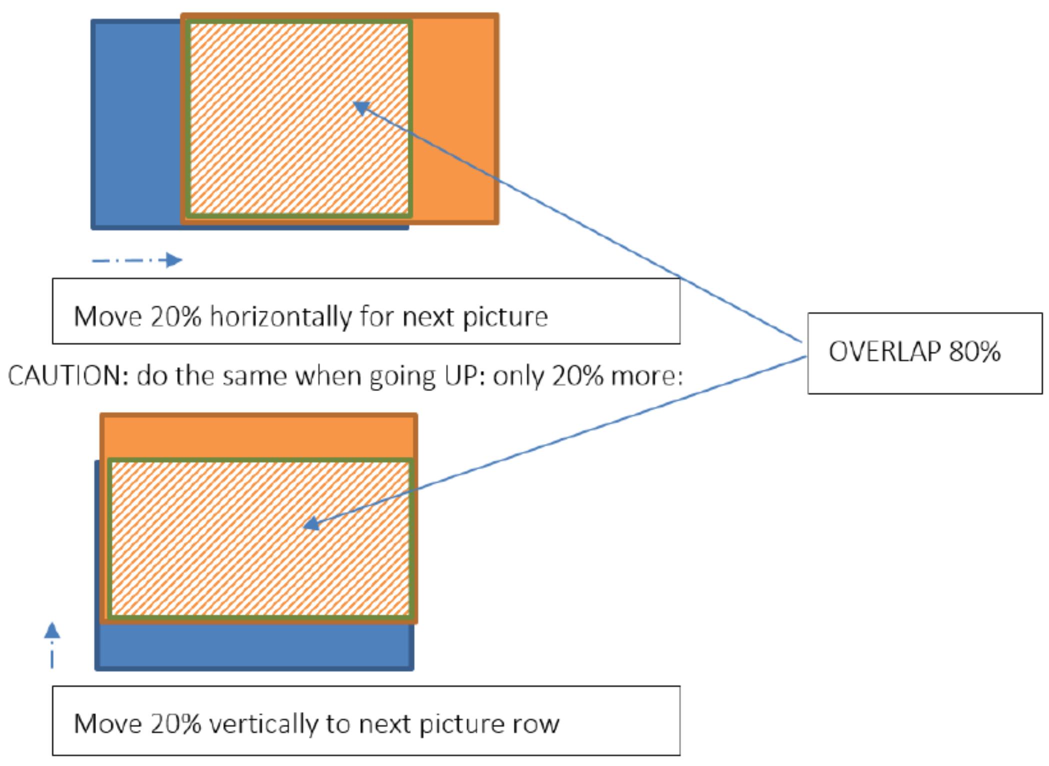


Figure 3-1 Horizontal and vertical overlapping

- Maximum resolution of the camera, adapted to the level of detail sought: the remote control generally indicates the size of a pixel on the ground depending on the altitude. The pixel being the smallest detail of an image, this size in mm gives the size of the smallest 3D detail visible on the model.

- As little compression as possible but the camera's own image enhancement treatments can be kept (correction of lens aberrations, contrast and colour enhancement, equalization of brightness differences). The .tiff format is very good but makes big files, the .jpg loses some details but is correct to learn or make simple models with mid-range files.

3.2 Manual Mode

The drone will be directly piloted from the control, by hand, but the photos can be taken automatically.

Reminder: fill the “drone mission sheet” and perform a complete pre-flight check (module 5: flight practise)

o Depending on the drone or camera an option of "**time-lapse**" shooting can be available, which will take a picture every “x” seconds. Make a trial flight and then analyse the result in overlapping to adjust the speed.

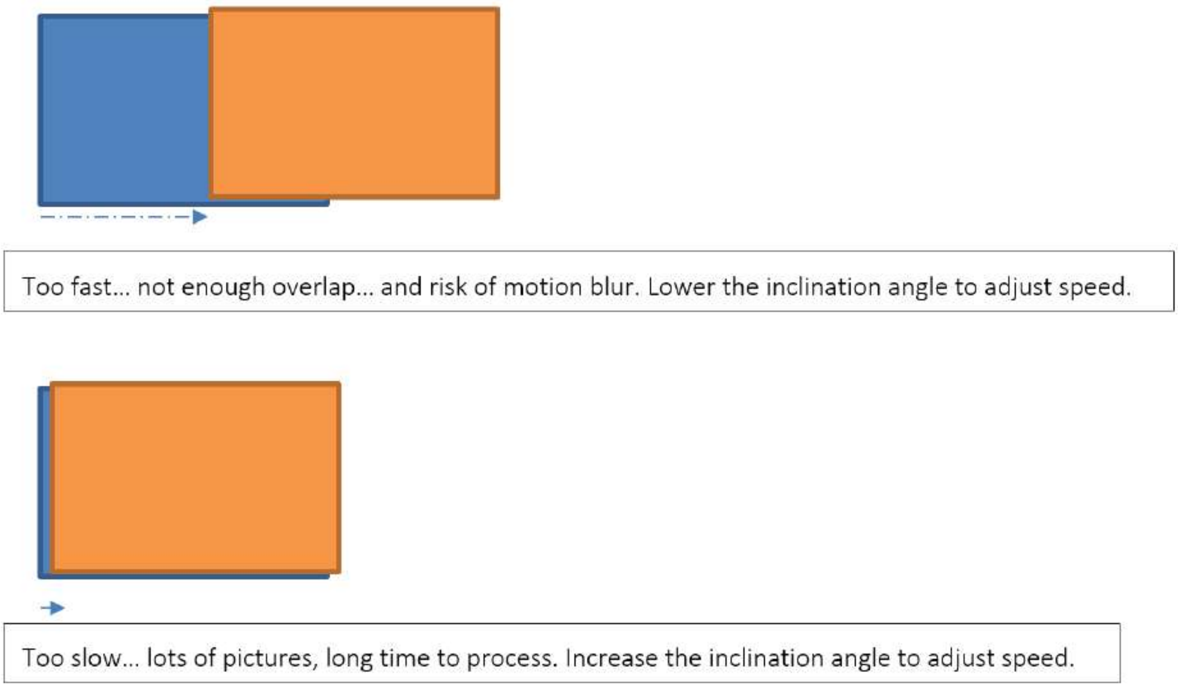


Figure 3-2 wrong overlapping due to wrong time-lapse setting or speed

o If the GPS has a good reception, we can also set up a " **GPS-lapse** " which takes a picture every " x " meters, to be adjusted to have a good overlap. Normally the distance is calculated in 3D so it works also when going up.

o also It is possible to program an automated "**timelapse or GPS-lapse**" photos and analyse the result.

The flight will consist in making a complete coverage of the area with the necessary overlaps.

See below the programmed flight for the possible trajectories, as it is the same principle.

Manual flight is required in facade photogrammetry, even if there are automatic systems with programmed waypoints.

NB: in manual mode, a short test-flight is necessary to adjust the parameters of speed and "xxx-lapse" of shooting to obtain the good overlap.

3.3 Principle of land photogrammetry with a drone

Fly over the place to be digitised in 3D and cover the entire zone with overlapping pictures.

- best results with a grid flight
- best results with a second flight with an angle on the camera and a grid flight
- fly far away from the perimeter to model to ensure good overlap at the edges.

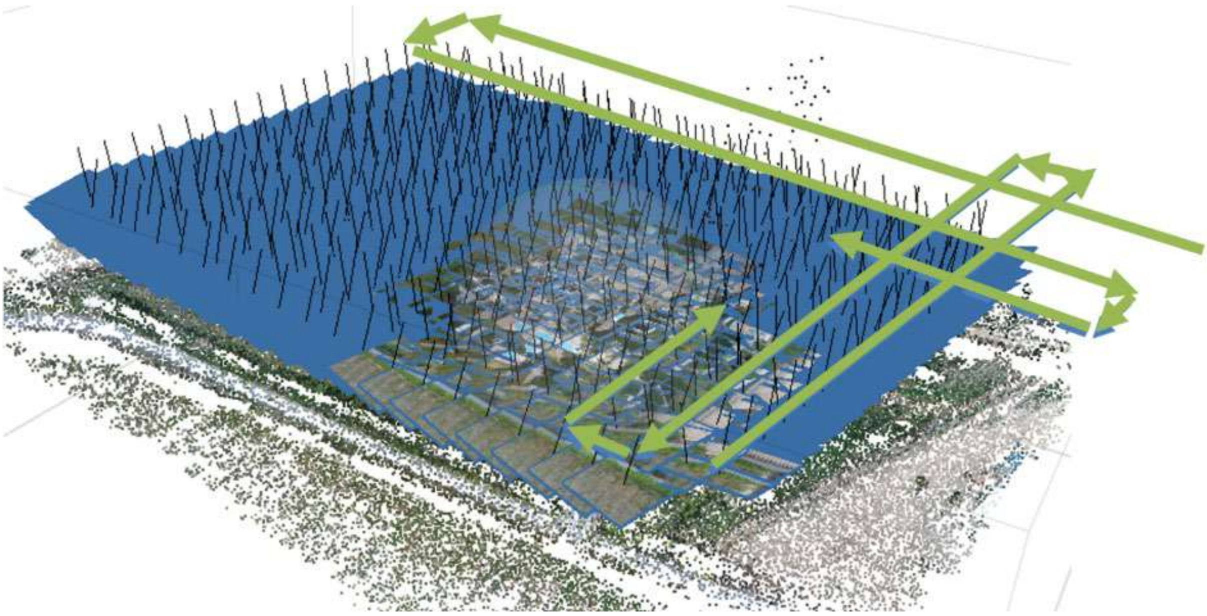


Figure 3-3 Grid drone flight and overlapping photos for 3D ground photogrammetry

↑ in the example above ,black lines indicating the direction and position of each shot. The taken picture is shown in a blue frame with its inclination. The arrows indicate the flight of the drone, here a grid flight. Note:

- the overlap of the pictures
- the constant altitude
- the regularity of the spacing
- the angle (about 10°) of the camera to the vertical

Figure 3-4 photo sequence with good overlap and camera tilt

In case of buildings, it is interesting to add more views of the façades, such as a circular flight:

← an additional circular flight helps to get a good model of buildings or under trees.

Here only one altitude is represented but it can be interesting to fly several altitudes.

Figure 3-5 circular drone flight for 3D building photogrammetry

3.4 Positioning geolocation targets

In order to geolocate the model obtained, and/or to adjust its dimensions, it is essential to position targets that are clearly visible on the photos. **See module 6 Geolocation**.

Usually, the geolocation points or markers are defined by square or circular targets on a wooden or metallic backing. For photos or videos taken at 20 m or 30 m height, targets of 20 cm or 30 cm size (or diameter) are usually sufficient.

However, at low flying heights, simple wooden stakes marked with fluorescent spray can be sufficient.

The geolocation points or markers should, as far as possible, be as far apart as possible, well distributed over the entire area to be modelled (periphery and central area if possible). If these markers are not to appear in the model, it will be necessary to extend the area to be worked on to put the markers on the outer periphery of the area to be modelled.

- At least 4 targets (recommended number: at least 5 markers to have controls on the quality of these points and to be able to eliminate those which are not very reliable, the Metashape software recommends 10).
- Strongly static during the whole shooting period
- GNSS RTK surveys with centimetric accuracy
- Different numbers on the targets to recognise them quickly on the photographs.

Figure 3-6 ground geolocation target surveyed by GNSS

Figure 3-7 ground geolocation target with number

3.5 Dimensional targets or measures on buildings

To calibrate (give the right dimensions) a model not geolocated by ground targets, it is necessary:

- Either position on the building two graduated staffs (levelling staffs, for example), one horizontally, the other vertically. However, these staffs will appear on the 3D model and can be damaging to the aesthetics, they can be positioned at the edge and then removed from the final frame.

- Or measure with a measuring tape a distance between two well identified and precise elements to be able to transfer this measurement to the model later (between two windows for example).

See in chapter “Processing”.

3.6 Case of a model completed with a scan

If the photogrammetric model is needed together with a laser scan model, it is interesting to have common targets for both models to ensure a good match.

In this case, the targets follow the specifications of the scan: at least 3, at different heights on the walls.

If the drone is equipped with an RTK GNSS receiver, then the accuracy for the point cloud is enhanced, and its native geolocation makes it easier to register with a LiDAR geolocated point cloud.

3.7 Principles of facade photogrammetry with a drone.

There are few principles when façade is being surveyed:

- Stand 10 to 15 m in front of a building facade, altitude 3m, fly facing the facade, horizontal camera axis perpendicular to the façade

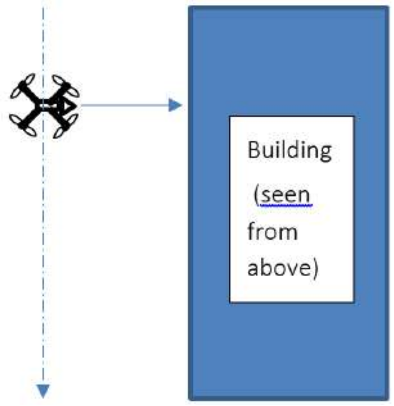


Figure 3-8 traveling face to a building

- Flight path in horizontal translation perfectly parallel to the facade. Fly 20 to 30m.

Figure 3-9 pictures of a building for façade photogrammetry

- Go up vertically by 5m at the end of the facade
- Repeat a passage in the other direction, at 8m high
- ...etc.

Figure 3-10 path for façade photogrammetry

Pictures:

Manually : look in the display, use the grid to detect when you have move about 20% away from the previous picture. Press the trigger. Move to the next frame 20% away, press… you must ensure 80% overlapping.

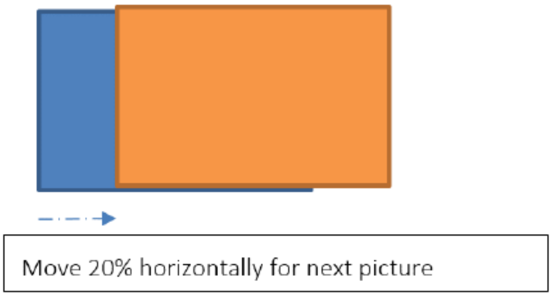


Figure 3-11 horizontal overlap

Here is a tip :

Memorise the position of the next picture:

Here the middle of the beam

On next picture the middle of the beam is the edge of the photo

Figure 3-12 horizontal overlap tip

The same technique is necessary for the vertical overlapping

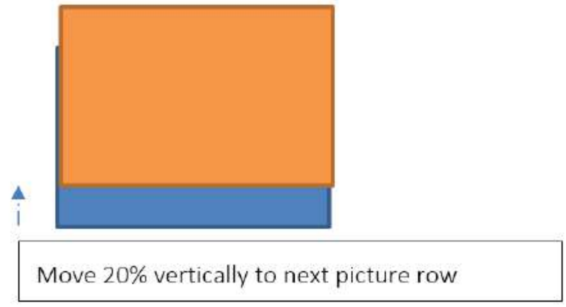


Figure 3-13 vertical overlap

Here is a tip, illustrated by a vertical overlap:

Memorise the position of the next picture:

Here the planting border at the foot

On next picture the planting border is the edge of the photo

Figure 3-14 vertical overlap tip

Automatically: use the time-lapse or the GPS-lapse as explained above.

NB: it is not a problem to have a big overlapping (95% for instance).

3.8 Principles of entire building photogrammetry :

By façade after facade : Proceed façade after façade (Fig.3-15), the corners must have been shot each time.

Figure 3-15 path for façade and 3D building capture

It is necessary to "see" the connected façades.

A vertical shooting of the angles, 45° from the facades and facing the angles is very interesting.

By circular flight:

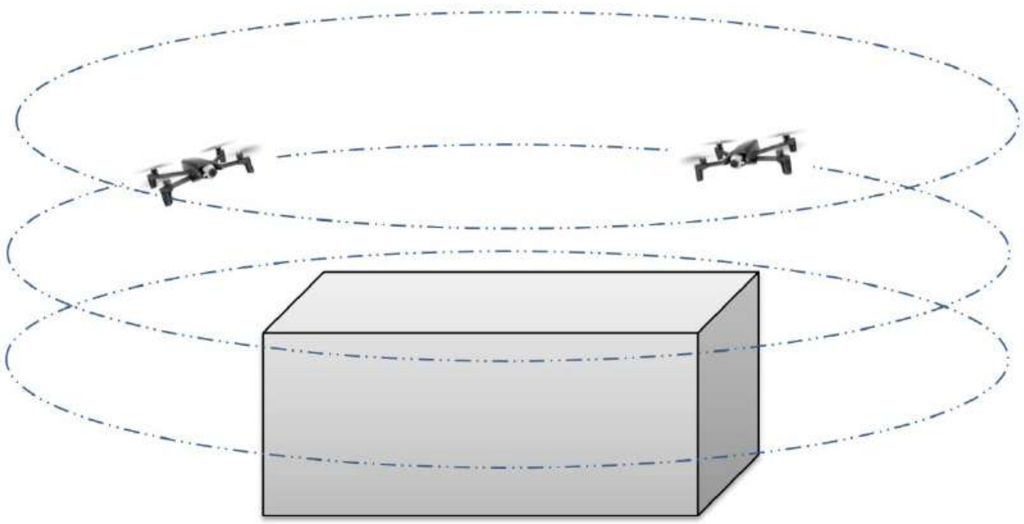


Figure 3-16 circular flights for 3D building

- On the lowest circle flight, the camera is horizontal, or even tilted up to "see" under the balconies or outside walkways (in this case the brightness must be adjusted to obtain good details in the shadow)
- When going up, tilt down the camera to keep the building centred.
- If trees are around the building, it can be necessary to make a close façade flight (see above). This flight will be processed apart from the rest of the pictures, then merged with the rest of the model

- Varying the diameter of the circles is not usually necessary and can mislead the software, tying to match a close-up shoot with a photo from further away.

A circular flight is also useful around a mountain peak, or around a hill.

4. Programmed flight

The drone is piloted by a software that will analyse the perimeter to be surveyed and determine an ideal course while respecting the needs of covering the photos.

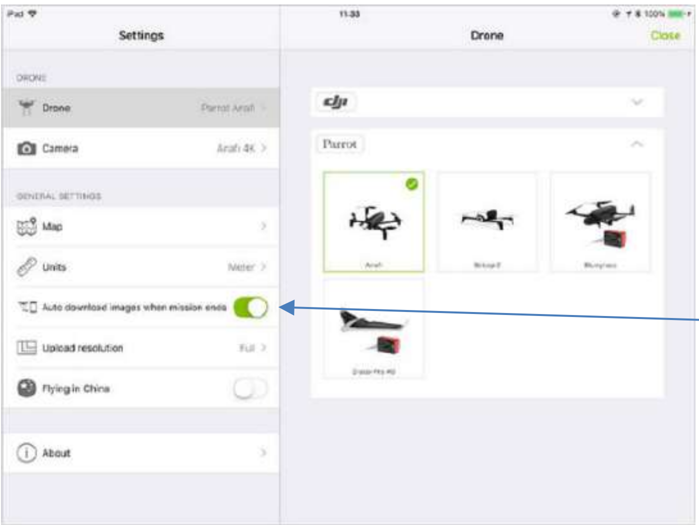
This flight is only applicable for a surface on the ground or a building in circular flight

- No photogrammetry of facade
- No photogrammetry of complex or high buildings

4.1 Programming principles

Illustrated with the software " PIX 4D Capture" which is free and European.

- Choice of the drone and general settings



Recommendation: do not download the pictures from the drone automatically : it drains battery, fills up the memory of the smartphone used with the remote control and takes time. Use directly the card of the drone.

Figure 4-1 Pix4DCapture settings

- Longitudinal and transverse photo overlap
- Drone speed
- Camera angle

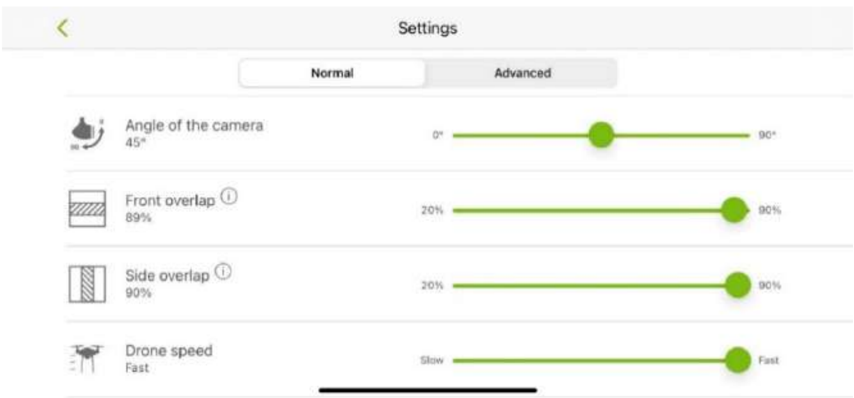


Figure 4-2 Pix4DCapture overlap settings

A first flight at a vertical angle downwards (90°) is essential.

Another flight at a different angle, for example 60°, can be added to capture vertical details or under tall trees (you must be able to see under the foliage, the trunk must be clear).

An overlap of 80% is normally sufficient, in both directions.

A fast speed can lead to a lack of detail if the light is low (heavy cloud cover) by spinning effect because the aperture will be long (exposure time) and the diaphragm very open (lack of depth of field so slight blur possible).

The lower the camera flies, the slower its speed must be to avoid blur.

Next screen: ***Type of flight***

Figure 4-3 Pix4DCapture flight path selection

Grid flight: the program will select the path depending on your camera settings and altitude to ensure a good overlap. It will set also the speed to ensure a good image quality.

For a good 3D model a double grid with a 80° down camera is required. Select "polygon" if the area to survey is not rectangular, or to avoid flying over the public domain or properties without permission.

Circular flight: recommended for a building, and even possibly several circles at different heights and camera tilt.

Next screen: ***position and shape of the flight mission***

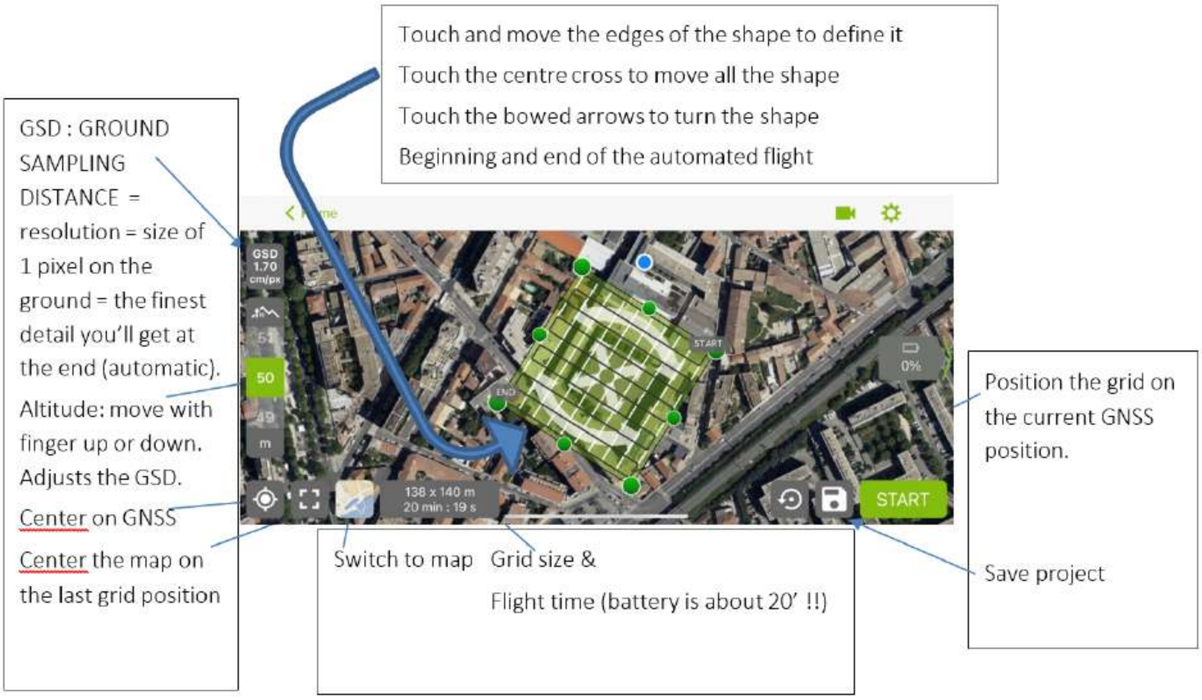


Figure 4-4 Pix4DCapture flight path setting on map

Always select an area larger than the part to be mapped to avoid missing overlaps on the edges. CAUTION: if it is required to map an entire plot of land, this means that an overflight authorization for the neighbouring plots is needed, and often also for the public domain-it is a flight in specific category!

Altitude: be careful with the setting, the drone may hit an obstacle that would be higher than its altitude, **a manual test flight with location of the highest point may be necessary**. A too high altitude will give a less good resolution on the ground (GSD). Fly between 20 and 30m. the program does not overfly obstacles: the altitude remains **constant. The altitude is measured only from the take-off point!**

Flight time: check the flight time to avoid interrupting the automatic flight if the battery runs out. The software usually resumes where it was interrupted. One can program 2 flights in a single grid to change the battery, the 2nd flight being rotated by 90° with respect to the first, which in the end makes a double grid...

The **GSD** : Ground Sampling Distance. The size of 1 pixel of the photograph projected to the ground. It depends on the altitude, the focal length, the camera sensor resolution and size. The altitude can be adjusted, but remember that if there is relief, then the GSD will change according to the height of the drone above the ground or construction. The GSD is the smallest detail you'll get on your final model (if the processing keeps the precision...)

Next screen: ***Check list and start***

... follow instructions...

Next screen: ***drone flight***

Figure 4-5 Pix4DCapture mission display while the drone is flying

Next screen: ***images download***

Check the quality of the pictures by selecting some of them. If there is blur or, not enough detail, change the parameters and relaunch the mission.

It is recommended not to download the pictures from the drone : it drains battery and fills up the memory of the smartphone used with the remote control. Choose it on the first screen.

It is possible to secure the images by uploading them in the cloud.

5. Processing

5.1 Example software: Agisoft Metashape

There are many photogrammetry software such as: PIX4DMapper, Meshroom, Recap pro, 3DF Zephyr., The overall operation of these programs is very similar.

Here are the steps for the processing: the steps, sometimes hidden in other software, are clearly visible and progressive.

5.2 Loading pictures

Menu **workflow**: Add photos (select the photos one by one or by list)
or **Add a folder... (better option to add all the photos taken by the drone and pre-selected in a folder)** (select « single camera »)

Note : it is possible to sample a video (with specific software) to extract photos.

A "shunk" (as named in Metashape) is a group of photos processed together

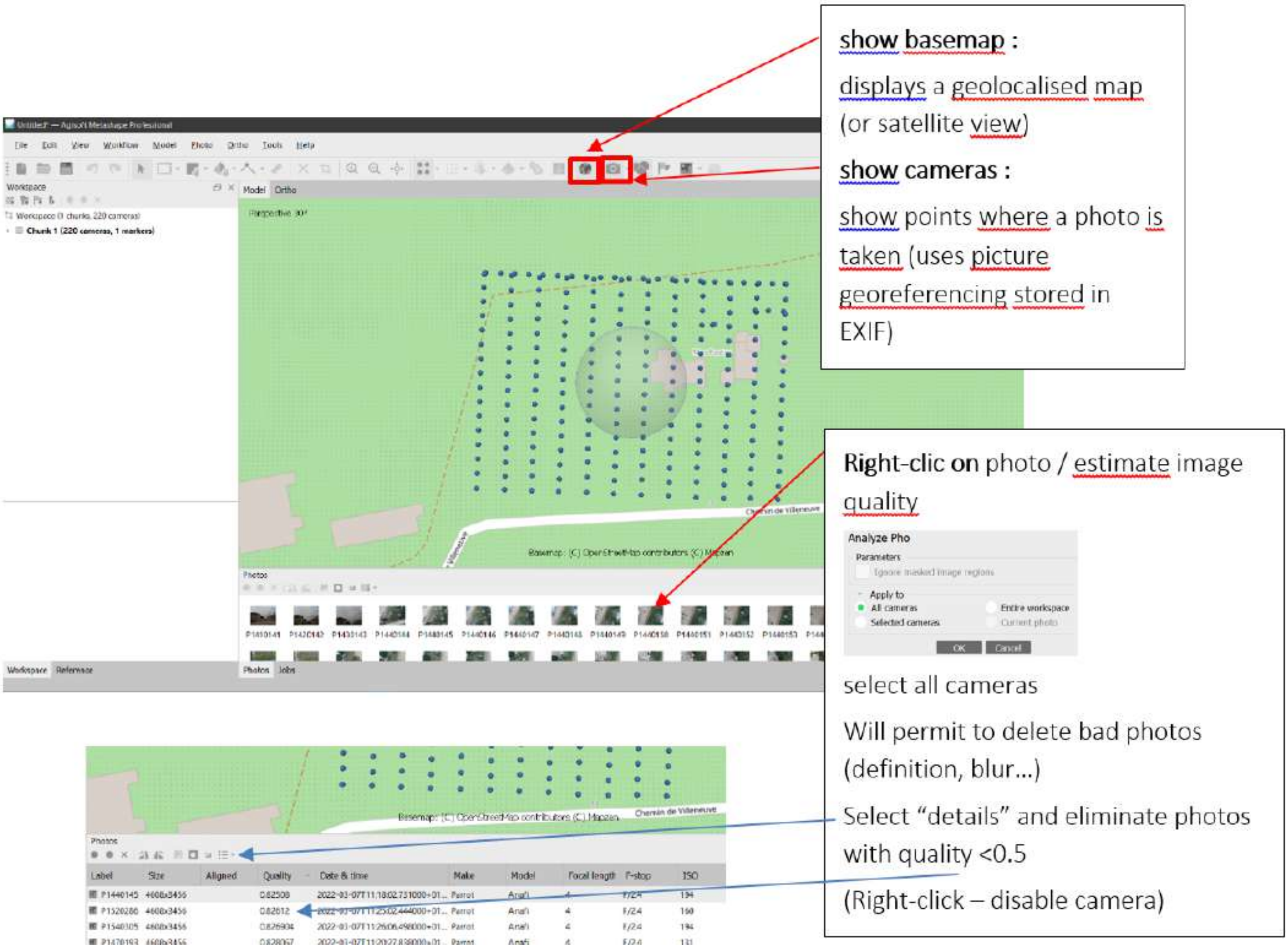
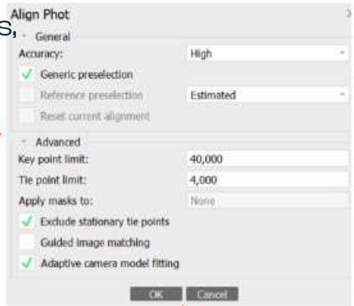


Figure 5-1 Metashape loaded pictures

5.3 Align photos

At this stage, the software looks for common points between the photos, finds the relative positions and orientation of the photos, in order to build a sparse point cloud model.



Menu **workflow** : **Align photos...**

High quality is good for the rest of the process, but takes a long time

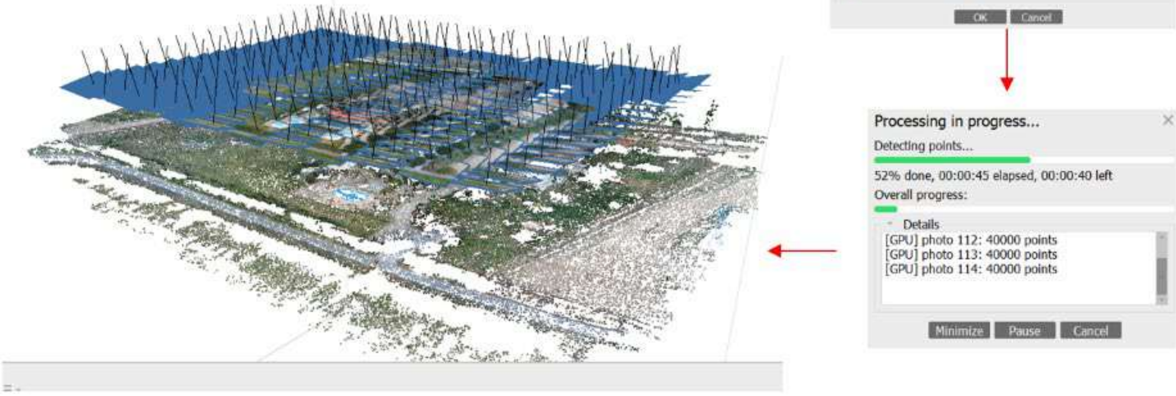


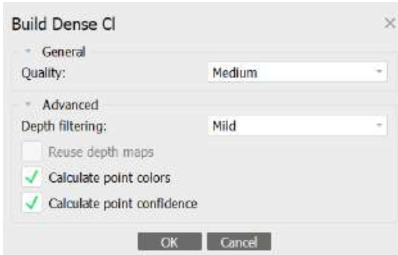
Figure 5-2 Metashape aligned photos with heights and lines of sight

This first step is essential to begin the process, it is the heart of photogrammetry.

The photo alignment uses different parameters to proceed:

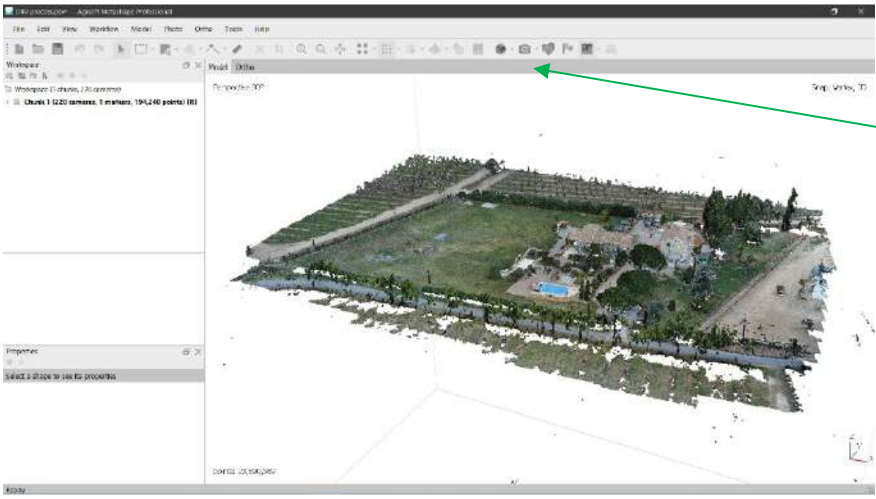
- Photo numbering: usually a number "x" photo is next to the number "x-1" so they should overlap.
- Geolocation: the drone records for each photo a Geographic position (lat., long., height) even if it is not very accurate, it helps because from one photo to the other, the relative accuracy is good. It is much better with an RTK drone (centimetric accuracy)
- Point matching: this the heart of the process, the software recognises shapes, colours, contours that match (minimum 4 similitudes) and computes the relative position of the camera for two photos, then for 3, etc.

5.4 Creating a point cloud



Based on the positions of the photos, the program calculates the depth of the points of each photo to combine them into a single dense point cloud.

Menu **workflow : build dense cloud…**



To switch on/off the pictures

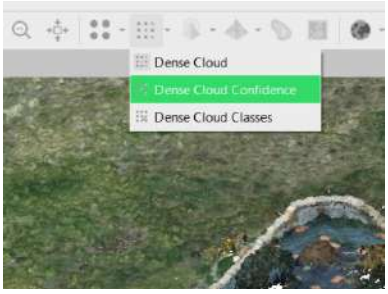
Figure 5-3 Metashape dense point cloud

Down: On this display some places are white : no point is present here, it's a "hole " in the point cloud.

- Under roof overhang
- Under trees
- In a dark shadow
- On a hidden (from cameras) side

Each point is coloured according to its original place in the photograph.

Figure 5-4 Metashape point cloud with white gaps where no point was built



By selecting "dense cloud confidence" check the quality

The scale is on the bottom right: blue 100% confidence, Green medium, and red bad confidence !

This point cloud scan is not very good for trees and facades details, but sufficient for the ground, terrace, small walls and roofs.

Enough to draw the plan, obtain dimensions, ground relief, prepare a project.

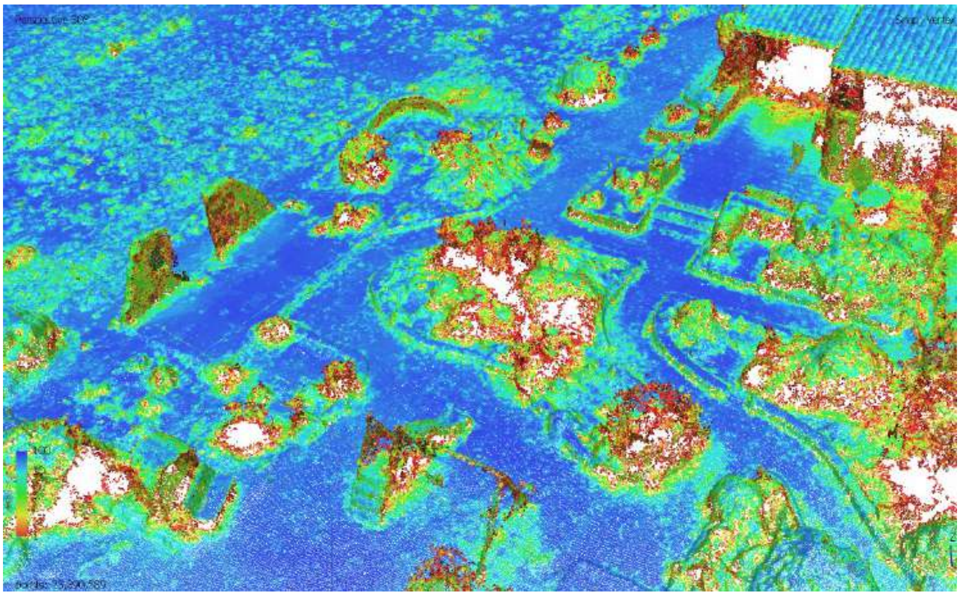
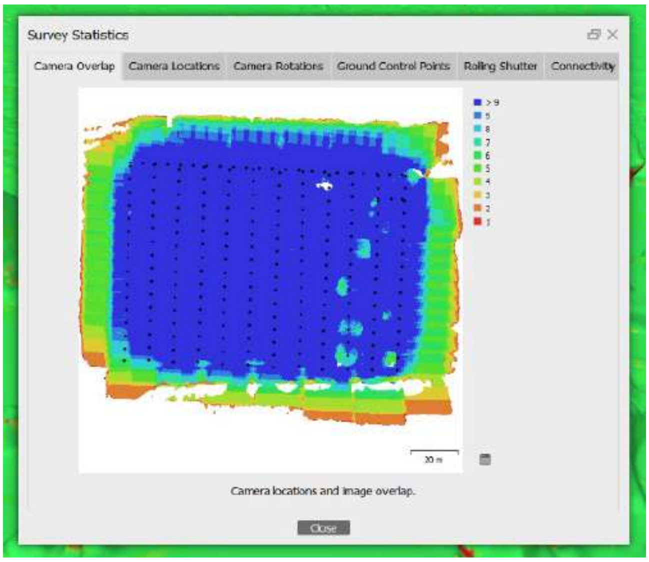


Figure 5-5 Metashape point cloud confidence

Camera overlap check: to be sure the points will be defined by a sufficient number of overlaps in the area to survey, click in the menu "tools // survey statistics"



In the blue colour, the points are present in more than 9 photos, it makes it easier to the software to create the 3D model.

If the area of the land or object to be modelled is entirely covered by the blue colour then it is OK, it is still good down to 5 photos

If not, some pictures should be added.

Figure 5-6 Metashape overlap map

5.5 Scaling and georeferencing a point cloud

It is very important to scale the point cloud: no plan, no measure, no insertion in another project is possible without that.

There are 2 methods:

- By coordinates: some points have been surveyed with a GNSS or a linked total station, at least 4, but better with more, and we find them on the photos, set a marker on them, and match the point cloud to these markers surveyed coordinates. The advantage is that at the same time the point cloud is accurately localised.
- By measured distances: on the worksite the distance between marked or remarkable points is measured and reported in the model. This solution doesn't accurately locate the point cloud, the accuracy is still the one of the photos, so the one of the drone's GNSS.

Control of the coordinate system of the photos

The photos have been georeferenced by the drone, but without RTK, the accuracy is metric: not good for scaling and linking to a legal coordinate system.

NB: example with the French legal system: RGF93.

Display the "reference" window with View // Reference then tab "reference" down the workspace window.

- - Identify in which coordinate system the photos are referenced

Usually, it is the international WGS84 system, used by the GNSS of the drone.

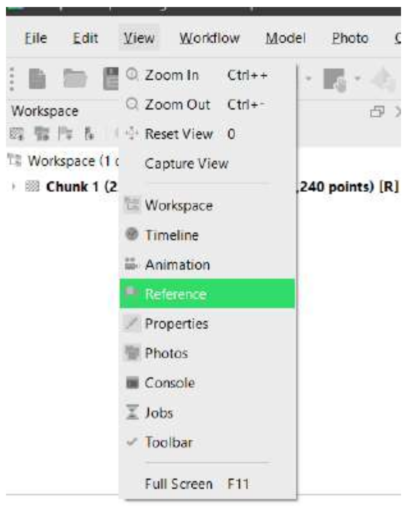


Figure 5-7 Metashape references displaying choice

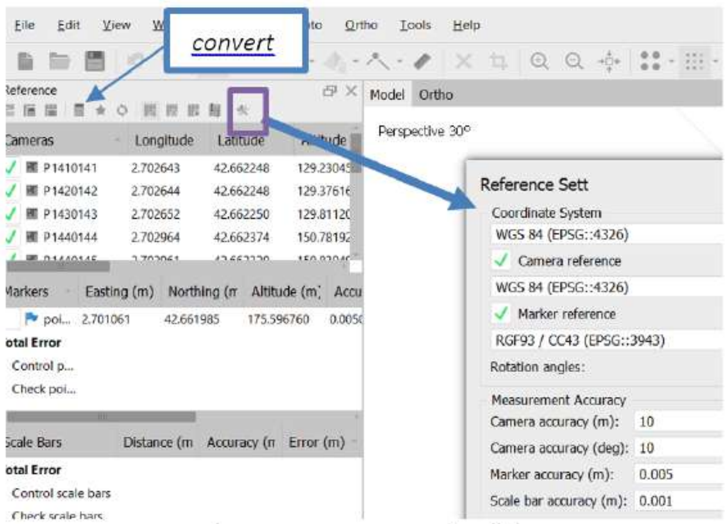


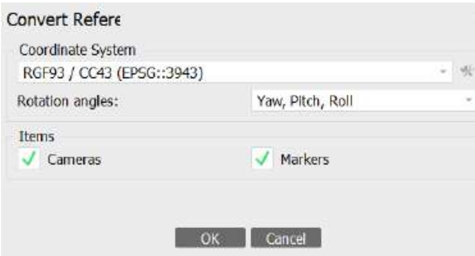
Figure 5-8 Metashape coordinate system setting and converting

(EPSG = European Petroleum Survey Group, codes all the euro systems, see module geolocation)

- If the photos are not in the same coordinate system as the references, you have to convert the photos in the system of the references with the command **Convert.**

Example : the control shows that the coordinates are WGS84, but the references/details are expressed in RGF93

Select the arrival system : the system you want to geolocate your point cloud in, the system in which your points coordinates are.



result :

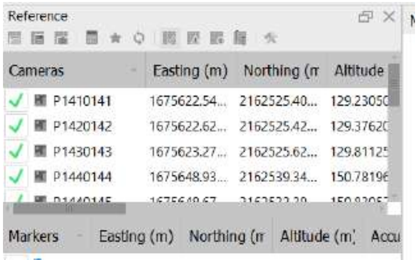
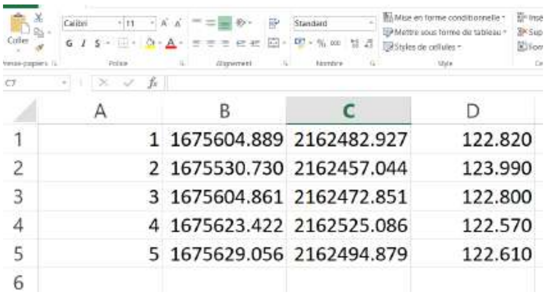


Figure 5-9 cameras focal point in the new coordinate system

- Import the references from a CSV file: name, easting, northing, elevation,



	A	B	C	D
1	1	1675604.889	2162482.927	122.820
2	2	1675530.730	2162457.044	123.990
3	3	1675604.861	2162472.851	122.800
4	4	1675623.422	2162525.086	122.570
5	5	1675629.056	2162494.879	122.610
6				

Figure 5-10 Excel CSV file containing the references names (A) and coordinates (B, C, D)

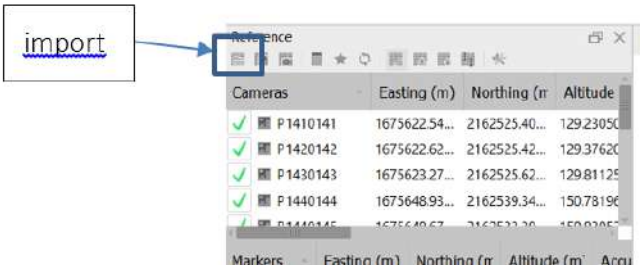


Figure 5-11 importation icon

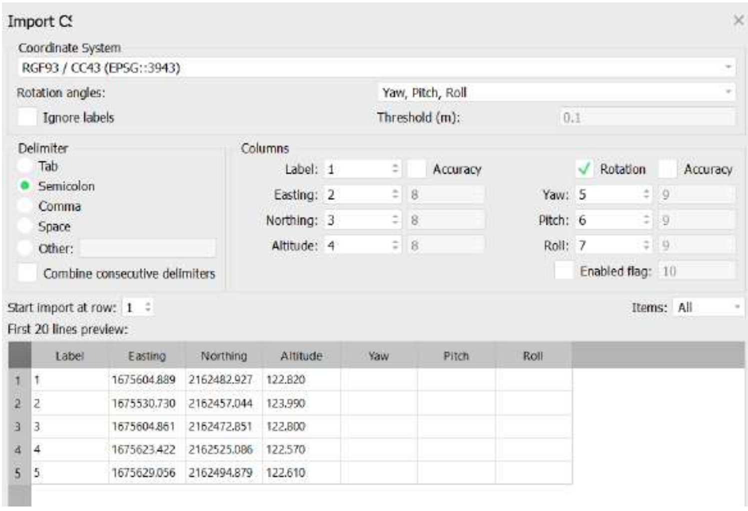


Figure 5-12 reference list loaded for import

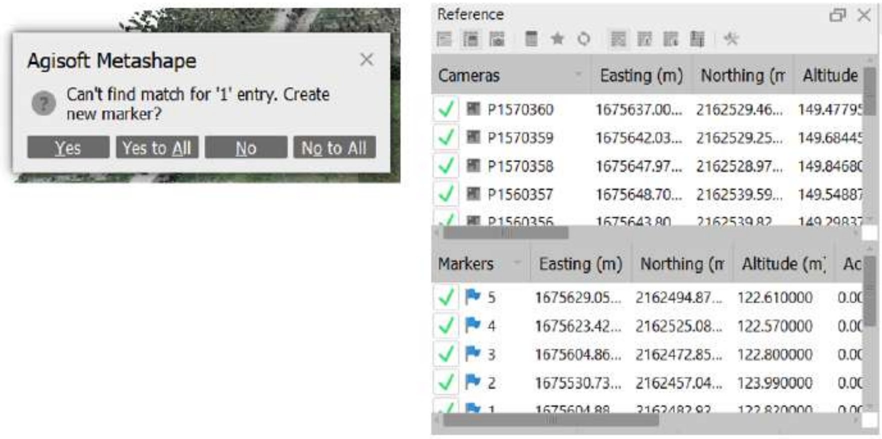


Figure 5-13 markers created after import of references

Tab “yes to all” and the software will create markers with the name of the references.

The points appear on the dense cloud:

> Example below presents the work that is not very professional. The references are angles or natural landmarks/spots and not targets as previously mentioned. They are not exactly in the right place.

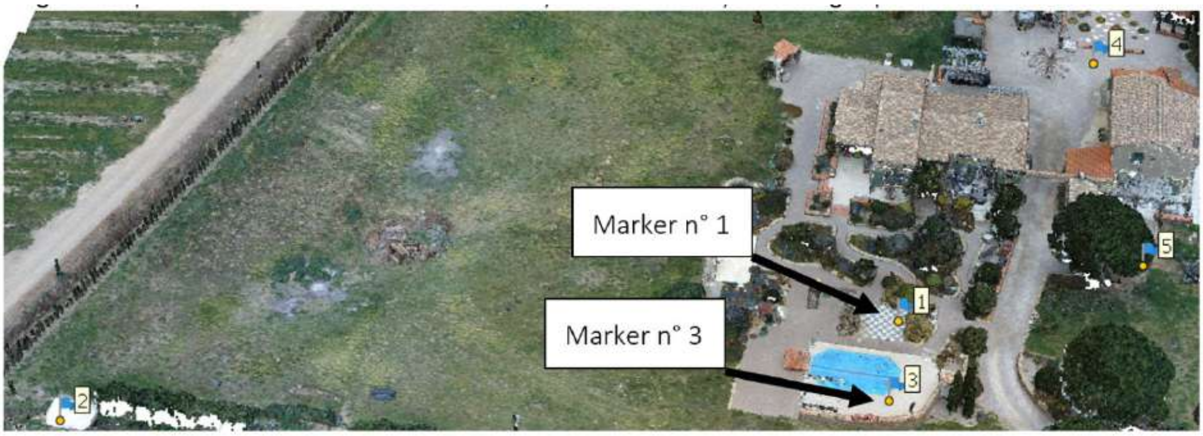


Figure 5-14 markers created on the point cloud

The photos containing a marker are identified by a flag:

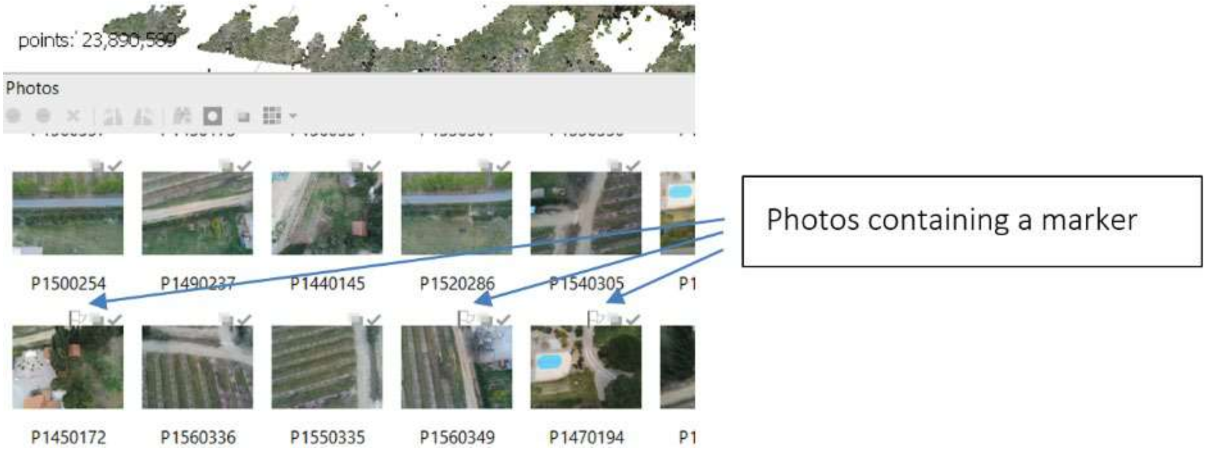


Figure 5-15 photos containing markers identified by a flag

Note: Right-click on the number of a marker (in the reference tab or on itself) to display only the photos in which this marker is present.

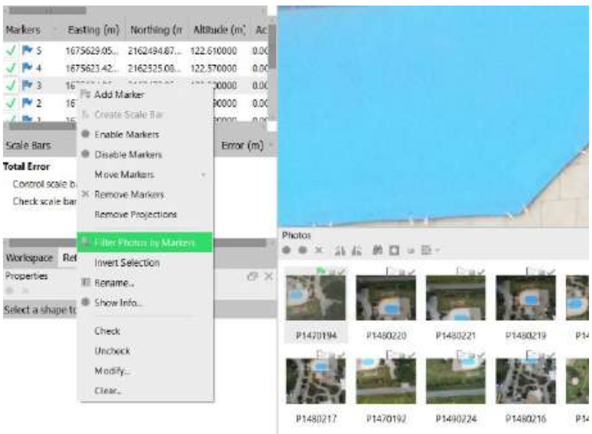


Figure 5-16 auto-select photos with a specific marker

To redisplay all the photos, click on the binocular (reset filter).

Double click on one photo and reposition each marker to its precise position directly in the photo.

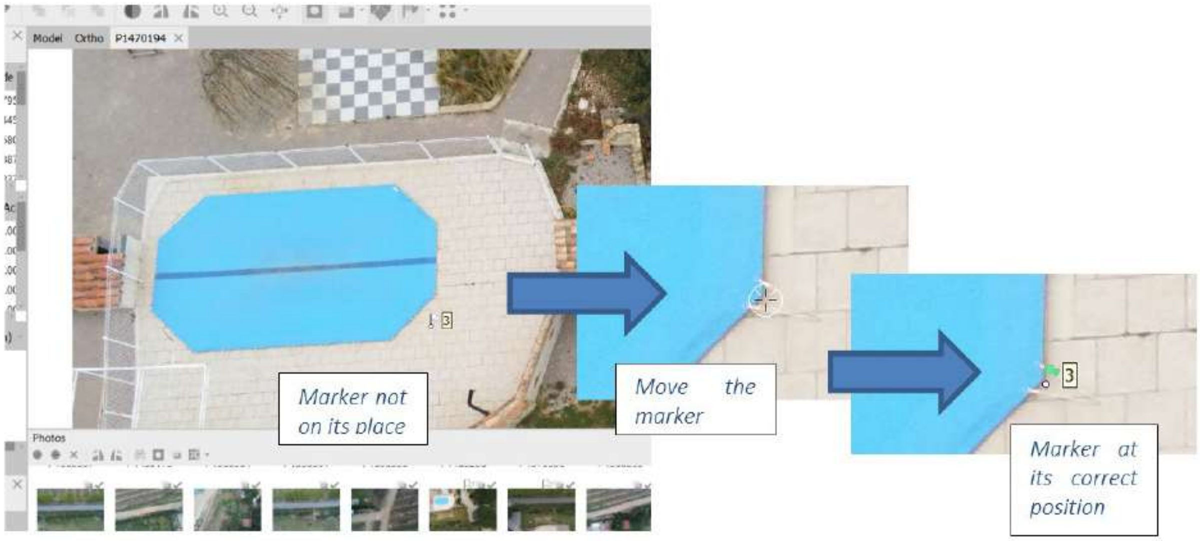


Figure 5-17 markers positioning

On a first photo, select a marker (by clicking on it) and place it on the identified reference (cross, paint mark, ...). Then check on 2 or 3 photos containing the same marker, the good positioning of the marker.

Note: Don`t forget to place targets () on the ground !

- The scaling points that are to be used for the scaling calculation of the point cloud should be checked and those (usually less reliable) that are just to be used as control points should be unchecked.

- Once the points have been repositioned and the scaling points checked, the calculation that transforms the point cloud to fit the reference points must be launched.

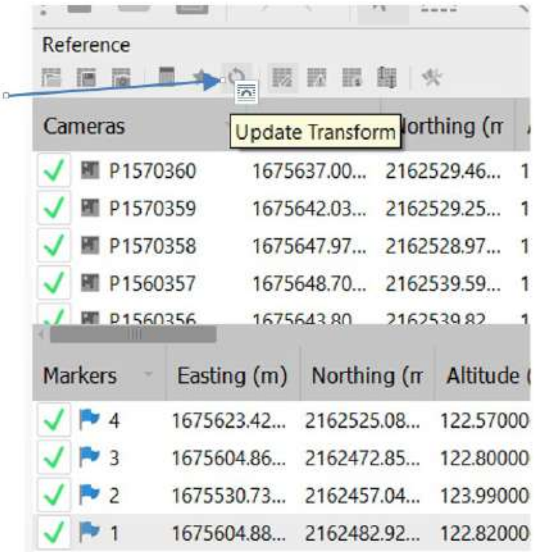
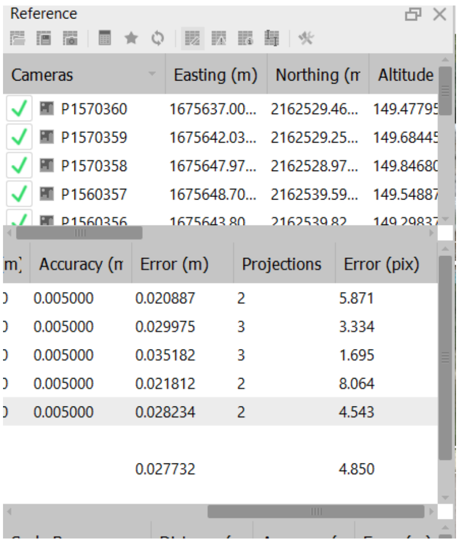


Figure 5-18 launch transformation calculation

The **quality control** of the transformation and the points used should be monitored to adjust the points used if necessary.

If the errors seem to be consistent for the reference points used, it is possible to proceed to the next step.



Slide the references coordinates to visualise the results of the transformation: here only 2.78cm average error – acceptable.

Figure 5-19 relative positioning errors on markers after transformation

Figure 5-20 point cloud accurately scaled and geolocated

5.6 Scaling of the point cloud by dimensional markers

This scales the point cloud but does not geolocates it.

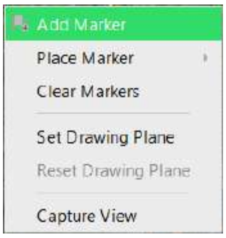
Mainly used for buildings (or objects).

For this work, one or more dimensional references are needed: measure some items on the building.

Figure 5-21 dimensions measured on a door

Method: Metashape Scale bars

Double-click on a photo down the screen to display it in the centre, right-click: Choose: Add marker



- Position on the concerned photos the markers (Point 1, Point 2 ...) corresponding to the known distances and if necessary reposition them on other photos, until the correct positioning of these.

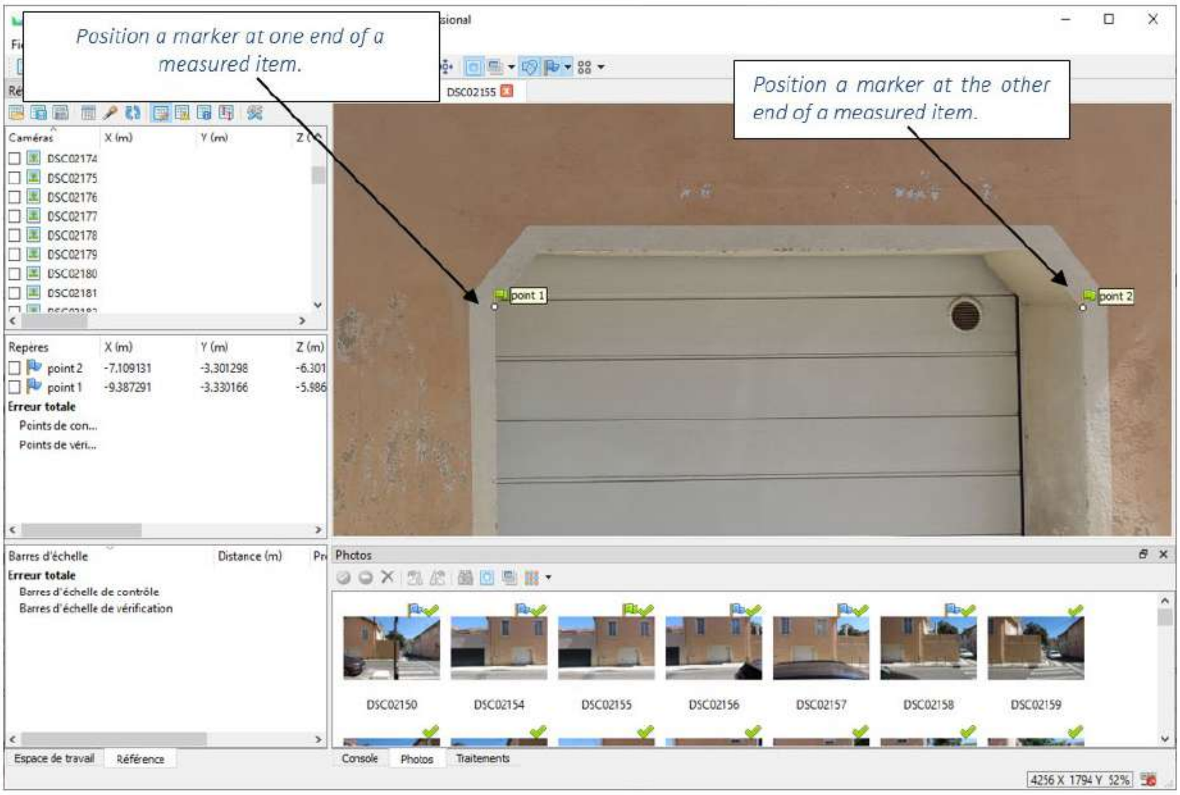


Figure 5-22 markers on a photo

- Select using the Ctrl key the Reference tab, select the 2 markers concerned by a known distance.

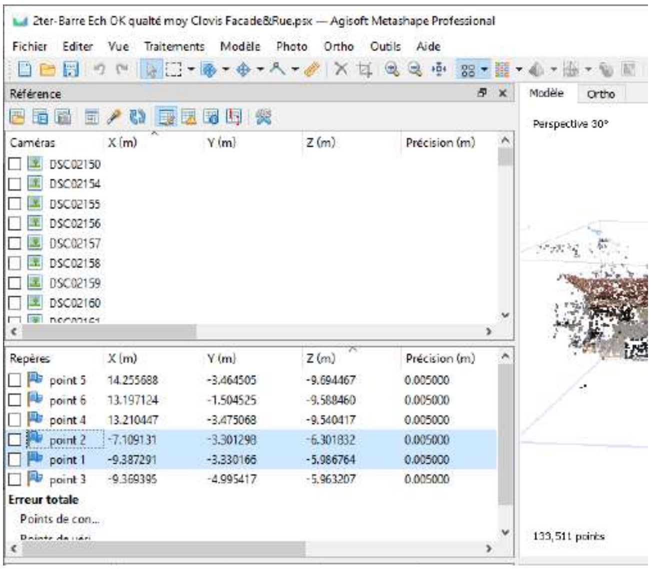


Figure 5-23 scaling points selected

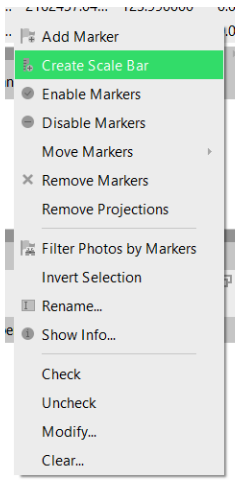


Figure 5-24 contextual menu to create a scale bar

- By right-click on one selected point, display the contextual menu and select:

“create a scale bar”.

- Double-click in the distance box after the newly created scale bar and enter its known length in meters.

Do so with all lengths measured on the worksite.

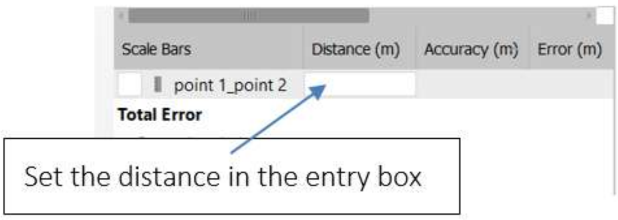


Figure 5-25 distance setting

- **Update the transformation to take into account the created scale bar.**

r

Nota: As for the reference points, the checked scale bars are taken into account for the transformation calculations, while the unchecked ones are used only as a control.

- Verify the quality of the transformation by checking the values of the errors resulting of the transformation.

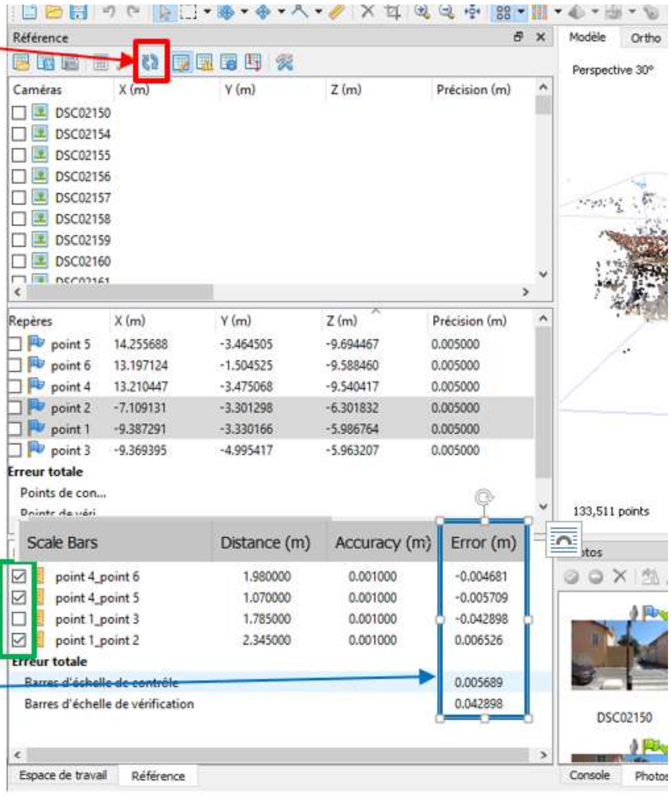


Figure 5-26 accuracy check after transformation of the point cloud

Check the scaling

Once the scaling is done, never mind the method, it is possible to measure the distances between different points with the Ruler command

(space key to delete).

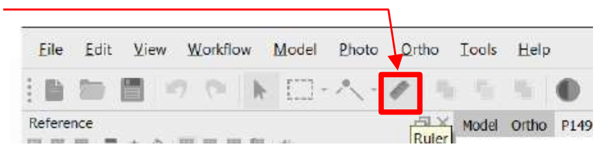


Figure 5-27 manual dimensional check after transformation of the point cloud

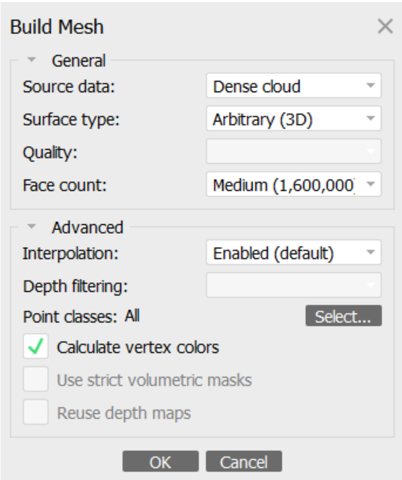
6. Obtaining a simple mesh or mesh with textures

6.1 Elaborating a 3D mesh

This step allows to create polygonal surfaces from the dense cloud.

It is then possible to visualize the modelling with different display modes (Shaded, Solid, wired).

Menu **workflow** : **build mesh…**

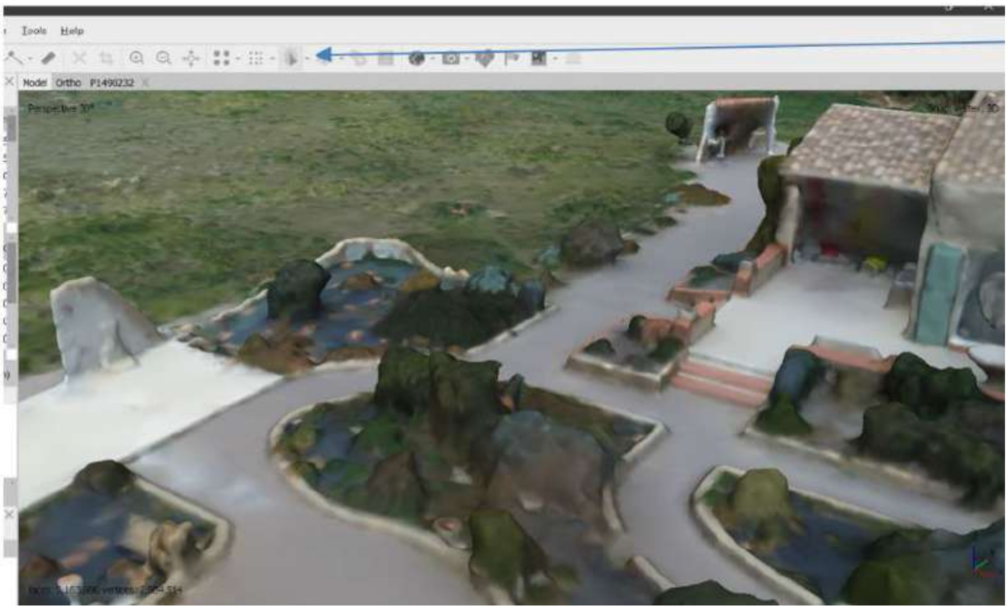


Using "**arbitrary**" creates a usual 3D mesh with faces all around the objects; "**height field**" is a surface coming up vertically, better for terrains, planar surfaces, landscapes, heap volume in a quarry… it uses less memory and power from the computer.

Face account depends on processing capabilities of computer used, the expected result, and the capacity of the computer of your customer to visualise the mesh…

Interpolation lowers the number and the size of holes in the model, if disabled, all holes stay and have to be post-processed. **Extrapolation** fills all holes, but sometimes it generates a false geometry, it can be post-processed also.

Click to select the mesh view



Side: The mesh with high face count

Figure 6-1 mesh made with "high" face count

Down :The mesh with medium face count

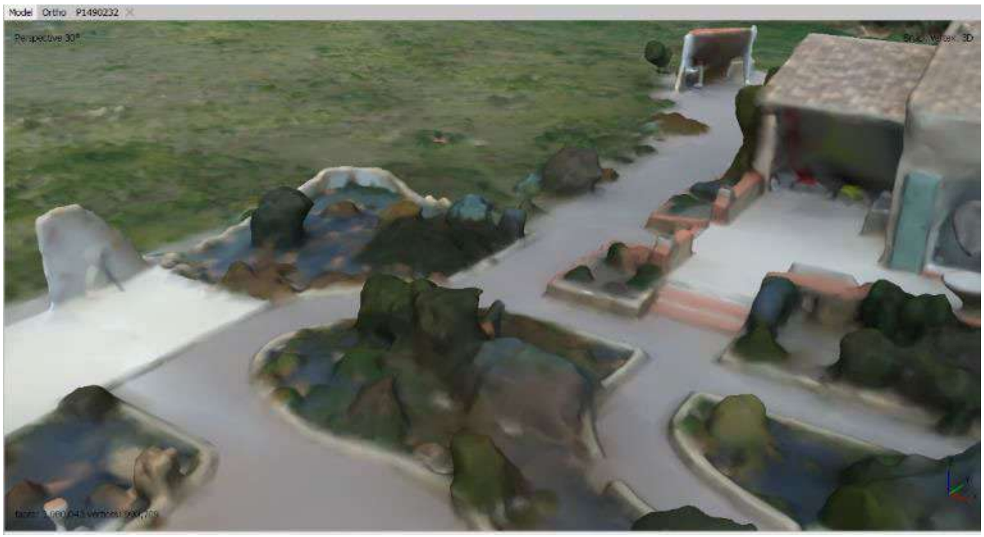


Figure 6-2 mesh made with "medium" face count

NB: the highest the alignment, the better the mesh.

With the icon "mesh view"  one can see

- The mesh without colours "solid view"

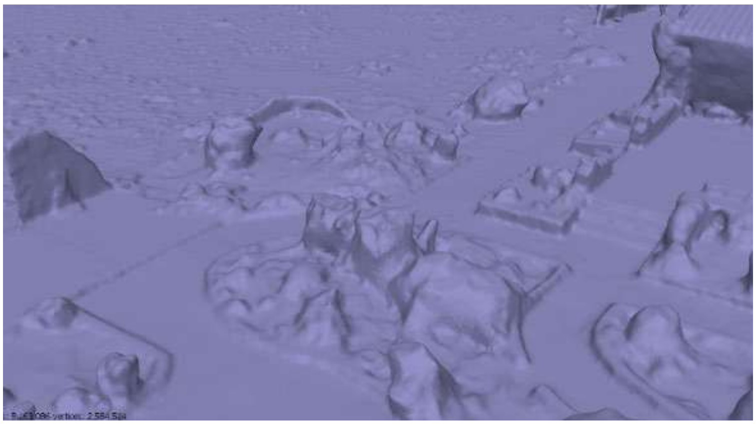


Figure 6-3 mesh in solid view

- The wireframe of the mesh

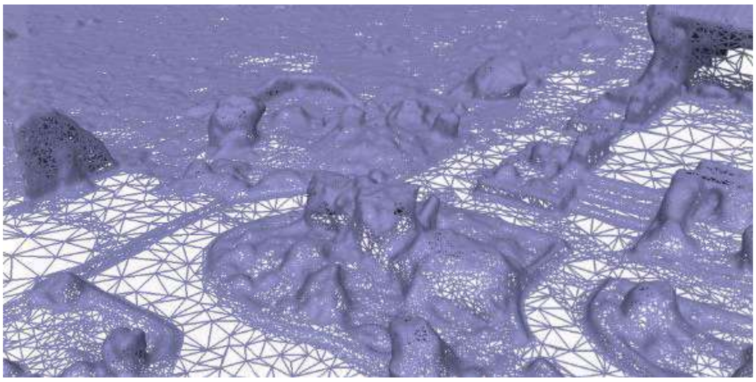
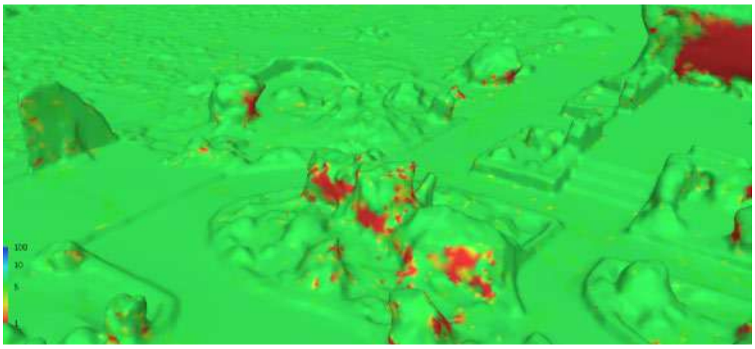


Figure 6-4 mesh in wireframe view

- The confidence of mesh, here it is not very good :



blue= 100%,

green= not so bad,

red= bad

Figure 6-5 confidence of the mesh

6.2 Creating a texture on the mesh

Precaution: if the photos are not uniform in brightness or colour, use "tools // calibrate colour" and the software will perform a standardisation of colours to obtain a better texture.

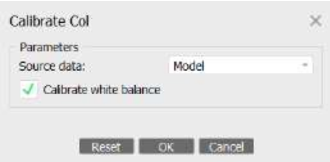


Figure 6-6 colour calibration of photos before creating a texture

This step allows to choose and apply the parameters for creating the textures (from the photos) that will be applied to the 3D model in the next step. A good texture allows to obtain a much better visual quality of the final model.

Workflow: build texture...

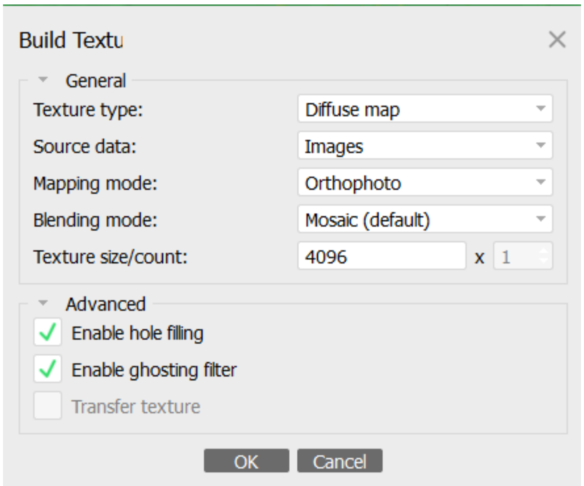


Figure 6-7 build texture processing menu

"Diffuse map" is the normal texturing mode ("normal" calculates illumination for post processing and "occlusion" applies shades from background)

Source from images is the most accurate

Mapping "orthophoto" places the colours for ortho view, and "adaptive orthophoto" places colours with a better accuracy on vertical objects (better for facades or cliffs)

Blending "average" uses the colours of the better defined point from the photos.

Filling the holes gives a blank-free result, but spreads out the texture as much as possible.

Enable ghosting filter eliminates moving objects that are unclear or not present in all pictures.

NB: apply a single image as texture can make a funny effect if you give another photo than the one of the place to model...

Textured model

Note the details like the pavement, the edges of the low walls; but still not perfect.

Figure 6-8 textured mesh

6.3 Generating a tiled model

A tiled model allows to store models of large areas or very fine models of small areas: the details are shown only when zooming in.

Menu **process** : **build a tiled model**

Depth maps are usually chosen and stored, dense cloud is an alternative

Set quality and pixel size (here default values)

If the tile size is small, the faster the visualisation

Other options are default

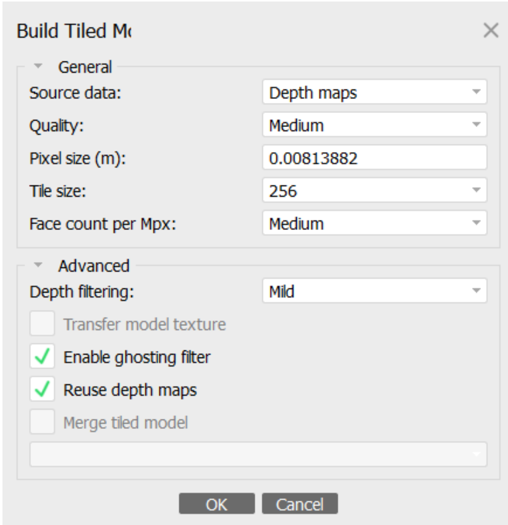


Figure 6-9 tiled model processing menu

The tiled model is very realistic:

Figure 6-10 tiled model view

The pavement is photo-like, so as the low walls but look at the angle of the house... not correct!
Inside the covered terrace notice the stretched photos of the "hole filling" option.

The whole model, with the markers, still at the same right place: the mesh didn't modify the geometry or geolocation.

Figure 6-11 whole tiled model - note the marker's position still right

Let's have a look at some details...

The pool is surrounded by a
Wire fence... it has disappeared,
But can be seen on the wall side
And the pool-house side

Figure 6-12 tiled model defaults on the pool's wire fence

The roof gutter is not straight, so as the garage door

The tree trunk is absent

The structures of the car port have no posts.

Figure 6-13 tiled model defaults

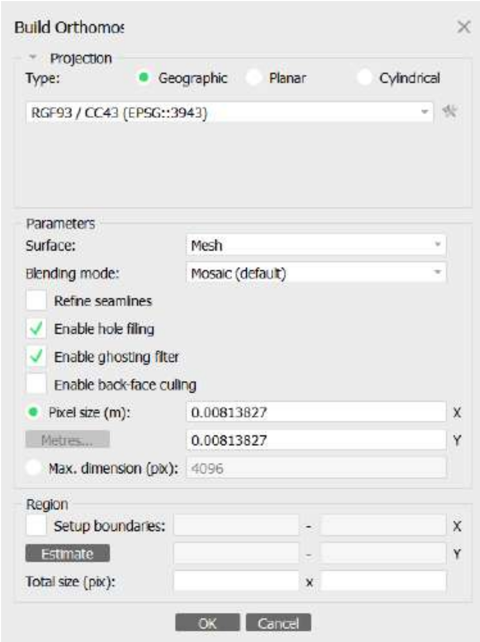
Cause: no (good) photo to define them = need mode pictures, for example by a circular flight around the houses, then merge the chunks and re-build the mesh.

7. Obtaining an orthophoto or orthomosaic

This step creates a 2D image of the model obtained by orthogonal projection of the mesh on a flat or developable surface.

NB: all errors or holes in the mesh will be seen on the orthomosaic, it is just a projection.

Menu **process** : **Build an orthomosaic**



Here it is a land, so the projection is geographic, in the legal system of the country. If it was a façade, chose "planar" and set 3 points on the façade to project it on the plan they define.

Please use all default values

Enable ghosting filter is not in the default

A region can be defined not to generate an orthophoto of the whole model.

Figure 7-1 orthomosaic processing menu

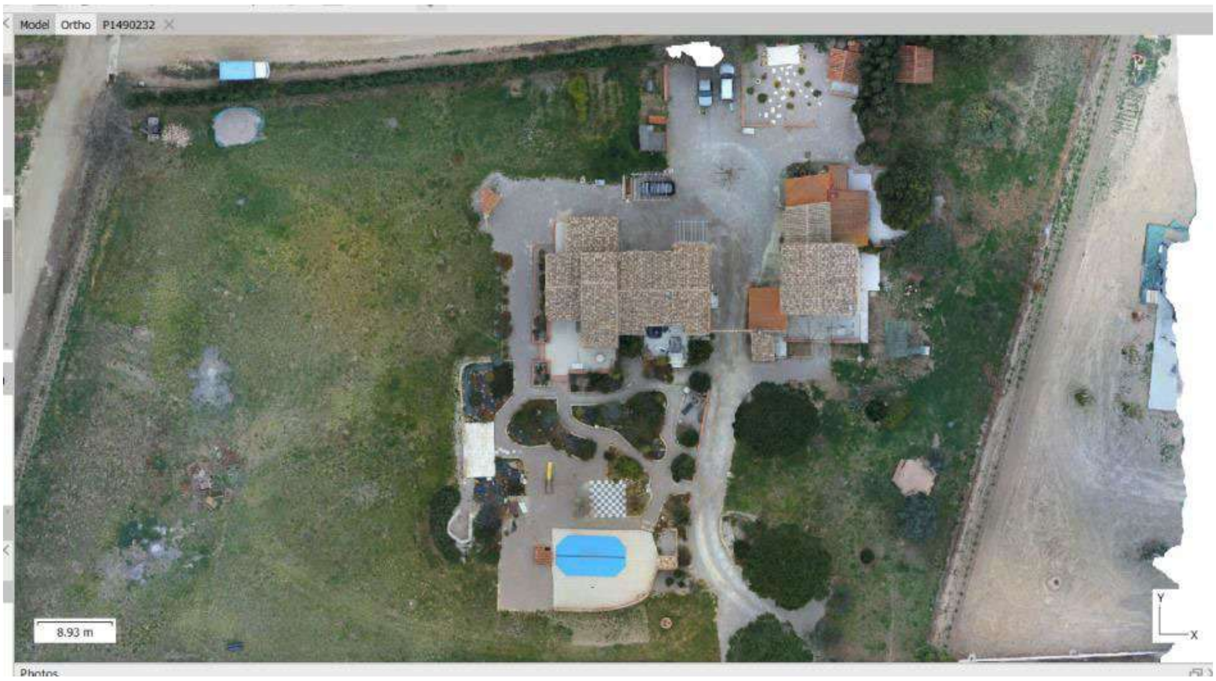


Figure 7-2 orthomosaic result

In order to assure correct scaling please check the dimensions of some objects .

Additionally, the above can be achieved by comparing some coordinates obtained by a classical instruments survey.

8. Create a digital elevation model

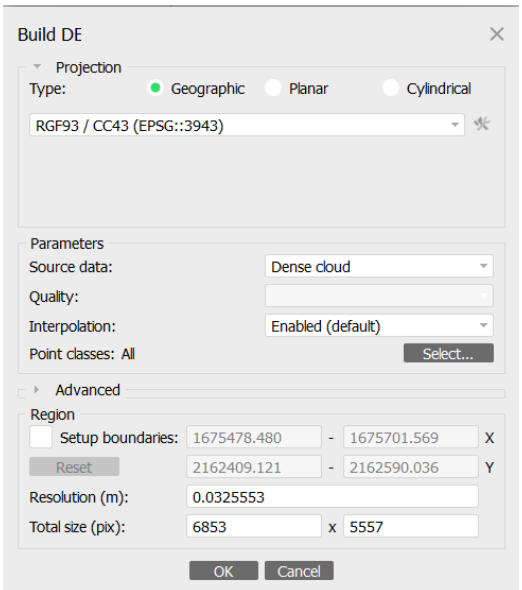
This step creates a "2.5D plan view" with elevations stored in a related regular grid.

Two kind of results can be obtained:

- The DSM: digital surface model = all the points of the model with their elevation related to the surface of the earth. Everything is on the DSM: vegetation, buildings, fences... plus the ground.
- The DTM: digital terrain model = only the ground = it has to be filtered by a previous operation on the mesh : classification of the mesh. This operation will make "automatically" the difference between the ground, trees, buildings... and then the ground can be filtered to obtain only the 2.5D terrain, the DTM.

Build a DSM

Menu **workflow : build DEM...**



Use a planar projection to set a "zero" reference different from the geographic elevation.

Dense cloud is the recommended source

For the DSM enable interpolation

The resolution of the elevation grid is automatic, but it is possible to reduce the area to be treated

Figure 8-1 DEM processing menu

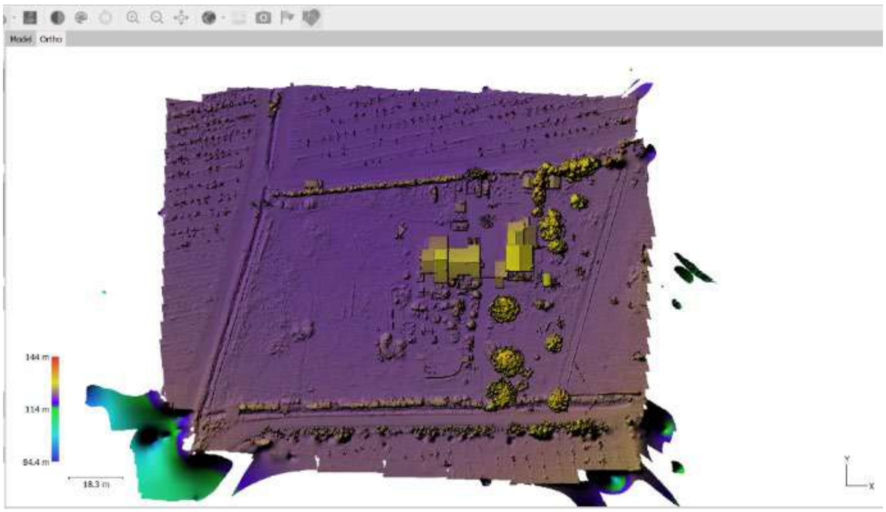


Figure 8-2 DEM result

Result: without precaution on the dense cloud edges

View the result on the "ortho" display

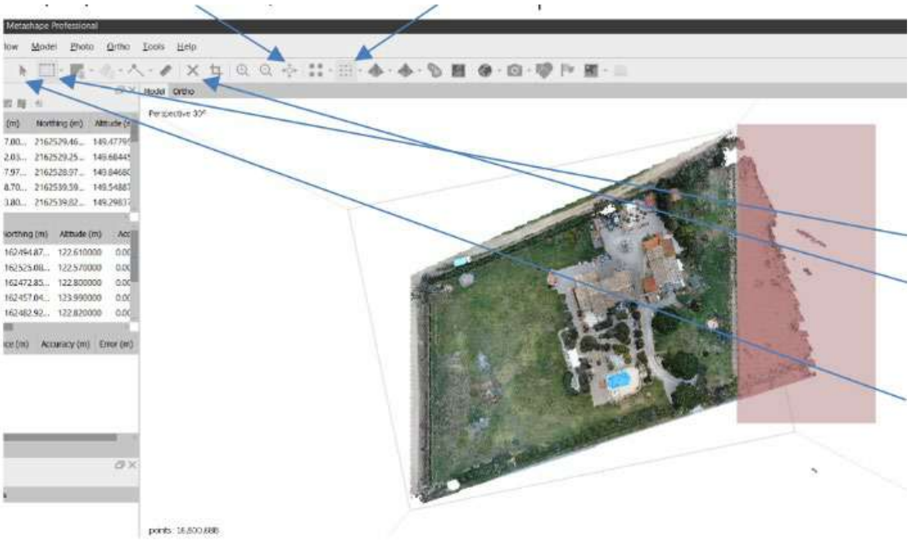
Here the interpolation work made aberrations on the edges.

Our dense cloud was bad on the edges, let's cut it out!

Cutting the dense cloud

The dense cloud must be limited to the place to model and the good points:

Display the face view, and the dense cloud



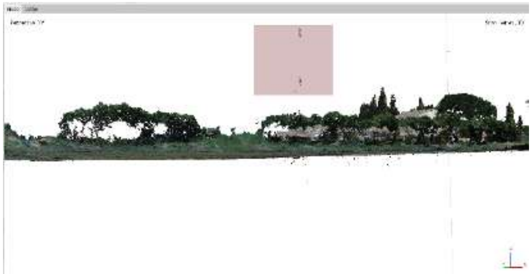
Turn the cloud to place one side parallel to the window (stay in the X,Y plane view, don't go 3D)

Use the rectangle selection

Click "delete"

Go back to the arrow move and repeat with all sides

Figure 8-3 dense cloud cutting in plane view



do it on the side also, with a X,Z or Y,Z view

Figure 8-4 dense cloud cutting in elevation (side) view

Record project to finalise.

The point cloud now only contains the plot to compute, good points.

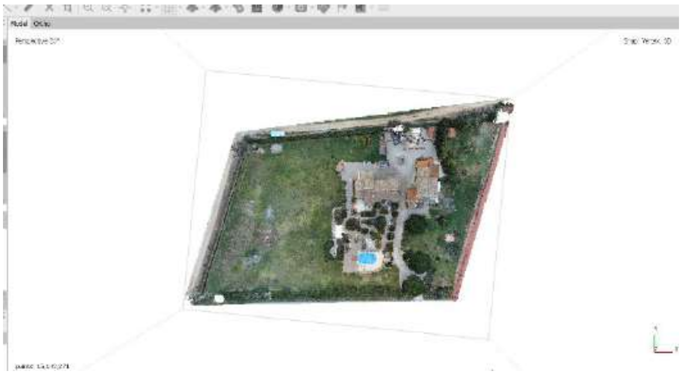
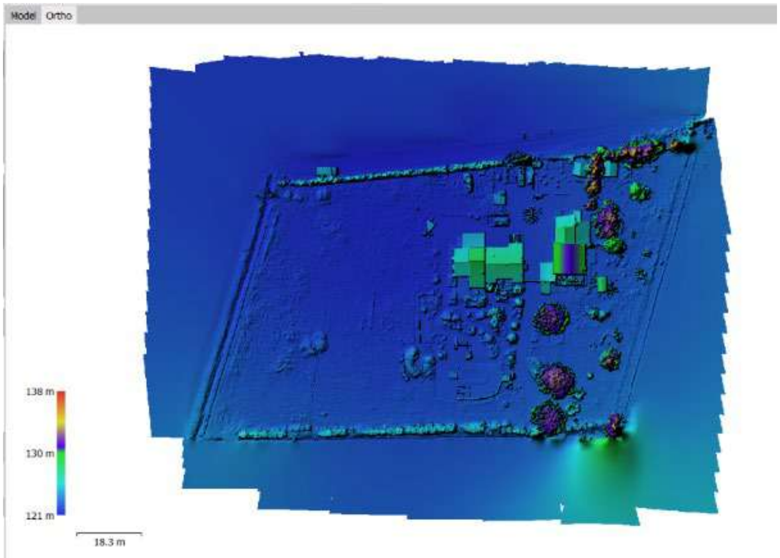


Figure 8-5 dense cloud limited to the worksite

Repeat the operation: Menu **workflow** : **build DEM...**



the previous DEM is replaced

There are still incoherencies at one edge but now the colour scale is correct

Note the roof of the highest construction in different colours

Figure 8-6 DEM limited to the worksite

Note the edges of the DEM are still large: the model always extends to the limit of the photos. photos should be cropped...

Build a DTM : classification first

Before processing to the “build DEM” it is mandatory to classify the point cloud.

This operation will attach each point to a category: ground, vegetation, buildings... then it will be possible to create a new DEM with only the ground to obtain a proper Digital Terrain Model.

Menu **tools** : **dense cloud classify ground points...**

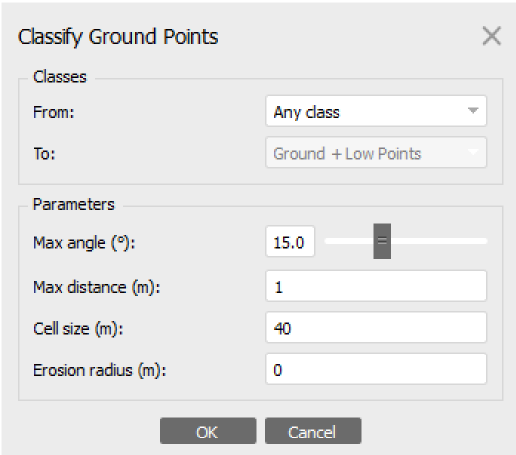


Figure 8-7 dense cloud classification menu

Try first with the default values:

The 15°angle is ok for soft slopes, if the slopes are higher, place a higher angle, or if there are rocks on the ground or cliffs. This angle is a test between two points to classify.

Max distance is the vertical maximal variation between 2 close points: eliminates walls, trunks...

A cell contains no ground point, place it large

The erosion radius is a distance to exclude point at the basis of non-ground point, it eliminates their “stump”.

Make tests to obtain the right DTM.

Display the result with the toolbar.

The ground class is coloured in brown

Change the settings, and try again if not correct: below figure pictures the result of the “1m max distance”: walls measure up to 1m high.

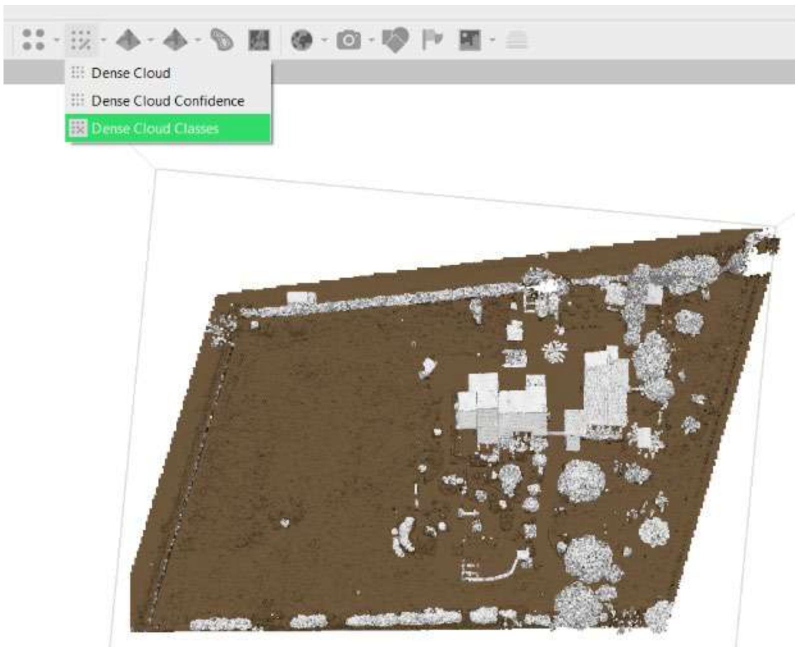


Figure 8-8 dense cloud ground class points

Figure 8-9 dense cloud ground class points seen close : walls are in the wrong class because of the "1m max distance" set

Next try with 0.1m of max distance and 0m erosion radius :

The walls are totally removed, but not all the little vegetation

Figure 8-10 dense cloud ground class correct points

Menu **workflow** : **build DEM...**

Click "select" next to "point classes" and select only "ground"

Interpolation is enabled

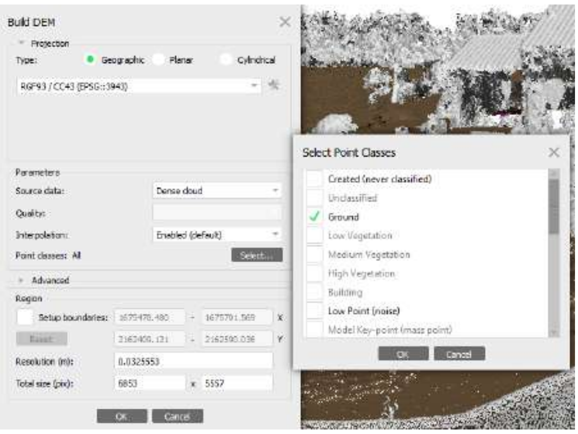


Figure 8-11 build DEM menu with ground selection for DTM

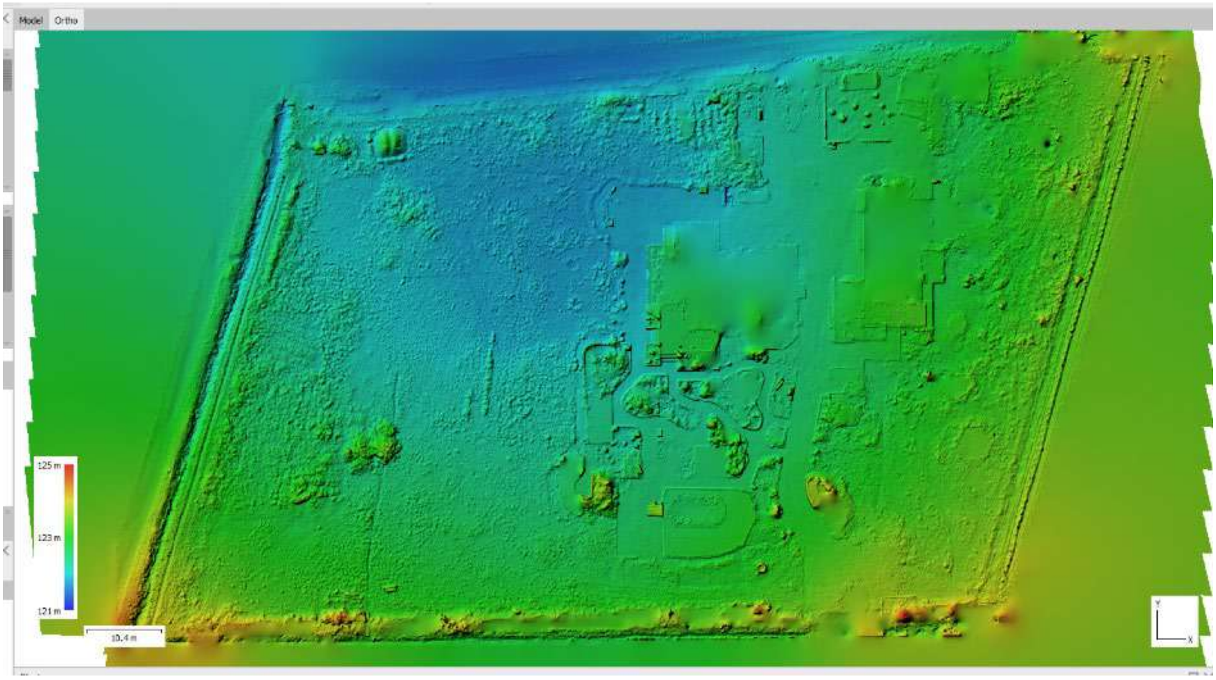


Figure 8-12 obtained by processing only the ground class points

The DTM excludes the houses, walls, trees.

But it keeps low vegetation, low constructions

It is not a real DTM as if it was surveyed with a total station and a prism pole, or a LIDAR drone flight.

The only way to obtain the real DTM by photogrammetry is to have no vegetation at all, like in a quarry:

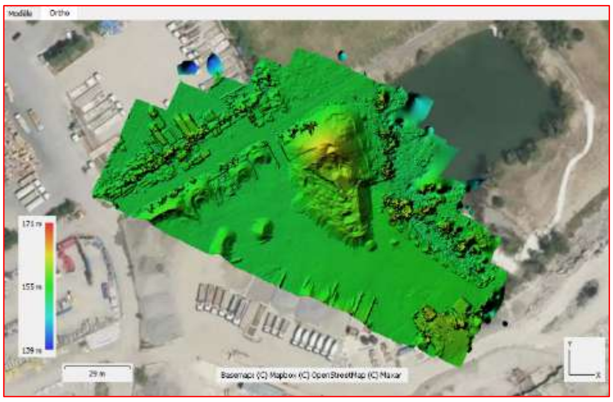
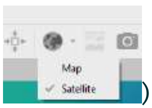


Figure 8-13 DTM of a quarry

This DTM of a quarry is very accurate.

The satellite view is displayed (click



)

As the model is geolocated, it positions perfectly in the satellite view. (problem: it is not possible to select the satellite view source with version under 2.0 of metashape)

On this magnified part, see how the "no ground" part are filled: like a stretched canvas between the points all around.
Under houses, cars, trees. See also that the low vegetation is falsely integrated to the DTM…

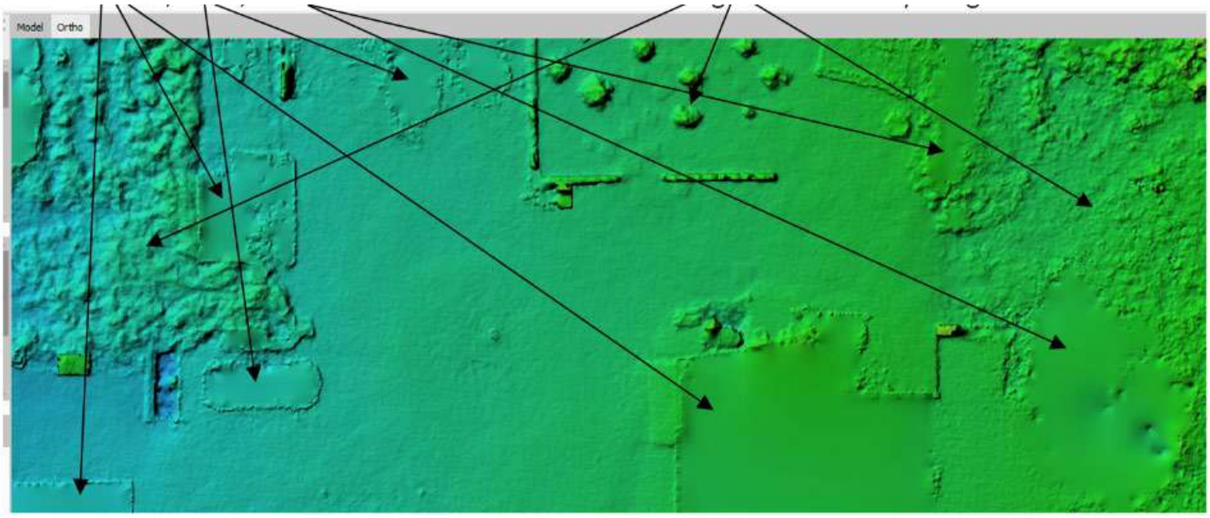


Figure 8-14 DTM after processing

The same place in the tiled model:

Figure 8-15 tiled model showing all the items removed by classification to obtain the DTM

9. Multiclassifying a point cloud

In the previous step the classification concerned only the ground, let's refine the classification, to remove only some objects, and maybe get an even better DTM...

Menu **tools : dense cloud classify points**

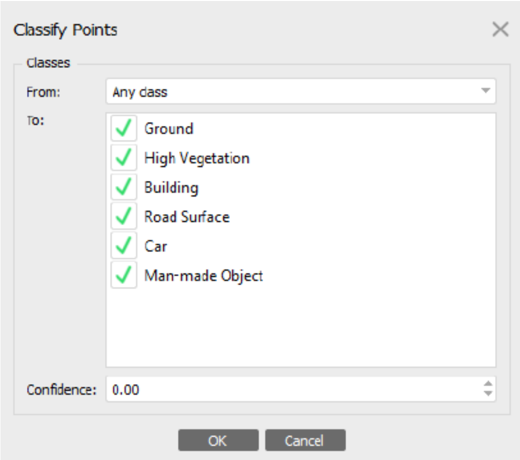
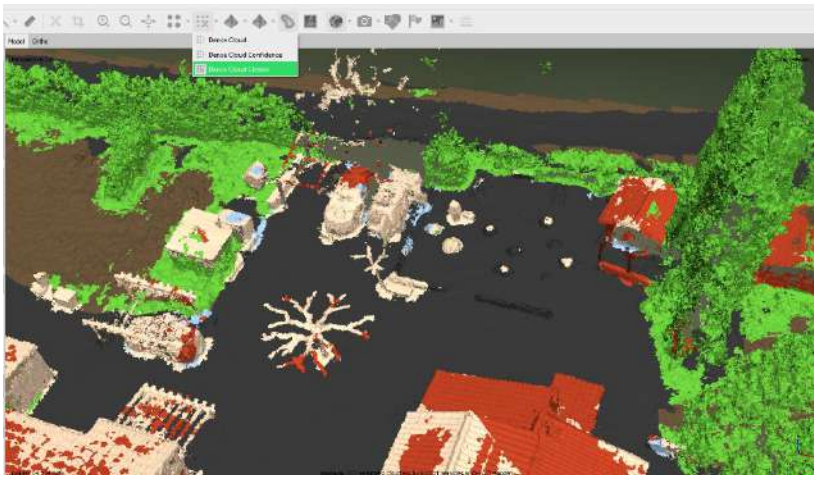


Figure 9-1 classify points menu

Select all, or not.

Confidence vary from 0 : all points will be classified

To 1 : a point that cannot be clearly classified will remain unclassified



result: (click dense cloud classes)

green=vegetation

brown=ground

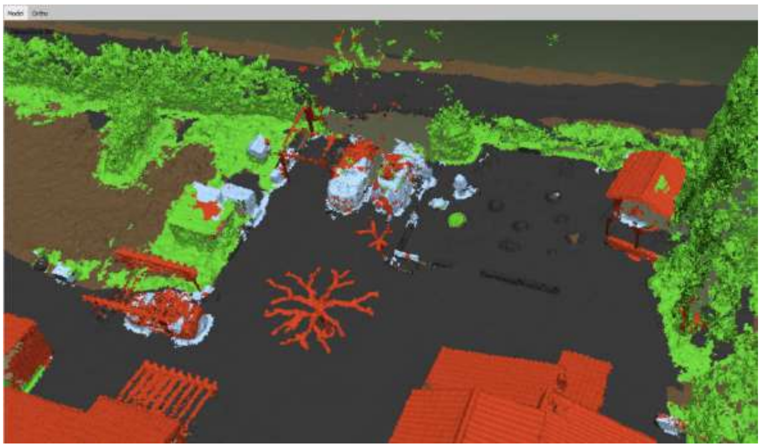
red=buildings (!!)

dark=road

light blue=car (!!)

light brown=man-made objects (!!)

Figure 9-2 classified points bad result



Refine it by unselecting "man-made objects":

- a bit better, particularly for buildings
- not for cars
- not for the central tree (it is now a building)
- not for low vegetation

Figure 9-3 classified points better result, still not perfect

Please use this classification to obtain a DTM, with ground + road selected:

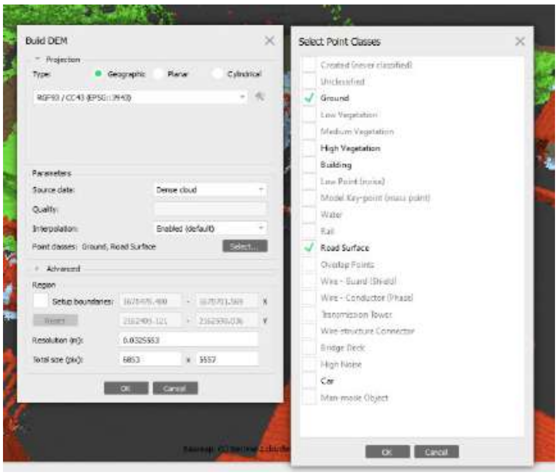


Figure 9-4 DEM menu with ground and road selected for DTM

Result on same place:

Badly classified points appear, we should manually classify them in the good category:

Building

Low vegetation

Global result:

Some errors have to be corrected

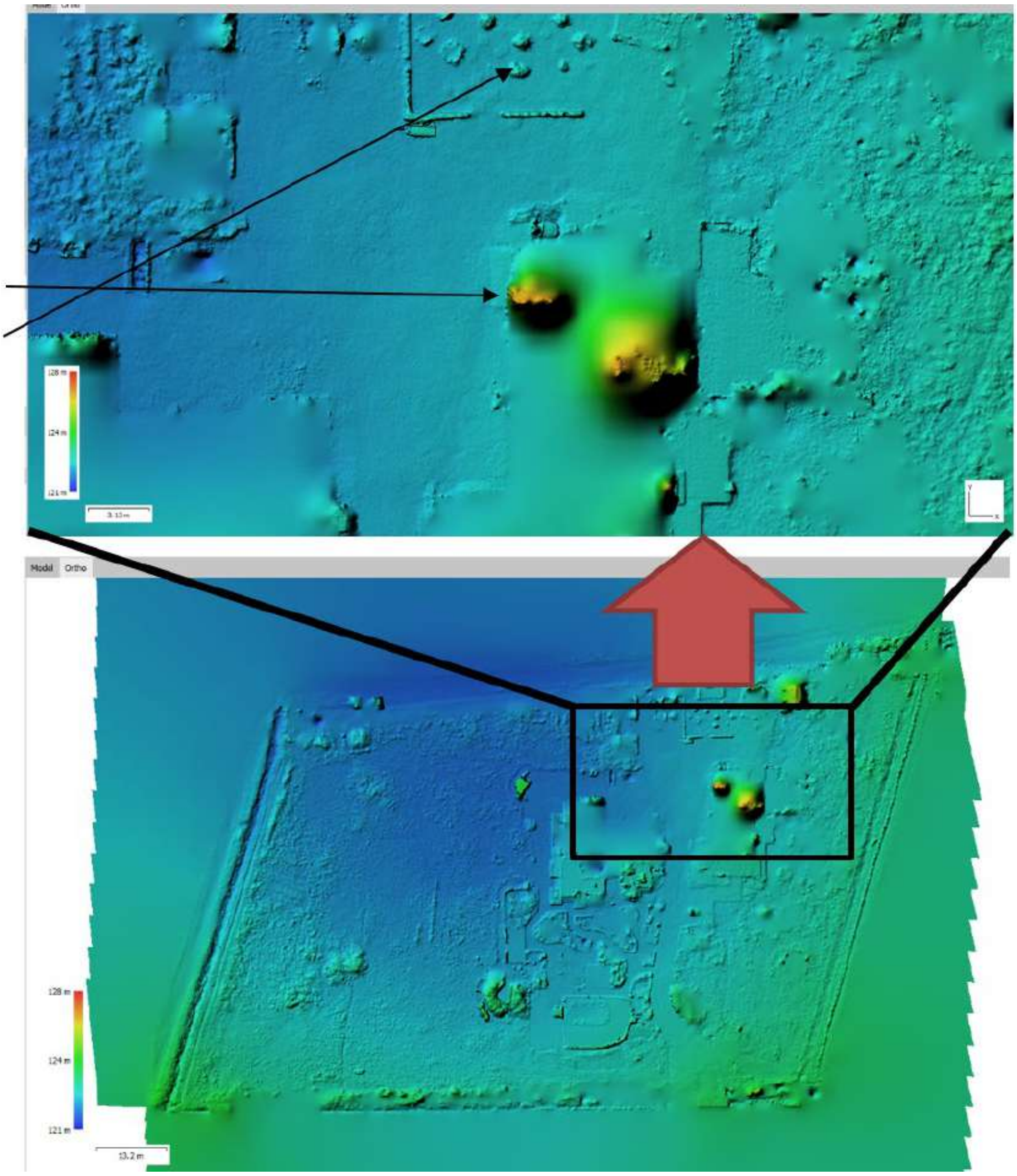


Figure 9-5 DTM result with ground and road selected and zoom on details

Next please assign manually the classes to have a more realistic DTM.

Manual classifying: first display only the ground and road surface points (tools // dense cloud // filter by class)

Figure 9-6 point cloud displaying only ground and road surface

Select the points to change:

Figure 9-7 rectangle selection of some badly classified points

Once the points are selected, go to

Tools // Dense cloud // assign class (possible only if the points are previously selected)

And assign the right class

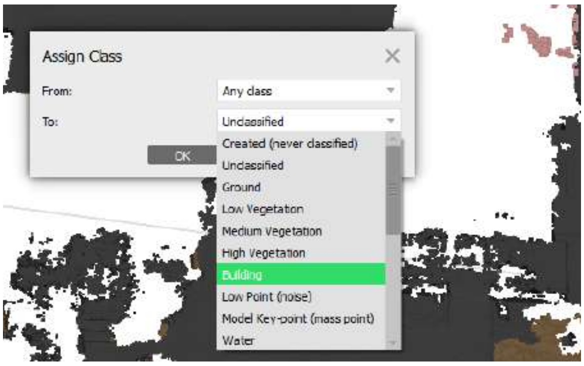


Figure 9-8 assignment of the class "building" to the selected points

The point disappear from the display because they are no longer in the displayed classes, so you can work on the entire cloud by comparing to the actual wrong DTM (toggle between "model" and "ortho").

Move the model so as to see the points above the ground:

Here the BBQ wall was classified as ground

And crated a mistake in the DTM

Figure 9-9 selection of points in a side view

Next re-compute the DEM with selecting only "ground" and "road surface" classes

And the last detail on the DTM becomes:

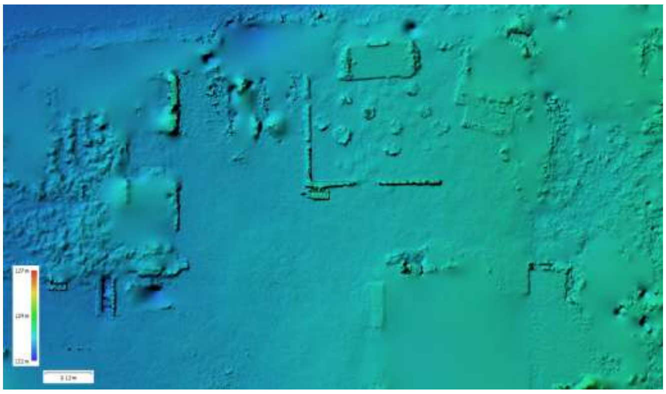


Figure 9-10 previous DTM zoom on details, now corrected

With a much better global result:

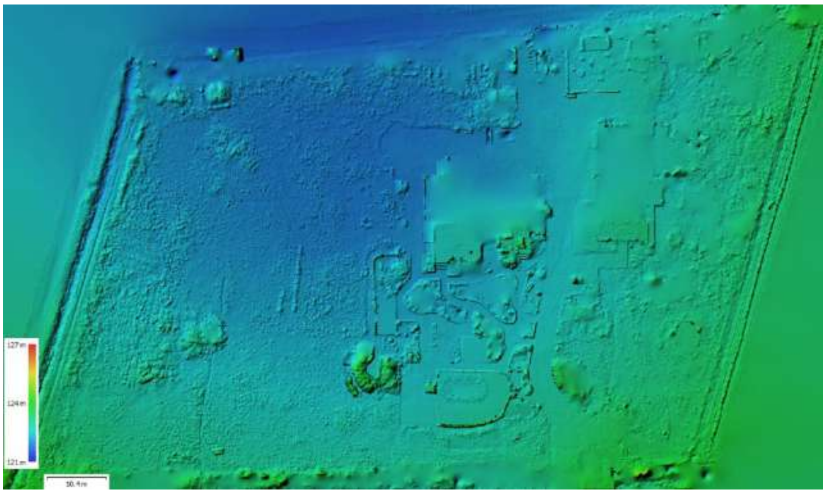


Figure 9-11 DTM result after classification refinement with ground and road selected

Remember: the low vegetation (grass, herbs...) IS the DTM in photogrammetry so a REAL DTM will only be achieved if there is NO vegetation.

10. Exporting a digital model and create a video

10.1 Export a model

Export with menu file // export

Choose your convenient 3D export format and what you need to export.

It all depends on the destination software and the use of the model. Check what kind of 3D or 2D file the destination software can open.

- Point cloud: E57 is common, or LAZ (PDF works but when opening it with pdf reader it is a bit difficult to move the point cloud or the model)
- Model : STL is common
- Tiled model : default TLS works
- Orthomosaic: JPG or TIFF or google maps tiles

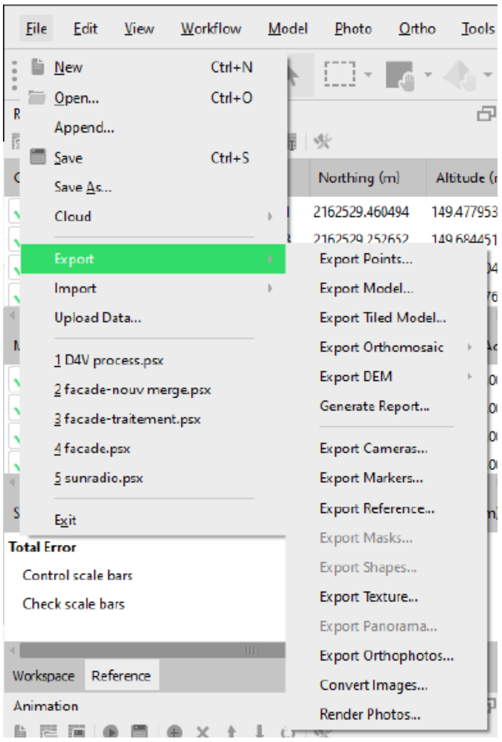


Figure 10-1 export menu

Open in a viewer

Example of free viewer : Agisoft viewer (of course!) but there are many others.

To view any 3D or 2D model : use "add layer"

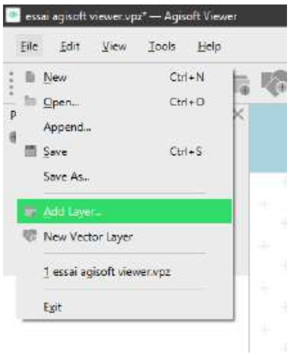


Fig. 10-2 file menu in Agisoft viewer

Move the model by using the mouse wheel (hold click to change view, roll to zoom)

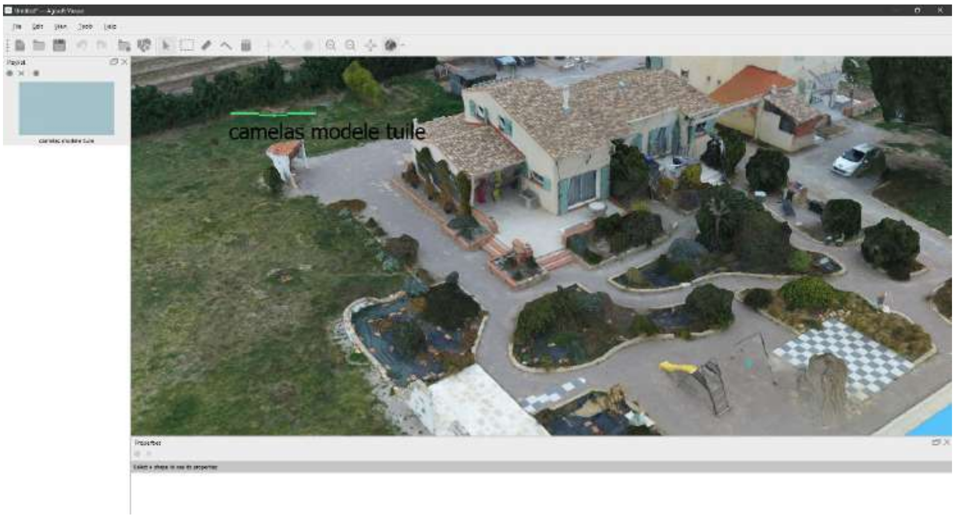


Figure 10-2 Agisoft viewer

10.2 Metashape video recording

One of the most simple ways to present work is to create a video of the turning model.

It can be shared with anyone !

Simple « turning model » video

If settings remain unchanged, a circular path is created along which a virtual camera is facing the model.

Proceed to record and obtain a 30 seconds MP4 file of the model turning in the air.

Display the « animation » window at the left down the screen :

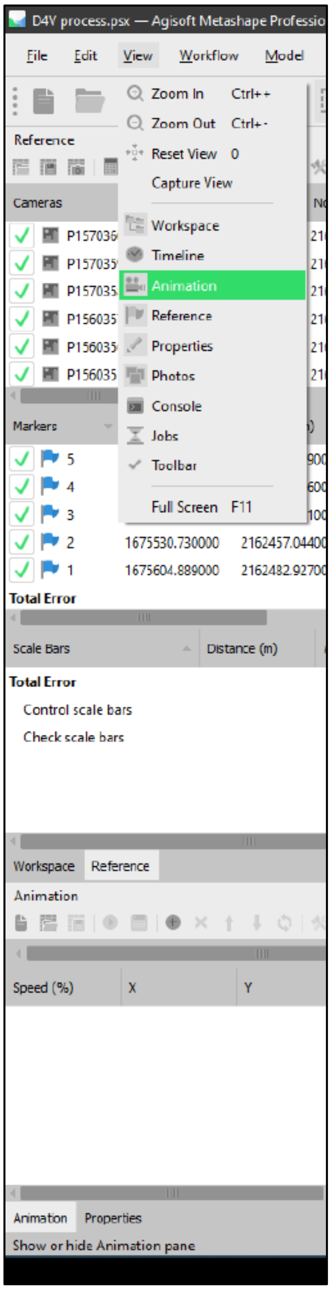
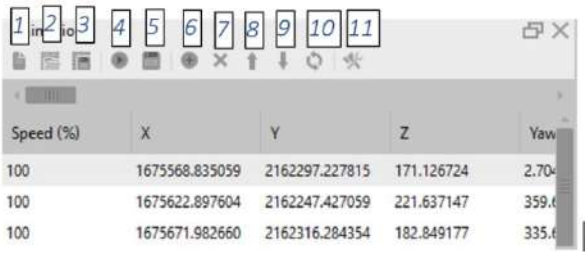


Figure 10-3 switch on the animation window

The animation window will appear on lower left



1: Create a new animation

2: load a camera path

3: record a camera path

4: play animation in metashape main screen (except angle of view)

5: capture animation, makes a MP4 file

6: add the actual main screen view in the path

7: delete a camera position

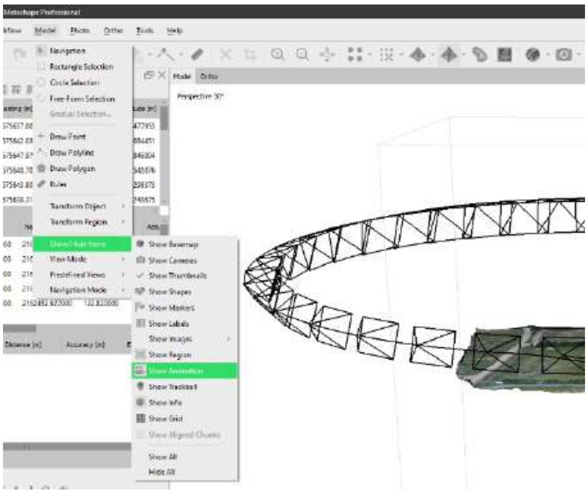
8 & 9: moves a camera position in the list

10: update the path and the list

11: settings

Move the cursor to see each camera position displayed in the main screen

- Click « create » [button1] set to “horizontal” and leave the default key frames number



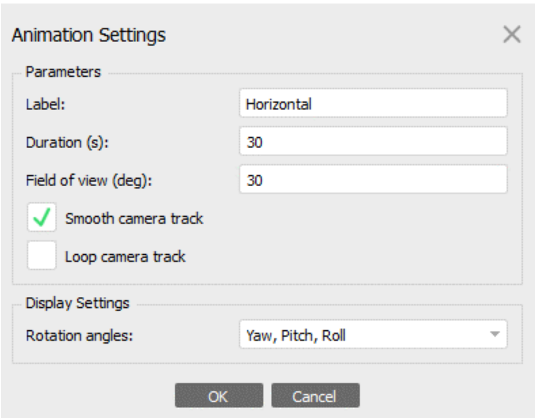
Display the camera path and orientation: use menu Model // show/hide items // show animation.

Each cone is a camera position (“key frame”), linked by a spline (or a straight line if “smooth camera track” is unchecked, see “settings” below).

Figure 10-4 display the path and camera positions

- click “play” [button4] to see the animation
- click “capture” [button5] to record a MP4 file

In case a different video is needed please click “settings” [button11] and



change the duration value

change the field of view, to zoom in and see your model bigger in the video

smooth camera track checked in case you move the camera points of view

loop camera track to close the path

angles are the names you prefer to orient the camera

Figure 10-5 animation settings window

NOTA : when the angle of view is modified, the result is not displayed in the main screen (when press “play”), you can only see it in the MP4 video file.

Video with a specific camera path

Click "create" and adjust the number of camera positions: The "key frame count" is the number of position around the model, linked by straight lines.

The path can be modified by selecting the tip of the cone and moving it.

Setting a specific view in the Model display is also available (with the usual moves of the mouse) following adding it to the path by clicking the "append" button ( ).

Not very easy...

50 key frames (default) : very circular movement.

Figure 10-6 camera movement with 50 key framescamera movement with 50 key frames

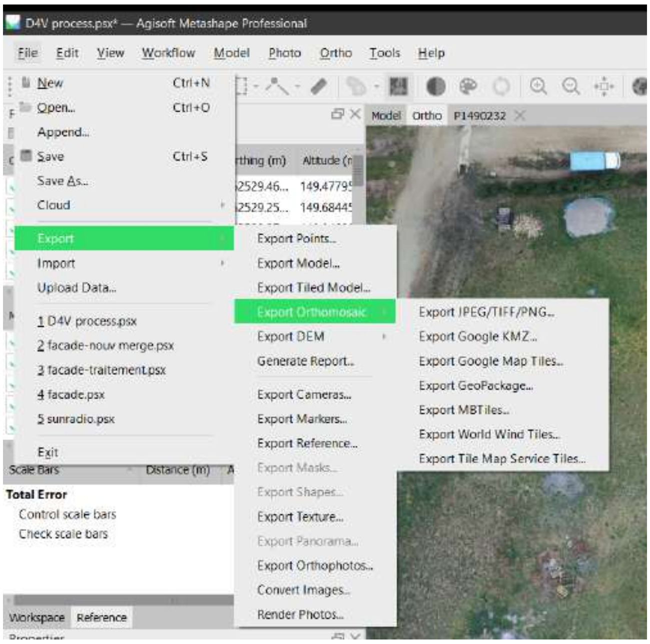
10 key frames and "smooth camera track" unchecked: the movement will not be a real circle but follow the lines and go "in and out"

Figure 10-7 camera movement with 10 key frames and no smooth camera track

Record the new video and check the result and so on...

11. Drawing a plan from a model or an orthomosaic

The orthomosaic can be used to produce a plan on a CAD software. Particularly if your scaling is accurate.



Export the orthomosaic in jpeg or tiff format to use it in a software to draw the plan.

Figure 11-1 file menu and select export JPEG/TIFF/PNG

Use the markers to position the orthophoto on the right coordinates before drawing.

Figure 11-2 worksite plan obtained with the scaled orthomosaic on Autocad

List of figures