Version 2

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Structure-from-motion multi-view photogrammetry applied to linear-scan sediment cores images V.2

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ABSTRACT

Image acquisition is the first step to save primary color information for environmental samples before disturbing them with other, mainly destructive analyses. The improvement of RGB cameras and image processing algorithms allows to obtain a metrically calibrated image at high resolution called ortho-image. The way to obtain this image requires the processing of several raw images acquired along the sample. We propose a semi-automatic method that uses metrically calibrated targets to create the ortho-image with Agisoft Photoscan or Metashape software.
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KEYWORDS

Structure from motion, Photogrammetry, Sediment core, Automatic image assembly, Orthorectification, Agisoft Metashape, Agisoft Photoscan

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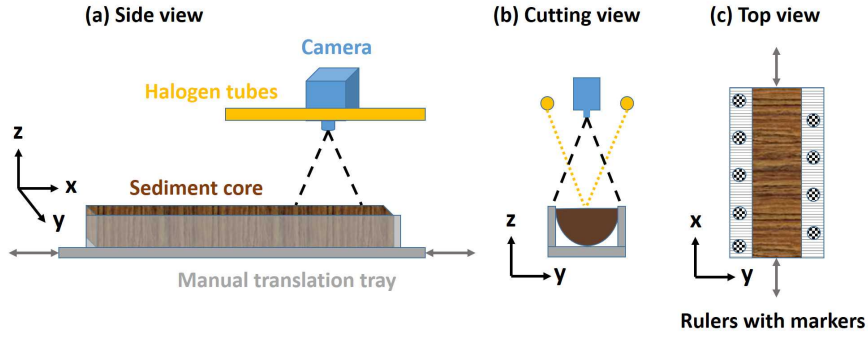
General description of the acquisition bench

1



Schematic description of the sediment core image acquisition tray by linear scanning

2

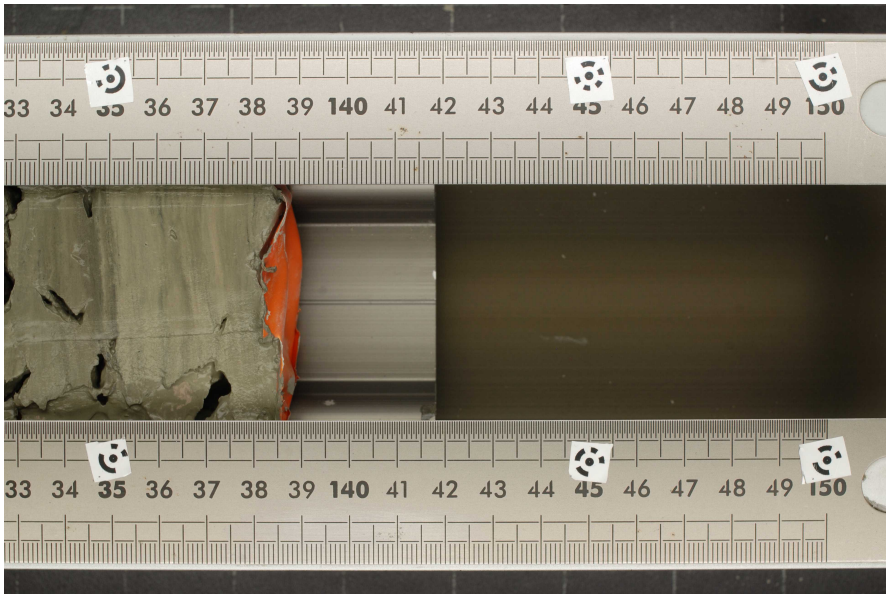


Image obtained with the acquisition bench. Sedimentary core surrounded by two rulers and markers

Camera acquisition parameters and calibration

3

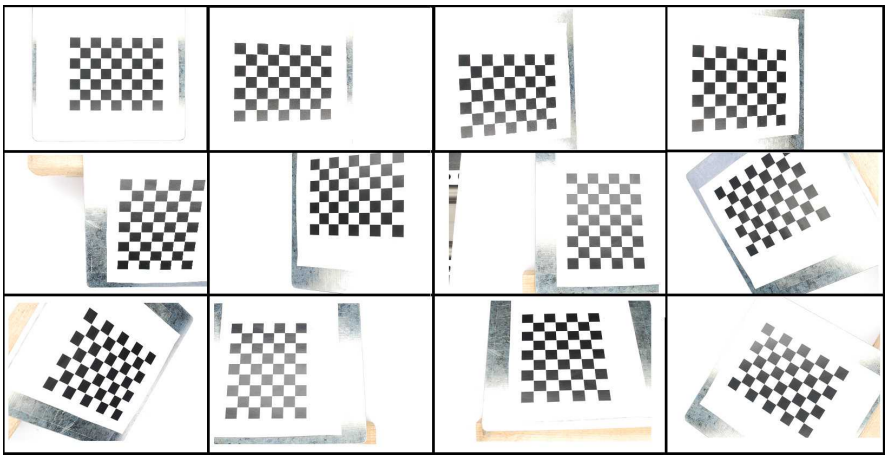
It is important that the parameters related to the camera (shutter speed, aperture, etc.) are fixed throughout the acquisition. The autofocus must also be disabled.

4 With the chosen acquisition parameters, the camera must be calibrated in two steps:

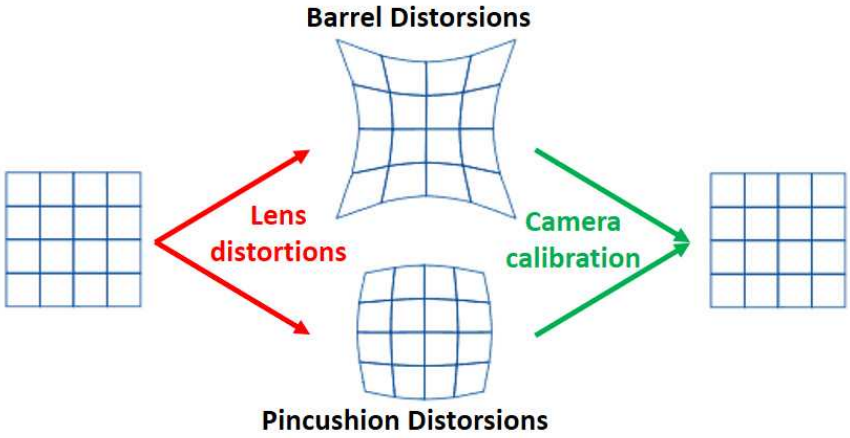
4.1 The first is to perform a white balance, in order to obtain relevant colors according to the lighting, this is called radiometric correction.

4.2 The second consists in taking pictures of a checkerboard from several angles and over the entire

surface acquired by the camera. This allows to correct the images for geometric distortions induced by the lens that imply that the pixels are not square.

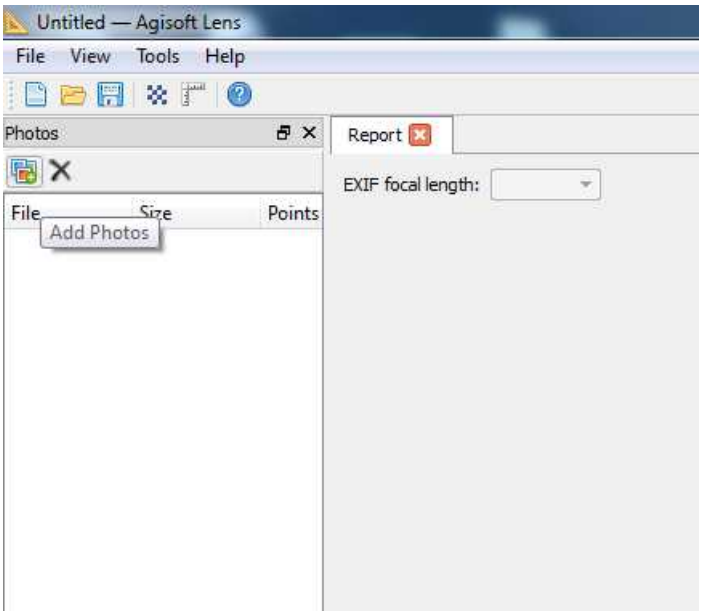


Images of a checkerboard from several angles to estimate and correct geometric distortions

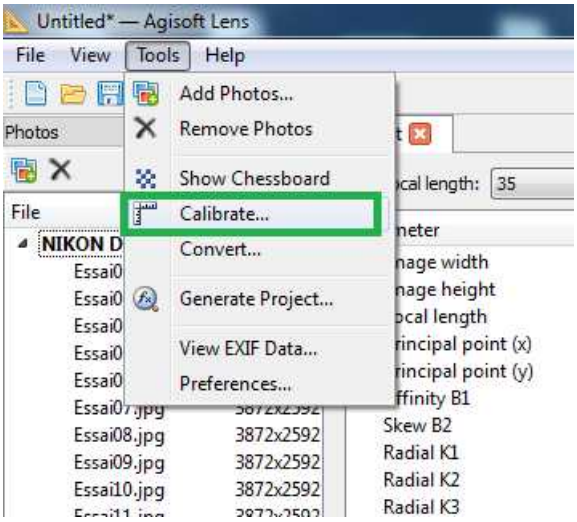


Schematic representation of geometric distortions

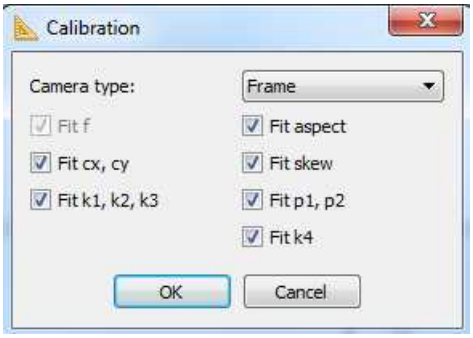
The Agisoft Lens software uses these checkerboard images to estimate the corrections to be applied to the images.



Importing images



Estimation of distortions and corrections



Estimation of distortions and corrections

Parameter	Value	Std Error
Image width	3872	
Image height	2592	
Focal length	6920.31	8.33543
Principal point (x)	38.5544	10.6292
Principal point (y)	18.1709	10.0175
Affinity B1	5.49436	1.19621
Skew B2	2.06652	1.1059
Radial K1	-0.318467	0.0315086
Radial K2	10.6337	1.82587
Radial K3	-194.687	40.1366
Radial K4	1191.93	87548.5
Tangential P1	0.000834325	0.000387833
Tangential P2	0.00141209	0.000383861

Example of estimated parameters

Recommendations on coded markers and their georeferencing

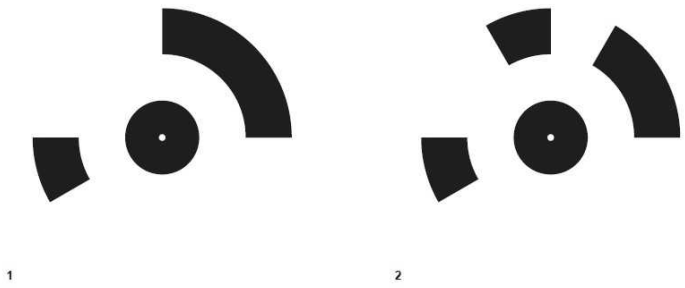
5 The method described in this protocol relies on markers placed on rulers along the sample to create a planar spatial reference (z=0).
The Agisoft Photoscan or Metashape software proposes a list of markers all different which will be automatically recognized by the software.
These markers must be placed in a regular way so as to be present on three successive images to allow a good registration of the images and at a size not exceeding 30 pixels for the central circle. In our case, the markers are 10 cm apart and have a diameter of 1 cm.

Markers should be printed on a material that does not get damaged and remains clean from sediment and water. They should also not be plastified as this will reflect light, and the algorithm will be distorted. For these reasons, we decided to use a mat adhesive paper.

These targets should be cut in squares and not in circles, keeping in mind that the targets are circles on a white background.

If a marker is damaged, it will probably be necessary to replace it with a new one that must be different from the others.

6 Each marker, defined by the software, is numbered and must be georeferenced to constrain the models with this landmark created with the rules and markers.
The georeferencing is performed by measuring the position of the marker's center relative to a point defined as the origin. In our case, the origin was chosen as one of the corners of the sedimentary core frame by the rulers.
The marker numbers and their positions are recorded in a csv file which will be used by the software.



Example of markers

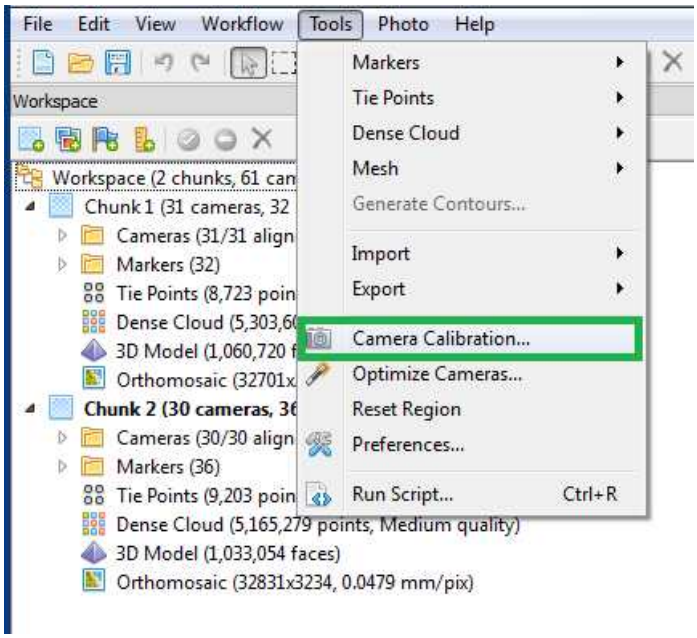
Image acquisition

7 The acquisition of the images must be carried out to have sufficient overlap between the successive images.
In our case, we have chosen an overlap of 75% so that each point of the sample is present on 4 images.

Creation of the orthoimage

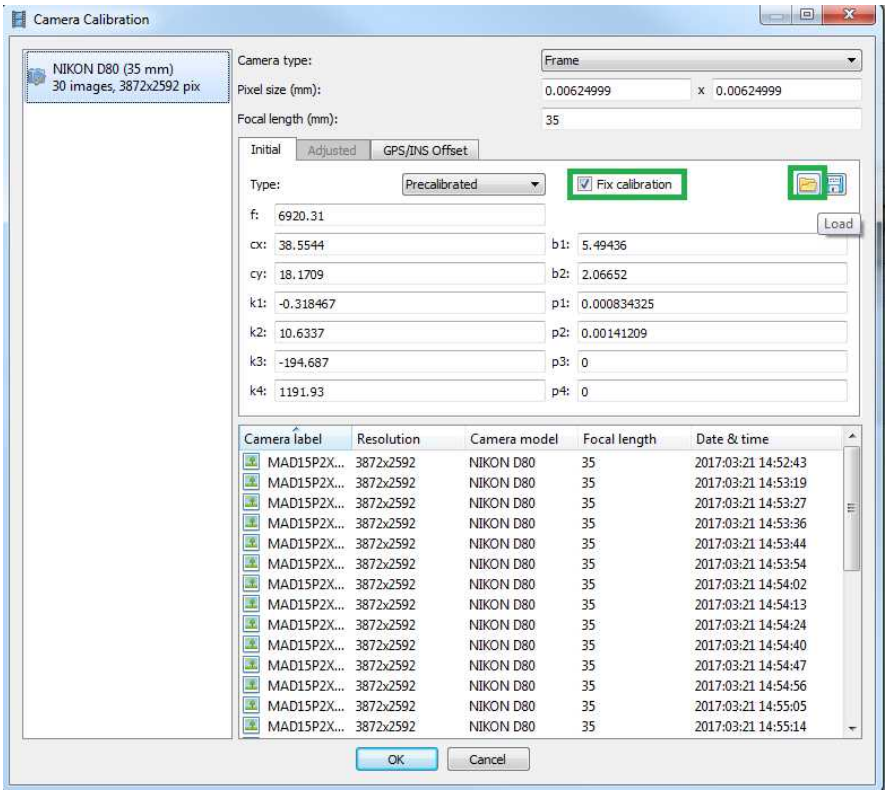
8 1) Importing images
Select the images with the "Add Photos" icon in the Workspace tab or in Workflow > Add Photos...

9 2) Corrections with camera settings
Now that the images have been loaded, they need to be corrected with the camera settings. You have to import them by going to Tools > Camera Calibration...



Loading camera distortion correction parameters

Then load the parameters with the "load" icon. Set the calibration to be applied to all images by checking the box.



Loading camera distortion correction parameters

10 3) Marker detection

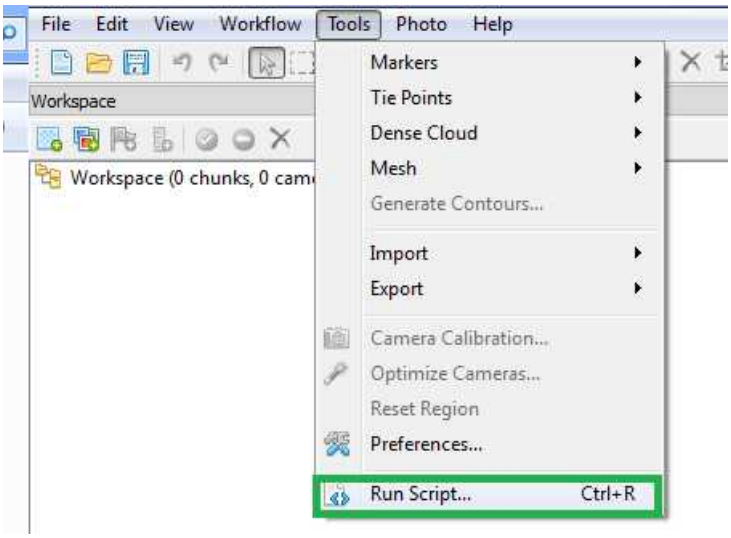
Two methods can be used to detect and georeference the markers. One automatic and one semi-automatic.

10.1 Automatic method:

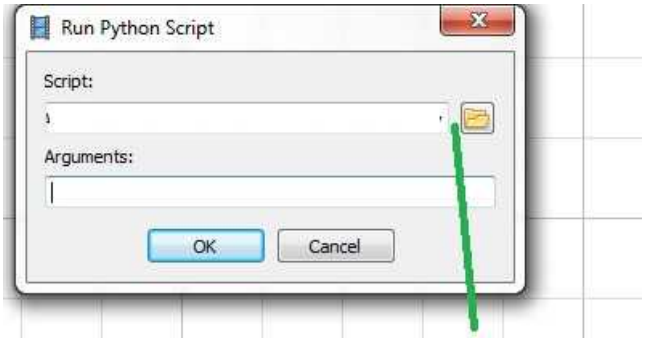
A Python script has been developed to detect the markers and retrieve their positions in the csv file previously created in step 6.[It can be found on github]().

> It is possible that this script must be corrected, because in the case of a change of version of the Agisoft software, the command tags may be different.

Load the script that will automatically detect the markers and associate them with their coordinates (x, y, z). To do this go to Tools > Run Script...

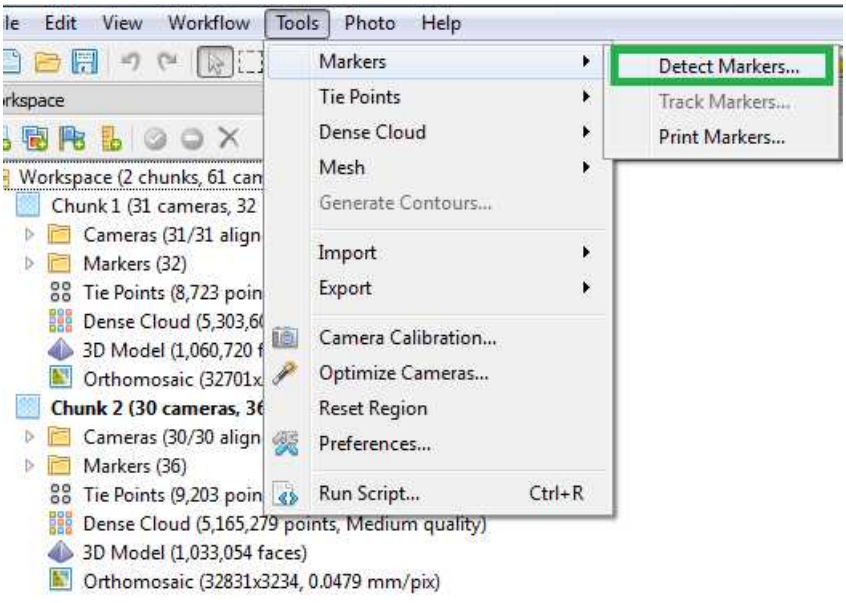


Opening the Python script



Opening the Python script

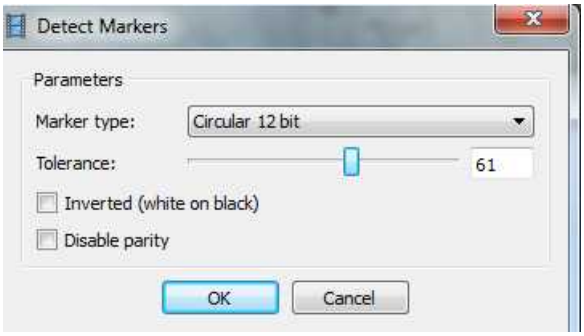
10.2 Semi-automatic method:
Markers can be detected in Tools > Markers > Detect markers...



Marker detection

Then define the markers to be detected according to those that have been printed and placed on the

rulers.



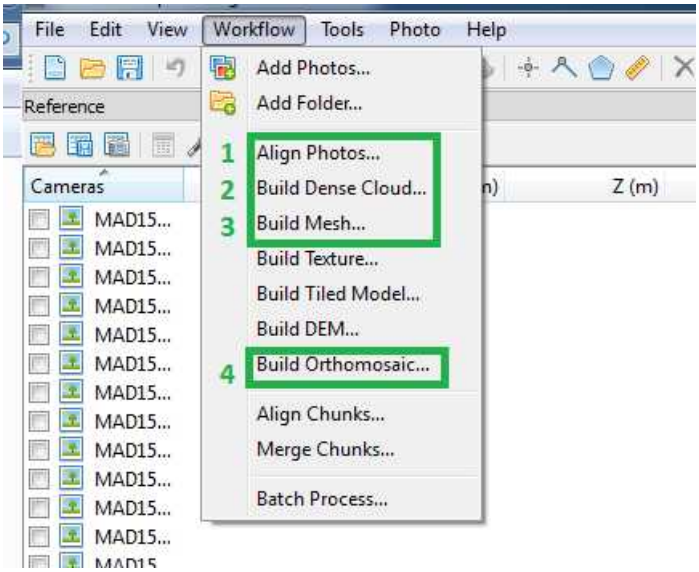
Markers to be detected

After the markers have been detected, it is necessary to manually enter their positions in x,y, and z in meters.

Markers	X (m)	Y (m)	Z (m)
5cm_h	0.050000	0.000000	0.000000
15cm_h	0.150000	0.000000	0.000000
25cm_h	0.250000	0.000000	0.000000
35cm_h	0.350000	0.000000	0.000000
target 18	0.450000	0.080000	0.000000
target 23	0.550000	0.080000	0.000000
target 24	0.650000	0.080000	0.000000
target 29	0.750000	0.080000	0.000000
target 30	0.850000	0.080000	0.000000
target 63	0.450000	0.000000	0.000000
target 64	0.550000	0.000000	0.000000
target 65	0.850000	0.000000	0.000000
target 66	0.950000	0.000000	0.000000
target 69	0.650000	0.000000	0.000000
target 70	0.750000	0.000000	0.000000
target 71	1.050000	0.000000	0.000000
target 72	1.150000	0.000000	0.000000
target 78	1.450000	0.080000	0.000000
target 82	1.150000	0.080000	0.000000
target 83	1.500000	0.080000	0.000000
target 84	1.540000	0.080000	0.000000
target 87	1.250000	0.080000	0.000000
target 88	1.350000	0.080000	0.000000
target 89	1.540000	0.025000	0.000000
target 121	1.250000	0.000000	0.000000
target 122	1.350000	0.000000	0.000000
target 123	0.050000	0.080000	0.000000
target 124	0.150000	0.080000	0.000000
target 127	1.450000	0.000000	0.000000
target 128	1.500000	0.000000	0.000000
target 129	0.250000	0.080000	0.000000
target 130	0.350000	0.080000	0.000000
target 151	-0.030000	0.000000	0.000000
target 152	-0.030000	0.085000	0.000000
target 153	0.950000	0.080000	0.000000
target 154	1.050000	0.080000	0.000000

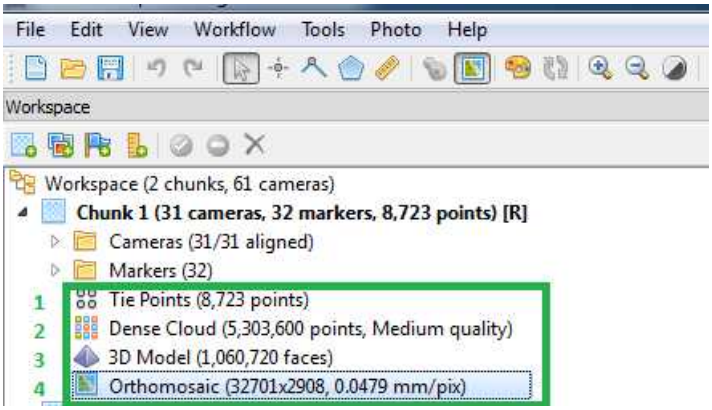
Manual georefencement of each marker with z=0

10.3 Now that everything has been calibrated and the markers defined, it is necessary to follow the order of the Workflow for the creation of the orthoimage.



Workflow for the creation of the orthoimage

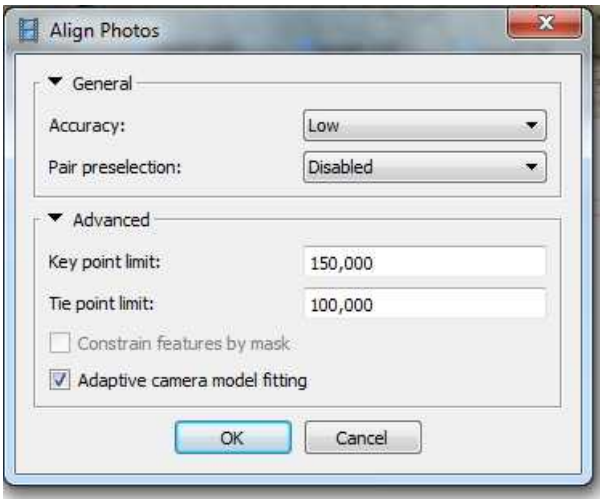
The different stages of the model are visible in the Workspace tab (bottom left) by unrolling Chunk:



Each step of the modeling

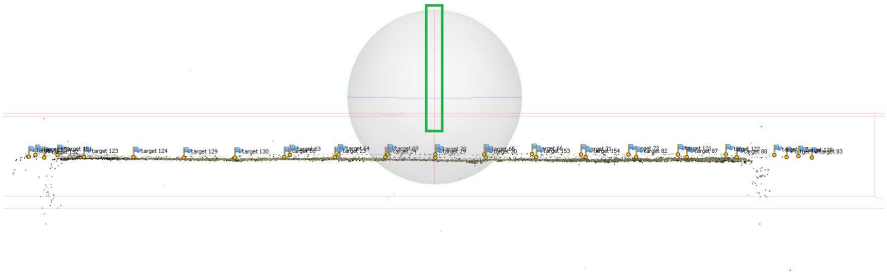
11 4) Registration and assembly

11.1 The first step is the alignment of the images which estimates the analog pixels between them, the positions of the cameras and creates tie points that correspond to the connection points between the images.
Go to Workflow > Align Photos... then select settings.

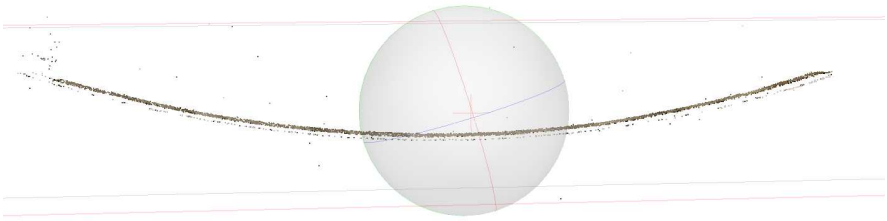


First step of the alignment

This step is the most important. It is important to check that, following these calculations, the reconstruction is horizontal. If a curved shape appear, it is a well-known “dome or arc effect” due to the miss-estimations of pixel positions in x, y, and z typical of linear image acquisition.
To do this, use the radius of the sphere to rotate the model, by staying pressed with the left click, you can rotate it. There may be some points that are not correct, they will not prevent the continuation of the steps. The main thing is that the model is horizontal.



Correct reconstruction



Poor reconstruction

The reconstruction error of the marker positions is also estimated, allowing to estimate areas where new control points have to be added manually to optimize the model. To add control points, select locations on images with right click > Create Marker and right click > Place Marker for the following images to associate a marker to multiple images. It may be necessary to de-align the images, before aligning them with the new control points.

Markers	X (m)	Y (m)	Z (m)	Accuracy (m)	Error (m)	Projections	Error (pix)
target 18	0.450000	0.080000	0.000000	**0.000500**	0.001332	4	0.018
target 23	0.550000	0.080000	0.000000	**0.000500**	0.000611	4	0.033
target 24	0.650000	0.080000	0.000000	**0.000500**	0.000445	4	0.040
target 29	0.750000	0.080000	0.000000	**0.000500**	0.000888	4	0.037
target 30	0.850000	0.080000	0.000000	**0.000500**	0.001011	3	0.031
target 63	0.450000	0.000000	0.000000	**0.000500**	0.001797	4	0.030
target 64	0.550000	0.000000	0.000000	**0.000500**	0.001568	4	0.052
target 65	0.850000	0.000000	0.000000	**0.000500**	0.001849	3	0.057
target 66	0.950000	0.000000	0.000000	**0.000500**	0.001670	4	0.072
target 69	0.650000	0.000000	0.000000	**0.000500**	0.001274	4	0.055
target 70	0.750000	0.000000	0.000000	**0.000500**	0.001135	4	0.045
target 71	1.050000	0.000000	0.000000	**0.000500**	0.000886	4	0.068
target 72	1.150000	0.000000	0.000000	**0.000500**	0.001703	4	0.051
target 78	1.450000	0.080000	0.000000	**0.000500**	0.001824	2	0.005
target 82	1.150000	0.080000	0.000000	**0.000500**	0.000434	4	0.020
target 83	1.500000	0.080000	0.000000	**0.000500**	0.002306	1	0.000
target 87	1.250000	0.080000	0.000000	**0.000500**	0.000696	3	0.013
target 88	1.350000	0.080000	0.000000	**0.000500**	0.000321	4	0.014
target 121	1.250000	0.000000	0.000000	**0.000500**	0.000604	4	0.039
target 122	1.350000	0.000000	0.000000	**0.000500**	0.000506	4	0.025
target 123	0.050000	0.080000	0.000000	**0.000500**	0.000639	4	0.034
target 124	0.150000	0.080000	0.000000	**0.000500**	0.001602	4	0.017
target 127	1.450000	0.000000	0.000000	**0.000500**	0.001550	2	0.004
target 128	1.500000	0.000000	0.000000	**0.000500**	0.003098	1	0.000
target 129	0.250000	0.080000	0.000000	**0.000500**	0.001596	4	0.006
target 130	0.350000	0.080000	0.000000	**0.000500**	0.000731	3	0.014
target 151	-0.030000	0.000000	0.000000	**0.000500**	0.002954	3	0.073
target 152	-0.030000	0.085000	0.000000	**0.000500**	0.002701	3	0.052
target 153	0.950000	0.080000	0.000000	**0.000500**	0.000529	3	0.047
target 154	1.050000	0.080000	0.000000	**0.000500**	0.000464	4	0.035
target 157	-0.068000	0.025000	0.000000	**0.000500**	0.039387	3	0.066
target 158	-0.067000	0.065000	0.000000	**0.000500**	0.039974	3	0.089

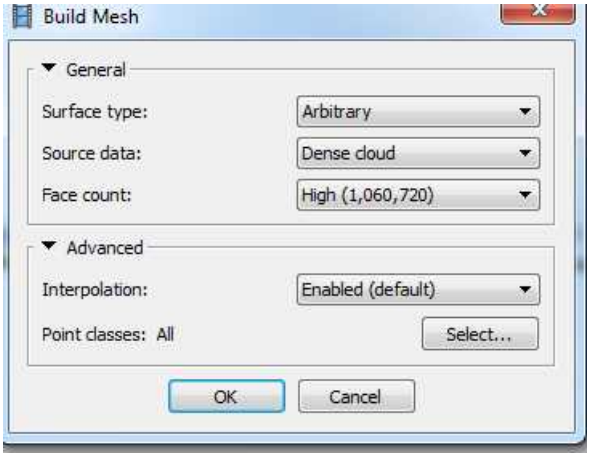
Reconstruction errors

11.2 The second step is the dense cloud that estimates a reconstruction of the depth of each photo and determines its coordinates with the multiview stereo correspondence and the previous estimate of the image geometry.
To calculate the dense cloud, go to Workflow > Build Dense Cloud.

Dense cloud step

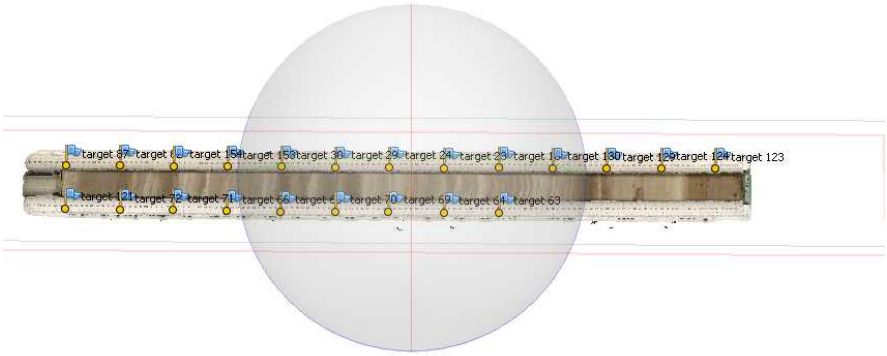
12 5) Mesh and orthorectification:

12.1 The algorithm then uses the points of the dense cloud to generate a closed surface with triangular surfaces, this step is called meshing.
It can be made with Workflow > Build Mesh...

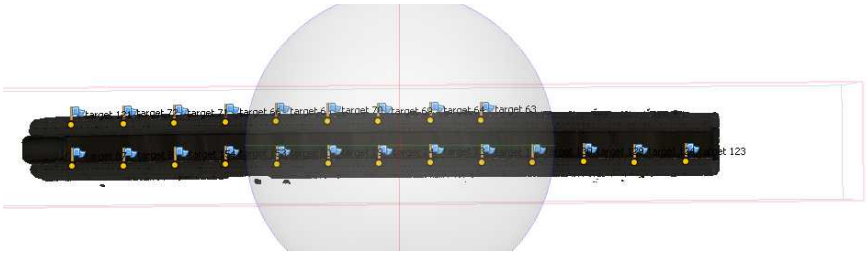


Mesh step

Look at the result of the 3D model. In the case of a very dark image it means that the model is upside down, otherwise the model is in the right direction. This is to be taken into account in the next step.

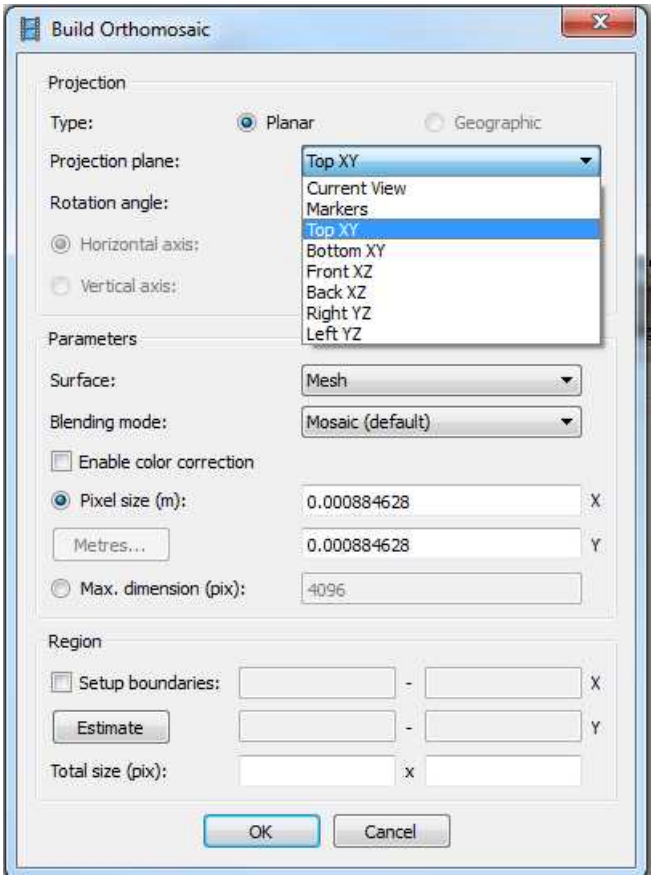


Model in the right direction

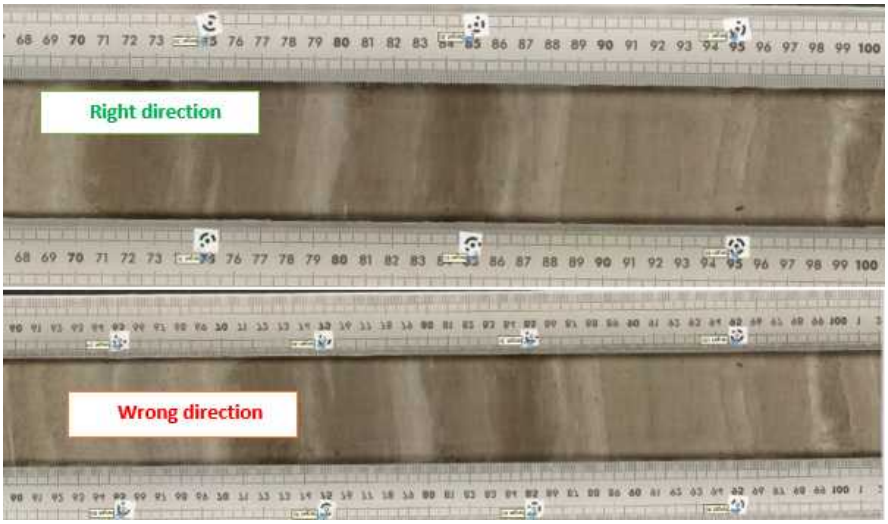


Model in the wrong direction

12.2 Finally, the orthorectified image is estimated from the projection of the colored mesh in a 2D space to correct perspective image and projection distortions.
To perform this step, go to Workflow > Build Orthomosaic...
If the model is in the right direction then select the default settings, otherwise change Top XY to Bottom XY.



Orthoimage creation step



Othoimage according to the direction of modelling

Finally it is possible to export the orthophoto with File > Export Orthomosaic > Export JPEG/TIFF/png...