TUTORIAL

UASMaster 5.7

Trimble

UASMaster Tutorial for Version 5.7 and higher

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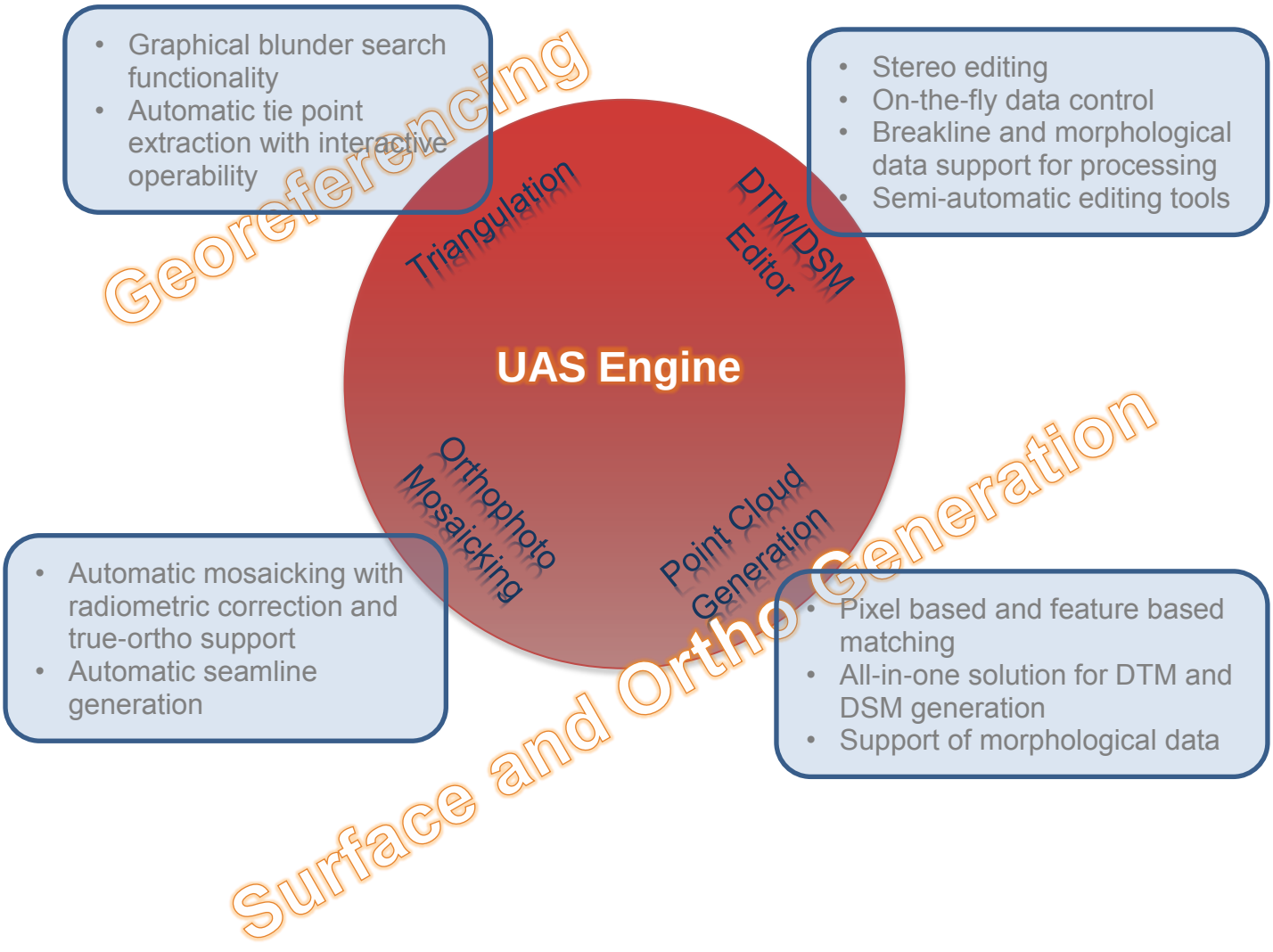
1. About “UASMaster”

UASMaster offers a complete photogrammetric workflow for data coming from Unmanned Aerial Systems (UAS). The software is open for any hardware and offers a streamlined batch processing with QA/QC tools. Various editing tools are available to get the best possible result. UASMaster is bridging the gap between simple black-box workflows for non-photogrammetrists and photogrammetric expert workflows.

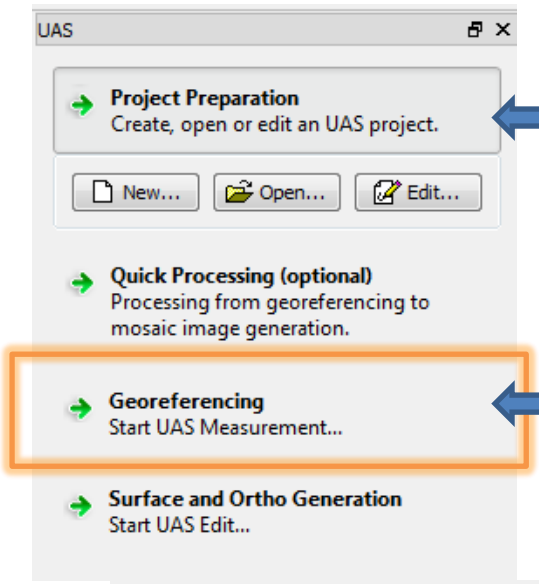
Limitations:

- 2000 images
- 40 Mpix
- Single point cloud file export (no tiling)
- Single mosaic file export (no tiling)

1.1. Modules in “UASMaster”

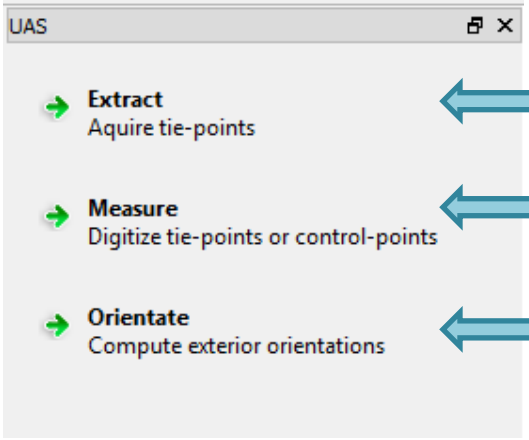


1.1.1. Modules for Georeferencing



Project setup:
- Define coordinate system
- Define camera
- Assign given data (images, ground control points, GNSS, IMU)

Georeferencing:
- Acquire tie points
- Manual ground control point measurement
- Compute exterior orientation with camera calibration

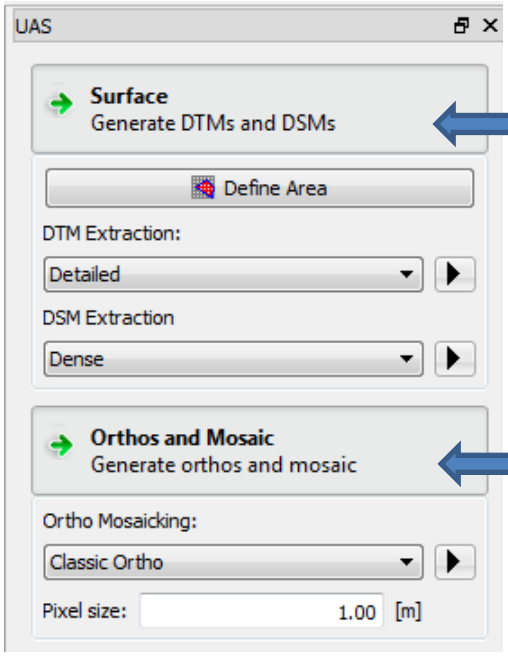


New UAS engine for robust tie point extraction, offering different strategies for different image types.

Manual ground control point measurement.

Strategies for different levels of camera quality

1.1.2. Modules for Surface and Ortho Generation



Creates automatically:
- DTM (feature-based method)
- DSM (cost-based method)

Optional: digitize polygon (area of interest

Creates automatically:
Ortho-mosaic
- Classic ortho (no occlusion test)
- True ortho (with occlusion test)

2. Project setup

2.1. General information about the project

For this manual a block with 41 images was selected. Figure 1 shows the block structure with the projection centers of the images.
In general, this tutorial only reflects a standard workflow in "UASMaster".
The block is characterized as follow:

- ground pixel size: 0.04 m
- number of images: 41
- number of longitudinal strips: 7
- number of cross strips: 0
- average overlap: 60% / 80%
- average terrain height: 90 m
- control points / check points: available
- type of terrain: open field
- UAS: Trimble UX5

For UAS projects we assume an accuracy of the GNSS antenna coordinates of about 10 m.

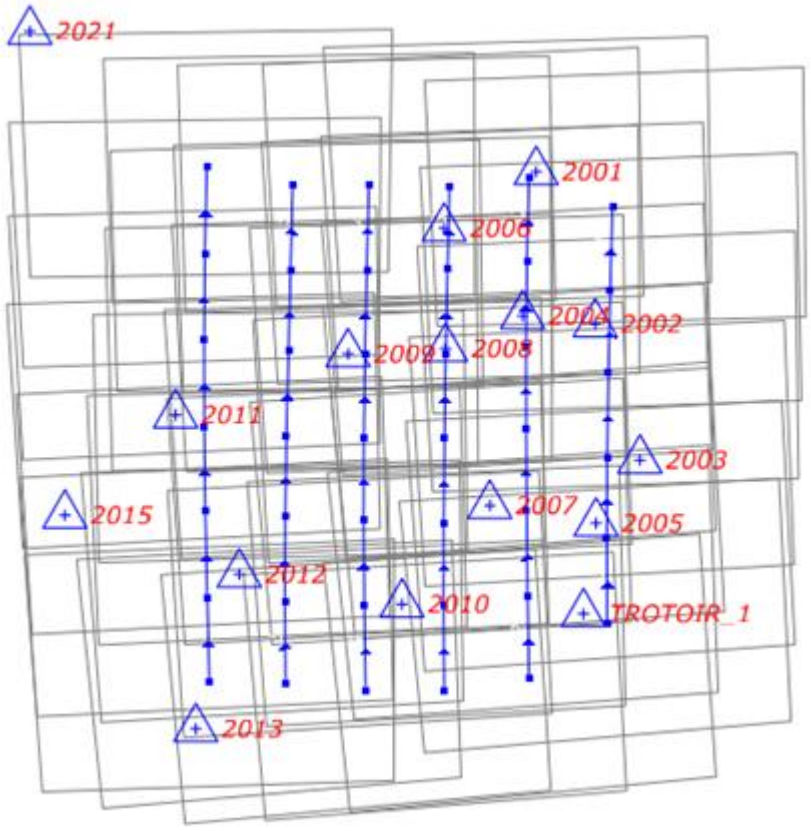


Figure 1: Flight layout of the entire block

2.1.1. Sample data: TrainingData_UAS

The training data project will need about 500 MB of disk space. The data is organized in the following subdirectory structure:

[drive]:\...\TrainingData_UAS\Images\
includes 41 images in .JPG format

[drive]:\...\TrainingData_UAS\Input\

- UASMaster_GNSSIMU_LatLong.csv
  GNSS coordinates and IMU values

- UASMaster_GroundControlPoints.gcp
  ground control coordinates

- UASMaster_Sketches_GCP.docx
  Sketches of positions of ground control points

[drive]:\...\TrainingData_UAS\input*.*

Backup\

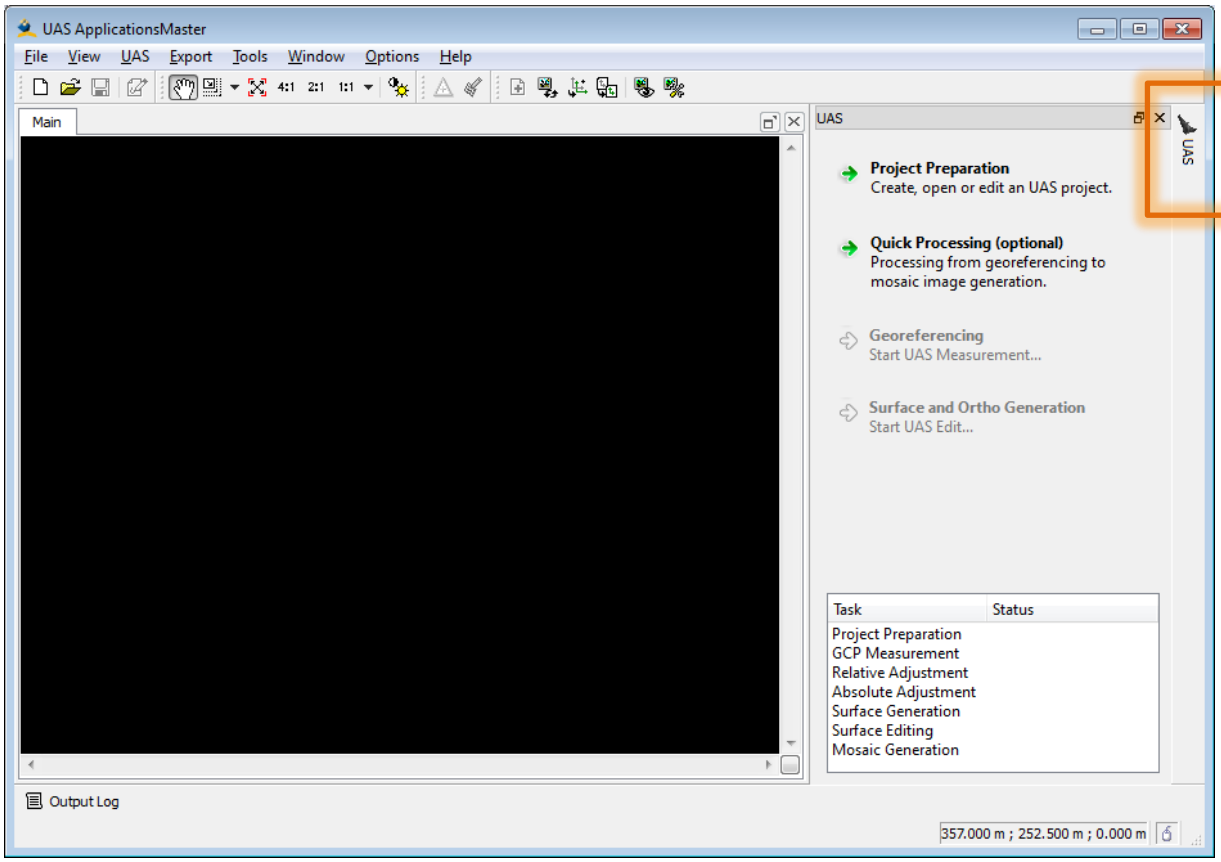
Tutorial_Complete.*
Successfully processed project

Tutorial_prepared.*
prepared project (project setup☑)

The project files stored in the Input>Backup folder could be used for self-monitoring, however they will not be used for the work through the tutorial. A step by step operation method is preferred which will implicate the generation of a new project file.

2.2. Project Preparation

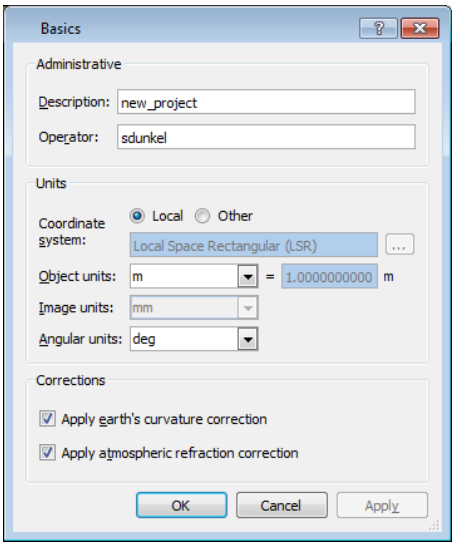
Starting "UASMaster" by clicking on the icon will open the UAS ApplicationsMaster interface.



Selecting the tab UAS at the right side of the menu opens resp. closes the UAS menu. The workflow order is designed from top to bottom.

The “Project Preparation” offers the possibility to create a new project and to open or edit an existing one.

2.2.1. Create a new project - Basics

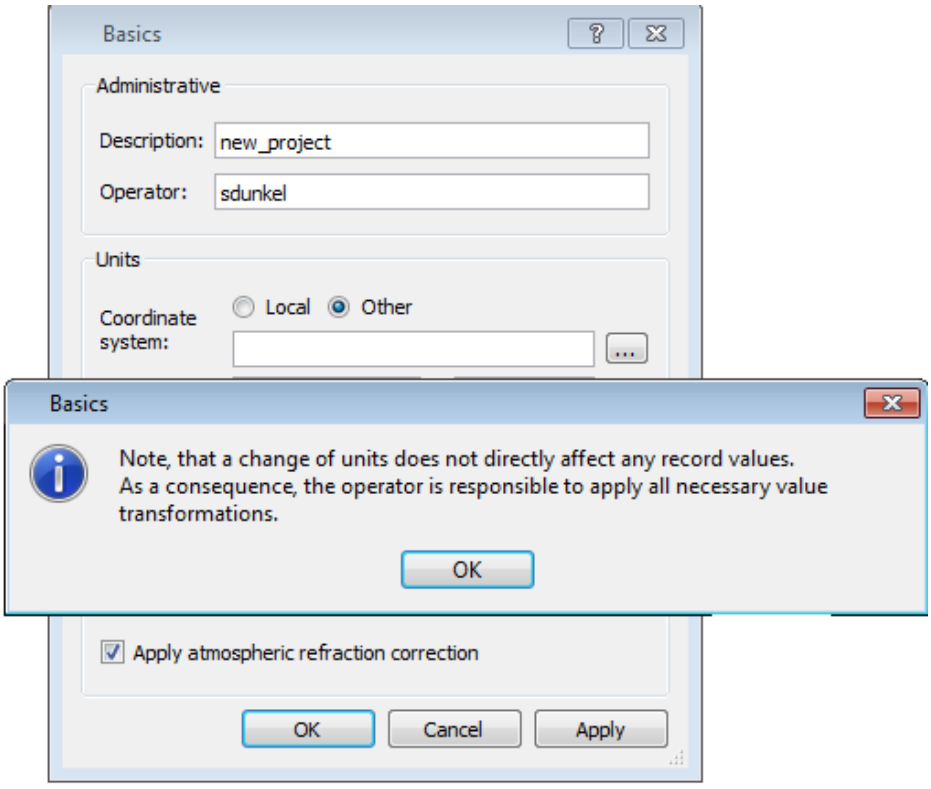


Creating a new project will open the “Basics” widget. Beside the administrative settings the target coordinate system has to be defined.
All results will refer to this coordinate system.

2.2.1.1. Steps to work through

- “Administrative” entries:
  Description: enter project name, e.g. *Tutorial*
  Operator: enter your name
- Section “Units”:
  Definition of the target coordinate system

Selecting “Other” a message will appear which informs the user that already stored project data will not automatically be transformed to the new entries.

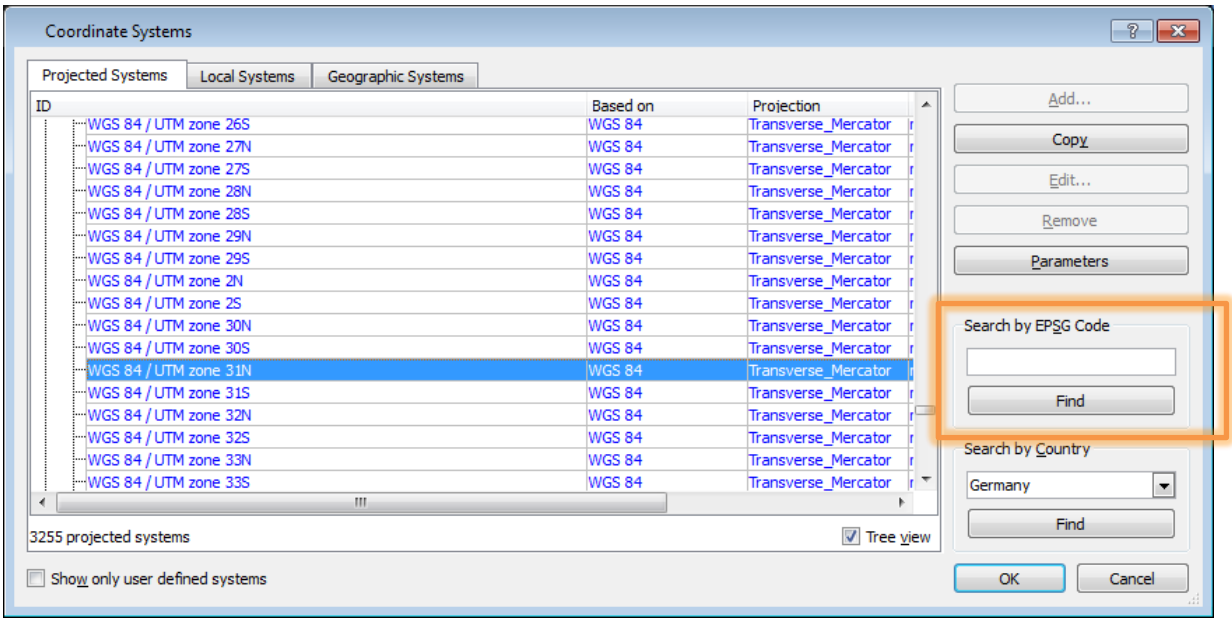


Setting up a new project this will not have any effect, because till now no data has been imported and therefore no transformation into a new system needs to be done. Continue by selecting “OK”.

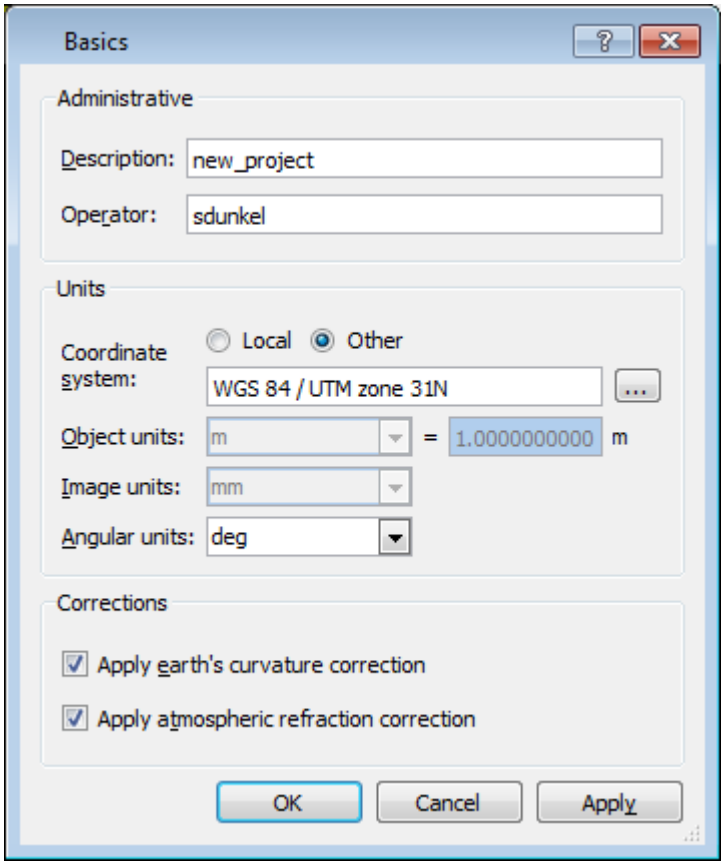
The target coordinate system of our project is WGS84, UTM zone 31N (EPSG code: 32631).

Use the browse (…) button to select the

WGS84 / UTM zone 31N system in the “Projected System” tab or enter



the EPSG code: *32631* into the corresponding text field.



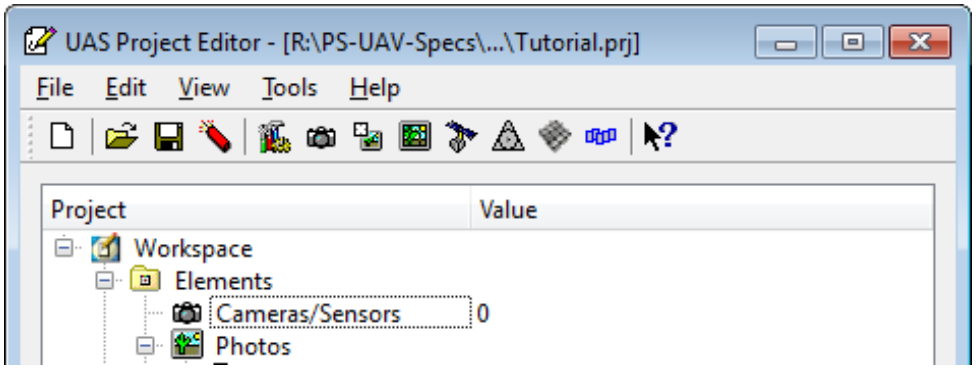
The object and image units are defined automatically with the selection of the coordinate system and cannot be changed. The angular units, however, could be set to degree, grad or radians.
The correction for earth curvature and atmospheric refraction should be activated!

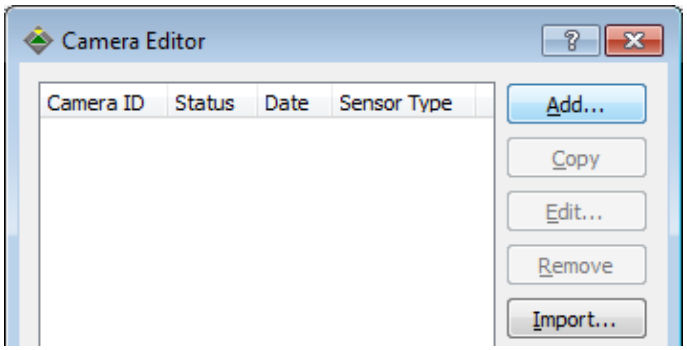
Press OK for accepting the entries and exiting the menu.

2.2.2. Camera definition

For the definition of the camera you need at least the information about the sensor size and focal length. For some cameras predefinitions are stored.

Double clicking on “Camera/sensors” icon launches the “Camera Editor”.





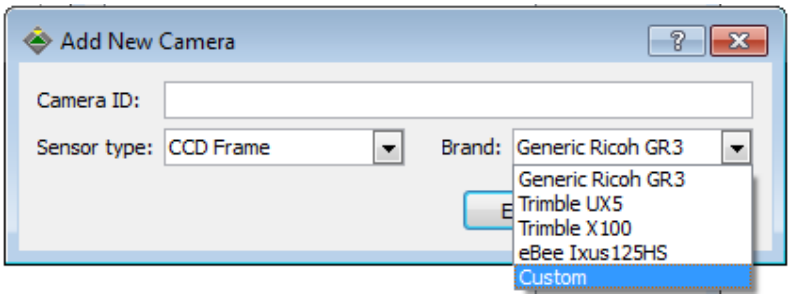
The camera editor offers the possibility to add a new camera or to import a camera from another Inpho project file.

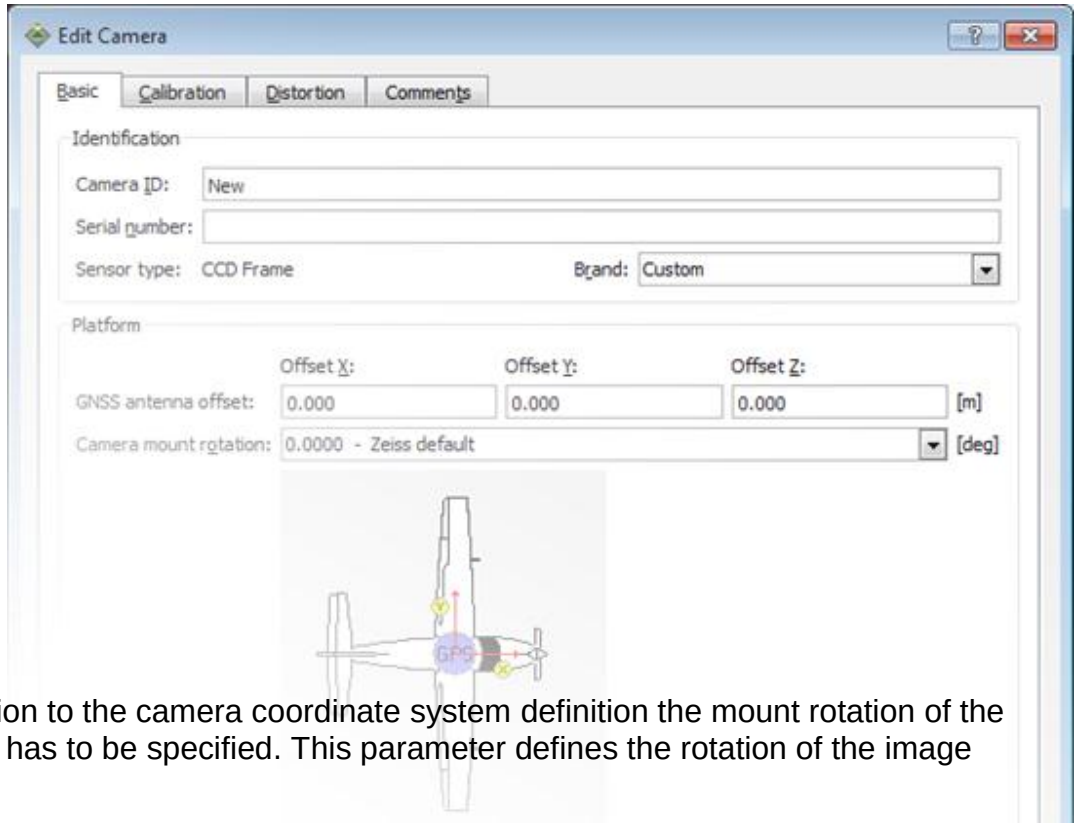
Tip: If all defined cameras will be exported into one common Inpho project file, which is available in the company's network, this can serve as a database for all cameras associated with Inpho software.

2.2.2.1. Add a new camera

To add a new camera, select the ***Add*** button in the "Camera Editor" window. Enter the new camera name ***Camera ID*** text field, specify "CCD Frame" for ***Sensor Type*** and select the ***Brand*** of the camera if a predefinition is available.

In case there is no predefinition stored, select ***Custom*** and then ***Edit***.

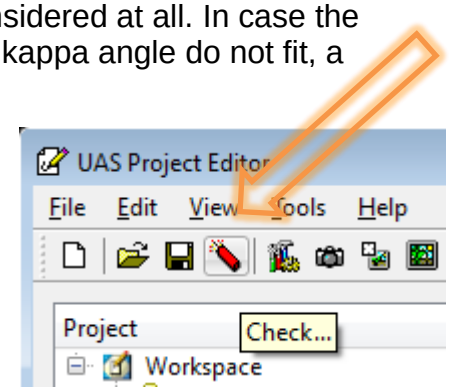


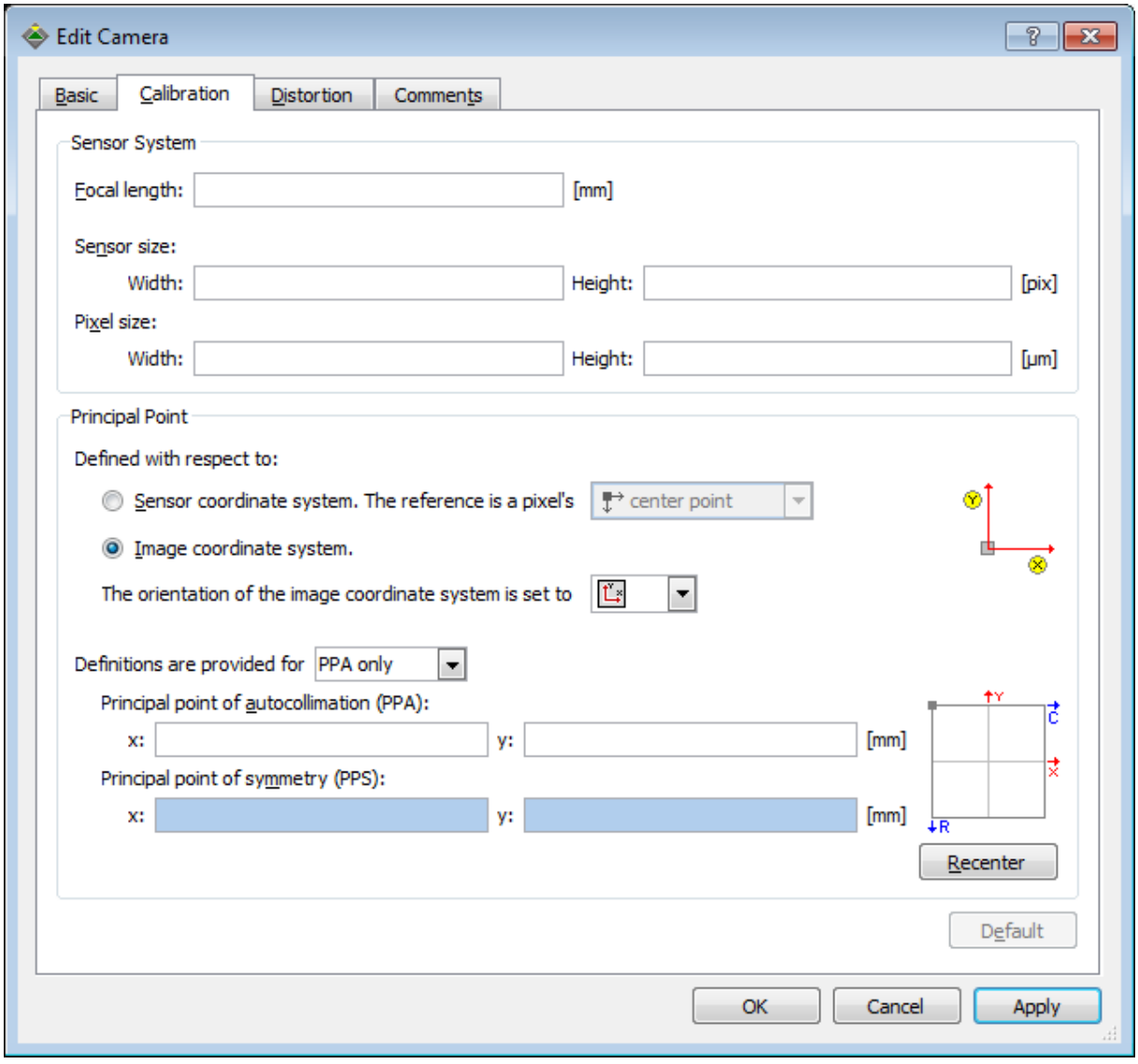


In addition to the camera coordinate system definition the mount rotation of the camera has to be specified. This parameter defines the rotation of the image

coordinate system with respect to the flight direction of the aircraft. The parameter is used to calculate the approximate kappa rotation from the strip azimuth. But as soon as IMU data is available the mount rotation is not used for the rotation angle consideration. The mount rotation is then just used to check the definitions and could be as well not considered at all. In case the mount rotation angle + strip azimuth and the IMU kappa angle do not fit, a 'Kappa integrity message' appears.

Checking the explanations in the Project Validator, the correct mount rotation can be entered in the "Basic" tab of the Camera Editor.

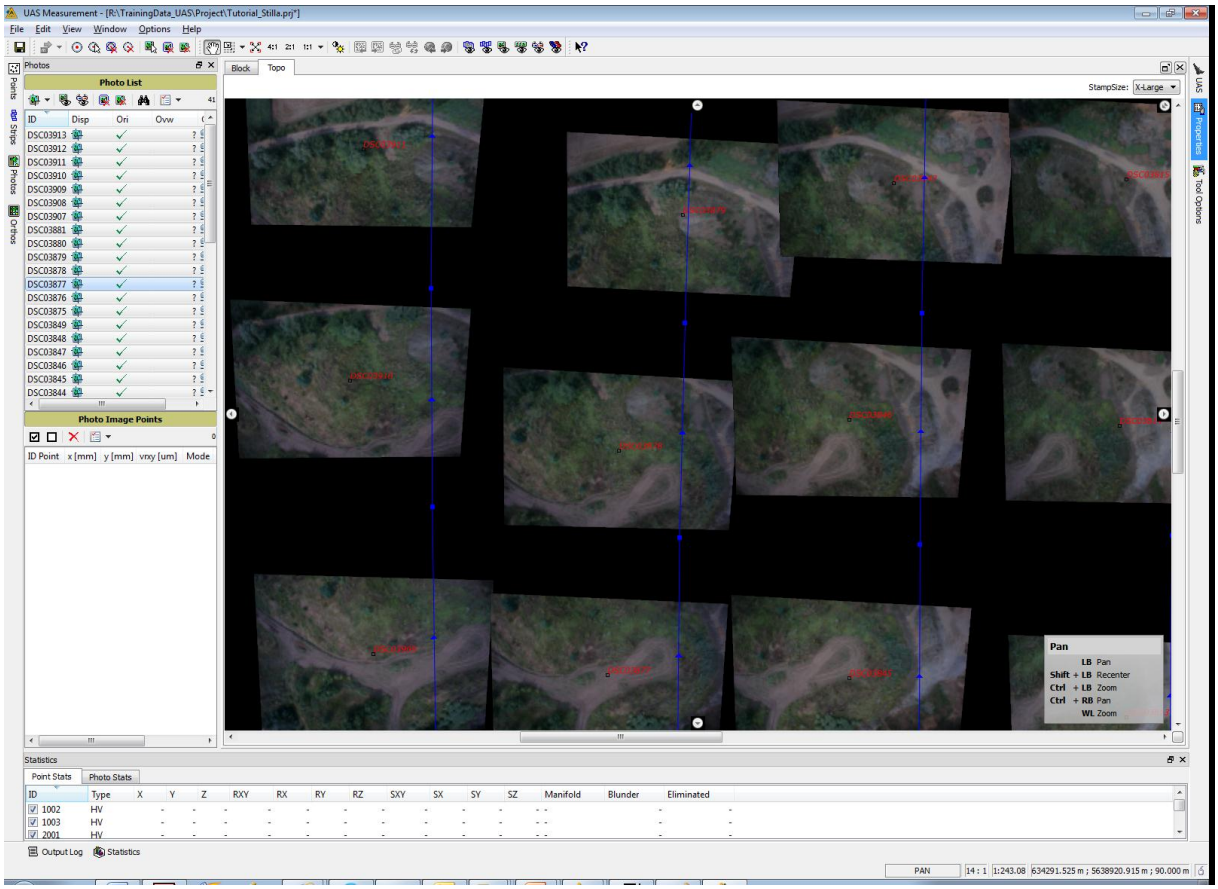




Enter the focal length, the sensor size (respectively to the actual shape – landscape or portrait) and the pixel size.

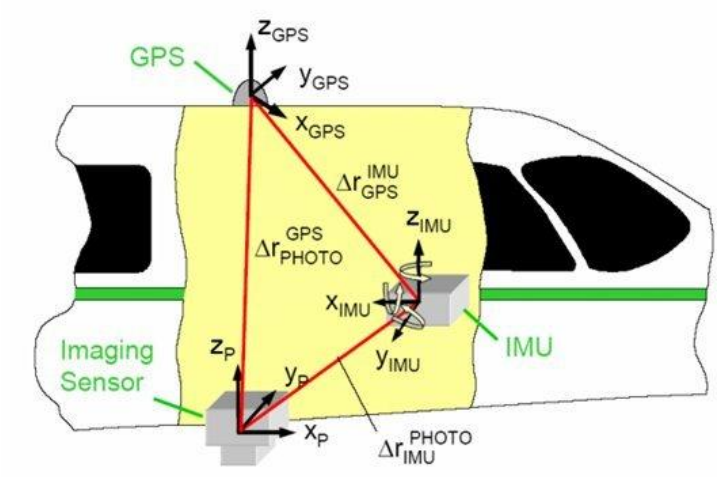
Definition of the image coordinate system

The orientation of the image coordinate system has to be defined with the X-axes pointing in flight direction. A correct definition is necessary for a correct rotation of the images. In case no information about the flight direction is available check the overlap of the images in the **"UAS Measurement"**. If the image displayed in the “Block Overview” or in “Topo Viewer” seem to have a wrong rotation, change the rotation of the image coordinate system.



Note: For UAS projects we strongly recommend that the X axis of the camera coordinate system is pointing in flight direction. The reason is that the UAS systems are using an inertial system which refers to the “airplane”.

That means that the integrated GPS/inertial angles refer initially to the IMU sensor axis not to the image coordinates system of the camera. The rotation angles are presented as navigation angles (roll, pitch, yaw) not as photogrammetric angles (ω, φ, κ).

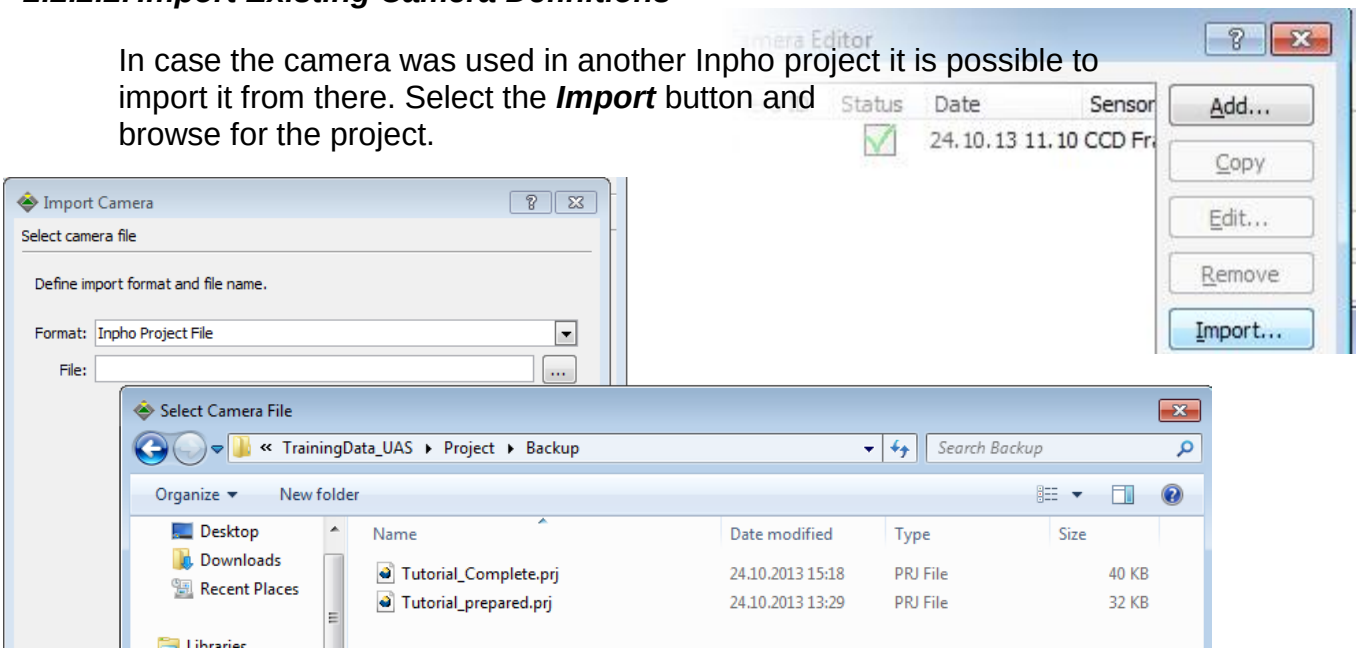


Definition of the principal point

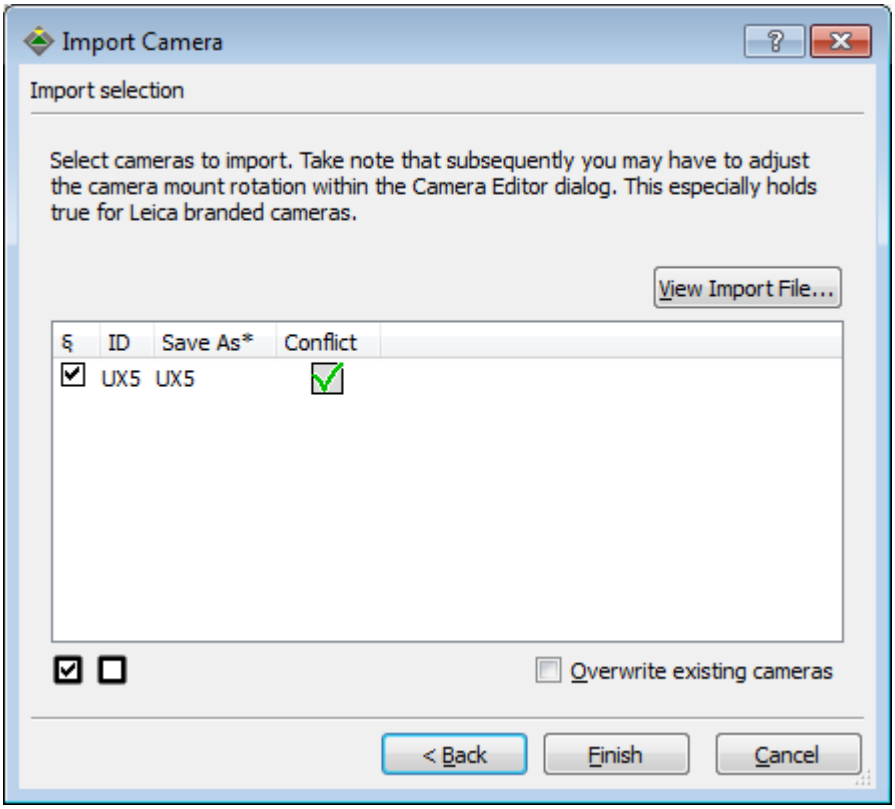
The principal point defines the origin of the image coordinate system. For UAS systems usually no displacement values are available except the system was calibrated during a previous project, then these values should be imported.

2.2.2.2. Import Existing Camera Definitions

In case the camera was used in another Inpho project it is possible to import it from there. Select the ***Import*** button and browse for the project.



Select the camera(s) to be imported and select “Finish”. In case a camera is imported having the same name like an already existing one, a “Conflict” will be announced.

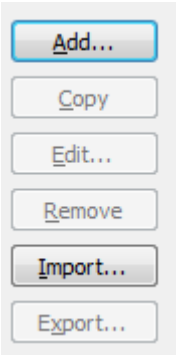


It is always better to use a “calibrated” camera than to start from the beginning with rough values. The computation times will decrease a lot, especially for bigger projects.

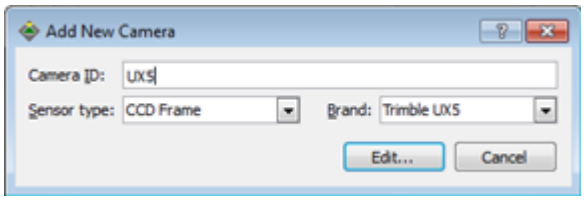
2.2.2.3. Steps to work through

Recall the project data:
UAS: Trimble UX5, 41 images, mean terrain height: 90 m, target coordinate system WGS84/UTM 31N

- Double-click on Cameras/Sensors in the “UAS Project Editor”. This will open the “Camera Editor”

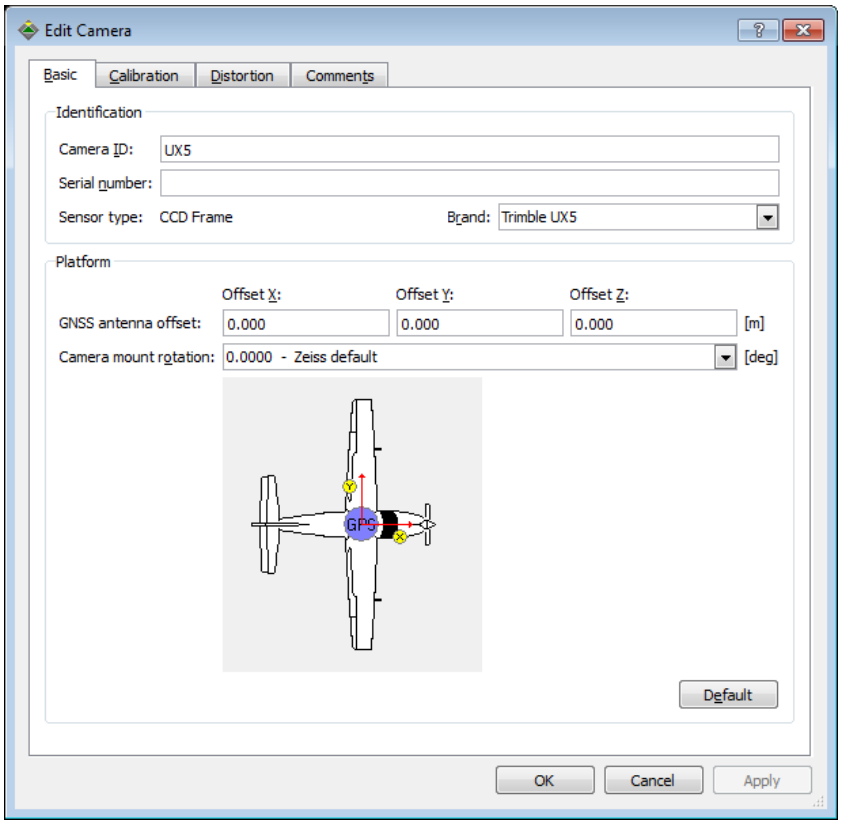


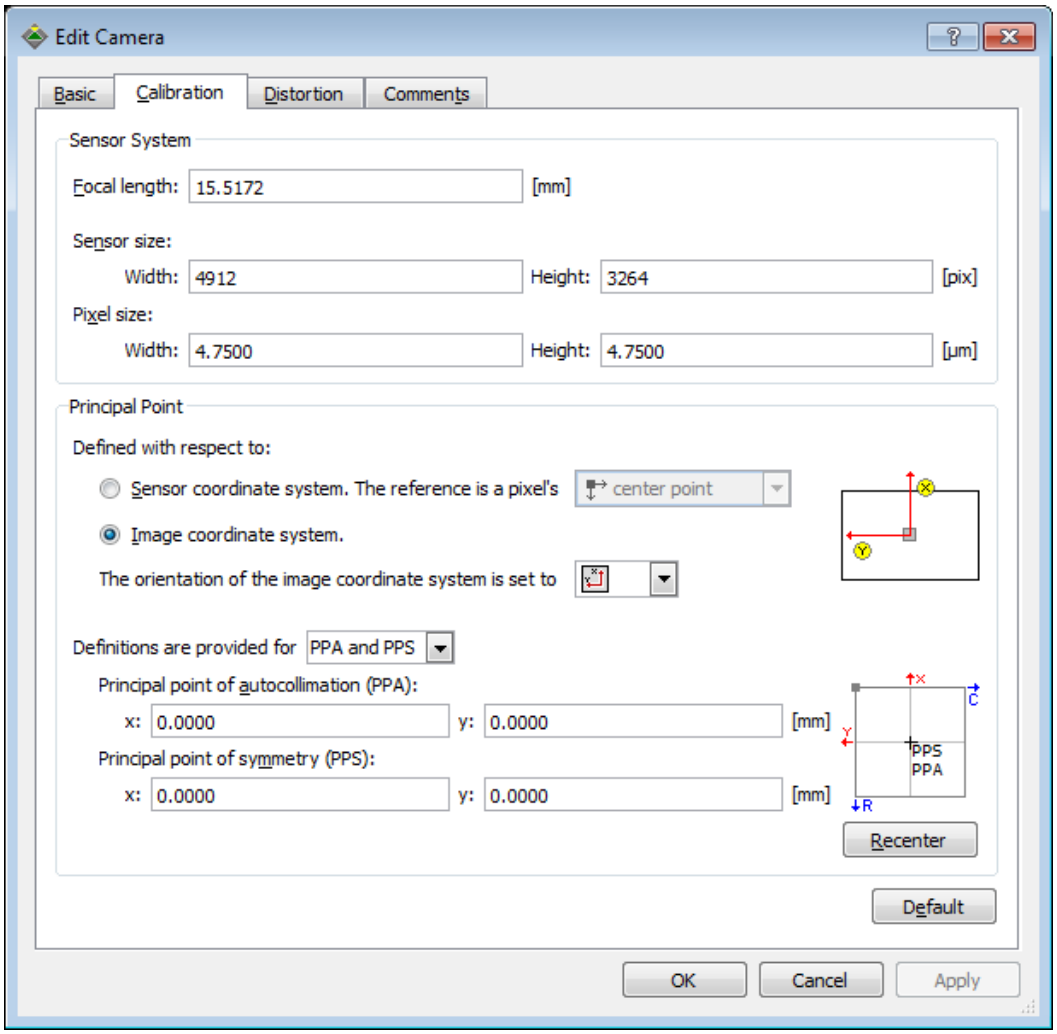
- Select the ***Add*** button and the window “Add New Camera” will appear.



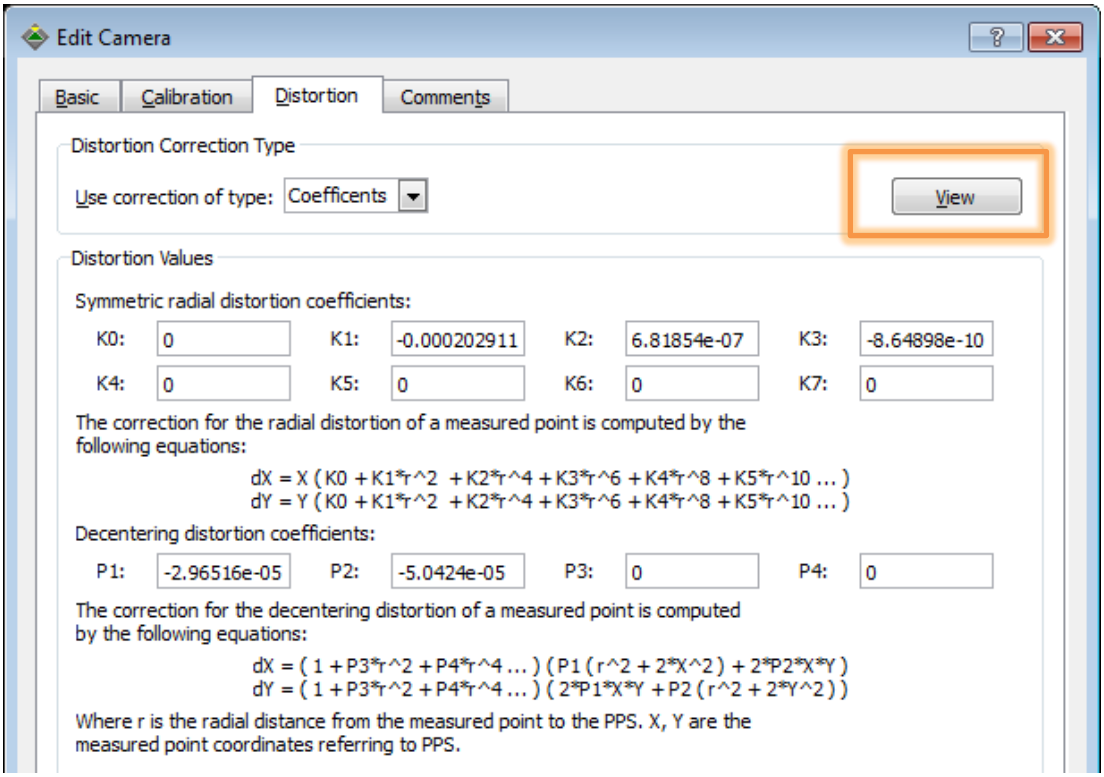
Enter the new camera name, e.g. *UX5* into the ***Camera ID*** text field, specify “CCD Frame” for ***Sensor Type*** and select as ***Brand:*** *Trimble UX5*

- Click on the ***Edit*** button and check the predefinitions of the camera

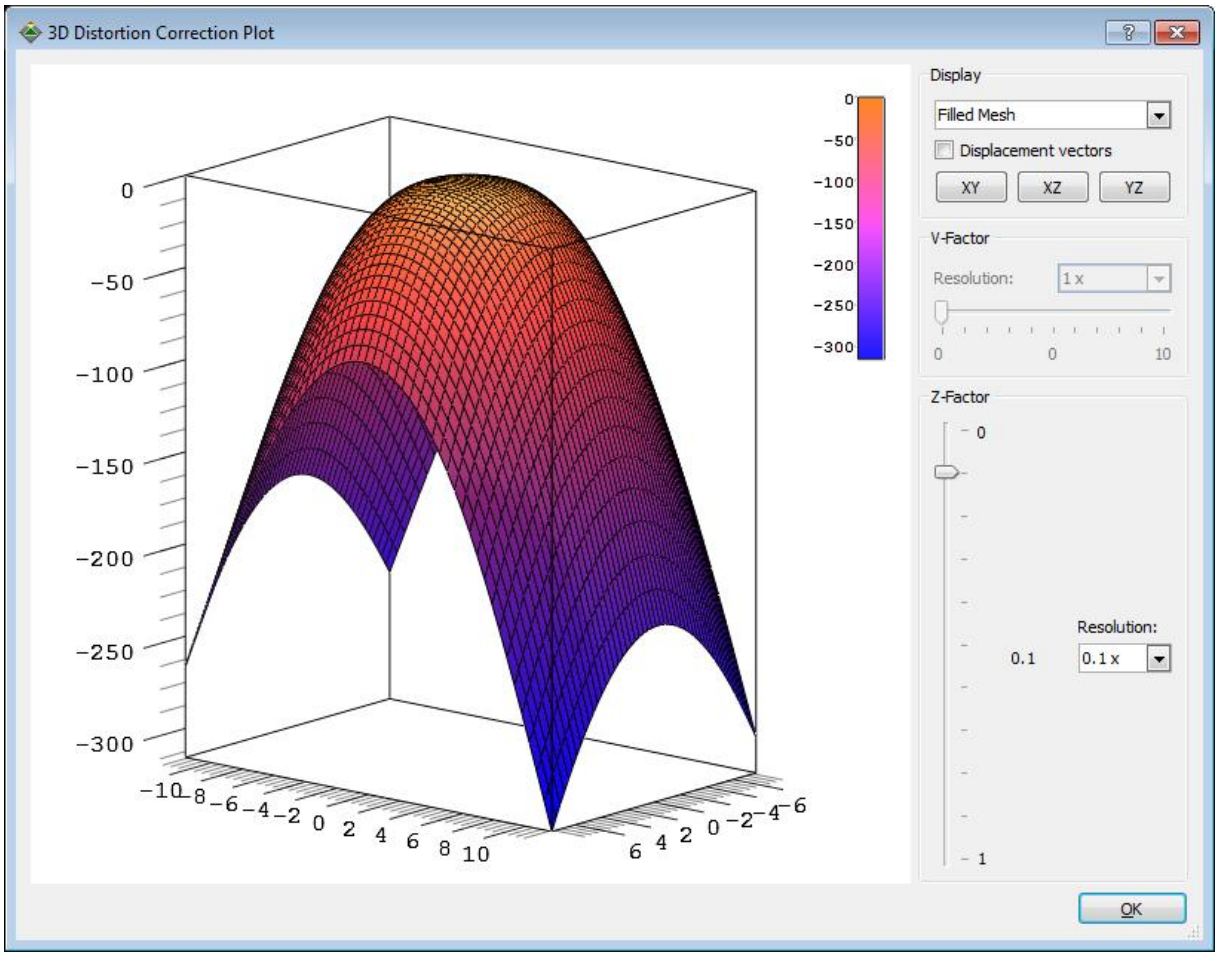




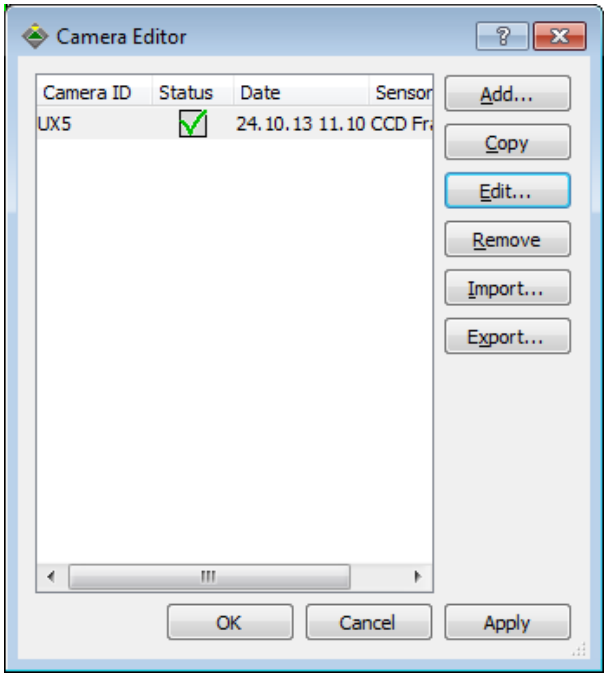
Predefinition of focal length, sensor size, pixel size and distortion coefficients.



The distortion model can be represented also graphically by selecting ***View***
The model will show radial symmetric distortions only (no decentering effects)-

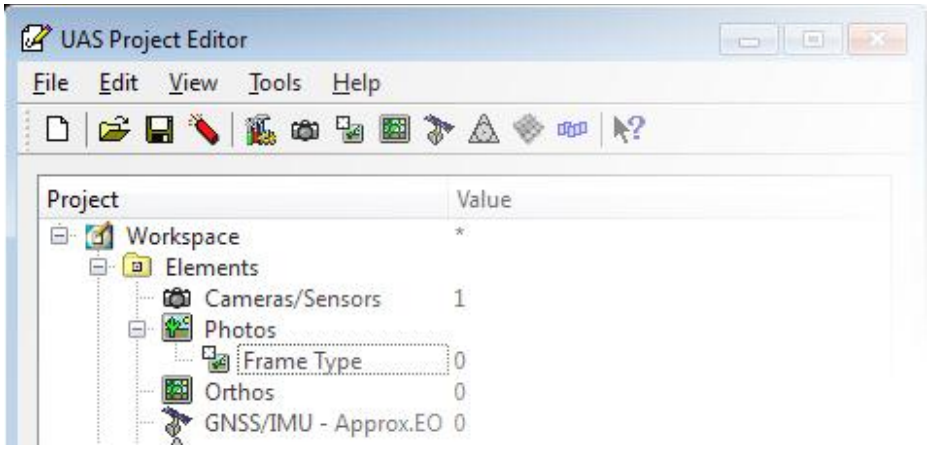


In case a predefinition will be used, check the focal length and sensor size. Available distortion values should be kept, because they serve as initial values. Due to the fact, that UAS sensors have quite big distortions a predefined distortion model from a default camera of the same type is better than a “zero” model (no distortion). This will improve the projection of the ground control point position into the images.



- Close the “Camera Editor” with ***OK***.

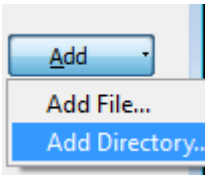
2.2.3. Photo Definition



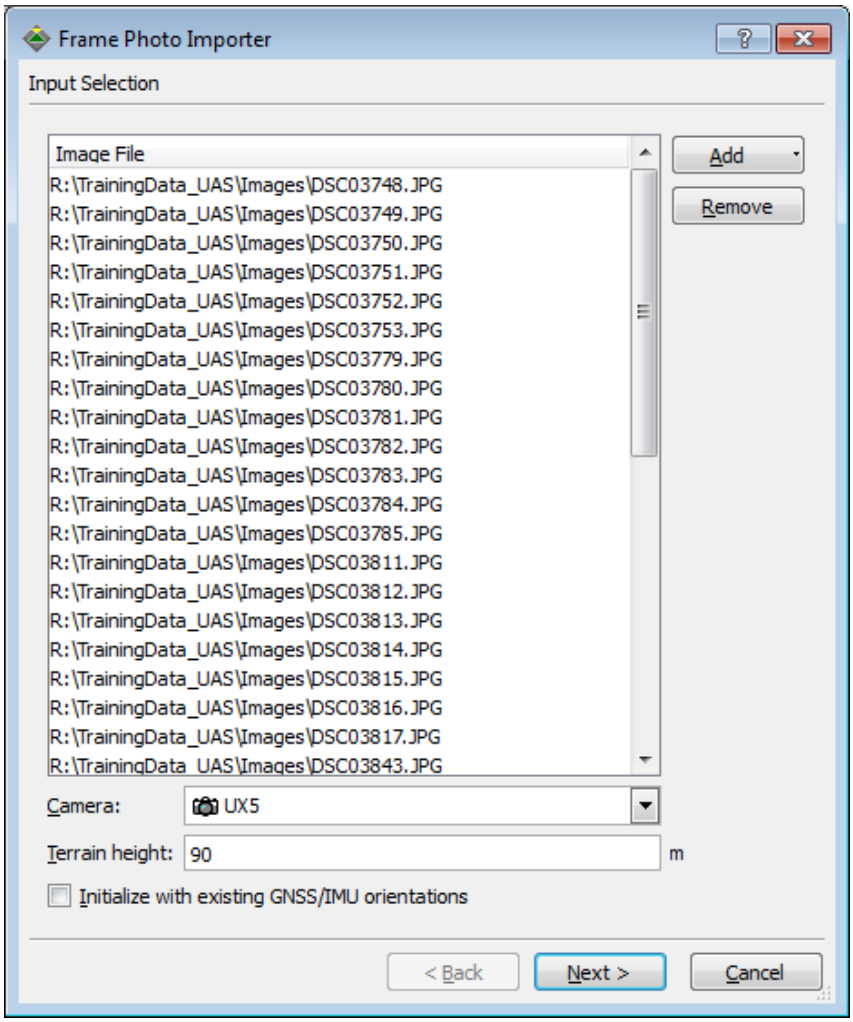
2.2.3.1. Steps to work through

Recall the project data:
UAS: Trimble UX5, 41 images, mean terrain height: 90 m, target coordinate system WGS84/UTM 31N

- Double-click on “Photos > Frame Type” to open the photo importer dialog
- Use the ***Import…*** > ***Image Files*** function to load all the image files located in one directory.
  The ***Add…*** function is only used to manually add ONE or manually selected images
- Select ***Add…Add Directory***, to load all images into the project.
  The directory of the training data example can be found on:
  \\TrainingData_UAS\Images\



- In case the project file would imply more than one camera, the correct one has to be assigned in the text field ***Camera***. For the training project the camera you defined *e.g. UX5* should be selected.
- Furthermore the mean terrain height has to be defined. Usually a rough average value of all heights of ground control points needs to be calculated. In our example it’s about 90 m.
  Enter in the text field ***Terrain Height*** *90*
- The checkbox ***Initialize with existing GNSS/IMU orientation*** may be left unchecked, as GNSS/IMU values are not yet imported



Next will open the ***Identification Extraction*** dialog which allows defining the characters that should be used to construct a photo ID from the photo file name. Image ID's may consist of any character excluding characters being used by the operating system (&%\...).
The table shows all image files that will be loaded with their extracted photo ID. The rules to extract the photo ID's from file names are set either to:

… use digits only
(e.g. 123_12.tif will create photo ID 12312, however be careful with two images 1_11.tif and 11_1.tif because both will create photo ID 111!)

... all digits from left until first non-digit character
(e.g. 123_12.tif will create photo ID 123)

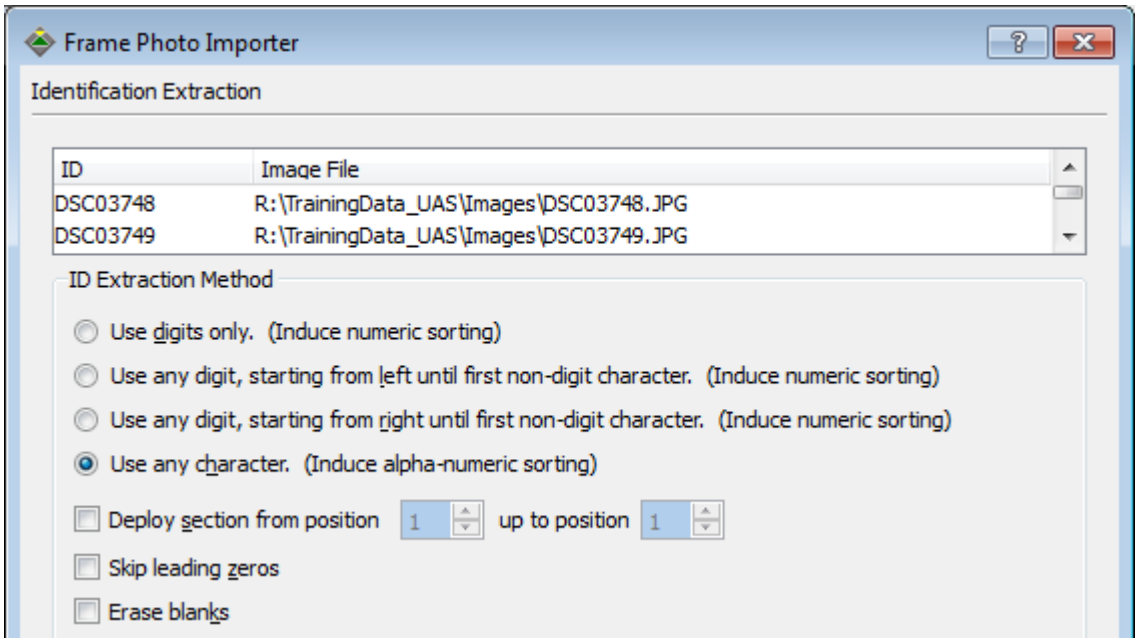
... all digits from right until first non-digit character
(e.g. 123_12.tif will create photo ID 12)

… any character
(e.g. 123_12.tif will create photo ID 123_12)

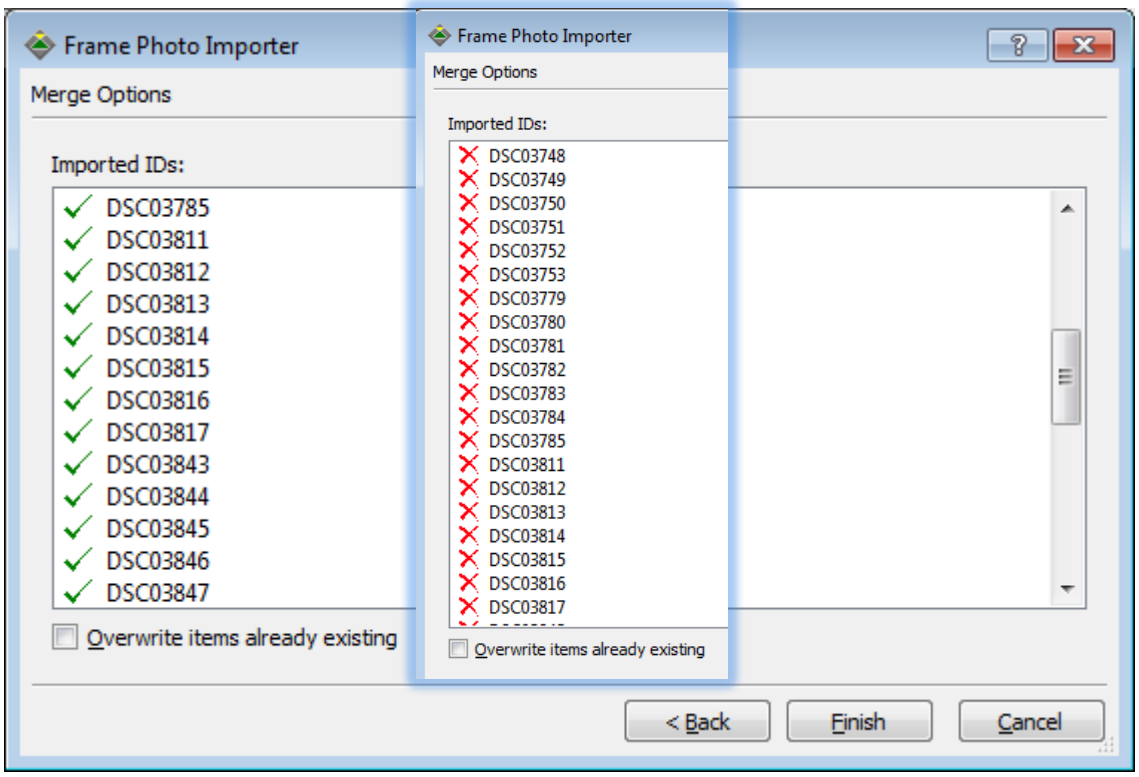
...display section from...up to...
(e.g. 123_12.tif will create photo ID 123_12)

Additionally, leading zeros can be skipped and all blanks inside an image name can be erased.

For the training data set, the default setting ***Use any character (Include alpha-numeric sorting)*** should be used.



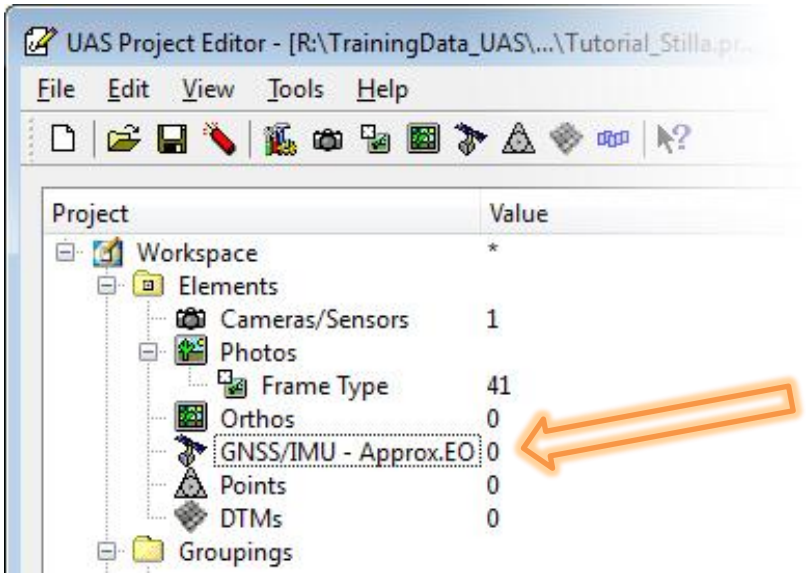
- Check in dialog ***Merge Options*** if no conflicts due to identical image IDs will be announced.



For conflicts a red cross will be display for the corresponding image(s). Then you have the possibility to overwrite the existing ones (activate check box) or you modify the ID extraction by selecting ***Back*** or you ***Cancel*** the import.

- Close the dialog by selecting ***Finish*** and close the “Frame Photos” importer with ***OK***.

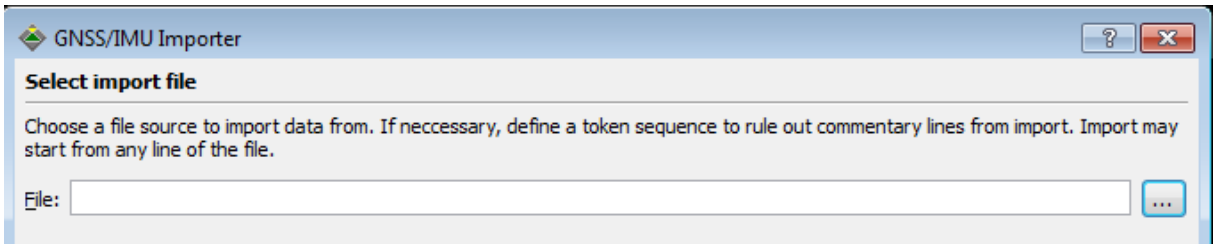
2.2.4. GNSS/IMU – Approx.EO



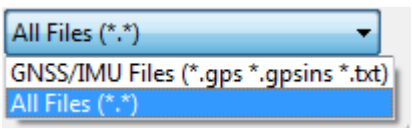
The dialog is used to define projection center coordinates and/or rotations, no matter if they are coming from GNSS/IMU or if they are just digitized coordinates. In case there is a mixture of good (about 10m) and bad GNSS/IMU observations there is a possibility to activate only the “good” ones for later adjustments. All imported positions will be used as approximate exterior orientations but only the activated ones will be used as constraints in the adjustment. The “bad” observations may be deactivated by changing the activation column after import.

2.2.4.1. Steps to work through

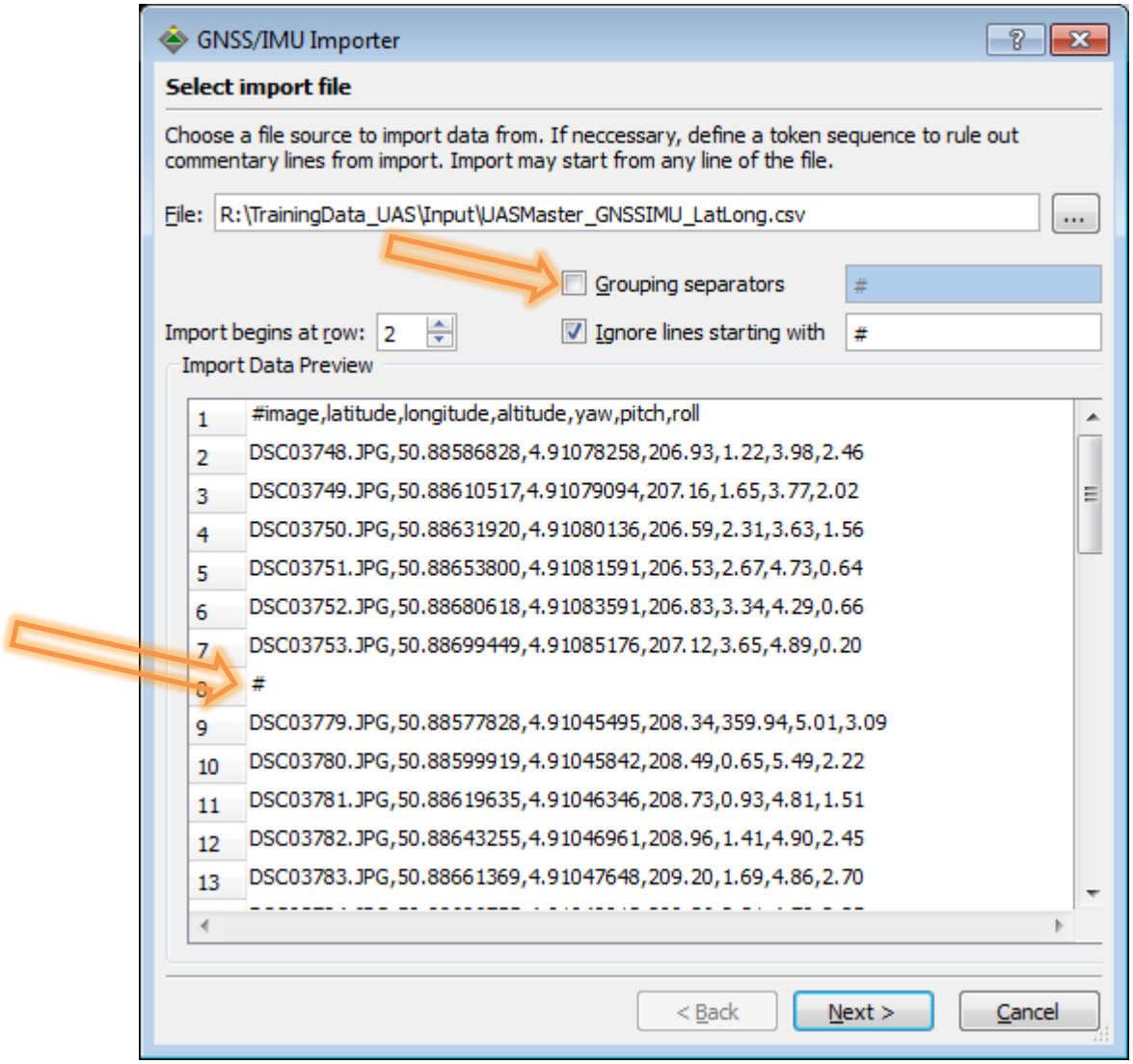
- Double-clicking on GNSS/IMU – Approx.EO will open the “GNSS/IMU Importer”



Browse for the file *\\TrainingData_UAS\Input\UASMaster_GNSSIMU_LatLong.csv* in which the projection center positions and rotations are stored. Follow the steps of the import wizard and use the filter “All Files *.*” for selecting the file.



- Start the import at line 2; the header of the file - line 1- clarifies the structure of data (#image,latitude,longitude,altitude,yaw,pitch,roll). This is of great importance for the correct assignment of rows during import.

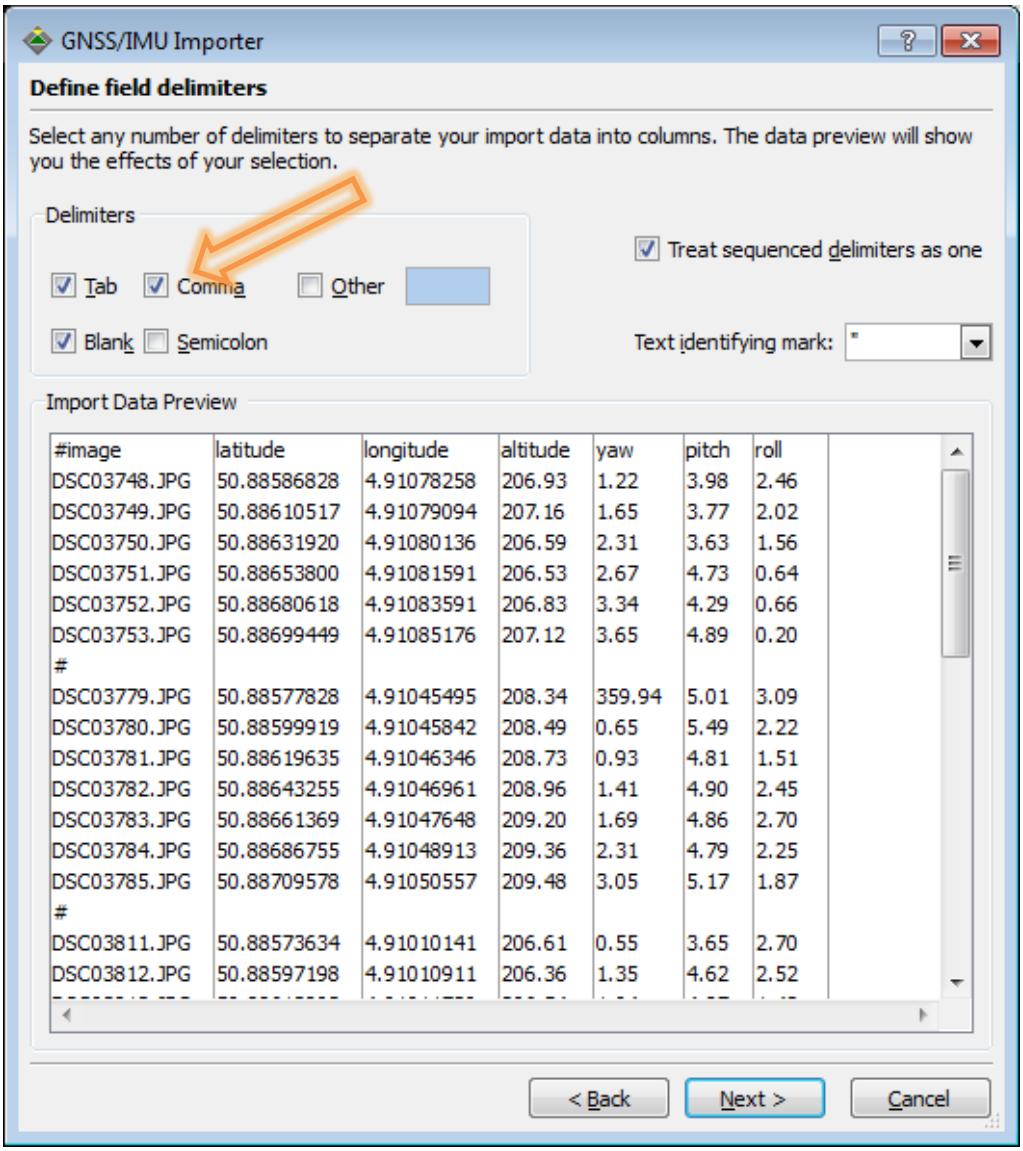


- Deactivate “Grouping separators” checkbox and enter in the text field of “Ignore lines starting with” the # sign and activate this checkbox
or
activate the “Grouping separators” checkbox and enter the # sign in its text field and deactivate the checkbox for “Ignore lines starting with” .

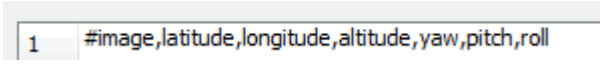
  The first possibility will import the data without any strip definition, the second possibility will take care of the predefinition of the strips.

  Grouping separators can be activated, considering an indicator sign (here #). If grouping separators are activated they are used to automatically create the strip layout from this information.
  Usually the file will not be prepared in this way so we do not activate this feature.
  Ignore lines starting with allows to ignore lines starting with a specific character.

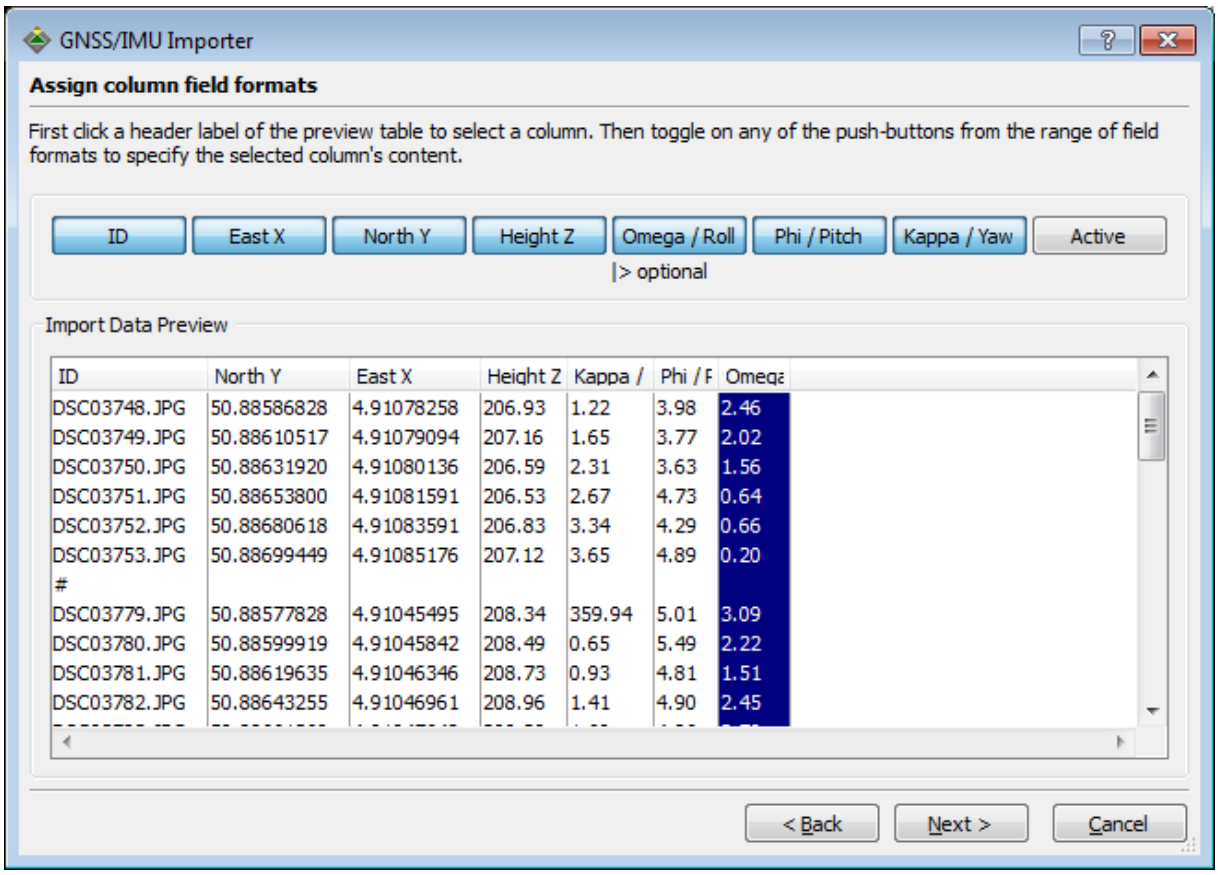
- ***Next*** takes you to the delimiter specification.
  As default delimiters are used Tab and/or Blank. The current data set uses a "," as delimiter. Activate the checkbox ***Comma***



- ***Next*** opens the "Column assignment"
  Click into the table's column header to select a column. Then click the button that shows the data type that this column should be assigned to. Remember the information of the header line of the file:

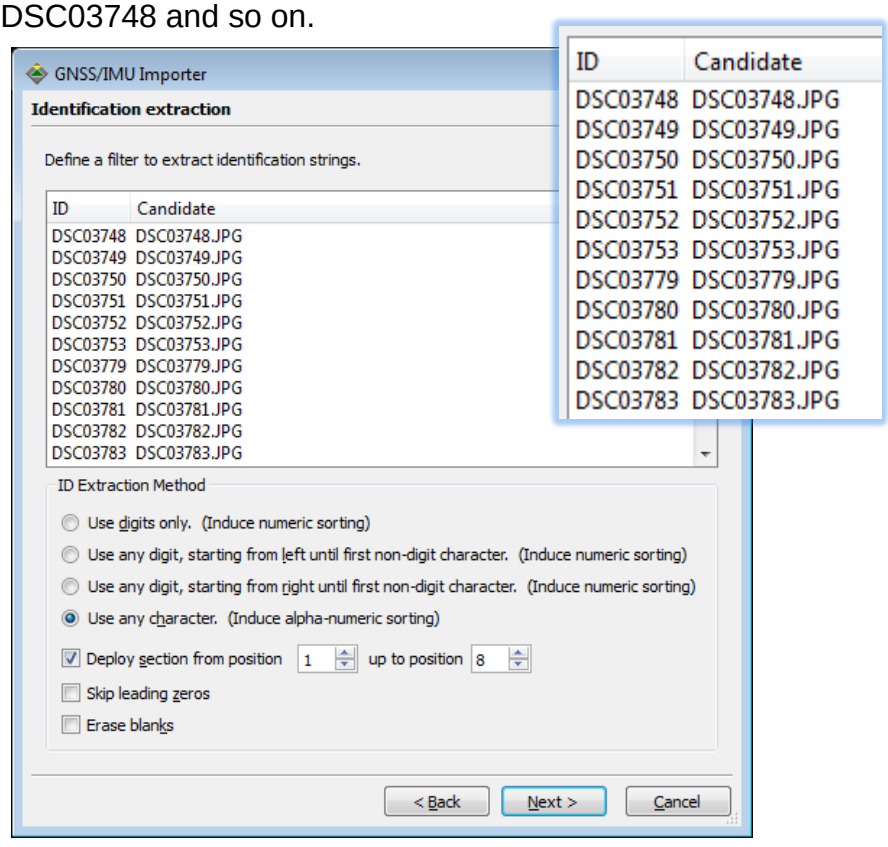


  Assign the first column *#image* to ***ID***
  the second column *latitude* to ***North Y***
  the third column *longitude* to ***East X***
  the fourth column *altitude* to ***Height Z***
  the fifth column *yaw* to ***Kappa / Yaw***
  the sixth column *pitch* to ***Phi / Pitch***
  the seventh column *roll* to ***Omega /Roll***

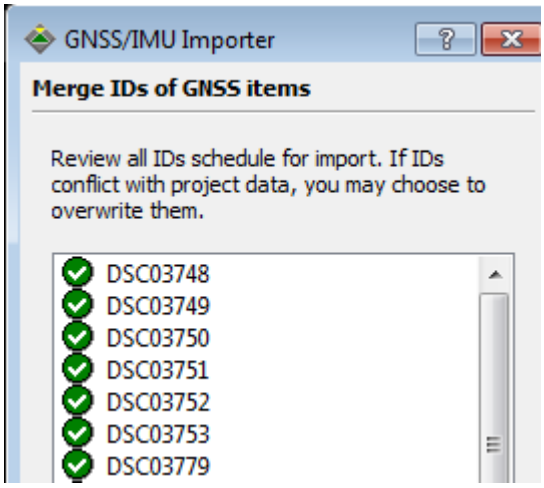


- ***Next*** opens the “Identification Extraction” dialog. It is necessary to synchronize the photo center IDs with the photo IDs.

  Use deploy Section from position 1 up to position 8
  This will change the proposal “Candidate” e.g. DSC03748.JPG to “ID” DSC03748 and so on.

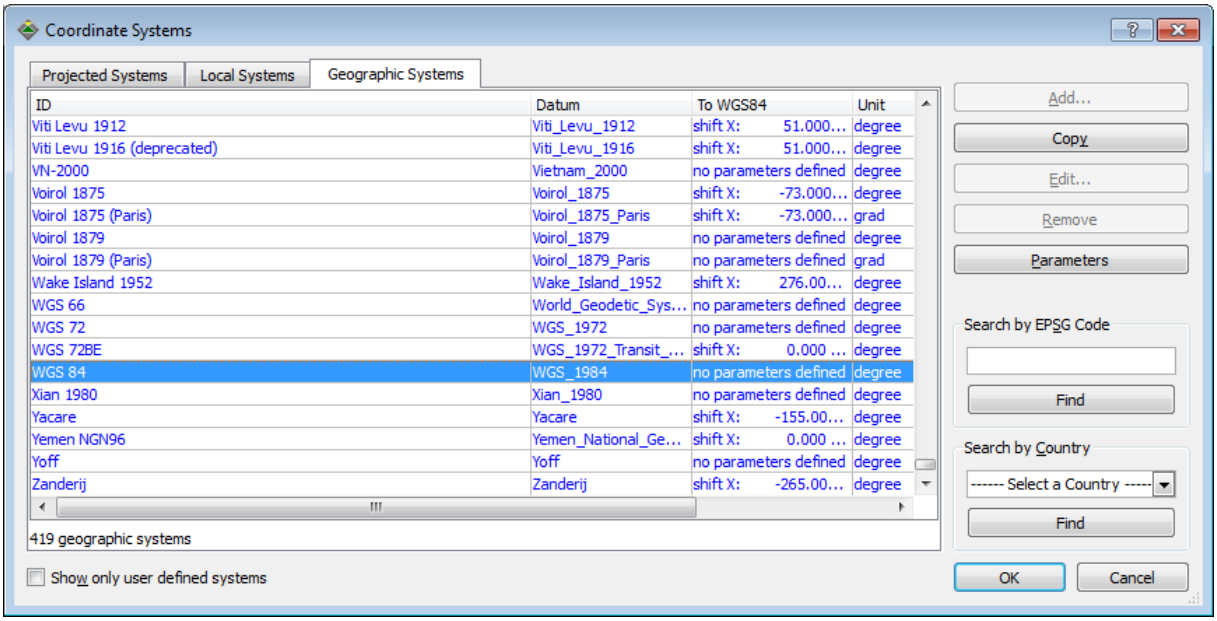


- ***Next*** informs about conflicts (identical ID) between already existing and to be imported points.

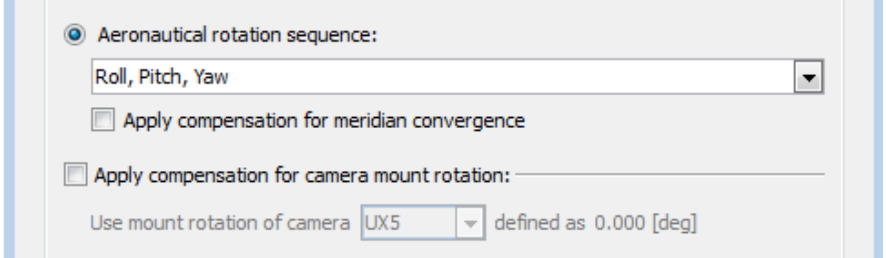


- ***Next*** is the specification of the coordinate system the data is referring to. The GNSS/IMU data is given as WGS84 geographic coordinates.

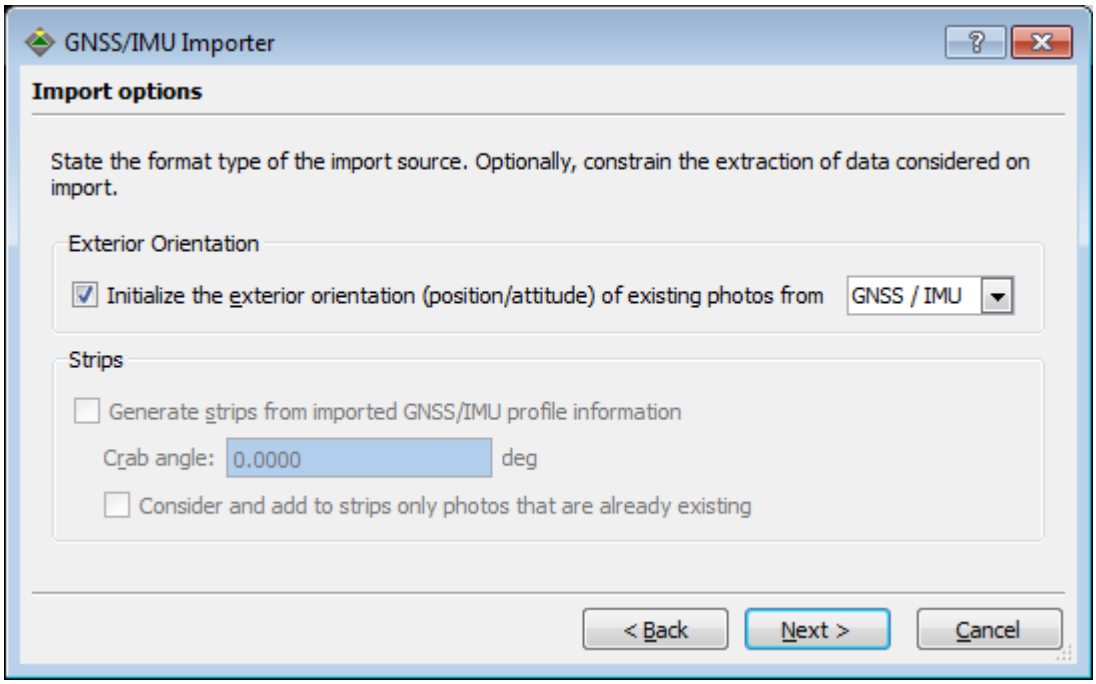
  Select “Other” for “Coordinate system:” select the “Geographic Systems” tab and scroll to WGS84.



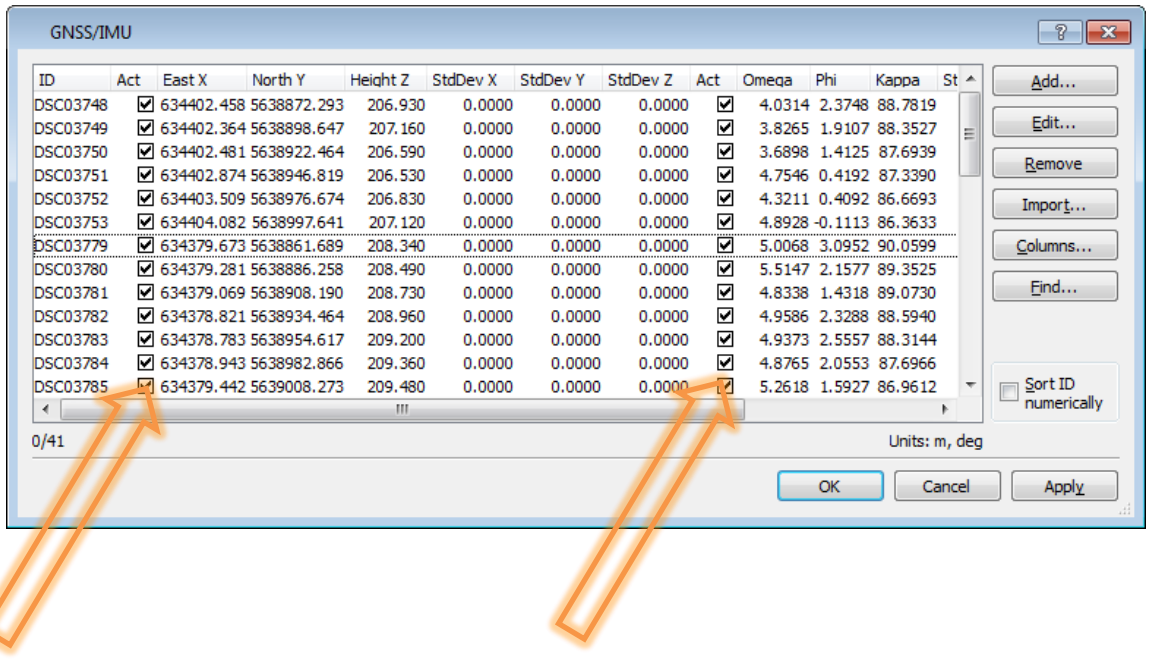
- The “Rotation system” of the GNSS/IMU data is given in “Aeronautical rotation sequence”



- ***Next*** opens the last dialog of the “GNSS/IMU Importer”. The “Exterior Orientation” of the photos will now be initialized using the GNSS/IMU positions/rotations. In case no IMU rotations are available the initialization can be done also with GPS only or with GPS and strip information.
  Activate *Initialize the exterior orientation from GNSS / IMU*
  In case a “manual” strip definition is imported, the “Strips” section is activated. Then the checkbox “Generate strips from imported GNSS/IMU profile information” can be selected for generating the strips at this step. Alternatively this can be done later.



- Click ***Finish*** to close and finish the import wizard.
  All observations should be activated.

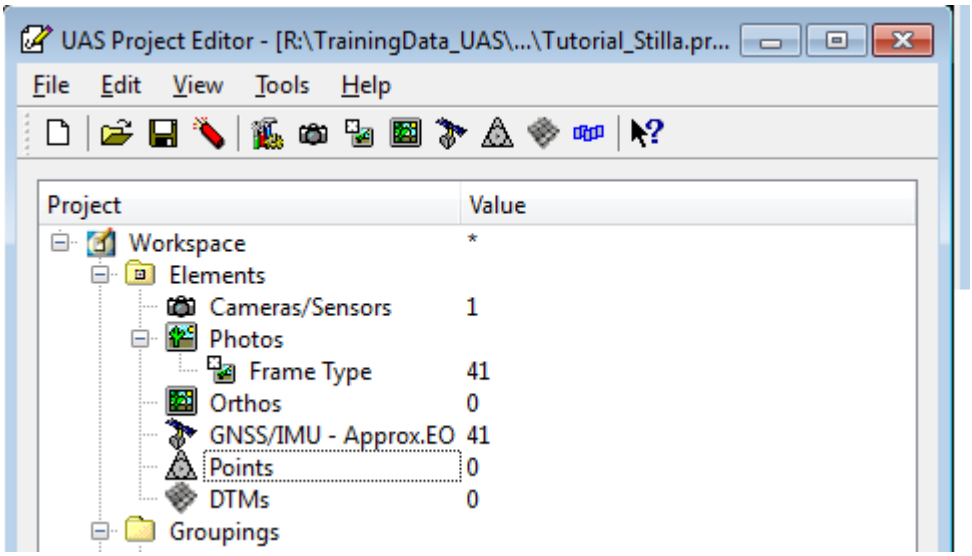


2.2.5. Points

Finally we import the ground control points. They are already given in the target coordinate system (WGS84 UTM 31N).

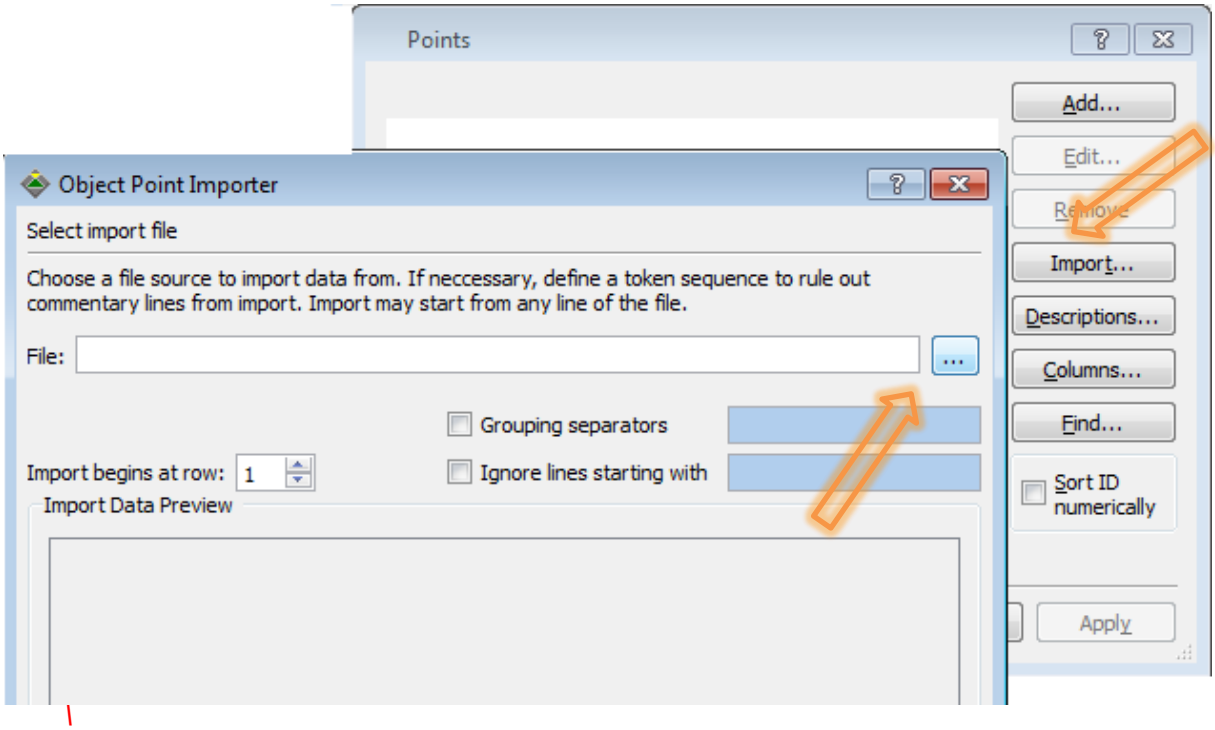
2.2.5.1. Steps to work through

- Select “Points” from the “UAS Project Editor”.

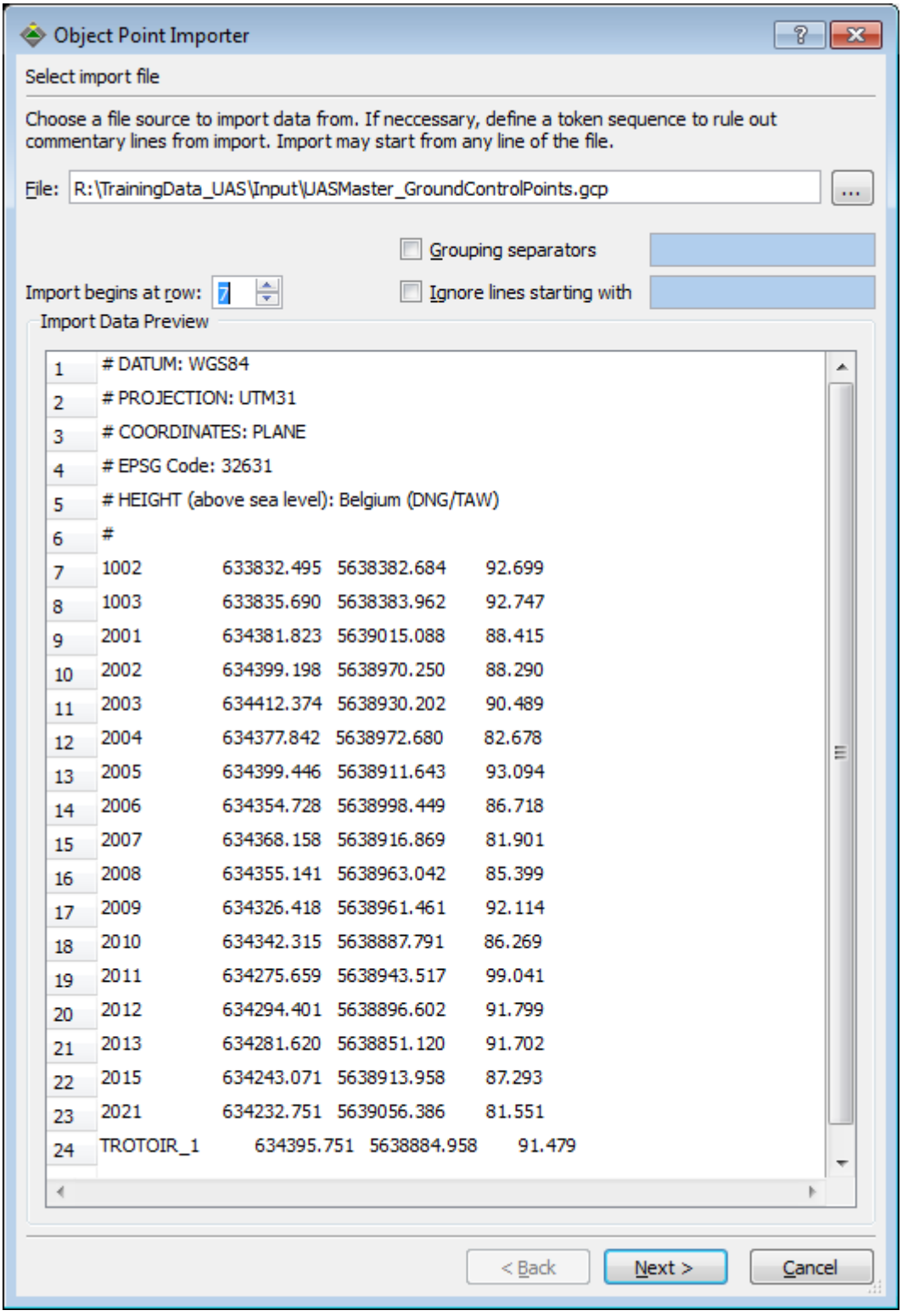


- Select ***Import*** button from the menu and browse for the file the ground control point coordinates are stored in

  TrainingData_UAS\Input\UASMaster_GroundControlPoints.gcp

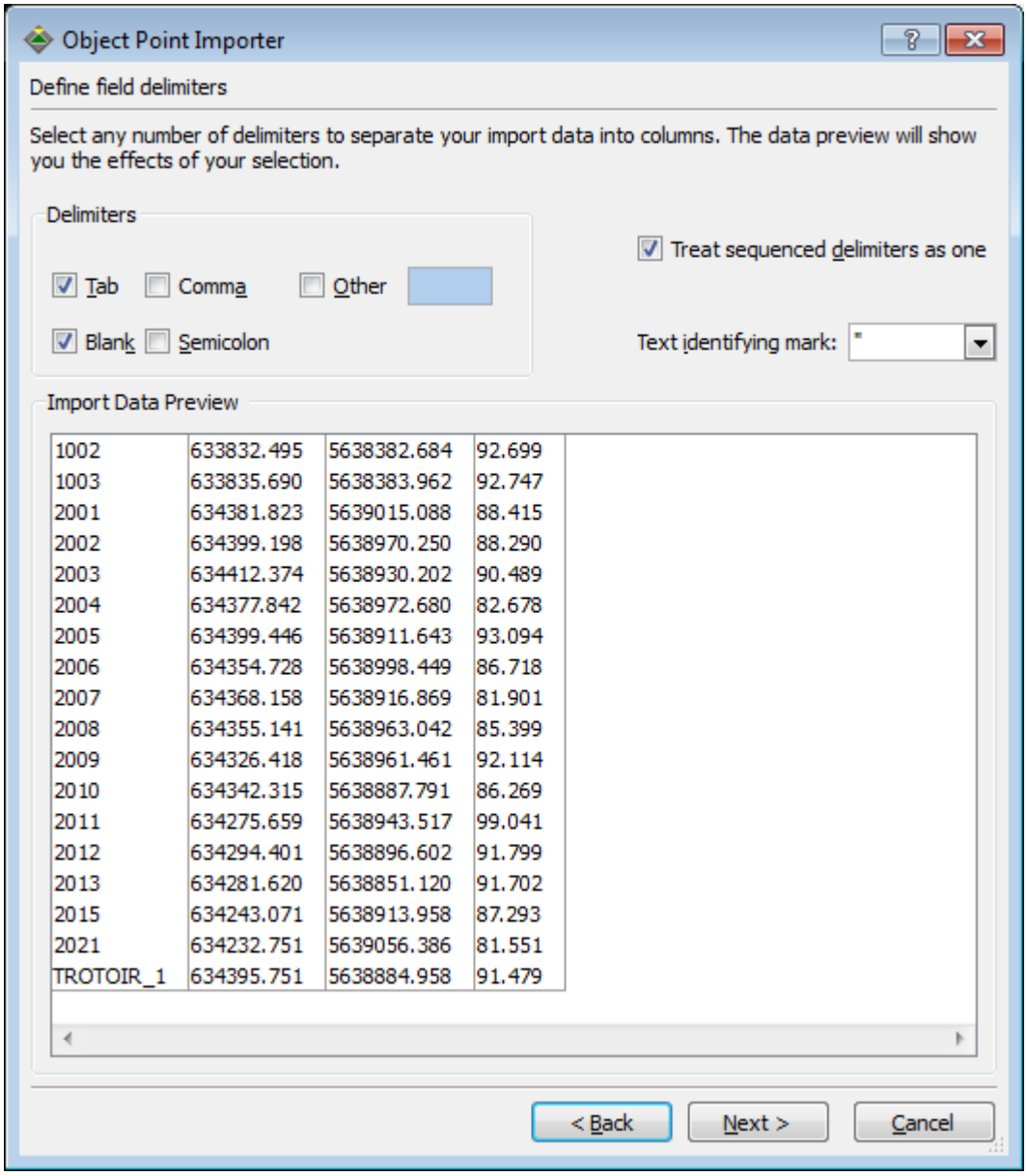


\

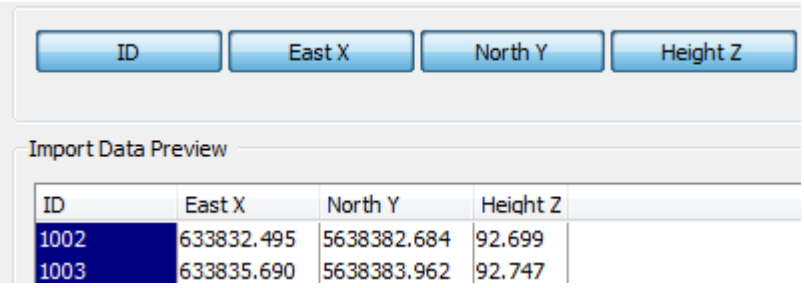


- The preview of the data shows a header information from line 1 to 6, so the import should start from line 7
  Select for “Import begins at row:” *7*

- ***Next*** starts the "Define field delimiters". The preview shows an already correct column separation which means, that the delimiters in the input file are blanks and/or tabs.

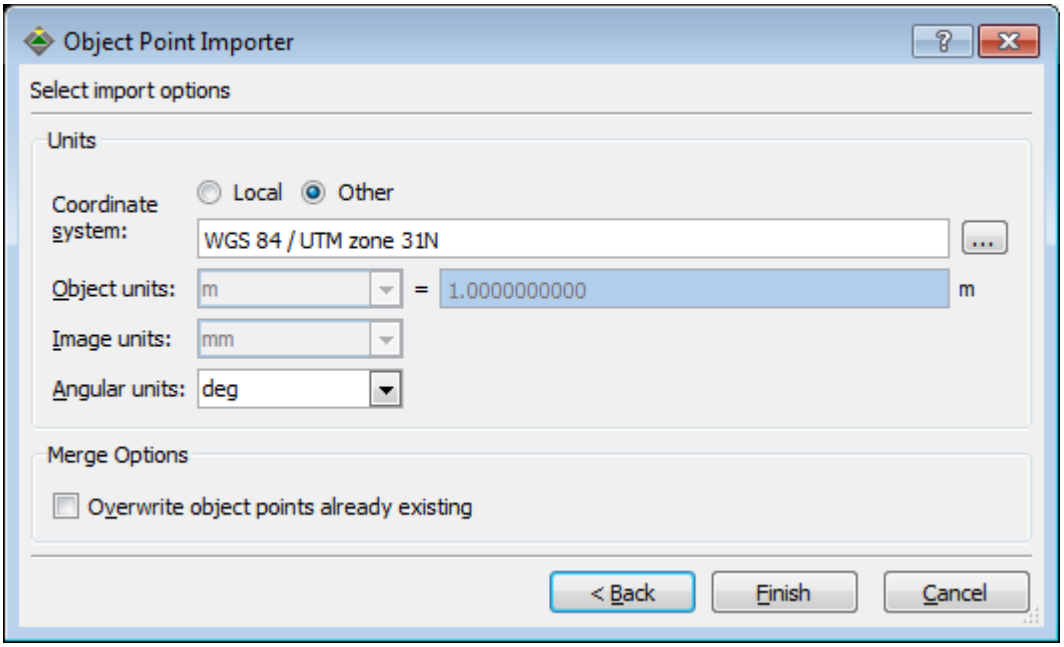


- ***Next*** opens the page "Assign column field formats"
  Specify which data is in which column:
  first column : *ID*
  second column: *East X*
  third column: *North Y*
  fourth column: *Height Z*

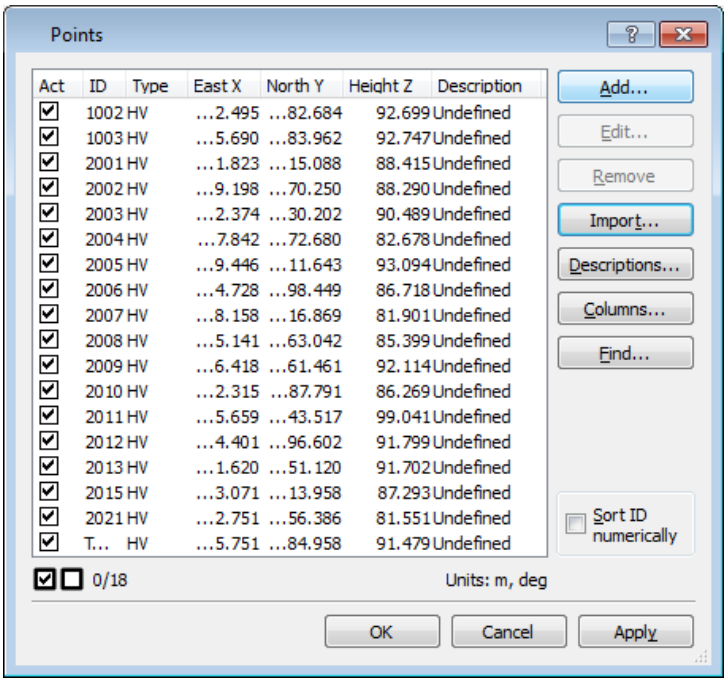


- Then the “Identification extraction” will appear. Prepare the control points numbers. For the training data set use the default setting “Use any character”. Then the point ID will be used as they are.

- The next dialog allows the assignment of the coordinate system to the input data..



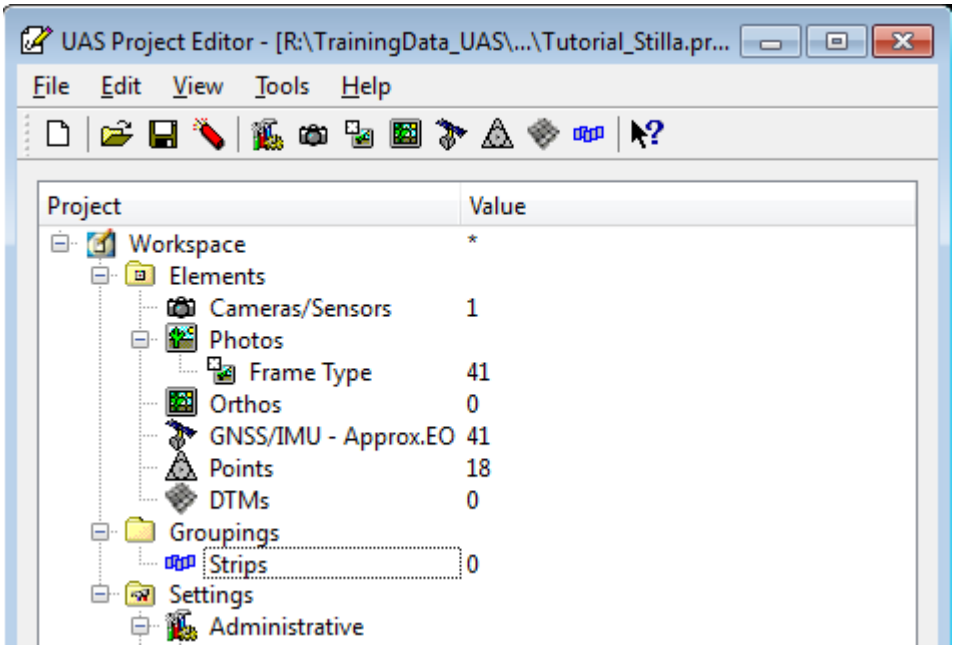
Because the ground control data is given in the target system no other setting has to be done. For other data sets define the corresponding system.
Continue with ***Finish***.



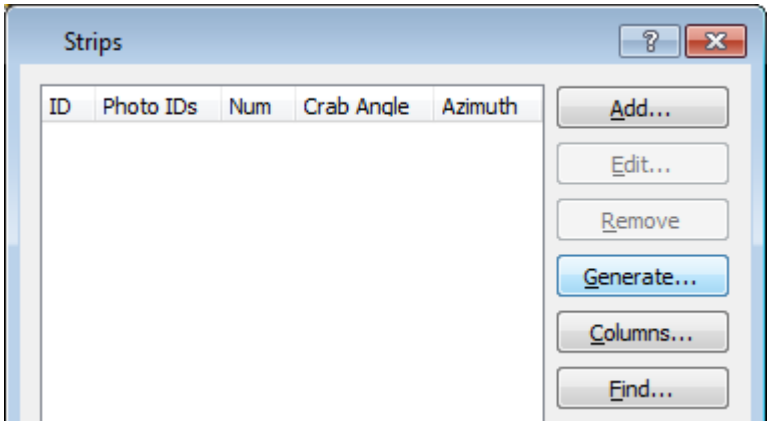
All ground control points are imported and active. Finish the import with OK.

2.2.6. Create Strips

If you haven't created the strips during the GNSS/IMU import you have to create or recreate them with the "Strip Generation Wizard".



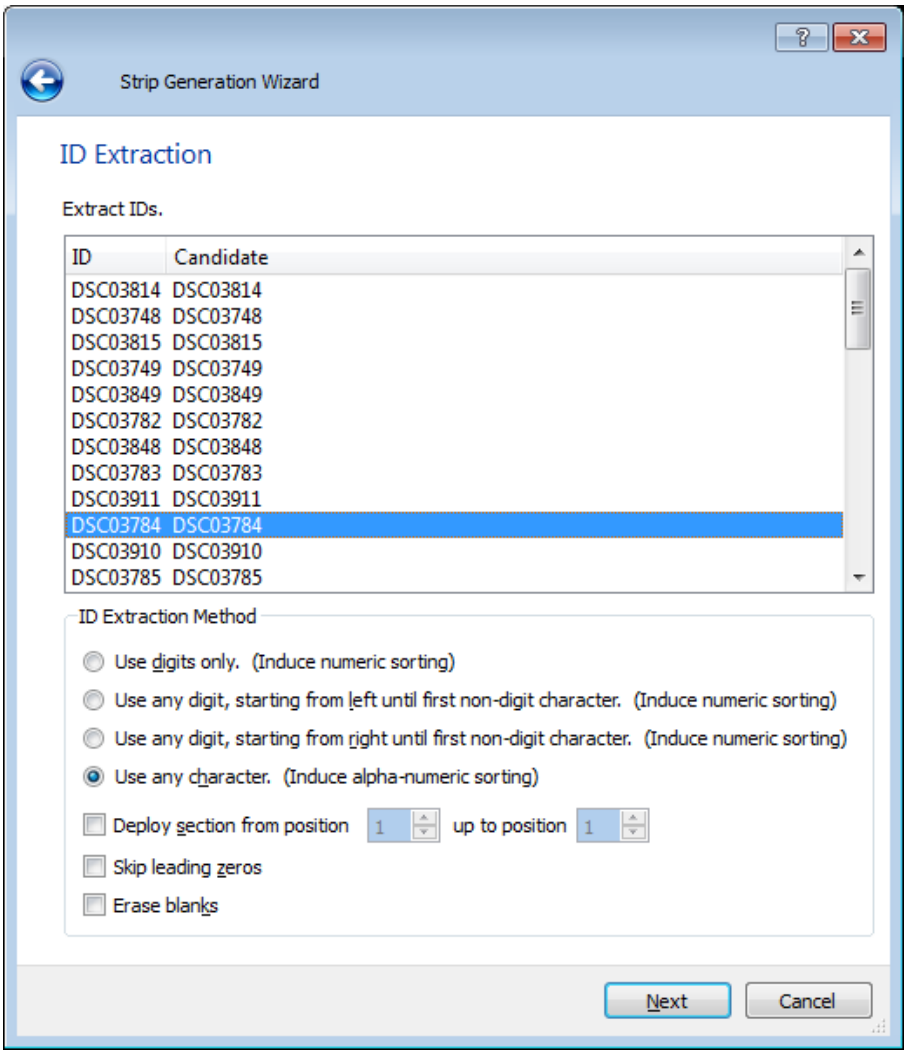
- Select in the Groupings section "Points" from the "UAS Project Editor".



- Clicking on Generate will open the "Strip Generation Wizard". The first window informs that the strips will be generated from the photo ID information. Continue with ***Next***.

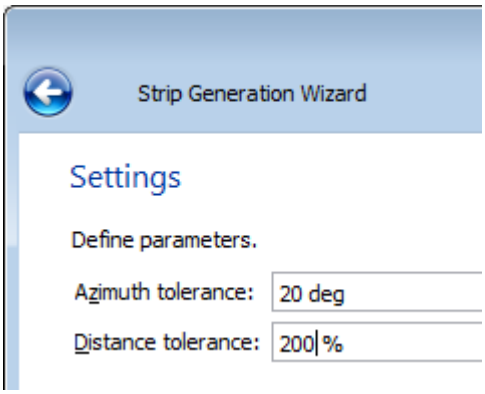
- The strip definition relies on photo information, i.e. on unique identification IDs which should be as simple as possible and the approximated exterior orientation parameters. . The automatic procedure might not work successfully if very long or complicated identifiers are used as input data.

  Use the default setting "Use any character" for the training data set.



Continue with ***Next***

- The ***Azimuth and Distance tolerance*** limiting the number of photos to be taken into account when creating a strip.

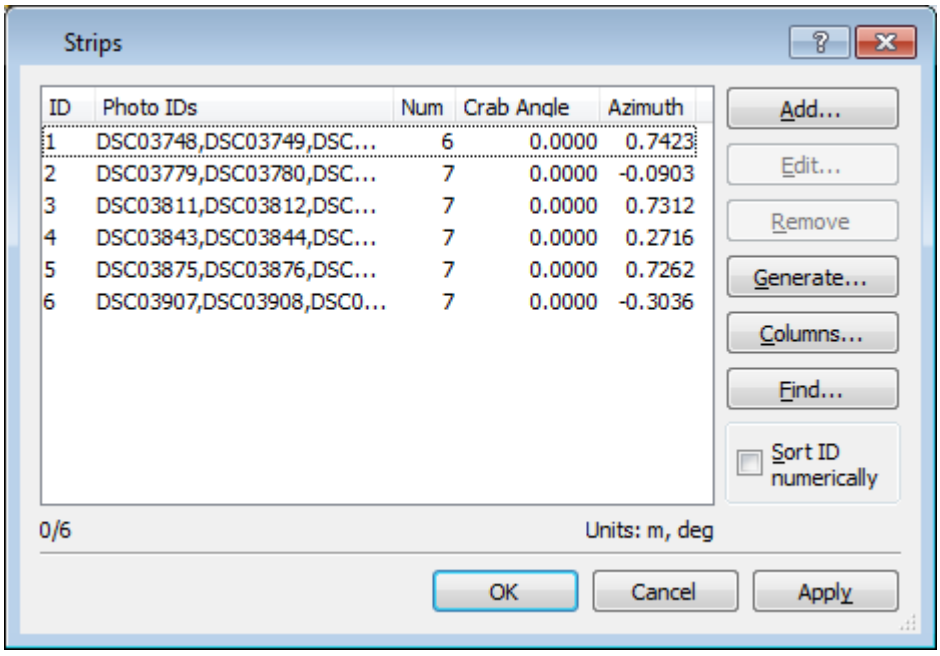


  If the azimuth deviation between the strip azimuth and the next photo exceeds the specified threshold, a new strip is created.

  How to understand the Distance tolerance? During the strip creation, the base distance between neighboring images is being calculated. If a distance tolerance of 0% is entered a new strip will be generated if this “base length” is exceeded, 100% means the distance of two base lengths are exceeded, 200% means three base lengths are exceed and so on.
  Due to the fact that UASs are very susceptible to wind and are in addition not as steady as photogrammetric systems, the entries for “Azimuth tolerance” and “Distance tolerance” should be defined with

increased values.
Use the following value for the training data set:
20 deg for “Azimuth tolerance”
200% for “Distance tolerance”

- ***Next*** starts the strip generation, a progress window will be displayed. Select ***Finish*** closes the wizard.

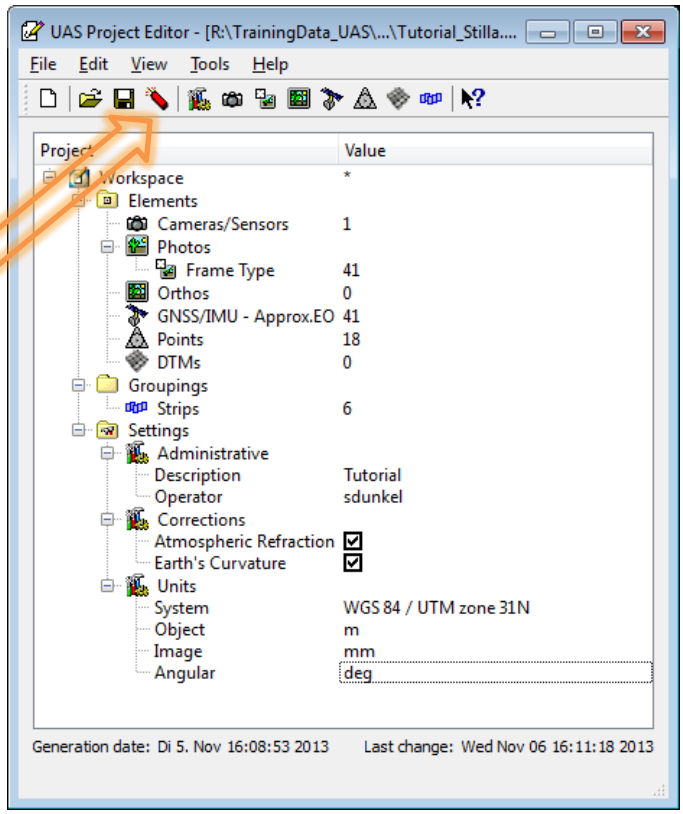


6 strips should have been created. The “Strips” dialog shows the created “Strip ID” the assigned photos in this strip, the “Number of photos” in the strip, the “Crab Angle” and the calculated “Azimuth” angle.

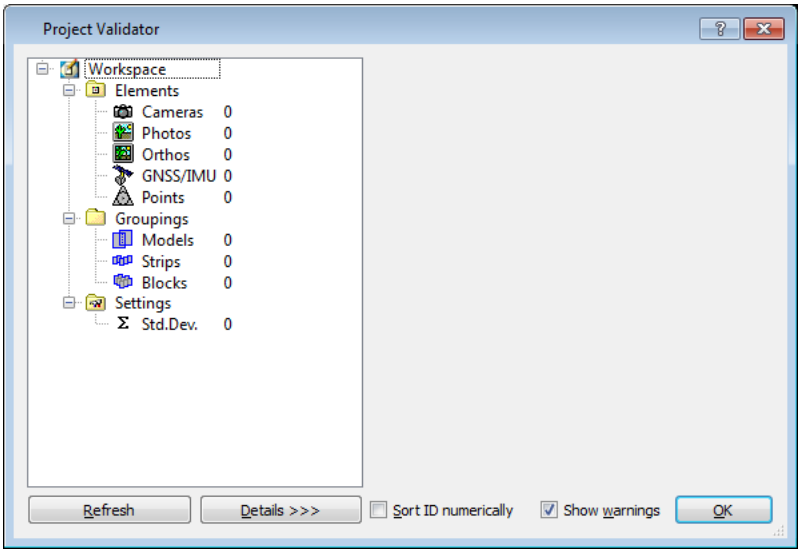
Each strip can be edited by selecting it and changing its image definitions.

2.2.7. Finishing project definition

The project definition should be now complete without any remaining errors.



Use the “Project Validator” to get detailed information of announced warnings and errors.



If all is ok leave the “Project Validator” and then the “UAS Project Editor”.

To recapitulate the project setup we offer the possibility of viewing the video tutorial: *VideoTutorial_UASMaster-ProjectSetup_(English).mp4*

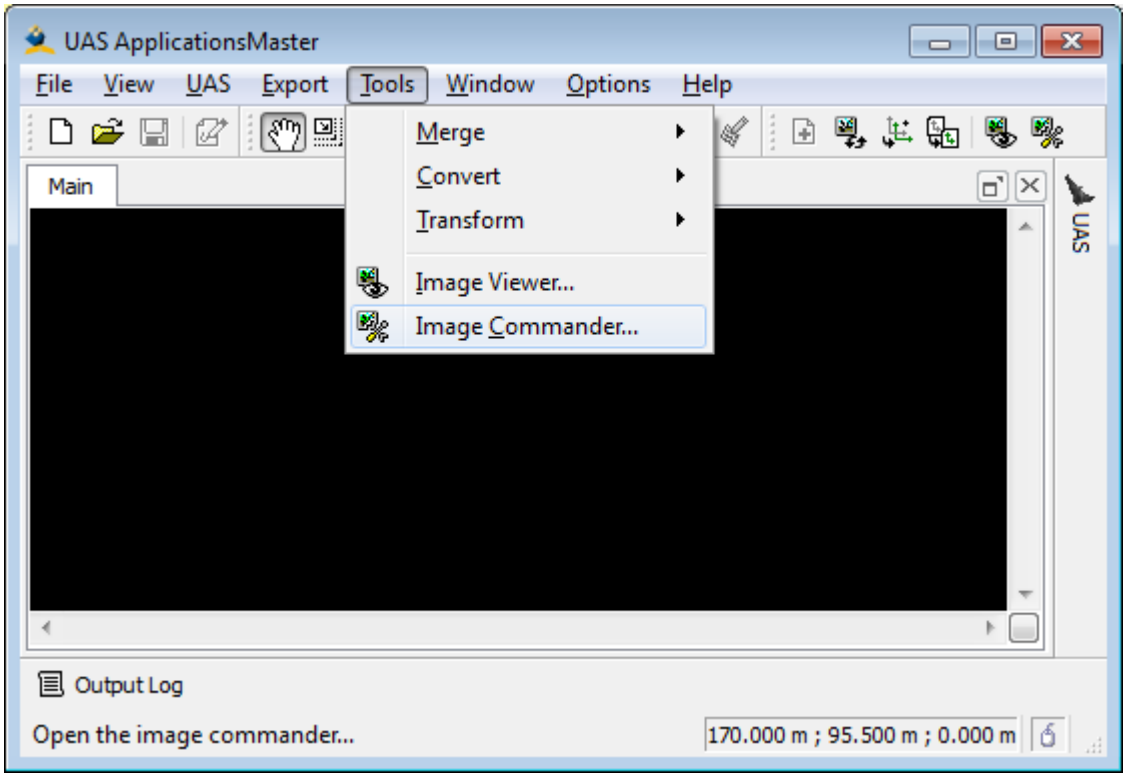
2.3. Image overviews

For Jpeg images no image overviews will be created. The whole image will be loaded into the RAM of the computer. The resampling of the displayed image extract, e.g. during control point measurement, will be done on the original resolution. For bigger projects and a small capacity of RAM .this could be very time consuming.

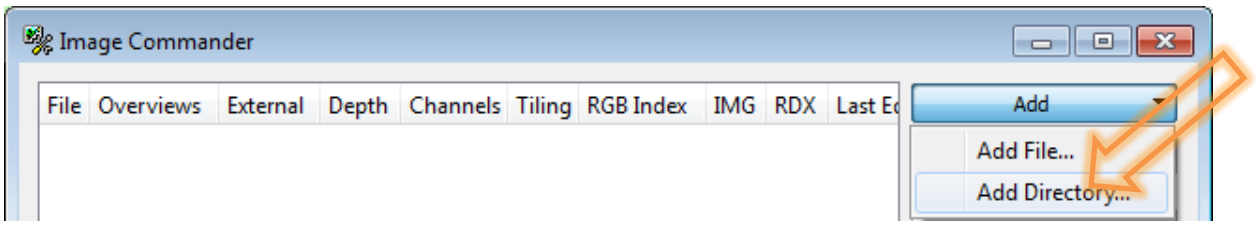
Using images in TIFF format, image overviews (image pyramids) have to be created. This will result in much faster processing and displaying times.

2.3.1. Creating Image overviews for images in TIFF format

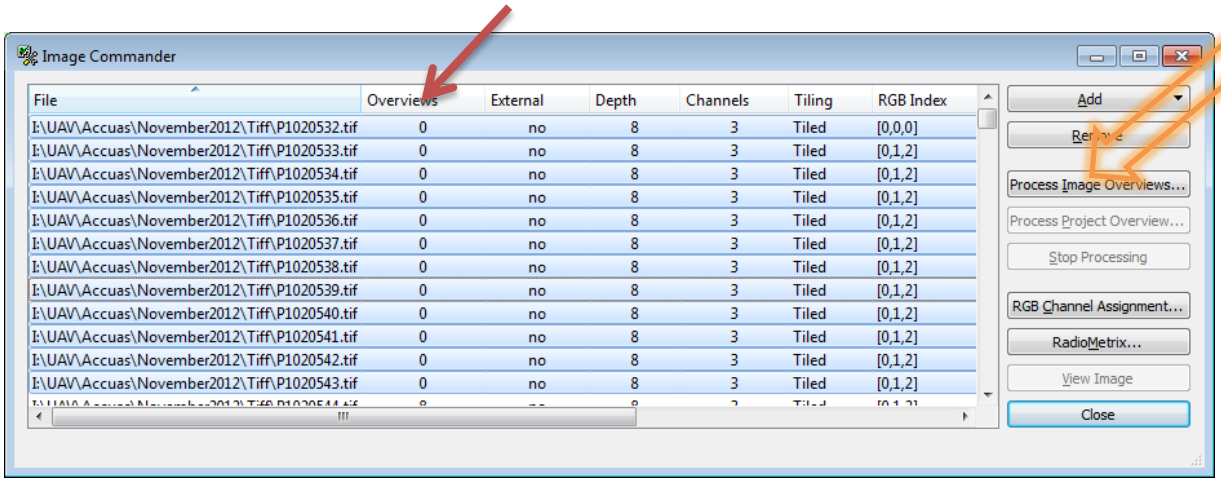
The “Image Commander” can be used for creating the overviews of the TIFF images.



It can be launched from the ***Tools*** menu in the “UAS ApplicationsMaster” interface.

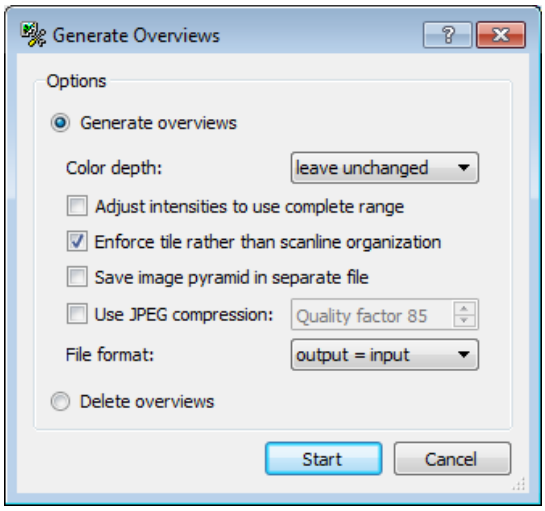


- ***Add*** the directory where the images are stored

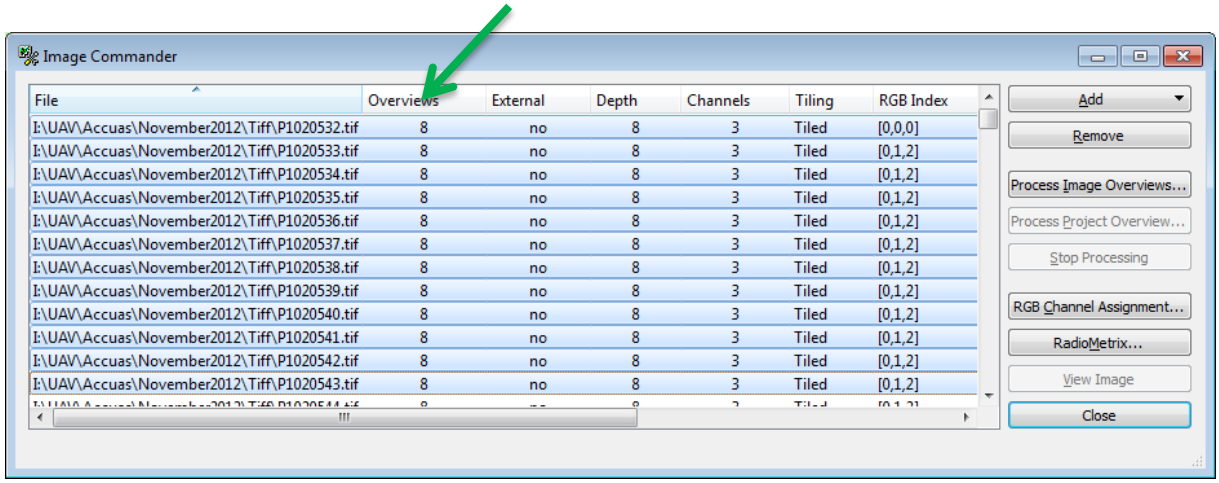


All available images in the directory will be listed. This includes information about existing “Overviews”, “Type” of overview (External or Internal),”Depth” of image (here 8bit), the number of “Channels”, the type of the TIFF format (here Tiled) and the channel assignment.

Select the image overview option to calculate overviews for Tiff images by selecting the button ***Process Image Overviews***.



In general the default settings are recommended – create tiled tiff format with no compression. The number of overviews is automatically defined based on the image extent.
It is possible to store the image pyramid in separate files instead of creating internal pyramids.
Start will initiate the processing. The result will be listed accordingly.



3. Georeferencing

3.1. Strategies

The strategy of the Georeferencing depends strongly on the quality of input data. In case a camera with a rough distortion model is available – like the Trimble UX5 – the Georeferencing will need less effort.
Apart from that also the block structure has a big influence to the work you have to invest for this production step.

3.1.1. Strategy for projects using a camera with distortion model

a) Measurement of ground control points
b) Acquire tie points
c) Camera calibration using the extensive mode

In case the ground control point location is difficult it could be beneficial to change this strategy to the following:

a) Acquire tie points (relative orientation)
b) Measurement of ground control points
c) Adjustment using type “weak”
d) Camera calibration using the extensive mode

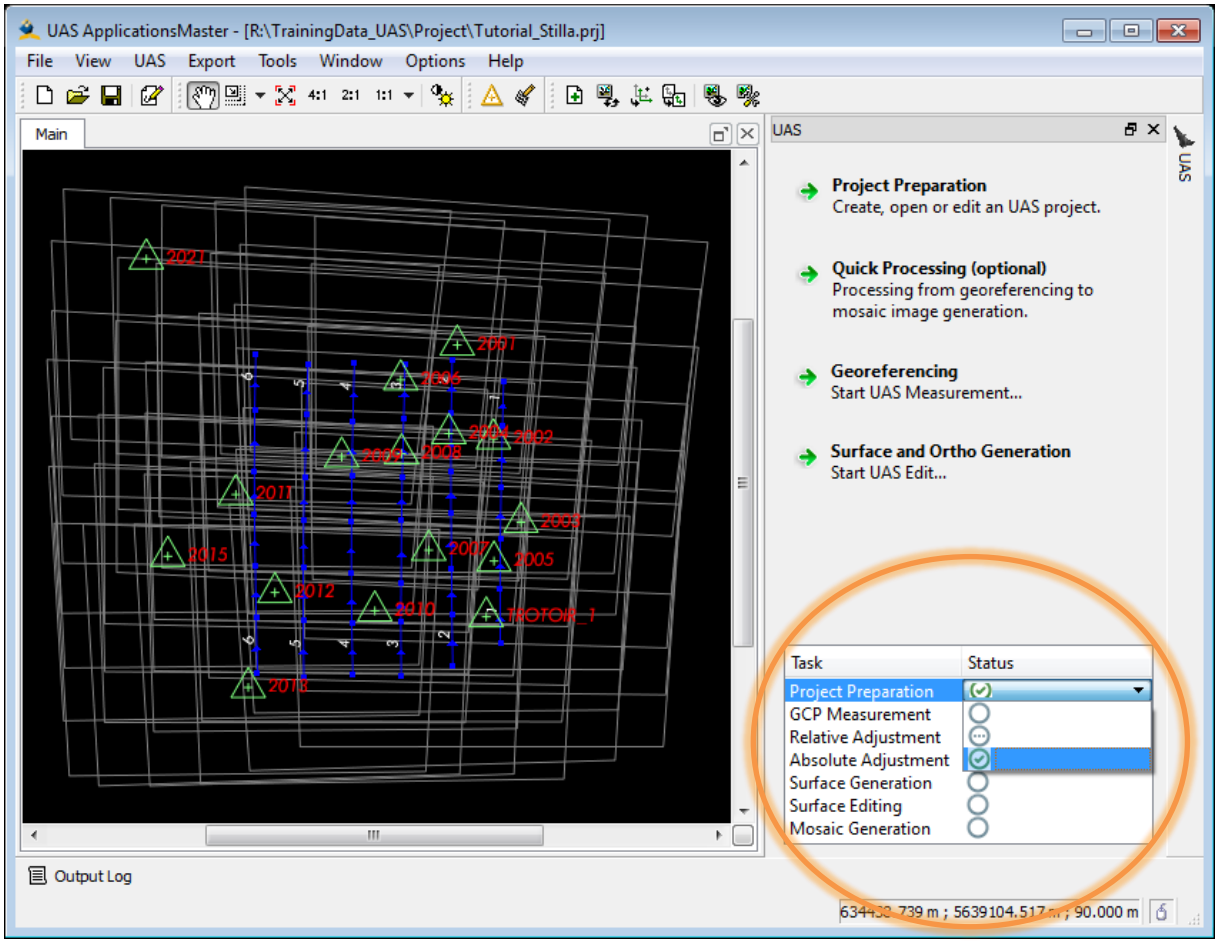
The advantage of processing the relative orientation first is that the image section the control point is positioned to fits much better. This allows a faster measurement of the control points.
The final adjustment is necessary to check if there is no error in the control point measurement.

3.1.2. Strategy for cameras without distortion model

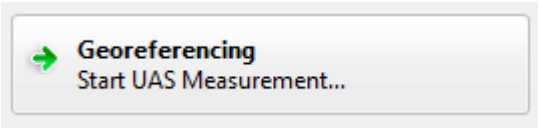
a) Acquire tie points (relative orientation)
b) Measurement of at least 2-3 ground control points
c) Adjustment using type “weak”
d) Measurement of the remaining ground control points
e) Adjustment using type “weak”
f) Camera calibration using the approximate mode
g) Check and if applicable measure remaining ground control points
h) Camera calibration using the extensive mode

3.2. Acquire tie points

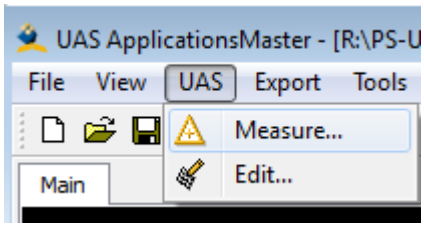
After the project setup the “Main” window of the “UAS ApplicationsMaster” shows the footprints of the defined images, the rough position of the entered control points and the position of the strips.
Refresh the “Status” of your project and set the “Task” ***Project Preparation*** to done ☑.

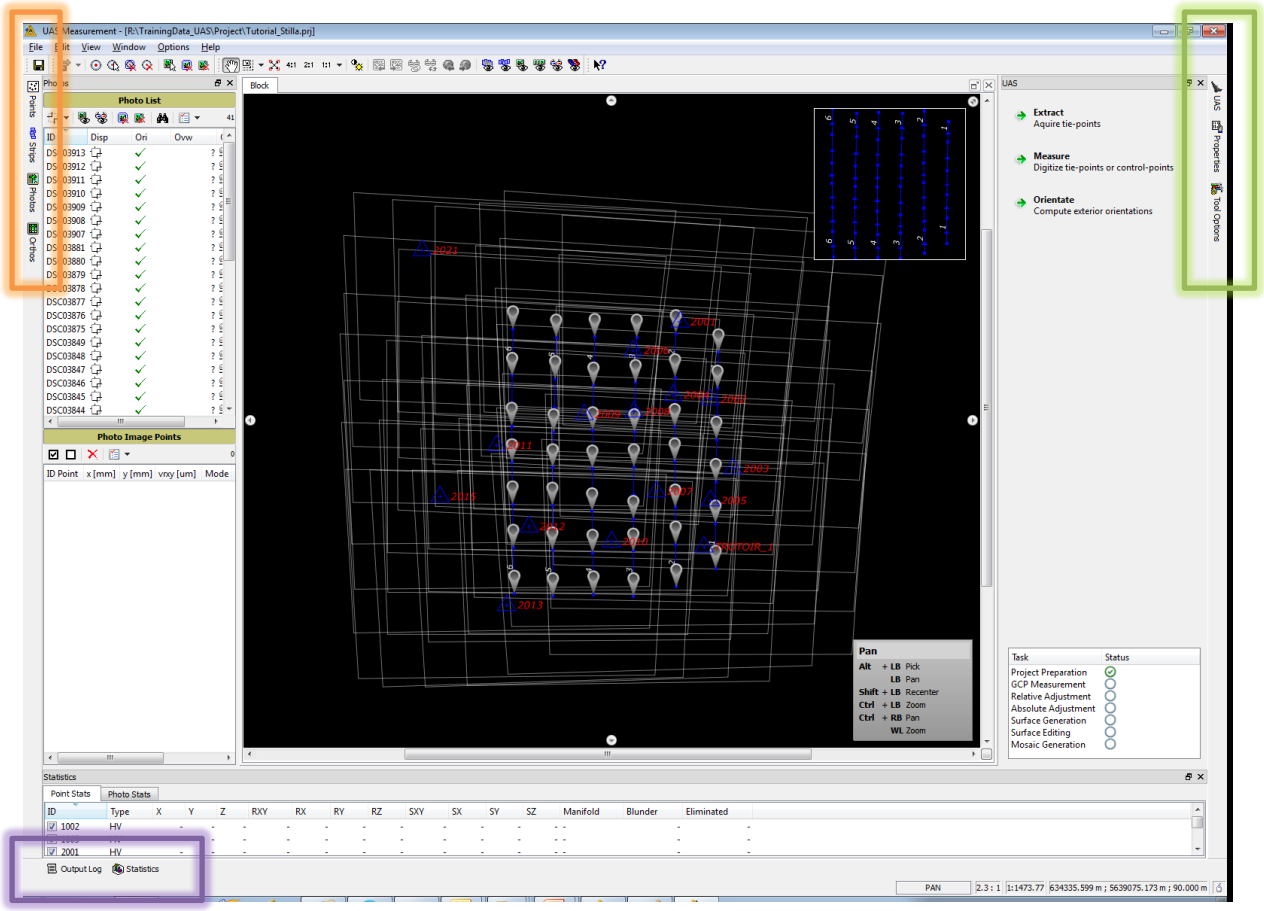


Clicking on “Georeferencing” at the right side of the “UAS ApplicationsMaster” interface will open the “UAS Measurement” dialog.



It is also possible to start this dialog selecting “UAS“ and “Measure” on the “UAS ApplicationsMaster” interface



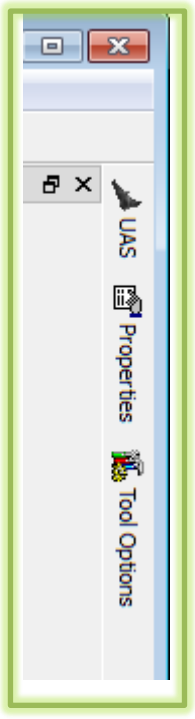


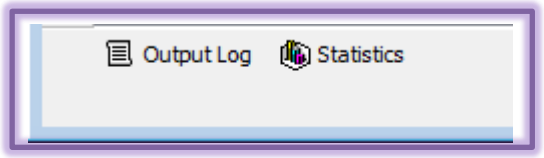
General information about the interface

Lists and tables are used for navigation, information and editing. On the left side of the main programs frame you will find toggle menus to show the lists for ***Points, Strips, Photos*** and ***Orthos***.

On the right side of the main programs frame you will find buttons to show the ***UAS*** window (to select the processing step), ***Properties*** list (to select symbols/items to be displayed and to show analysis results) and the ***Tool Options Window*** (to select all options for a selected tool such as the measurement mode).

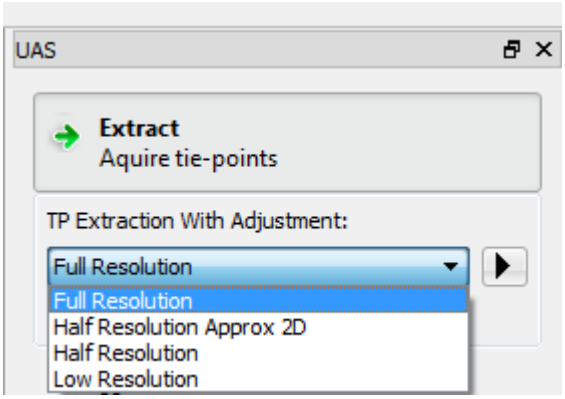
On the lower left side you will find the ***Output Log*** (messages/errors) and the ***Statistics*** listing.





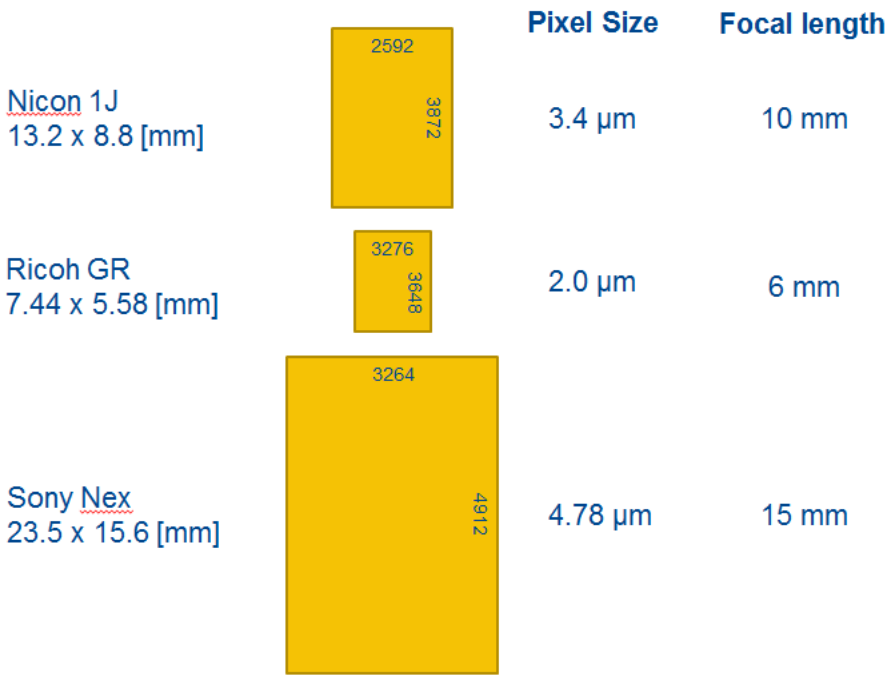
For the extraction of the tie points a sift operator is used. The matching will be carried out for the whole image area. The tie points will be used for the whole process, no tie points will be removed from the project. At the end the operator can decide if he wants to delete not used tie points (***Statistics***) or to keep them for further runs.

UASMaster offers for the tie point extraction with adjustment of the block four methods.



3.2.1. Extraction methods

The extraction method to be used depends again on the used camera and the quality of the images (blurred, compressed, no forward motion). The used sensors are very small and respectively they get very small pixel sizes. Imagine that your project is flown in 70m height and using a SonyNex camera will result in a GSD (ground sample distance) of 2cm. For smaller sensors (smaller pixels) this value will be much smaller. Noticing the image quality, it is not realistic to expect an accuracy < 2cm in terrain although the “Full resolution” would theoretically result in higher accuracies. So we recommend for smaller sensors the method of “Half Resolution” because the processing is much faster and the accuracy comparable to the actual result using the “Full Resolution”.
In most of the cases using the method of ***Full Resolution*** will not produce better accuracies but much longer processing times.



Full Resolution
Full resolution will extract tie points up to level 0 (original pixel size). It could increase the accuracy for pixel sizes bigger 4µm. Be aware, that the processing needs much longer.

Half Resolution Approx 2D
This method should be used for images with very bad Kappa values or unknown rotations. It results in an improvement of the planimetric accuracy and the azimuth angles. Nevertheless the method should not be used for big projects, resp. not for plenty of images.
Examples:

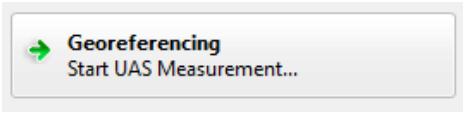
- Use if „Half Resolution“ is not working
- Use for Balloon projects
- Use directly for images having bad kappa values, select the „images of interest“, measure manual tie points and proceed the tie point extraction via „Half 2D).

After the processing a tie point extraction using ***Half Resolution*** has to be done.

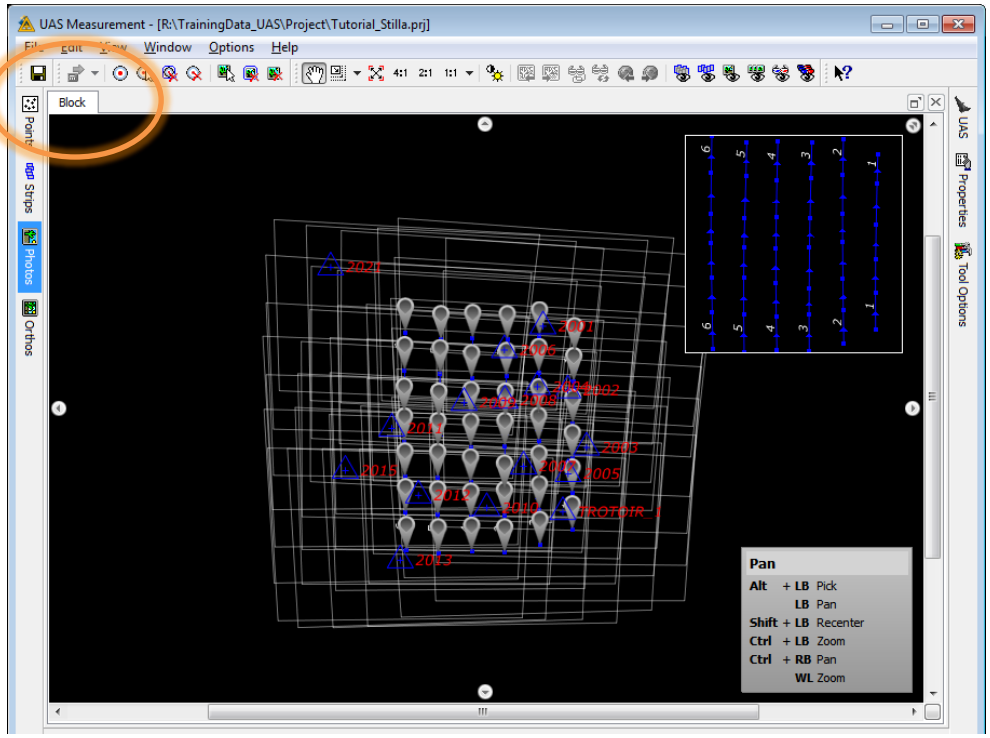
Half Resolution
This method will fit as default for the majority of projects. The tie point extraction will be done on level 1, which means on a resolution of twice the pixel size.

Low Resolution
This method is good for a quick processing but with less accuracy.

3.2.2. Steps to work through



- After project setup start the “Georeferencing”
  The “UAS Measurement” dialog appears. The project will be display in the ***BLOCK*** view.



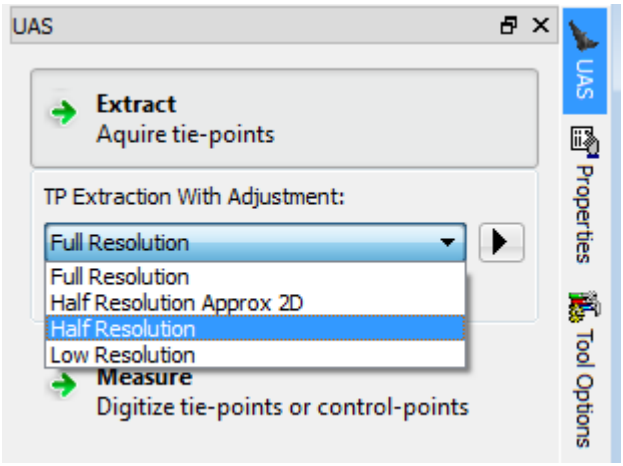
The ***Block*** View is

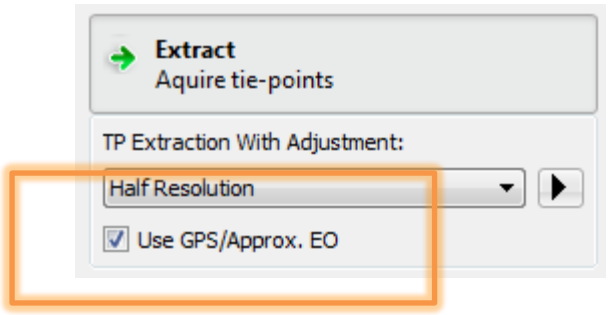
- Displaying images north oriented by projecting the images with the exterior orientation parameters to the mean terrain height. Allowing a block overview with real image content.
- Projecting control, check and tie points into the images.
- Displaying strips with arrows indicating the flight direction
- Displaying analysis content

The displayed projection center markers indicate the adjustment status.

- Open the UAS side menu by clicking on the UAS tab on the right side of the “UAS Measurement” interface

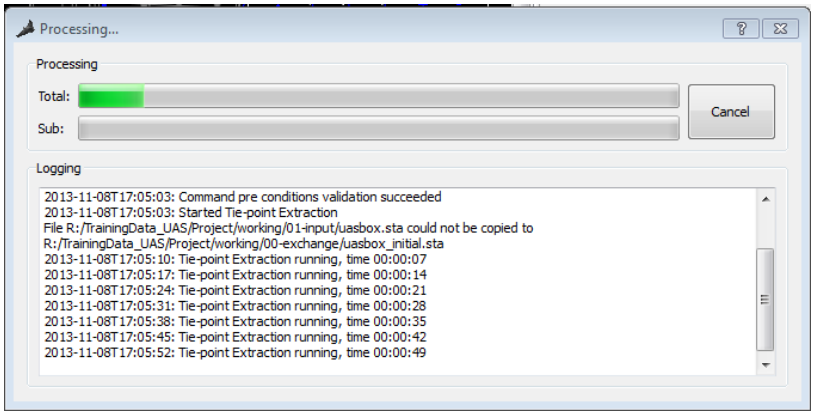
- Select ***Extract*** and a sub-menu will be opened.
  Select the tie point extraction method ***Half Resolution.***
  The matching is then performed on a GSD of 4 cm.



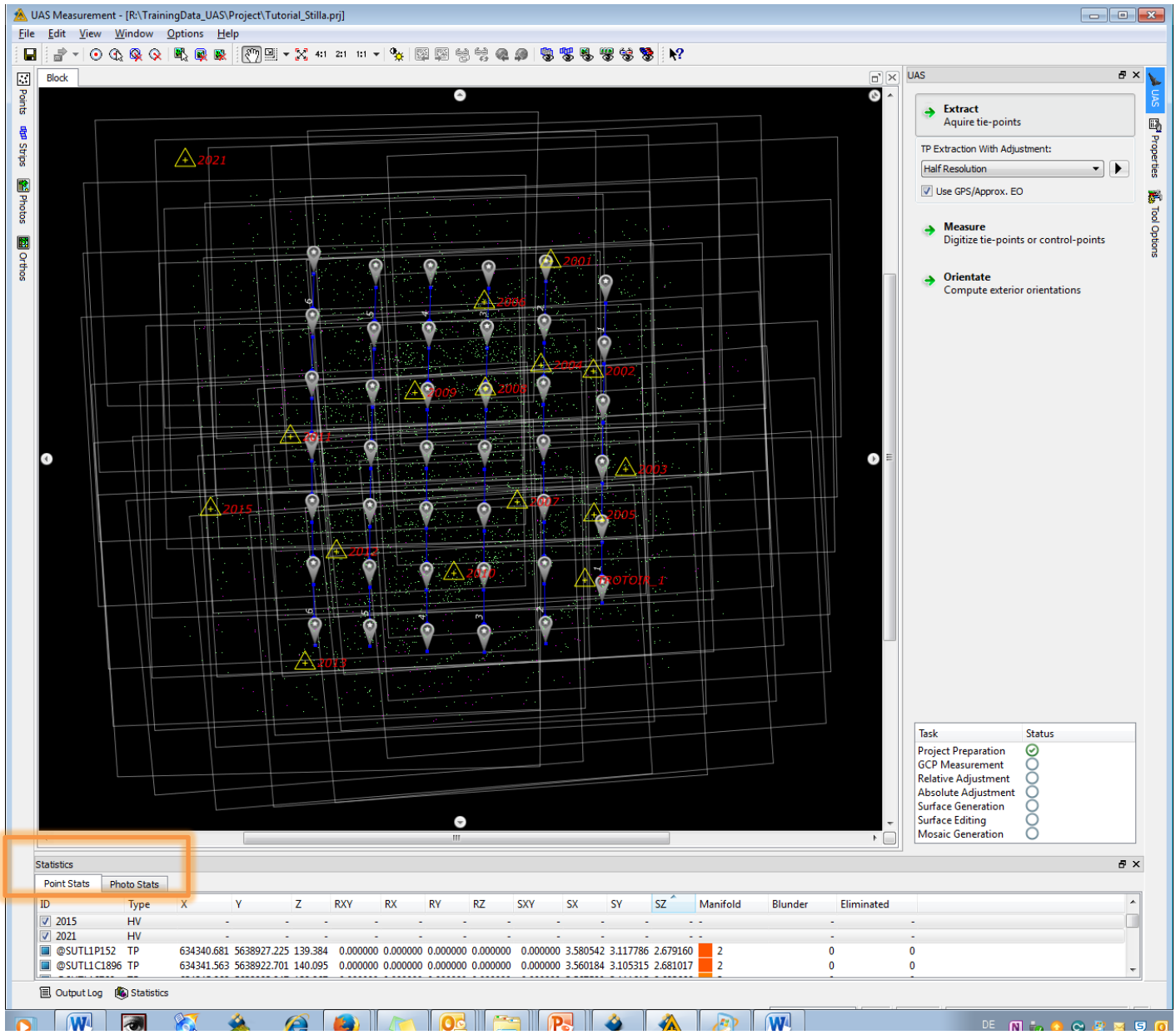


Remark: By default the checkbox for “Use GPS/Approx. EO” is activated. Then all GNSS positions activated in the “UAS Project Editor” will be used for the adjustment.

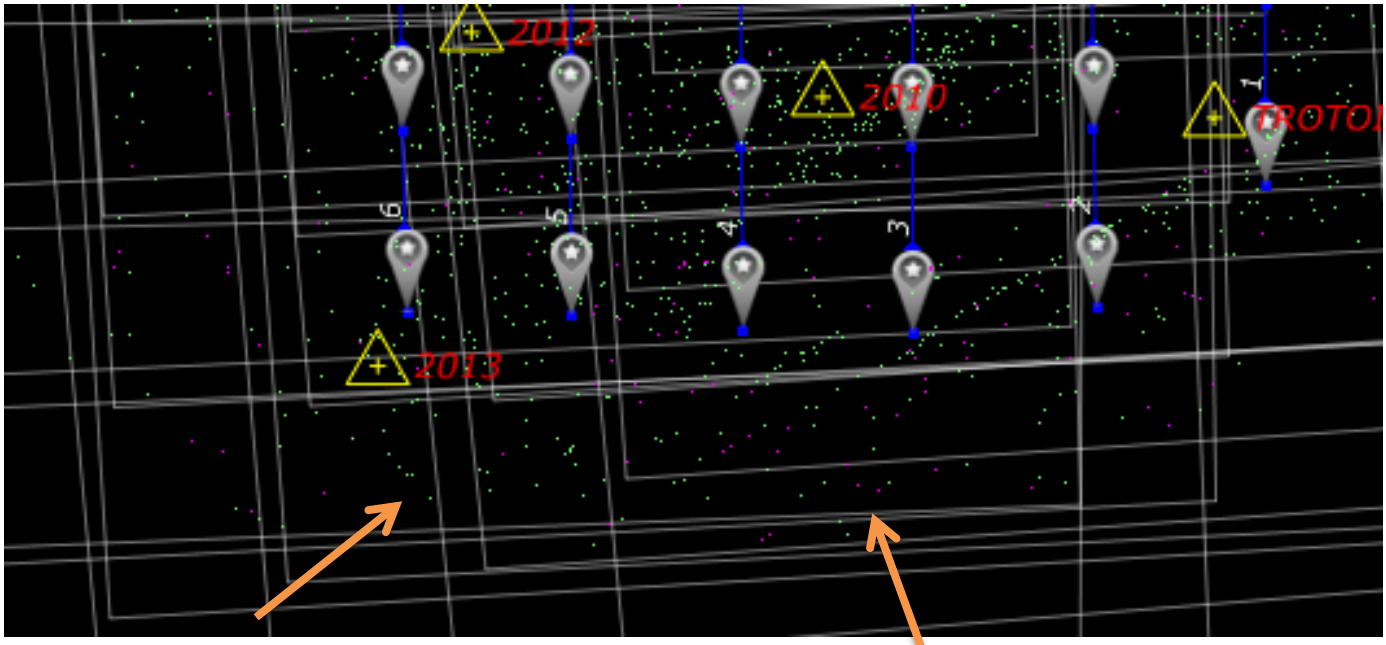
In a ***Processing*** window the processing progress can be tracked.



- After finishing the processing, the Block viewer shows the relatively oriented footprints, the control point positions, the strips and the tie points. All images used in the adjustment and therefore having updated exterior orientation values are marked with a “*”. In the training example all photos could be used, all projection center markers have a “*”.



All used tie points are displayed in green color. When sorting to SX (or SY or SZ) in the “Statistics” window all tie points being excluded from the adjustment are sorted at top of the list. Selecting them in the list will show all these tie points in pink color in the “Block view”.

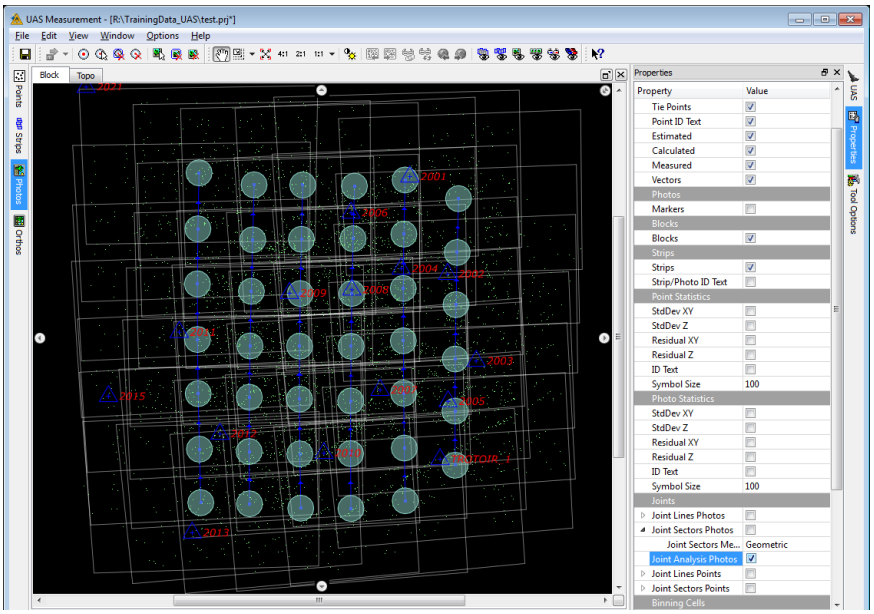


green points > used for adjustment

pink points > not used for adjustment

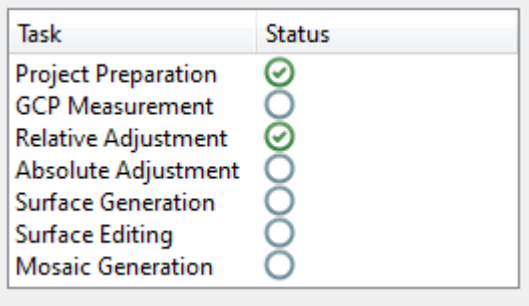
Remark:
All matched tie points remain in the project, doesn't matter if they are used for adjustment or not. Pink does not mean that they are wrong but they do not fit to the current configuration. After a camera calibration and the corresponding refinement of the exterior orientation pink points can change to green ones.

- Before starting with the control point measurement, check the distribution of the tie points in the photo and the general connection of the photos.
  The analyzing tools of the "UAS Measurement" can be enlarged by clicking on the ***Properties*** tab on the right side of the interface



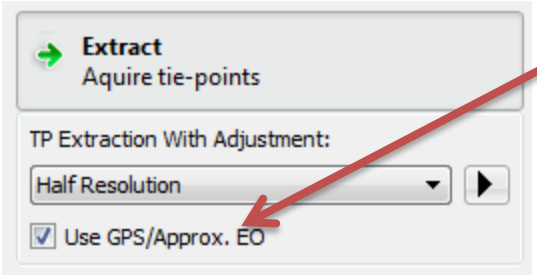
Activate the ***Joint Analysis Photos*** option to check if all images are connected. In case all images are marked with a circle and the same color, the block is completely connected. In our example, the display shows that all photos are well connected so we continue with the control point measurement.

- Document the finished processing step by ticking off the status of "Relative Adjustment"



3.3. GPS/Approx. EO

The approximate exterior orientation values should be used for the adjustment only if they are about 10m or better.



In case the values are worse they serve as initial values only. The ***Use GNSS/Approx. EO*** checkbox should be deactivated.
If many ground control points are available, the GNSS values also could not be used, because the accuracy of the ground control point coordinates is usually much better.

Remark: By default the checkbox for "***Use GPS/Approx. EO*** is activated. Then all GNSS positions activated in the "UAS Project Editor" will be used as observations for the adjustment.

3.4. Point Measurement

3.4.1. General

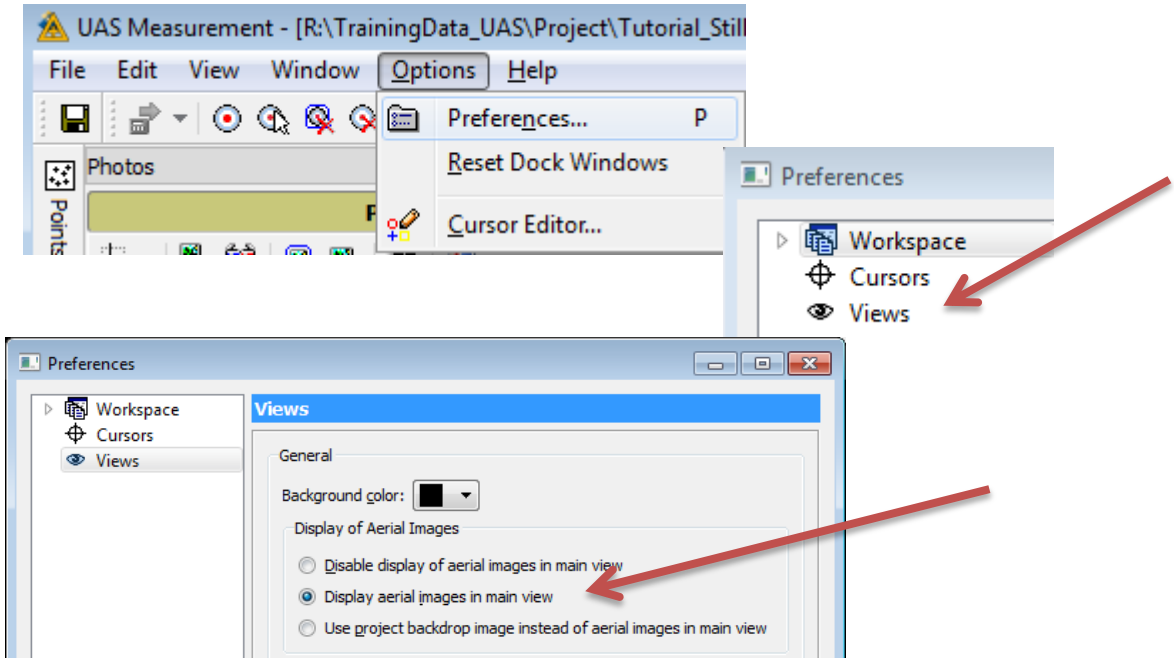
Generally, there are two possible workflows in "**UASMaster**": Either doing all control point measurements before starting the automatic tie point extraction or doing the automatic tie point extraction before measuring any ground control.

Control points should be measured in beforehand whenever it is needed to stabilize the tie point matching because difficulties are expected (forest regions, water…).

In other cases the control point measurement can be done after the tie point extraction. This has the advantage that bad control point measurements will not influence the automatic tie point matching and typically after a relative orientation (tie point extraction without using ground control) the projection of ground control points is much closer to the position to be measured in the photo. Therefore the measurement is much easier.

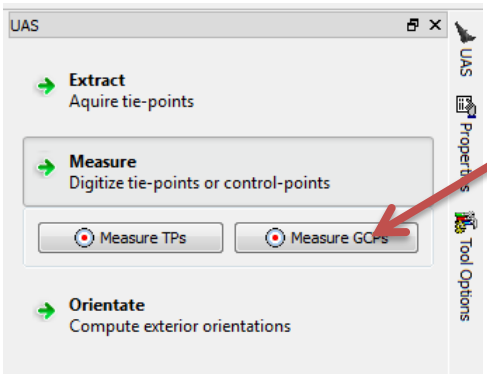
When starting the UAS Measurement the first time, select on the menu bar ***Options*** and "**Preferences**" to define viewing properties and shortcuts for a convenient use of the tool.

To get a coarse overview of the block, you should activate in the sub-menu of ***Views*** the ***Display aerial images in main view*** option. This is optional and not required for the ground control point measurement.



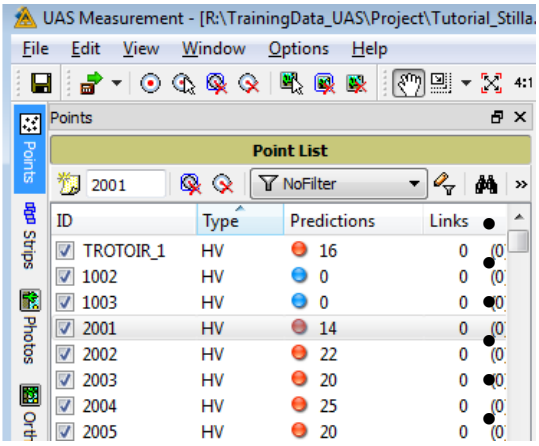
3.4.2. Steps to work through

- Select ***Measure*** and ***Measure GCPs***



1

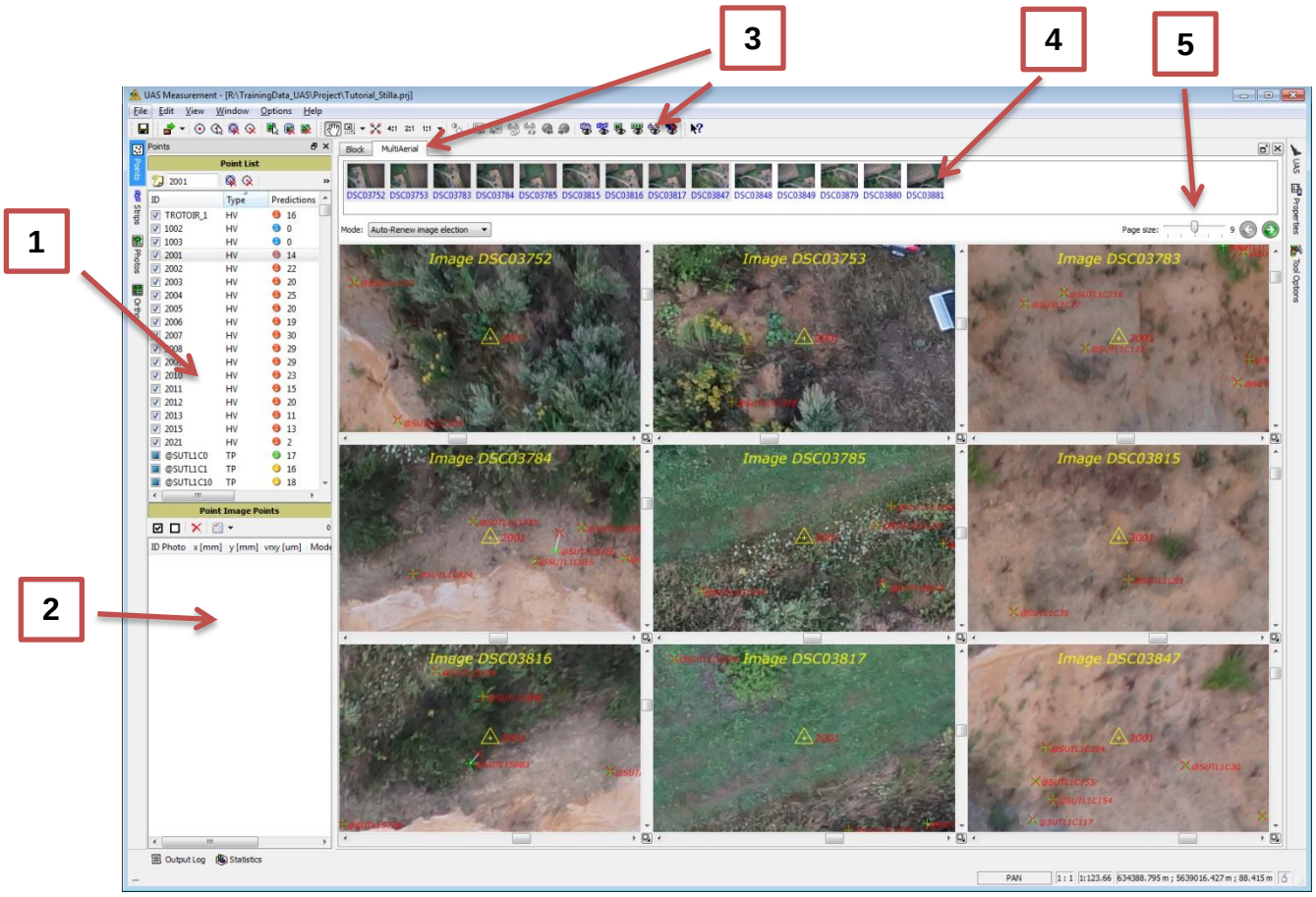
Select on the left side of the "UAS Measurement" interface the ***Point List*** and sort according ***Type***. Now the ground control points are listed at the top of the list.



The first column of the list shows the ***ID*** of the control point, the second the ***Type***.
The following types are possible:

HV	*Horizontal and Vertical control point*
HO	*Horizontal control point*
VE	*Vertical control point*
CHV	*Horizontal and Vertical Check point*
CHO	*Horizontal Check point*
CVE	*Vertical Check point*

(CHECK points are not used for adjustment)



1 ***Point List*** showing the ***ID*** and the ***Type***. Furthermore the ***Predictions*** informs in how many photos the point could be measured.
The ***Links*** shows the actual measurements.
How to understand the interface
The ***Point List*** shows all available ground control points, check points and tie points.

2 ***Point image Points*** displays the measured image coordinates

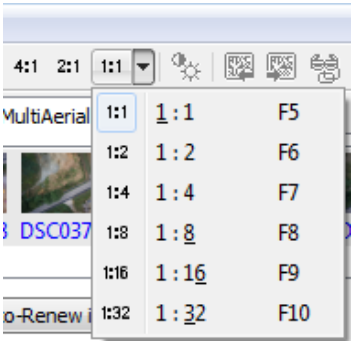
3 *In the* ***MultiAerial viewer*** the measurement will be carried out in mono mode. The ***MultiStereo viewer*** should be selected if you want to measure the points in stereo.

4 Stamps of all photos the point could be measured in

5 The ***Page size*** slider allows selecting the number of measurement windows in the display. This works only for the MultiAerial view. For the MultiStereo the view it is fixed to 4 windows.

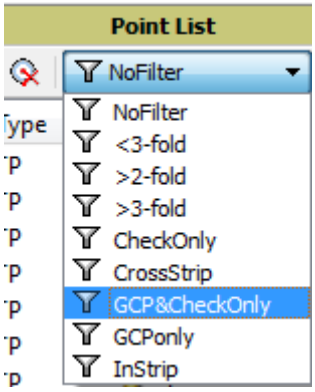
- Select a point in the **Point List.** In case you would like to measure points in stereo, activate View – Displays – **Multi-Stereo Viewer** (or click on the corresponding icon).

- Identifying the control point. The displayed section of the image does typically not represent the correct location of the control point. To find the correct position, enlarge the area by selecting another zoom level offered at the menu bar



In case you did the tie point matching first, the projection of the points might disturb the measurement of the ground control points.

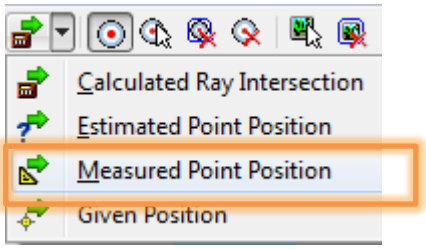
To show the control points and check points only, use the filter options (dropdown box) and select the ***GCP&CheckOnly*** option. This will exclude the tie points for the display as well as for anaylsis options. Please make sure to change the filter option back to ***NoFilter*** in case matching is performed or block analysis is done.



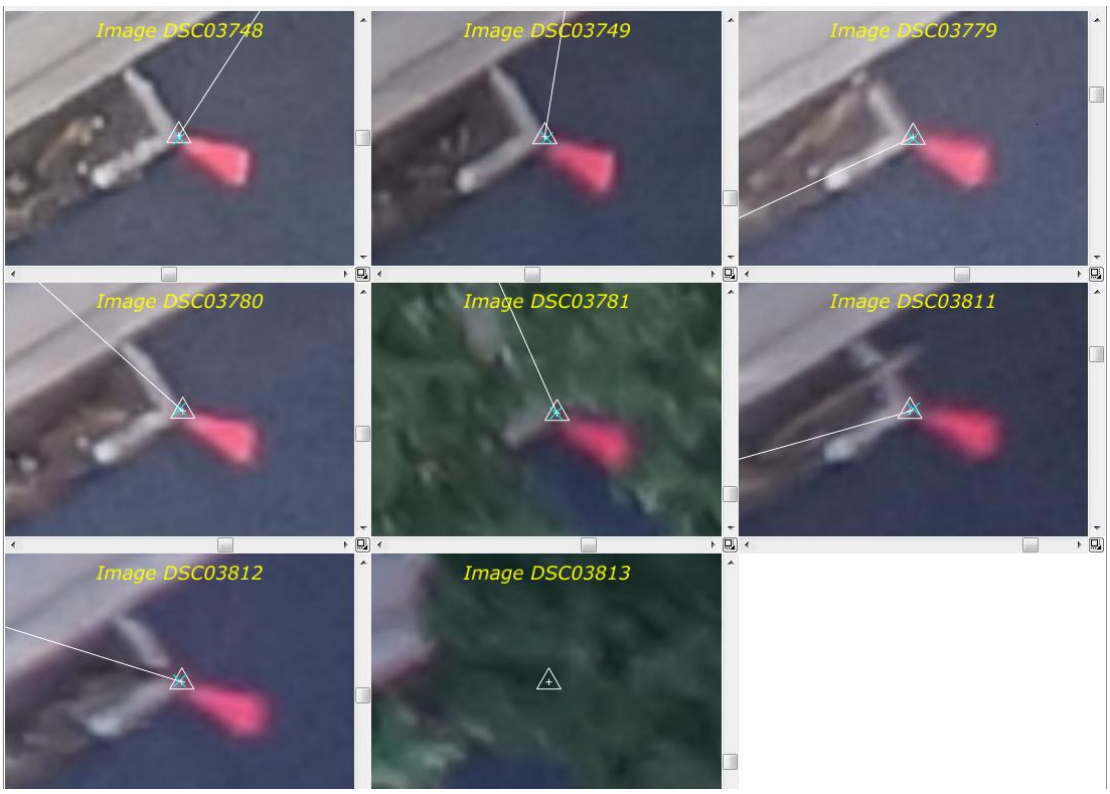
A single click into an image results in a point measurement if ***Measure*** is active. By default the ***Manual*** measuring ***Mode*** is selected.

Measure the position of the point roughly in each photo, use the button to open the photos on the next page.

Then select another zoom level e.g. **4:1** and use the ***Move to*** button to center the measurement windows to the ***Measured Point Position***

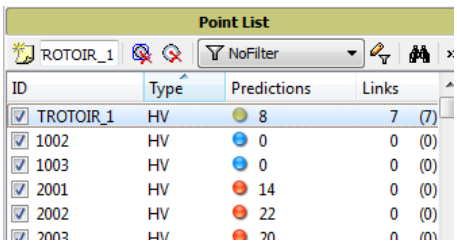


Measure now the point in the correct position.



Measurement of control point TROTOIR_1.

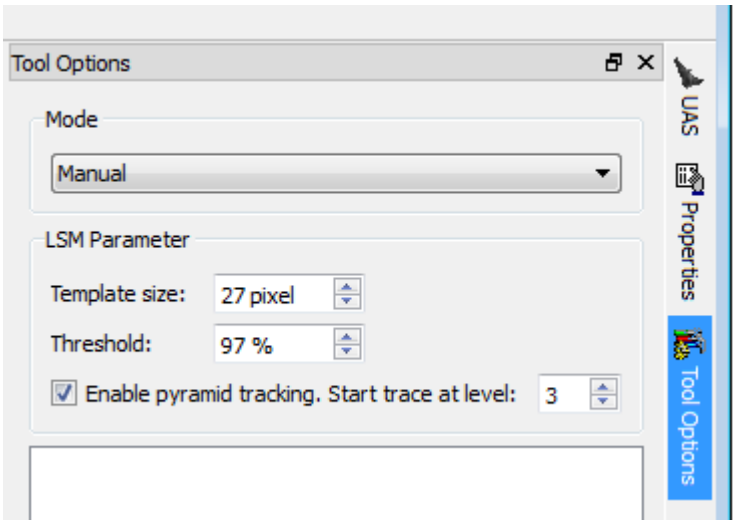
The ***Point List*** shows for the predictions a yellow dot, because the point could not be measured in all photos.



There is also a ***Semi-automatic*** and a ***Full-automatic*** measuring mode available which can be selected with a right mouse click into a displayed photo.

Manual**:** This option activates the manual measurement mode. A click with the left mouse button into an image will place a measurement to the desired position.

Semi-Automatic**:** This allows least squares matching assisted measurement of points. This mode requires that the points have to be measured in each image. But with each new measured position the software is transferring the measured point into the images already measured. Successful matching will be represented by a green square.
The size of the square represents the size of the matching template. If you have problems, e.g. shadow, set the template smaller.



Note: The Semi-Automatic mode will most probably fail, if your point position is not on a ground (e.g. corner of buildings, pole points). Points on elevated objects have to be measured in most cases stereoscopically.

Note: Please double check the refined measurements carefully, to make sure the matched position is in fact the correct location.

Hint: for semi-automatic measurement it is recommended to deactivate the ***Pyramid Tracking***.

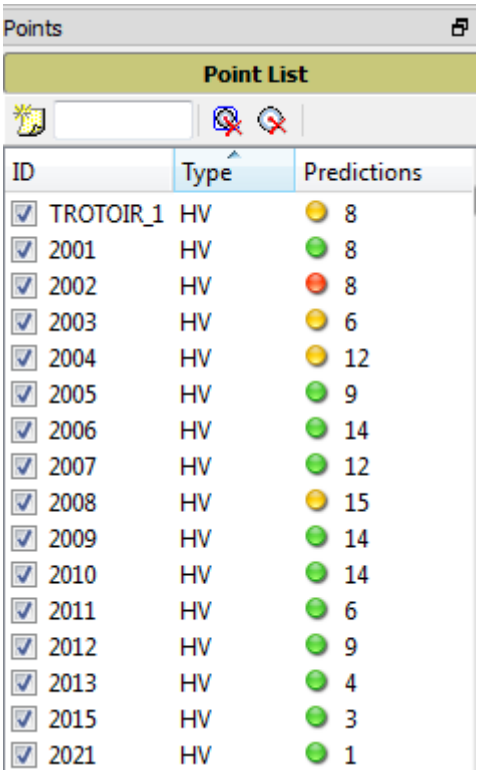
Full-Automatic: This allows least squares matching assisted measurement of ground controls, check and tie points by defining the position of a point in just one image. When activated click with the left mouse button in one of the images at the exact position you would like to have the point measured. The software will then project the measured position into all other images in the Multi-Aerial or Multi-Stereo View and will do a least squares matching of the point.
Note: The Full-Automatic mode will most probably fail, if the projection of a point into other images is insufficient based on rough orientation values or if the point location is not on the ground (e.g. corner of buildings, pole

points). Points not on the ground have to be measured in most cases stereoscopically.

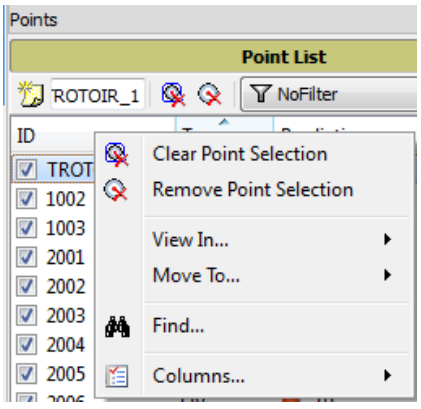
Hint: for full-automatic measurement it is recommended to deactivate the ***Pyramid Tracking***.
To be successful in full automatic point measurements, it is essential to have good orientations (e.g. to do a relative orientation – automatic tie point matching – first) and to have a mean terrain height definition as good as possible.

For projects with no camera calibration and bad image quality the Semi-automatic and Full-automatic measure mode fails very often.

- Continue with the ground control point measurement until all of them are measured. When the measurement is finished the point list should look similar to the next screenshot.



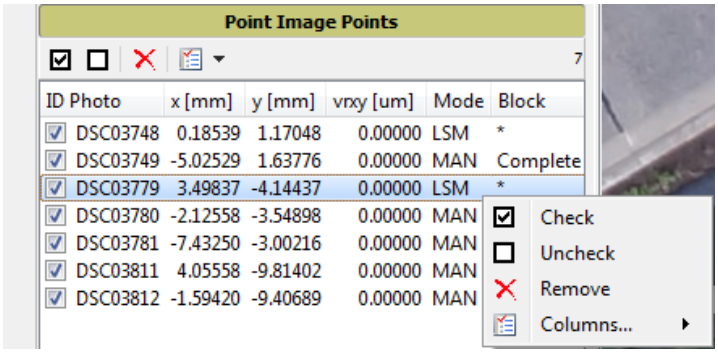
3.4.3. Editing functions



Remove a point
Select a point in the point list, press the right mouse button and select ***Remove*** in order to delete all measurements of a point. For given points (ground control or check points) only the image measurements are removed, in case of manually measured tie points, the complete point is being removed from the list.

To delete a selected point or its measurement directly from the views, press the right mouse button (while positioning the cursor in one of the point views) and select either ***Remove Image Coordinate*** or ***Clear Image Coordinates***.
Remove Image Coordinate removes the current measurement only and **Clear Image Coordinates** deletes all image measurements of this point.

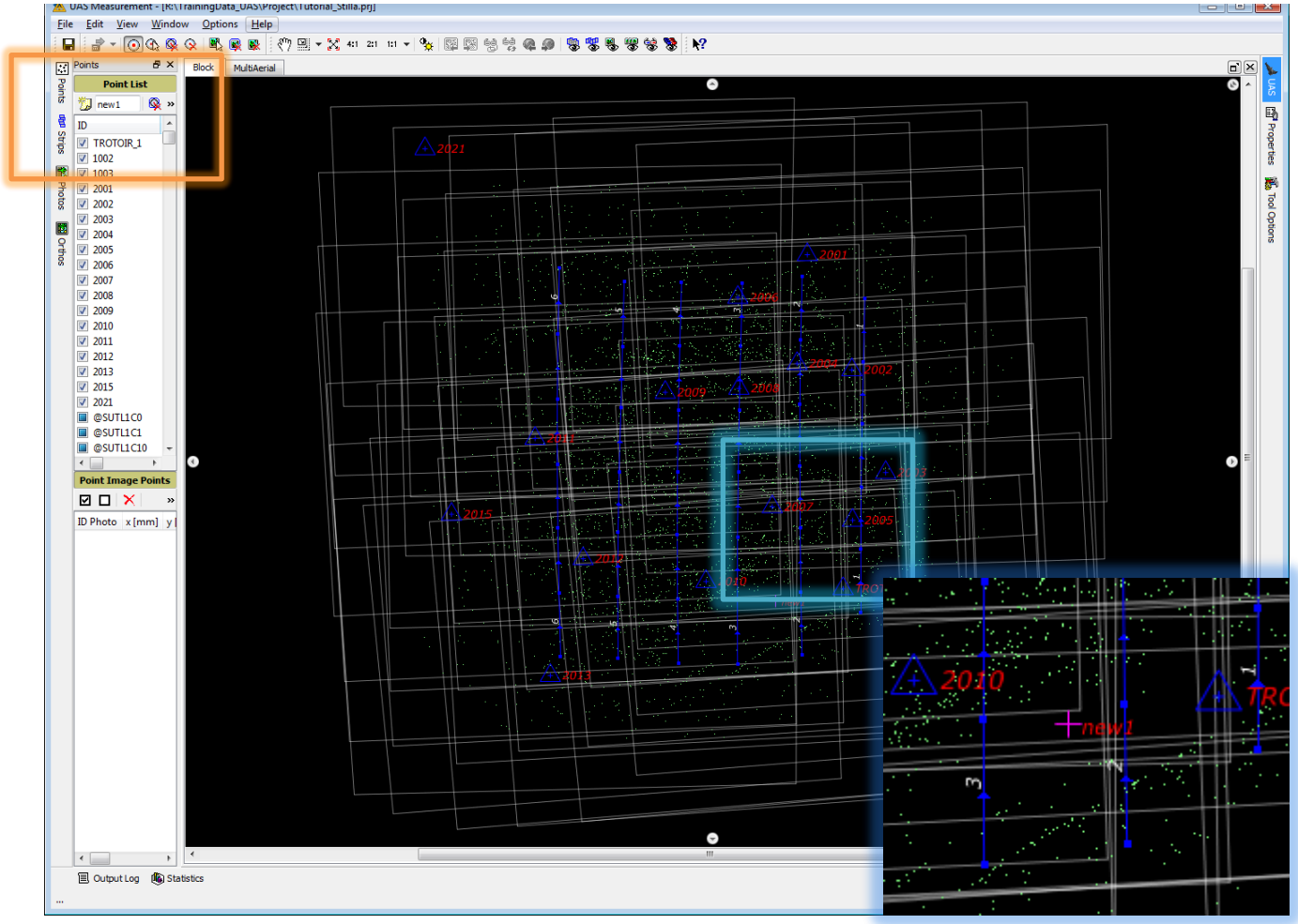
Furthermore it is possible to remove photo measurement directly from the ***Point Image Points list***.



3.4.4. Measurement of new tie points

In case of an insufficient block connectivity in some areas it could be necessary to measure additional manual tie points.

- Select the ***Measuring Mode*** 
- Enter a new point ID into the *Point ID input field* of the ***Point List***
- ***Click*** with the left mouse button **in** the ***Block*** or ***Topo View*** to a position where you would like to have the point measured.
  Alternatively you may either have the ***Multi-Aerial*** and ***Multi-Stereo*** views already opened to measure the point into these opened images. A third option would be to select any number of images from the images list and click the "***Open in Aerial Viewer***" to launch the ***Multi-Aerial View*** with the selected imagery to measure manual tie points..



- In case the point is measured in the **Block** or **Topo View** in manual mode, the new tie point is being listed in the point list dialog but not yet measured.

- Select the new generated tie point from the list to open it in the Multi-Aerial Viewer. The Multi-Aerial view displays now all images the new tie point is projected to..

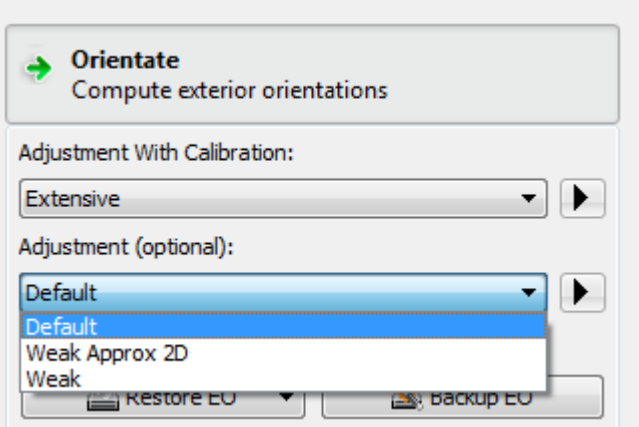
- Use the ***Zoom*** function to get a good view on the designated point position.

- ***Refine*** the ***position***
- Continue measuring the next points if necessary.

3.5. Orientate

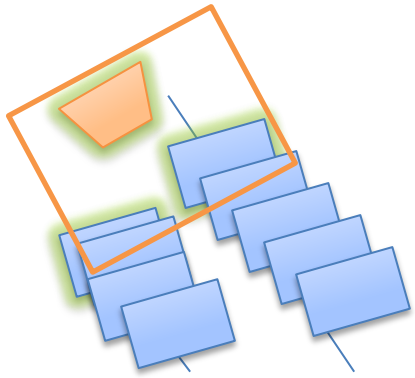
The orientate dialog includes options to run adjustments including camera calibration as well as running the adjustment only (optional).

3.5.1. Adjustment (optional)



There are three adjustment methods available. The ***Default*** method should be used only in case your camera is calibrated and you measure or re-measure some tie points or ground control points

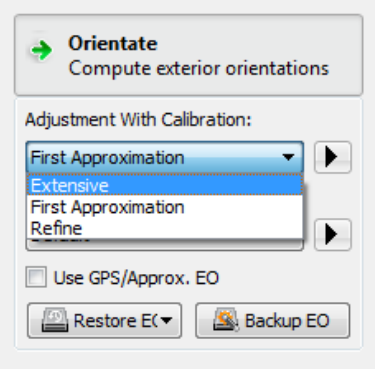
Weak Approx.2D should be used for images where the weak adjustment failed. In such a case select in the “UAS Measurement” tool the floating image(s) as well as the images the floating image should be connected to and measure some manual tie points. Then start the ***Weak Approx.2D adjustment***. A planimetric adjustment and a correction of the azimuth angle will be performed. In case this is successful and the photos are connecting the ***Weak*** adjustment should be started again.



Weak This method should be used if your camera is not calibrated or your block configuration is unstable. This indicates that the EO is not very good, so that the adjustment needs to run with weaker accuracy limits.

Note: All 3 adjustment options are optional. They are only necessary if **re-measurements** were performed in the block, the measurements should be checked or if adjustment parameters were changed. The result of a previous run will be treated as a good approximation and will be used, together with the new measurements, as a basis for a new block adjustment.

3.5.2. Camera Calibration



A camera calibration using the method ***First Approximation*** should be used for cameras having no distortion information available. The ***Adjustment with Calibration*** results in general in a first distortion model for the camera, and therefore in better projections for the ground control points (easier measurement). In addition more tie points can be kept and used during the adjustment as the orientation and camera fit much better and former “pink points” are now used and will become green ones.

The ***Extensive*** calibration has to be done for all cameras, no matter if having a high or low quality camera. This calibration requires usually a distortion model to perform the best calibration of the camera. Five subsequent calibrations will be performed. The ***Extensive*** calibration should be selected for cameras with given distortion models like the Trimble UX5 or after a calibration run with the ***First Approximation*** method.

Refine should be used in case additional ground control points have been measured after an ***Extensive*** camera calibration has been carried out. The new ground control points could have an influence on the camera model and therefore need to be included into the calibration. Selecting the ***Refine*** option, a single calibration will be performed.

3.5.3. Restore EO

Restoring the EO rewinds the exterior orientation to the initial values.

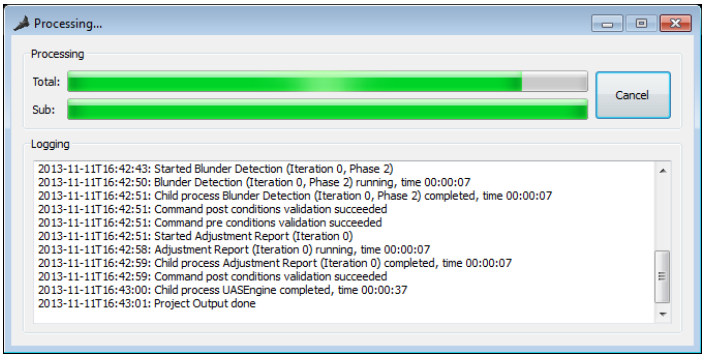
3.5.4. Backup EO

Saves the current EO for the selected images. EO values being listed under the “Frame Type” (in in Project Editor) are being transferred to the “GNSS/IMU

– Approx. EO” dialog and would be used as initial values in further processes. This option is optional!

3.5.5. Steps to work through

- For the training project first run an ”Adjustment (optional)” using the method ***Weak*** to check the control point measurements. This should is recommended as the ground control point measurement was done after the tie point matching. The adjustment with ***Weak*** is required to make sure no erroneous ground control point measurements are in the block that would influence the camera calibration in a negative way.



A processing window displays progress and possible error messages. Now the project is ready for a camera calibration.

- Then start the camera calibration using the ***Extensive*** method, because the training example includes a camera with an initial distortion model.

- After the process, check if there are more tie points used for the adjustment (less pink points).

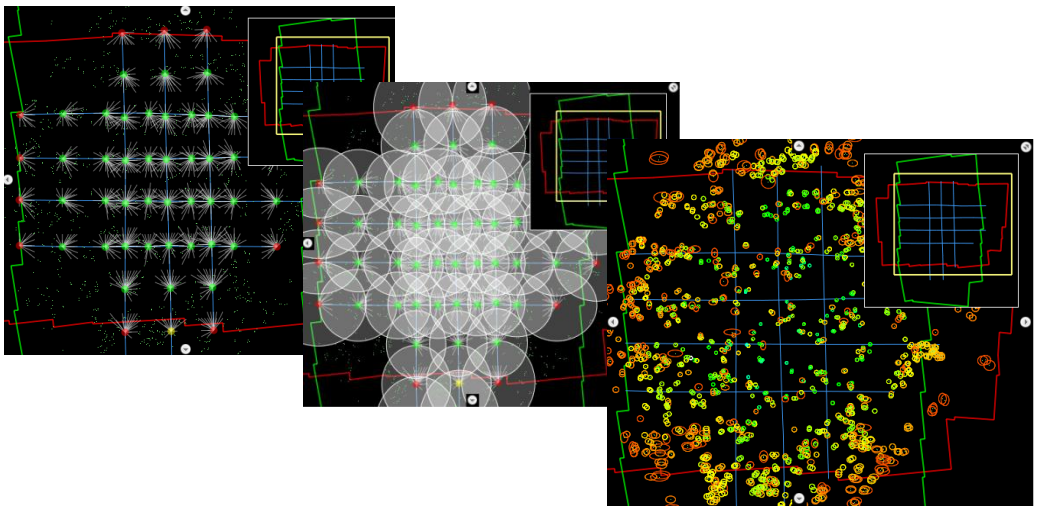
- Check if the ground control point measurements could be improved, as based on a refined orientation and better camera calibration, points are projected into more images and therefore can be measured in more images.

- Based on the output, decide if the final adjustment is sufficient or if a further refinement of the camera calibration is required.

3.6. Checking the results

The most effective way to analyze your block with respect to standard deviations, point density and block stability is to use the analyzing possibilities in the ***Properties*** menu. Review connectivity or error ellipses and residual vectors to check point accuracy. If you discover areas with an insufficient point density or points with large residuals or error ellipses, you may have to add tie points manually, using the "**UAS Measurement**" tool and post-processing the adjustment (default method) again. The strip display and the footprint analysis help to find suspicious orientations.

Note: Incorrect orientations may result from insufficient tie point density, but also from lack of control information or erroneous control point measurements. Incorrect interior orientations or incorrect approximations of photo centers may result in mismatches of tie points or even a total lack of tie points in the corresponding image. The graphics leads a user to check specific areas. There are often several possibilities for the same reasons.



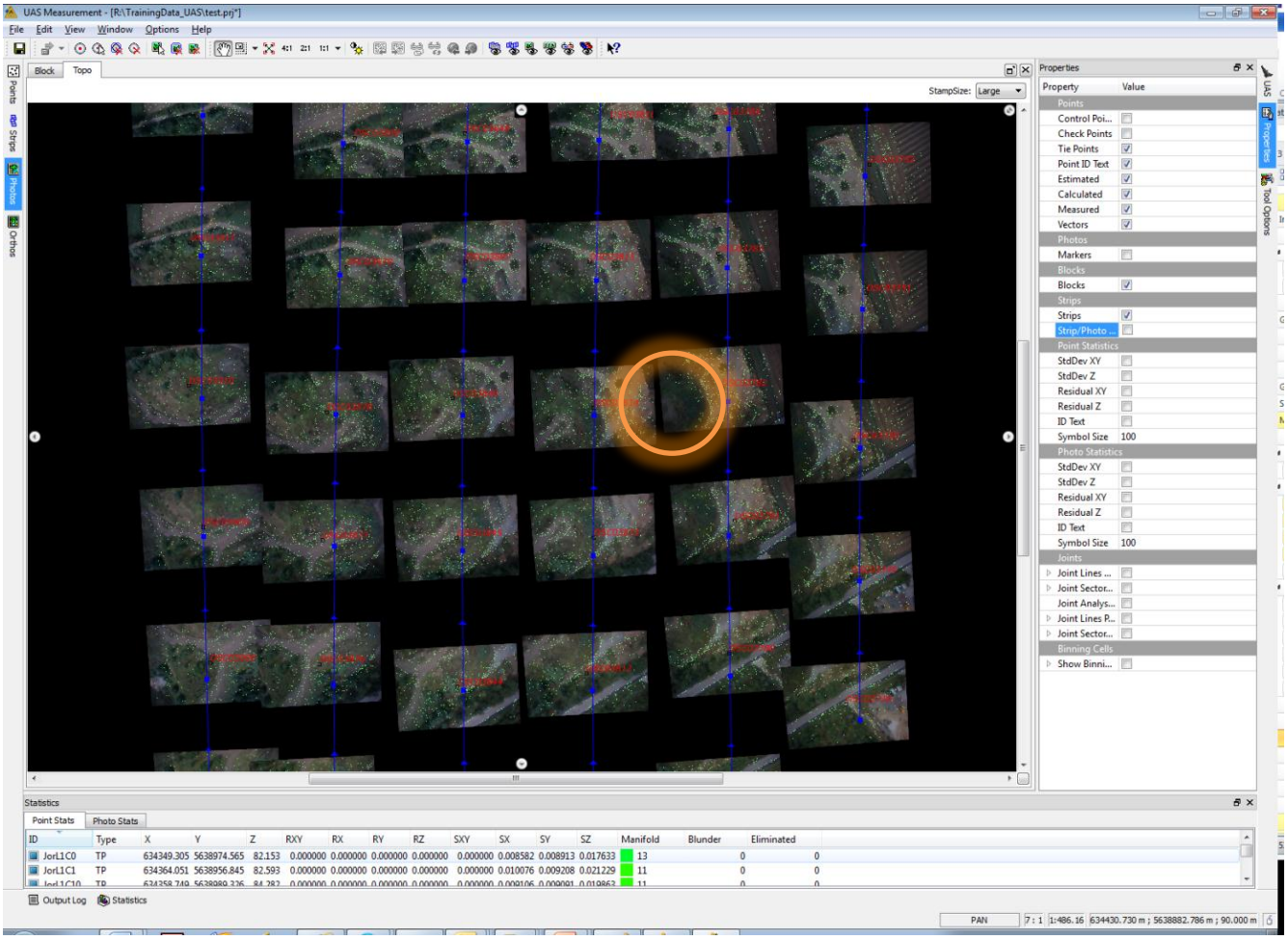
A variety of analysis functions is available in the ***UAS Measurement*** tool. However, they are not described in detail in this tutorial. More detailed description of the analyzing options is available in the MATCH-AT reference manual.

Furthermore you can check the distribution using the ***Topo*** Viewer

The Topo View is

- Displaying images north oriented. Considering the exterior orientation angles and the position of images within a strip. The view allows to check the image relation and image content without having image overlay of adjacent images.
- Projecting control, check and tie point measurements in the images.

- Displaying strips

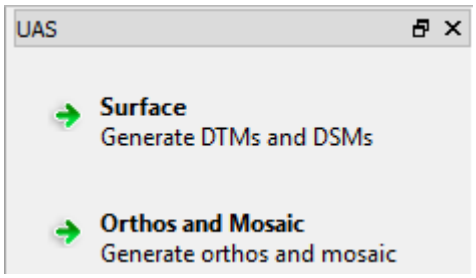


Checking the photos, it can be recognized, that in photo *DSC03782* a part has no tie points (forest). Because the general connection is good here no further action is necessary. For other projects it may be necessary to add manual tie points in some areas

3.7. Statistics

In the Statistics list of the UAS Measurement tool all points with their terrain coordinates and their standard deviations are listed. Having accepted the final result of the adjustment, it is now possible to remove the unused tie points (pink points) from the list. However this is not mandatory.

4. Surface and Ortho Generation

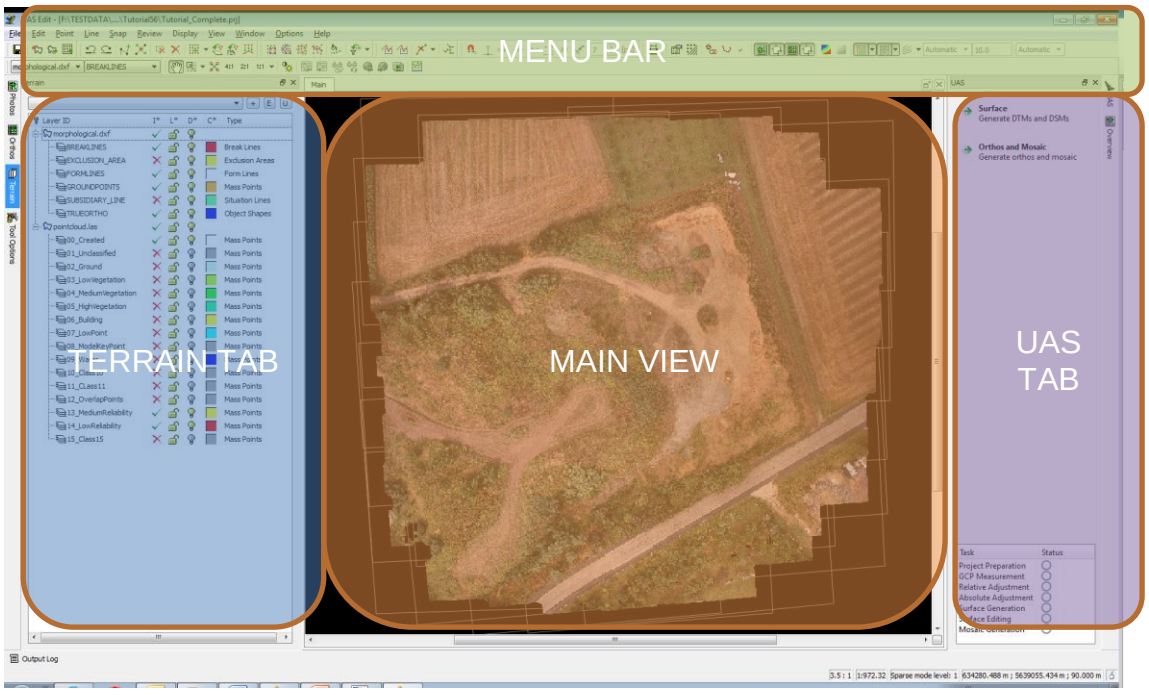


Surface and Ortho Generation needs well orientated aerial images. It is important to have a completed Georeferencing process in UASMaster, before continuing the Surface and Ortho Generation.

The Surface Generation creates from the images a point cloud. Only areas covered from at least two images can be used to create a point cloud. Areas with insufficient coverage will create gaps in the point cloud.
Insufficient coverage in the block is not an error from the software, but a limitation from the given data.

The Ortho Mosaic Generation can only calculate ortho photos, if there is height information given. If areas of images do not have height information, due to gaps in the point cloud or if the images are in the outer boundary of the block, than these parts of the images will not be used in the Ortho Mosaic Generation.

4.1. UAS Edit GUI



UAS Edit is the module from UASMaster, where point clouds are generated and edited and Ortho Mosaics are generated.
The Menu Bar contains all functions for editing. In this tutorial we will only focus on a few functions, typical used for the point cloud editing and Ortho Mosaic generation.
The Terrain Tab shows always two layer structures.

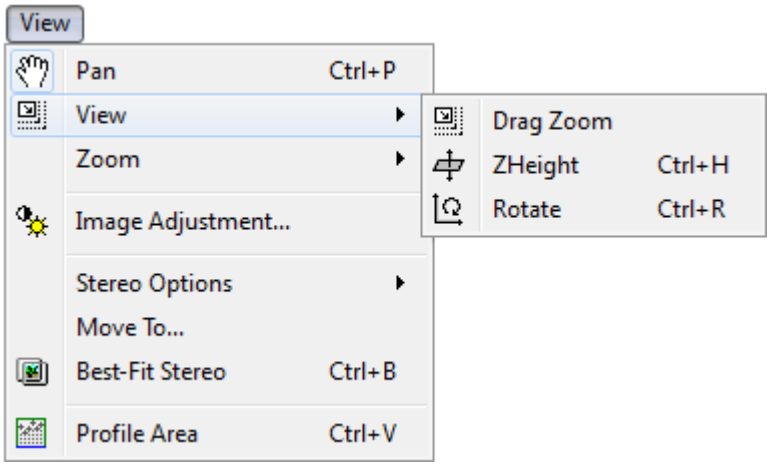
- The morphological structure can be used to create new breaklines, exclusion areas or other line types.
- The point cloud structure contains the automatically generated points from the DTM or DSM run.

The UAS Tab offers functions to automatically generate a point cloud and Ortho Mosaic for the project.
The Main View displays all generated data.

It is not possible to create new layers or to delete layers, as UASMaster uses this layer structure for organizing all points and lines in the project.

4.1.1. Navigation

If you are familiar with the navigation in UASMaster you can skip to the next chapter. Chapter 4.1.1.1 and 4.1.2 explain how to pan and zoom and how to use the Profile and Stereo View.



- **View functions**

4.1.1.1. Pan

Pan allows panning through the current view, without changing the zoom level.

Pan can be used in

- Main View
- Aerial View
- Profile View
- Ortho View
- Stereo Views

Hint: ***Pan*** is available with **CTRL+**Right-mouse-button.

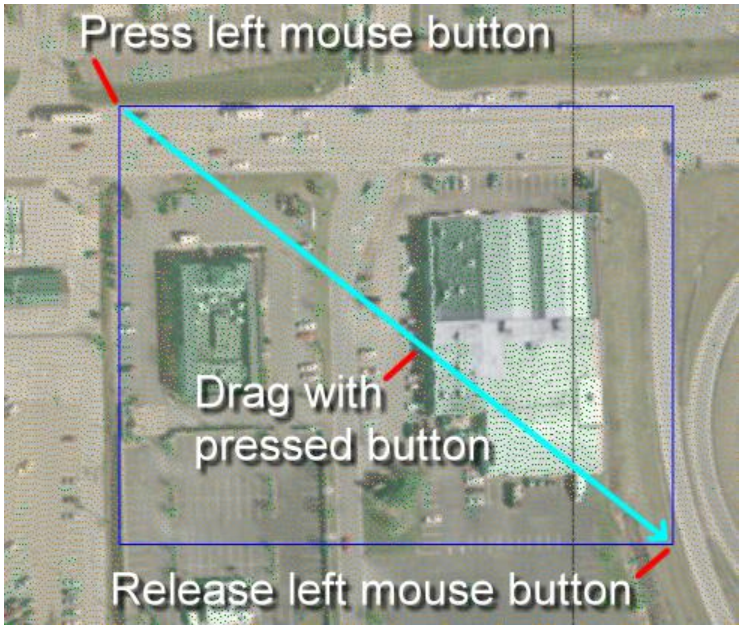
4.1.1.2. Drag Zoom

Drag Zoom displays a selected section from the current view.

Drag Zoom can be used in

- Main View
- Aerial View
- Ortho View
- Stereo Views

The system mouse selects through dragging a box over the desired section.



- **Drag Zoom or Selection**

4.1.1.3. ZHeight

ZHeight allows changing the cursor in Z in the Stereo Views.
The function is not available in other views.

ZHeight can be used in

- Stereo View

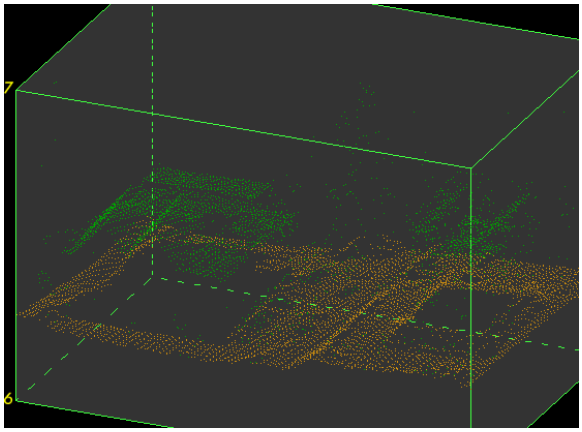
ZHeight is available in all stereo views with pressed right-mouse-button and move the cursor up or down in the stereo view.

Selecting ***ZHeight*** from the menu bar allows performing the functionality with pressed left-mouse-button and move the cursor up or down in the window.

4.1.1.4. Rotation

Rotate the data cube with the right-mouse-button **pressed** and moving the mouse in the desired direction.

Selecting ***Rotation*** from the menu bar allows executing the function with the left-mouse-button.



The data cube can be rotated around the mathematical x-z-axis, fix to an automatically determined origin.

4.1.1.5. Real Zoom

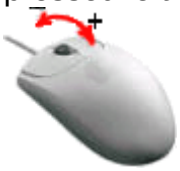
Real Zoom changes the magnification of the view. The change of the zoom is continuously adjustable in “+” and “-“.

Real Zoom can be used in

- Main View
- Aerial View
- Profile View
- Ortho View
- Stereo Views

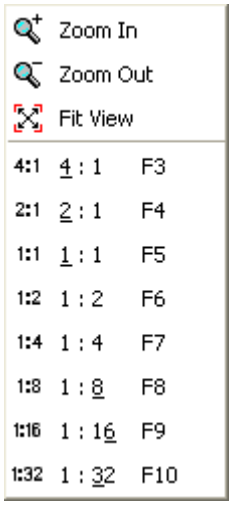
with the mouse-wheel..

Real Zoom can be done with the wheel of the mouse.
Selecting Real Zoom from the menu bar allows performing the functionality with pressed left-mouse-button and move the cursor up or down the window.



- **Mouse-wheel Zoom**

4.1.2. Zoom



- **Zoom functions**

ZOOM IN/OUT

Zoom In or **Zoom Out** changes step-wise the viewing area of the current window. UAS Edit changes the viewing area with a factor of 40%.
Starting with a 100 by 100 pixel viewing area and using **Zoom**

In, the next step will be 60 by 60 pixel.
Vice versa, using **Zoom Out**, the next step will be 140 by 140 pixels.

Zoom In/Out is executed through

- clicking with the left-mouse-button of the system mouse into the desired view
- Using the command ZoomOutSlow and ZoomInSlow for the Immersion Box mouse

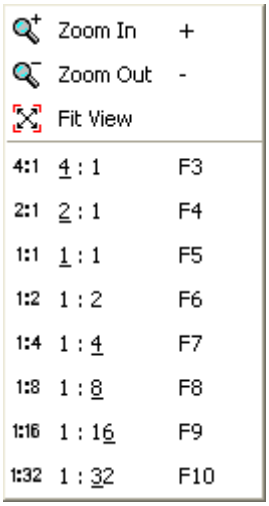
FIT VIEW

Fit View changes the zoom automatically to display the complete project area.
References for ***Fit View*** are the loaded and displayed images respectively footprints and the imported and displayed vector data.
Fit View is executed through

- clicking with the left-mouse-button of the system mouse into the desired view
- Using the command FitView for the Immersion Box mouse

ZOOM LEVELS

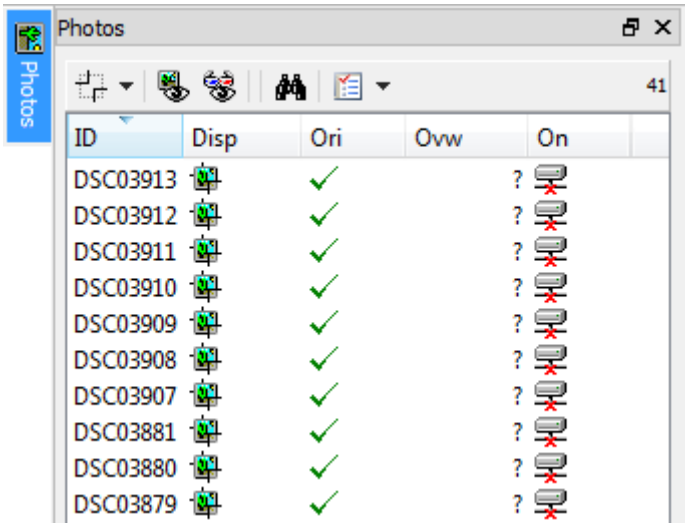
The pyramid zoom levels can be directly accessed and display the images in 4:1, 2:1, 1:1, 1:2, 1:4, 1:8, 1:16 and 1:32. The zoom level 1:1 displays the image in its original resolution. Zoom levels can be used for aerial and ortho images.



- **Zoom functions**

4.1.3. Photos Tab

The Photos Tab displays the imported image files in a spread sheet form. Only active images can be used for Stereo View.



Images cannot be removed in the Photos Tab directly.
To remove images, use **UAS ApplicationsMaster**, and ***Edit Project…***.
If the images do not have pyramid levels, the UAS ApplicationsMaster offers functions to create additional pyramid levels.
Image pyramids (overviews) are necessary to use Stereo View in the UAS Edit.

4.1.3.1. Photos Spread Sheet

IMAGE ID:

The Image ID column lists all existing images. Images are categorized into Aerial and Ortho. Aerial and Ortho Imagery are displayed in a tree view.

IMAGE DISPLAY:

Display can have the status:
Image On
Image Off
Image and Footprint Off

Images with the status Image On, are displayed in the Stereo View.
Aerial images with the status Image Off, are only displayed in the Stereo View with their footprints.
Images with the status Footprint Off are not considered for Best-Fit View. Images with missing pyramid levels are set to status *Image and Footprint Off*.

ORIENTATION:

Orientation can have the status:
✓ Checked
✗ Crossed
Images with the status crossed, are images with missing orientation values or camera information.

OVERVIEW:

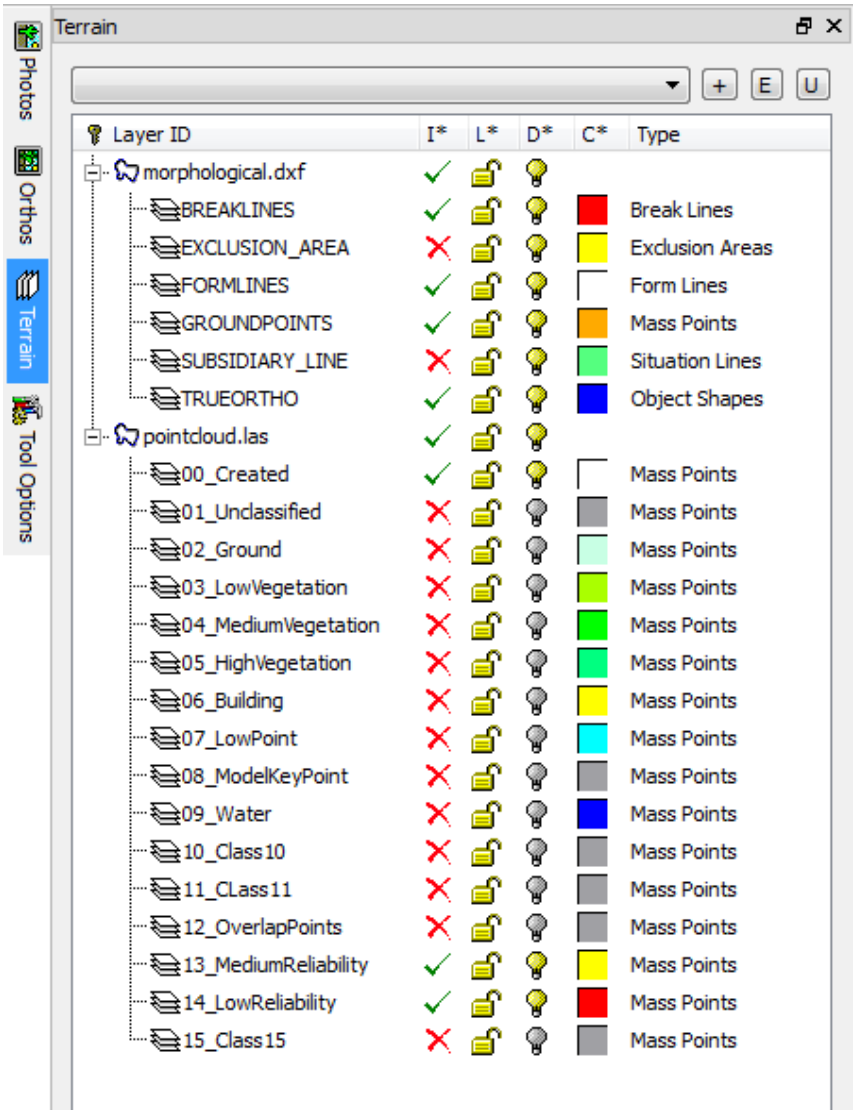
Overview displays the number of pyramid levels existing for the imagery.

ONLINE:

Online can have the status:
Online
Offline
Online checks if the imagery is online or not. The file path can be reassigned for the images in the UAS ApplicationsMaster, using ***Edit Project…***.

4.1.4. Terrain Tab

The Terrain Tab displays the generated point clouds calculated from UASMaster.
It is possible to run the DTM or DSM point cloud generation multiple times. The result of each process will be added to the given layer structure and accumulated.
After the point cloud generation the points will be automatically placed into the layer “00_Created”.
Using classification tools or the re-classify tool, it is possible to move the points to different layers and to organize the data more efficiently.



4.1.4.1. Terrain Spread Sheet

LAYER ID:

The Layer ID morphological.dxf offers all needed line types for the classic and true ortho generation.
The Layer ID pointcloud.las offers the standard LAS 1.2 classes for reclassification.

INTERPOLATE [I*]:

Interpolate can have the status
✓ On
✗ Off

Only files and layers with the status “Interpolate On” will be used for the online contour lines and colored grid generation and for height-interpolation of points and lines, when digitizing in a 2D View.

Hint: Only data with status “Interpolate On” is used for the ortho mosaic generation.

LOCK [L*]:

Lock can have the status
On
Off
Files and layers with the status “Lock On” cannot be selected or edited.

LAYER DISPLAY [D*]:

Display can have the status:
On
Off
Files and layers with the status “Display On” are displayed in the views. It is not possible to copy, move or draw points and lines on layers, which are Off.

COLOR [C*]:

- **Color Palette**

Color can have any value from the existing color palette.
Points and lines from the active Layers are displayed according to the selected color.

LAYER TYPE:

Type can have the status from all existing ***Type Codes***.
Layers with a specific ***Type Code*** can only maintain points or lines.
Please be aware, that exporting data to specific formats (e.g. Winput) will use the information of the Type.

4.2. Surface Generation

In Surface generation you can generate automatically for the complete project or a defined area a point cloud. The density of the point cloud is depending on the method used (DTM or DSM). The result is automatically loaded into UAS Edit and displayed in the Main View.

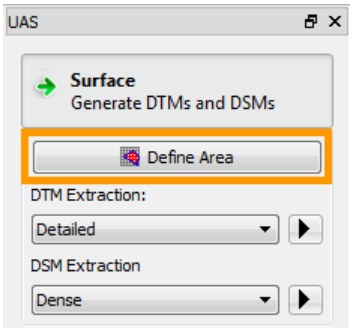
In the next steps you can now:

- use the editing tools to eliminate errors,
- add additional morphological data (e.g. breaklines) to enhance the point cloud,
- Re-Run the automatic point cloud extraction on a small polygon

Finally all data (point cloud and morphological data) should represent the correct terrain model.
With the correct terrain model the ortho photo mosaicking can be started.

All these steps take place in the UAS Edit and can be directly accessed and viewed. The final products are the edited point cloud and the ortho photo mosaic.

4.2.1. Area Definition



Define Area allows to limit the output of the point cloud extraction. If no area is defined, UASMaster will use the complete project for the point cloud extraction.

To create an area definition, select the function and start digitizing a polygon in the Main View.
To remove your selection, select the Define Area function and hit the ESC key. Continue with a different function afterwards.

4.2.2. DTM Extraction

The DTM Extraction uses two basic matching algorithms: **Least Squares Matching (LSM)** and **Feature Based Matching (FBM).**

FBM is a matching strategy that is very robust. It only needs coarse approximations and is very fast. Therefore it is mostly used in the beginning of the process, to quickly establish a good basis. It is about 1/3 pixel accurate.

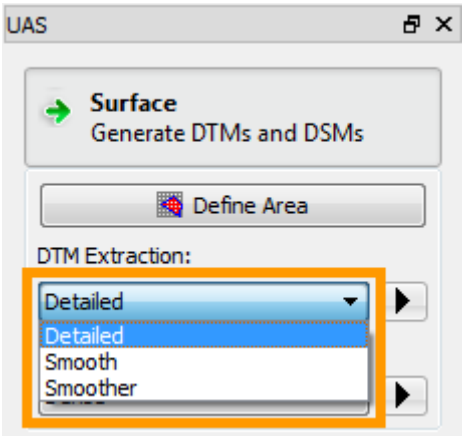
The matching process computes values from one image that describe the appearance of a certain found feature. These values must be found in the second image as well.

LSM is a matching strategy that is very accurate. But it needs better approximations and is slower than FBM. It is mostly used in the refinement at

the end of the process or to refine points to obtain a good point precision. It is about 1/10 pixel accurate.

The matching process creates a template (21x21 pixels) from one image and overlays it onto the second image. There it will be shifted until the square-root of the square-sum of gradient residuals converges to a minimum. LSM is therefore an iterative process.

DTM Extraction Options:

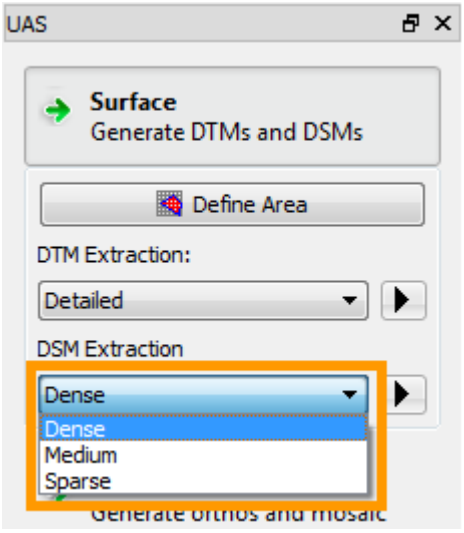


- Detailed: Generates a DTM up to Level 0 of the ground sample distance (GSD) and uses the precise optimization. The final result generates a grid with 27x GSD from Level 0.
- Smooth: Generates a DTM up to Level 1 of the ground sample distance and uses the balance optimization. The final result generates a grid with 30x GSD from Level 1.
- Smoother: Generates a DTM up to Level 2 of the ground sample distance and uses the balance optimization. The final result generates a grid with 30x GSD from Level 2.

4.2.3. DSM Extraction

The DSM Extraction uses the **Cost-Based Matching (CBM)** algorithm.

DSM models are computed with a **Cost-Based Matching** strategy. To explain the theory of cost-based matching is rather complicated and should not be the purpose of this documentation. Briefly, cost-based matching is a pixel-by-pixel matching technique unlike feature based matching or least squares matching which are rather area based.



For each pixel of one image the corresponding pixel in the second image to match is searched through a path in a so-called 3D-cost-cube. A variety of cost functions (e.g. also the correlation coefficients are cost functions) are considered to find the way along a minimum cost path. Each direction in the 3D-cost-cube represents a x-y movement in the image to match. Finding the pixel with the lowest cost generates a lowest-cost 3D model – our surface model. Unlike propagated ***Semi-Global-Matching*** techniques, **UASMaster** does not use mutual functions (e.g. to compensate for color changes etc.).

DSM Extraction Options:

- Dense: Generates a DSM up to Level 0 of the ground sample distance (GSD) and uses the UAS optimization. The final result generates a grid with 3x GSD from Level 0.
- Medium: Generates a DSM up to Level 1 of the ground sample distance and uses the UAS optimization. The final result generates a grid with 3x GSD from Level 1.
- Sparse: Generates a DSM up to Level 2 of the ground sample distance and uses the UAS optimization. The final result generates a grid with 3x GSD from Level 2.

4.2.4. DSM Generation Exercise

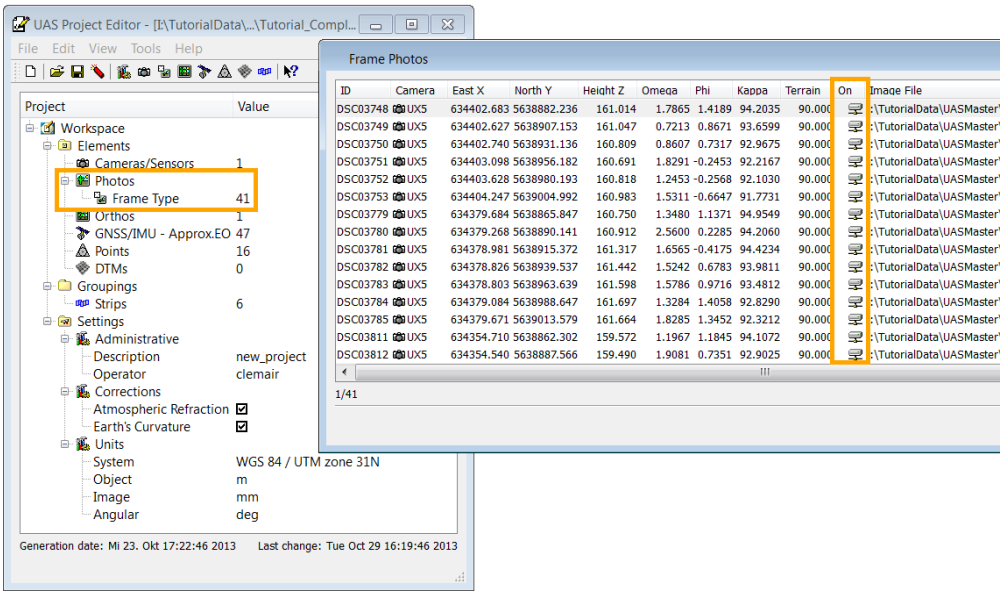
Let's create a DSM point cloud for our demo data set.

1. Select the Surface button from the UAS Tab 

2. Select from the DSM Extraction dropdown box the option: "Dense"
3. Start the point cloud generation, clicking the process icon 

If your process is not starting, please check following things:

- Are your image paths correct? You can go to the UAS Project Editor and look at ***Frame type photos*** for the file paths.



They should show the correct image file path and show the online status correct.

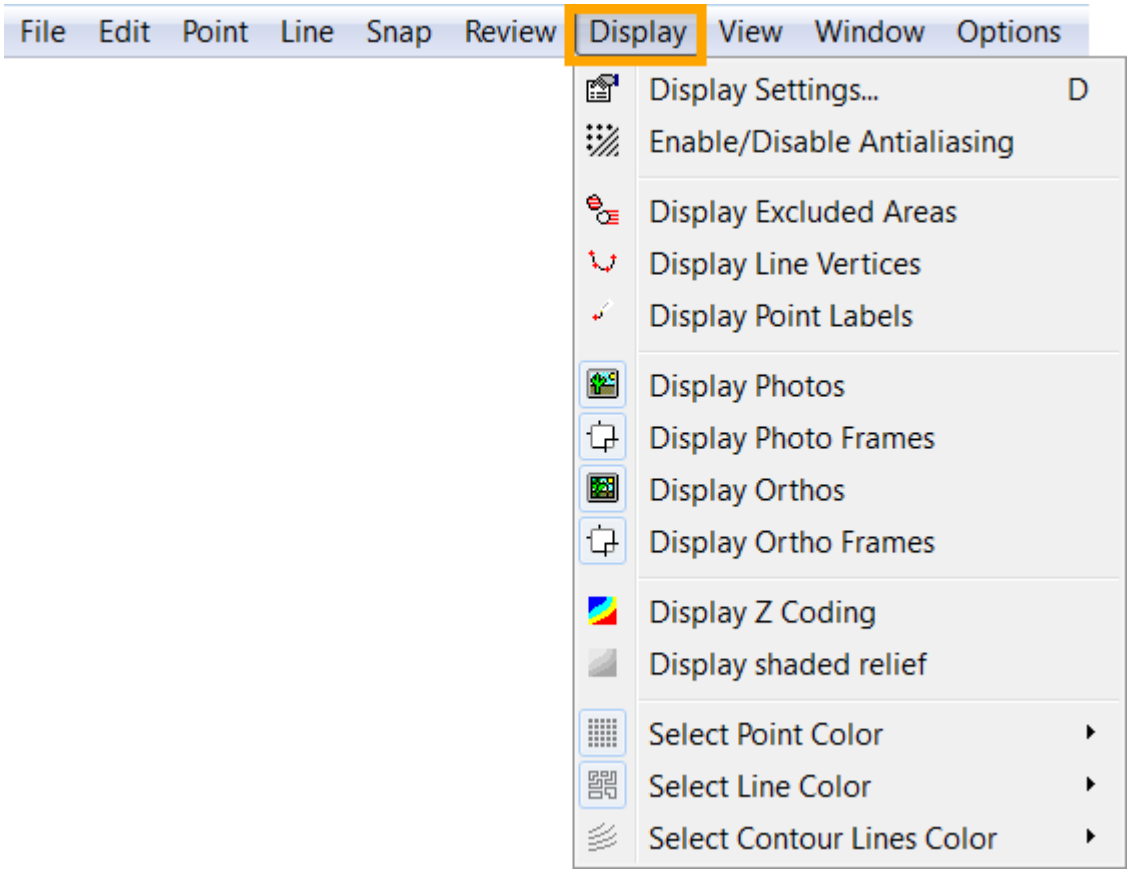
- Do you have write permissions in your project folder?
- Do you use a project file with correctly georeferenced images? To check, you can use for testing our already completed demo project file "UX5_completed.prj".

4.3. Surface Editing

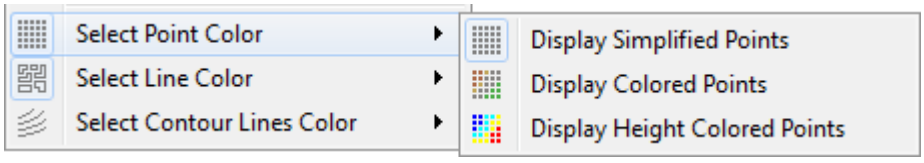
Surface editing is needed to eliminate the errors in the automatic point cloud. Errors in the point cloud would cause a wrong ortho mosaic generation at this georeferenced position.
To detect errors UAS Edit offers display options, which allow an easy detection of errors.
Errors can be searched in Profile View or Stereo Views.
To correct the error UAS Edit offers Selection Tools and Modification Tools.

4.3.1. Display Options

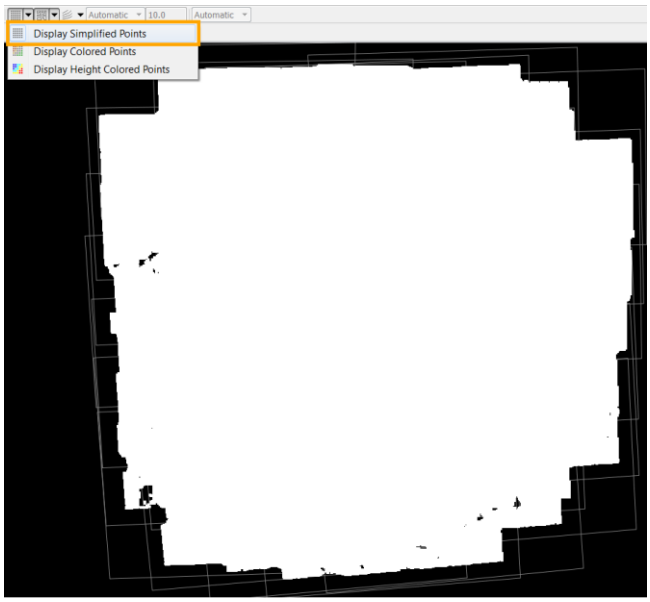
For error detection we will focus in this tutorial only on a few Display options. You can find the display options in the Menu Bar here:

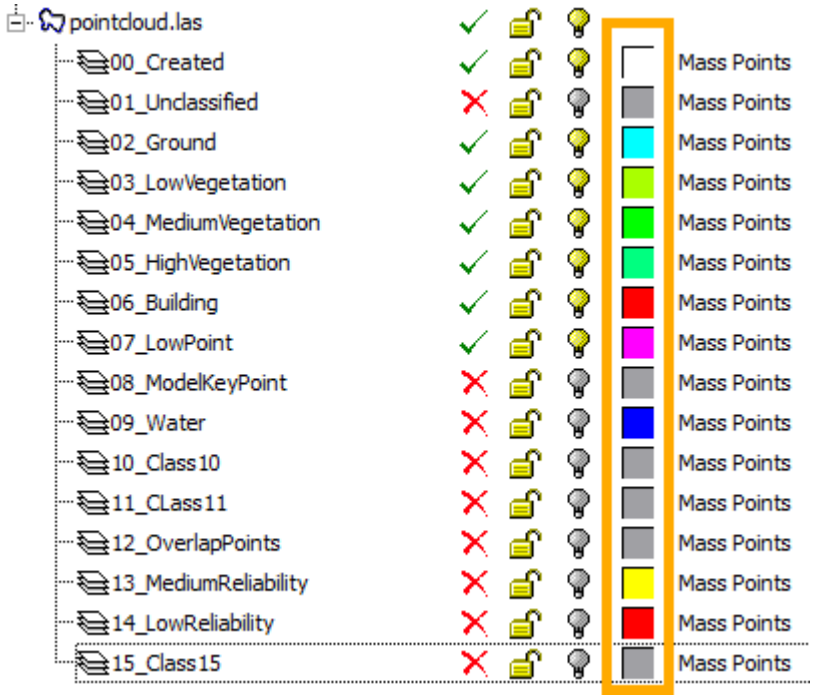


4.3.1.1. Points



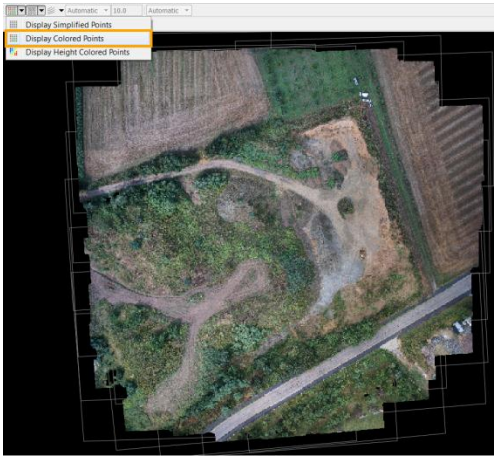
Display Simplified Points is using the color settings in the Terrain Tab.





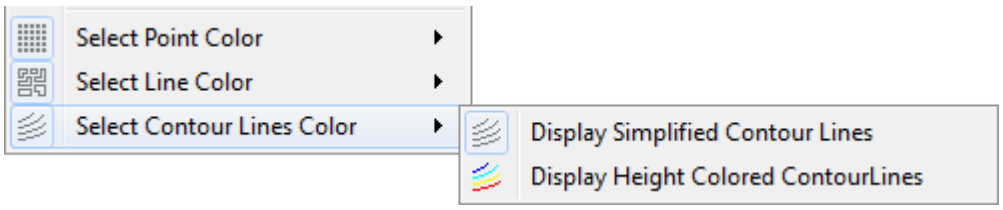
In this example all points are displayed white, as all points are currently in the layer “00_Created”.
Classifying the points into different layers allows an easier interpretation of the data. The layers are using the LAS standard classes. Typically for terrain models points should be in the ground layer. Surface models use typically the ground with high vegetation and buildings.

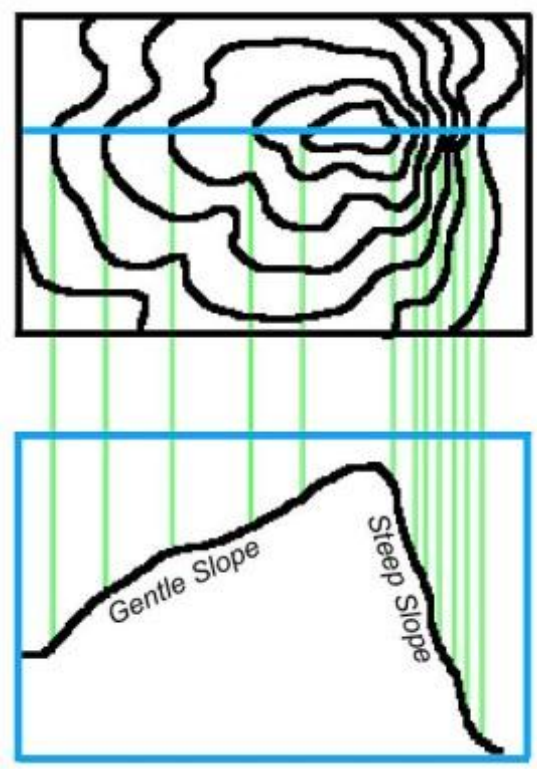
Display Colored Points is using the color information (e.g. RGB values) stored with each single point during the point cloud matching process.



In this example we see the colored point cloud. The points are still in the layer “00_Created”.
Colored points make interpretation very easy. The color information helps to classify a point correctly into vegetation, building or ground.

4.3.1.2. Contours



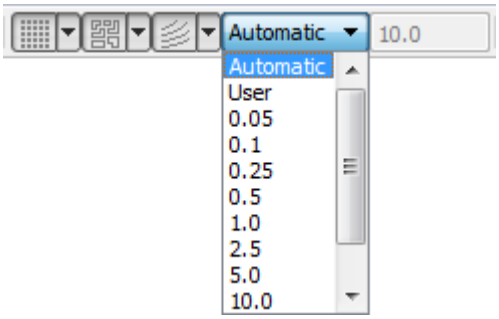


Contour lines represent millions of points with a few lines, making the interpretation much easier and less overwhelming.
Contour lines are denser drawn if the terrain slope is steeper, indicating a “peak” or “valley”. More spaced contour lines indicate a gentle slope and less change in height.

The graphic on the left shows in the upper image a birds view and in the lower image a profile view. The blue line in the upper image is the represented profile line in the lower image.

The amount of contour lines at one spot indicates the height change at the location. The contour interval step can be set in the menu bar:

Automatic: The min/max heights from the current Main View are collected and UAS Edit uses an automatic contour interval fitting to the min/max values.



User: Selecting User allows entering in the right text field an individual numeric value for the contour interval.

Predefined: The dropbox offers predefined contour interval values.

Contours uses all data with an active interpolation flag.

4.3.1.3. Shaded Relief

Shaded Relief uses all data with an active interpolation flag.

Depending of the slope normal and the sun angle and direction, the shaded-relief display varies. UAS Edit offers settings for the sun angle and direction.

Shaded relief uses the settings of the Display Settings  .

Display Settings allow changing values for Shaded Relief and Height Coding parameters. Following parameters are available for Shaded Relief:

AZIMUTH

The angle of the x-axis to the sun, measured counter clock-wise. The illumination of the sun is calculated as parallel light.

ELEVATION

The angle from the horizon to the sun. The illumination of the sun is calculated as parallel light.

DIFFUSE

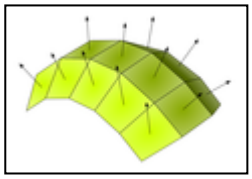
Diffuse light represents a directional light cast by a light source. The light rays of diffuse light illuminate an object from different directions and are therefore not in sorted parallel direction. Diffuse light does not cause strong shades but generates a smooth light impression

AMBIENT

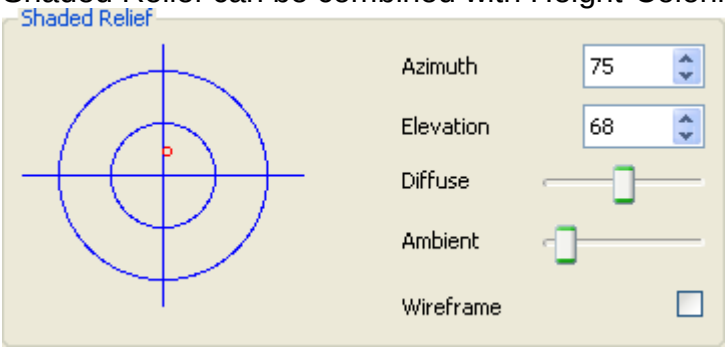
Ambient light is the average volume of light that is created by emission of light from all of the light sources surrounding the objects. The ambient slider defines how much ambient light the object receives. Generally, about 0.1 to half is good. A setting of 0.0 means that the object does not receive any ambient light; it is only lit by light that actually gets to it. A setting of 1.0 means that it is lit by all of the world's ambient light. Increasing the Ambient setting has the effect of flattening the shading, since the ambient light washes the diffuse shading out.

WIREFRAME

Shows the internal raster, which is used to calculate the normal vectors for the shading. The raster size is fixed and cannot be set.



Shaded Relief can be combined with Height-Coloring and Contours.



4.3.2. Profile View

Profile View can be used to select from an active scene in the ***Stereo View, Main View*** or ***Ortho View*** a Profile View.

Point and line data of the selected area is displayed in the Profile View.

Profile View can be used in

- Main View
- Ortho View
- Stereo View

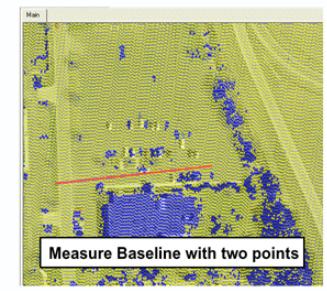
The Profile View needs an area selection. It can be undocked and closed.
The Profile View allows separating easily ground points from off ground points, with a minimum of measurement steps. The function is designed for LIDAR editing and classification, but can be used for any other DTM data as well.

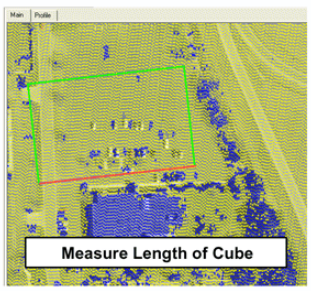
The area selection is done by measuring in total three points of a rectangular data cube. The first two points define the baseline of a cube. The third point defines the depth of the cube.

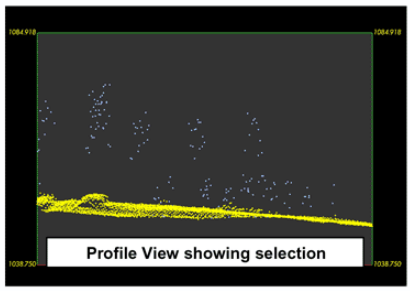
Profile areas can be measured either in 2D or 3D.

PROFILE SELECTION

1.  Press Profile-Icon
2. Measure baseline and depth with 3 clicks
3. The view will be added to the Tab-Dialog







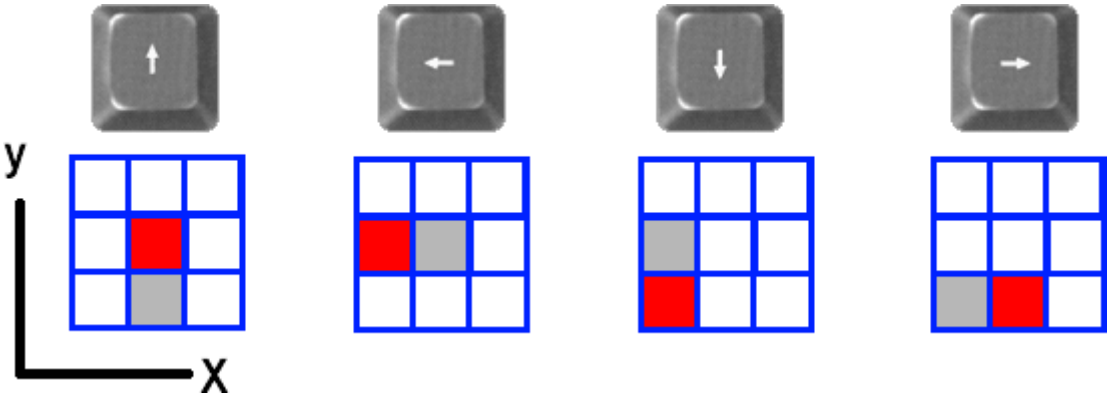
4.3.2.1. Arrow Keys for systematic editing

The selected ***Profile View*** can be moved patch-wise with the arrow keys. Additionally the Profile View can be panned with the function pan and zoomed with the function real zoom.

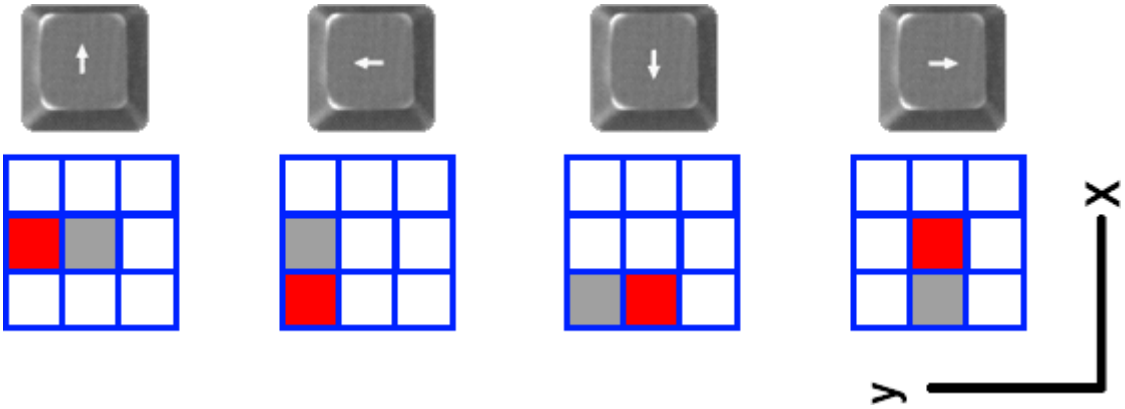
The current profile view area is displayed in the main view.

The measurement of the baseline represents always the mathematical x-axis. According to the shape of the cube, the y-axis is set automatically.

Stepping right, means moving in direction of the mathematical x-axis.



- **Example showing baseline measured at bottom side**



- **Example showing baseline measured at right side**

4.3.3. Stereo View

Stereo The ***Stereo View*** appears as a tab dialog, attached to the Main View.

The stereo view shows aerial imagery and vector data in stereo mode.
Vector data can be displayed with the available ***Active Display***.

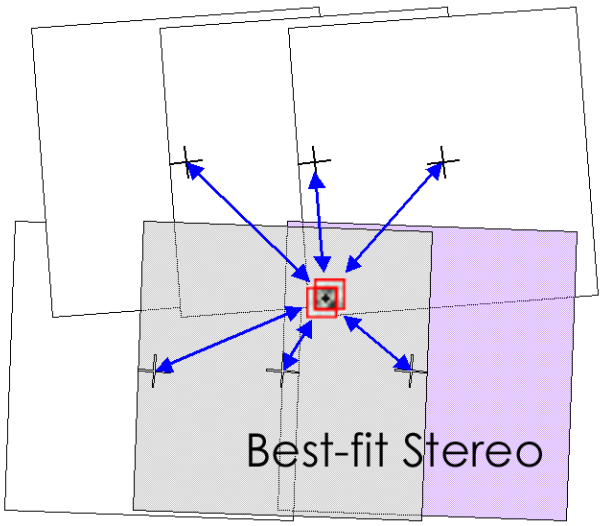
The Stereo View allows collecting, editing and viewing 3D data in stereo.
Data can be reviewed in 3D to check points and lines overlaid to the aerial images to check the absolute x-y-z position.

Height changes can be done with the Navigation function ***ZHeight***.

The Stereo View needs orientation data for the aerial images given. Having insufficient orientated images result in inadequate stereo view.
As an option, the Stereo View automatically switches to another pair of images if the current view position is outside or close enough to the border of the current image pair.

4.3.3.1. Best-fit Stereo

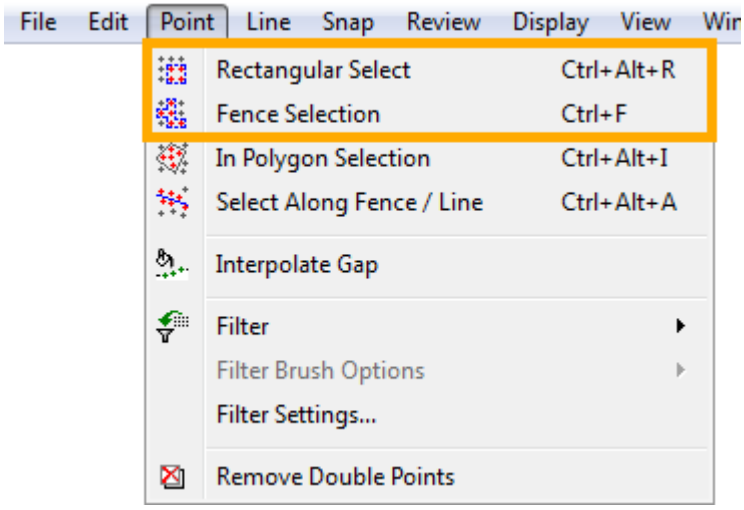
Best-fit stereo can be used to select from an active scene in the ***Main View*** the best-fitting Stereo View.



- **Best-fit Stereo - Stereo pair selection**

UAS Edit determines the closest projection centers of a stereo pair from the selected best-fit position.

4.3.4. Selection



Rectangular Select. All points inside the rectangular selection are affected.

Rectangular Select can be used in

- Main View
- Stereo View
- Ortho View
- Profile View

The selection is made through dragging a box over the desired section.

Hint: ***Rectangular Select*** can select single points with the system mouse. To select a single point, just make a left-mouse button click to the single point.

Only points within the snapping range will be selected.

Fence Select. All points inside the polygonal fence selection are selected.

Fence Select can be used in

- Main View
- Stereo View
- Ortho View
- Profile View

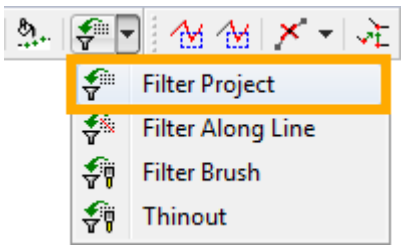
The selection is made through measuring a polygon with clicking left-mouse-button for the vertices around the desired section. To finish the measurement click the right-mouse-button in the current view and select “End” or double click left-mouse-button.

4.3.5. Modification Tools

The tutorial will only present a subset from all existing modification tools.

- The filter project tool allows an automatic classification of the points into ground and off ground points.
- The Classify Selected Object tool, allows to manually classify the points into the different layers from UAS Edit.
- The Interpolate Gap tool allows to digitize a polygon and to fill the gap with new points, using the heights of the surrounding vector information.
- Create Point/Line allows to digitize in stereo or mono new vector data.

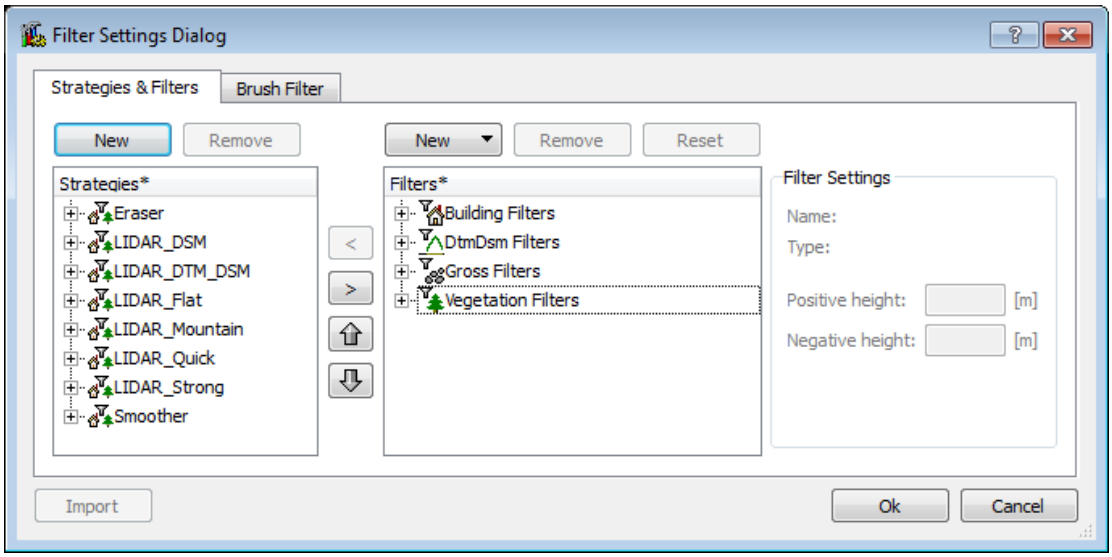
4.3.5.1. Filter Project



Filter Project allows filtering with a defined strategy the complete project.

A strategy includes one or multiple filters.
Four filter types are supported:

- Building
- DtmDsm
- Gross
- Vegetation



4.3.5.2. Classify Selected Objects

Classify Selection allows moving selected vector data into the currently selected layer.

Classify Selection allows moving points and lines.

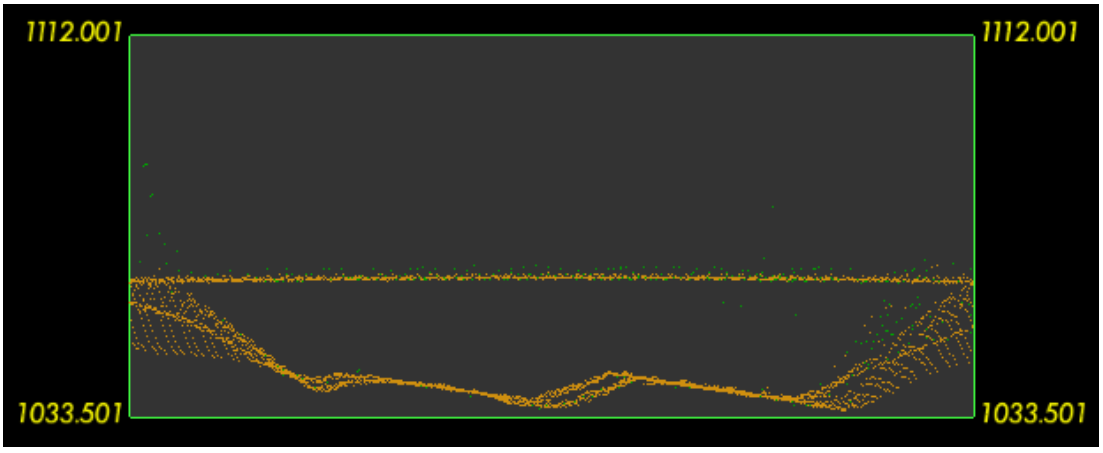
Classify selection can be used in

- Main View
- Profile View
- Stereo View

Classify Selection needs a pre-selection to be executed.
To move the current selection to the active layer, select ***Classify Selection***.

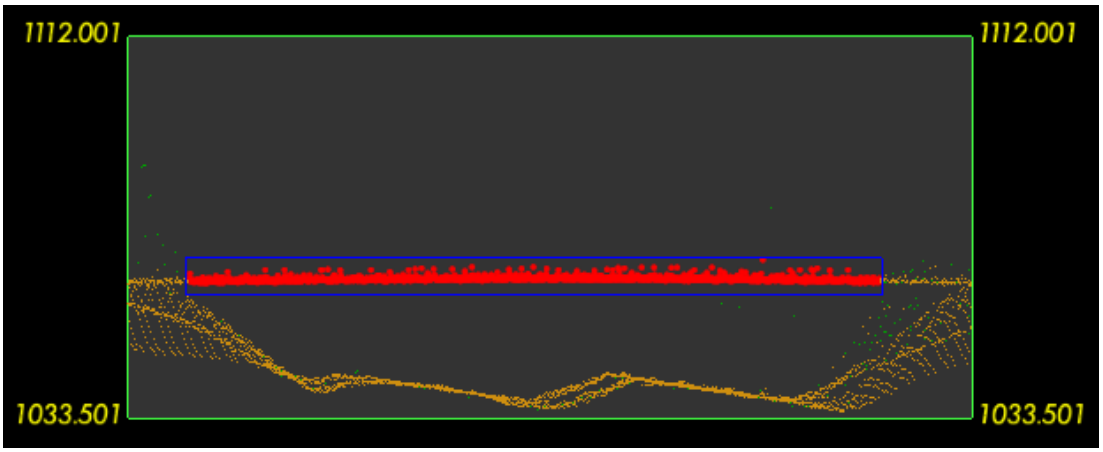
Example

Start by choosing an area containing data to classify, e.g. by opening a Profile View.



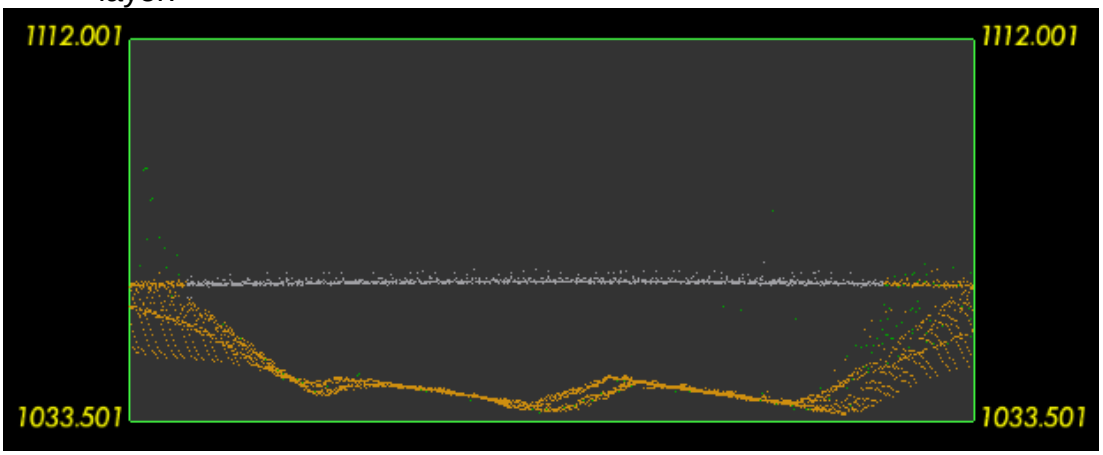
- **Profile View before classification**

Select points (or lines, when classifying in other views) to be classified using the selection tools.



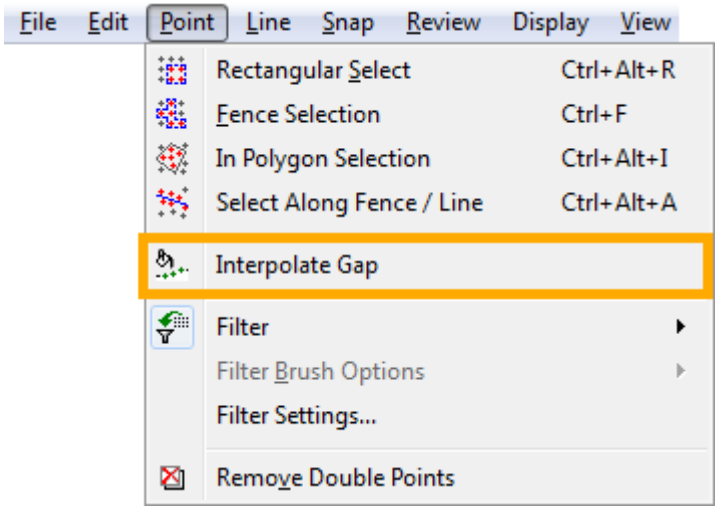
- **Profile View showing selection to be classified**

Press the Classify button. All selected objects are moved to the active file and layer.



- **Profile View showing result of classification**

4.3.5.3. Interpolate Gap



Interpolate Gap allows filling points into a measured polygon.

Interpolate Gap can be used in

- Main View
- Stereo View

Steps to work through

INTERPOLATE GAP

1. Select current layer to fill-in points
2. Press Interpolate Gap-Icon
3. Measure polygon

Depending on the point type of the current layer, two different methods will be applied.

UAS Edit uses the entered grid spacing values of the Option Tab to fill the defined polygon.

- **Interpolate Gap Options Tab**

Confirming the grid spacing will insert north oriented mass points with equally spaced points inside the previous measured polygon.

Option: Fill with constant Z
Instead of interpolating for each point an individual height, it is possible to set all points to the same constant height. To activate the option, please check the box and enter the height.

4.3.5.4. Create Point / Line

Create Point/Line will check the current layer type and enables to measure either a new point or a new polyline.

It is not possible to measure both points and lines on the same layer.

Create Point/Line can be used in

- Main View
- Ortho View
- Stereo View

Create Point/Line offers following Tool Options:

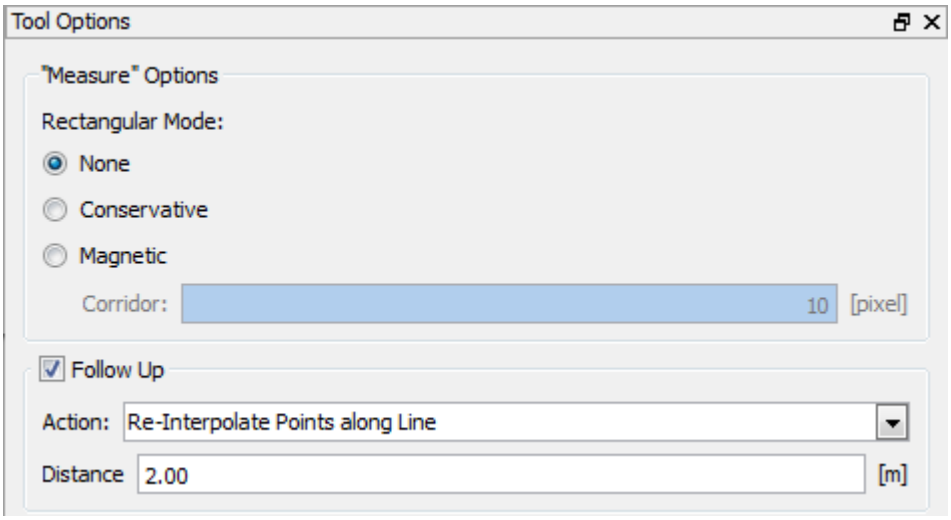
RECTANGULAR MODE

Square Measurement Tool allows measuring line segments rectangular to each other. There are currently two types of square measurement functions available:
Conservative Measurement and Magnetic Measurement

Both functions are calculated based on planimetric constraints, and do not consider the z-dimension.
Type **CONSERVATIVE MEASUREMENT** creates with every measurement a perpendicular line to the previous one.
Type **MAGNETIC MEASUREMENT** creates only perpendicular lines, if the new measured point has a position within a given threshold.
The threshold is calculated with a corridor along a technical perpendicular line, going through the last measured point.

FOLLOW UP

Follow Up is an option, which can be activated with the check box.
Follow Up actions are executed automatically after finishing the measurement of a line or point.
There are currently two follow up functions available:
Reinterpolate Points along line and ***Delete***.



The height of the new position is depending on the view and the existing vector data in the local area.
Using a stereo view, the height can be set manually.
Using a 2Dview DTMaster will interpolate the new height according to the existing local vector data around it.

4.3.5.5. Set active Layer

The active layer is used as target layer for:

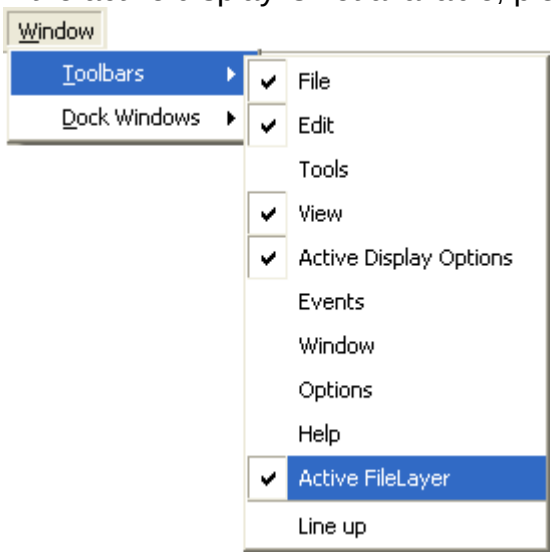
Create point/line

Interpolate Gap

Classify selected objects

Set active layer from menu bar

The set active display dialog is placed by default in the menu bar. Choose from the drop-down menus an active file and layer.
If the active display is not available, please activate it in the Window tool bar.



4.3.6. Set active layer from Layer Tab

Right-click on a layer and select ***Set as active layer.***
The active layer is set automatically.

4.3.6.1.1. Create Line Exercise

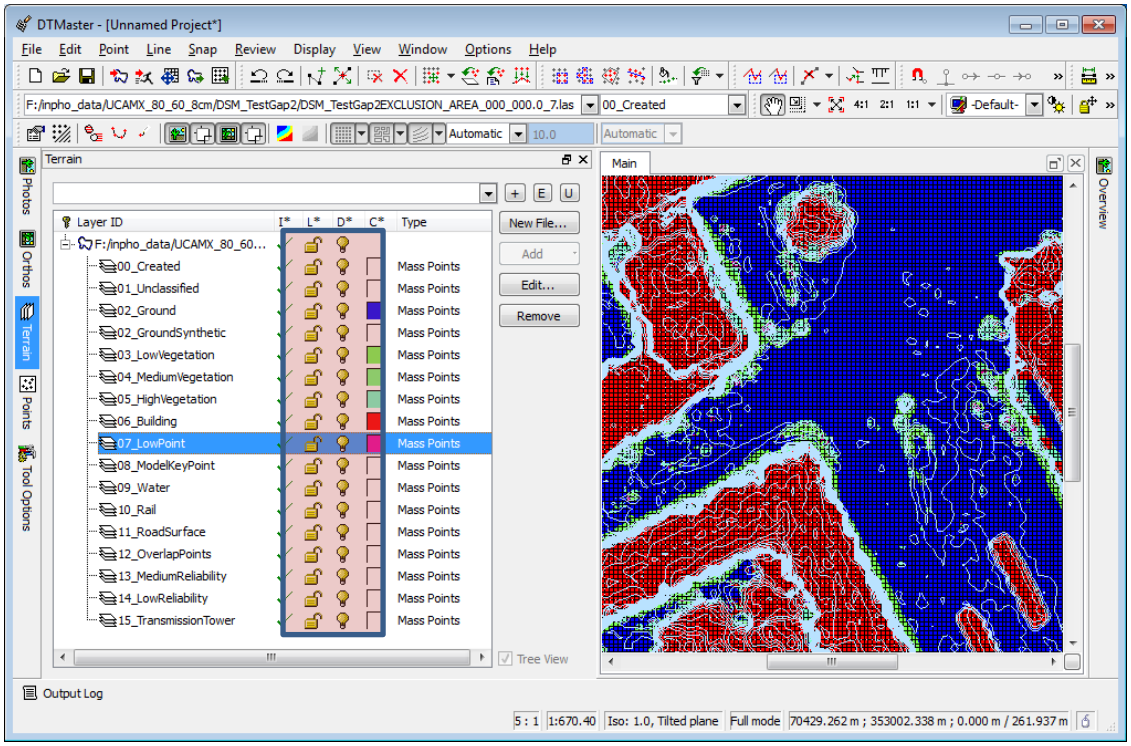
Let's create a line:

1. Select the active layer Breaklines
2. Select Create Point/Line
3. Click with the left mouse button in the Main View

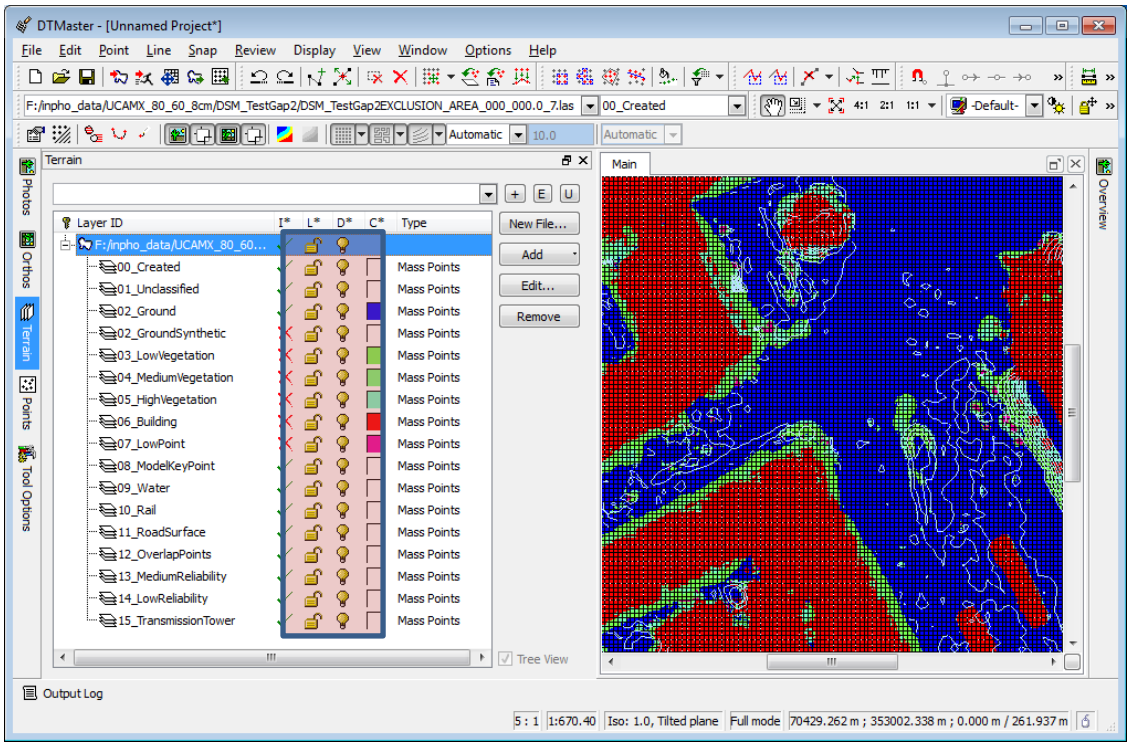
You should see a polyline appear. Continue clicking the left mouse button for more vertex points. To finish the line press the Enter button from the Num lock.

4.3.7. WYSIWYG

UASMaster tries to offer an intuitive ortho mosaic handling. All the data you can see in the current moment in UAS Edit will be used for the ortho mosaic process.
Important to know: the interpolation flags are considered and will influence your final result. Only layers being activated with the interpolation flag are being used for the ortho mosaic process.

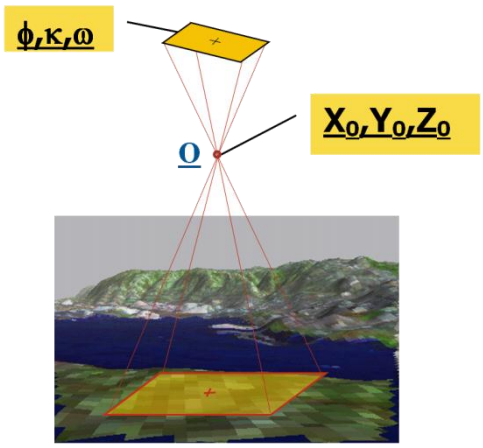


The contour lines in this image are on top of the buildings and the vegetation. Running the ortho mosaic process, will include this height information.

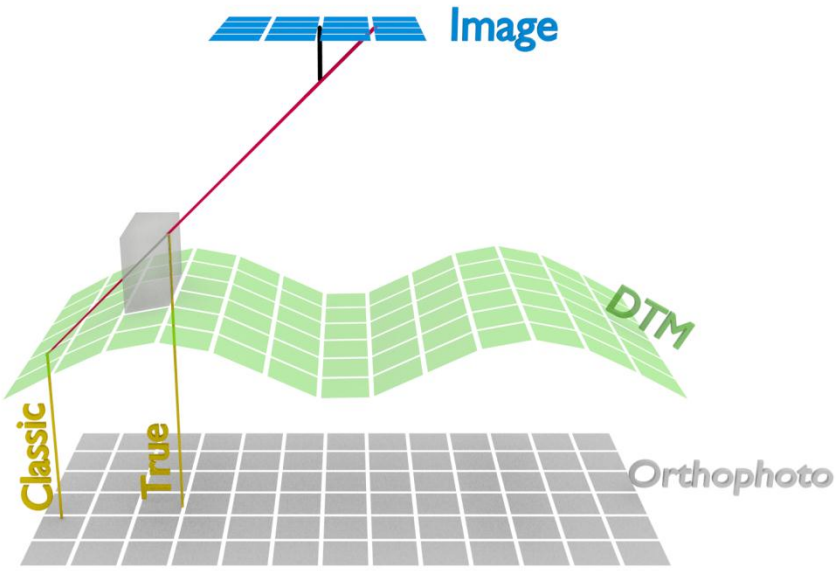


The contour lines in this image are only calculated from the blue ground points. You can see the interpolation flags in the red box deselected for the vegetation and building layers. Running the ortho mosaic process, will not use the points on top of the buildings and trees.

4.4. Orthos and Mosaic Generation



Images captured from cameras using a perspective view cause terrain distortion. The images cannot be mosaicked together or overlaid on maps without first being converted (“orthorectified”) to an orthogonal view, typically a view looking straight down from infinity.
The conversion needs information about the height at each position in the ground, to place the pixel to the correct position. Therefore we need the terrain model.



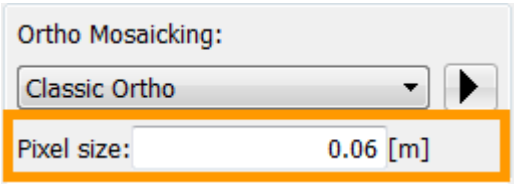
4.4.1. Classic Ortho

The classic orthophoto generation does not check for occlusion and uses only the terrain model (DTM) without object information (e.g. building) and ortho-rectifies the image according to the DTM.
Classic orthophotos will have objects higher than ground misplaced, depending on the angle of view from the projection center.

4.4.2. True Ortho

The true orthophoto generation checks the data for occlusion and uses the object shapes together with the DTM.

4.4.3. Pixel Size



The pixel size entry field in UAS Edit should represent the ground sample distance. The ground sample distance can easily be calculated from the flying height above ground and the focal length of the camera.

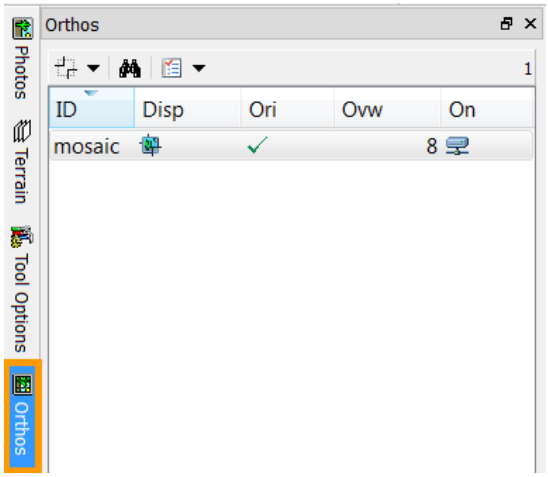
$GSD_{ground} = \frac{H_O}{c} \times p_{x,y}$
H_O: Flying height (Plane above Ground [not sea level])
c: Focal length of camera

Please do not enter a smaller value for your orthophoto mosaic ground sample distance, as the value calculated from your imagery.

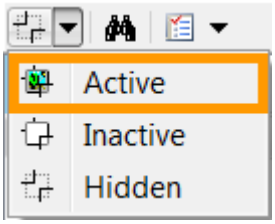
Example with following given data:
$H_O = 1000\ [m]$
$c = 100\ [mm]$
$p_{x,y} = 6\ [\mu m]$

$$GSD_{ground} = \frac{1000\ [m]}{0{,}1\ [m]} \times 0{,}000006\ [m]$$
$$GSD_{ground} = 0{,}06\ [m]$$

4.4.4. Review Result



After processing the ortho mosaic in UAS Edit, the ortho mosaic is automatically linked to the project file. To take a look at the orthophoto mosaic, please go to the Ortho Tab, select the mosaic and activate the display:



The orthophoto mosaic is displayed in the MainView and can be overlayed with the existing point cloud and morphological data.

Erroneous orthophoto mosaic areas are caused from wrong terrain model data and therefore corrections to the point cloud and morphological data are needed to create a correct orthophoto mosaic for the situation.

4.4.5. Ortho Mosaic Generation Exercise

Generate for the complete project a 3cm orthophoto mosaic.

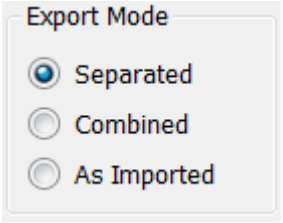
1. Activate all images
2. Check the interpolation flags for your point cloud and morphological data and activate if needed the necessary layers
3. Enter 3cm for pixel size and hit the run button 

4.5. Output

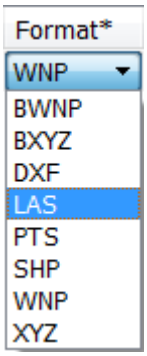
UAS Edit has three major outputs:

- Point cloud
- Morphological Data
- Ortho Mosaic

4.5.1. Export Vector Data

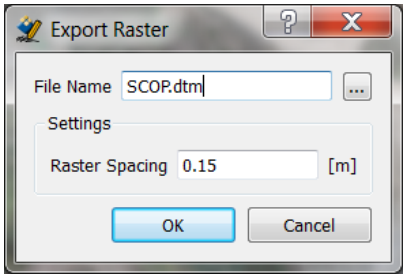


Separated: Each data set can be exported to a different file and file format.
Combined: All data sets will be combined into one file and one file format.
As Imported: If you imported data into UASMaster you can export it to the same file with the same file format (overwrites the imported file!).



These are the file formats that can be exported with Export Vector Data.

4.5.2. Export Raster



The Export Raster will take all layers with an active interpolation flag and creates from this data an interpolated raster model, stored in the SCOP DTM format. The SCOP DTM format can be used very efficient in the INPHO software family.

DTM

Binary SCOP Model Format.

The SCOP Model Format applies a hybrid representation of the surface.
It includes a grid to represent continuous areas, intermeshed with vector-type data such as break lines or form lines to facilitate the representation of sudden changes in continuity (break lines, highs and lows), or more gradual changes in it (form lines).
Border lines, break lines and form lines are stored with their original points and their intersection points with grid lines.
Spot heights, off-terrain points and control points are stored with their original coordinates.

4.5.3. Ortho Mosaic

UAS Edit creates for the complete project one single ortho mosaic. The output is placed into the project folder and automatically named **mosaic.tif**.

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Licensee may not directly or indirectly export or re-export, or knowingly permit the export or re-export of the Software (or portions thereof) to any country, or to any person or entity subject to United States export restrictions or any export and import control laws in the Territory in contravention of such laws and without first obtaining appropriate license.

Use, duplication, or disclosure of the Software by the United States Government is subject to restrictions as set forth in subparagraph (c)(1)(ii) of the Rights in Technical Data and Computer Software clause at DFARS 252.227-7013.

8. General

Except as otherwise stated herein, this License Agreement contains the entire agreement and understanding between the parties regarding the subject matter hereof, and replaces any prior written or oral understanding regarding such subject matter. Any different or additional terms or conditions contained in any Licensee purchase order are hereby rejected and shall not be deemed part of this License Agreement. Any attempt to sublicense, assign or transfer any of the rights, duties or obligations hereunder is void.

9. Choice of Law

This License Agreement shall be governed by the laws of the State of California and applicable United States Federal law without reference to “conflict of laws” principles. The United Nations Convention on Contracts for the International Sale of Goods will not apply to this License Agreement. Exclusive jurisdiction and venue of any dispute or action arising from this License Agreement or the Software shall lie exclusively in the federal or state courts located in the County of Santa Clara, California. You hereby consent and agree not to contest such jurisdiction, venue and governing law.

Notwithstanding the above, if you acquired this product in Canada, this License Agreement is governed by the laws of the Province of Ontario, Canada. In such case each of the parties to this License Agreement irrevocably attorns to the jurisdiction of the courts of the Province of Ontario and further agrees to commence any litigation that may arise under this License Agreement in the courts located in the Judicial District

of York, Province of Ontario. If you acquired this product in the European Union, this License Agreement is governed by the laws of The Netherlands, excluding its rules governing conflicts of laws and excluding the United Nations Convention on the International Sale of Goods. In such case each of the parties to this Agreement irrevocably attorns to the jurisdiction of the courts of The Netherlands and further agrees to commence any litigation that may arise under this License Agreement in the courts of The Hague, The Netherlands.
Trimble reserves all rights not expressly granted by this License Agreement.

10. Country Unique Terms

If You purchased a license to the Software in any Territory specified below (the “Local Territory”), this section sets forth specific provisions as well as exceptions to the above terms and conditions that apply in such Local Territory. To the extent any provision applicable to the Local Territory set forth below (the “Local Provision”) is in conflict with any other term or condition in this agreement, the Local Provision will supersede such other term or condition with respect to any licenses purchased in the Local Territory.

Belgium and France

(a) Limitation of Liability (Section 5): The following replaces the terms of this section in its entirety:

Except as otherwise provided by mandatory law, Trimble’s liability for any damages and losses that may arise as a result of the performance of its obligations in connection with this License Agreement is limited to the compensation of only those damages and losses proved and actually arising as an immediate and direct consequence of the non-fulfillment of such obligations (if Trimble is at fault), for a maximum amount equal to the charges You paid for the Software that has caused the damages. This limitation shall not apply to damages for bodily injuries (including death) and damages to real property and tangible personal property for which Trimble is legally liable.

UNDER NO CIRCUMSTANCES IS TRIMBLE, OR ANY OF ITS LICESORS AND/OR SOFTWARE DEVELOPERS, LIABLE FOR ANY OF THE FOLLOWING, EVEN IF INFORMED OF THEIR POSSIBILITY: (i) LOSS OF, OR DAMAGE TO, DATA; (ii) INCIDENTAL OR INDIRECT DAMAGES, OR FOR ANY ECONOMIC CONSEQUENTIAL DAMAGES; (iii) LOST PROFITS, EVEN IF THEY ARISE AS AN IMMEDIATE CONSEQUENCE OF THE EVENT THAT GENERATED THE DAMAGES; OR (iv) LOSS OF BUSINESS, REVENUE, GOODWILL, OR ANTICIPATED SAVINGS.

The limitation and exclusion of liability herein agreed applies not only to the activities performed by Trimble, but also to the activities performed by its suppliers and Software developers, and represents the maximum amount for which Trimble as well as its suppliers and Software developers, are collectively responsible. This limitation shall not apply to damages for bodily injuries (including death) and damages to real property and tangible personal property for which Trimble is legally liable.

Germany and Austria

(a) Warranty (Section 4): The following replaces the terms of this section in its entirety:

Trimble warrants that the Software provides the functionalities set forth in the associated documentation ("Documented Functionalities") for one (1) year following delivery of the Software when used on the recommended hardware configuration. Non-substantial variation from the Documented Functionalities does not establish any warranty rights. THIS LIMITED WARRANTY DOES NOT APPLY TO SOFTWARE PROVIDED TO YOU FREE OF CHARGE (FOR EXAMPLE, UPDATES, OR ACADEMIC OR EVALUATION LICENSES) OR SOFTWARE THAT HAS BEEN ALTERED BY YOU, TO THE EXTENT SUCH ALTERATION CAUSED A DEFECT. To make a warranty claim, you must return, at Trimble's expense, the Software and proof of purchase to Trimble. If the functionalities of the Software vary substantially from the agreed upon functionalities, Trimble is entitled, by way of re-performance and at its own discretion, to repair or replace the Software. If that fails, you are entitled to a reduction of the license fee or to cancel this License Agreement.

(b) Limitation of Liability (Section 5): the following paragraph is added to this Section:

The limitations and exclusions specified in this Section will not apply to damages caused by Trimble intentionally or by gross negligence. In addition, Trimble shall be responsible up to the amount of the typically foreseeable damages from any damage which has been caused by Trimble or its agents due to the slightly negligent breach of a material contractual duty. This limitation of liability shall apply to all damage claims, irrespective of the legal basis thereof and in particular, to any pre-contractual or auxiliary contractual claims. This limitation of liability shall not, however, apply to any mandatory statutory liability under the product liability act, or to any damage which is caused due to the breach of an express warranty to the extent the express warranty was intended to protect You from the specific damage incurred. This clause shall not be intended to limit liability where the extent of liability is provided by mandatory law.

Italy

(a) Limitation of Liability (Section 5): the following replaces the terms of this section in its entirety:

Apart from damages arising out of gross negligence or willful misconduct for which Trimble may not limit its liability, Trimble' liability for direct and indirect damages related to the original or further defects of the Software, or related to the use or the nonuse of the Software or related to any case whatsoever for breach of the Agreement, shall be limited to the fees paid by you to Trimble for the Software or for the part of the Software upon which the damages were based.