OrthoEngine Training Tutorial

OrthoEngine is a software package accompanying PCI Geomatics which is used for the orthorectification of aerial and satellite imagery and stereo DSM creation. In this tutorial you learn the basics of the orthorectification/stereophotogrammetry by undertaking some exercises in ArcMap and OrthoEngine.

Structure of the tutorial

The tutorial is divided into four sections: First, the **assessment and preparation of the data** in ArcMap. Second, the **setting up of the project, point collection and orthorectification** in OrthoEngine. Third, the **creation and editing of a DEM** from orthoimages, including the geocoding of the individual epipolar DEMs in Focus. And fourth, **troubleshooting** commonly experienced problems during undertaking these types of applications. The instructions are aimed at someone with a fair knowledge of ArcMap, and a basic knowledge of photogrammetry and remote sensing. You are encouraged to constantly consult the help files in both ArcMap and OrthoEngine to gain a fuller understanding of the concepts and procedures used. It is also suggested that you study Chapter 3, *Basic Principles of Photogrammtry,* of *Remote Sensing and Image Interpretation* by TM Lillesand, RW Kiefer & JW Chipman 2004.

Some terms:

Aerial photography - Photographing terrain on the ground by cameras mounted in aircraft. Also referred to as aerial photos, air photos or aerials. For the purposes of this tutorial, aerials can be thought of as only those taken at a non-oblique angles (ie. from directly above).

DEM/DSM/DTM - These terms refer to Digital Elevation Model, Digital Surface Model and Digital Terrain Model which are all land surfaces represented in digital form in an elevation grid or lists of 3D coordinates. Although there is a lot of confusion in the literature regarding these terms, the most agreed upon definition is that DEMs are a superset of both DSMs and DTMs, with DSMs representing the elevation values of the actual surface ie. including vegetation, buildings etc. while DTMs represent the elevation of the hypothetically bare surface. DSMs are usually created through the stereoscopic correlation of aerial photographs (stereophotogrammetry) or high/very high resolution satellite imagery; high resolution radar interferometry; and LIDAR. DTMs are commonly created by the interpolation of existing topographic elevation data (contours and point heights determined by stereophotogrammetry and surveying respectively); interpolation of LIDAR "ground" points; and medium/low resolution interferometry (e.g. SRTM); and stereoscopic correlation of medium/low resolution satellite imagery (e.g. GDEM).

Georeferencing - A process of assigning map co-ordinates to image data to conform to a map projection grid.

Orthoimage - An aerial photograph or satellite image that has been georeferenced, rectified and corrected for terrain displacement. Distance/area measurements can be accurately calculated on an orthoimage.

Orthorectification - A form of rectification which corrects for terrain displacement.

Photogrammetry - The process of making scale maps allowing precise measurements from aerial photographs.

Rectification - A process of making image data conform to a map projection.

Resolution - Level of detail in data. Usually measured in pixel size e.g. 1 pixel = 1m.

Stereoscopy - The science and art that deals with the use of binocular vision or observation of a pair of overlapping photographs.

(adapted from http://www.toronto.ca/mapping/catalogue/pdf/definition.pdf ; http://ads.ahds.ac.uk/project/goodguides/gis/sect44.html ; http://www.thefreedictionary.com/photogrammetry)

As can be seen from the definitions above, orthorectification is the process where an image of the earth is put into its "correct" position, defined according to either a geographical grid or a 2D projection, and distortion caused by terrain is corrected.

PART A: Data assessment and preparation

In this section of the tutorial you will use ArcMap to assess the data given to you for this exercise. You will also undertake a degree of data preparation by clipping the input data to a more usable size.

A number of datasets are provided in your Training folder. The first one you should have a look at is the three raw aerial files (*1109_03_116.img, 1109_03_117.img* and *1109_03_118.img*) in the Training > Raw folder.

1. Launch Arc Map, and load the images into a new empty map. Ignore the warning about the missing spatial reference information.

A couple of points can be noted:

- The images overlay each other. Because they lack a projection, Arc Map displays them with the bottom left corner at 0,0.
- The content of each images overlap between images. This is done deliberately to allow for stereo viewing.
- Each aerial has data around the edges. For example, image *1109_03_118.img*:

1/20000	Rough image scale
1109 Gansbaai	Job number and area name
Strip 003	Strip number (each flight job contains a series of back-and-forth strips)
19.11.2005	Date when image was taken
10:24:22	Time when image was taken (note the 20 second difference between images)
0118	Photo number

FS100	Film speed 100 ASA/ISO (sensitivity to light indicator)
1/500	Shutter speed of camera
f/4.0	Lens aperture (f-stop)

This data refers to the camera information, which is not relevant at this point. More important are the second three sets of data, which provide the latitude, longitude (in WGS 84 degrees, minutes and seconds) and flying height above sea level of the plane when the images were taken. You will use these to get a rough idea of where your images will lie.

2. Load the *mosaic.tif* from the Training>Reference folder, and right-click "Zoom to Layer". Then click on Full Extent. Your view will show mostly white. This is because mosaic.tif is projected to LO19 with a Hartebeeshoek Datum, which is about 3800 km south of the coordinates of 0,0 (where the raw images are).

3. Create an Excel file with a heading structure similar to the screenshot below.

A2

	A	B	C	D	E	F	G	H
1	Name	S_deg	S_min	S_sec	E_deg	E_min	E_sec	
2								
3								
4								
5								

4. The XY position of the camera when the aerial was taken is given in the bottom right corner in degrees minutes and seconds. Thus 341913.7S is actually 34°19'13.7"S. Enter this into your excel file for each image. Save the excel file as ImageCenters.xls (Excel 97-2003 Workbook format) in a new folder in Training your training folder called DeleteMe.

5. In your *ImageCenters.xls* calculate the coordinates in decimal degrees. The formula for this is (DEG)+(MIN/60)+(SEC/3600). Make the south points negative and name the south field y and the east field x.

6. In ArcMap, change the Data Frame coordinate system to WGS 84.

7. Run Tools > Add XY Data. Browse to *ImageCentres.xls* and select *sheet1$*; the X and Y fields should automatically fill in the correct spreadsheet fields of x and y. Select WGS 84 as the coordinate system, and click OK. The resulting points should overlay the mosaic file, giving you an indication of where your raw aerials lie.

8. You will now use the ArcMap Georeferencing toolbar to get an idea of the extent of each image. Load the Georeferencing toolbar, and select *1109_03_117.img* as the target layer.

9. You will now use links (also called control points) to get the raw image into roughly the right area. Zoom to *1109_03_117.img*. Click on the Add Control Points button on the Georeferencing Toolbar and click on one of the bunkers on the Arabella Golf Estate in the east of the image. Use the zoom tools to zoom back to *Mosaic.tif*, click the Add Control Points button again, and click on the same bunker. Repeat this for a point in the north and a point in the west of the image (road intersections may work best). As you click the links, the raw image will readjust itself, and you may have to switch *Mosaic.tif* off to see the aerial. When you have your three links, move *Mosaic.tif* to the bottom of the table of contents.

10. If not loaded already, load the Effects Toolbar and select *1109_03_117.img* as the target layer. Use the swipe layer tool to see the accuracy of your georeferencing.

You will note your georeferencing is not very accurate. This because this image contains a fairly dramatic change of elevation from the south to the north, and georeferencing in ArcMap cannot account for this. The purpose of the georeferencing is threefold. First, it gives you an idea of the extent of each image. This is important if your input information dataset (georeferenced imagery and DEM) needs to be clipped from a larger dataset. Second, by using the swipe tool it becomes possible to identify similar features between the aerial and the georeferenced image. In this case the georeferenced image is of a fairly good quality and similarities are easy to identify, however this is not always the case. Third, it gives you an idea of the orientation of the image. In this case the raw aerials were orientated with north at the top of the screen, but again this is not always so. Aerials will be rotated in OrthoEngine (if necessary), and observing them in ArcMap helps to determine the direction of rotation (90, 180, -90 etc).

Georeferencing in ArcMap is therefore a useful skill to have. Load the help files and search for *Georeferencing raster datasets*. There is a short clip showing you what you have already done in more detail.

Final note: The links you create for each image are temporary until you Update Georeferencing or Rectify. Save them in a table if you wish to recall them, but do NOT make them permanent.

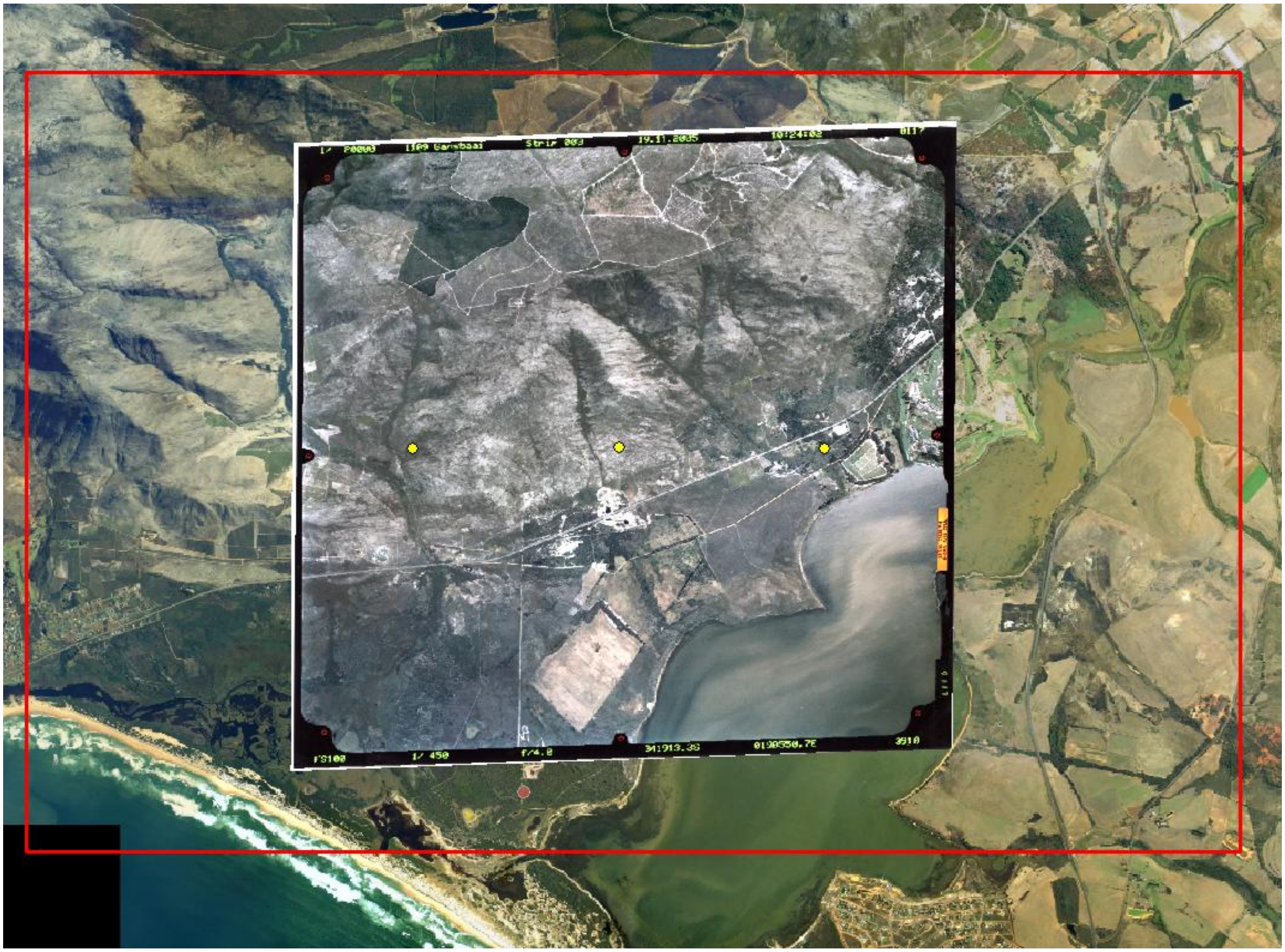
You will now clip your input data to a more manageable size. Strictly speaking this is not absolutely necessary for this exercise, but it is still valuable to know.

11. Zoom to the extent of your *mosaic.tif* layer.

12. You will now create a mask with which to clip your input data. Create a new polygon feature class with the same projection as *mosaic.tif* (LO19). Name it InputMask and store it in your DeleteMe folder.

13. Change the Data Frame coordinate system to that of *mosaic.tif*. Ignore any messages informing you of Datum errors.

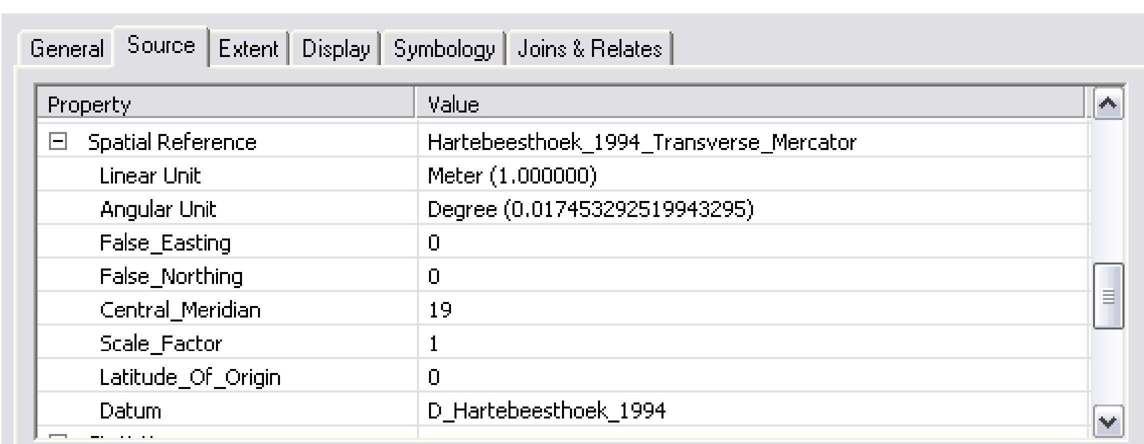
14. Start editing your InputMask, and create a new rectangular feature which you are sure will completely encompass your aerials when orthorectified. Use the rectangle tool on the Advanced Editing toolbar to get a perfect rectangle and stop editing and save your edits when you are done. See the figure below for an example.



15. Select the tool Spatial Analyst Tools > Extraction > Extract by Mask. Put Mosaic.tif as the input raster, InputMask as the feature mask, and name the output raster MosaicClip.img, stored your DeleteMe folder.

16. Load the InputDEM_LO19.img and repeat the extraction. Name the output raster DEMClip.img, stored in your DeleteMe folder.

You now have the necessary input required for orthorectification. However, before proceeding to OrthoEngine, it is always a good idea to double check the projections for each dataset. Open the properties for each clipped raster and verify that the projections look as follows.



Property	Value
Spatial Reference	Hartebeesthoek_1994_Transverse_Mercator
Linear Unit	Meter (1.000000)
Angular Unit	Degree (0.0174532925199433295)
False_Easting	0
False_Northing	0
Central_Meridian	19
Scale_Factor	1
Latitude_Of_Origin	0
Datum	D_Hartebeesthoek_1994

PART B: Orthorectification in OrthoEngine

In this section you will set up the orthorectification project using the input data and camera calibration certificate, collect ground control points (GCPs) and tie points, and undertake the orthorectification of the images.

1. Launch **OrthoEngine 10.3**

2. Start a new project. Name the file BotTraining.prj and store it in your Training > DeleteMe folder. Note that the extension for OrthoEngine projects is .prj, which is the same as projection files for ArcGIS.

3. Under **Name** type "Three image orthorectification and DSM creation for OrthoEngine training". Leave description blank.

4. Under **Math Modelling Method** select **Aerial Photography**. A new set of options will appear. By default these are correct for this project: the **Camera type** is **Standard aerial**, and the **Exterior orientation** is **Computed from GCPs and tie points**. Click **OK**.

5. The **Set Projection** box appears. Here you will set your GCP and output projections, and specify your output cell size. Under **Output projection**, click on the dropdown arrow and select **Other**. A list of **Other Projections** will appear. Click on the **User Projections** tab and scroll down and select **ZALo19**. Click accept.

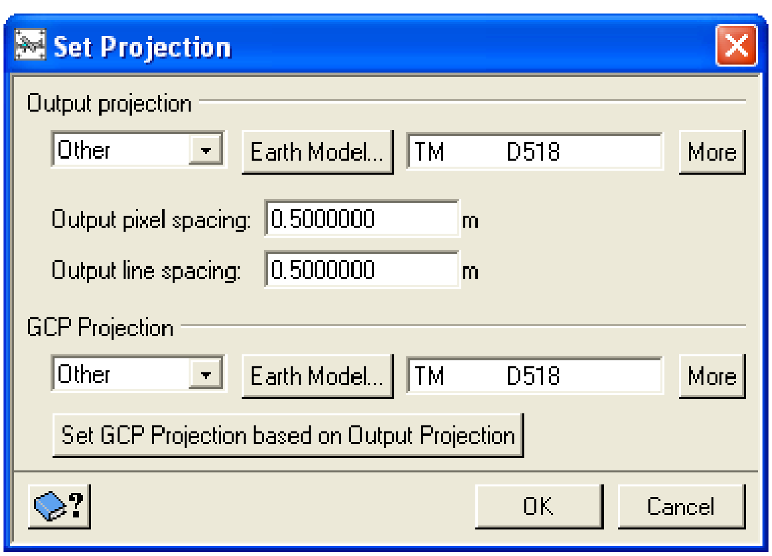
Note: the ZALo projections in OrthoEngine still specifies the datum (or Earth Model) as Cape Datum. This is incorrect for this and all projects since 1999.

6. Click on **Earth Model…** and scroll down and select **D518 Hartebeeshoek 94**. Your projection now has the correct datum specified.

7. Click the **Set GCP Projection based on Output Projection** button. Your **GCP Projection** should be the projection of your reference data, which as we saw in ArcMap with *Mosiac.tif*, is in a LO19 projection with a Hartebeeshoek Datum.

8. Set **Output pixel spacing** and **Output line spacing** to 0.5m. Your final orthophotos will now have a resolution of 0.5m per pixel.

9. Click **OK**.



The next screen that appears requests the **Aerial Camera Calibration Information**. This is also known as the interior information. Some of this information is available from the aerial itself, but most will require a camera calibration certificate. Have a look at the little orange square on the right side of one of the aerials, it will display the following: **WILD 15/4 UAG-S No. 13352 153.69**. Accompanying this exercise is the calibration certificate of this camera (Wild__RC30_15_4_UAGS_S__LensNo_13352_DD20030212.pdf).

Note the following:

> **WILD** is the camera make
>
> **15/4 UAG-S** is the Lens Type
>
> **13352** is the Lens Number

The other figure, 153.69, is the focal length of the camera, which is the first parameter required.

10. Enter 153.69 as the **Focal length** of the camera in mm.

The camera calibration certificate will contain the other parameters required.

11. Browse through the calibration certificate to find the offsets for the **Principal point offset.**

From the help files you will note:

> In the **Principal point offset** boxes, type the x and y offsets in millimeters. The principal point offset is calculated as:
>
> `Principal point of symmetry (POS) + Principal point of autocollimation (PPA) - Indicated principal point (IPP)`
>
> The POS, PPA, and IPP values can be obtained from the camera calibration report.

From the calibration file you will note:

> **Principal point of autocollimation (PPA) and principal point of symmetry (PPS)**
> referred to central cross (FC), see diagram

	x (mm)	y (mm)
PPA	-0.008	-0.001
PPS	-0.005	0.010

Since the IPP is not provided in the calibration certificate we can consider its offset to be zero. Therefore the algorithm for Principal point offset (X,Y) is PPS + PPA.

12. Calculate the **Principal point offsets** for X and Y and enter them into the table.
13. To enter the **Radial Lens Distortion**, click on the **Compute From Table…** button. Change **Distance units** to **mm** and sequentially enter the **Mean** distortion for each radial distance, as read from the calibration certificate.

Radial distortion (micrometers) referred to principal point of symmetry (PPS)
(Positive values denote image displacement away from center)

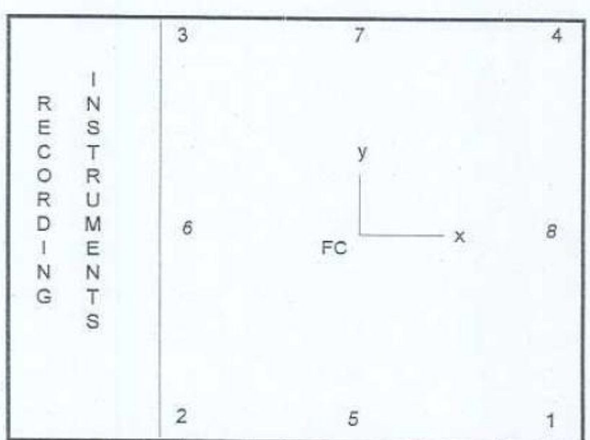
Radius mm	Half - Sides 1	3	2	4	Mean
10	0.0	-0.7	-0.3	-0.6	-0.4
20	-0.3	-1.2	-0.8	-0.9	-0.8
30	-0.4	-1.4	-0.8	-1.6	-1.0
40	-0.4	-1.0	-1.1	-1.3	-0.9
50	-0.3	-1.4	-1.3	-1.3	-1.0
60	-0.8	-1.3	-1.1	-1.9	-1.2
70	-0.2	-1.8	-1.5	-1.6	-1.2
80	-0.2	-1.4	-1.2	-1.4	-1.0
90	1.1	-1.0	-0.7	-1.1	-0.4
100	1.9	-0.3	0.9	-0.1	0.6
110	2.0	0.8	1.9	1.3	1.5
120	1.6	1.7	1.4	1.6	1.5
130	0.9	2.3	0.8	1.4	1.3
140	-0.1	2.0	0.0	0.5	0.6
148	-1.1	0.1	-1.4	-1.0	-0.8

Decentering distortion is not specified in the calibration report and can thus assumed to be zero.

14. Enter the **Fiducial marks** for the edges and corners as specified in the calibration certificate.

Fiducial marks, referred to central cross (FC)

	x (mm)	y (mm)		x (mm)	y (mm)
1	106.004	-106.004	5	0.000	-111.995
2	-106.000	-105.999	6	-112.010	0.004
3	-106.005	106.005	7	-0.007	111.996
4	105.996	105.996	8	112.003	-0.002

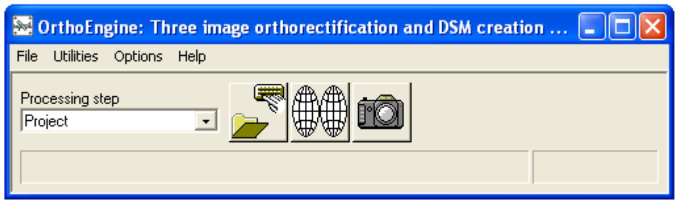


as seen on focal plane frame

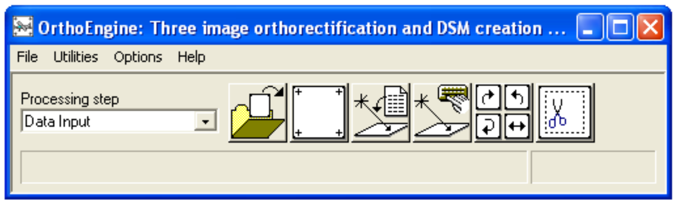
15. Specify 1:20000 as the **Image scale**, as read off the top left of the aerial photos.

16. **Earth radius** is not given on either the aerials or the calibration certificate. In this case, however, our extent is too small for this to matter. Leave it blank and click OK.

Your screen will now revert to the **Project Processing** step, as shown below. The three buttons to the right activate the three steps you have just completed, should you need to alter any of the information.



17. To move onto the next step, click the dropdown arrow under **Processing step**, and select the next option **Data Input**. A new set of buttons to the right will appear.



18. The first button **Open a new or existing image** is used to enter the images into the project. Click this button and select **New Image**. Browse to your three images in the Training > Raw folder, select them all and click **Quick Open** and then **OK**. You will see the image titles and paths now displayed. Click **Close**.

19. You will now specify the fiducial points for each image. Click the **Collect fiducial info** button. The **Open Image** box appears with the fiducial collection box in the background. Select the first image on the list and click **Open**. Two things will now happen. A viewer opens displaying a three-scale view of image 1109_03_116.img, and the fiducial collection box now has the heading **Fiducial Mark Collection for Photo:1109_03_116**.

20. Take some time to familiarize yourself with the viewer navigation tools and with the content of the image. The most often used tools are **Zoom In, Zoom Out** and **Pan**. In the help files, read up on *Understanding enhancements*, and examine the functions of the **Enhance** tool (you will also use this one often). Use variants of the Enhance tool to adjust the display of different areas of the image.

21. Navigate to the top left hand corner of the image, and click the red cross (in the upper left pane) on the red crosshair fiducial. Zoom in to get a more accurate position. When you are satisfied that the red cross is dead center in the fiducial, click **Set** for the **Top Left** fiducial in the **Fiducial Mark Collection** box. You will see the image XY coordinates filled in for this fiducial.

22. Repeat this for all the fiducials on this image. You will notice that after placing five fiducials the error values are calculated. You should aim to keep these as low as possible (under 0.6P is best). Adjusting the **Calibration edge**, which specifies where on the aerial the photo information is stored, can often lower these values. In this case, leave it as **Left**.

23. Collect the fiducial values for the other two images.

Note: For future reference, rotation of images includes the rotation of any fiducials already set.

The other three functions of the **Data Input Processing Step** regard the input of exterior information, the rotation of images and the setting of a clip boudary. In this case, exterior information will be calculated from the GCPs and camera model and rotation is not necessary as the input aerials all face north. However, you will be using clipping to remove the aerial borders.

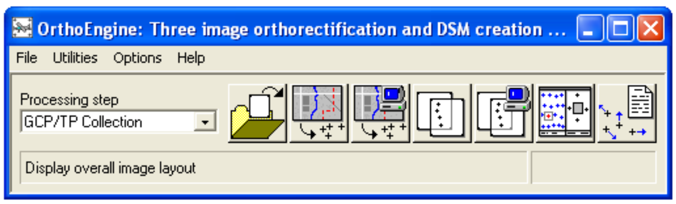
24. Click **Define clip region** and open 1109_03_116.img. **Zoom to overview**.

25. You should note a red box along the boundaries of the image. Resize the box to exclude the borders of the aerial photos (have the corners roughly close to the corner fiducials). For more exact measurements you can alter the size and origin of the clip box using the **Define Clip Region** coordinates box.

Note: Clipping affects only output data, thus any GCPs or tie points specified outside of the clip area will still be used in the orthorectification algorithm.

With the interior and exterior information now properly set up, you can move onto the collection of GCPs and tie points.

26. Click the dropdown arrow under **Processing step**, and select the next option **GCP/TP Collection**. A new set of buttons to the right will appear.



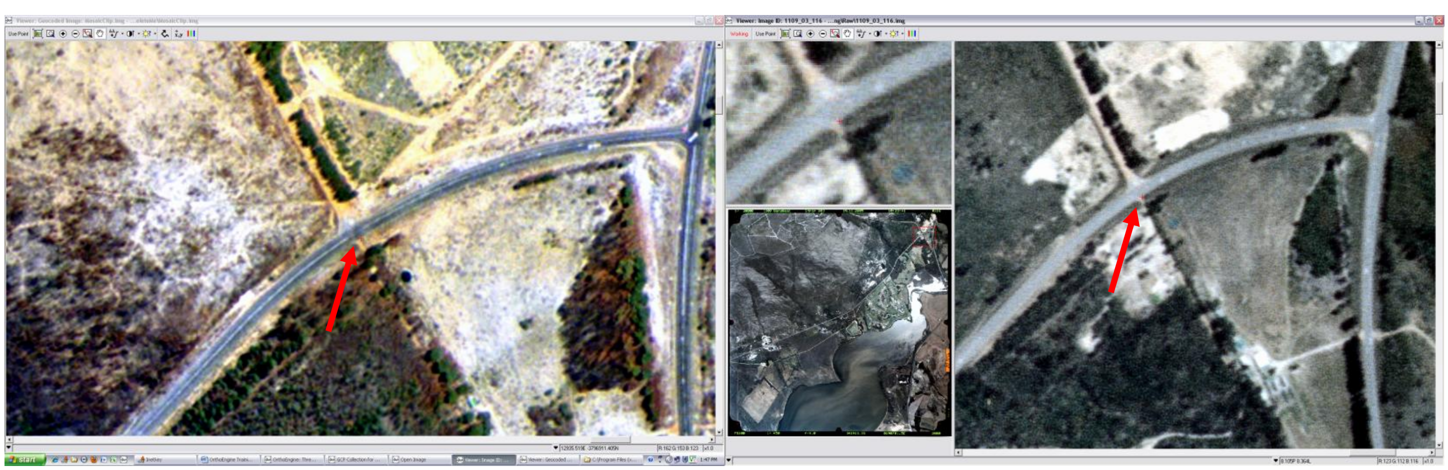
The first button is again the **Open a new or existing image** button, which performs exactly the same task did the one on the **Data Input Processing Step**. The second and third buttons concern GCP collection, the third and fourth buttons concern tie point (TP) collection and the last two buttons concern the visual and statistical analysis of the collection of GCPs and TPs.

27. Click on the **Collect GCPs Manually** button. Select *1109_03_116.img* as the image you wish to collect GCPs for, and click open. Click **Default** if asked to assign RGB to bands and click **Load & Close** (always do this if asked). A viewer displaying *1109_03_116.img* will open.

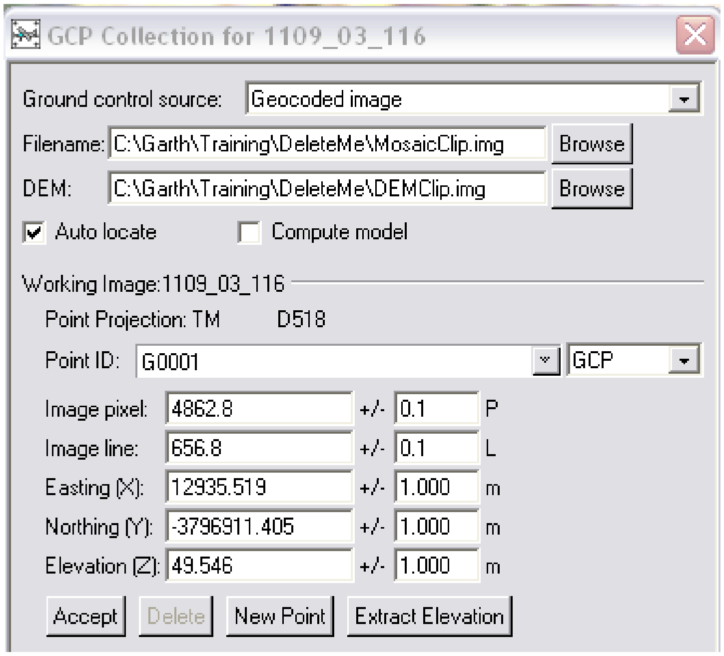
28. Pull up the **GCP Collection for 1109_03_116** box. Under **Ground control source**, click the dropdown arrow and select **Geocoded image**. Browse to and select *MosaicClip.img*. A viewer displaying *MosaicClip.img* will open.

29. In the **GCP Collection for 1109_03_116** box, click the **Browse** button next to **DEM:** and browse to and select *DEMClip.img.* No viewer opens for the DEM, but you will now be able to determine the elevation for any point you select.

30. Navigate to and place the red cross on a common point on each image, as can be seen in the figure below. When you are satisfied with the placing of each red cross, click **Use Point** in the top left of each viewer. You will see the **image pixel/line** and **XY coordinates** filled in the **GCP Collection** box for the GCP you are collecting (G0001).



31. Next, click **Extract Elevation**. This obtains the elevation from your DEM for this point. For the GCP collected above, your GCP Collection box will look similar to the figure below.



32. Click **Accept.** Your GCP is now assigned to the image.

33. Collect **ten to twelve** GCPs for this image. In the help files, read up on **Understanding ground control points**, and apply that knowledge to your collection of GCPs.

You will now collect GCPs for *1109_03_117.img*. GCPs that lie within an overlapping area to *1109_03_116.img* can be collected as **Stereo GCPs** (i.e. they reference two or more raw images). You are encouraged convert as many of your GCPs to Stereo GCPs as possible.

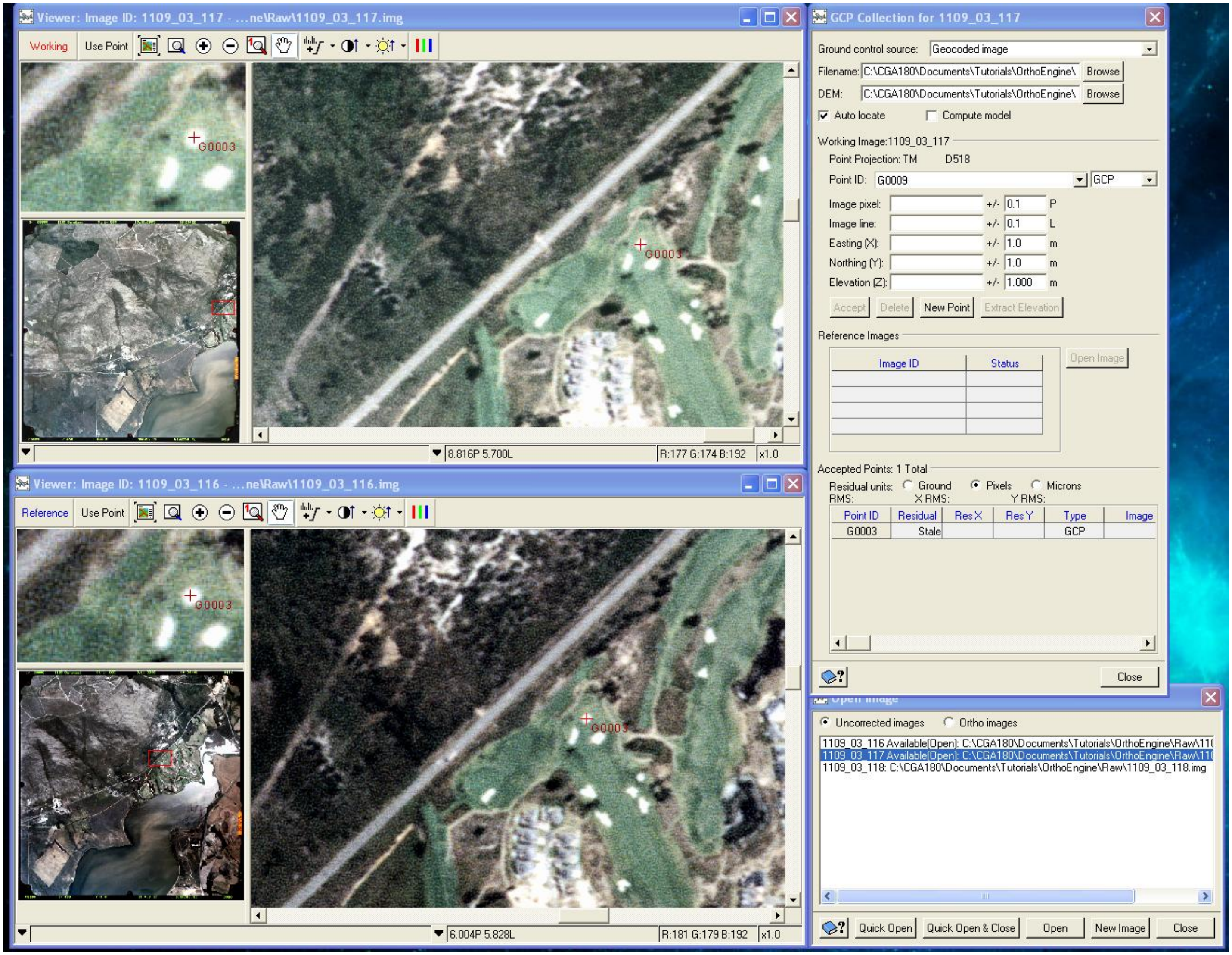
34. Close the viewer displaying *1109_03_116.img* and open *1109_03_117.img***.** Now reopen *1109_03_116.img* and under **Accepted Points** select **G0001**. You will snap to this point in the viewer.

35. Click on the viewer displaying *1109_03_117.img*. Can you navigate to **G0001** in this image? If not, move onto **G0002** and repeat this process.

36. When you find a point that you can see in both images, click the red crosshair onto that point in *1109_03_117.img* and click **Use Point**. You will notice that the **GCP Collection** box now focuses on *1109_03_117.img* rather than *1109_03_116.img* and displays 1109_03_116 under **Image ID** in **Reference Images**.

37. Click **Accept** if you are happy with the positioning of the stereo GCP in both aerials, as well as the reference imagery.

The screenshot below demonstrates an example of a stereo GCP designated in the centre of one of the bunkers on Arabella Golf Course.



38. To return to the list of GCPs for *1109_03_116.img*, double click it in the **Open Image** dialogue box.

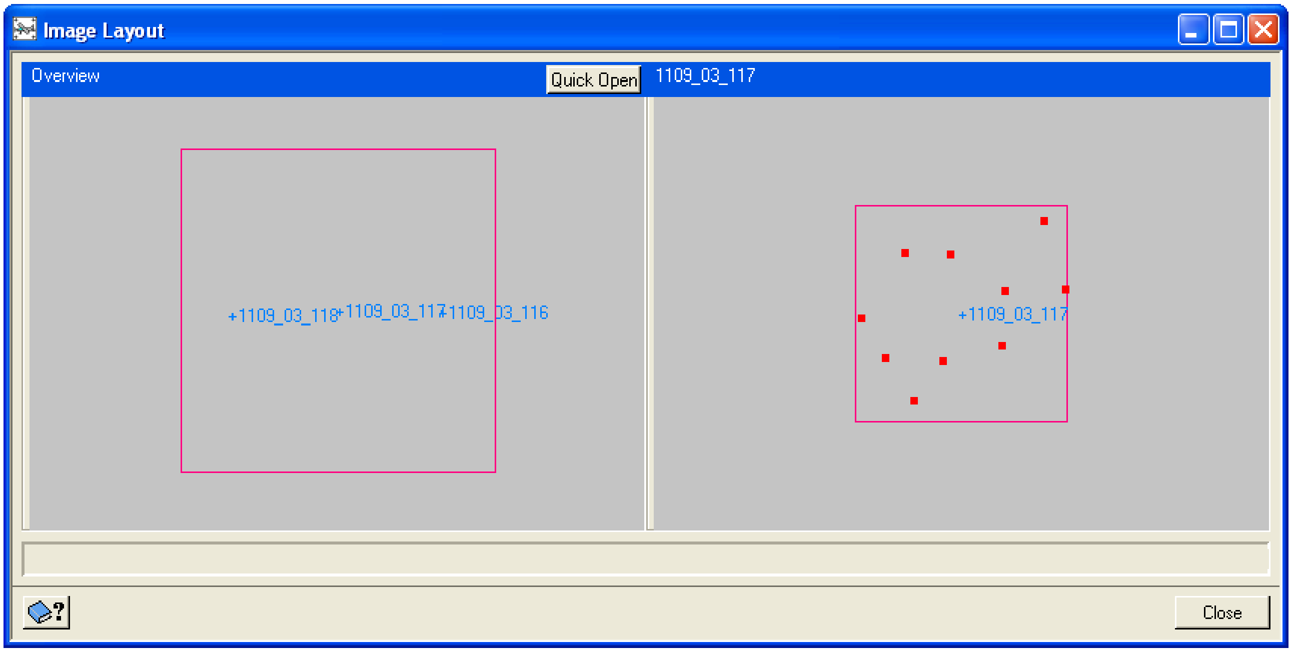
39. Click on your GCPs for *1109_03_116.img*, and convert as many of them to stereo GCPs as possible.

40. Once you have converted all the possible GCPs from *1109_03_116.img* to stereo GCPs on *1109_03_117.img*, close *1109_03_116.img* and click **Zoom to Overview** on *1109_03_117.img.* You will note that only the east of the image has GCPs, as that is where the overlap lies. Using the technique described in steps 30-32, collect a number of GCPs in the west of the image.

41. Convert as many GCPs as possible from *1109_03_117.img* to stereo GCPs in *1109_03_118.img*.

42. Finish GCP collection by defining a few non-stereo GCPs in the west of *1109_03_118.img*, where there is no image overlap.

43. Once you have collected your GCPs, close the **GCP Collection** box and click the **Display overall image layout** button. This view provides a graphical representation of the areas that your images cover, similar to the dialogue box displayed below. By clicking on the name of the file you can see where each of your GCPs lie in that image. This view is also useful for determining whether you have bad GCPs. Often, where mistakes with GCP collection have been made, the image will display in an unexpected position or at a different size to the rest of the imagery. If this occurs, you may have to delete and recollect your GCPs.



44. Close this layout view.

You will note after collecting three stereo GCPs for an image that the viewer will attempt to jump to the area where it thinks the stereo GCP should lie. This is an automatic application of the orthorectification algorithm and as well as cutting down on your navigation time also provides you with an indication of how good the orthorectification will be - snapping close to the actual position indicates a good orthorectification and vice versa. Increasing the number of GCPs and tie points will improve the orthorectification.

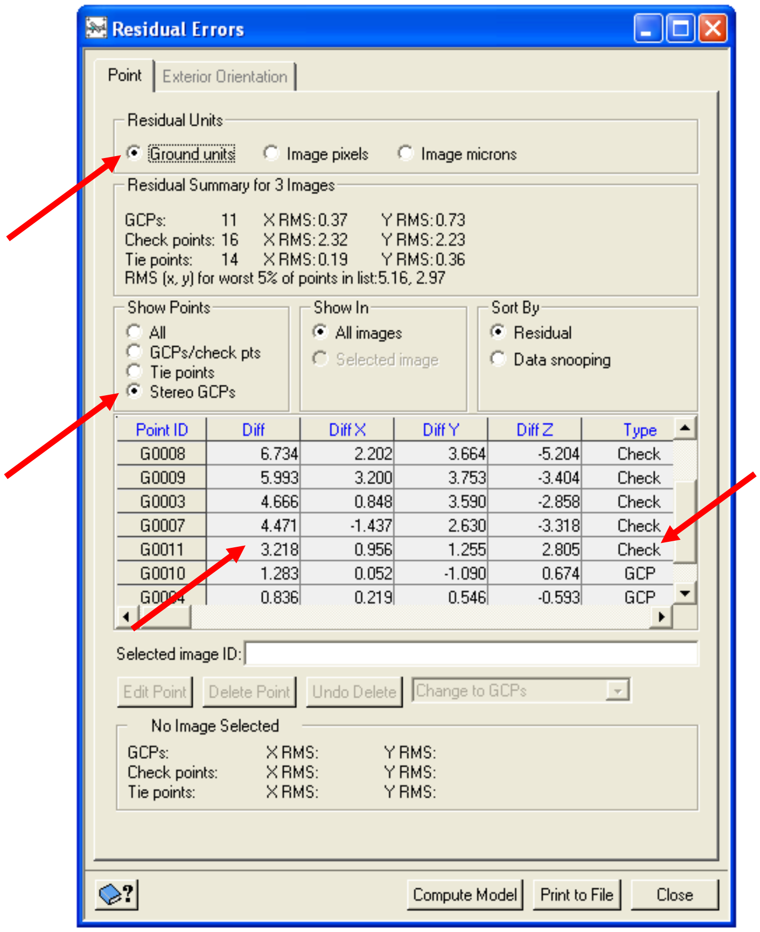
45. You will now collect tie points between the images. Click on the **Manually collect tie points** button. Select 1109_03_116 and open it, and repeat for 1109_03_117. Select a site common to both images and click **Use Point**, as you did with the GCP collection.

46. In the **Tie Point Collection** box, click **Accept**. Your tie point is now assigned to the two images.

47. Collect **ten** tie points for each adjacent image. In the help files, read up on **Understanding tie points**, and apply that knowledge to your tie point collection.

48. Once your tie points are collected, click again on **Display overall image layout** to have a look if your images are still roughly in the correct place. If one image is has a much greater area than the others or is off position, you may have erroneous GCPs or TPs. If you are satisfied, close the display.

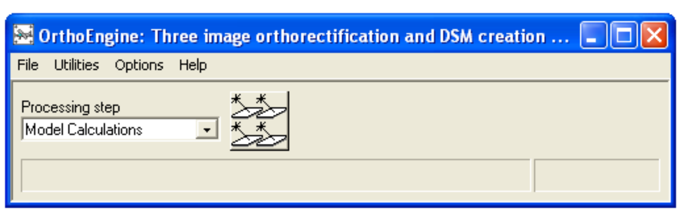
49. Click on the **Residual report** button and click **Compute Model** (see step 38 if this fails). Residual reports (also known as RMS errors) provide a statistical output of the errors of each GCP and TP. These errors are related to one another, therefore one erroneous point will raise the residual values of all of the points. For this exercise you ideally would want to keep your stereo GCP residuals to below 2m (click **Ground units** to see in meters). If residual errors are above 2m, you need to find the point (or points) which are erroneous. To exclude the GCP from the residual calculation (and orthorectification) you can select it and click **Change to GCP/Check Point** and click **Compute Model**. The residual calculation algorithm will run without taking the check point into account. If you have checked the erroneous GCP, the residual values should drop to acceptable levels. Unfortunately tie points cannot be checked, only deleted. See the following image as an example.



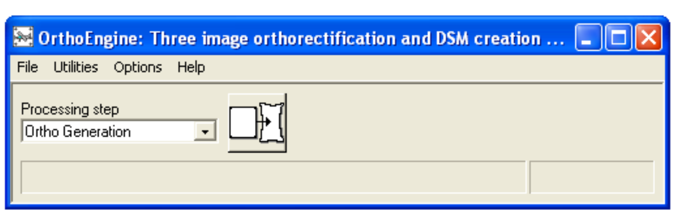
50. If you are satisfied with your residual values, close the **Residual Errors** box.

You will now run the model and undertake orthorectification of the imagery.

51. Click the dropdown arrow under **Processing step**, and select the next option **Model Calculations**. Click **Compute model.** You should get a message saying *Bundle adjustment has completed*. If you get a fail message, it is likely that your GCPs are inaccurate. Assess your residual values of each of your GCPs to see that they are acceptable. Delete or check those which are out. Another reason for model calculation failure is insufficient GCPs. Add more if prompted. If your bundle adjustment was successful, click OK.



52. Click the dropdown arrow under **Processing step**, and select **Ortho Generation**. Click **Schedule ortho** generation.



53. In the **Ortho Image Production** box, select all of the unprocessed **Available images** and move them across to **Images to process**. Click on the top file, you will note below that the default name for the orthophoto to be generated is the name of the file with an "o" in front of it. The default folder is the folder containing the project file. You can change this by clicking browse and defining your own name and folder, but in this case you will leave it as default.

54. Under **Ortho Generation Options**, browse for *DEMClip.img* and select as the DEM to be used. Leave **Background elevation**, **Elevation scale** and **Elevation offset** blank. Change the working cache to 512Mb and leave the rest as default.

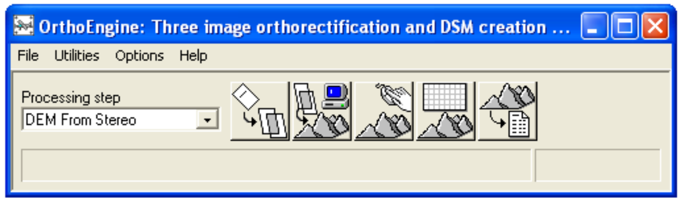
55. Click **Generate Orthos**. Depending on the speed of your pc, this may take between 50 seconds and 15 minutes per orthophoto.

Now that you have created your orthos, you will now use them to generate a DSM using stereoscopic correlation.

PART C: DSM creation in OrthoEngine

In this section you will create a DSM from the ortho images you have created. This process has three steps: first, creating individual epipolar DEMs from overlapping image pairs, then geocoding the individual epipolar DEMs from these images, and finally manipulating the DEMs to create one seamless DSM.

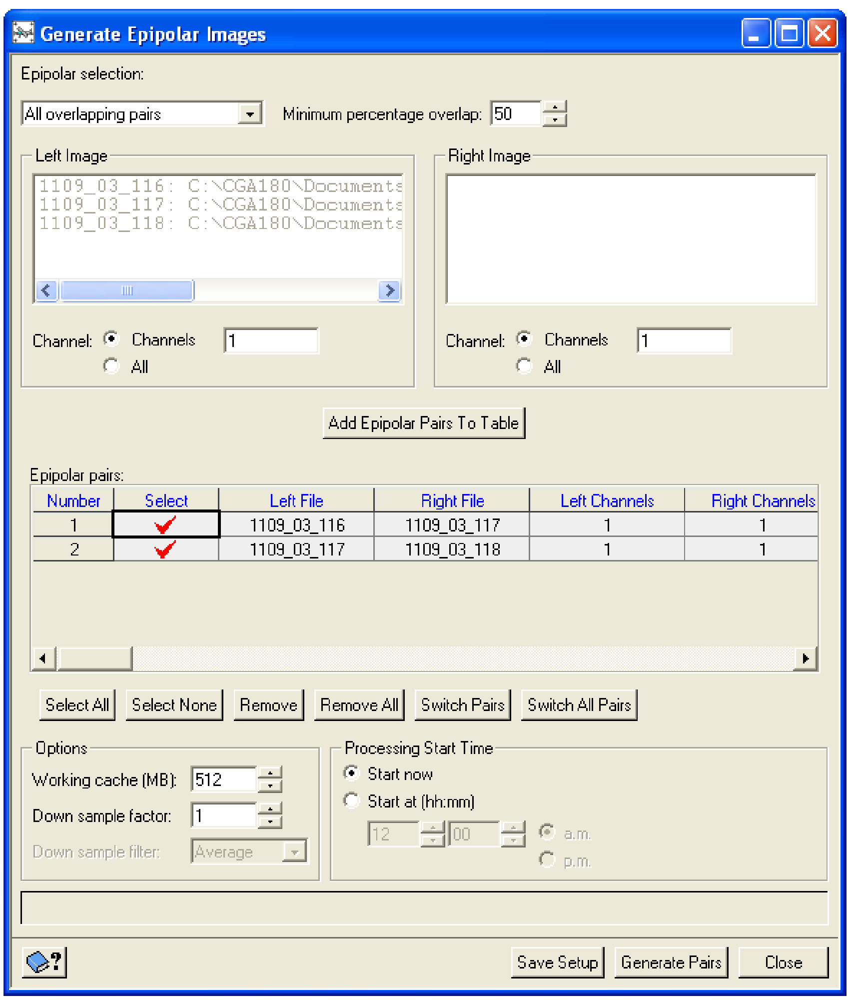
1. Click the dropdown arrow under **Processing step**, and select **DEM from Stereo**.



2. Click **Create Epipolar Image**.

3. Under **Epipolar selection** change **User select** to **All overlapping pairs** and click **Add Epipolar Pairs To Table**.

4. Change **Working cache (MB)** to **512**, if it is not already. Your dialogue box should look as follows:



5. Click **Generate Pairs**. You will be warned that this process may take a while to complete. Since you only have to generate two epipolar images, this should not take longer than 5 minutes. Click **Yes** to run the tool.

6. Once your epipolar pairs have been successfully generated, close the **Generate Epipolar Images** dialogue box and click on **Extract DEM Automatically**.

7. In the bottom left corner of the dialogue box, click the help button and read up about **Extracting a digital elevation model from epipolar pairs**. Once you have a fair understanding of the theory close the help file.

8. Click **Select All** to select all of the **Stereo pairs** (another term in OrthoEngine for epipolar pairs).

9. Although it is always a good idea to double check the minimum and maximum elevation for your study area, you can in most cases trust the default values provided. Leave them, as well as **Failure value** and **Background value** as default.

10. Set the **DEM detail** to **High**.

11. As a rule of thumb, set the **Pixel sampling interval** i.e. output resolution to just smaller than 10x the ortho resolution. In this case we set the output resolution as 0.5m (this is determined by the scale of the imagery, which is a function of flying height and focal length), so we can set the **Pixel sampling interval** to 4, which returns a **Resolution** of **4.3**. Read up **Understanding pixel sampling and DEM detail** in the help files for more details.

12. Check **Use clip region**.

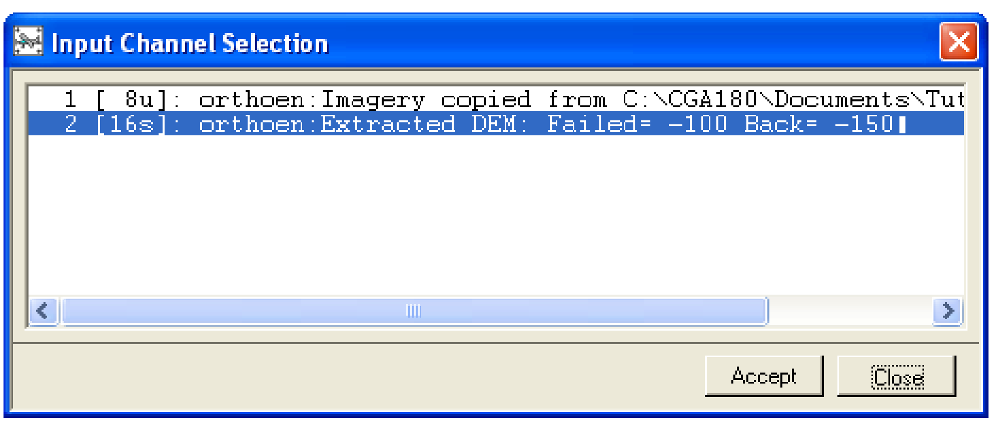
13. Click **Extract DEM**.

By clicking on **Create Geocoded DEM** it is possible to automatically geocode and mosaic the individual DEMs into one final product. Although this a procedure can save time, it is valuable to learn how to manipulate and mosaic the individual epipolar DEMs yourself. Once you are experienced with manual editing of DSMs you are encouraged to try the automatic extraction.

14. Close the **Automatic DEM Extraction** dialogue box when the DEMs have extracted correctly, and click the **Geocode Extracted Epipolar DEM** button.

15. Browse to your epipolar DEMs (in the same folder as your orthos). They are named *dem_1109_03_116_1109_03_117.pix* and *dem_1109_03_117_1109_03_118.pix*. Open one of them.

16. Under **DEM channel** click **Select**. Some DEMs have multiple channels (similar to the Red, Green and Blue channels of the aerials). These channels might include the imagery that was used to generate them and the score channel (degree of correct correlation to the input DEM). Make sure you select the channel named **Extracted DEM**.



17. Leave the other parameters as default, but store your output in the same folder, as the same name as the input epipolar DEM with "geo_" in front of it e.g. *dem_1109_03_116_1109_03_117.pix* becomes *geo_dem_1109_03_116_1109_03_117.pix*.

18. Set the **Pixel spacing** as **10m**.

19. Leave **Fill holes** as **Yes**. This will interpolate the failed values in the DEM and therefore enhance DEM quality.

20. Click **Geocode DEM**.

21. Repeat this for the other epipolar DEM.

22. Close the **Geocode Extracted Epipolar DEM** dialogue box.

23. Save your project and close OrthoEngine.

The assessment, manipulation and mosaicking of the DEMs will undertake in ArcMap.

24. Open ArcMap and load both of the geocoded DEMs.

25. Right-click the top DEM in the Table of Contents and click **Properties > Symbology**.

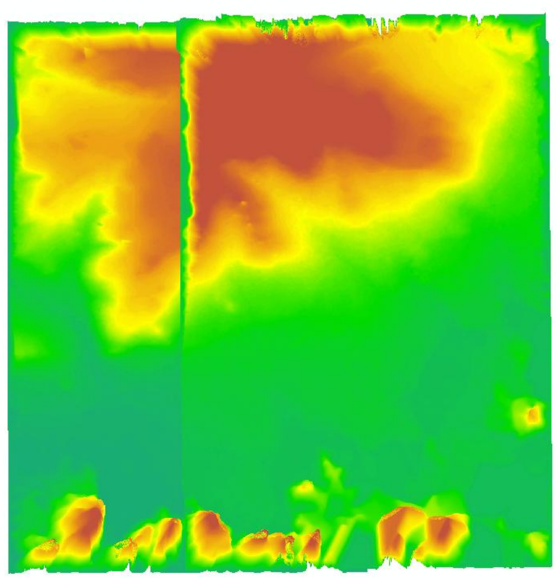
26. Under **Type** select **Standard Deviations** (calculate statistics, if necessary). Leave **n: 2**.

27. Select the brown/red to navy blue colour ramp and click **Invert**.

28. Check **Display Background Value** and enter -150 as the background value figure (you may have to type "150" and then add the "-" sign afterwards).

29. Click **OK.**

30. Repeat this for the other geocoded DEM. Your DEMs should look as follows:



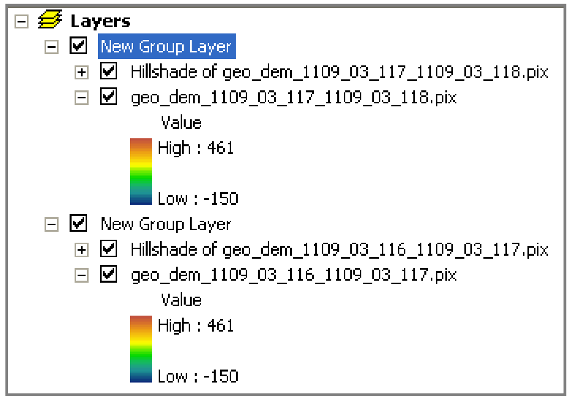
You will notice that the DSMs suffer from typical but significant errors close to the borders. These errors (and others) will be more apparent when the DSMs are displayed with hillshades.

31. On the spatial analyst toolbar, click **Surface Analysis > Hillshade** (you can also find this tool in ArcToolbox).

32. Leave all parameters as default and create a hillshade. Repeat for the other DSM.

33. In **Properties > Display** of the hillshades, set **Transparency** to **60%**.

34. In the Table of Contents group the hillshade with its corresponding DEM, as follows:

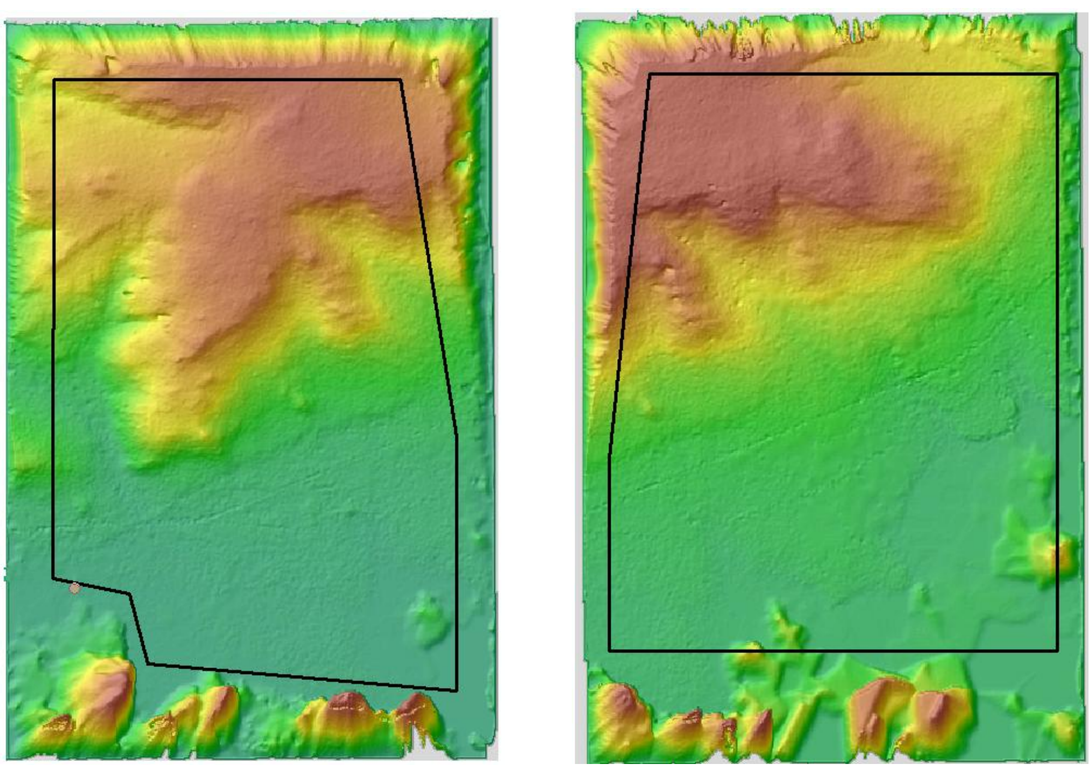


You can now compare one DEM to the other by clicking the group on and off, or using the **Swipe** effects tool. As you can see, there is a tail-off edge effect near the borders, as well as spike artifacts in the south. This is typical over water and near the edges of the overlap area. You will now create a mask and clip out the "good" areas of each DEM, and then mosaic them together.

35. In ArcToolbox click **Data Management Tools > Feature Class > Create Feature Class**.

36. Create a new polygon feature class your new feature class *Mask1* and store it in your DeleteMe folder.

37. Start an edit session and digitize a suitable clip mask to extract the DEM. Examples are given below:



38. Create a second feature class *Mask2* for the second DEM.

39. In ArcToolbox, navigate to **Spatial Analyst Tools > Extraction > Extract by Mask** and use this tool to extract the error free parts of each of the DEMs. Add an "x_" to the filename as the output names and save as .img format e.g. *x_geo_dem_1109_03_116_1109_03_117.img*

40. In ArcToolbox, run **Data Management Tools > Raster > Raster Dataset > Mosaic to New Raster**.

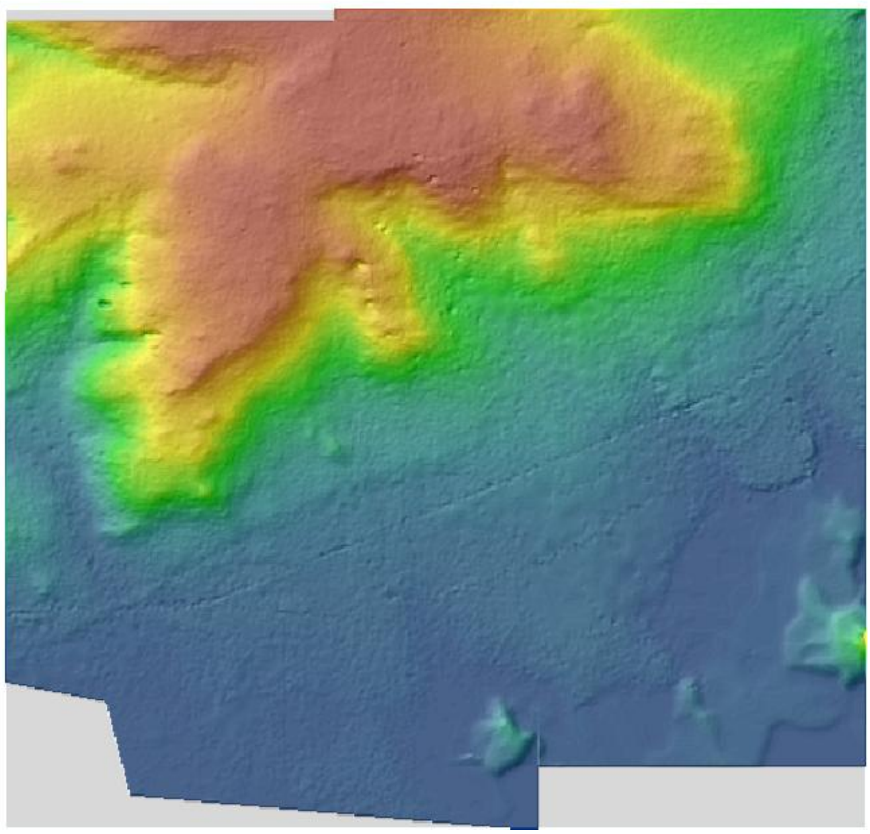
41. Enter your extracted DEMs as **Input Rasters** and your DeleteMe folder as the **Output Location**. Name the output raster *as Botvlei_DSM_v01.img*.

42. Set the **Coordinate system for the raster** to the same as the geocoded DEMs (LO19) and the **Pixel type** as **16_BIT_UNSIGNED**.

43. Set the **Cellsize** as **10m** and the **Mosaic Method** as **BLEND**.

44. Run the mosaic.

45. Alter the symbology and create a hillshade to visually inspect your final result.



Troubleshooting

I cannot find my *ImageCenters* excel file in ArcMap's Add XY Data tool

This is probably because it is saved as an .xslx file (Excel 2007), which ArcMap cannot read. Resave the file in the format of Excel 97-2003 Workbook and retry.

My XY points loaded from my excel file do not overlay my *mosaic.tif* file.

This is most likely a result of incorrect values in your excel file. Make sure your decimal degree calculation formula is correct, and that the latitude points (North-South) are negative. Also make sure your data frame and your imported points file are defined as WGS 84.

When georeferencing in ArcMap I get a message "The control points are collinear or not well distributed. This will affect the warp result"

This regards the placement of your control points, which are either in a line or too focused on one area of the aerial. You may notice your adjusted aerial is skewed as a result. The best placement of three control points is in a triangle, with the control points as close to the edge of the photo as possible.

My OrthoEngine viewers cannot be altered to any view setup other than maximum (full screen) and minimum (Windows taskbar only). Restore does not work and I cannot move my viewer windows.

This is a bug in OrthoEngine, and is particularly annoying when trying to work with dual screens. You can restore the movement flexibility of the viewers by saving your project, closing OrthoEngine, going to *C:\{Installation folder}\PCI Geomatics\Geomatica_V102\user* folder and deleting *orthoeng.prf*. A new *orthoeng.prf* file will be created when you reopen your project, but this time the viewers will handle correctly.

OrthoEngine crashes with a message "Application terminated due to unknown exception".

Unfortunately this happens sometimes for no discernable reason. Save constantly and hope this is not a recurring bug within your specific project.

When I try to Compute model in the Residual errors box I get a message telling me that exterior orientation is needed.

Run the model by going to the Model Calculations processing step and clicking compute model. Your residual values should now be updated.

If I add extra files to the project they are not listed in the Rotate Image screen.

Another bug. Save, close and reopen and they will be there.