A digital elevation model (DEM) is a digital raster surface representing the elevations of a terrain for all spatial ground positions in the image. Traditionally most common DEMs used in geomatics industry will contain only elevation values of the true ground surface however they can also sometimes contain many of the other features located upon the surface as well. When it contains more features then actual ground data then it is often referred to as a digital terrain model (DTM) or a digital surface model (DSM). Digital terrain / surface models contain elevation values representing the actual ground surface as well as other objects such as buildings and trees.

With PCI OrthoEngine, DEMs can be extracted from a stereo pair of images, which are adjacent images of the same area taken from different view points. This method can be very useful for creating a DEM for inaccessible areas or for creating a 3D surface to integrate into your orthorectified mosaics of the same area providing an even more enhanced product. This tutorial demonstrates how to use two standard aerial photographs with camera calibration information to interpolate a digital surface model from for the overlapping region of the imagery.
Step1 (Create a new Project)

- Create a new project with an Aerial Photography Math Model using the Standard aerial option for the Camera type and Compute from GCPs and tie points to calculate the exterior orientation. (Optional) You can use User Input to import the exterior orientation that was calculated in a previous project or by other triangulation software.

- In the Set Projection window select the output projection, enter the desired pixel size and the GCP projection for the source information and click the OK button.

- The Standard Aerial Camera Calibration Information window should open automatically after completing the Set Projection window, if it does not then open the window with the Set camera calibration button found in the Project processing step.

- Enter the focal length of the camera in millimeters.

- (Optional) If you have a table of distortion pairs from your Camera Calibration document then you can use it to enter the Radial Lens Distortion, however most projects can work fine without this information.

- Under Decentering Distortion, type the coefficients or click No Distortion if the coefficients are not available.

- In the Fiducial Marks portion of the window:
  - Click one of the Position options where the fiducial marks will be collected (Edge, corner, or both).
  - In the X and Y boxes, type the x and y coordinates of the fiducial marks in millimeters.
  - If you do not have calibrated fiducial coordinates, click the Compute From Length button and use a ruler to measure distance between the fiducial marks on the paper copy of the image.
• Enter the nominal scale in the Image scale box and then click the OK button to continue.

Step2 (Open Photos)

• Add the first photo to your project and then open it up to begin processing.

• Zoom into the top left fiducial mark of the photo and click the center of it to define the position of it, click the Set button of the corresponding point in the Fiducial Mark Collection window. Then continue collecting the remainder points on the image and clicking the OK button when completed.
Step 3 (Collect GCPs and TPs)

- Open the Collect GCPs manually panel and collect at least 4 good GCPs from a known Ground Control source (vectors, geocoded image, GPS etc).
- Go to the Model Calculations processing step to compute the model or ensure that Compute Model option in the GCP collection panel has been selected to automatically compute the bundle adjustment. (Once you have at least 4 good GCPs and when your RMS error is acceptable then repeat the steps above with the second image.
- After you have collected GCPs for both images, and you have obtained a relatively low RMS then collect Tie Points for the overlap region between the two images to help refine the model.

Step 4 (Create Epipolar images)

- Click the Create Epipolar Image button found from the DEM From Stereo processing step to open the Generate Epipolar Images panel.
- Under Left Image section of the window click on your left image, the right image should then appear in the list of available images for the right hand side. Click the right hand image and then click Add Epipolar Pairs To Table button to record the pair into the List of Epipolar Pairs list.
- Click the Generate Pairs button to start the process.

Step 5 (Extract DEM)

- From the DEM From Stereo Processing step list, select the Extract DEM automatically button.
- Click in the Select column under Stereo pairs to select epipolar pairs that you just generated
- In the Minimum elevation and Maximum elevation boxes, type the estimated elevation for the terrain in the stereo pair. (The minimum and maximum elevations are used to estimate the search area for the correlation. This increases the speed of the correlation and reduces errors. If the resulting DEM contains failed values on peaks or valleys, increase the range).
- In the Background value box, type the value used to represent the "No Data" pixels in the DEM (The "No Data" or background identifies the pixels that lie outside the extracted DEM overlap area so they are not mistaken for elevation values).
In the DEM Detail list, click the level of detail that you want in the extracted DEM (DEM Detail determines how precisely you want to represent the terrain in the DEM. Selecting High, Medium or Low determines at which point in correlation process you want to stop. Low means that the process stops during the coarse correlation phase on aggregated pixels so the level of detail in the DEM will be quite low. High means the process continues until correlation is performed on images at full resolution).

In the Output DEM channel type list, select 32 bit.

In the Pixel sampling interval list, click the number of image pixels and lines (sampling frequency) that will be used to extract one DEM pixel (Pixel Sampling controls the size of the pixel in the final DEM relative to the input images. The higher the number you choose, the larger the DEM pixel will be, and the faster the DEM is processed).

Under Geocoded DEM, select Create Geocoded DEM to geocode and merge the epipolar DEMs together. However, if you want to edit the DEM before it is geocoded do NOT select Create Geocoded DEM, and click the Extract DEM button.

If you choose to geocode your DEM then in the Output filename box, type the path and an output file name for the geocoded DEM file (.pix) and click the Extract DEM button.
Step 6 (Edit DEM)

Digital elevation models extracted from images often contain pixels (and sometimes large areas) with failed or incorrect values. PCI Geomatica gives you the ability to edit the DEM in order to smooth out these irregularities and create a more pleasing continuous raster surface. The image below to the left is the result of the DEM extraction process explained above from two adjacent standard stereo photos. The image on the right is the result after using the editing tools to interpolate the failed values (the jagged edges also contain data that is not relevant to the surface and can be clipped out of the image to avoid confusion with the clipping subset tool).

- From the Processing step list, select DEM From Stereo, click the Manually edit generated DEM button (this will open Focus and initiate the DEM editing tools).
- From the DEM Editing dialog box, choose your DEM that you just created by clicking Browse and open the file with the File Selector.
- Choose the layer that contains the DEM from the Layer list box.
- Type the value assigned to pixels that have no elevation values because the image correlation failed in the Failed box and the value assigned to the area that lies outside the DEM in the Background box.
- Enable Save option and choose a file from the File list box. Type a name for the new layer or select an existing layer from the Layer list box.
- Enable the Load results to input check box.
- Under the Mask operations portion of the window, click the New Mask Layer button.
- Click the Mask failed areas button to generate a bitmap mask representing all parts of your DEM that are equal to your failed area.
- If your failed areas are relatively small and spread out across the image then using then interpolating the failed cells based on surrounding ones will often be enough to create an continuous surface.
Under the Filtering and Interpolation part of the window select your method of interpolation, select the Use Mask radio button and then click the Apply button.

Above is a screen capture of the raster surface before interpolation with a red bitmap mask representing failed areas. Below is the same area of the raster surface after it was interpolated.
Step 7 (Examine Results)

- Examine the resultant output in the Focus window and then continue editing if necessary.

Bad results in your surface can often be related to several factors including, the data, the stereo coverage, the accuracy of the model generated from your control etc. If there are larger more complex failed areas in the surface that could not be easily corrected with the editing tools then you may want to return to OrthoEngine and try generating the Epipolar images again or extracting the DEM but using different parameters (such as increasing the down scale factor or using a score channel). For more information see Applying Tool Strategies for Common Situations in Digital Elevation Models in the PCI Geomatica help files.

The failed areas from the DEM extracted in this example were interpolated with no problems and only required one attempt to create a continuous surface. The image below is a screen capture from Focus demonstrating the spatial fit of the interpolated surface with both the orthophotographs created from the original stereo images and the vector control sources that were used to correct the imagery.