Automatic DEM Extraction Module: Description

The Automatic DEM Extraction module is an add-on module to CATALYST Professional Essentials.

The Automatic DEM Extraction module allows you to create Digital Elevation Models (DEMs) from stereo airphotos, stereo images and RADAR data. Image correlation is used to extract matching pixels in two overlapping images and then use the sensor geometry from a computed math model to calculate x, y, and z positions. Automatic DEM extraction allows you to batch epipolar generation, batch the DEM extraction process, geocode DEMs, and create absolute or relative DEMs.

CATALYST is a PCI Geomatics Enterprises Inc. brand, which has been introduced to put our leading-edge technology into the hands of decision makers. CATALYST provides proven algorithms rooted in photogrammetry and remote sensing to offer engineers, environmental management, and geospatial professionals access to leading edge and scalable software solutions and platforms.

Table of Contents

Module Prerequisites

OrthoEngine Automatic DEM Extraction is an add-on module for the CATALYST Professional Essentials bundle and comes included with any of the following bundles: Satellite bundle, Airphoto bundle, SAR bundle, Complete bundle, Developer bundle.

Supported Sensors

The Automatic DEM Extraction module supports the following aerial, satellite, and RADAR sensor types.

Aerial Sensors
- All digital and video frame images
- All scanned, standard air photos

Satellite Sensors

In general terms, DEM extraction should work for any satellite sensor that produces stereo data. The following list shows known sensors that have been tested:

Optical Sensors
- ALOS PRISM
- ASTER
- Cartosat-1
- DEIMOS-2
- EROS
- Gaofen-7
- GeoEye-1
- Gokturk-1
- IKONOS
- IRS
- Kazeosat-1
- KOMPSAT-2
- KOMPSAT-3
- Landsat-8
- PeruSat-1
- Pleiades
- QuickBird
- SPOT 1-7
- SuperView-1
- WorldView 1, 2, 3, 4
- ZY-3
- ZY3-2

Radar Sensors
- ASAR
- COSMO SkyMed
- KOMPSAT-5
- RADARSAT 1 / 2
- RISAT-1

DEM Extraction Methods

Users can choose from one of two methods for extracting their digital elevation model (DEM).

- Normalized cross-correlation (NCC)
- Semi-global matching (SGM)

NCC

Matching points in a left and right input image are found using image correlation. The image disparity for the point pair is computed and this value, combined with the geometric model for each image, is used to compute the scene elevation for the corresponding scene point.

The image correlation is performed on an image pyramid that is constructed for each of the input images. The base level of an image pyramid is the original image, the next highest level is the original image resampled to a coarser spatial resolution, the level after that is the previous level resampled to a coarser spatial resolution, and so on. The location in one image that matches the current point in the other is first found at the coarsest resolution level for both images. This location is then used as the starting point for finding the match at the second coarsest resolution, and so on until the match is found in the original images.

This multi-resolution approach to image matching is faster than searching for matches in only the full-resolution images, and results in fewer false matches.

SGM

The implementation of SGM is done by image-matching along epipolar lines using the SGM method first proposed by Hirschmuller in 2005. The SGM algorithm produces excellent detail and few blunders, or *errors*, even at full resolution. However, the basic algorithm does have some drawbacks, such as higher computation time, very high memory consumption, and sensitivity to variations in local lighting conditions. With each implementation of the SGM algorithm, various approaches have been taken to work around these difficulties with varying degrees of success.

Our implementation of the SGM algorithm was developed in-house. It is proprietary and full details are not available. Our implementation uses a tiled approach based on pyramid resolutions with multiple cost functions (including mutual information) to achieve stability over varying local lighting conditions while retaining the highest possible detail. The algorithm self-adjusts to compensate for small errors in the epipolar line. Innovative memory-management techniques limit RAM usage to 2 GB or less, even if the disparity in the images is thousands of pixels (which can occur in some satellite scenes of mountain ranges).

Epipolar Pairs

Epipolar pairs increase the correlation process speed and reduce the possibility of incorrect matches. Stereo pairs are reprojected, ensuring that the left and right images have a common orientation, and matching features between the images appear along a common x-axis.

Using epipolar pairs, you can:
- Choose from the following pairs:
  - User Select – selects a pair manually
  - Maximum Overlapping Pairs – selects the pair with the highest amount of overlap
  - Minimum Percentage Overlap – specifies the lowest percentage of acceptable overlap
  - All Overlapping Pairs – selects all pairs that overlap above a minimum percentage
- Limit the amount of memory used to generate epipolar pairs
- Define a Down-sample factor to reduce an epipolar image resolution
- Define a Down-sample filter
- Set up epipolar-pair start times

DEM Extraction

Using DEM extraction, you can:
- Specify the minimum and maximum elevation to estimate a search-area correlation
- Specify a failure value to represent any failed (uncorrelated) pixel values in the resulting DEM
- Specify a background value to represent any 'no-data' pixel values
- Set the DEM detail to high, medium, or low for the needed level of detail
- Select an output DEM channel type to 16-bit signed or 32-bit real
- Specify a pixel sampling interval for the number of image pixels and lines used to extract one DEM pixel
- Use a clip region to process a specific area only
- Fill holes and filter interpolated failed values and filter elevation values automatically
- Create a score channel to represent the correlation score for each DEM pixel
- Delete an epipolar pair after use
- Create a Geocoded DEM by using geocoding stored in the project
- Set up DEM extraction start times

DEM Editing

The DEMs may contain pixels with failed or incorrect values. You can edit a DEM to smooth out irregularities and create a more accurate model, and in turn, generate more accurate orthorectified images. For example, areas such as lakes often contain misleading elevation values; setting those areas to a constant value improves the model that will produce a more accurate representation of the lake in the ortho image.

Using the Focus DEM Editing window requires only a DEM; that is, a raster channel in a writable format. To fully use all the functionality available in the DEM Editing window, however, and to produce the best possible DEM, the DEM file should contain additional information. In particular, if the DEM file was extracted from epipolar images, you can make use of that imagery to help with your editing.

DEM files created using our technology contain extra information that facilitates DEM editing, including a cutline vector segment and file-level metadata.

The main toolbar on the DEM Editing window provides quick access to several functions that facilitate working with the DEM.

The following table describes the buttons on the DEM Editing toolbar:

Button	Label	Description
Display DEM	Display DEM	Toggles the display of the digital elevation model layer in the Focus viewer.

Button	Label	Description
	DEM Display Options	Allows you to set display options for the DEM layer. Choose from: • *Grayscale Shaded Relief:* displays the DEM using grayscale hill-shading, where a top-left light source and the elevation values are used to cast shadows. • *Color Shaded Relief:* displays the DEM using colored hill-shading, where a top-left light source and the elevation values are used to cast shadows. • *Dynamic Color Shade Relief:* displays the DEM using colored hill-shading, where a top-left light source and the elevation values are used to cast shadows. This option, the default setting, automatically re-renders the color display of the DEM as you pan or zoom across the viewer so that only the pixels currently being viewed are the basis of the colorization. Typically, editing is most effective when the DEM is displayed as a *Dynamic Color Shaded Relief*.
	Enhancements	Allows you to apply enhancements to the images automatically loaded in the Focus viewer. Available enhancements are: • None • Linear • Root • Adaptive • Equalize • Infrequency • Tail Trim (toggle) • Exclude Min/Max (toggle) • Set Trim % Select the Auto Re-enhance option so that, as you pan across the data, the view is automatically refreshed in the Focus viewer to apply the selected enhancement.
	View DEM Polygons	Toggles the visibility of existing DEM polygons. If a Status layer exists, this option also displays polygons from that layer.

5

Button	Label	Description
☑	Set View As Verified	Creates a status polygon using the full extents of the current display area and sets its status to *Verified*.
1:1	Define Preview Region	Allows you to specify a rectangular region to be displayed in a separate viewer. After you define the preview region, the Full Res. Ortho Preview window opens, displaying a preview of the full-resolution ortho image computed using the modified DEM.
	Open FLY!	Launches CATALYST Professional's FLY! application. FLY! uses the modified DEM and ortho imagery (when available) to allow interactive 3-D display. The FLY! view is centered on the current view, but is restricted to 4096 DEM pixels in x and y.
💾	Save	Saves the modified DEM and all other associated layers.
↩ ↪	Undo/Redo	Allows you to undo or redo previous actions.

Functions

With a license for the Automatic DEM Module, the following functions can be executed either independently or sequentially via an EASI™ or Python™ script. They may also be available in the Algorithm Librarian in CATALYST Professional's Focus and Modeler application.

- AUTODEM - Generates a digital elevation model from stereo images – OpenMP enabled
- DEMADJUST - Adjusts (raises/lowers) a raster DEM to elevation points held in a vector layer so that it better fits the elevation points.
- DEMMETA - Adds standard DEM-related metadata tags to an existing DEM raster.
- DSM2DTM – Convert a DSM to DTM
- DSMMERGE - Used to merge (multi-angle) geocoded DSMs that were typically produced by EPIPOLARDSM and geocoded using GEOCODEDEM. Imagery associated with the geocoded DSM can be simultaneously merged at the same time producing a rough ortho image co-registered with the DSM.

- ELEVRMS - Reads elevations from a digital elevation channel and compares the elevations with elevation values from a given GCP (ground control point) segment or from a vector segment
- ELGCPRMS - Generate elevation data RMS report - GCP
- ELVECRMS - Generate elevation data RMS report - vector
- EPIPOLAR - Generates epipolar images from stereo pairs or raw images – OpenMP enabled
- EPIPOLARDSM - Creates a raster digital surface model (DSM) from epipolar stereo pairs using the Semi-Global Matching (SGM) method.
- GEOCODEDEM - geocodes epipolar digital elevation models by reprojecting to the ground coordinate system – OpenMP enabled
- SGMMERGE - Merges a nadir-backward and nadir-forward epipolar DSM, created with the EPIPOLARDSM algorithm, into a single, final DSM, and then applies optional filtering.