

OrthoPro: The Z/I Imaging¹ Approach for the Orthophoto Production

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ABSTRACT

The latest product from Z/I Imaging, ImageStation OrthoPro, provides customers with unparalleled operations to construct, edit, rectify, mosaic, tone balance, and autododge multiple images into a single or multiple set of user-defined output products, including USGS Digital Orthophoto Quads (DOQ) and Quarter Quads (DOQQ). This information is controlled through an Access database.

OrthoPro provides several different workflows using various sources (digital images and DEM data) from one format and coordinate system to another. The OrthoPro product is built on top of the Intergraph GeoMedia CAD mapping package.

1. INTRODUCTION

A digital orthophoto is a geo-referenced image created from a perspective photograph, or other remotely sensed imagery in which the displacement within the image due to sensor orientation and terrain relief has been removed. Orthophotos combine the image characteristics of a photograph with the geometric qualities of a map. The orthorectified image can be used as a backdrop for a geographic information system (GIS) or for heads-up digitizing and map revision.

The digital orthophoto is created by scanning an aerial photograph (negative or diapositive) with a precision photo scanner. The scanned aerial photo or satellite imagery is then digitally rectified to an orthographic projection by processing each image pixel through photogrammetric space resection equations (Figure 1). This process requires, as input, either control point coordinates (given and/or adjusted) and corresponding image coordinates, or exterior orientation parameters, and a digital elevation model (DEM).

This paper describes the OrthoPro main features and its orthophoto production workflow. The OrthoPro product provides the necessary functionality to generate orthophotos from triangulated imagery (aerial and satellite). Elevation data can be a grid, TTN, USGS DEM, USGS SDTS DEM and DTED format or any combination of these. The DEMs are selected from a list and their footprints can be viewed graphically. OrthoPro has the ability to specify multiple DEM files for each photo or area. In addition, OrthoPro makes use of the full coordinate system support within GeoMedia. This allows sources to be in a different datum and projection from the output product. OrthoPro contains a number of features specifically targeted at the production of USGS DOQs and DOQQs such as a database of USGS quads and USGS output formatters.

2. GEOMEDIA

GeoMedia® is a complete Windows-based information integrator, serving as visualization and analysis tool and a platform for custom GIS solutions. GeoMedia allows users to quickly and simply “point-and-click” to investigate features such as parcels or roads. Users can build queries, add information to existing queries, and save queries. All queries may include features from many different GIS databases, such as MGE, Arc/Info, ArcView, AutoCAD, and MapInfo (Figure 2). GeoMedia requires no proprietary development language. It supports open application development using industry-dominant tools, such as Visual Basic and PowerBuilder.

¹ Z/I Imaging Corporation, a wholly owned subsidiary of Intergraph Corporation, and Z/I Imaging GmbH, a wholly owned subsidiary of Carl Zeiss, are now operating but completely independent. Upon approval of U.S. Department of Justice, Z/I Imaging GmbH. will become a wholly owned subsidiary of Z/I Imaging Corporation.

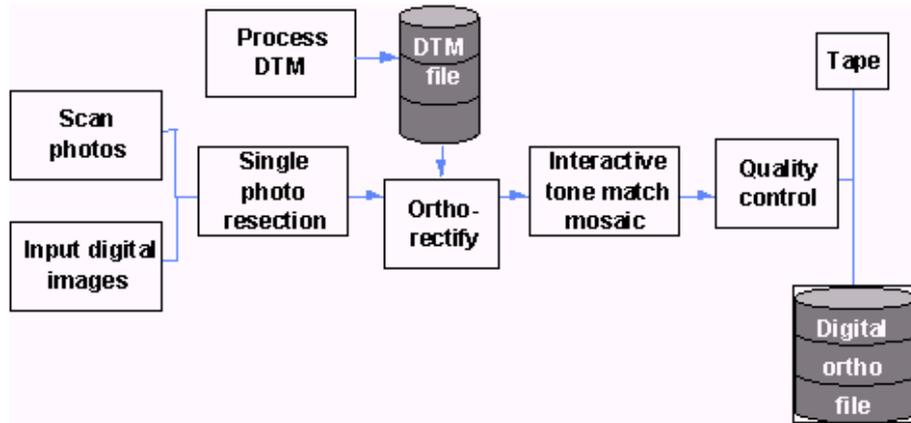


Figure 1: Orthophoto Rectification and Mosaicking Workflow.

GeoMedia supplies display, manipulation, and storage of footprint boundaries and mosaic line definitions for OrthoPro. It also provides basic image display and user interface operations. OrthoPro’s tonal balancing custom functionality is developed within the GeoMedia environment.

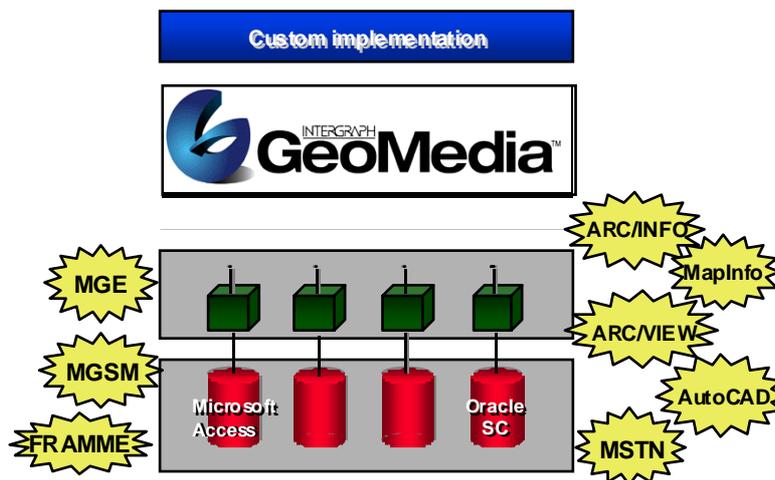


Figure 2: GeoMedia.

3. IMAGES TATION ORTHOPRO MAIN FEATURES

The ImageStation OrthoPro product offers the following major features (Intergraph, 99):

- Seamless integration in GeoMedia
- Ortho Planning – From within the GeoMedia environment the user can display a map, select an ImageStation Photogrammetric Manager (ISPM) project, display images and their footprints, select the output product either graphically or with key-ins, and display footprints of available elevation files.
- Rectification, Dodging, Mosaicking – After selecting mosaic boundaries graphically and defining blend types either by default or individually, the mosaicking/tonal balancing process runs in batch. During the process, the photos are tone balanced for optimal viewing and seamless mosaicking. Digital dodging is another option, which may be selected to improve the output image during the mosaic process.

- Seamline Definition – Within GeoMedia, draw arbitrary seam lines over the source images to define how the sources will be stitched together to form the output product
- Digital dodging for “hot spot” removal and compensation for vignetting and other non-uniform exposure problems.
- Global Tone Balancing – An automatic algorithm to match the radiometry of all of the images being used in the product.
- Image Clipping - The ability to specify a clipping area to eliminate fiducial and marginal information from the final output product.
- Quality Control tools – Basic measurements within GeoMedia to assess the quality of the products. The control points from the ISPM project may be automatically placed in the GeoMedia display for QC/QA.
- Multi-Threaded Orthorectification – A batch process that can take advantage of multiple processor machines allowing a multi-CPU processor to handle a large image load
- Outputs multiple products in one run.
- Can use disparate elevation sources with different coordinate systems - Grid, TTN, USGS DEM USGS DTED, and USGS SDTS DEM.
- Through GeoMedia, Automated Coordinate System Transformations occur between the source data in ISPM, elevation data, and the output orthoimage.

4. IMAGES TATION ORTHOPRO WORKFLOW

OrthoPro provides a more complete system in support of the orthophoto generation workflow. OrthoPro assumes that the user has performed an adjustment on all input images, and now wishes to generate a mosaicked, tonally correct orthophoto. The product combines functionality from existing Z/I Imaging products (Madani, 1999a). It uses ISPM for photogrammetry project setup, file management, and importing triangulation data from several third-party packages such as BINGO, BLUH, PATB, and PATM, and from a user-defined ASCII file format. It uses GeoMedia for product planning, mosaic line definition, basic image display, coordinate system transformation, the user interface to tonal correction, and graphical image selection.

An *ortho project* is an Access database file that contains all of the predefined feature and other data that are needed to create OrthoPro products. The ortho project also records all the operations, including all the parameters that are defined through the OrthoPro workflow, such as the project area coordinates, pixel size, rotation angle, ISPM project and its unorthorectified source images, product areas, orthorectification settings, seamlines, and so on.

Setting up an ortho project is the first task that is performed when using ImageStation OrthoPro.

Project setup consists of creating a GeoMedia GeoWorkspace, creating and opening a project, and setting display preferences (optional). A GeoMedia GeoWorkspace is a file that contains all of the OrthoPro-specific data. This file is created automatically and stores predefined features that OrthoPro will display in GeoMedia.

In this step, an output coordinate system for the orthos and the final product or products must be defined. However, it does not have to be the same coordinate system as the input data. OrthoPro converts all input coordinate systems automatically.

The output coordinate system may be defined by one of the following options: Current GeoMedia Workspace Coordinate System, Coordinate System of a Design File, and Define Explicitly. The Define Explicitly option can be used to change the coordinate system settings of the ortho project and to refine the output coordinate system. It is also possible to use a MicroStation design file to define an output coordinate system for the ortho project.

When the ortho project filename and output coordinate system are defined, the New Ortho Project command creates the ortho project file and an associated GeoMedia warehouse file to store the

feature data that will be displayed in the GeoMedia map view. When the ortho project has been created successfully, the OrthoPro control dialog box appears in the GeoMedia map view, and the GeoMedia legend is updated with the features of the ortho project. The predefined features in the Legend are assigned default colors and styles to easily differentiate the kinds of data that will be input or digitized in the GeoWorkspace later in the OrthoPro workflow (Figure 3).

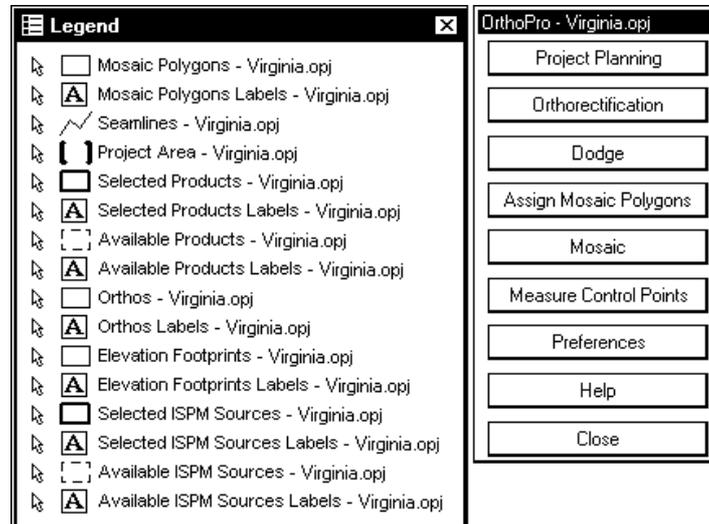


Figure 3: ImageStation OrthoPro Control Dialog Box.

4.1. Project Planning

After you have created and opened your new ortho project, you must follow the steps of the workflow below to define the specific input and output parameters of the OrthoPro product or products. The first step is to select the Project Planning command on the OrthoPro control dialog box.

This workflow allows some variation: you can define a project area before or after you select image sources, depending on the method you use, and you can select unorthorectified ISPM images, images that are already orthorectified, or both.

You define a project area by specifying area coordinates, by drawing the project area in a map view, or by creating a minimum bounding rectangle (MBR) around the footprints of selected images or around other features in a mapview (Figure 4).

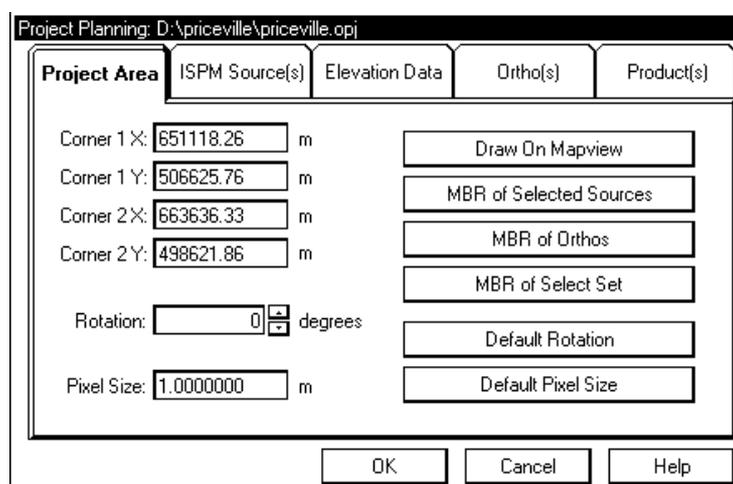


Figure 4: Project Planning Dialog Box.

If you know or can predict the coordinates of an area that will contain your products and source images, you can define the project area by coordinate key-in before (or after) you select the source images. Other project area placement options include place minimum bounding rectangles (MBRs) of source raw images or orthophotos, create project areas around image footprints, or other features.

4.1.1. Input Sources

Input sources can be either raw photos (with exterior orientation) in ISPM format or imported orthophotos. Selecting ISPM sources consists of selecting the ISPM project and then selecting images from the project. When you select the project, a list of available project images appears in the Available Sources. For an aerial photo project, only images that have completed interior and exterior orientations will be listed. The exterior orientation may be either given or computed. For multi-sensor projects, only images that have drive rational functions will be listed (Figure 5).

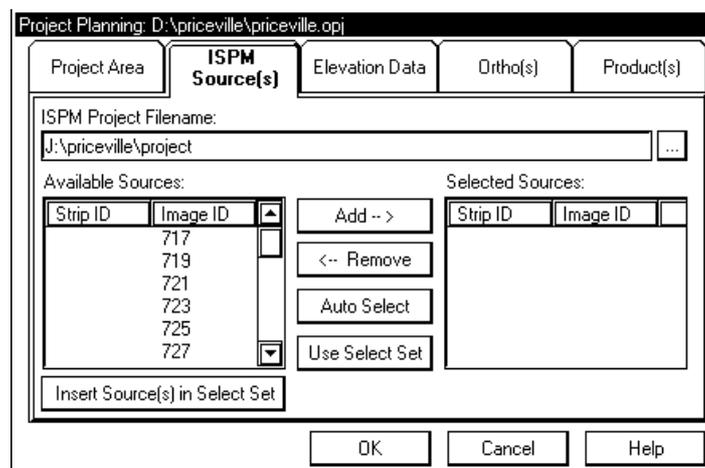


Figure 5: OrthPro Input Data Options.

There are three methods of selecting source images from an ISPM project: list selection, footprint selection, and automatic selection. To obtain a general idea of how your mosaicked product or products will appear, you can also display selected ISPM source images, not just their footprints, in the map view. Do so by adding the footprints of one or more Selected ISPM Sources or Available ISPM Sources to the GeoMedia select set and then selecting Insert Source(s) in Select Set on the ISPM Source(s) tab.

4.1.2. Selecting Elevation Data

If you are using ISPM sources, you may specify elevation data in the Elevation Data tab of the Project Planning dialog box. Valid elevation data files are Intergraph grid (.GRD), Intergraph triangulated (.TTN), USGS digital elevation model (DEM) files, and NIMA digital terrain elevation data (DTED) files. OrthoPro supports 7.5- x 7.5-minute (SDTS format), 1- x 1-degree (DEM data record format) , and any valid USGS DEM file in either of these formats. Also supported are standard DTED Level 0, Level 1, and Level 2 files. Any number of elevation data files may be used. For .GRD and .TTN files, the coordinate system must be indicated by either defining one or specifying the design file from which the files were created.

You can select one or more elevation files to provide the best coverage of the source images that you want to orthorectify. Two factors affect the quality of the resulting digital orthophotos: the completeness and the density of the elevation coverage.

Elevation coverage is complete when the region captured by aerial or satellite imagery is entirely included in an area represented by one or more elevation data files. In areas without coverage, OrthoPro Rectify lets you specify that the average elevation value be used for processing or that pixels of a specific intensity value be used to fill these areas in the orthophoto. Complete coverage is not absolutely necessary but provides more accurate results.

Orthophotos that are more accurate are obtained when DEMs with closer data spacing are used. The orthophotos will be more accurate if OrthoPro Rectify processes the denser DEMs first. The Move Up and Move Down controls in the Data Elevation tab of the Project Planning dialog box are used to prioritize the list of data elevation files.

You can specify orthorectified images, such as a digital orthophoto quadrangle (DOQ), an image orthorectified in OrthoPro but in a different project, an ISPM image that has previously been orthorectified, or an image that has been orthorectified by other means, to be the images used to mosaic product(s). You can select a single orthorectified file or all ortho files in a specified directory.

4.2. Orthorectification

Orthorectification is an automatic process. The operator simply selects the photos to be rectified from the list of input sources, edits rectification parameters, and then pushes the "Rectify" button. The user can choose output pixel size in ground units or by defining the number of rows and columns in the output image. The user can also define the type of resampling method, the pixel spacing for the anchor points, different tile sizes, the number of overviews and how they are processed, and the coordinates and rotation of the output image (Madani, 1999b). As photos are rectified, they are displayed in their georeferenced location within GeoMedia. If the user's input sources are already orthorectified, this step is unnecessary.

OrthoPro provides OrthoPro Rectify as an external environment to process images as a separate process. This makes it possible to orthorectify a large number of images as a batch process and to perform other tasks in GeoMedia while orthorectification is taking place. During orthorectification, the ortho project remains locked, and no other OrthoPro commands can be used until the orthorectification is complete. However, you can close the ortho project, without affecting orthorectification still in progress, to perform other GeoMedia tasks or even to work on another ortho project.

You can also exit GeoMedia while orthorectification is in progress to free system resources and thereby improve the performance of OrthoPro Rectify. When the process is finished, you can restart OrthoPro, reopen the project, and continue your workflow.

4.2.1. Reviewing And Editing Ortho Properties

You will typically need to define orthorectification parameters, such as the interpolation method, (Nearest Neighbor, Bilinear, Cubical Convolution), transformation type (Given, Computed), output pixel size, pixel spacing for anchor points, image clipping, different tile size, type and the number of overviews, and output file format to be used (TIFF, INGR, USGS). You can define these parameters for individual input images or for a group of images using the OrthoPro properties dialog box (Figure 6).

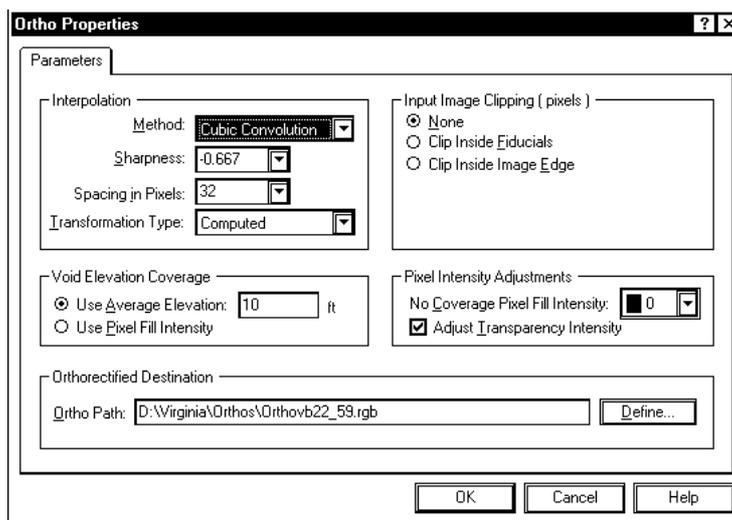


Figure 6: Ortho Properties Dialog Box.

You may assign different values to those areas of an orthorectified image that lie outside the elevation data coverage depending upon which option is selected (Average Elevation, Pixel Fill Intensity, and Adjust Transparency Intensity).

The Adjust Transparency Intensity option adjusts resampled pixels that are equal to the No Coverage Pixel Fill Intensity value so that this value can be used as a transparency value. Without the adjustment, setting the pixel fill to be transparent for overlaying another image or viewing against a background color would also cause pixels inside the image itself to be transparent. If the no-coverage value is in the range 0-127, a coverage pixel that is equal to this value will be incremented by one. If the no-coverage value is 128-255, a coverage pixel that is equal to this value will be decremented by one.

4.2.2. Checking Orthorectification Results

When the Status column in the OrthoPro Rectify project window indicates that an entry is "Complete," it means that a digital orthophoto has been created from an ISPM source image.

If OrthoPro is running and the ortho project is open, each orthophoto and its footprint and label features are automatically inserted in the map view as it is completed (unless you have used the Preferences command to disable this action).

4.3. Dodging

Image dodging is also an automatic process. The user interface is practically identical to the Orthorectify step. The operator simply selects the photos to dodge, chooses some optional parameters, and selects the "Dodging" button. As photos are dodged, they will be displayed in their georeferenced location within GeoMedia.

4.3.1. How Does Dodging Work

The tiles of an image are divided into smaller squares (subtiles). The greater the number of subtiles in an image, the better the dodging results that are obtained. Therefore, OrthoPro Dodge automatically calculates the optimum (smallest) subtile dimension to be used based on the size of the input file and available memory. An average pixel value is then calculated for each subtile from

all the pixel values in the subtile or from only those that fall within a range that you have specified. The result is an array of average pixel values per subtile.

The average pixel value of each subtile has to be manipulated to create a correction lookup table (LUT) that is applied to the pixels in the subtile. However, since correction LUTs are applied on a subtile-by-subtile basis, there is the risk of generating a visible edge along subtile boundaries where one row of pixels has received one correction factor and the next row a different one. Therefore, a *low-pass filter* smoothing algorithm is next used to process the subtiles before the correction LUTs are calculated. In this way, a more gradual transition of correction values across an image is obtained. The filter is a convolution algorithm, in which subtiles are first grouped into *neighborhoods*, also known as *kernels*, of a size that you can specify. A new value for the center subtile is calculated from its original value and those of the subtiles that surround it.

4.4. Seamline Definition

The purpose of drawing seamlines is to define the lines at which overlapping digital orthophotos will be joined to form a mosaic. Seamlines also divide the project area into mosaic polygons that define which parts of the associated orthophotos will be used as the pieces of the mosaic. Now that the rectified images and output area rectangles are displayed, the user may begin to partition the output area into a set of non-overlapping contiguous polygons. Each polygon will be added by digitizing over the rectified/dodged images. While generating seamlines, all of the GeoMedia features editing commands are at the user's disposal, including SmartSketch™ technology. Seamlines may also be generated using other vector sources such as MicroStation design file. The operator's objective is to develop a topological map of the orthophotos. The seamlines can be as simple as straight lines in the overlap area, or digitized vectors around image identifiable features (Figure 7).

4.5. Assign Mosaic Polygons

The purpose of creating and assigning mosaic polygons to orthorectified images is to define which areas of which of these images will be used to create the final mosaic. Once the seamlines are defined, a semi-automatic process generates polygons from the seamlines and the project boundary.

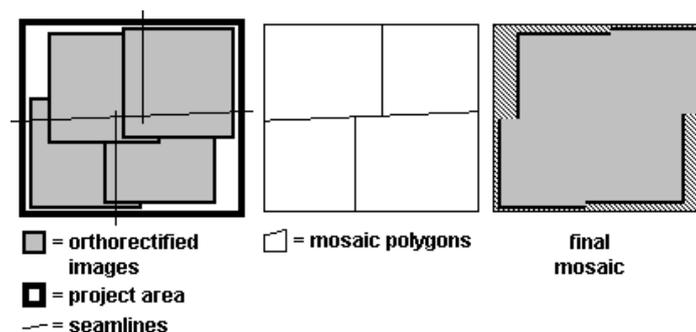


Figure 7: Project Boundary and Seamlines.

Each polygon is automatically assigned an image as its corresponding source. The user can change these assignments or select polygons to be treated as black holes (the more common choice).

Since the application is mosaicking multiple photos, problems arise with the traditional method of defining a line between two images. The input to the batch mosaicking process must be a topology of closed polygons. Each line segment (edge) that makes up a polygon is connected with an input image on either side of the edge.

To accomplish this, the application must allow the user to define polygons graphically, while viewing the individual rectified images that are to be mosaicked together. Each edge defined by the user must be assigned “Left” and “Right” images, and a blend type, either automatically, through defaults, or explicitly. The application will allow any number and shapes of closed polygons, and handle polygons contained within polygons (holes).

4.6. Mosaic Images

The Mosaic step is yet another automated step. OrthoPro provides OrthoPro Mosaic as an external environment to process images as a separate process. This makes it possible to mosaic products as a batch process and to perform other tasks in GeoMedia (or even exit GeoMedia) while products are being generated. The user may select which output products to generate, and what format to generate them in. OrthoPro performs the tonal balancing, mosaicking and product cutting in one process.

4.6.1. How Does Tonal Balancing Work?

Before starting or scheduling a job, you can select a tone matching option for the selected products. Tone matching is a tone balancing process that modifies the brightness and contrast of mosaicked images to give the finished mosaic a consistent tone. OrthoPro offers three options: *none*, *all*, and *multi-source* products. A multi-source product is one that is actually mosaicked from different images, whereas a *single-source* product is one that is created entirely from a single image (Figure 8).

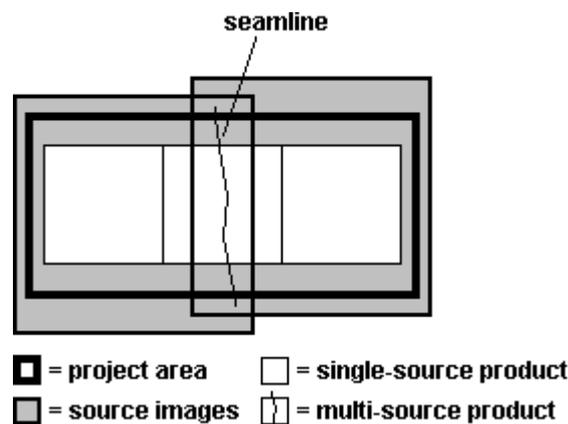


Figure 8: Single-source and Multi-source Ortho Products.

Creating a consistent tone in a single-source product is often unnecessary and adds to processing time. However, specifying tone balancing for all selected products will achieve a more consistent tone across all the products.

Tone balancing works by comparing image values in the overlap regions. Samples of gray values are taken along the seamlines for each overlapping pair of images that are to be mosaicked together. Lookup tables are computed and applied to each image such that the difference between common pixels in the overlapping images are minimized. This provides for a uniform appearance of contrast and brightness across the mosaic. The lookup-table operations applied during tone balancing are global to an ortho image. Localized adjustments to the ortho images, such as correction for uneven exposure and vignetting are applied during dodging. Although dodging is an optional step, it is frequently necessary in order to obtain even radiometry across a mosaic of several ortho images.

When the command creates mosaic polygons, it also automatically assigns each polygon to the orthorectified image that overlaps it. If more than one image overlaps a polygon, it is assigned to the image whose center is nearest to its own center. (If no image overlaps it, it is still assigned to the nearest image in the same manner, although no imagery will fill the polygon in the final mosaic). By assigning a polygon to an image, the command identifies the part of the image that will be mosaicked to create the final product or products.

4.6.2. Reviewing And Editing Product Properties

You will typically need to define parameters, such as mosaic attributes and the output file format to be used, for the products that you create with OrthoPro Mosaic. You can define parameters for individual products or for a group of products (Figure 9).

Some of the mosaicking options are listed below:

- **Feathering Distance** - Specify the number of pixels of image on each side of a seamline that will be involved in feathering, or a type of tonal blending, to make the seamline invisible in the final product. This setting applies only to seamline features whose blending attribute was set to "Yes" when the features were drawn.
- **Ground Resolution** - Specify the distance on the ground to be represented by each pixel in the output product.

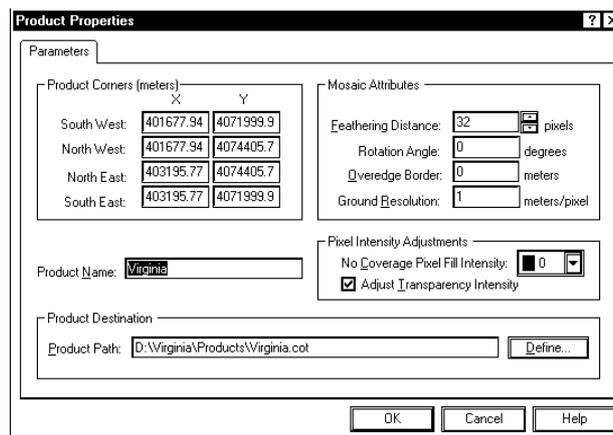


Figure 9: OrthoPro Mosaic Parameters.

- **Overedge Border** - Specify the number of meters of additional output image to extend beyond the border of the product. Overedge imagery facilitates tonal matching and mosaicking of adjacent images.
- **Selecting Tone Matching Option** - Tone matching is a tone balancing process that modifies the brightness and contrast of mosaicked images to give the finished mosaic a consistent tone. OrthoPro provides three options for tone matching: *none* of the selected products, *all* of the selected products, and *multi-source* products. A multi-source product is one that is actually mosaicked from different images, whereas a *single-source* product is one that is created entirely from a single image. Creating a consistent tone in a single-source product is often unnecessary and adds to processing time. However, specifying tone balancing for all selected products will achieve a more consistent tone across all the products.

- **No Coverage Pixel Fill Intensity** - Enter a pixel intensity value that will be used by the Use Pixel Fill Intensity Value option to fill pixels in a product where there is no input data. Select a value from 0 to 255.
- **Adjust Transparency Intensity** - Select this option to adjust pixels that are equal to the No Coverage Pixel Fill Intensity value so that this value can be used as a transparency value. Without the adjustment, setting the pixel fill to be transparent for overlaying another image or viewing against a background color would also cause pixels inside the image itself to be transparent. If the no-coverage value is in the range 0-127, a coverage pixel that is equal to this value will be incremented by one. If the no-coverage value is 128-255, a coverage pixel that is equal to this value will be decremented by one. A check indicates that the option has been selected.
- **Defining Image Output Properties** - Use the options to define image output parameters for the products you create with OrthoPro Mosaic (Figure 10).

4.7. Measuring Control Points

The Measure Control Points command adds a quality assurance component to the OrthoPro workflow by measuring control points and recording error statistics for the final products. Using control point coordinates from an ISPM project, the command superimposes control point markers on the specified product or products at their predicted locations in units of the output coordinate system. Selecting a control point from a list centers its marker in the map view.

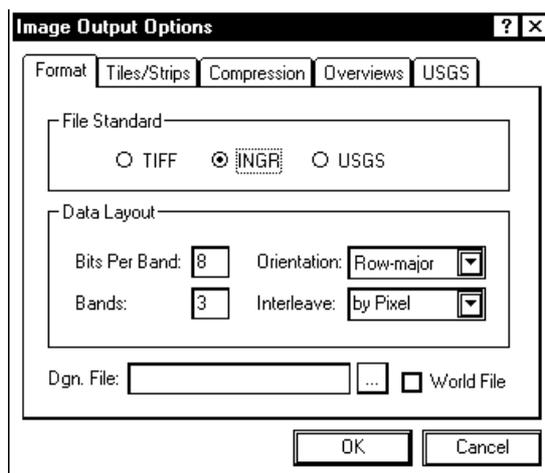


Figure 10: OrthoPro Output Options.

When a control point in the OrthoPro product is measured, any offset from the predicted point is recorded, and error statistics, always expressed in linear (X, Y) units or geographic (Lat, Lon) units, are computed. As all or a subset of the available control points are measured, the overall average absolute error figure and the RMSE figure are continually updated. The RMSE figure can be written to the headers of USGS-format products. It is also possible to generate a report of error statistics. This report includes all pertinent information, including the ISPM control point data, the control points included in the measured products, the X and Y errors and the magnitude of error for each measured point, and the RMSE figure.

5. REFERENCES

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