MOSAICKING

Tutorial

Mosaicking Raster Geodata

with

TNTmips®

Before Getting Started

This booklet introduces procedures for creating raster image mosaics in TNTmips®. The Mosaic process provides two modes for assembling images: automatic positioning of georeferenced images, and manual positioning by placing tie points between pairs of overlapping images. The exercises in this booklet introduce the Mosaic interface and show you how to use the many tools for creating a nearly seamless mosaic, including integrated masking with processing areas, contrast and color matching, and varied overlap processing options.

Prerequisite Skills This booklet assumes that you have completed the exercises in the tutorial booklets *Displaying Geospatial Data* and *Navigating*. Those exercises introduce essential skills and basic techniques that are not covered again here. Please consult those booklets for any review you need.

Sample Data The exercises presented in this booklet use sample data that is distributed with the TNT products. If you do not have access to a TNT products CD, you can download the data from MicroImages' web site. In particular, this booklet uses sample files in the MOSAIC data collection.

More Documentation This booklet is intended only as an introduction to mosaicking raster objects. Details of the process can be found in a variety of tutorial booklets, color plates, and Quick Guides, which are all available from MicroImages' web site (go to http://www.microimages.com/search to quickly search all available materials, or you can narrow your search to include only tutorials or plates.

TNTmips and TNTlite® TNTmips comes in two versions: the professional version and the free TNTlite version. This booklet refers to both versions as "TNTmips." If you did not purchase the professional version (which requires a software license key), TNTmips operates in TNTlite mode, which limits object size and does not allow preparation of linked atlases.

The Mosaic process is not available in TNTview, TNTedit, or TNTatlas. All of the exercises can be completed in TNTlite using the sample geodata provided.

Randall B. Smith, Ph.D.,24 July 2006

It may be difficult to identify the important points in some illustrations without a color copy of this booklet. You can print or read this booklet in color from MicroImages' web site. The web site is also your source for the newest tutorial booklets on other topics. You can download an installation guide, sample data, and the latest version of TNTlite.

http://www.microimages.com

Welcome to Mosaicking Raster Geodata

The Mosaic process in TNTmips lets you combine raster images of varied types into a single mosaic image. You can mosaic grayscale rasters, RGB color raster sets, or color composites. The input components do not have to be of the same type; you can mosaic different types of grayscale rasters, RGB raster sets with color composites, or even color with grayscale rasters.

Image positions in the mosaic can be established in two ways. If all input images are georeferenced, use the Automatic positioning option to automatically place the images in the specified map projection. If some or all of the images lack georeferencing, use the Manual positioning mode to place tie points between pairs of overlapping images. Manual mode uses a bundle adjustment algorithm to compute a least-squares best fit for all tie points and any available ground control points.

A number of options allow you to fine-tune the appearance of the mosaic. You can define the geographic extents of the mosaic manually by drawing an extents box or match the extents to a reference object. If you want to exclude parts of the input images from the mosaic, such as the fiducial marks and marginal data blocks on scanned aerial photographs, there is no need to crop the images prior to entering the mosaic process. Simply define Processing Areas to automatically mask unwanted portions of each input object (or object set) as the mosaic is processed.

The Mosaic process allows you the option to apply contrast enhancement to each input raster in constructing the mosaic and to set up contrast matching of input objects. You can specify a reference for matching or match all objects to a model histogram. There are also a number of options for processing overlap areas to produce nearly imperceptible transitions between input images.

- ☑ launch the Mosaic process (Raster / Mosaic)
- ☑ press [Close] on the Tip of the Day window
- ☑ from the Layer Menu on the Mosaic window, choose Default Name / File and Object Name
- ☑ choose File / Exit
- ☑ reopen the Mosaic process

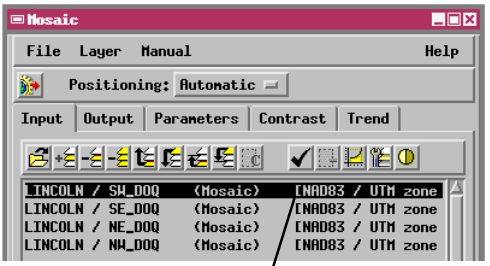
The exercises on pages 4-10 introduce the Mosaic process interface, and illustrate how to mosaic grayscale rasters, set the output cell size, and define the geographic extents of the mosaic. Pages 11-12 show you how to create processing areas to crop the input images. Some causes of spatial mismatch in mosaics are reviewed on Page 13. The exercises on pages 14-19 introduce use of contrast and contrast-matching for grayscale and color mosaics. Mosaic layouts, raster overlap operations, and trend removal are discussed on pages 20-23. The exercises on pages 24-27 cover mosaicking DEMs, gap-filling, compression, and handling of no-data areas. Pages 28-31 provide an overview of the manual mosaic mode.

Making Your First Mosaic

STEPS

- ☑ click the Add icon button on the Input tabbed panel 
- ☑ use the standard Select Objects window to navigate to the LINCOLN Project File in the MOSAIC data collection and select raster objects NW_DOQ, NE_DOQ, SE_DOQ, and SW_DOQ (in that order)
- ☑ click the Run icon button and use the File / Object Selection procedure to create a new Project File MOSAICS and a new raster object 

As an introduction to the Mosaic process, we mosaic four georeferenced images using the Automatic positioning option. The images are segments of adjacent (and overlapping) digital orthophoto quadrangles covering part of Lincoln, Nebraska. The georeference information for each raster is used automatically to determine its position in the mosaic. These relative positions are also automatically shown in the View window.



The input rasters are listed on the input panel of the Mosaic window. The last raster added is the default active raster; its listing is highlighted in black.

The View window automatically displays georeferenced input objects in their correct relative positions. Overlapping objects are stacked in the order in which you added them (last on top). The extents box and object label for the active raster are drawn in red.

The completed mosaic is automatically displayed in the Mosaic Result window.

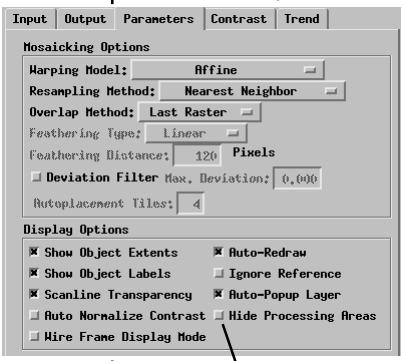
Explore Display Options

The manner in which input objects are displayed is controlled by the Display Options settings on the Parameters tabbed panel. The default settings (used in the first exercise) display each input raster with a colored box outlining the object extents (Show Object Extents) and a label with the name of the Project File and object (Show Object Labels). These and other display options can be turned off or on using the corresponding toggle buttons. Changes in these settings do not take effect until you redisplay the View window.

If your input rasters are very large, you may wish to turn on the Wire Frame Display Mode (with Object Extents and Object Labels also turned on). In Wire Frame mode, only the extents box and label are displayed, which speeds up redisplay while still allowing you to see the spatial relationships between the different input objects. If you are working with many input rasters, you may also wish to temporarily turn off the Auto-Redraw feature.

STEPS

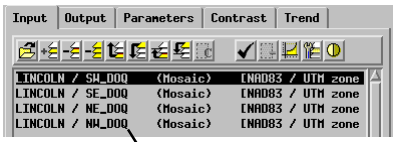
☑ click on the Parameters tab to expose the Parameters panel



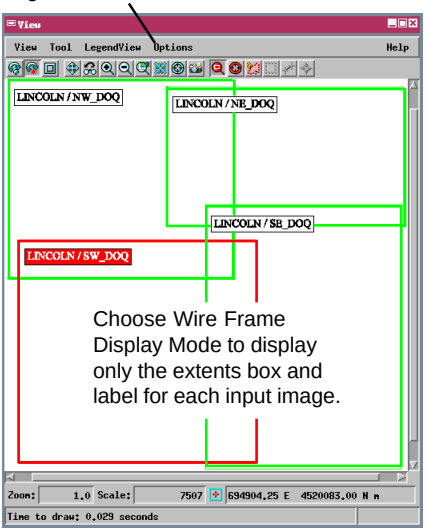
Default Display Options settings on the Parameters tabbed panel.

☑ turn off the Scanline Transparency toggle button on the Display Options panel

Choose Color from the Options menu to open the Color Editor window and adjust the background color of the View and Mosaic Results windows.



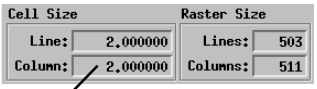
The Mosaic window input list uses the layer name option that is set from the Layer / Default Name menu: object description (the default), object name, or file and object name. The illustrations in this booklet show the file and object name (the selection you were instructed to make when you first opened the Mosaic process). A change in the Default Layer Name setting takes effect in the next Mosaic session.



Change Output Cell Size

STEPS

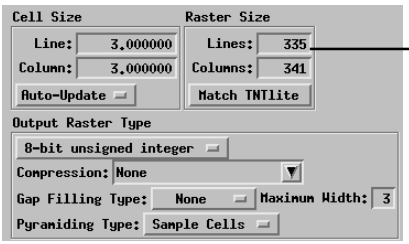
- ☑ expose the Output tabbed panel on the Mosaic window
- ☑ in the Cell Size controls change the Line and Column values to 3.0
- ☑ click the Run icon button and direct the output raster to the MOSAICS Project File



Default Cell Size and Raster Size settings used in the previous exercise.

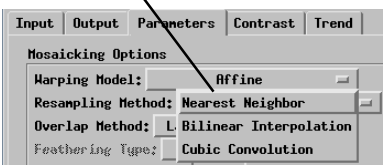
The raster cell size of the output mosaic is controlled by the values in the Line and Column text boxes on the Cell Size portion of the Output tabbed panel. The default values are provided by the input raster with the smallest cell size (and therefore the highest spatial resolution). The four Lincoln DOQ input rasters all have a line and column cell size of 2 meters, so the mosaic produced in the first exercise also has a 2-meter cell size.

If rasters in an input set have differing cell sizes, you can choose any one of them to control the cell size of the mosaic by selecting the raster from the list in the Auto-Update menu on the Cell Size portion of the Output tabbed panel. You can also enter an output cell size manually, as in this exercise.



The Raster Size values update automatically when the output cell size is changed. Increasing the mosaic cell size reduces the number of lines and columns in the output raster and reduces its spatial resolution.

The Resampling Method menu on the Parameters tabbed panel lets you determine how input cell values are sampled to create mosaic cell values. The available choices are Nearest Neighbor, Bilinear Interpolation, and Cubic Convolution. Consult the tutorial booklet Rectifying Images for an explanation of these resampling methods.



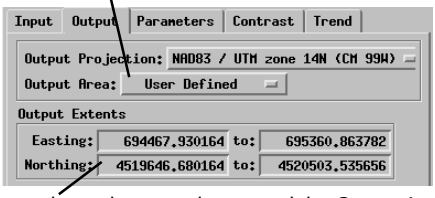
Output mosaic with reduced raster size and reduced spatial resolution.

You can close the Mosaic Result window at the end of each exercise (by choosing Close from the window's File menu) to reduce screen clutter as you move to the next exercise. Another Mosaic Result window opens automatically each time you generate a new mosaic.

Define Output Extents Manually

The Output Area option menu gives you several ways to control the geographic extents of the output mosaic image. The previous exercises used the default Total Extents option, wherein the mosaic assumes rectangular extents equal to the total geographic extents of the set of input objects. The User-Defined option matches the output raster extents to a rectangular box that you draw in the View window using the Output Area tool.

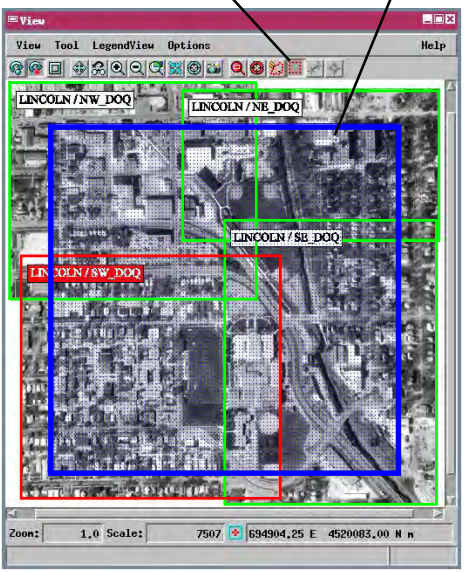
Select User-Defined from the Output Area option menu.



Once you have drawn and accepted the Output Area box, its extents are shown in the Output Extents text boxes.

Click on the Output Area icon button to draw an output extents box.

When you click the right mouse button to accept the extents box, the selected area is shaded.



STEPS

- ☑ in the Output tabbed panel reset the Line and Column Cell Size fields to 2.0
- ☑ select User-Defined from the Output Area option button
- ☑ click the Output Area icon button on the View window 
- ☑ place the mouse pointer near the upper left corner of the image area
- ☑ click and hold the left mouse button as you drag the mouse pointer toward the lower right corner of the image area to create an extents box, then release the mouse button
- ☑ drag an edge or corner of the box to resize it if necessary, keeping the box within the image area
- ☑ click the right mouse button to accept the output area
- ☑ run the Mosaic process 

Mosaicked image. The geographic extents and cell size together determine the size of the output image.

Match Extents to a Reference Object

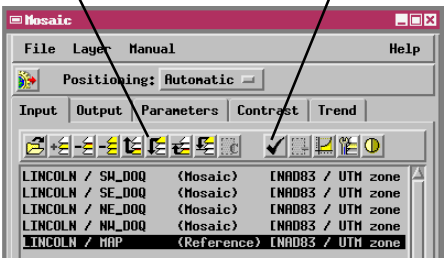
STEPS

- ☑ click the Add icon button on the Input tabbed panel
- ☑ select the MAP object from the LINCOLN Project File
- ☑ click the Reference icon button; the status of the MAP object changes from Mosaic to Reference
- ☑ click the To Bottom icon button above the input object list to move the highlighted MAP object to the bottom of the list
- ☑ on the Output tabbed panel, select Match First Layer from the Output Area option menu
- ☑ run the Mosaic process

You can also match the extents of the output mosaic to the first (lowest) object in the input list. Move any desired object to the bottom of the list, then choose the Match First Layer option from the Output Area menu on the Output tabbed panel. If you don't want this reference object to become part of the output image, press the Reference icon button to change its status from Mosaic (used to create the output image) to Reference.

Move an object to the bottom of the input list to use it to control the extents of the mosaic.

Use the Reference icon button to toggle object status between Mosaic and Reference.



Reference MAP object displayed on top of the input DOQ images before being moved to the bottom of the input object list.

Mosaicked image with extents matched to the MAP raster object.

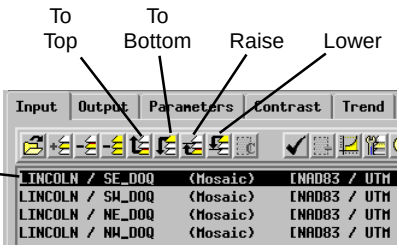
Change Input Object Order

The default method of handling overlapping images in the Mosaic process uses the topmost raster in each overlap area for the output image. (We will explore other options in a later exercise). In the Lincoln DOQ images, for example, the high school building lies in the overlap between rasters SW_DOQ and SE_DOQ. In the previous exercises the image of the high school in the output mosaic came from SW_DOQ, which overlies SE_DOQ. This overlap order was determined by the order in which you added the input rasters.

If you would prefer to have the darker image of the high school from SE_DOQ appear in the mosaic, you can use the icon buttons above the Input list to change the overlap order of the input images. You could either raise SE_DOQ or lower SW_DOQ.

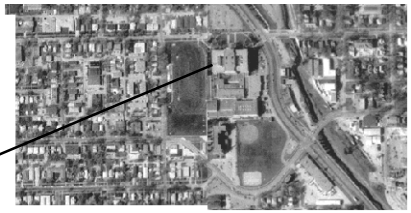
STEPS

- ☑ change the Output Area setting on the Output tabbed panel to Total Extents
- ☑ select the MAP object in the Input list and press the Remove icon button 
- ☑ select the SE_DOQ object in the input list and press the Raise icon button 
- ☑ run the Mosaic process 



Object SE_DOQ raised above SW_DOQ in the input list and displayed overlapping it in the View window.

With the Auto-Popup Layer display option turned on (on the Parameters panel), you can view any input raster in full, regardless of its position in the stacking order, by making it the active raster. Simply click on the Input list entry for the desired raster. The View window redraws with the new active raster temporarily on top of any overlapping images. (The order of images in the input list and in the output mosaic does not change.)



Lower part of the output mosaic incorporating the high school image from SE_DOQ.

☑ press the Remove All icon button on the Input panel when you have completed this exercise (choose No when asked if you want to save the layout) 

Choose the Output Projection

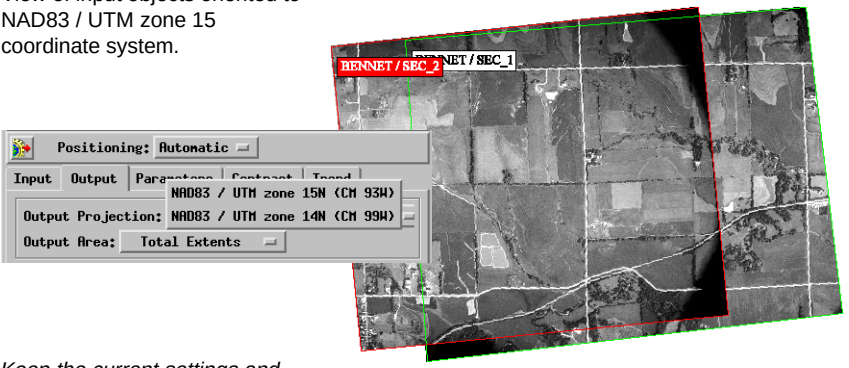
STEPS

- ☑ click the Add icon button on the Input panel 
- ☑ select objects SEC_1 and SEC_2 from the BENNET Project File
- ☑ on the Output tabbed panel, change the Output Projection menu to NAD83 / UTM zone 14N and note the change in orientation of the input objects in the View window

Objects SEC_1 and SEC_2 are extracted portions of scanned airphotos that have been georeferenced to the Universal Transverse Mercator (UTM) coordinate system but assigned to different UTM zones. SEC_1 is georeferenced to the UTM zone 15N and SEC_2 is georeferenced to a UTM zone 14N (both using North American Datum 1983). Neither photo is oriented to its projection (raster lines and columns are not parallel to coordinate system grid lines).

You can orient the mosaic to either of these input coordinate systems by making the appropriate selection on the Output Projection menu on the Output tabbed panel. All input object coordinate reference systems are automatically shown on this menu, with that of the first-added object selected by default. All input objects are automatically reprojected to the selected coordinate system (if necessary) in the mosaic raster. The View window automatically shows the input objects in the selected coordinate reference system as well, providing a preview of the orientation of the mosaic.

View of input objects oriented to NAD83 / UTM zone 15 coordinate system.



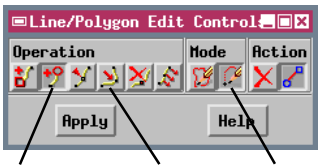
View of input objects oriented to NAD83 / UTM zone 14 coordinate system.

Keep the current settings and continue on to the next page.

Create a Processing Area for Masking

The scanned photos used in this exercise exhibit severe vignetting (darkening toward several corners). You probably wouldn't want these dark areas included in a mosaic. To eliminate them, you can define a processing area for each input raster (or RGB raster set) and set the Image Area option to Processing Area. Only the portion of the image inside the processing area is then included in the final mosaic image; unwanted parts of the image outside the processing area are ignored. (As you will see later, the Image Area menu is necessary because processing areas can serve several functions in the mosaic process.)

Clicking on the Processing Area icon button opens the Line / Polygon Edit Controls window. Use these edit controls to draw and edit an appropriate polygon to define the processing area. When you click the right mouse button (or press [Apply]) to accept the polygon, the processing area is outlined and shaded in color in the View window.



Add End Drag Vertex Stretch

The Line / Polygon Edit Controls are described in detail in *Getting Started: Editing Vector Geodata*.

STEPS

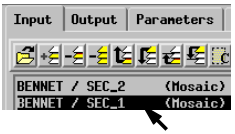
- ☑ choose Processing Area from the Image Area option button on the Input panel

- ☑ click the Processing Area icon button on the mosaic View window 
- ☑ change the Mode setting of the Line / Polygon Edit Controls window to Stretch
- ☑ use the Add End operation to add vertices to outline a Processing Area polygon for the SEC_2 photo as illustrated
- ☑ use the Drag Vertex operation to adjust the polygon shape as needed
- ☑ press the right mouse button to accept the polygon

Use the Line / Polygon Edit Controls to create a processing area for the SEC_2 photo.

Keep the current settings and continue on to the next page.

Create a Second Processing Area

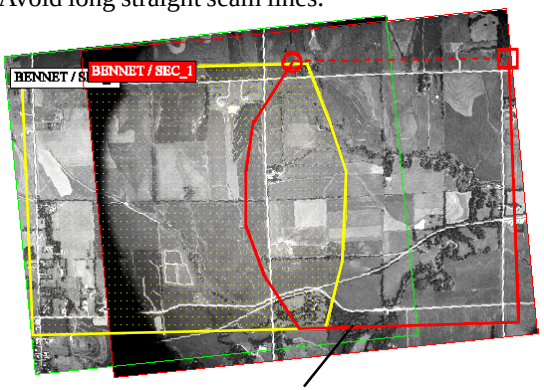


STEPS

- ☑ select the BENNET / SEC_1 object from the input list
- ☑ use the Line / Polygon Edit Controls to create a new processing area for the SEC_1 photo
- ☑ run the Mosaic process 

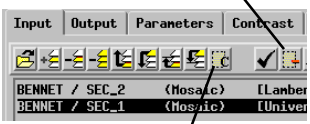
A processing area is specific to a particular input raster (or RGB raster set), so you can create a unique processing area for each input object, if needed. Before creating another processing area, select the appropriate object from the list on the Input panel; a processing area you draw is applied only to the currently selected object.

You can use processing areas to design custom cut lines between overlapping objects to make seams in the mosaic less obvious. If possible, draw the processing area boundary for the top object within areas of uniform tone or color, rather than following tonal boundaries in the image. Cross linear features such as roads or railroads at low angles (rather than a right angle) to minimize visual mismatch in position. Avoid long straight seam lines.



Create a new processing area for the SEC_1 photo (shown before accepting the selected area). The current area is shown in red, while any others are in yellow.

The Clear Area icon button deletes the processing area for the currently selected raster object.



The Clear All icon button deletes all current processing areas.

Mosaic of the designated portions of the two photos oriented to UTM zone 14N. Vignetted portions of the photos have been trimmed off.

Causes of Spatial Mismatch in Mosaics

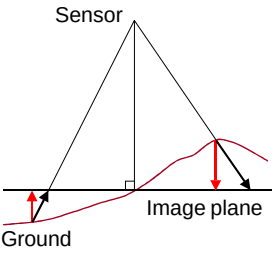
As you examined the mosaic created in the preceding exercise, you may have noticed some slight misalignment of roads and other features along the seam between the input images. This is probably a good point to stop and consider the potential causes of such problems.

When you mosaic scanned planimetric or topographic maps, all map features are presumed to be shown in their correct horizontal positions, as if each object were viewed from a unique vantage point directly overhead. If the maps have the same projection and coordinate system, we might expect features at the seam to match exactly. However, minor mismatches might occur because of georeferencing errors or cartographic errors in the original maps.

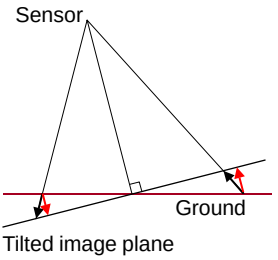
There are additional sources of image mismatch when you mosaic remotely-sensed images, because all objects in a particular image were viewed from a single vantage point and that view point varied from image to image. The perspective view of a single image can cause the apparent positions of ground features to be displaced from their correct horizontal positions. Relief displacement and tilt displacement (illustrated at right) are the main causes of this spatial distortion, which contributes to errors in georeferencing component images. These effects are most obvious in low-altitude images, such as air video and aerial photographs (including those used in the last exercise). An object pictured in adjacent photos may be displaced from its true position by different amounts and in different directions in each image. When the photos are mosaicked, the two images of the same ground object are not placed at the same location in the mosaic.

Common Distortions in Remotely Sensed Images
Ground positions project along sight lines (black arrows) to the image plane, producing several types of horizontal displacements. Red arrows show projection directions needed to maintain correct relative positions.

Relief Displacement: horizontal position shifts arising from the differing elevations of ground objects.



Tilt Displacement: horizontal object shifts resulting from a tilted image plane (sensor not pointed straight down).



To produce the best mosaic from georeferenced images showing tilt displacement, first use automatic raster resampling to reduce the tilt effects (see the tutorial booklet entitled *Rectifying Images*). Removing relief displacement requires full stereoscopic modeling of image pairs to produce an orthophoto (see the tutorial booklet *Making DEMs and Orthophotos* for more information).

Apply Contrast Tables

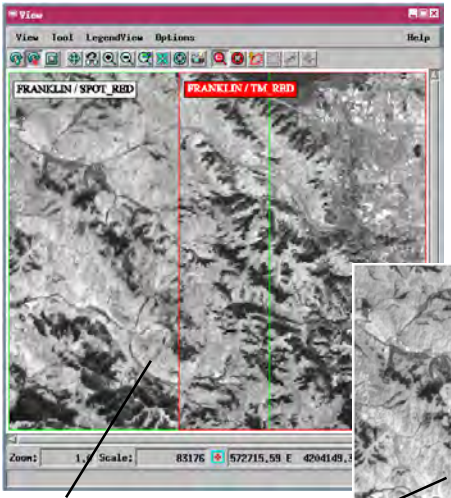
STEPS

- ☑ press the Remove All icon button on the Input panel and choose No when asked if you want to save the layout
- ☑ click the Add icon button and select objects SPOT_RED and TM_RED from the FRANKLIN Project File

- ☑ on the Contrast panel, make sure that the Apply Contrast Tables toggle button is turned on
- ☑ run the Mosaic process

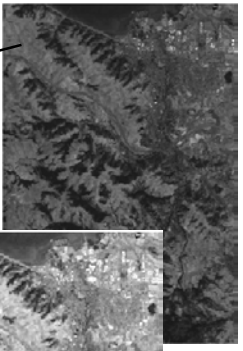
TNTmips allows you to enhance the brightness and contrast of images for display by creating and saving contrast tables. A contrast table maps each raw raster value to a corresponding screen brightness value, enhancing the display of the image while preserving the original numerical values in the raster. The Mosaic process automatically uses the saved display parameters for each input raster to display it in the View window. If you last viewed the raster in the Display process using a saved contrast table, that contrast table will be used automatically to display the raster in the Mosaic View window.

When the Apply Contrast Tables toggle button on the Contrast panel is turned on (the default state), contrast-enhanced values are transferred to the output mosaic rather than the raw input raster values. Using this option ensures that the mosaic incorporates the results of your previous contrast-enhancement efforts with the individual input rasters.



Both input rasters in this exercise are displayed automatically with saved Exponential contrast tables. Contrast-enhanced values were transferred to the output mosaic.

Input raster TM_RED displayed with no contrast enhancement for comparison.



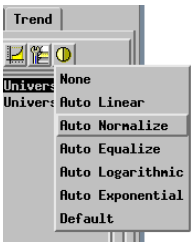
Set Contrast All Layers

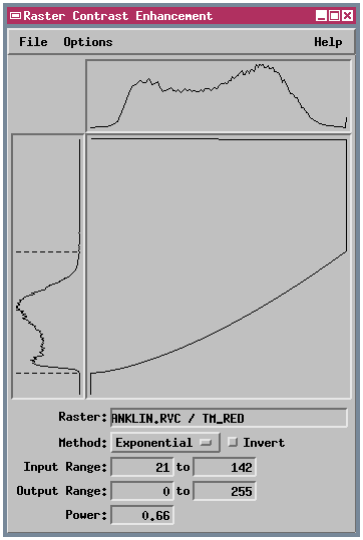
You can also adjust the contrast of any grayscale input raster in the Mosaic process. Pressing the Contrast icon button on the Input panel opens the standard Raster Contrast Enhancement window for the currently-selected input raster. You can change the contrast method, modify the ranges, or make any other adjustments just as you would in the Spatial Data Display process. (For more information on contrast enhancement, see the tutorial booklet entitled *Getting Good Color*).

STEPS

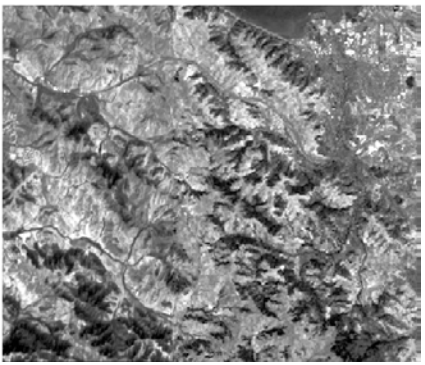
- ☑ on the Input panel, click the Contrast icon button 
- ☑ close the resulting Raster Contrast Enhancement window by choosing Close from its File menu
- ☑ click the Set Contrast All Layers icon button  and select Auto Normalize
- ☑ run the Mosaic process 

The Set Contrast All Layers icon button allows you to apply a single automatic contrast enhancement method to all of the input rasters. The dropdown menu that opens when you press this icon button includes the standard automatic contrast enhancement methods provided in the Display process. If the Apply Contrast Tables toggle button is turned on, contrast-enhanced values computed using the selected automatic method are transferred to the mosaic. The Default option on the menu returns contrast enhancement for each input raster to the default state.





Mosaic created with Auto Normalize enhancement applied to each input raster.



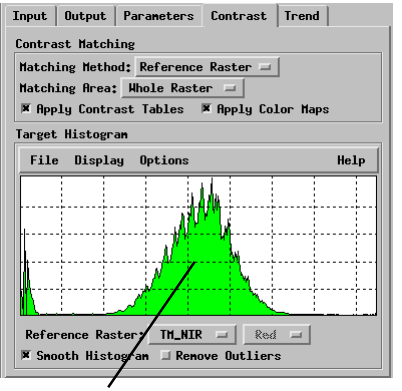
When you apply contrast in creating a mosaic, either using contrast tables or setting automatic enhancement for all input rasters, a Linear contrast table is created for the resulting mosaic raster. This table ensures that the contrast-enhanced mosaic is displayed as intended in the Display process without further automatic enhancement.

Contrast Match Grayscale Rasters

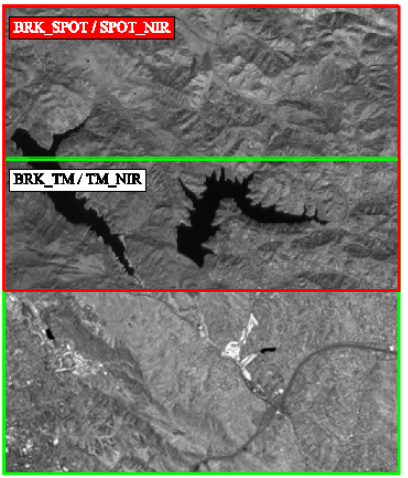
STEPS

- ☑ click the Remove All icon button on the input panel and do not save the layout
- ☑ make sure the Auto Normalize Contrast option is turned off on the Parameters panel
- ☑ click the Add icon button and select object TM_NIR from the BRK_TM Project File and object SPOT_NIR from the BRK_SPOT Project File
- ☑ select TM_NIR from the Auto-Update menu in the Cell Size portion of the Output panel
- ☑ select Reference Raster from the Matching Method option button on the Contrast panel
- ☑ select TM_NIR from the Reference Raster option button
- ☑ turn on the Smooth Histogram toggle button
- ☑ run the Mosaic process

Grayscale rasters that you mosaic commonly will show differing brightness ranges and differing contrast. The Contrast panel provides several contrast matching options. When you choose the Reference Raster option, you then must select one input object as the Reference Raster for contrast matching. The Mosaic process matches the brightness histogram of each input object as closely as possible to the histogram of the Reference Raster.



The histogram for the selected Reference Raster is displayed for your inspection in the Target Histogram panel.



Input grayscale rasters with differing contrast.

Mosaic with contrast matching.

Mosaic RGB Color Raster Sets

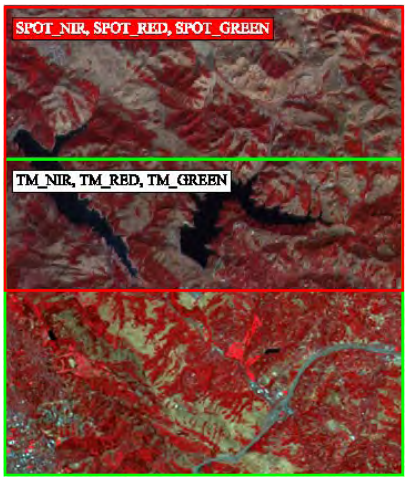
When you apply contrast matching to RGB raster sets, histogram matching is applied separately to the red, green, and blue color components. The brightness and contrast of each color component are independently adjusted to match the corresponding component of the reference set. This procedure adjusts the overall color balance of each input raster set to match the color of the reference set. In this example, a darker SPOT image is matched to a brighter Landsat Thematic Mapper raster set. The selected bands are Near Infrared (displayed as red), Red (green), and Green (blue). This combination yields an image similar to a color-infrared photograph, with vegetated areas appearing in red.

Instead of choosing a reference raster and adjusting the contrast of the other input objects to match it, you can choose to match all input images to a model brightness distribution. The two available models are Equalize (an equal number of cells at each brightness level) and Normalize (a normal or Gaussian distribution of brightness). Both of these models apply the greatest contrast enhancement to the most populated range of brightness values in each image.

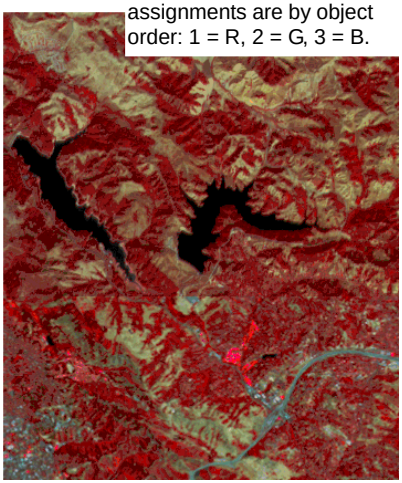
STEPS

- ☑ click the Remove All icon button on the input panel 
- ☑ choose Add Project File (RGB) from the File menu, and select the BRK_TM and BRK_SPOT Project Files
- ☑ select TM_NIR from the Auto-Update menu in the Cell Size portion of the Output panel
- ☑ on the Contrast panel set the Contrast Matching Method to Reference Raster and choose the TM raster set as the reference
- ☑ run the Mosaic process and  name the Red, Green, and Blue output raster components

The Add Project File (RGB) option adds the first three rasters in the selected Project File as an RGB raster set. Color assignments are by object order: 1 = R, 2 = G, 3 = B.



Input RGB raster sets with different color balance.



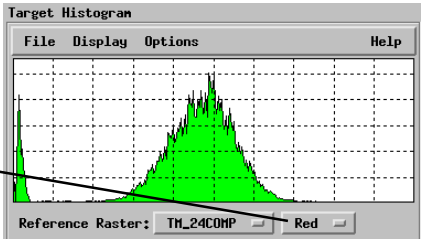
Mosaic with contrast matching.

Mosaic Color Composites

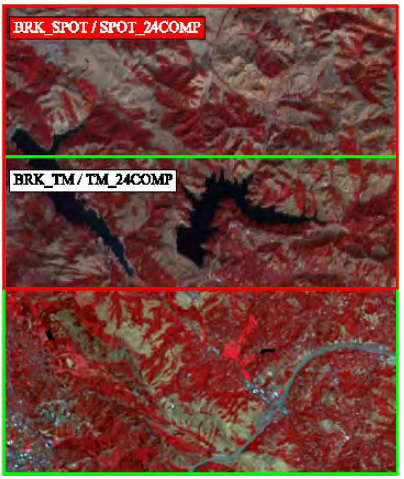
STEPS

- ☑ click the Remove All icon button on the input panel 
- ☑ click the Add icon button on the Input panel 
- ☑ select object TM_24COMP from the BRK_TM Project File and object SPOT_24COMP from the BRK_SPOT Project File
- ☑ select TM_24COMP from the Auto-Update menu in the Cell Size portion of the Output panel
- ☑ on the Contrast panel choose TM_24COMP as the Reference Raster
- ☑ run the Mosaic process 

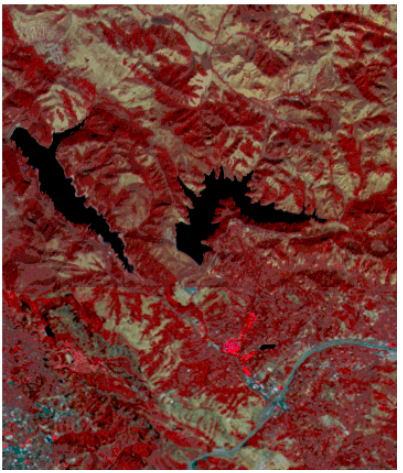
You can also mosaic color composite rasters such as 24-bit or 16-bit composites (with separate red, green, and blue values stored for each raster cell) or 8-bit composites with color maps. When you perform contrast matching with color composites, the Mosaic process automatically creates red, green, and blue histograms for each input object. Contrast matching is then done exactly as it would be with RGB raster sets. The best color matching results are achieved with 24-bit composites such as those used in this exercise (or when matching RGB and 24-bit composites). Composite 16-bit or 8-bit rasters will usually not yield as close a color match.



Use this option button to choose which one of the three histograms (Red, Green, or Blue) from the reference raster (or raster set) is displayed for inspection in the Target Histogram pane. Each of these histograms is used as the target for contrast matching for its respective color, regardless of which one is currently displayed. If you are using the Selected Area matching option for the reference image, the histogram of the matching area is shown.



Input color composites with different color balance.



Mosaic with contrast matching.

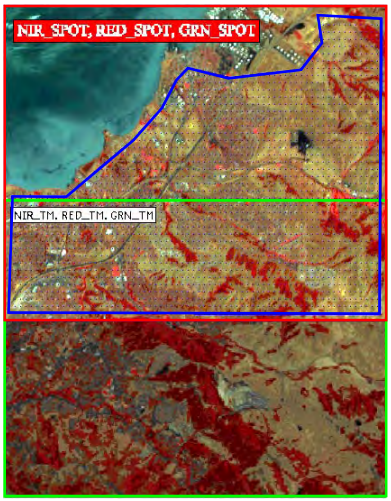
Match Contrast Using Processing Areas

The Matching Area is the portion of an input object used to build a histogram for contrast matching. The default selection is Whole Raster. By drawing processing areas for one or more input objects, and choosing Selected Area as the Matching Area option, you can designate which portions of the input images control the matching process.

In this example, we want to match the darker Landsat image to the brighter SPOT image. But the latter image includes a large area of turbid, sunlit water and some very bright structures, neither of which are present in the Landsat image. In order to produce the best match for the more typical land areas in the two images, we draw a processing area for the reference SPOT image that excludes the water and anomalous structures. Histograms computed from this area (one for each color) are used as the target histograms for matching. The histogram-building process reverts to the whole-raster mode for the Landsat image, for which we didn't define a processing area.

STEPS

- ☑ click the Remove All icon button on the input panel
- ☑ choose Add RGB Rasters from the File menu, and select objects NIR_TM, RED_TM, and GRN_TM from the PINOLE Project File
- ☑ repeat the last step, selecting objects NIR_SPOT, RED_SPOT, and GRN_SPOT
- ☑ set the Image Area option at the bottom of the Input panel to Whole Raster
- ☑ set the Contrast Matching Method to Reference Raster and choose Selected Area from the Matching Area menu
- ☑ select the SPOT raster set as the contrast reference
- ☑ draw a processing area for the SPOT image as shown below left (outlined in black)
- ☑ run the Mosaic process



Input raster images with processing area for reference Landsat image for matching.

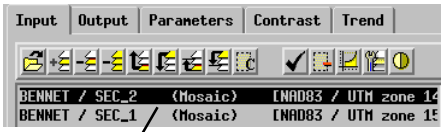
Portion of mosaic with contrast matched to selected area.

Save and Open Mosaic Layouts

STEPS

- ☑ click the Remove All icon button on the input panel
- ☑ click the Open Layout icon button
- ☑ select object MOS_LAYOUT from the BENNET Project File

The Mosaic process allows you to use almost any number of input objects and to define processing areas, reference objects, overlap processing, contrast matching, and other processing parameters. When you are setting up a complex mosaic process, it is a good idea to save the mosaic layout using the Save Layout option on the File menu. The input object list and all process settings are saved in a layout object that you name and place in a Project File of your choice.

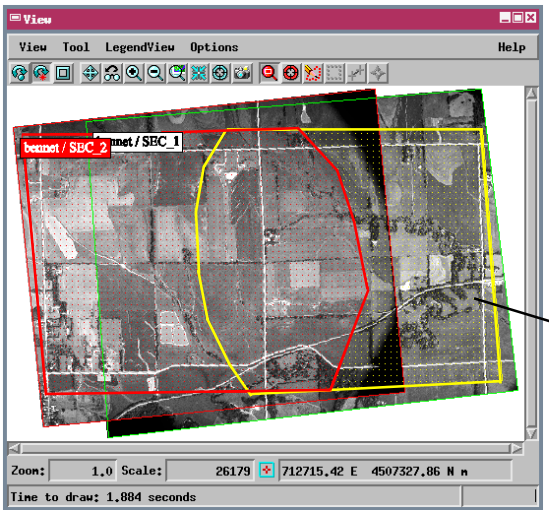


Input list after opening the MOS_LAYOUT object.

If you need to modify or add to the mosaic at a later time, you can load the saved layout using the Open Layout icon button or the corresponding option on the File menu. All input objects are added in the correct order, and all Mosaic option selections and parameter values are set as they were when you saved the layout. You can then add other input objects or modify settings as needed. The layout you open here includes processing areas and other settings that you will add to in the next exercise.

If a mosaic layout object that you save refers to input objects in different Project Files, do not move these files to different directories or drives after saving the layout. If you do, the Mosaic process may not be able to find them.

If you repeatedly make mosaics using subsets of a large group of airphoto or airvideo images, you can save a mosaic layout which includes the entire set of images, then use an extents box to define the input objects needed for the current mosaic. Saving the layout in Wire Frame Display Mode speeds loading of the layout.



View window with Bennet airphotos and processing areas restored from the MOS_LAYOUT object.

Keep the current settings and proceed to the next page.

Trend Removal

Spatial brightness variations related to illumination and lens effects are common in aerial photographs and video images. Shadowing due to oblique illumination can cause one side of an image to appear significantly darker than the other. This is a linear (first-order) brightness trend. Lens effects can cause a radial darkening of the image (second-order trend). These trends can cause brightness mismatches across the image seams in a mosaic, since the same area can look brighter than average in one image but darker than average in the adjacent one.

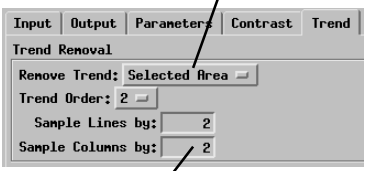
The controls on the Trend panel allow you to automatically process input images to reduce or remove brightness trends prior to contrast matching and assembly of the mosaic. You can choose the trend order and base the trend removal on the whole raster or on a portion of the image selected by a processing area. In order to speed processing for larger images, trend analysis can utilize a sample of the image cells, with the size of the sample determined by the sampling interval.

The Bennet airphotos used in this exercise show a westward brightening due to sun angle, and a radial darkening related to lens effects. A combination of second-order trend removal and contrast matching provides a much closer match between the two images than contrast matching alone.

STEPS

- ☑ on the Trend panel choose Selected Area from the Remove Trend option button
- ☑ select 2 from the Trend Order option button
- ☑ change the value in the Sample Lines by: field to 2, and repeat for the Sample Columns by: field
- ☑ run the Mosaic process 

Choose Selected Area to use a Processing Area to determine the portion of the image used for trend removal.



The sampling interval for trend removal is set by the values in these fields (the default value is 4).

Mosaic produced using contrast matching (settings saved in the layout) and second order trend removal. The linear and radial brightness variations in the original images are noticeably reduced, providing a better match along the seam. Compare with the raw image mosaic on page 12.

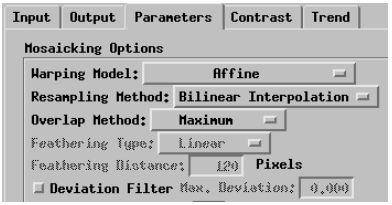
Raster Overlap Options

STEPS

- ☑ click the Open Layout icon button and select BRK_LAYOUT from the BRK_TM Project File
- ☑ on the Parameters panel, choose Maximum from the Overlap Method option button
- ☑ run the Mosaic process

In the previous exercise you may have noticed that the mosaic still showed a detectable edge between the pair of input raster objects even after you applied contrast matching and trend removal. This and previous exercises used the default Last Raster method of handling the overlap area between input objects, which simply uses the topmost raster in each overlap area to create the output image. Using this method can leave sharp seams in a mosaic despite your other efforts at matching input images.

The Overlap Method option menu on the Parameters panel allows you to choose different ways to process the overlapping portions of input rasters to create more gradual transitions between them. Aside from the Last Raster and First Raster options, these methods assign overlap cell values on the basis of a comparison, sampling, or mathematical combination of corresponding cell values from the input images.



The Average method uses the mean of the corresponding input cells. The Maximum method chooses the maximum value, while the Minimum method does the opposite. In the Chessboard method, input cell values from the overlapping rasters are regularly alternated in two dimensions to form a chessboard pattern. The Random Mixing method uses a weighted average of corresponding input cells, with relative weights assigned randomly. All of these methods work best when there is very good cell-by-cell registration between the overlapping rasters.

Mosaic using the Maximum overlap option.

Try repeating this exercise using different overlap options so you can judge their effects for yourself. Then keep this mosaic layout open and go on to the next exercise.

Feathering Overlaps and Deviation Filter

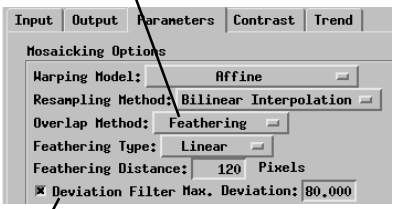
Like the Random Mixing method, the Feathering option computes the weighted average of the corresponding input cells to determine the output cell value, but in this method the weighting factors vary systematically with distance from the image boundaries. The weighting coefficients for each image are 0 at the boundary and increase inward to 1.0 at the feathering distance from the edge. Larger feathering distances provide a more gradual transition.

STEPS

- ☑ on the Parameters panel, choose Feathering from the Overlap Method option button
- ☑ turn on the Deviation Filter toggle button and set the Max. Deviation to 80.00
- ☑ run the Mosaic process 

When you use any of the overlap options designed to blend the overlapping images, local extreme differences in corresponding cell values in the overlapping rasters may lead to spurious results. These differences may result from poor spatial match of the input rasters or local changes in the ground materials (such as new roads or buildings) in overlapping images acquired on different dates. The Deviation Filter allows you to selectively reject such extreme differences in input cell values when performing these overlap operations. Turning on the Deviation Filter toggle button activates the Max. Deviation numeric field, in which you can enter the maximum allowed difference in cell value. If corresponding input cell values differ by more than this value, the filter overrides the selected overlap operation and uses the Last Raster value instead. Exercise caution in using this feature, as the non-blended areas may contrast markedly with the surrounding feathered overlap area, as shown in this example along the shoreline at the south end of the western lake.

With the Feathering method you can choose either a Linear or Nonlinear variation in weighting relative to image edges.



The Deviation Filter allows you to selectively reject extreme differences in input cell values when performing overlap operations.

Mosaic using the Linear Feathering option. The two black areas are lakes.

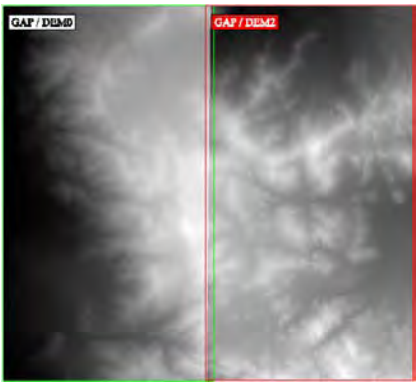
Mosaic Digital Elevation Models

STEPS

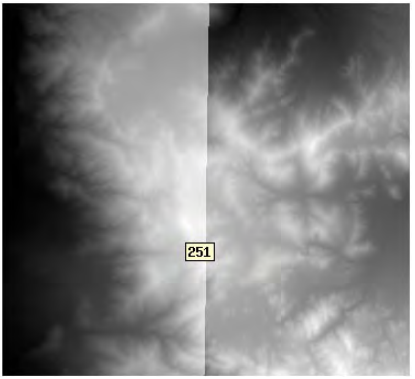
- ☑ click the Open Layout icon button and select DEM_LAYOUT from the GAP Project File
- ☑ run the Mosaic process
- ☑ on the Contrast panel, turn off the Apply Contrast Tables toggle
- ☑ run the Mosaic process again

When mosaicking certain types of raster objects, such as Digital Elevation Models (DEMs), input cell values should be transferred to the mosaic without alteration to ensure fidelity to the original data. In such cases you should use the Nearest Neighbor resampling method (set on the Parameters tabbed panel) to avoid smoothing the cell values. In addition, be sure to turn off mosaic options that might alter the mosaic values, such as contrast matching, applying contrast tables, and trend removal.

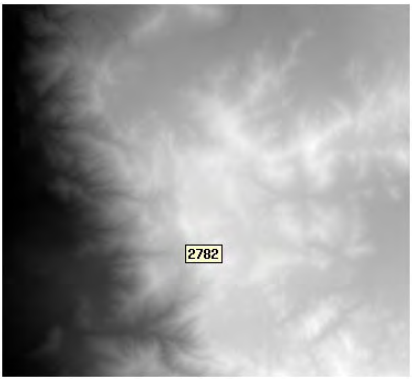
Most DEMs are stored as 16-bit integer or decimal (floating-point) values to faithfully replicate the original elevation range without scaling. Applying contrast tables to such rasters during mosaicking converts the original cell values to screen brightness values (0 to 255) and also results in tone mismatches across seams in the mosaic. Both of these results are undesirable, so be sure to check that the Apply Contrast Tables toggle on the Contrast panel is turned off before mosaicking DEMs or similar non-image rasters.



Input DEMs with contrast tables.



Mosaic run with applied contrast tables shows tone break across seam and has cell values in the range 0 to 255.



Mosaic without applied contrast shows no break across seam and contains correct elevation values.

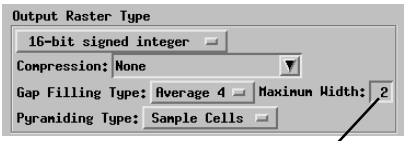
Fill Gaps

With some mosaic projects, the problem is not dealing with overlap between component objects, but compensating for lack of overlap between them. This problem occurs most commonly with tiled spatial data such as digital elevation rasters distributed by map quadrangle. Although the boundaries between adjacent elevation rasters should be coincident, in practice there may be gaps between them that are one or two cells wide.

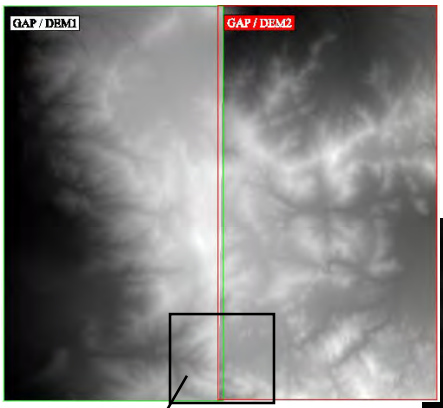
The Mosaic process enables you to automatically "fill" the gaps between adjacent mosaic components. The gap-filling filter interpolates values for narrow strips of no-data cells in the mosaic using the values of adjacent cells with real data values. The two gap-filling options use the average of either the four neighboring or eight neighboring cells to interpolate values for individual gap cells.

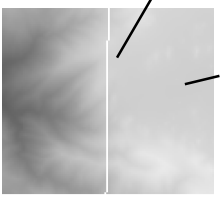
STEPS

- ☑ click the Open Layout icon button and select GAP_LAYOUT from the GAP Project File
- ☑ on the Output tabbed panel select Average 4 from the Gap Filling Type menu
- ☑ set the Maximum Width field value for gap-filling to 2
- ☑ run the Mosaic process

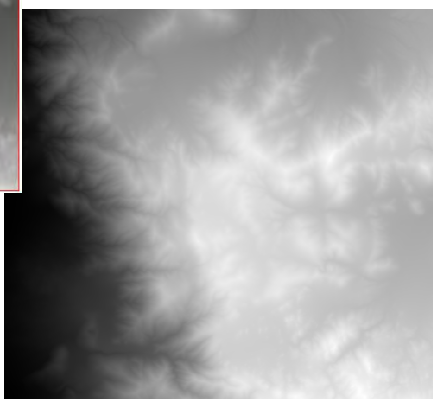


The Maximum Width parameter specifies an upper limit to the width of the gap that is allowed to be filled. No-data cells along the edges of the mosaic and those in gaps wider than this threshold are left unchanged. For maximum efficiency and speed, set the smallest value necessary to cover the width of the gaps between your input objects.



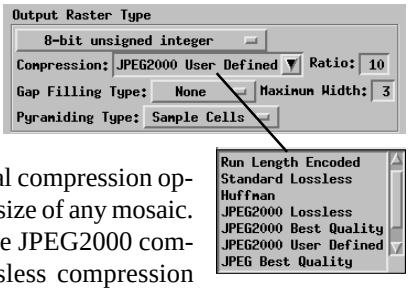


Portion of mosaic run with gap-filling turned off. A gap or seam of no-data cells remains along the quadrangle boundary.

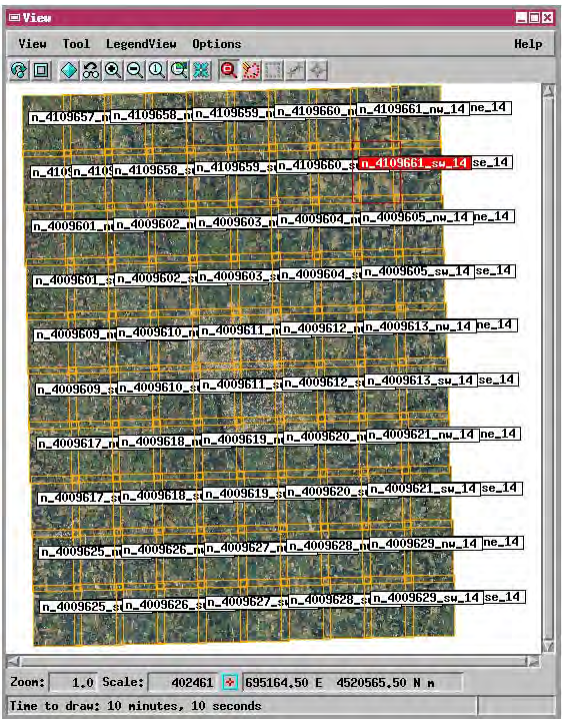


Full mosaic with boundary gap filled.

Compression for Large Mosaics



You can use the Mosaic process to create mosaics covering large areas at high spatial detail that nevertheless fit in manageable file sizes. The Compression menu on the Mosaic window's Output tabbed panel provides a number of internal compression options that you can use to reduce the stored size of any mosaic. For a very large mosaic, choose one of the JPEG2000 compression options. These include a Lossless compression option, a Best Quality option that analyzes the image to determine an appropriate lossy compression level, and a User-Defined option that lets you specify a target compression ratio. JPEG2000 allows high lossy compression with minimal degradation of color fidelity or spatial detail. Aerial or satellite images can be compressed at ratios of 10:1 or higher without significant compression artifacts. Compression procedures have been optimized to handle very large image sizes (gigabytes of data) while efficiently managing physical and virtual memory.

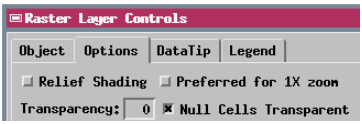


Mosaic layout of 100 color digital orthophoto quadrangle images (each raster about 145 MB in size) covering Lancaster County, Nebraska. The mosaic created from these images covers over 3700 square kilometers at 1-meter cell size; with JPEG2000 10:1 compression, it is 1.3 GB in size. A small area of the mosaic is excerpted in the illustration below to show the image detail.

No-Data Areas and Null Masks

After you run the Mosaic process, there may be areas in the rectangular mosaic raster (usually around the edges) that are not covered by any of the input objects. Although these blank or "no data" areas are part of the raster object and thus must have some numeric value assigned to their raster cells, in most cases you probably would want these areas to be transparent when the mosaic is displayed.

The Mosaic process handles these no-data areas by automatically creating a null mask to differentiate image and non-image cells in the mosaic. The null mask is stored as a subobject of the mosaic raster, and a pyramided version of it is also stored with each mosaic pyramid tier. The null mask is recognized automatically by the TNTmips Display process and used to render the no-data areas transparent whenever you display the mosaic with the Null Cells Transparent option turned on in the Raster Layer Controls window's Options tabbed panel.



A null mask provides several advantages over simply assigning a value in the mosaic raster itself as null. The mosaic's image data values may already spread over the full raster data range, leaving no unused value available to assign as null without affecting real image areas. In addition, a null value cannot be used in rasters with internal lossy compression such as JPEG2000, which does not support the concept of null value. Use of a null mask provides a global solution that works with rasters of any data type or compression method.

Mosaic with no-data areas around the edges, which are flagged automatically in the null mask. Displayed with Null Values Transparent setting on (above) and off (below).

Manual Mosaicking

STEPS

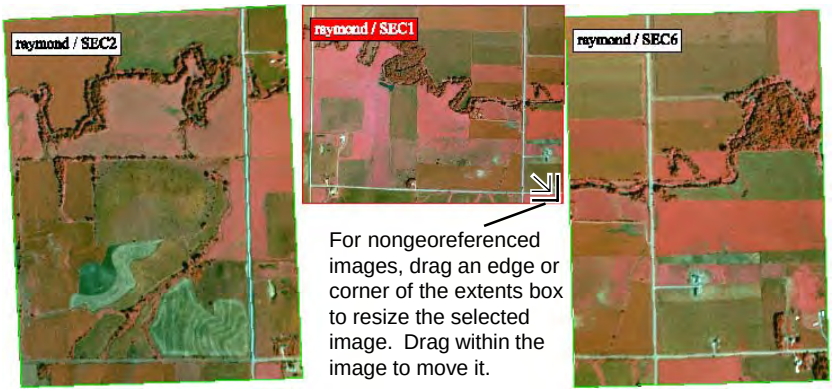
- ☑ click the Open Layout icon button and select MAN_LAYOUT from the RAYMOND Project File
- ☑ note that the Positioning menu option has changed to Manual
- ☑ select SEC1 in the Input list
- ☑ click on the Manual Positioning icon button on the View window
- ☑ drag the lower right corner of the extents box for the middle photo (SEC1) to enlarge it
- ☑ click the right mouse button to redraw the image
- ☑ repeat until features in SEC1 appear at about the same scale as in the flanking images
- ☑ drag SEC1 to the right if necessary to uncover the right edge of SEC2

Keep the current settings and proceed to the next page.

Change to Manual positioning mode when you want to mosaic a set of nongeoreferenced objects or a mixture of georeferenced and nongeoreferenced images.

Nongeoreferenced objects can be selected only in Manual mode. When you add the input objects, georeferenced images are automatically placed in their correct relative positions within the View window. (If you are adding a mixed set of objects, add a georeferenced object first in order to establish the correct window coordinate system.) Nongeoreferenced images are tiled horizontally to the right of the first-placed image, in the order in which they are added. (The number of image tiles in a row is set by the Autoplacement Tiles setting on the Parameters panel. Additional images are tiled beneath the previous row.)

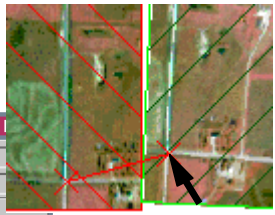
The left and right images in this layout are georeferenced, but the middle one has no georeferencing or cell size. The middle image therefore is not initially displayed at the correct scale relative to its neighbors. After selecting the nongeoreferenced object in the input list, use the Manual Positioning tool to move or resize it to make it easier to identify and place tie points for pairs of adjacent images.

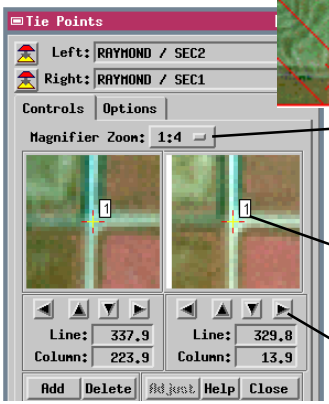


Place Tie Points for the First Image Pair

In Manual mode you must place tie points to establish the position of a nongeoreferenced image relative to its neighbors. Tie points identify corresponding locations in a pair of overlapping images. At least three tie points are required for each image pair, and they should be distributed to cover as much of the overlap area as possible. Members of a pair are designated Left and Right to identify their magnifier image in the Tie Points window. To designate an object as Left or Right, select it in the Input list, then click the corresponding Replace icon button at the top of the Tie Points window.

After designating the image pair, use the Define Tie Points tool to establish a preliminary tie point location in the View window. Then use the controls in the Tie Points window to refine the position before adding the tie point.



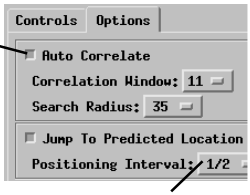


You can change the zoom level of the magnifier windows as needed.

Click on a point in a magnifier frame to snap the tie point to it.

Use the arrow buttons to make fine adjustments in the tie point position.

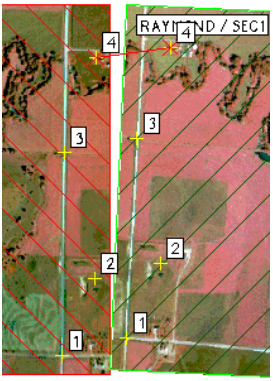
The Auto Correlate option operates when at least three tie points have been added. After you place another preliminary tie point, clicking in one magnifier frame launches a spatial correlation process that automatically locates the corresponding point in the other image.



The Positioning Interval setting defines the increment of position change (in pixels) triggered by the arrow buttons.

STEPS

- ☑ select Define Tie Points from the Manual menu
- ☑ with SEC1 still selected in the Input list, in the Tie Points window click the Replace icon button for the Right image 
- ☑ select SEC2 in the Input list and click the Replace icon button for the Left image
- ☑ click the Define Tie Points icon button in the View window 
- ☑ drag a line connecting the road intersection in the lower right corner of SEC2 with its counterpart in SEC1
- ☑ in the Tie Points window, use the arrow buttons beneath the magnifier windows to refine the tie point positions, then click [Add]
- ☑ add three more tie points as shown below

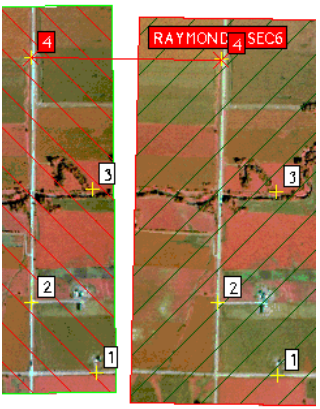


Keep the current settings and proceed to the next page.

Complete Tie Points and Run Mosaic

STEPS

- ☑ select SEC1 in the Input list
- ☑ click the Manual Positioning icon button
- ☑ move the SEC1 photo to the left until you uncover the left edge of SEC6
- ☑ designate SEC1 as the Left image and SEC6 as the Right image
- ☑ click the Define Tie Points icon button and place tie points for this image pair as suggested below

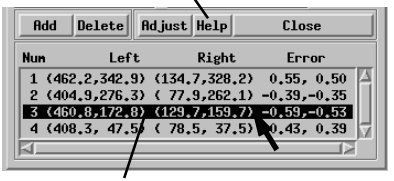


- ☑ click [Adjust] to preview the final image placement and a summary of position errors
- ☑ run the Mosaic process

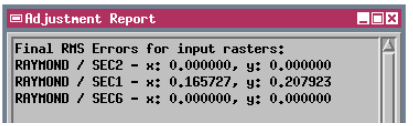
Final mosaic image resulting from the tie point locations shown.

Manual mosaic mode computes a least-squares best fit for all tie points and any available ground control points and uses the resulting locations to position component images in the mosaic. The Adjust button on the Tie Points window lets you preview the results of this bundle adjustment before you create the mosaic. You can update the model after placing tie points for each image pair, or wait until all tie points are placed. When you adjust the model, the updated positions are used to place the images in the view window, position errors are calculated for the current image pair, and an Adjustment Report window appears, listing the RMS (root-mean-square) position errors for each image (0 for fully georeferenced images). You can return to specific tie points and adjust their position if necessary to improve the model results.

Click [Adjust] to preview the mosaic results.



Click on a list entry to select the tie point for editing.



Input and Output Raster Types

The Mosaic process accepts a full range of input raster types including binary (1-bit), grayscale, RGB color separates, and color composites. The range of grayscale rasters includes 2-bit and 4-bit integer, signed or unsigned 8-, 16-, or 32-bit integer, and floating point (32-bit or 64-bit). Color composite types include 24-bit and 16-bit RGB and BGR composites and 8-bit composites with a color map.

You will usually get the best results from the Mosaic process if all input raster objects contain the same data type. However, the process does allow you to include different raster data types in a mosaic. The default output raster type depends on the specific input raster types and is designed to preserve the maximum data fidelity. The sections below summarize these relationships.

Grayscale Input	**Grayscale Output**
All same bit-depth and sign	Same as input
All same bit-depth, signed and unsigned	Signed integer
Different bit-depths	Highest bit-depth
32-bit unsigned and 32-bit floating point	32-bit floating point
32-bit signed and 32-bit floating point	32-bit signed integer

If you mix signed and unsigned integer rasters, be aware that no scaling of raster values is performed by the Mosaic process, so some loss of data may occur if input values extend beyond the range of the output raster type.

Color Input	**Color Output**
All RGB	RGB
All 24-bit composite	24-bit composite
All 16-bit composite	16-bit composite
Same bit-depth RGB- and BGR composite	RGB-composite
All 8-bit composite with color map	RGB
RGB and any composite	RGB
Composites with different bit-depth	Maximum composite bit-depth

There is no option to produce an 8-bit color-mapped mosaic. You can use the Color Conversion process (Raster / Combine / Convert Color) to convert a completed color mosaic to an 8-bit composite raster if desired.

Mixed color and grayscale

You can also mix color and grayscale rasters in a mosaic if you lack complete color image coverage. The grayscale input raster will appear in grayscale in the color mosaic raster or RGB raster set.

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