GEOREFERENCE

Tutorial

Georeferencing

with

TNTmips®

and TNTedit™

Before Getting Started

This Getting Started booklet introduces the techniques for adding geographic control to your project materials. You will use this Georeference process to define the map projection, location, and scale of your geodata objects. Adding georeference information creates geographically interrelated objects (e.g., geodata sets). The TNT products automatically relate georeferenced objects to each other when they are displayed, measured, combined, mosaicked, and otherwise manipulated. Accurate georeferencing of your objects is an important step in preparing your geospatial materials for further use in the TNT products.

Prerequisite Reading This booklet assumes that you have completed the exercises in *Displaying Geospatial Data* and *Navigating* tutorials. Those exercises introduce essential skills and basic techniques that are not covered again here. To find out more about Map Projections, read the associated tutorial, *Map Projections*.

Sample Data The exercises presented in this booklet use sample data distributed with 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 the objects in the CB_COMP and CB_DLG Project Files in the CB_DATA data collection. Make a read-write copy of the sample data on your hard drive; the exercises will not work if you use the read-only sample data on the CD-ROM.

More Documentation This booklet is intended to be only an introduction to Georeferencing. Consult the TNT online reference manual, which includes over 55 pages on the Georeference process, for more information.

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 the size of your project materials and enables data sharing only with other copies of TNTlite.

The Georeference process is part of TNTmips and TNTedit. It is not available in TNTview or TNTatlas. All the exercises can be completed in TNTlite using the sample geodata provided.

Keith Ghormley, 26 September 2003

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:

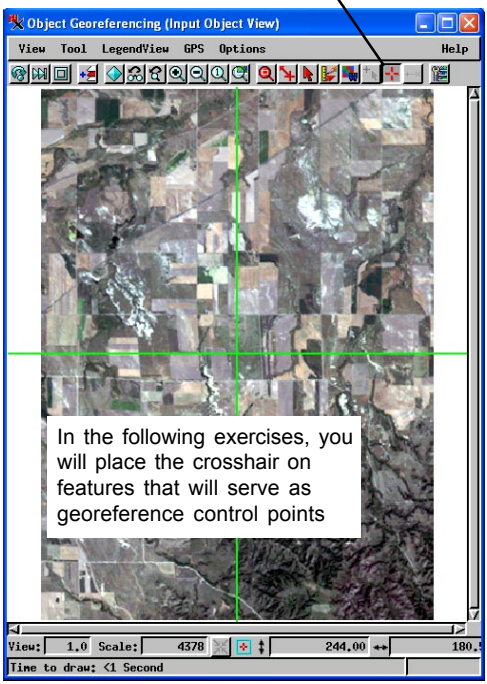
http://www.microimages.com

Starting the Georeference Process

The Georeference process lets you create and store control information that relates raster cells or vector, CAD, or TIN elements to a coordinate system and map projection. TNTmips keeps the coordinate values for your control points and related parameters in a georeference subobject.

For our initial exercise, begin by selecting Edit / Georeference from the TNTmips menu. Select File / Open from the menu in the Object Georeferencing window and open the LITEDATA / CB_DATA / CB_COMP / _16BIT_RGB raster object. For these exercises we will use the Lat-Lon coordinate system. Lat-Lon is the simplest system, but it is not a true map projection, and so has significant disadvantages for many uses. Refer to *Getting Started: Map Projections* for important background information.

The crosshair tool is selected in the Input Object View window in the Add mode



Once you have georeferenced a geodata object in any projection system, then it will relate correctly to all of your other project materials no matter what system they use for georeference. All of the TNT products automatically reconcile the georeference control and map projections of all project materials.

STEPS

- ☑ select Edit / Georeference from the TNTmips menu
- ☑ select File / Open and select LITEDATA / CB_DATA / CB_COMP / _16BIT_RGB
- ☑ click [Skip] in the Select subobject dialog
- ☑ click [OK] in the Georeferencing Options dialog to accept the Lat-Lon coordinate system
- ☑ click [OK] to close the message dialog about the limitations of the Lat-Lon system

The exercises on pages 3-5 of this booklet show you how to select an object, a coordinate system, and other projection parameters. Exercises on pages 6-9 introduce techniques for adding, editing, and deleting control points. Other topics are introduced on pages 10 through 15.

Adding Control from a Reference Object

A **control point** locates the same position on both the input and the reference objects.

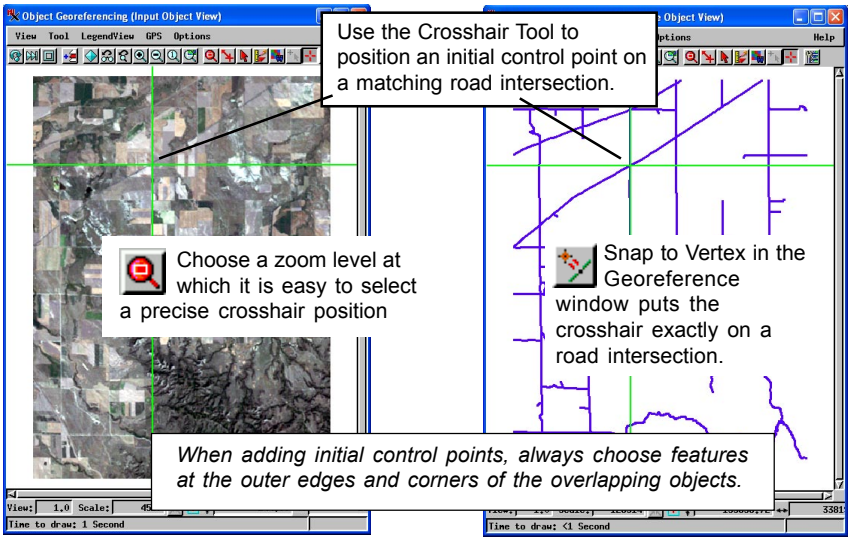
NOTICE: the process opens in the "Add Mode" which lets you add control points.

STEPS

- ☑ select Options / Show Reference View in the Georeference window
- ☑ In the Reference Object View, add LITEDATA / CB_DATA / CB_DLG / ROADS
- ☑ the Crosshair tool in both View windows should be selected
- ☑ select matching features
- ☑ click the Apply icon button in the Georeference window

One of the easiest ways to establish georeference is to place control points on the input object using a **reference object** that already has georeference control. In the exercise on page 3, you opened 16BIT_RGB as the input object. Now add a reference object using the Reference Layer Controls window. (If the Reference Layer Controls window is not already open, go to the Options menu in the Georeference window and click the Show Reference View toggle.) Click the Add Layer icon button in the Object Georeferencing: Reference Object View window, and add LITEDATA / CB_DATA / CB_DLG / ROADS.

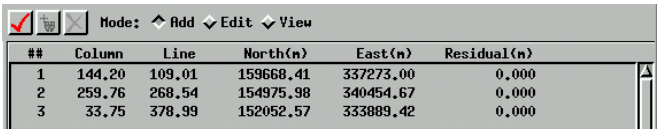
Make sure that the Add Mode check button is selected in the Georeference window and that the Crosshair tool is selected in both view windows. Click the left mouse button on matching features, such as road intersections, in each View to place the crosshairs. You can adjust the crosshair position by dragging them or clicking the left mouse button on a new location. Click the Apply icon button in the Georeference window to add a control point.



The Overlay View

Each time you add a control point, a numbered item is added to the list of control points in the Georeference window. The same number displays in each View window next to the new point's tick mark. Since the ROADS reference object has State Plane georeference, the control point list shows State Plane coordinates.

New control points appear on the list in the Georeference window.



Control point numbers appear with their tick marks in the View windows.

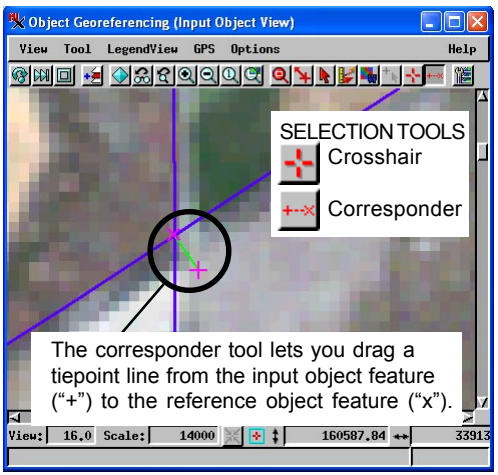
After you add at least three non-colinear control points using separate View windows, you can switch to an Overlay View. Add the same CB_DLG / ROADS vector object to the Input Object View as instructed in the STEP list on this page. The DLG lines display over the raster object according to the georeference that your initial control points have established. Now instead of identifying common points with the Crosshair tool in separate windows, you can use the Corresponder tool in the overlay view.

STEPS

- ☑ add at least three control points at matching locations using separate View windows
- ☑ add LITEDATA / CB_DATA / CB_DLG / ROADS to the Input Object View window 
- ☑ close the Reference Object View window
- ☑ select the corresponder tool in the Input Object View 

Select the Corresponder tool in the Input Object View. The corresponder tool is an elastic line with a '+' on one end and a "x" on the other end. Position your cursor on an **input** object feature (marked with the '+' end) and drag the elastic line to the corresponding **reference** object feature (marked with the 'x' end). (The next exercise gives more detail about the Corresponder tool.)

Vocabulary: the **Input Object** is the object that is being georeferenced (in this example, the 16_BIT raster object). The **Reference Object** is the object from which the Georeference process gets control information (in this example, the CB_DLG / ROADS vector object).



The Corresponder Tool

STEPS

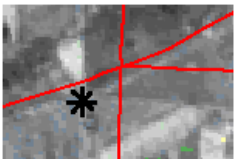
- ☑ position the mouse cursor on a feature in the input object
- ☑ hold down the left mouse button and drag the Corresponder tool to the matching feature on the reference object
- ☑ click the Apply icon button to add the control point 
- ☑ click the Redraw button 

Use the Corresponder tool to add several more control points in the overlay mode. Position the mouse over a feature in the input object. Then hold down the mouse button and drag the corresponder tool's elastic line to the same feature in the reference object.

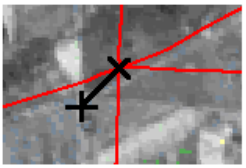
IMPORTANT: always drag the tool FROM the **input** object TO the **reference** object.

*The (+) end of the corresponder tool marks the position of the **input** object, and the (X) end of the Corresponder tool marks the location on the **reference** object.*

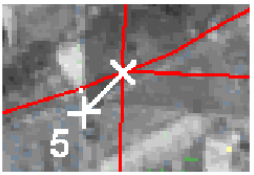
Click the Apply button to accept a tiepoint pair. Click the Redraw button, and the new control point is used to adjust the overlay position.



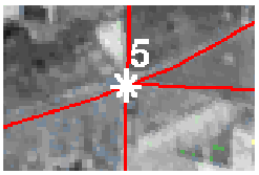
Position the left mouse button on a feature in the input object.



Drag the Corresponder tool to the matching feature on the reference object.

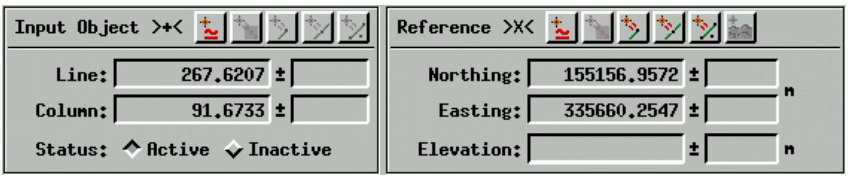


Click the Apply icon button to accept the control point.



Press the Redraw icon button, and the layers are adjusted to the new control information.

With each redraw, the Georeference process uses all the control information to determine the new overlay relationship. If the control points don't "agree", you may see mismatches, even at control point positions. The next lesson shows how to adjust control points.



The Input Object panel in the Georeference window shows the position of the control point in terms of the input object.

The Reference panel in the Georeference window shows the position of the control point in terms of the reference object.

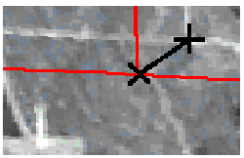
Edit and Delete Control Points

Editing Controls let you move or adjust an existing control point location. First, push in the Edit Mode radio button. Then select the control point you want from the list in the Georeference window. The highlight color of the selected control point changes in the view window. Use the Corresponder tool to reposition the control point.

The Snap to Element, Snap to Vertex, or Snap to Endpoint icon buttons tell the process to snap the reference object end (X) of the corresponder tool to the nearest element, vertex, or endpoint, in the ROADS reference object. In particular, use the Snap to Vertex icon button to snap the (X) end of the Corresponder tool to road intersections in the reference object. Click the Apply icon button to update the control point, and click [Redraw] to view the change. You can click the Delete icon button to delete a control point that you don't want.

STEPS

- ☑ activate the Edit radio button
- ☑ select a control point from the list
- ☑ adjust the +/X ends of the Corresponder tool 
- ☑ click the Snap to Vertex icon button 
- ☑ click the Apply icon button 
- ☑ click the Redraw icon button to view the change 
- ☑ select another control point
- ☑ click the Delete Control Point icon button to delete a control point 

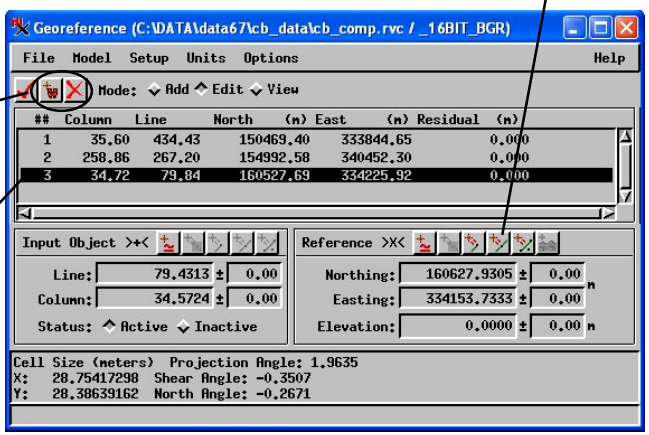


Adjust the Corresponder tool while using the Edit Mode.

The Snap to Vertex icon button snaps the (X) end of the Corresponder tool to the node at the road intersection in the reference object.

When the Edit toggle is selected, the Delete and Find Selected Point buttons become active.

Select a control point that you want to edit.



Keep the input object open for use in additional exercises.

Selecting Coordinate Systems

For more information on Coordinate Systems and map projections, also see the tutorial booklet: *Map Projections* from MicroImages, and *Map Projections — A Working Manual* by the U.S. Geological Survey (1987).

Vocabulary: a reference system for defining precise locations on the Earth's surface is called a **coordinate system**; a coordinate system may be independent or tied to a particular map projection.

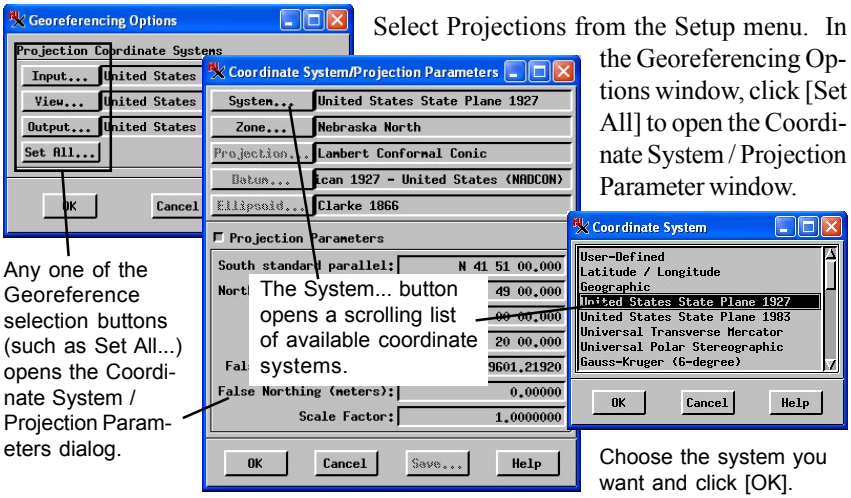
STEPS

- ☑ select Projections... from the Setup menu
- ☑ click [Set All...]
- ☑ click [System...]
- ☑ select "United States State Plane 1927" from the list and click [OK]

When you are ready to save your new georeference control, select Save from the File menu in the Georeference window. Standard object selection dialogs let you name and describe your new georeference subobject.

The georeference process lets you select the coordinate system and map projection for your georeference control. Your choice may be determined by (1) the geometric characteristics of the input object, such as a scanned map that was printed in a certain projection, or (2) the system used by your other project materials, such as a reference object you use for control points. For example, when you saved the georeference for _16BIT_RGB, the system automatically chose State Plane since that was the system of the ROADS reference object.

You can choose any map projection consistent with your input object. Your output projection can be different from your input projection. You can view coordinates in yet another projection and coordinate system. Thus you could enter control points in Lat/Lon, view coordinates in UTM, and save the georeference in State Plane.



Select Projections from the Setup menu. In the Georeferencing Options window, click [Set All] to open the Coordinate System / Projection Parameter window.

Any one of the Georeference selection buttons (such as Set All...) opens the Coordinate System / Projection Parameters dialog.

Choose the system you want and click [OK].

Selecting Other Projection Parameters

You can also specify values for the other projection parameters associated with a selected coordinate system. In this example, select the State Plane zone for the _16BIT_RGB raster object.

Click the Zone button to open the Zone Selection dialog, which lists the State Plane zones for the United States and its territories. Select "Nebraska North" from the scrolling list and click [OK] to accept it. "Nebraska North" will be displayed in the text box beside the Zone button.

The default projection parameters, including the projection, datum, and ellipsoid, are displayed in other text fields. Detailed projection control fields can be viewed when the Projection Parameters check button is pushed in. These fields differ from projection to projection; for the Lambert Conformal Conic projection used with State Plane, these fields include the south and north standard parallels, the central meridian, the origin latitude, false easting and northing values, and scale factor. Click [OK] to accept the current values, and close the Coordinate System / Projection Parameters dialog.

The georeference process provides default Projection Parameters for each coordinate system and zone you select.

Vocabulary: a device for representing all or part of a rounded surface on a flat sheet is called a **projection**; projection parameters include the zone, datum, ellipsoid, orientation, and scale settings.

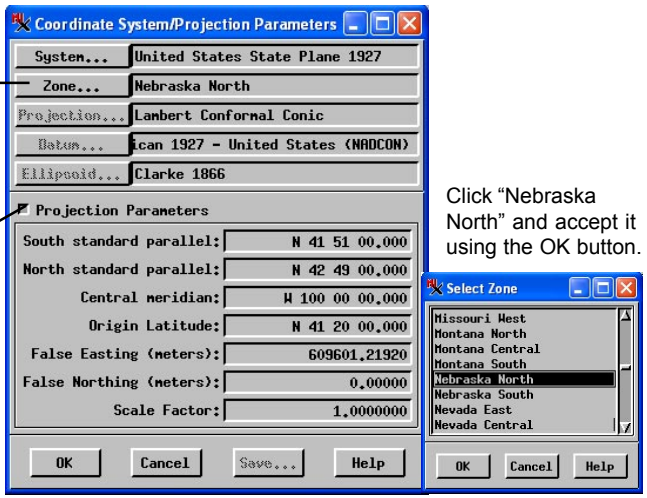
STEPS

- ☑ click [Zone...]
- ☑ select "Nebraska North" from the scrolling list
- ☑ click [OK] to accept the selected zone
- ☑ click [OK] to close the Coordinate System / Projection Parametrs dialog

Click [Zone...] to open the Zone Selection dialog.

The Projection Parameters toggle hides / shows the current parameter values.

Different sets of projection control fields are associated with different map projections.



Click "Nebraska North" and accept it using the OK button.

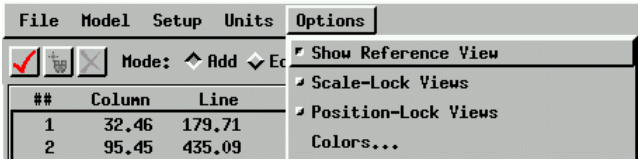
Georeference a Raster Using a Raster

STEPS

- ☑ remove the CB_DLG / ROADS reference object 
- ☑ turn on the Show Reference View toggle in the Options menu in the Georeference window
- ☑ click the Add Layer icon button and add _16BIT_BGR as the reference object 
- ☑ mark additional matching locations using the Crosshair tools 
- ☑ click the Apply icon button 

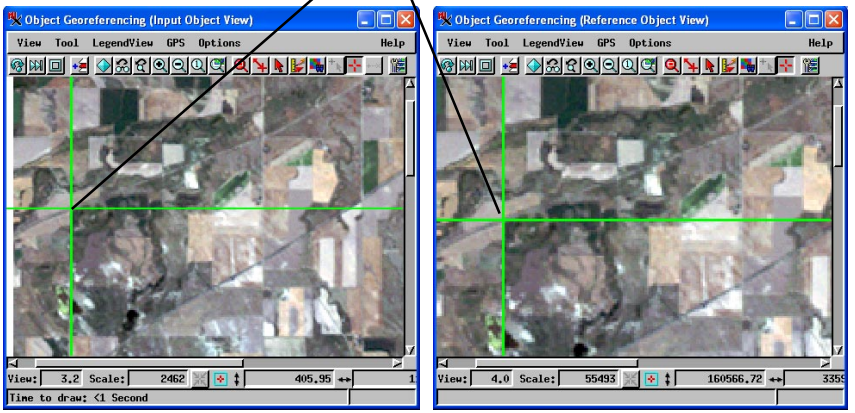
You can add control points using any type of georeferenced object as the reference object: raster, vector, CAD, or TIN. In this exercise we will add control points to the _16BIT_RGB georeference by using _16BIT_BGR as a reference object in a separate view.

Recall that to add new control points, the Add Mode radio button must be active. Remove the CB_DLG / ROADS reference layer and open a reference View window (go to the Options menu in the Georeference window and click the Show Reference View toggle). Add _16BIT_BGR as the reference object. Use the Crosshair tools in both views to mark matching features (see page 4). Click the Georeference window's Apply button (or click the right mouse button in a view window) to add new control points. You can adjust or delete a control point using the Edit Mode as described on page 7.



Open the Reference View window and add _16BIT_BGR as the reference object.

Select matching locations using the Crosshair tool.



The Raster / Raster Overlay View

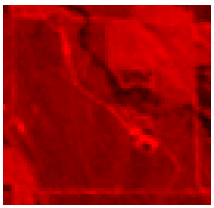
The georeference process lets you using two rasters in a single View window, automatically displaying them in complementary monochrome colors. The **input** raster displays in **red**-scale; the **reference** raster overlays in transparent **green**-scale, and the combined effect shows in yellow-scale. Where the images are misaligned, red and green fringes are visible along feature edges.

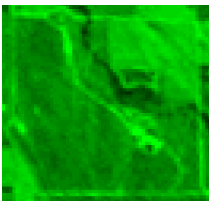
Close the Reference Object windows and add _16BIT_BGR as a reference layer to the Input Object window. The Georeference process automatically redisplays the two raster layers in the red/green monochrome mode. Scroll and zoom to view a feature edge that shows red or green fringing. Toggle the Hide/Show layer controls to be sure you understand the relative position of the **input / red** feature and the **reference / green** feature. After you draw a correlation tie point line (**from red to green**), click the Autocorrelate icon button in the Georeference window to automatically adjust the control point position.

STEPS

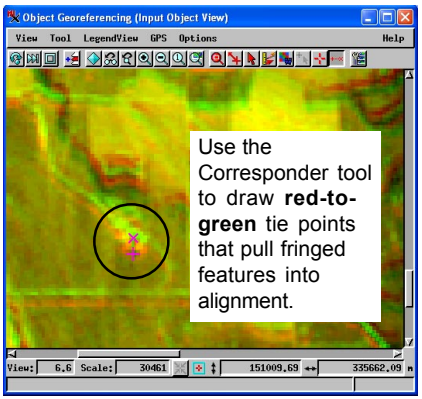
- ☑ make sure you have at least three control points and close the Reference Object windows
- ☑ Add _16BIT_BGR to the Input Object View window 
- ☑ toggle the Hide/Show layer controls to examine feature locations 
- ☑ select the corresponder tool and draw a new tiepoint line on mismatched features 
- ☑ click the Autocorrelate icon button to adjust the position of each endpoint 
- ☑ click the Apply button 

The input raster is displayed in red-scale.



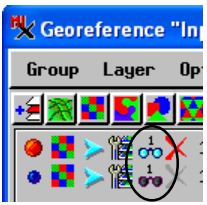


The reference raster overlay is displayed in green-scale.



When the two layers overlay correctly, the view shows the image in yellow-scale, with no red or green fringes.

The overlay view shows red and green fringing along feature edges when there is a spatial mis-match.



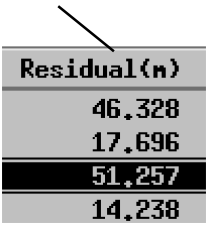
Toggle the show/hide layer controls to view one layer at a time to identify feature edges.

Minimizing Residuals

STEPS

- ☑ select Affine, Plane Projective, and Bilinear model options from the Model menu, and compare the residual values associated with each model and control point
- ☑ with the Edit Mode active, select a control point with a large residual value
- ☑ double check the control point placement, and edit the position if necessary
- ☑ click the Apply icon button and [Yes] on the Verify window, and notice the Residual values for the control points are adjusted to conform to the ideal grid
- ☑ click the Redraw Icon button to view the change on the View window

The units in which residual values are indicated in parenthesis in the title of the Residuals Column.



Accurate georeferencing is important in preparing your geospatial materials for quantitative analysis in TNTmips. While using any map projection selected, it is important to know how well the coordinates selected fit with the ideal grid. **Residuals** provide a measure of how well the control points match the ideal grid.

Residual values are the distances between the control points selected and the location of the control points predicted by the georeferencing model selected (or the deviation from the locations predicted by the model). If some values in the Residuals column in the Georeference window are much larger than most other residual values, it is an indication that the control points selected do not fit well with the model for the coordinate system. Choose any option from the Model menu to view the Residual values. In general, if the residual values are an order or more greater in magnitude than the cell size, your georeference control may need to be adjusted.

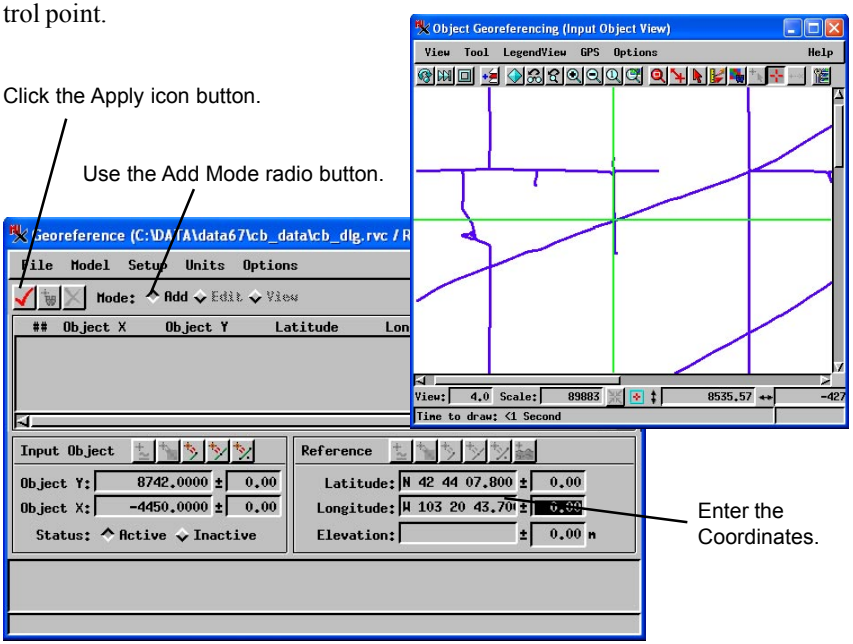
Note: Many kinds of project materials naturally have large residuals that should not necessarily be corrected by using estimated coordinates. Airphotos, for example, have systematic distortions of perspective and elevation so that even when control points are accurately placed, you get high residuals, especially as elevation and distance from the center of the photo increase. Keep correct control points and use that control in resampling or rectification processes to conform the geometry of the project materials to the map projection you want. (Refer to the tutorial booklet *Making DEMs and Orthoimages*)

Enter Known Coordinates

Another way to establish the georeference is by acquiring map coordinates from global positioning survey data, reference maps, or conventional land survey information. Simply locate the survey point's position using the mouse, and fill in the Coordinate values as described below. After you open the input object (in this example, the CB_DLG/ROADS vector object), click the Skip button on the Select Subobject dialog, activate the Add Mode radio button, and select the coordinate system used by your source of data in the Georeferencing Options dialog. Use the Crosshair tool and the Input Object View window to select the location by positioning the mouse cursor, and click the left mouse button at the desired location on the View window. Next enter the known Coordinate values (see illustration below) in the Reference numeric fields on the Georeference window. Then click the Apply icon button to accept the settings, and add the new control point.

STEPS

- ☑ use LITEDATA / CB_DATA / CB_DLG / ROADS as the input object
- ☑ click [Skip] on Select Subobject dialog
- ☑ activate the Add Mode radio button
- ☑ select a control point location using Crosshair tool on the Input Object View window 
- ☑ select Latitude / Longitude coordinates
- ☑ enter the coordinates in the Latitude, Longitude, and Elevation text fields
- ☑ click the Apply icon button 



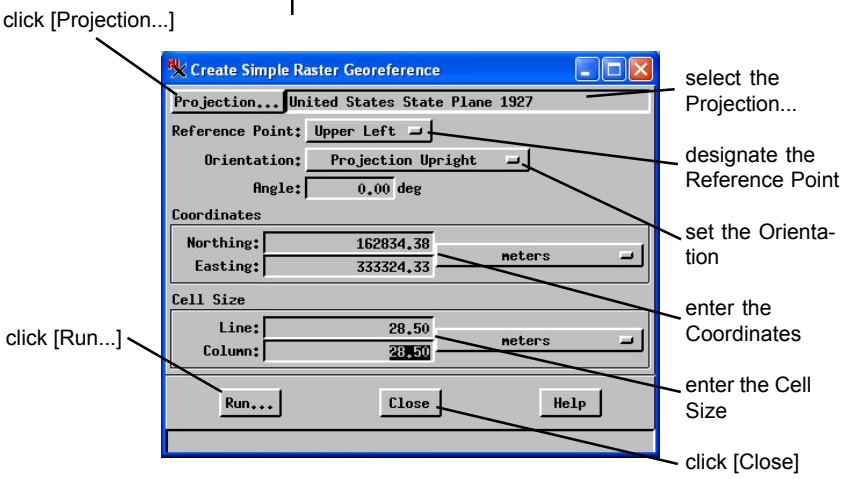
Simple Georeferencing

Use the Make Simple option to georeference rasters when you know the coordinate system, cell size, and coordinates for a corner or center location.

STEPS

- ☑ choose the Make Simple option from the File menu
- ☑ select the United States State Plane (1927) projection and Nebraska North zone
- ☑ assign the Reference Point location as shown below
- ☑ set the Orientation type, the Coordinates, and Cell Size values as shown below
- ☑ click [Run...] and select the LITEDATA / CB_DATA / CB_COMP / 16BIT_RGB raster object from the CB_DATA Project File
- ☑ click [Close]

You may know the coordinate system, cell size, and coordinates for a corner or central cell location from reference materials supplied by the source of your raster object. You may be able to determine such parameters using a reference map; you can select the Make Simple option on the main Georeference window to open the Create Simple Raster Georeference dialog. For this exercise, open that dialog, click the Projection button, and use the Coordinate System / Projection Parameters and associated windows to select the United States State Plane (1927) and the Nebraska North projection and zone. You can then create a simple georeference subobject if you select Upper Left as the Reference Point, select Projection Upright from the Orientation option menu, enter the coordinate values "162834.38" and "333324.33" in the Northing and Easting numeric fields, and type "28.5" in both Cell Size numeric fields. Then, click [Run...] and use the standard File / Object Selection process to select the CB_COMP / 16BIT_RGB raster object from LITEDATA / CB_DATA. When complete, the message line displays the message, "Georeference saved..." and the Simple Georeference subobject is saved. Then click the Close button.



What Next?

When you are satisfied with the correspondence of the input object with the reference materials, *always save your work before exiting the process*. When the georeference subobject has been saved, the text "Georeference Control Points Saved..." appears in the message line at the bottom of the Georeference window. The georeference control points, coordinates, and associated parameters specific to the selected coordinate system / map projection that you created are saved as a subobject for future use with the parent object. Select Exit from the File menu in the Georeference window to close the window and exit the Georeference process.

Refer to the *Georeferencing* section of the TNTmips reference manual for information on Make Implied georeferencing for vector, CAD, and TIN objects; reading from and saving as text files; georeferencing models; digitizing; using residuals; and other georeferencing options.

Learn more about selecting and using map projections in the TNT products with the companion tutorial booklet *Map Projections*.

Each object in your project materials needs only one georeference subobject. If you create an additional georeference subobject, you should delete any older georeference subobjects and thereby prevent subsequent confusion about which one is the "good" one.

STEPS

- ☑ select Save from the File menu
- ☑ use the standard File / Object Selection process to designate a name and description for the georeference subobject you have created
- ☑ select the Exit option from the File menu to close the Georeference window and exit the Georeference process

Other References

Cromley, Robert G. (1992) *Digital Cartography*, New Jersey, Prentice-Hall, Inc. pp. 10-18.

U.S. Geological Survey, (1987). *Map Projections — A Working Manual, U.S. Geological Survey Professional Paper 1395,* Washington, DC, U.S. Government Printing Office.

Wolberg, George (1990). *Digital Image Warping*, Los Alamitos, California: IEEE Computer Society Press. 318 pp.

Wolf, Paul R. (1983). ***Elements of Photogrammetry***, Second Edition. New York: McGraw-Hill. pp. 597-601.

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TNTlite TNTlite is a free version of TNTmips, TNTedit, and TNTview for students and professionals with small projects. You can download TNTlite for your computer (about 100MB) from MicroImages' web site, or you can order TNTlite on CD-ROM (shipping charges apply).

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