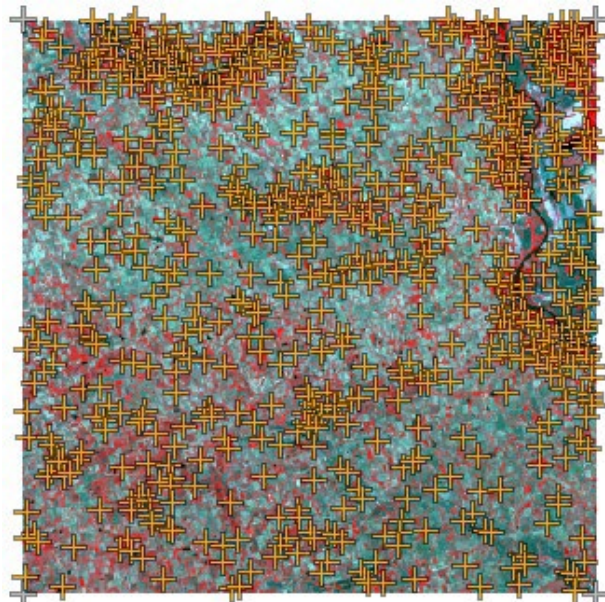


Auto-Register to Reference Image

Creating georeference control points manually for a large aerial or satellite image to improve its registration to reference geodata can be a time-consuming task. The Georeference process in TNTmips (Main / Georeference) provides an Auto-Register operation that can automatically generate hundreds to thousands of control points for an input image using a reference image of the same area. This operation lets you set a maximum residual value to accept for individual control points and the desired minimum spacing between points. The reference image you use does not have to match the cell size, coordinate reference system, or extents of the input image. For accurate results you should use a reference image with spatial resolution equal to or better than that of the input. The reference image can be a single grayscale raster, an RGB display of separate image bands, or a color-composite raster. It can reside in a TNTgis Project File, any image file format supported for direct use (GeoTIFF, GeoJP2, ...), or in a standard web tileset structure (Google Maps, Google Earth, or Bing Maps) on your local network or on the web. You can specify one or more pairs of input and reference bands or color-composite components to use to auto-register the images. You can also select a geometric object containing desired control point map locations to guide the operation. The control points produced are automatically shown in the georeference views and in the control point list at the completion of the operation. Lens distortion in aerial camera images should be removed in the Lens Correction process (Image / Resample and Reproject / Lens Correction) before using them in the Auto-Register operation.



The illustration above shows a SPOT satellite image scene (4-bands, with color-infrared combination shown) in the Georeference Input View with 800 control points (orange) generated automatically from a reference natural-color orthoimage (shown and described below) using the Auto-Register procedure in the Georeference process. All of the auto-generated control points have residuals less than two image cells. This scene is 6000 columns by 6000 lines in size with 10-meter cell size and shows an area in southeastern Nebraska. The inactive control points at the image corners (gray) are derived from the nominal georeference control provided with the SPOT scene, which in this example offsets image features 200 to 300 meters from their correct locations (see illustrations below). The control points are listed in the Georeference window illustrated to the left.

(continued)

Auto-Register

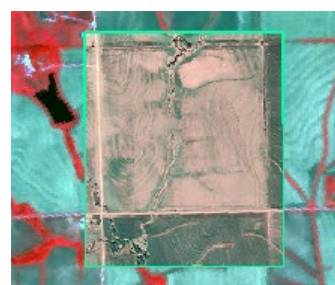
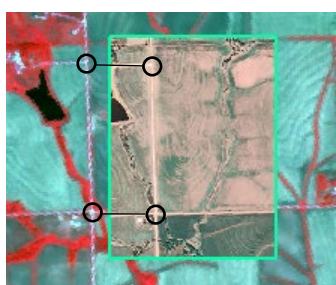
ID	Column	Row	Easting	Northing	Longitude
1	1,00	1,00	715821,17	4552262,38	N 96 25 49,10 N 41
2	6000,00	1,00	776619,49	4539788,29	N 95 42 46,84 N 40
3	6000,00	6000,00	764574,10	4480963,71	N 95 52 50,66 N 40
4	1,00	6000,00	703805,74	4493520,91	N 96 35 32,83 N 40
5	724,92	13,95	723301,40	4550592,11	N 96 20 30,98 N 41
6	930,80	81,19	725265,60	4549493,37	N 96 19 08,34 N 41
7	1128,35	83,66	727284,70	4549052,27	N 96 17 42,51 N 41
8	1167,78	5,98	727845,90	4549725,95	N 96 17 17,59 N 41
9	1465,87	83,50	730737,30	4548346,51	N 96 15 15,70 N 41
10	2567,99	55,09	742010,10	4546333,49	N 96 07 16,21 N 41
11	2997,40	74,82	746328,90	4545242,77	N 96 04 13,06 N 41
12	3809,92	90,34	754502,90	4543422,23	N 95 58 26,24 N 41

804 Control Points: 800 Enabled; 4 Disabled
 Cell Size (meters): X = 10,3363 Y = 10,0021
 Projection Angle: -11,6328 North Angle: -9,7714
 RMS Residual (Enabled, cells): X = 0,64 Y = 0,60 XY = 0,88
 RMS Residual (Disabled, cells): X = 6,29 Y = 0,90 XY = 6,36
 Mean Absolute Residual (Enabled, cells): X = 0,49 Y = 0,44
 Mean Absolute Residual (Disabled, cells): X = 5,77 Y = 0,90



The reference image used for the auto-register operation for this example (left) is a color-composite mosaic of 1-meter resolution orthoimages downsampled to 4-meter cell size, with dimensions 33,562 columns by 24,908 lines. The locations of the original corner control points of the SPOT scene are shown in black. The green-light band of the SPOT image and green color component of the reference composite were used for auto-registration.

The overall Root Mean Square XY residual for the 800 control points generated by auto-register is 0.88 cell.



Close-ups of View-In-View overlays of the SPOT scene (outside green box) and the reference orthoimage (inside green box). Left illustration shows the SPOT scene with its original nominal georeference; linked black circles indicate corresponding ground features offset by about 300 meters. Right illustration shows excellent registration of the SPOT scene with the control points generated by auto-register.

Batch auto-registration of images is available in the Image / Auto-Register to Reference process. See the Technical Guide *Batch Automatic Image Georeferencing*.

Before starting Auto-Register, the input image must have sufficient initial georeference to allow approximate spatial registration between the input and reference images. This initial georeference might be corner control points automatically read from the nominal georeference provided with a satellite image, a few points you place manually, or a GPS location (read automatically from EXIF metadata) that specifies the camera location (but not the orientation) for an aerial image. You should also choose the Coordinate Reference System (CRS) to which to georeference the image; the selected CRS need not be the same as the reference image's CRS.

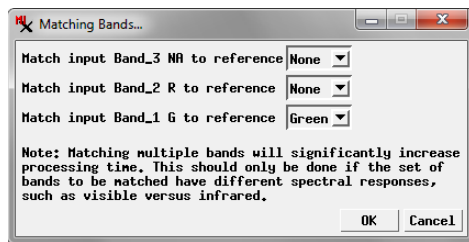
In the Auto-Register example illustrated on the previous page, the input 4-band SPOT 5 image and the the natural-color composite reference image have two pairs of bands/components in common: the SPOT Band_2 (red spectral band) spectrally matches the Red component of the reference composite, and SPOT Band_1 (green spectral band) spectrally matches the Green component of the reference composite (shown by the black bars below). In this example, the latter (green) pair was used for auto-registration.

Spectral Band	SPOT 5 Image	Reference
Blue		Blue
Green	Band_1	Green
Red	Band_2	Red
Near-Infrared	Band_3	
Mid-Infrared	Band_4	

Starting the Auto-Register Operation

The Auto-Register operation is launched from an icon button on the Georeference window's toolbar or from the File menu. If you have not already designated a reference image, you are prompted to select one. You can choose a grayscale image, color composite, or an RGB set of separate image bands. If either of the images has multiple bands or components, the Matching Bands window (illustrated below) opens so you can specify which of the displayed input band(s) or component(s) to match to which reference band(s) or component(s). This window lists each of the input bands or components and for each provides a menu from which you can choose a reference component or band, or None. The matching bands you designate should have similar spectral properties (see box above for an example).

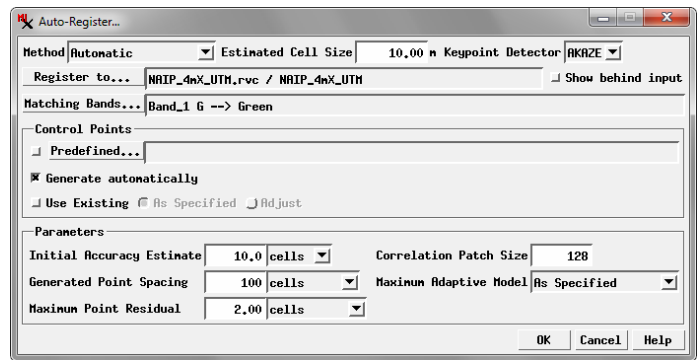
The Matching Bands window lets you designate one or more pairs of input and reference bands that have similar spectral properties.



A single matching pair of bands is usually sufficient to provide accurate control points. Using multiple pairs increases processing time and would only provide a benefit if the two matching pairs have significantly different spectral properties, such as a pair of green bands and a pair of infrared bands.

Auto-Registration Methods

After the matching bands are designated, the Auto-Register window opens to allow setting other parameters for the operation. The Method menu provides a choice of matching methods



utilizing keypoint matching and/or cross-correlation.

Keypoint matching is primarily used for finding the correct orientation and approximate position of aerial images that have been geolocated with a single GPS position but that do not have a known orientation. It finds and matches distinctive image features, called keypoints, in the input and reference images, using one of two options selected from the Keypoint Detector menu. For registration methods that involve keypoint matching you must also enter a value in the Estimated Cell Size field to establish the scale relationship between the input and reference images. Keypoint matching can only be applied when using a local reference image. See the Technical Guide entitled *Keypoint Matching for Image Registration* for a further explanation of this technique.

The *Cross-Correlation* technique performs local spatial image correlations on corresponding patches of the input and reference image to identify locations as candidate control points. Candidate points are identified and evaluated iteratively at different image resolutions to produce the final set of points with residual values that fall below your specified maximum value. The input image must be at least approximately located and oriented by multiple control points before the correlations are performed.

MicroImages has found that cross-correlation can produce a denser and more uniform distribution of control points than keypoint matching, thus it is the preferred technique for input images that are already properly oriented. For low-altitude aerial images of non-urban areas, matching keypoints may be clustered in certain portions of the input image where high-contrast features (roads, buildings, trees) are present (see illustration on the next page). Cross-correlation does a better job of finding image matches in lower-contrast areas. For geolocated aerial images with unknown orientation, the Auto-Register operation can use a combination of keypoint matching and cross-correlation to create a well-distributed set of georeference control points.

Automatic Method: this method adapts to the starting georeference status. If the input image has sufficient georeference control to establish its approximate location and orientation, cross-correlation alone is used to generate additional control points. If the input image is only geolocated with a single GPS location, keypoint matching at a reduced-resolution is first applied to establish the image orientation and provide an initial set of control points, then cross-correlation is applied to generate additional control points.

(continued)

Cross-Correlation Method: applies the image correlation technique to images that have sufficient georeference control to establish the image orientation. Otherwise, it operates as in the Automatic Method, applying keypoint matching at a reduced resolution first to establish the image orientation.

Auto-Register Georeference Results for a Geolocated Aerial Image (with Initial Orientation Unknown) by Different Methods



Estimate from Single Point (keypoint matching on reduced-resolution pyramid tier): 27 control points.



Keypoint Matching (on full-resolution image): 57 control points.



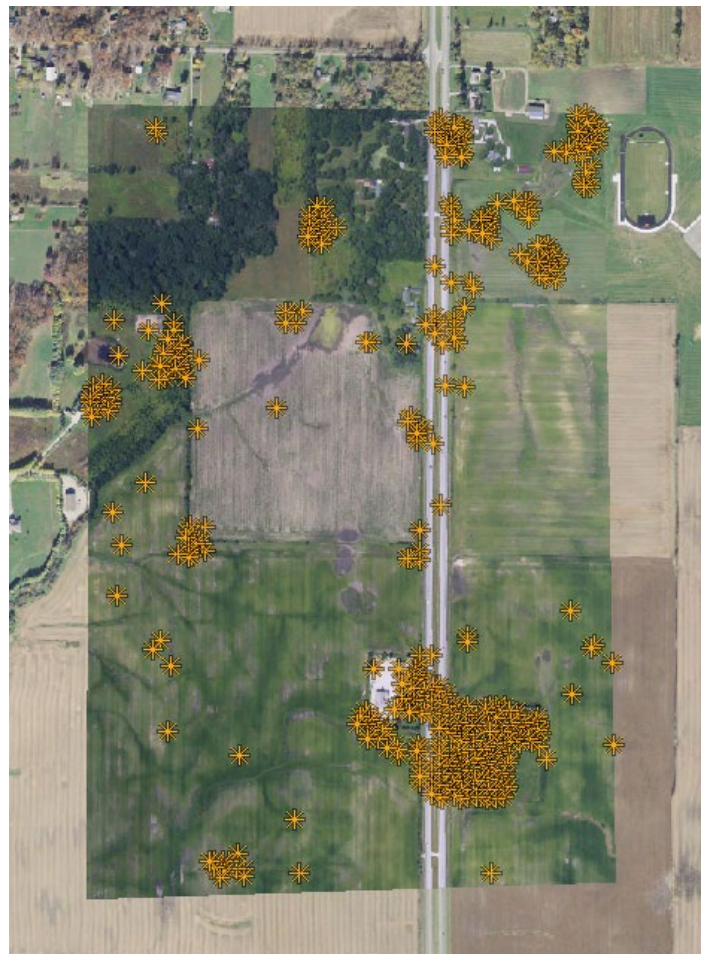
Automatic (keypoint matching on reduced-resolution pyramid tier followed by cross-correlation): 512 control points.

Keypoint Matching Method: performs keypoint matching at the highest common resolution of the input and reference image to find control points. This method is provided in case the reduced-resolution key point matching in the Automatic method fails to find sufficient keypoints to allow the second cross-correlation stage of the operation to proceed. Cross-correlation may then be applied to the result of the full keypoint matching step.

Estimate from Single Point: performs keypoint matching on the reduced resolution pyramid tier closest to the resolution of the reference image. This method is identical to the first stage of the Automatic method, and is provided as an investigative option if the Automatic method fails to find sufficient control points.

You can press the *Register to* pushbutton select a different reference raster; the file and object name of the selected raster are shown in the field to the right of the button. Press the *Matching Bands* pushbutton to reopen the Matching Bands window to change the assignment of matching bands/color components.

Turn on the *Show behind input* toggle button to have the reference raster automatically shown beneath the input image in the Georeference Input View window after the Auto-Register operation has completed.

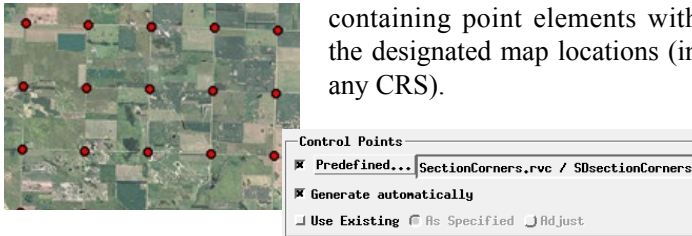


Auto-Register result using the Automatic method for the geolocated aerial image illustrated to the left, shown here overlaying the reference orthoimage with grid north at the top.

(continued)

Control Point Generation Options

The Control Points panel on the Auto-Register window lets you set options for generating control points. There are toggles for the options to generate control points automatically and to use a predefined set of control point locations to designate candidate locations (see illustration below). You can use either of these options alone or in combination. For the predefined point option you must choose an accurately georeferenced geometric object (vector, shape, or CAD) containing point elements with the designated map locations (in any CRS).



Display of section corner points (red symbols) from the US Public Lands Survey System, many of which correspond to section-line road intersections in much of the midwestern United States. A geometric object containing these corner points optionally can be used to designate predefined candidate locations for recognizable control points in auto-registering images from this region.

The *Use Existing* toggle button sets whether to keep pre-existing control points enabled in the final list or to automatically disable them, so that the final residual model and statistics are computed only from the auto-generated control points. Initial control points derived from nominal georeference provided with an image are likely to be much less accurate than the points found by auto-register, so it is advisable not to turn on the *Use Existing* option in this case. However, if you have manually placed accurate initial points from the reference or from GPS waypoints, you may want to keep them enabled after auto-register is complete. In that event, the radio buttons next to the *Use Existing* toggle set whether to keep the specified image coordinates for the existing points or to adjust the image coordinates in accordance with the new residual model.

Auto-Register Parameters

The following settings in the Parameters box apply to the

cross-correlation matching technique used in the Automatic and Cross-Correlation matching methods.

Initial Accuracy Estimate: this is an estimate of the typical spatial offset between input image features and their positions in the reference image. You can determine this manually by overlaying the input and reference image and measuring it, or use the nominal accuracy values for the image sensor type determined by the imagery provider. Setting a value much in excess of the actual accuracy can prevent auto-register from finding corresponding points.

Generated Point Spacing: the minimum spacing you would like between the generated control points. Smaller values will typically result in more control points being generated. Generating a large number of points (1000 or more) for medium and large satellite sensor images is beneficial in that a large number of accurate points in the residual model can dilute the effect of potentially less accurate points.

Maximum Point Residual: the maximum RMS residual value for accepting an auto-register control point. Candidate points with higher residual values are rejected. This parameter thus is a major control on the number of control points that are generated and their locations. Areas of an image with significant geometric distortion due to relief displacement will generate control points with higher residuals. A low maximum residual setting may result in rejection of all candidate points in these problem areas.

Correlation Patch Size: the size in cells of the square image neighborhoods used in each image to search for control points. The default setting (128 cells wide) is appropriate for medium to large images; a larger patch size significantly increases processing time.

Maximum Adaptive Model: you can choose to allow the auto-registration operation to try different residual models to evaluate the quality of the candidate control points. This menu lets you pick the highest-order model to allow or choose the *As Specified* option to use only the residual model you have set. If you allow, auto-register will switch to a higher order model if the resulting RMS residual is less than half that of the previous model.

