Registration Controls

The Registration Controls are found in the left hand column of the Register Module Interface.

Register Type

Register Type indicates the current dimensionality mode; 2-D, 3-D, or 4-D. This is set automatically by Register and is dependent upon the data selected. Choosing two single 2D slices or a single 3D volume will open the Register in 2-D mode, selecting two 3D volumes will open Register in 3-D mode. Note, if multivolumes are selected, additional volume controls became available under 3-D mode. See Volumes for additional information. The Register algorithm is selectable and users can choose between Surface Alignment or Mutual Information.

Surface Alignment

Surface alignment, also referred to as surface matching, is a geometry-based registration method. Surface alignment is fast and robust, even in the presence of image noise and incomplete overlap of the input image volumes.

Surface alignment tries to maximize the overlap between corresponding surfaces extracted from two image inputs. To use surface alignment both input volumes must contain common objects which need be explicitly segmented from the grayscale image data, for example the brain from an MRI data set saved as either a grayscale or binary image prior to use in Register.

Alternatively, if the object is segmentable via thresholding (e.g. the brain from a SPECT image,) a surface can be defined interactively within Register using the threshold controls.
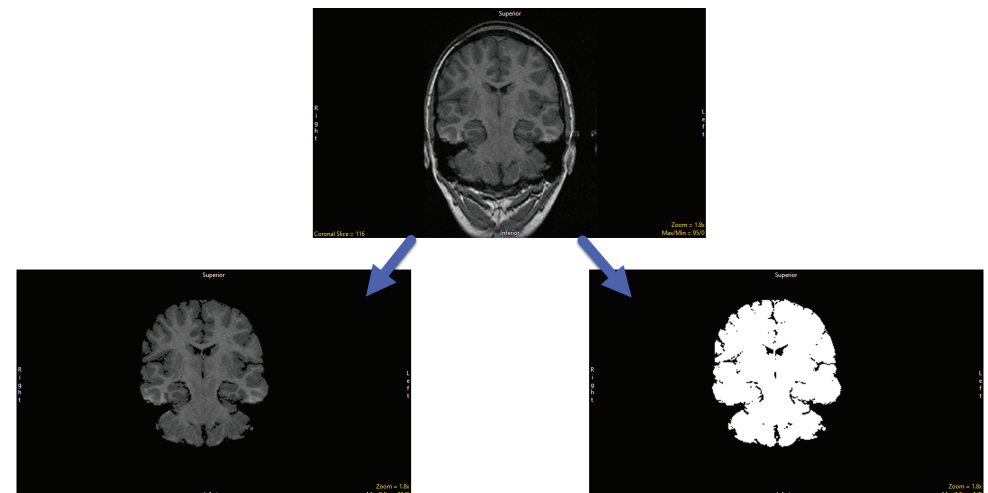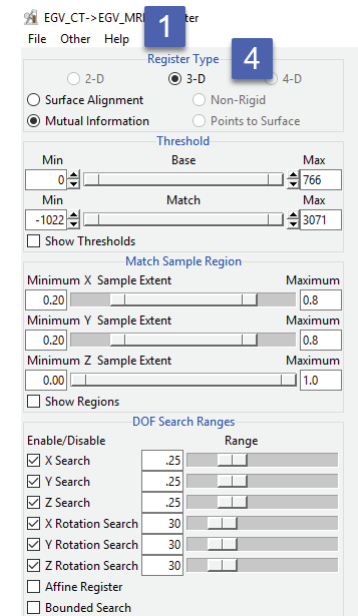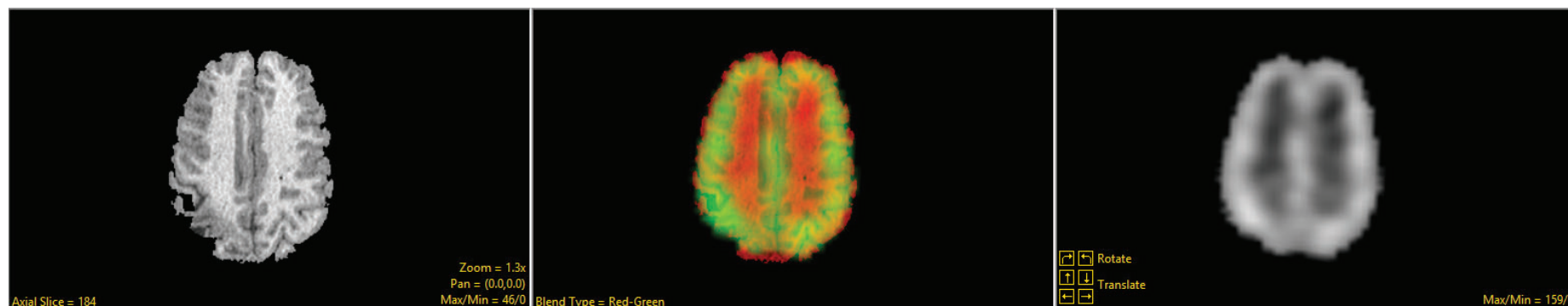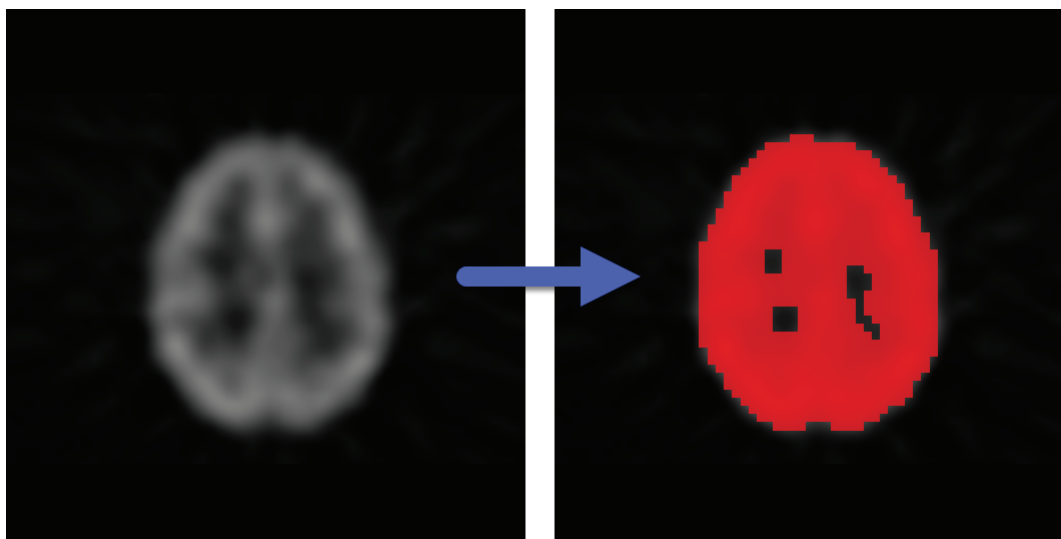
Registration Controls (continued)

A surface is extracted from both the base object (base image) and the match object (match image). The base object is used to create a chamfer distance volume. This is a volume in which each voxel has a value equal to the number of single-voxel steps from that coordinate to the nearest point on the base surface. Surface points are defined as any non-zero-valued voxel with at least one zero-valued orthogonal neighbor in 3-D space.

For the match object surface points are defined as any non-zero-valued pixel with at least one zero-valued orthogonal neighbor within the same slice. To evaluate the error at any orientation, the coordinates of the selected 'match surface' points are transformed into the space of the base image, and the chamfer volume voxel values at those coordinates are summed. If all the match surface coordinates land on the base surface, the sum is zero. The minima search algorithm is a variant of simulated annealing which searches for minima at randomly determined multiple starting orientations, researching promising minima at successively higher resolution until a best minima is found.
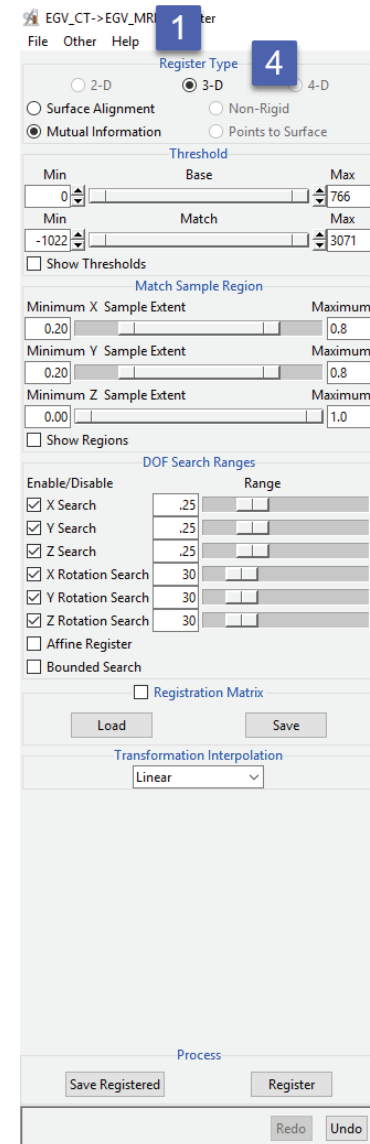
Registration Controls (continued)

Mutual information registration is proven to be effective for registering image data from different modalities. Mutual information seeks to align voxels whose values have common probabilities of being present in their respective image sets.

There are two components of the registration paradigm in Analyze:

1. The cost function used as the metric to judge when the volumes are in register.

2. The multiresolution search strategy used to find the global optimum of the cost function.

The mutual Information cost function is based on the individual and joint entropy measured from the voxel values in the base and match volumes. There needs to be enough overlap and mutually shared signal from common structures for a relationship to be found between the two volumes and for them to be successfully co-registered.

The mutual information algorithm determines the geometric transformation parameters used to spatially register the input data. The transformation parameters include both translation and rotation and scaling and shearing if enabled. The parameters are output in a homogeneous 4x4 matrix file. Image registration is achieved by transforming a volume using the transformation matrix.

Registration Controls > 2D

2D registration determines the geometric transformation parameters to be used to align 2D images, slice-by-slice or matching a series of slices to a single base slice.

Unregistered stack of 2D images   Registered stack of 2D images
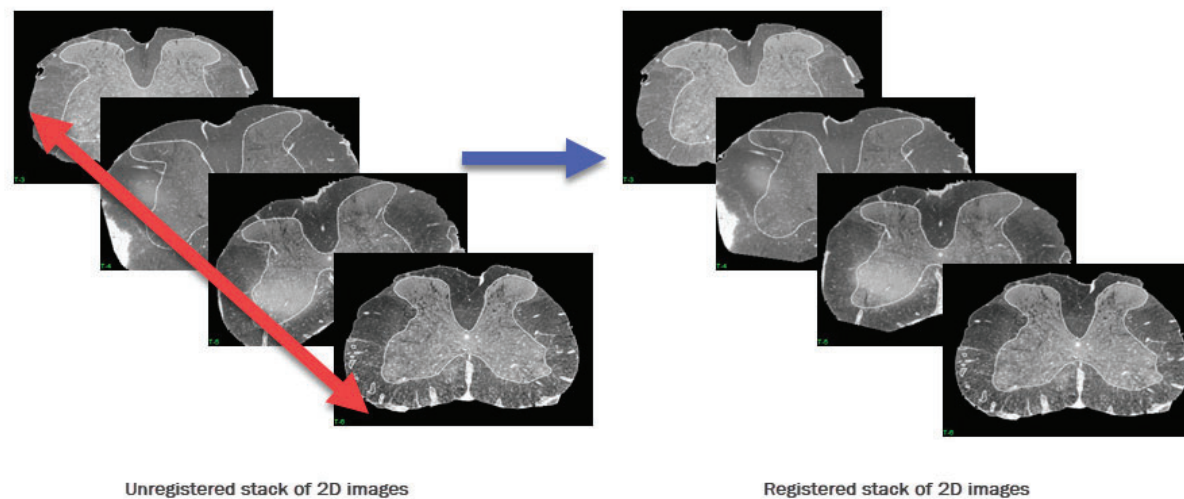
The following options are enabled/available with 2D registration:

2-D: The 2-D dimension mode is enabled when two 2D slices or a single 3D volume are loaded into Register.

Surface Alignment: Enables surface matching registration. The following options are available:

• **Threshold:** The Threshold double-ended slider bars for both the Base and Match data allows the end user to specify a range of threshold values to isolate common surfaces between the input images. Note, if common surfaces are not segmentable via thresholding the input data will need to be segmented prior to registration.

  · Base: The base threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slide for the base input data.

Registration Controls > 2D (continued)

2-D > Surface Alignment > Threshold (continued):

· Match: The match threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slide for the match input data.

- **Show Thresholds:** When enabled displays a filled preview of the minimum/maximum threshold value set for base and match input data.

Registration Matrix: When enabled displays the 4 by 4 transformation matrix.

- **Load:** Load a matrix file (*.mat file) for the match data set.

- **Save:** Save the current matrix file.

Transformation Interpolation: The transformation interpolation option allows users to specify the interpolation type to be used when transforming the match data set. Users can choose from:

- **Nearest Neighbor:** Allows users to select the nearest neighbor option for interpolation. Nearest Neighbor works by selecting the value of the closest voxel to which the interpolation resampling maps. This interpolation option is generally the fastest of the four available interpolation options.

- **Linear:** Allows users to select the linear option for interpolation. The linear algorithm applies a linear interpolation of grayscale intensity based on the distance of neighboring voxels from the interpolated voxel.

- **Bicubic:** Bicubic is the default interpolation option. The Bicubic option uses a cubic spline function to determine interpolated value, resulting in a smoother image that preserves detail.

- **Windowed Sinc:** Allows users to select the Windowed Sinc option for interpolation. The algorithm uses the windowed sinc function $\sin(x)/x$ to determine the interpolated value.

Registration Controls > 2D (continued)

Slices: This option is only available when a single 3D volume is selected for input for 2D registration. The slices sliders allow users to navigate through the base and match inputs.

- **Base:** The base slider controls the display of the base slice. This will also be the 2D slice used for registration.

- **Match:** The match slider controls the display of the match slice. This will be the slice registered to the base for single Matrix and Single Reference registration. See Process and Registration mode for information on other registration options.

Process: The process controls allow users to register and save registration result, the following options are available.

- **Save Registered:** Allows users to save the transformed match image, the fused image, or the transformed object map (if applicable). See File > Save Registered at the being of this module section for a full description of the save options.

- **Register:** Initiates the slice-to-slice registration.

- **Register Pairs:** Only available when a single 3D volume is loaded. The register pairs option registered the current match slice to the current base slice. To adjust the select of the base or match slice input use the Slices sliders.

- **Match Range:** Only available when a single 3D volume is loaded. The match range slider allows users to specify a range of 2D match images to be registered to the base image.

Register Mode: Only available when a single 3D volume is loaded. The registration mode allows users to select from the following options:

- **Single Matrix:** The single matrix option applies the transformation matrix created when registering the currently displayed match data set to the displayed base data to the range of match images selected using the match range slider. All images in the match range are transformed to the same single matrix.
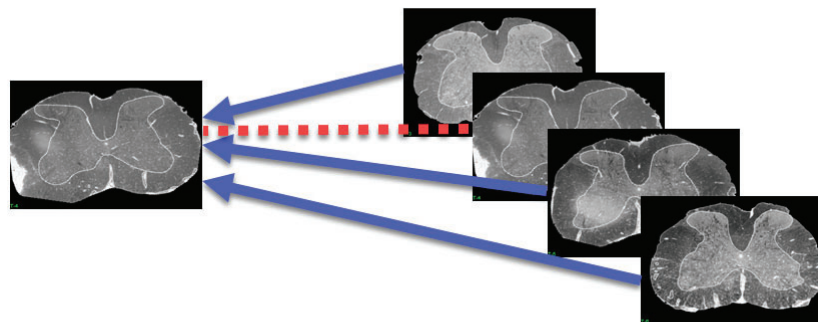
Registration Controls > 2D (continued)

Register Mode > Single Matrix (continued):
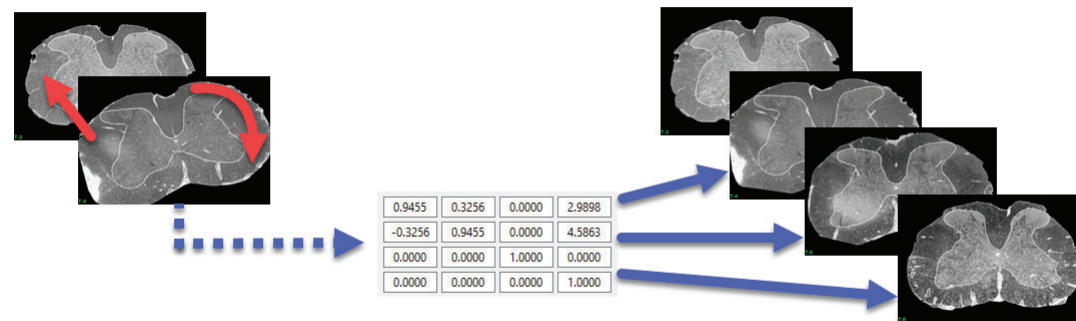
Single Matrix - the same transformation matrix is applied to all slices.

- **Single Reference:** The single reference option registers each of the match images specified in the match range, individually to the base image.
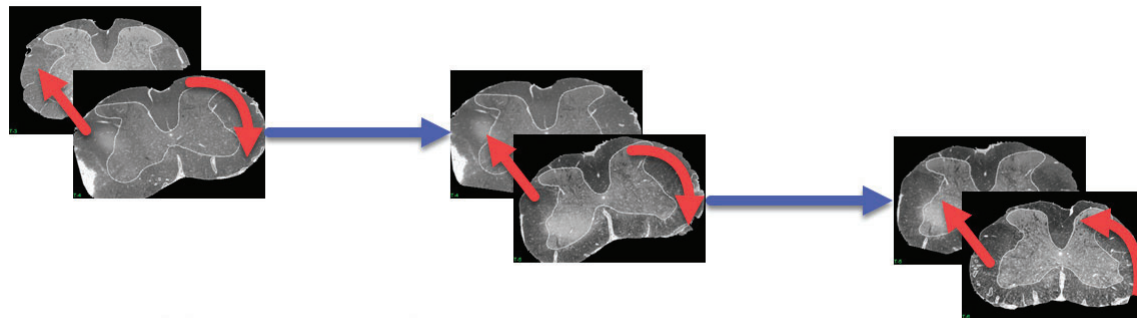

Single Reference - each slice is registered to a single base slice.

Registration Controls > 2D (continued)

Register Mode (continued):

- **Sequential:** Performs a sequential match image to base image registration within the specified match range. For example, match image 2 to base image 1, then match image 3 to based image 2, etc.

Sequential - each slice is registered sequential to its neighbor.

- **Register Sequence:** Only available for the single reference and sequential register modes. When selected initiates registration.

Redo: Reverses your last undo action. Redo is only available after using Undo.

**Undo:** Reverses you last action. Can reverse more than one action.

Registration Controls > 2D (continued)

Mutual Information enables mutual information-based registration. The following options are available:

- **Threshold:** The Threshold double-ended slider bars for both the Base and Match data allows the end user to specify a range of threshold values to consider for registration. The use of thresholding with mutual information-based registration is normally to remove background noise, artifact from implants, or other ranges of greyscale values from the data that could interfere with registration.

  · Base: The base threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slide for the base input data.
  · Match: The match threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slide for the match input data.

- **Show Thresholds:** When enabled displays a filled preview of the minimum or maximum threshold value set for base and match input data.

Match Sample Region: The match sample region slides allow users to increase or decrease the sampling density in the X, Y, and Z (if applicable).

- **Minimum X Sample Extent:** Use the slider to specify the x sampling density. Decreasing the x minimum value and increasing the x maximum value will increase the minimum x sample range [1]. Increasing the x minimum value and decreasing the x maximum value will decrease the minimum x sample range [2].
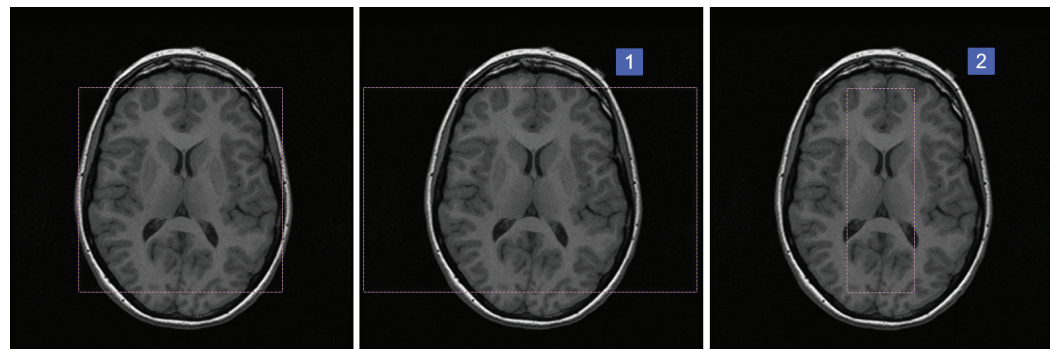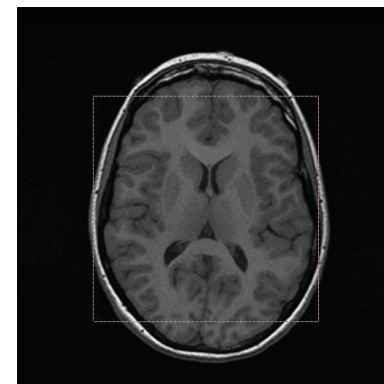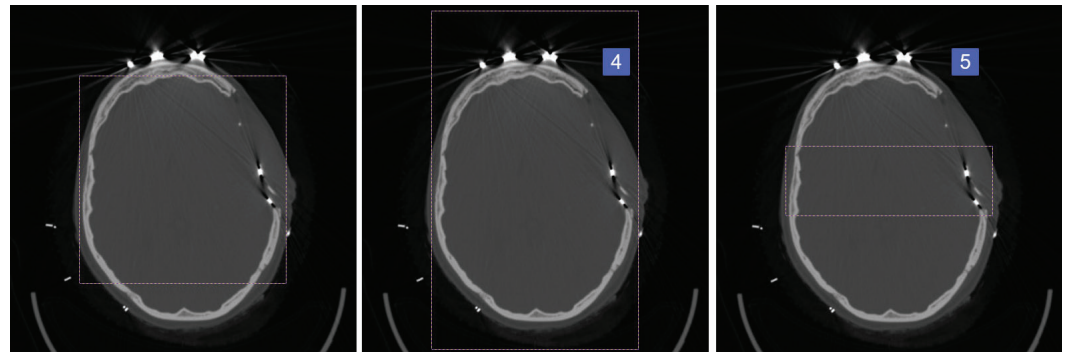
Registration Controls > 2D (continued)

Match Sample Region (continued):

The minimum and maximum values can also be adjusted to select a specific x region or exclude a region that could interfere with registration [3].

- **Y Sample Extent:** As with the minimum X sample extent, users can use the minimum Y sample extent slider to specify the minimum y sampling density. Decreasing the y minimum value and increasing the y maximum value will increase the minimum y sample range [4]. Increasing the y minimum value and decreasing the y maximum value will decrease the minimum y sample range [5]. The minimum and maximum values can also be adjusted to select a specific y region or exclude a region that could interfere with registration.

- **Z Sample Extent:** Use the slider to specify the z sampling density.

- **Show Region:** Enables the display of the sample extent on the match image, showing the region as a purple and white dashed box.
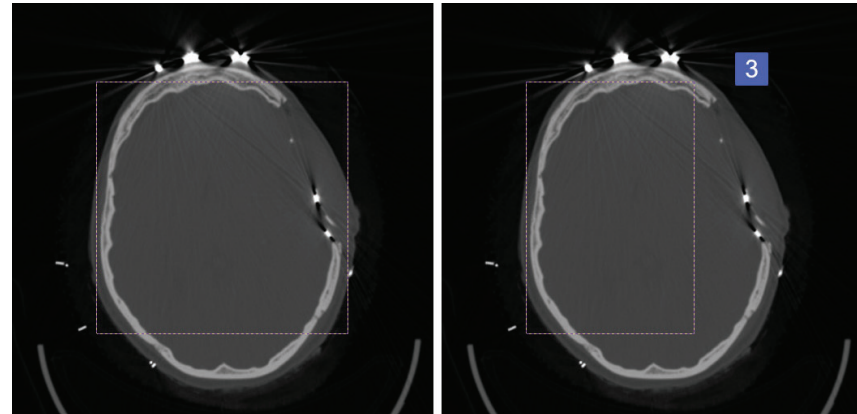
Registration Controls > 2D (continued)

DOF Search Ranges: The Degrees Of Freedom (DOF) search range allows users to adjust the default parameters set for registration.

- **X Search:** Allows users to adjust the maximum expected horizontal displacement (in either direction) of the match image in pixels.

- **Y Search:** Allows users to adjust the maximum expected vertical displacement (in either direction) of the match image in pixels.

- **Z Rotation Search:** Allows users to adjust the maximum expected rotation of the match image in degrees.

- **Affine Register:** Allows users to enable affine registration providing access to X and Y scale and shear search options:

    - **X Scale Search:** Adjust the maximum expected horizontal scaling difference between the match and base images
    - **Y Scale Search:** Adjust the maximum expected vertical scaling difference between the match and base images
    - **X Shear in Y Search:** Adjust the level of x shear in the y search.
    - **Y Shear in X Search:** Adjust the level of y shear in the x search.

- **Bounded Search:** Limits the total number of search steps. The registration algorithm, while robust in most cases, can fail to converge in extremely low-information situations. This option avoids program hang-up in those situations, and seldom significantly affects typical solutions.

Registration Matrix: When enabled displays the 4 by 4 transformation matrix.

- **Load:** Load a matrix file (*.mat file) for the match data set.
- **Save:** Save the current matrix file.

Transformation Interpolation: The transformation interpolation option allows users to specify the interpolation type to be used when transforming the match data set. Users can choose from:

- **Nearest Neighbor:** Allows users to select the nearest neighbor option for interpolation. Nearest Neighbor works by selecting the value of the closest voxel to which the interpolation resampling maps. This interpolation option is generally the fastest of the four available interpolation options.

Registration Controls > 2D (continued)

Transformation Interpolation (continued):

- **Linear:** Allows users to select the linear option for interpolation. The linear algorithm applies a linear interpolation of grayscale intensity based on the distance of neighboring voxels from the interpolated voxel.
- **Bicubic:** Bicubic is the default interpolation option. The Bicubic option uses a cubic spline function to determine interpolated value, resulting in a smoother image that preserves detail.
- **Windowed Sinc:** Allows users to select the Windowed Sinc option for interpolation. The algorithm uses the windowed sinc function sin(x)/x to determine the interpolated value.

Slices: This option is only available when a single 3D volume is selected for input for 2D registration. The slices sliders allow users to navigate through the base and match inputs.

- **Base:** The base slider controls the display of the base slice. This will also be the 2D slice used for registration.
- **Match:** The match slider controls the display of the match slice. This will be the slice registered to the base for single Matrix and Single Reference registration. See Process and Registration mode for information on other registration options.

Process: The process controls allow users to register and save registration result, the following options are available.

- **Save Registered:** Allows users to save the transformed match image, the fused image, or the transformed object map (if applicable). See File > Save Registered at the being of this module section for a full description of the save options.
- **Register:** Initiates the slice-to-slice registration.
- **Register Pairs:** Only available when a single 3D volume is loaded. The register pairs option registered the current match slice to the current base slice. To adjust the select of the base or match slice input use the Slices sliders.
- **Match Range:** Only available when a single 3D volume is loaded. The match range slider allows users to specify a range of 2D match images to be registered to the base image.

Register Mode: Only available when a single 3D volume is loaded. The registration mode allows users to select from the following options:

- **Single Matrix:** Applies the transformation matrix created when registering the displayed match data set to the displayed base data to the images selected using the match range slider. All images in the match range are transformed to the same single matrix.

Registration Controls > 2D (continued)

Register Mode (continued):

- · **Single Reference:** This option registers each of the match images specified in the match range, individually to the base image.
- · **Sequential:** Performs a sequential match image to base image registration within the specified match range. For example, match image 2 to base image 1, then match image 3 to based image 2, etc.
- · **Register Sequence:** Only available for the single reference and sequential register modes. When selected initiates registration.

Redo: Reverses your last undo action. Redo is only available after using Undo.

Undo: Reverses you last action. Can reverse more than one action.

Registration Controls > 3D

The 3-D dimension mode is enabled when two 3D volumes or one or more multivolumes (4D data sets) are loaded into Register.

Surface Alignment: Enables 3D surface matching registration. The following options are available:

- • **Threshold:** The Threshold double-ended slider bars for both the Base and Match data allows the end user to specify a range of threshold values to isolate common surfaces between the input images. Note, if common surfaces are not segmentable via thresholding the input data will need to be segmented prior to registration.
  - · **Base:** The base threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slide for the base input data.
  - · **Match:** The match threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slide for the match input data.

Show Thresholds: When enabled displays a filled preview of the minimum or maximum threshold value set for base and match input data.

Registration Controls > 3D (continued)

Registration Matrix: When enabled displays the 4 by 4 transformation matrix.

- **Load:** Load a matrix file (*.mat file) for the match data set.
- **Save:** Save the current matrix file.

Transformation Interpolation: The transformation interpolation option allows users to specify the interpolation type to be used when transforming the match data set. Users can choose from:

- **Nearest Neighbor:** Allows users to select the nearest neighbor option for interpolation. Nearest Neighbor works by selecting the value of the closest voxel to which the interpolation resampling maps. This interpolation option is generally the fastest of the four available interpolation options.
- **Linear:** Allows users to select the linear option for interpolation. The linear algorithm applies a linear interpolation of grayscale intensity based on the distance of neighboring voxels from the interpolated voxel.
- **Bicubic:** Bicubic is the default interpolation option. The Bicubic option uses a cubic spline function to determine interpolated value, resulting in a smoother image that preserves detail.
- **Windowed Sinc:** Allows users to select the Windowed Sinc option for interpolation. The algorithm uses the windowed sinc function $\sin(x)/x$ to determine the interpolated value.

Process: The process controls allow users to register and save registration result, the following options are available.

- **Save Registered:** Allows users to save the transformed match volume, fused volume, or the transformed object map (if applicable). See File > Save Registered at the being of this module section for a full description of the save options.
- **Register:** Initiates the 3D registration.
- **Register Pair:** Only available when the register mode is set to Single Reference or Sequential. Will initiate the registration of the current match volume to the current base volume.
- **Match Range:** Only available when one or more 4D multivolumes are loaded. The match range slider allows users to specify a range of 3D volumes in the 4D match multivolume to be registered to the base volume.

Registration Controls > 3D (continued)

Register Mode: Only available when a single 4D volume is loaded. The registration mode allows users to select from the following options:

· **Single Matrix:** The single matrix option applies the transformation matrix created when registering the currently displayed match data set to the displayed base data to the range of match data sets selected using the match range slider. All volumes in the match range are transformed to the same single matrix.

· **Single Reference:** The single reference option registers each of the match volumes specified in the match range, individually to the base volume.

· **Sequential:** Performs a sequential match volume to base volume registration within the specified match range. For example, match volume 2 to base volume 1, then match volume 3 to based volume 2, etc.

· **Register Sequence:** Only available for the single reference and sequential register modes. When selected initiates sequential registration.

Redo: Reverses your last undo action. Redo is only available after using Undo.

Undo: Reverses you last action. Can reverse more than one action.

Volumes: This option is only available when one or more 4D multivolumes are selected for input for 3D registration. The Volume sliders allow users to navigate through the volumes in the match and/or base input multivolumes.

· **Base:** The base slider controls the display of the base volume. This will be the volume used for single matrix and single reference registration.

· **Match:** The match slider controls the display of the match volume. This will be the volume registered to the base for Single Matrix and Single Reference registration. See Process and Registration mode for information on other registration options.

Mutual Information: Enables 3D mutual information-based registration. The following options are available:

• **Threshold:** The Threshold double-ended slider bars for both Base and Match data allows specificiation of a range of threshold values to consider for registration. The use of thresholding with mutual information-based registration is normally to remove background noise, artifact from implants, or other ranges of greyscale values from the data that could interfere with registration.

Registration Controls > 3D (continued)

Mutual Information > Threshold (continued): Enables 3D mutual information-based registration. The following options are available:

- **Base:** The base threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slide for the base input data.
- **Match:** The match threshold double-ended slider bar allows users to specify a range of threshold values using the minimum and maximum ends of the threshold slide for the match input data.

- **Show Thresholds:** When enabled displays a filled preview of the minimum or maximum threshold value set for base and match input data.

Match Sample Region: The match sample region slides allow users to increase or decrease the sampling density in the X, Y, and Z.

- **X Sample Extent:** Use the slider to specify the x sampling density. [1]
- **Y Sample Extent:** Use the slider to specify the Y sampling density. [2]
- **Z Sample Extent:** Use the slider to specify the Z sampling density. [3]
- **Show Region:** Enables the display of the sample extent on the match image. The region will be shown as a purple and white dashed box.

DOF Search Ranges: The Degrees Of Freedom (DOF) search range allows users to adjust the default parameters set for registration.

- **X Search:** Allows users to adjust the x translation search step.
- **Y Search:** Allows users to adjust the y translation search step.
- **Z Search:** Allows users to adjust the z translation search step.
- **X Rotation Search:** Allows users to adjust the rotation about the x search step.
- **Y Rotation Search:** Allows users to adjust the rotation about the y search step.
- **Z Rotation Search:** Allows users to adjust the rotation about the z search step.
- **Affine Register:** Allows users to enable affine registration providing access to X, Y, and Z scale and shear search options:
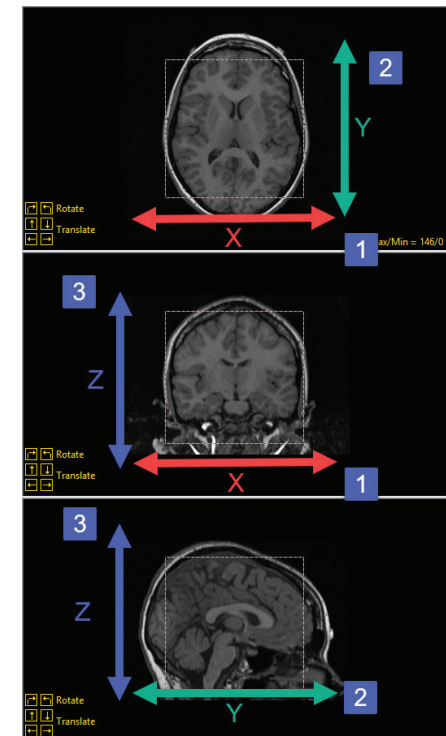
Registration Controls > 3D (continued)

DOF Search Ranges > Affine Register (continued):

- **X Scale Search:** Allows users to adjust the X scaling search parameter.
- **Y Scale Search:** Allows users to adjust the Y scaling search parameter.
- **Z Scale Search:** Allows users to adjust the Z scaling search parameter.
- **X Shear in Z Search:** Allows users to adjust the level of x shear in the z search.
- **Y Shear in Z Search:** Allows users to adjust the level of y shear in the z search.
- **X Shear in Y Search:** Allows users to adjust the level of x shear in the y search.
- **Z Shear in Y Search:** Allows users to adjust the level of z shear in the y search.
- **Y Shear in X Search:** Allows users to adjust the level of y shear in the x search.
- **Z Shear in X Search:** Allows users to adjust the level of z shear in the x search.

- **Bounded Search:** Limits the total number of search steps. The registration algorithm, while robust in most cases, can fail to converge in extremely low-information situations. This option avoids program hang-up in those situations, and seldom significantly affects typical solutions.

Registration Matrix: When enabled displays the 4 by 4 transformation matrix.

- **Load:** Load a matrix file (*.mat file) for the match data set.
- **Save:** Save the current matrix file.

Transformation Interpolation: The transformation interpolation option allows users to specify the interpolation type to be used when transforming the match data set. Users can choose from:

- **Nearest Neighbor:** Allows users to select the nearest neighbor option for interpolation. Nearest Neighbor works by selecting the value of the closest voxel to which the interpolation resampling maps. This interpolation option is generally the fastest of the four available interpolation options.
- **Linear:** Allows users to select the linear option for interpolation. The linear algorithm applies a linear interpolation of grayscale intensity based on the distance of neighboring voxels from the interpolated voxel.

Registration Controls > 3D (continued)

Transformation Interpolation (continued):

- **Bicubic:** Bicubic is the default interpolation option. The Bicubic option uses a cubic spline function to determine interpolated value, resulting in a smoother image that preserves detail.
- **Windowed Sinc:** Allows users to select the Windowed Sinc option for interpolation. The algorithm uses the windowed sinc function sin(x)/x to determine the interpolated value.

Process: The process controls allow users to register and save registration result, the following options are available.

- **Save Registered:** Allows users to save the transformed match volume, fused volume, or the transformed object map (if applicable). See File > Save Registered at the being of this module section for a full description of the save options.
- **Register:** Initiates the 3D registration.
- **Register Pair:** Only available when the register mode is set to Single Reference or Sequential. Will initiate the registration of the current match volume to the current base volume.
- **Match Range:** Only available when one or more 4D multivolumes are loaded. The match range slider allows users to specify a range of 3D volumes in the 4D match multivolume to be registered to the base volume.

Register Mode: Only available when a single 4D volume is loaded. The registration mode allows users to select from the following options:

- **Single Matrix:** The single matrix option applies the transformation matrix created when registering the currently displayed match data set to the displayed base data to the range of match data sets selected using the match range slider. All volumes in the match range are transformed to the same single matrix.
- **Single Reference:** The single reference option registers each of the match volumes specified in the match range, individually to the base volume.
- **Sequential:** Performs a sequential match volume to base volume registration within the specified match range. For example, match volume 2 to base volume 1, then match volume 3 to based volume 2, etc.
- **Register Sequence:** Only available for the single reference and sequential register modes. When selected initiates sequential registration.

Registration Controls > 3D (continued)

Redo: Reverses your last undo action. Redo is only available after using Undo.

Undo: Reverses you last action. Can reverse more than one action.

Volumes: This option is only available when one or more 4D multivolumes are selected for input for 3D registration. The Volume sliders allow users to navigate through the volumes in the match and/or base input multivolumes.

- **Base:** The base slider controls the display of the base volume. This will be the volume used for single matrix and single reference registration.

- **Match:** The match slider controls the display of the match volume. This will be the volume registered to the base for Single Matrix and Single Reference registration. See Process and Registration mode for information on other registration options.