Stereo Analyst for ArcGIS®

Geographic Imaging by ERDAS

December 2010

The Earth to Business Company

Printed in the United States of America.

Manager, Technical Documentation
ERDAS, Inc.
5051 Peachtree Corners Circle
Suite 100
Norcross, GA 30092-2500 USA.

Table of Contents

List of Tables

List of Figures

Foreword

An image of the Earth's surface is a wealth of information. Images capture a permanent record of buildings, roads, rivers, trees, schools, mountains, and other features located on the Earth's surface. But images go beyond simply recording features. Images also record relationships and processes as they occur in the real world. Images are snapshots of geography, but they are also snapshots of reality. Images chronicle our Earth and everything associated with it; they record a specific place at a specific point in time. They are snapshots of our changing cities, rivers, and mountains. Images are snapshots of life on Earth.

The data in a geographic information system (GIS) needs to reflect reality, and snapshots of reality need to be incorporated and accurately transformed into instantaneously ready, easy-to-use information. From snapshots to digital reality, images are pivotal in creating and maintaining the information infrastructure used by today's society. Today's geographic information systems have been carefully created with features, attributed behavior, analyzed relationships, and modeled processes.

There are five essential questions that any GIS needs to answer: Where, What, When, Why, and How. Uncovering Why, When, and How are all done within the GIS; images let you extract the Where and What. Precisely where is that building? What is that parcel of land used for? What type of tree is that? The extensions developed by ERDAS use imagery to let you accurately address the questions Where and What, so you can then derive answers for the other three.

But our Earth is changing! Urban growth, suburban sprawl, industrial usage, and natural phenomena continually alter our geography. As our geography changes, so does the information we need to understand it. Because an image is a permanent record of features, behavior, relationships, and processes captured at a specific moment in time, using a series of images of the same area taken over time lets you more accurately model and analyze the relationships and processes that are important to our Earth.

The extensions by ERDAS are technological breakthroughs that let you transform a snapshot of geography into information that digitally represents reality in the context of a GIS. Image Analysis™ for ArcGIS™ and Stereo Analyst® for ArcGIS are tools built on top of a GIS to maintain that GIS with up-to-date information. The extensions provided by ERDAS reliably transform imagery directly into your GIS for analyzing, mapping, visualizing, and understanding our world.

On behalf of the Image Analysis for ArcGIS and Stereo Analyst for ArcGIS product teams, we wish you all the best in working with these new products and hope you are successful in your GIS and mapping endeavors.

Introducing Stereo Analyst for ArcGIS

Welcome to Stereo Analyst for ArcGIS, the stereo feature collection extension for ArcGIS. Stereo Analyst for ArcGIS adds unique image viewing and feature collection capabilities to your ArcGIS desktop and uses the existing feature editing and collection capabilities available in ArcMap™.

With Stereo Analyst for ArcGIS, you can access image and feature datasets directly from a geodatabase. You can also collect new feature datasets accurately using oriented imagery as a reference backdrop. If you already have some feature datasets, you can edit them reliably in stereo using ArcMap editing tools.

Using a three-dimensional (3D) digital view of the Earth's surface created with oriented imagery, you can collect true, real-world 3D geographic information. By analyzing oriented imagery with Stereo Analyst for ArcGIS, even more information can be extracted from imagery. GIS professionals are no longer limited to collecting two-dimensional (2D) GIS data. You can use this data to build relationships into a GIS. Also, you can collect mass points with X, Y, and Z coordinates for the creation of a digital terrain model (DTM).

IN THIS CHAPTER

Getting Started

Stereo Analyst for ArcGIS supplies you with the tools you need to update and create accurate and reliable feature datasets for use in a GIS. You can use Stereo Analyst for ArcGIS in conjunction with two applications you're probably already familiar with—ArcCatalog and ArcMap. These applications let you easily manage all of your raster and feature datasets used in Stereo Analyst for ArcGIS.

Creating Your World in 3D

Stereo Analyst for ArcGIS creates an accurate 3D digital representation of the Earth's surface and geography using imagery. Using GIS-ready images, the contents of an image are recreated and represented in a 3D view. This 3D digital representation of the Earth is displayed on the screen.

By adding feature datasets to ArcMap, the features are superimposed on top of the 3D digital representation. Using the 3D digital picture of the Earth's surface as a reference source, the feature data is updated to "fit" the Earth and its associated geography. Once updates to the feature data are made, you can save the information or check it back into the geodatabase.

Gaining More Accuracy in GIS Data Collection

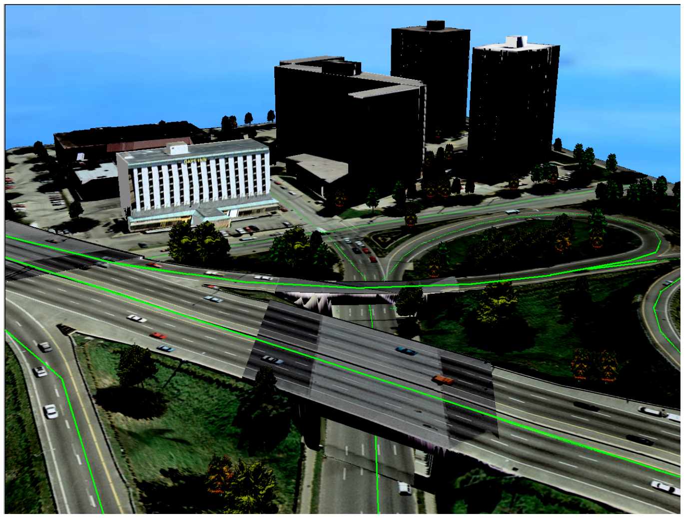
During the collection of accurate GIS feature data using Stereo Analyst for ArcGIS, a 3D floating cursor "floats" in the 3D digital depiction of the Earth's surface as displayed on the screen. This 3D floating cursor is also referred to as a ground point. (See **"Applying the 3D Floating Cursor" on page 175** for more information about the 3D floating cursor.)

The 3D floating cursor floats until you place it on the feature of interest. You can move the 3D floating cursor anywhere within this 3D digital representation. The 3D floating cursor can float above, below, or rest on the Earth's surface or feature of interest.

The 3D floating cursor has a 3D coordinate associated with it. As a result, wherever you move the 3D floating cursor, a new 3D coordinate displays. To ensure the accuracy of GIS feature data collected in Stereo Analyst for ArcGIS, the 3D floating cursor is positioned so that it rests on the feature being collected. A new 3D coordinate is computed, and the feature is accurately collected. (See **"Adjusting the 3D Floating Cursor" on page 177** for information about placing the 3D floating cursor on the feature of interest.)

The following figure shows buildings collected in stereo that are displayed in a virtual world.

Figure 1: Buildings Displayed in a Virtual World



Automated techniques have been developed in Stereo Analyst for ArcGIS to place the 3D floating cursor on the geographic feature of interest. This feature, Terrain Following mode, is used to facilitate accurate feature collection and editing. (See **"Using the Terrain Following Mode" on page 183** for information about the Terrain Following cursor.)

Accessing Image and Feature Data

Stereo Analyst for ArcGIS supports all of the raster and feature dataset formats currently supported by ArcMap. For example, raster format support includes: ArcSDE rasters, TIFF, ERDAS® IMAGINE® (.img), ERDAS Raw, ESRI™ Image Catalogs, GRID, GRID Stack, and Windows® BMP.

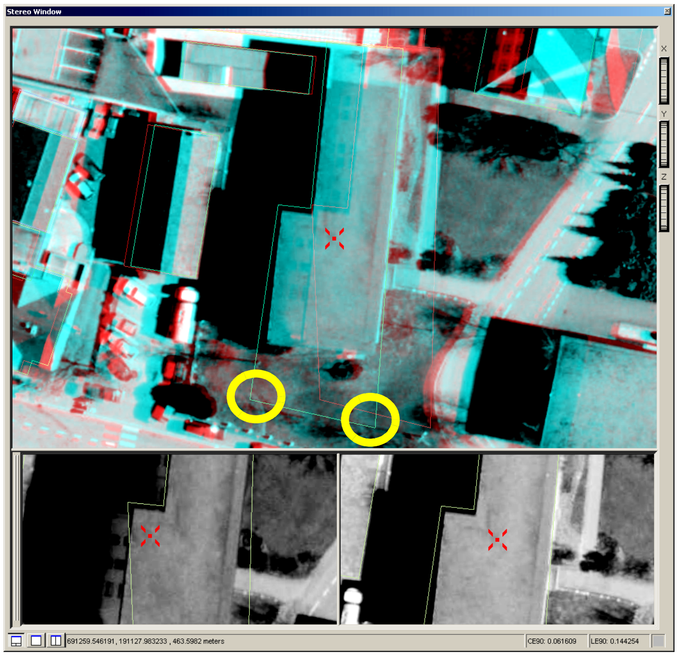
You can create new feature datasets using ArcCatalog. In addition to this, existing CAD formats such as DGN, DWG, and DXF are also supported by ArcMap for use in Stereo Analyst for ArcGIS. Personal and multiuser geodatabases created using ArcCatalog can be maintained to include up-to-date feature data.

Editing Features

Using the editing tools you're already familiar with in ArcMap, you can edit features that you create and features that you import in Stereo Analyst for ArcGIS. Display the Editor toolbar and choose the editing tools you need to modify feature datasets. Attribution information is updated accordingly.

You can easily update feature vertices to greater accuracy, as shown in the following figure.

Figure 2: Feature Vertices Updated to Greater Accuracy

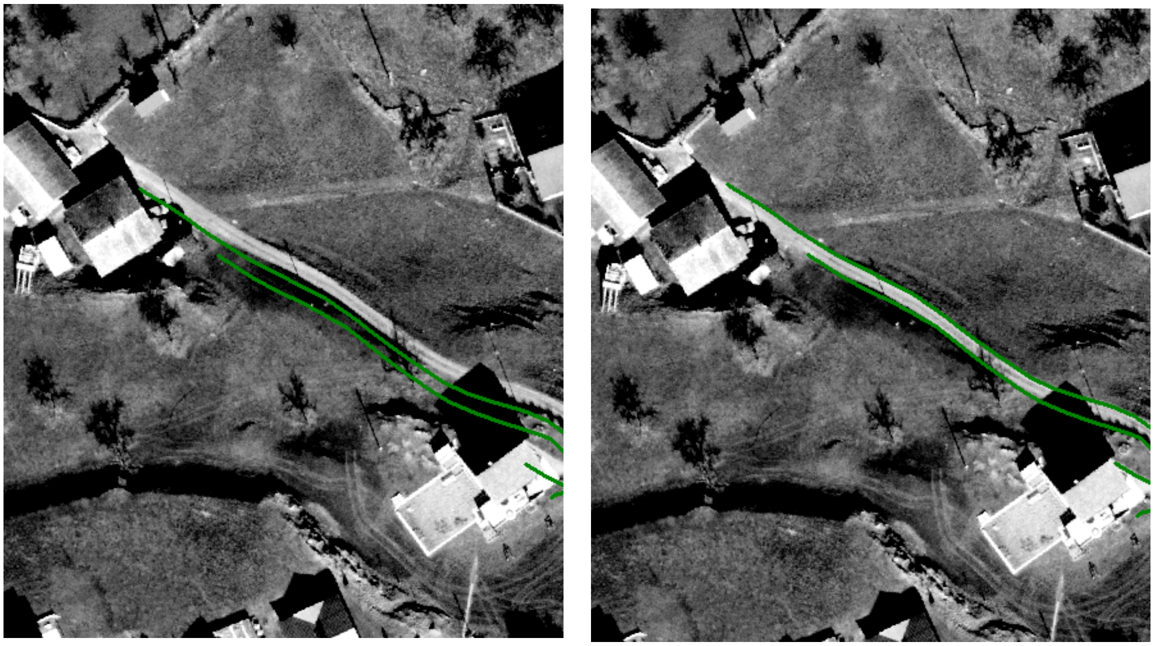


Updating Feature Data

Using Stereo Analyst for ArcGIS, you can update feature datasets to reflect the geography on the Earth's surface as recorded by an image. Highly accurate oriented images are used as a reference source for updating feature datasets. (See "Creating Oriented Images" on page 84 for information about oriented imagery.) Using Stereo Analyst for ArcGIS, updates to feature datasets are not only in 3D, but are also accurate 2D (planimetric) updates.

In the figure on the left, before editing, this road is not positioned correctly. In the figure on the right, the road clearly follows the feature.

Figure 3: Road Before and After Editing

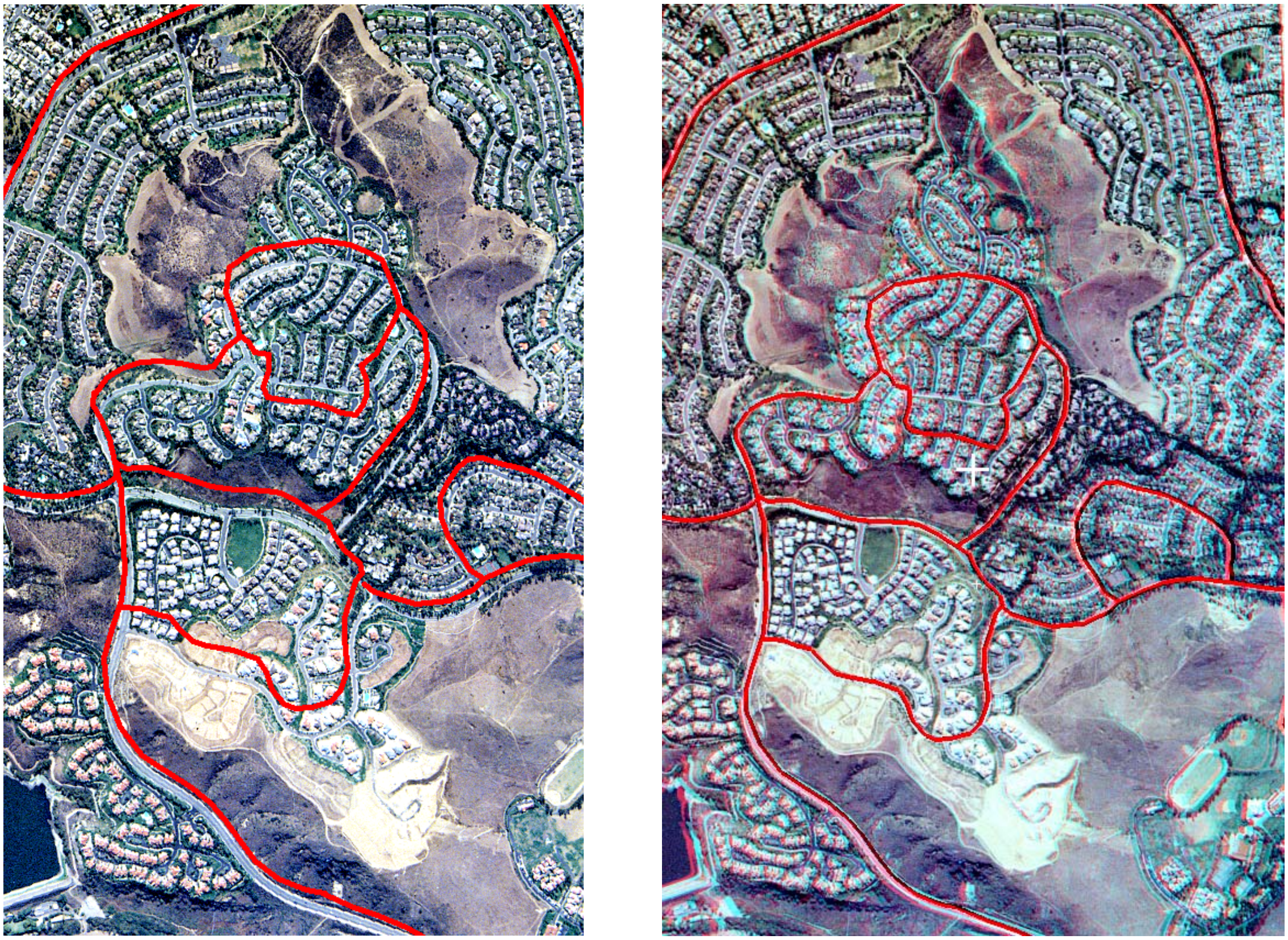


Collecting Features

Using the editing tools you're probably already familiar with in ArcMap, Stereo Analyst for ArcGIS lets you collect new features. The 3D floating cursor must rest on the feature of interest being collected to ensure the accuracy of the GIS data collected using Stereo Analyst for ArcGIS.

The figure on the left shows features collected in ArcMap. The figure on the right shows the same features collected in the Stereo window.

Figure 4: Features Collected in ArcMap and the Stereo Window

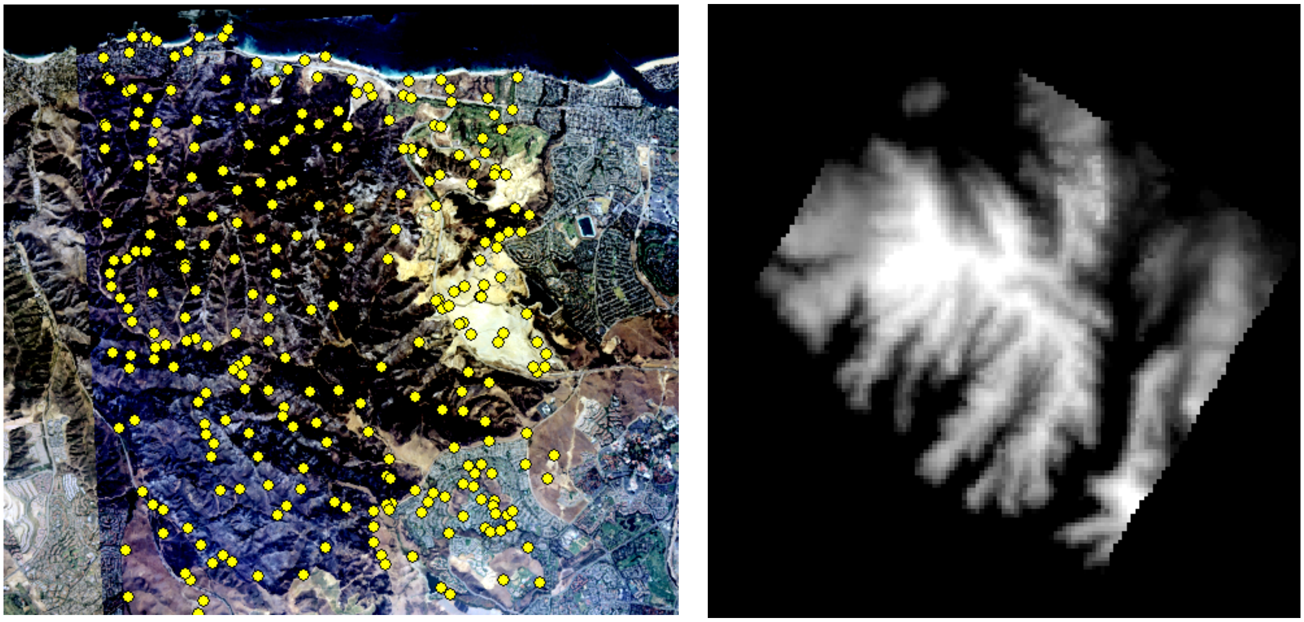


Collecting Points for the Creation of Elevation Models

Stereo Analyst for ArcGIS lets you collect elevation information directly from oriented imagery without requiring a digital elevation model (DEM). Because an accurate 3D digital representation of the Earth's surface is created on the screen using imagery, you can collect accurate 3D point feature datasets. With mass point data, you can easily create DEMs using Spatial Analyst, 3D Analyst™, or ERDAS IMAGINE.

The figure on the left shows mass points collected in Stereo Analyst for ArcGIS. The DTM on the right was generated from the mass points collected in Stereo Analyst for ArcGIS. ERDAS IMAGINE was used to create the DTM.

Figure 5: Images Showing Mass Points and DTM



Using ArcMap and Stereo Analyst for ArcGIS

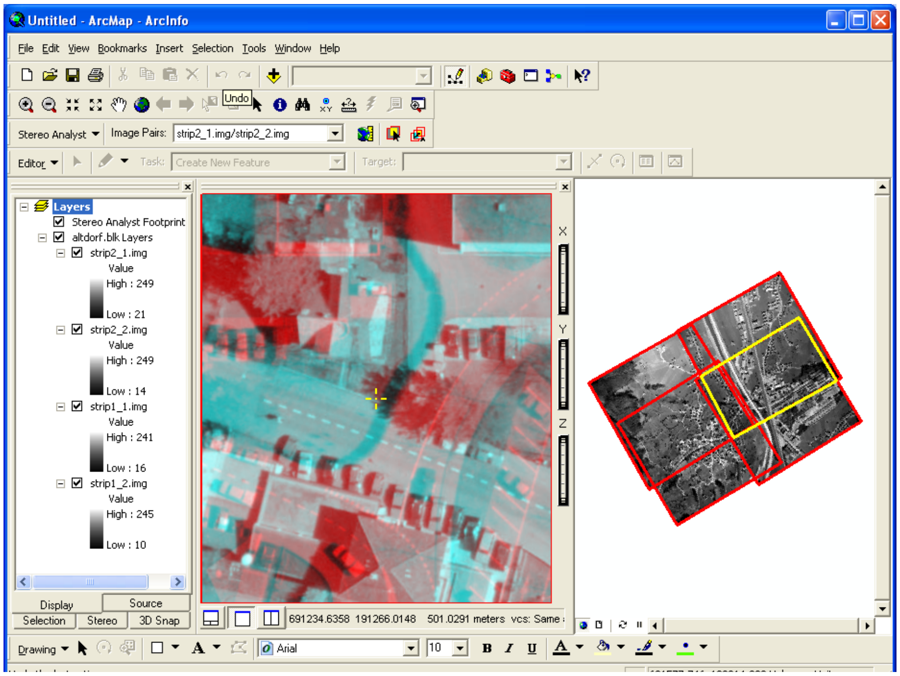
Stereo Analyst for ArcGIS adds several toolbars and features to ArcMap when it is installed. The toolbars include the following:

- **Stereo Analyst Toolbar** – This is the main toolbar, and it provides access to importers and exporters as well as preference settings.
- **Stereo View Toolbar** – This toolbar provides tools to manipulate data in the Stereo window.
- **Stereo Enhancement Toolbar** – This toolbar controls the operation of image enhancement in the Stereo window.
- **Stereo Advanced Editing Toolbar** – This toolbar provides better control over the handling of Z values while editing features.

- **Terrain Editor Toolbar** – This toolbar lets you edit points and breaklines, and perform editing tasks on areas of the terrain. Terrain Editor for ArcGIS is an optional extension for Stereo Analyst for ArcGIS. For more information, see **"Understanding Terrain Editor" on page 225**.

The Stereo window, which is the middle window in the figure below, can be docked inside the ArcMap window or undocked.

Figure 6: Stereo Window



Using these tools, you can perform actions such as selecting an image pair from a graphic display and modifying the behavior of the Stereo window.

You can also embed the Stereo window within the ArcMap window. The Stereo window is an extension to the ArcMap window and is used as the workspace for updating and collecting new feature datasets. Work conducted in the Stereo window is simultaneously reflected in the ArcMap data view.

Stereo Analyst for ArcGIS adds additional functionality to ArcMap. This includes a new Stereo Analyst for ArcGIS footprint layer and 3D snap options for feature editing. (See **"Using the Stereo Window with ArcMap" on page 152** for information on the footprint layer and **"Using 3D Snap" on page 201** for information about the 3D snap options.)

What Can You Do with ArcCatalog?

As you know, ArcCatalog is an application with which you can create and manage GIS data. ArcCatalog's ability to create layers is also applicable to Stereo Analyst for ArcGIS functionality. Use ArcCatalog to manage the feature datasets that often accompany a GIS mapping project. You can also browse photogrammetry projects and repair broken project links.

Learning More

If you are just learning about GIS, you might want to read the books about ArcCatalog and ArcMap: *Using ArcCatalog* and *Using ArcMap*. Knowing about these applications makes your use of Stereo Analyst for ArcGIS much easier.

See the quick-start tutorial in **"Quick-Start Tutorial" on page 11** if you are ready to learn about how Stereo Analyst for ArcGIS works. In this tutorial you learn how to change the display of image pairs using enhancement tools, navigate in a 3D digital space in the Stereo window, create 3D feature datasets from 2D feature datasets and vice versa, collect feature datasets, and edit feature datasets. The tutorial is written so that you can do the exercises using your computer and the example data supplied with Stereo Analyst for ArcGIS. If you'd rather, you can just read the tutorial to learn about the functionality of Stereo Analyst for ArcGIS.

Finding Answers to Questions

This book describes the typical workflow involved in creating and updating GIS data for mapping projects. The chapters are set up so that you first learn the theory behind certain applications, and then you are introduced to the typical workflow you'd apply to get the results you want. A glossary is provided to help you understand any terms you might not have seen before.

Getting Help on Your Computer

You can get a lot of information about the features of Stereo Analyst for ArcGIS by accessing the help. You can use the table of contents, index, or search feature to locate the information you need. You can access the help as follows:

- **Stereo Analyst for ArcGIS** – Select Stereo Analyst Desktop Help from the Stereo Analyst dropdown list on the Stereo Analyst toolbar.
- **Terrain Editor for ArcGIS** – Select Terrain Editor Desktop Help from the Terrain Editor dropdown list on the Terrain Editor toolbar. Terrain Editor for ArcGIS is an optional extension for Stereo Analyst for ArcGIS. For more information, see **"Understanding Terrain Editor" on page 225**.
- **ArcGIS** – Click Help on the ArcMap toolbar and select ArcGIS Desktop Help.

Contacting ERDAS

You can contact ERDAS for technical support, if needed, at 770-776-3650. Customers outside the United States should contact their local distributor. Visit ERDAS on the Web at www.erdas.com.

Contacting ESRI

If you need to contact ESRI for technical support regarding ArcGIS, refer to "Getting technical support" in the Help system's "Getting more help" section. The telephone number for technical support is 909-793-3774. You can also visit ESRI on the Web at www.esri.com.

ERDAS Education Solutions

ERDAS offers instructor-based training for Stereo Analyst for ArcGIS. For more information, go to the training Web site at www.erdas.com. You can follow the training link to training centers, course schedules, and course registration.

ESRI Education Solutions

ESRI provides educational opportunities related to GIS, GIS applications, and technology. You can choose among instructor-led courses, Web-based courses, and self-study workbooks to find educational solutions that fit your learning style and budget. For more information, visit the Web site www.esri.com/education.

Quick-Start Tutorial

This chapter provides the hands-on training you need to use Stereo Analyst for ArcGIS to complete your own mapping projects.

- **Exercise 1: Starting the Program** – You learn how to set up the work environment to run Stereo Analyst for ArcGIS.
- **Exercise 2: Adding Oriented Images** – You learn about populating the Stereo window with raster data and how to best examine the imagery.
- **Exercise 3: Converting Features** – You learn how to create a 2D feature dataset from a 3D feature dataset. You also learn how to create a 3D feature dataset from a 2D dataset using an elevation source.
- **Exercise 4: Collecting Features in 3D** – You learn how to use editing tools to collect 3D feature data in the Stereo window.
- **Exercise 5: Editing Existing Features** – You learn how to update existing features.

To start this tutorial, you must have ArcGIS and Stereo Analyst for ArcGIS installed on your computer system. Also, you must have access to the tutorial data that accompanies the installation CD. Ask your administrator for the location of the tutorial data if you can't find it in the default installation directory.

IN THIS CHAPTER

Exercise 1: Starting the Program

In the following exercises, we assume that you are using a single-monitor workstation that is configured for use with ArcMap and Stereo Analyst for ArcGIS.

If you have a dual-monitor configuration, you can spread out the applications so that the ArcMap application is displayed on one monitor and the Stereo window and the Stereo Analyst for ArcGIS toolbars are displayed on the other monitor. This type of setup is ideal for productive feature collection.

In this scenario, the ArcMap display serves as the cartographic station for verifying features that were collected or edited, and the Stereo window display serves as the main focus for collecting and editing feature datasets.

In this exercise, you learn how to start Stereo Analyst for ArcGIS and display all of its associated toolbars. You use the toolbars to gain access to all of the key functionality in Stereo Analyst for ArcGIS.

Preparing

This exercise assumes that you have successfully installed Stereo Analyst for ArcGIS on your computer. If you haven’t installed Stereo Analyst for ArcGIS, please do so now.

Starting ArcMap

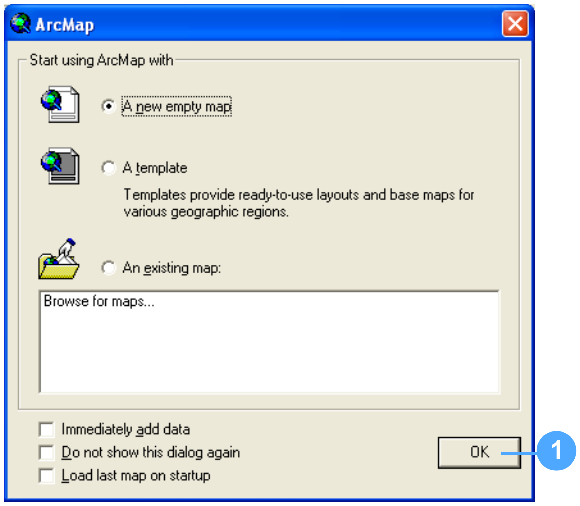
To start ArcMap, follow this step:

1. Click the **Start** button on your desktop, point to **All Programs**, point to **ArcGIS**, and then select **ArcMap** to start the application.

Adding the Stereo Analyst for ArcGIS Extension

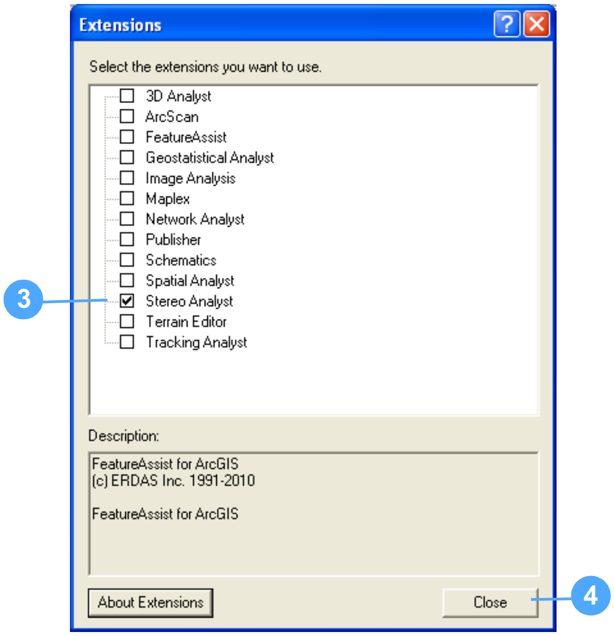
To add the Stereo Analyst for ArcGIS extension, follow these steps:

1. When the ArcMap dialog displays, keep the option to create a new map and click **OK**.



2. Select **Extensions** from the Customize menu to display the Extensions dialog.

3. Check the **Stereo Analyst** check box to add the extension to ArcMap.



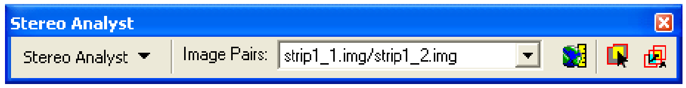
The extension is activated when the Stereo Analyst check box is selected.

4. Click **Close** to close the Extensions dialog.

Adding Toolbars

To add the Stereo Analyst for ArcGIS toolbars, follow these steps:

1. Click the **Customize** menu, point to **Toolbars**, and then select **Stereo Analyst** to add that toolbar to the ArcMap window.



With the Stereo Analyst toolbar, you can choose image pairs to view, open the Stereo window, import and export data, and much more.

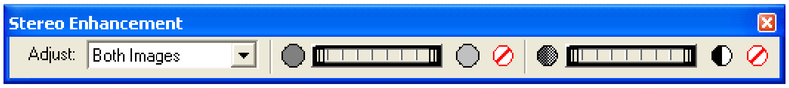
2. Click the **Customize** menu, point to **Toolbars**, and then select **Stereo View** to add that toolbar to the ArcMap window.

With the Stereo View toolbar, you can activate many of the special Stereo Analyst for ArcGIS modes, such as Terrain Following mode and Fixed Cursor mode.

Additionally, you can use the Continuous Zoom mode and the Image Roam Tool to adjust the extent of the image pair in the Stereo window.

Other tools let you synchronize the ArcMap and Stereo window displays, enter coordinates to drive to a specific location, reverse the left and right images, and update the feature display.

3. Click the **Customize** menu, point to **Toolbars**, and then select **Stereo Enhancement** to add that toolbar to the ArcMap window.



With the Stereo Enhancement toolbar, you can change the contrast and brightness display of both the individual images that make up the image pair as well as whole image pairs in the Stereo window.

4. Click the **Customize** menu, point to **Toolbars**, and then select **Stereo Advanced Editing** to add that toolbar to the ArcMap window.

With the Stereo Advanced Editing toolbar, you gain better control over the handling of Z values while editing features.

5. Click the **Customize** menu, point to **Toolbars**, and then select **Terrain Area Operators** to add that toolbar to the ArcMap window.

With the Terrain Area Operators toolbar, you can perform edits on sections of the terrain.

6. Arrange the toolbars in the ArcMap window so that you can easily access each of them.

Closing the Applications

If you plan to continue to **“Exercise 2: Adding Oriented Images”**, proceed to **Exercise 2: Adding Oriented Images** on page 15. Otherwise, exit ArcMap, which also closes Stereo Analyst for ArcGIS.

What’s Next?

In **“Exercise 2: Adding Oriented Images”**, you add oriented images to ArcMap and learn how to use some of the Stereo Analyst for ArcGIS tools in the Stereo window.

Exercise 2: Adding Oriented Images

In this exercise, you learn how to add multiple oriented images (rasters) to ArcMap and the Stereo window. These oriented images were created by importing data from the SOCET SET® digital photogrammetry software product.

Note: You must add at least two overlapping GIS-ready rasters to ArcMap before you can view or update existing features, or collect new features. See **“Working with Oriented Images” on page 83** to learn more about GIS-ready images.

Preparing

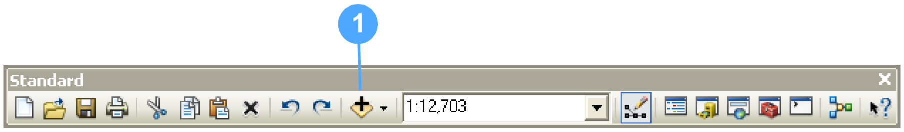
If you’re continuing the tutorial from **Exercise 1: Starting the Program** on page 12, proceed to the **“Adding Image Pairs”** section below.

If you’re starting this exercise from scratch, you should have ArcMap running with an empty data view and have Stereo Analyst for ArcGIS loaded and running. You should also have the Stereo Analyst for ArcGIS toolbars displayed.

Adding Image Pairs

To add image pairs to ArcMap and the Stereo window, follow these steps:

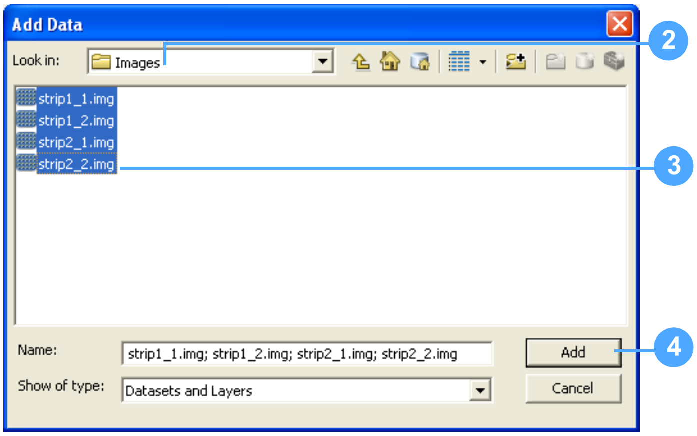
1. Click the **Add Data** button to display the Add Data dialog and select the rasters to add to ArcMap.



2. Navigate to the **\ArcTutor\StereoAnalyst\Images** folder.

3. Hold down the **Shift** key and select the images named **strip1_1.img** and **strip2_2.img**. This selects all of the raster images in the list.

4. Click **Add** to add the images to the ArcMap data view.



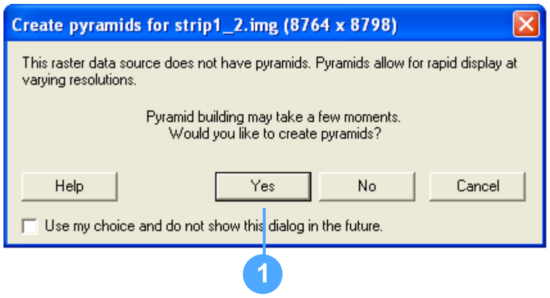
The photographs you are adding were recorded with a specially fitted camera used to capture photography from aircraft. Then, they were digitally scanned. Each pixel represents 0.16458 meters (approximately 16.5 centimeters by 16.5 centimeters) on the Earth's surface.

Creating Pyramid Layers

A pyramid layer is a version of the original raster that was resampled at a lower resolution. A raster dataset commonly has eight pyramid layers. Pyramid layers make navigating and displaying large raster datasets much faster at any resolution. Therefore, you should build pyramid layers for each of the raster images in this dataset.

To create a pyramid layer, follow these steps:

1. Click **Yes** in the Create Pyramids dialog to build pyramid layers for the first raster image, strip1_1.img.

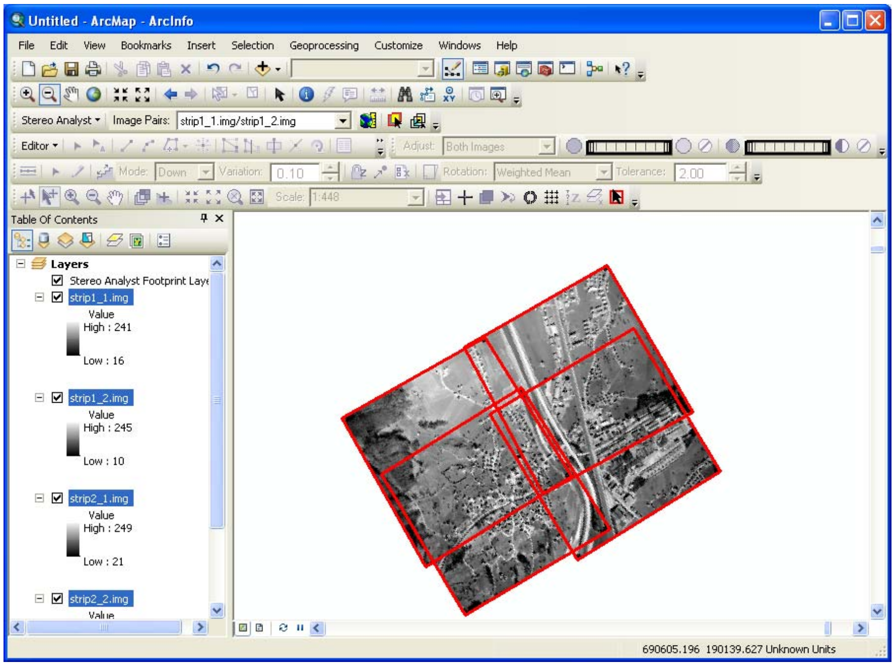


2. Click **Yes** in the next three Create Pyramids dialogs to generate pyramid layers for all of the images you use in this exercise.

Note: Once pyramid layers are created for a raster dataset, they do not need to be created again unless they are deleted. Pyramid layers are contained in files with an .rrd or .aux extension and are located in the same directory as the rasters with which they are associated.

Once the four raster images are added to ArcMap, they display with each raster footprint (red) and overlap area (yellow) indicated by graphical borders.

Note: A yellow border indicating an overlap area displays only if the Stereo window is open.



Note: By default, the display color for image footprints is red, and the display color for overlap areas is yellow. You can use different colors by changing the defaults in the Stereo Analyst Options dialog. To access the options, select Options from the Stereo Analyst dropdown list on the Stereo Analyst toolbar. Click the ArcMap Display tab, and use the dropdown lists to access and apply different colors for the Oriented image footprint color and the Selected Image Pair highlight color options. Click OK to accept the changes.

The rasters you see in the data view show two overlapping strips of photography, and each strip contains two overlapping photographs. The aircraft that recorded the imagery flew southeast to northwest, and the images appear diagonal in ArcMap as a result.

Note: Two adjacent rasters that overlap are referred to as an image pair. The overlapping portion of the two rasters is most useful in the Stereo window. It is this overlapping portion of two raster images that is used to recreate the Earth's surface digitally and in 3D in the Stereo window.

Because the images are diagonal, and their bounding boxes are squares, they might have dark background values that could distract you when viewing them in ArcMap. You fix that next.

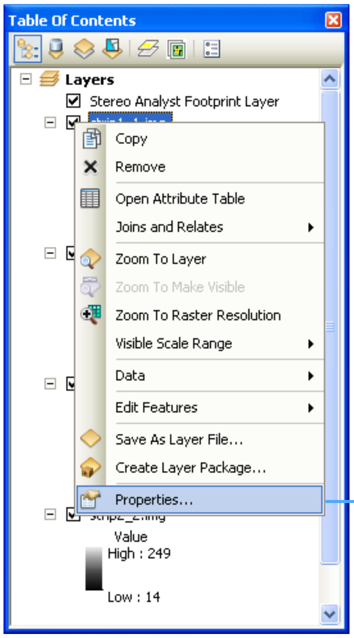
Changing Image Properties

You can alter the properties of each image so that the background values are transparent in the data view. To make the change, you must adjust the Layer properties for each raster image.

In these example images, the background value is 0 (which you can determine using the Identify tool) and displays in black. If you set the 0 value to No Color, those areas display transparent in the data view.

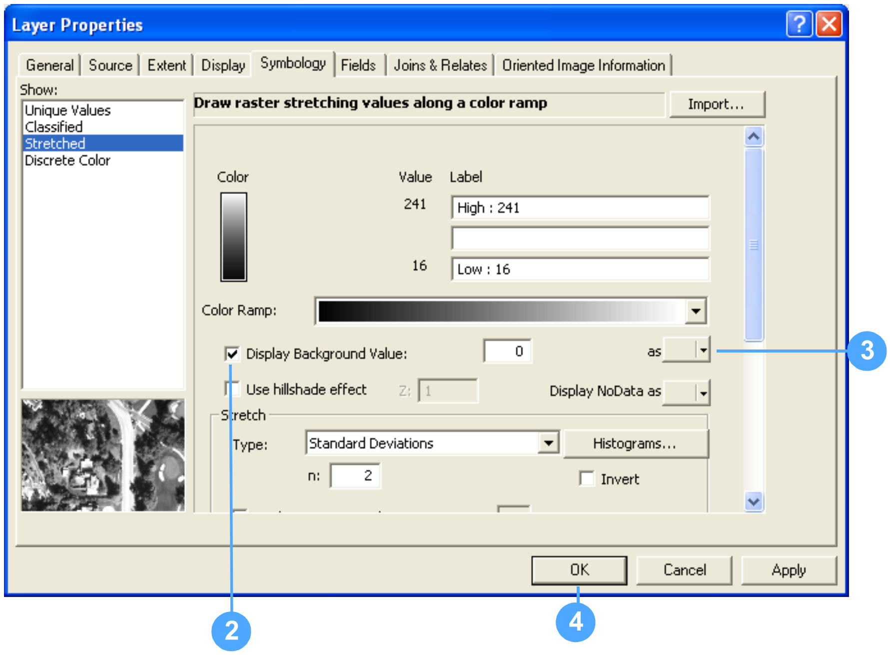
To change the properties of an image, follow these steps:

1. Right-click the title of the first image in the table of contents and select **Properties** to display the Layer Properties dialog.



2. Check the **Display Background Value** check box on the Symbology tab. Make sure the value is set to 0 (zero).

3. Select **No Color** from the Display Background Value As dropdown list.

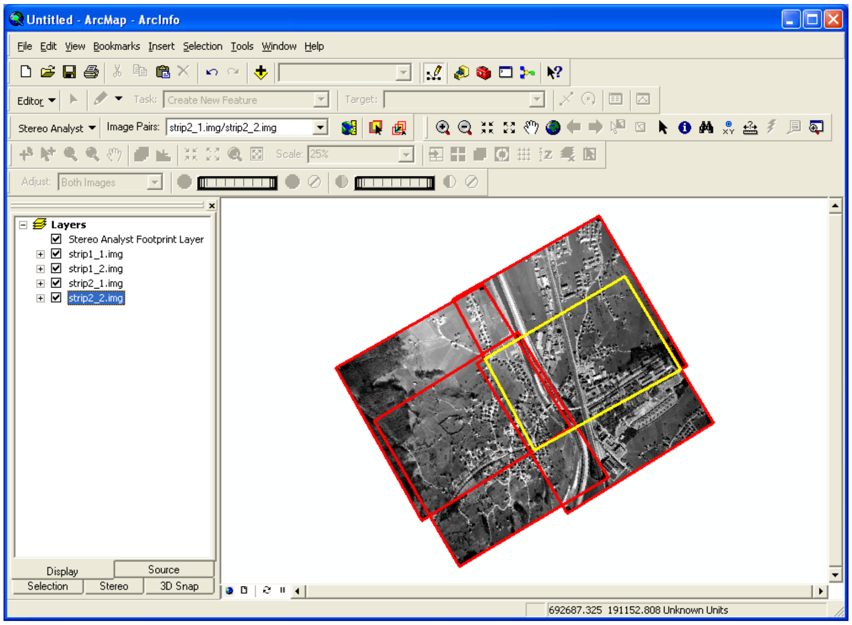


4. Click **OK**.

    The image redisplays in ArcMap with the background value 0 set to display transparently.

5. Repeat **steps 1 - 4** for the remaining three images listed in the ArcMap table of contents.

    Now, only the raster images, their vector footprints, and overlapping boundaries display in ArcMap.

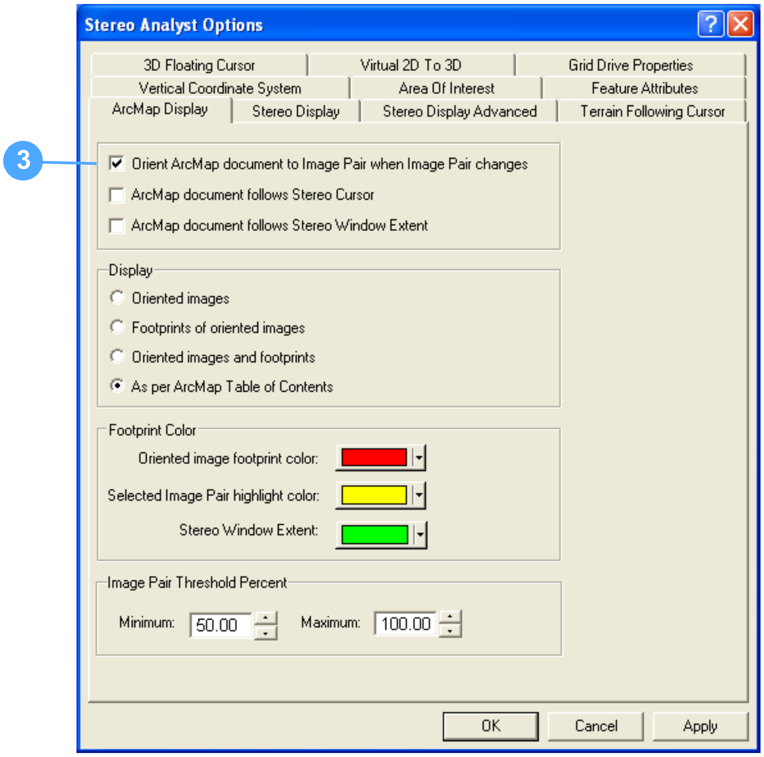


Changing the ArcMap Display

It is often helpful that the orientation of the display in ArcMap matches the display in the Stereo window. To ensure that this is always the case in the same ArcMap session, you can set an option in the Stereo Analyst Options dialog.

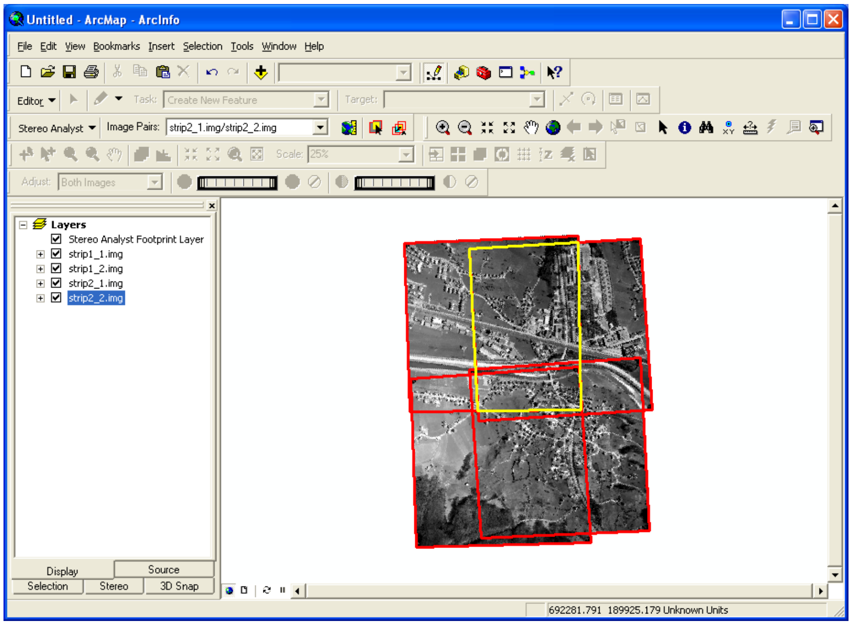
To change the ArcMap display, follow these steps:

1. Select **Options** from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Stereo Analyst Options dialog.
2. Click the **ArcMap Display** tab.
3. Check the **Orient ArcMap document to Image Pair when Image Pair Changes** check box.



4. Click **OK** to apply the orientation setting and close the Stereo Analyst Options dialog.

The display of the images in ArcMap changes. You see how the change compliments the images' display in the Stereo window in the section **Exercise 2: Adding Oriented Images** on page 23.



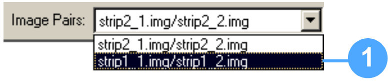
Changing the Image Pair

One or more image pairs consisting of two overlapping raster images might display in ArcMap. When you need to change the geographic extent displayed in the Stereo window, you can select a different image pair in ArcMap.

You can change an active image pair whose overlap portion is highlighted in yellow in two ways. Either use the Image Pairs dropdown list or use the Image Pair Selection tool.

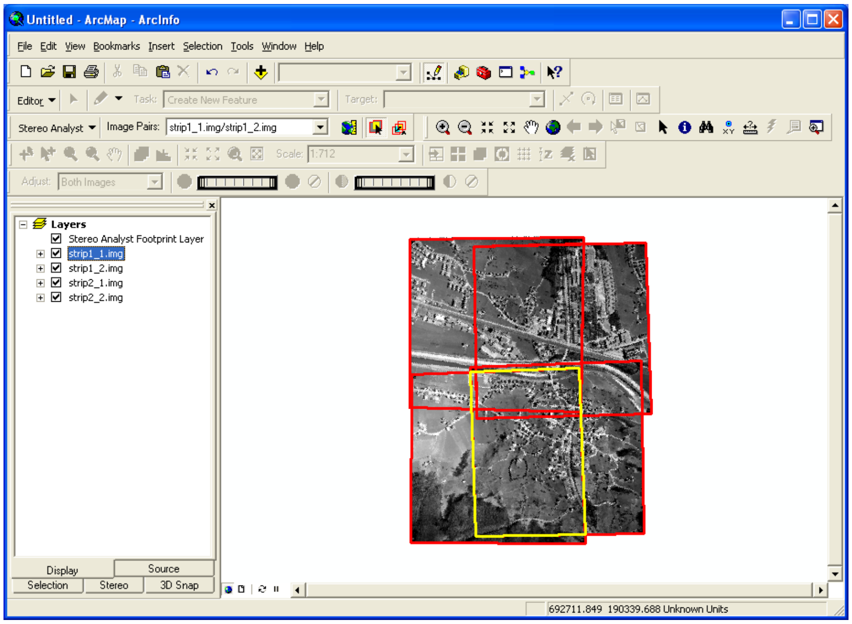
To change the image pair, follow these steps:

1. Select a different pair to make active (**strip1_1.img/strip1_2.img**) from the Image Pairs dropdown list on the Stereo Analyst toolbar.

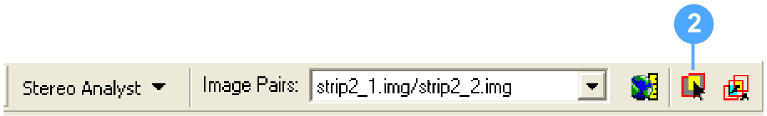


The yellow overlap graphic changes position to indicate the new active area of overlap for the strip1_1.img/strip1_2.img image pair.

The new image pair is the active image pair and is used to recreate a 3D digital representation of the Earth's surface in the Stereo window.

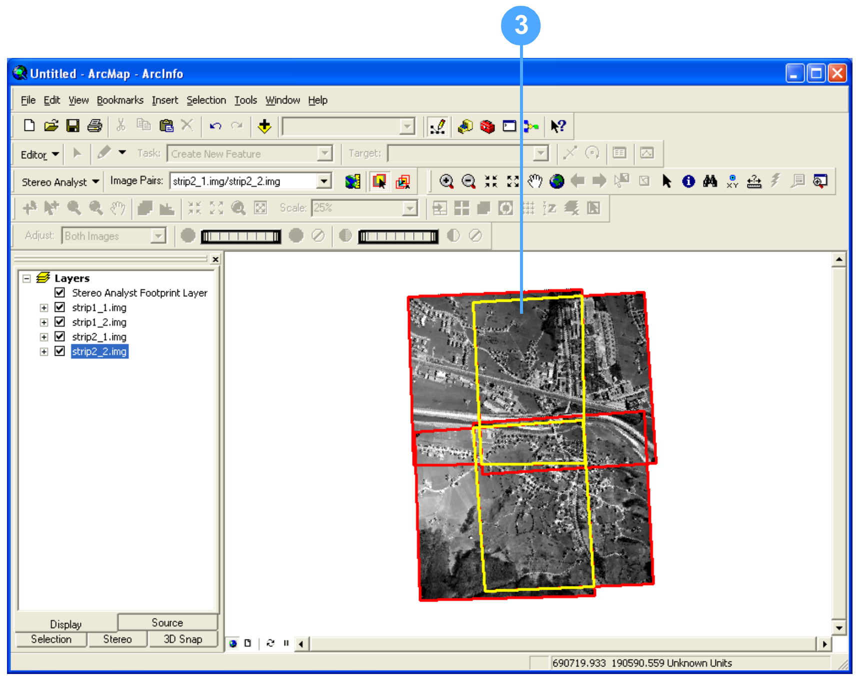


2. Click the Image Pair Selection Tool button to graphically select the original area of overlap—strip2_1.img/strip2_2.img. The button appears recessed when it is active.



3. Move your cursor over the original area of overlap. Notice that the area becomes highlighted in yellow as you move your cursor inside the overlap area.

4. Click to select the overlap area of strip2_1.img/strip2_2.img and make it the active image pair.



5. Click the Select Elements button on the Tools toolbar to disable the Image Pair Selection Tool.

   Note: If this toolbar does not display in the ArcMap window, click Customize, point to Toolbars, and then select Tools.

Working with the Stereo Window

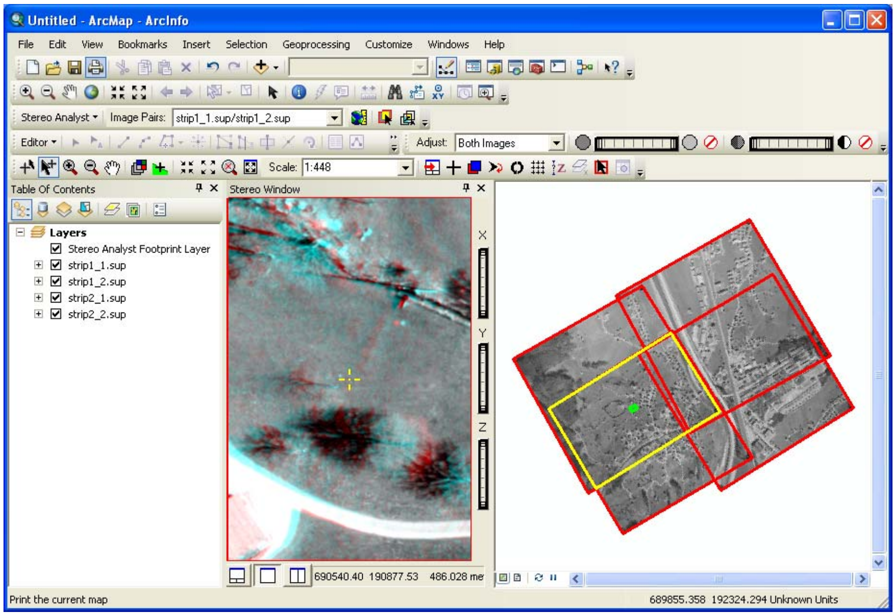
The Stereo window is where the image pair displays to recreate a 3D digital representation of the specific area of interest as recorded in the oriented images. You learn how to display it next.

Note: If your computer system doesn’t have a graphics card that supports quad-buffered stereo, Stereo Analyst for ArcGIS uses anaglyph rendering techniques to recreate and display the 3D digital representation of the area of interest. In this case, you need red/blue anaglyph glasses to view the image pairs in 3D. See the Stereo Analyst for ArcGIS product page at http://www.erdas.com for a list of supported graphics cards.

To display the 3D image in the Stereo window, follow these steps:

1. Click the Stereo Window button on the Stereo Analyst toolbar.

The ArcMap window contents adjust to include the Stereo window, which you can dock inside or outside the ArcMap window. You can also retract the Stereo window.



Initially, the Stereo window opens in 1-Pane view: one pane for the primary stereo scene, which displays the active image pair.

2. Double-click the Stereo window title bar to dock the Stereo window.

   The Stereo window docks inside the ArcMap window.

3. Click the Auto Hide button to retract the Stereo window.

4. The Stereo window retracts into the side of the ArcMap window where you see a tab.

5. Hold your mouse over the Stereo Window tab to dynamically open the Stereo window.

6. Click the Auto Hide button to hold the Stereo window open.

7. Click the Close button to close the Stereo window.

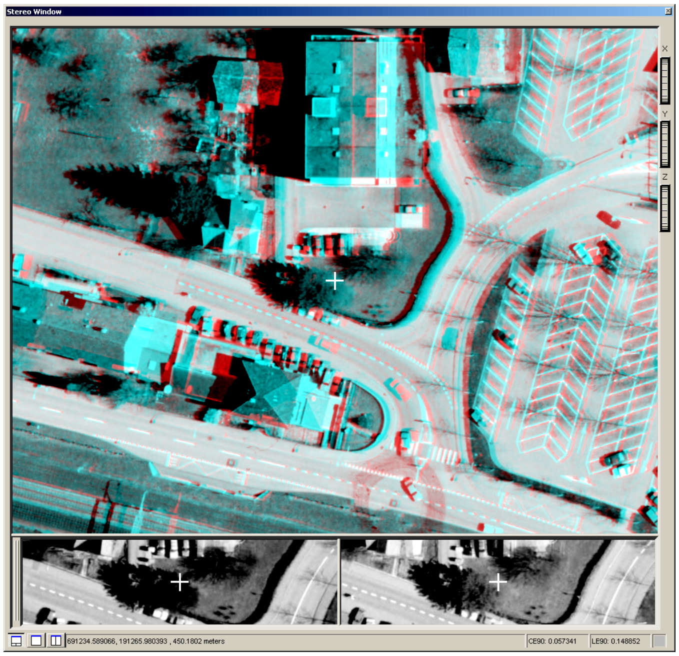
8. Resize the Stereo window to your liking. The cursor becomes a double-headed arrow at the extents of the window indicating that you can drag the window to a new size.

Adjusting the Display

To adjust the display, follow these steps:

1. Put on your stereo or anaglyph glasses.

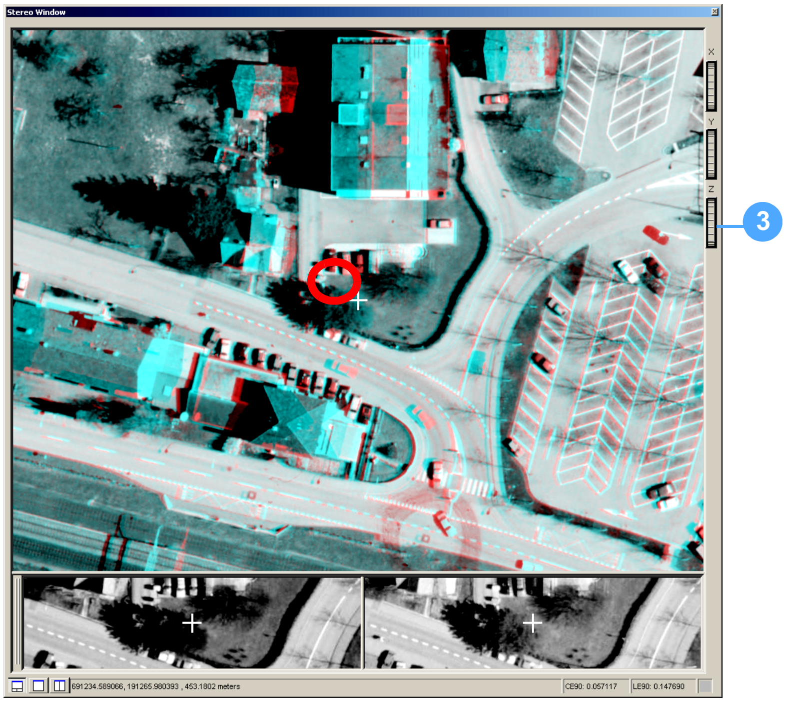
   You notice that the Stereo window display is 3D.



2. Click the Fixed Cursor Mode button on the Stereo View toolbar.

   When Fixed Cursor mode is active, the 3D floating cursor maintains its position in the center of the Stereo window while the image pair moves beneath it.

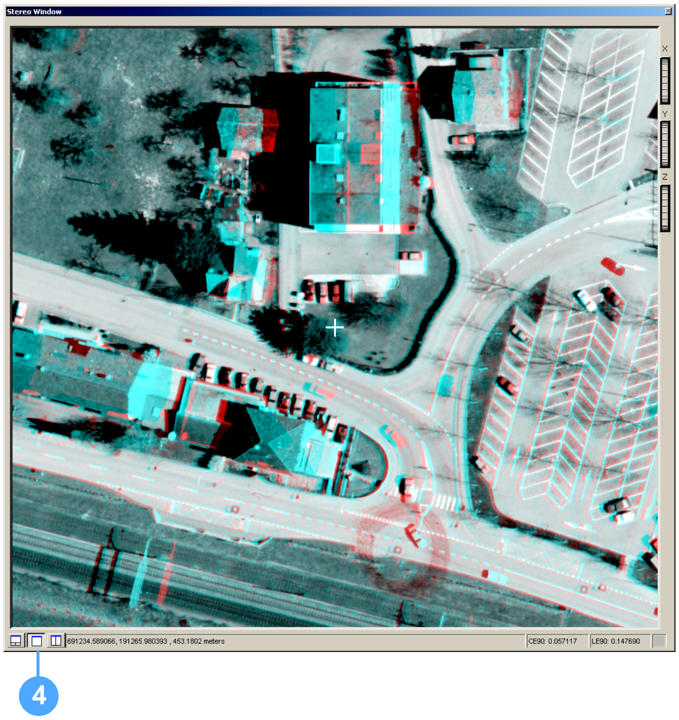
3. Click and hold on the Z thumb wheel located on the right-hand side of the Stereo window, and then move it slightly up or down until the same features overlap in both the right and left image views. In the following figure, the images have been adjusted so that the area around the 3D floating cursor, which is circled in red, is set for optimal stereo viewing.



Note: The cursor in the Stereo window is called the 3D floating cursor because it can float on, below, or above a feature.

By adjusting the Z thumb wheel, the height of the 3D floating cursor is modified by the movement of the images of the image pair. You can see the elevation change in the coordinates of the location of the 3D floating cursor, which displays on the status bar in the lower-left corner of the Stereo window.

4. Click the 1-Pane View button at the bottom of the Stereo window to enlarge the area of stereo display.



5. Click the Fixed Cursor Mode button to exit that mode.

   When you exit Fixed Cursor mode, the button no longer appears recessed on the Stereo View toolbar.

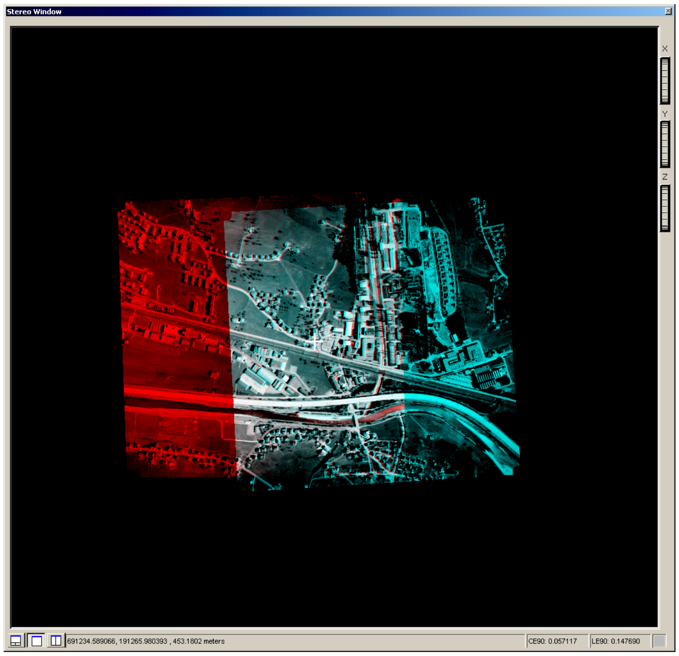
Adjusting the Zoom Ratio

To adjust the zoom ratio, follow these steps:

1. Click the Zoom to Data Extent button on the Stereo View toolbar to see the entire extent of the image pair displayed in the Stereo window.

If you are viewing in Anaglyph mode, the left image of the image pair appears red for nonoverlap areas; the right image appears blue for nonoverlap areas; and the overlap area is gray.

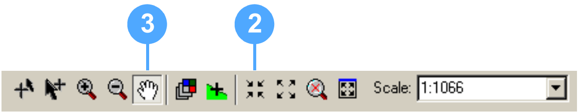
If you are viewing in Quad-buffered Stereo mode, the entire area appears gray, but you can see in 3D in the overlap area.



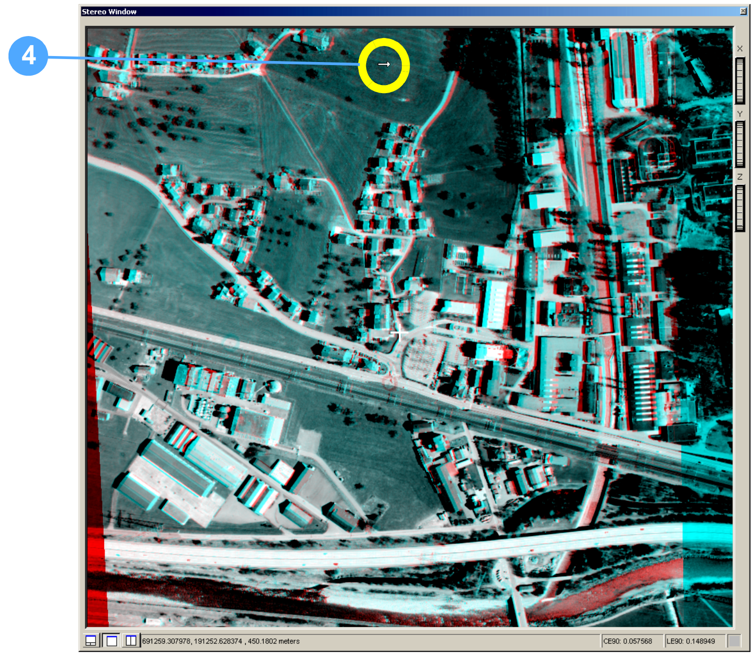
2. Click the Zoom In by 2 button until you see features on the Earth's surface displayed in 3D in the Stereo window.

3. Click the Roam Tool button, move your cursor (which appears as a hand) into the Stereo window, and double-click to activate Auto Roam mode.

The cursor changes into an arrow in Auto Roam mode.



4. Move your mouse in any direction to adjust the image pair's position in the Stereo window.



The arrow's proximity to the center of the Stereo window determines the speed of Auto Roam mode. If you are close to the center of the Stereo window, the speed is slow; if you are close to the edges of the Stereo window, the speed is fast.

5. Double-click an area that interests you in the Stereo window to return to normal Roam mode.

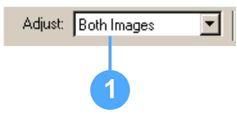
   The 3D floating cursor recenters in the middle of the Stereo window when you exit Auto Roam mode.

Adjusting Brightness and Contrast

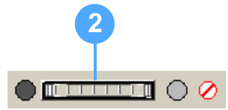
You can adjust the brightness and contrast of the image pair displayed in the Stereo window to suit your viewing and feature collection needs. By default, both images are adjusted together; however, you can also adjust each image separately by changing the setting in the Adjust dropdown list.

To adjust brightness and contrast, follow these steps:

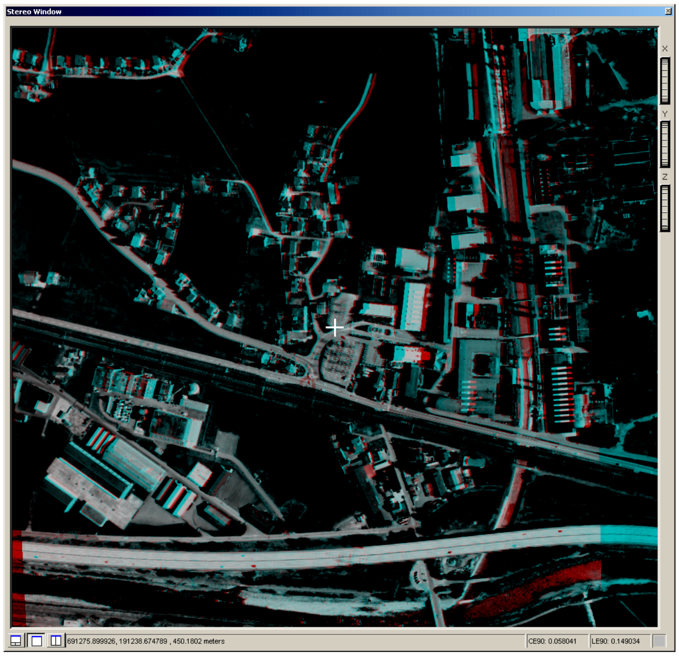
1. Make sure that Both Images displays in the Adjust field on the Stereo Enhancement toolbar.



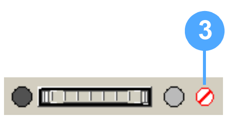
2. Drag the Brightness thumb wheel on the Stereo Enhancement toolbar right and left to see changes in the image pair displayed in the Stereo window.



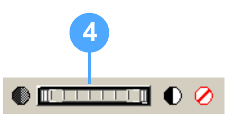
The following figure shows the image pair with decreased brightness.



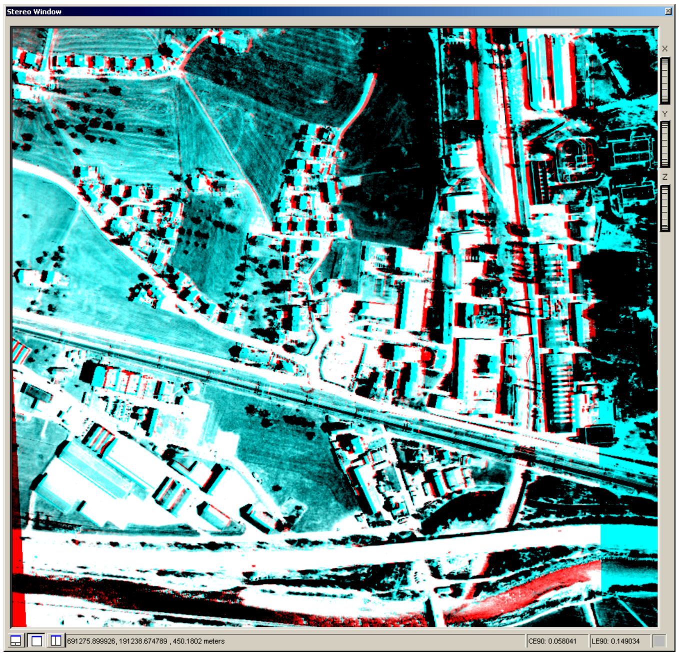
3. Click the Reset Brightness button.



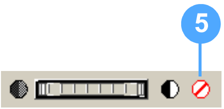
4. Drag the Contrast thumb wheel right and left to see changes in the image pair displayed in the Stereo window.



The following figure shows the image pair with increased contrast.



5. Click the Reset Contrast button.



6. Click the Close button in the top-right corner of the Stereo window to close it.

Closing the Applications

If you plan to continue to **Exercise 3: Converting Features** on page 32, do not remove any of the images currently displayed in ArcMap. Otherwise, exit ArcMap, which also closes Stereo Analyst for ArcGIS.

What's Next?

In **"Exercise 3: Converting Features"**, you learn how to use Stereo Analyst for ArcGIS tools to convert your 3D features to 2D features and vice versa.

Exercise 3: Converting Features

Two options are available for converting feature datasets from 3D to 2D and 2D to 3D—one is actual and one is virtual.

- **Actual** – Converts 3D features to 2D features, or converts 2D features to 3D features. In either case, the result is a new, separate file.
- **Virtual** – Converts a 2D feature dataset to 3D, but a separate file is not created. For more information, see **"Using Virtual 2D to 3D" on page 117**.

In this exercise, you learn how to convert 3D features to 2D. Then, you learn how to convert 2D features to 3D using an elevation source.

Preparing

If you're continuing the tutorial from **Exercise 2: Adding Oriented Images** on page 15, you can go to **Exercise 3: Converting Features** on page 33.

If you're starting this exercise from scratch, you should have ArcMap and Stereo Analyst for ArcGIS running with an empty data view. You should also have the Stereo Analyst and Stereo View toolbars displayed.

Adding Image Pairs

To add image pairs, follow these steps:

1. Click the Add Data button to select the rasters to add to ArcMap.
2. Navigate to the **\ArcTutor\StereoAnalyst\Images** folder in the Add Data dialog.
3. Hold down the **Shift** key and select the images named **strip1_1.img** and **strip2_2.img**. This selects all of the images in the list.
4. Click **Add** to add the images to ArcMap.

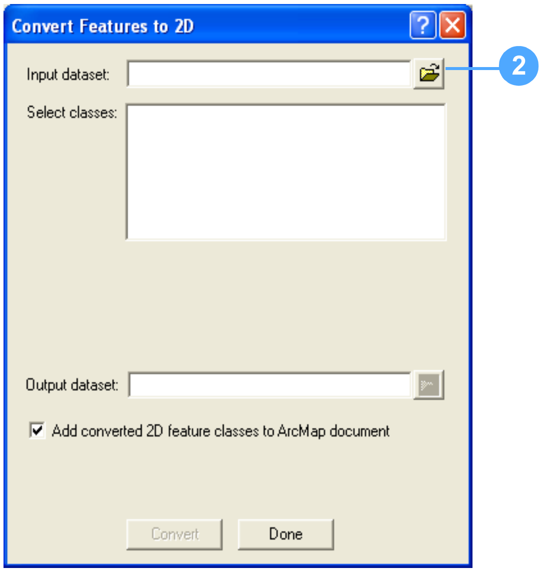
   Note: If you don't like the display of the background values in ArcMap, see **Exercise 2: Adding Oriented Images** on page 18 for instructions on how to change the display.

Converting 3D Features to 2D

The features, which are in the example geodatabase that comes with Stereo Analyst for ArcGIS, have X, Y, and Z values associated with each vertex and is therefore 3D. Stereo Analyst for ArcGIS provides you with a utility that quickly converts 3D feature data to 2D. You learn how to use that utility in this exercise.

To convert 3D features to 2D, follow these steps:

1. Select **Convert 3D Features to 2D** from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Convert Features to 2D dialog.

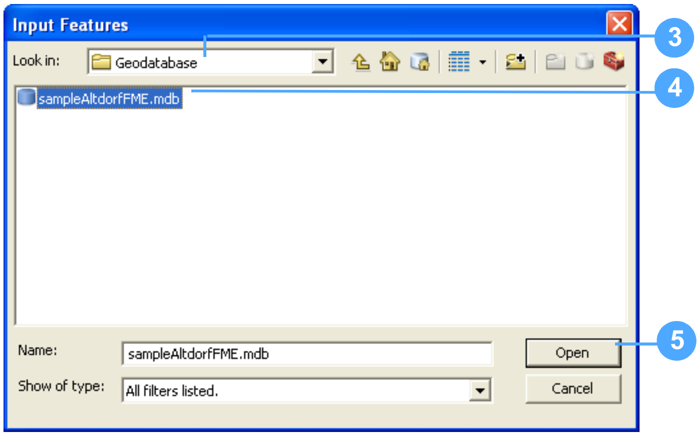


   In the Convert Features to 2D dialog, you can define input options and modify the parameters associated with converting 3D features to 2D features.

2. Click the browse button for the Input dataset field to display the Input Features dialog.

3. Navigate to the **\ArcTutor\StereoAnalyst\Geodatabase** folder.

4. Select the file named **sampleAltdorfFME.mdb**.



5. Click **Open** to add the feature classes in the geodatabase to the Convert Features to 2D dialog.

Selecting Feature Classes to Make 2D

To select feature classes to make 2D, follow these steps:

1. Go to the Select Classes box in the Convert Features to 2D dialog.

2. Delete all of the feature classes except the ones listed below by clicking each feature class, and then right-clicking and selecting **Delete**. You can delete several feature classes at one time using the Click+Shift or Click+Ctrl method.

   These are the features classes that should remain in the Select Classes box:

   CONTOUR_INDEX

   CONTOUR_INTERMEDIATE

   FREEWAY

   HOUSE

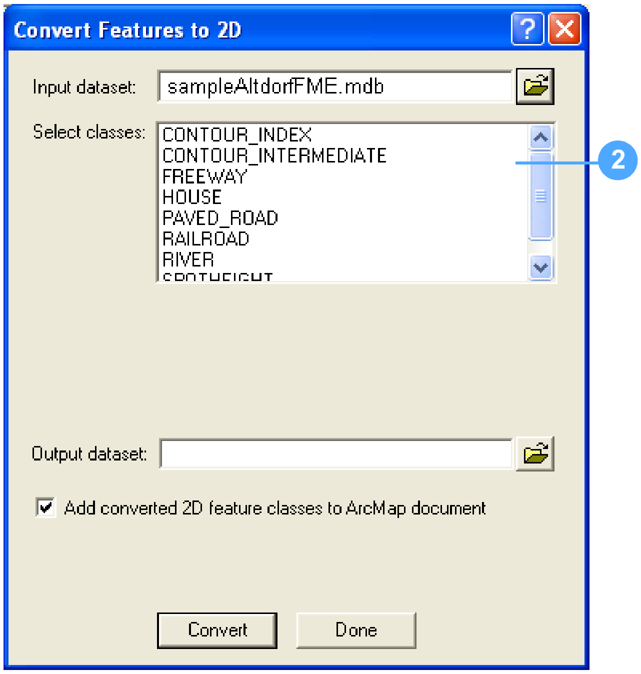
   PAVED_ROAD

   RAILROAD

   RIVER

   SPOTHEIGHT

Your Select Classes box should look like this:



If you delete a feature class unintentionally, you must reload the sampleAltdorfFME.mdb input dataset and then delete the appropriate features classes.

Selecting other Settings and Converting Features

To select other settings and convert features, follow these steps:

1. Type a name for the output dataset name in the Output Dataset field.

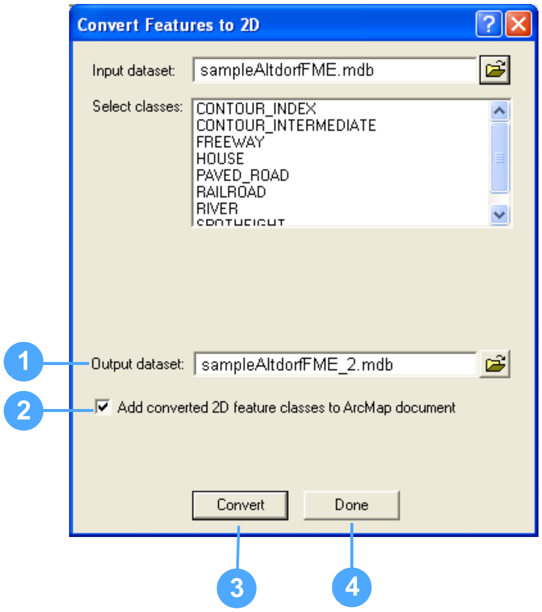
   You can name it like the input dataset, but with the additional element _2D. The contents of the original dataset are not changed, and a new file is generated. Unless you select a different location, the new file is placed in the same location as the input dataset.

2. Notice that the Add Converted 2D Feature Classes to ArcMap Document check box is selected by default.

   This option adds the converted feature datasets to the ArcMap table of contents and data view immediately after conversion. If this check box is not checked, you can add the 2D dataset to ArcMap at a later time.

3. Click **Convert** to begin the conversion process. Only the feature classes listed in the Select Classes box are converted.

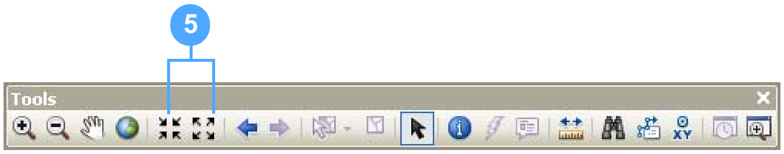
   A status bar displays at the bottom of the ArcMap window. You can view the percentage complete there as the process runs.



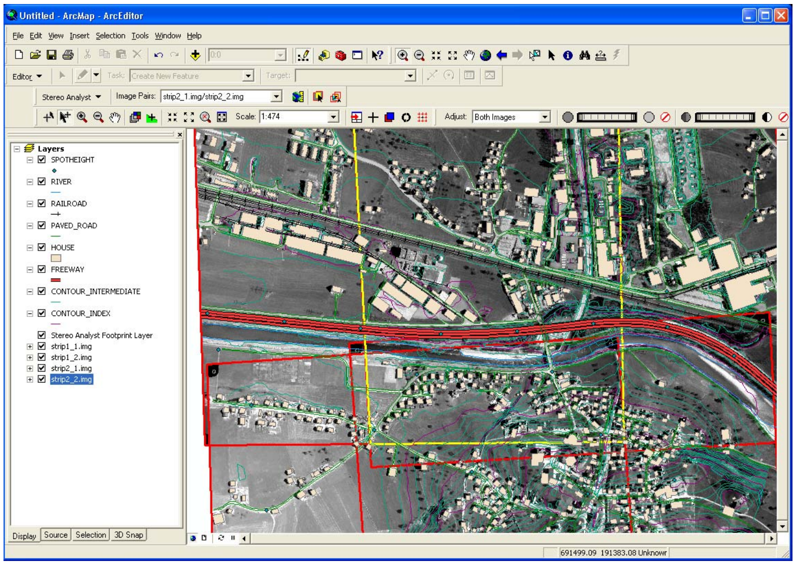
4. Click **Done** to close the Convert Features to 2D dialog when the process is complete.

   The new 2D feature classes display over the oriented images in ArcMap.

5. Use the Fixed Zoom In and Pan buttons on the Tools toolbar to clearly view the features in ArcMap.



You can use the ArcMap Identify tool to get information about individual features.



Confirming Features are 2D

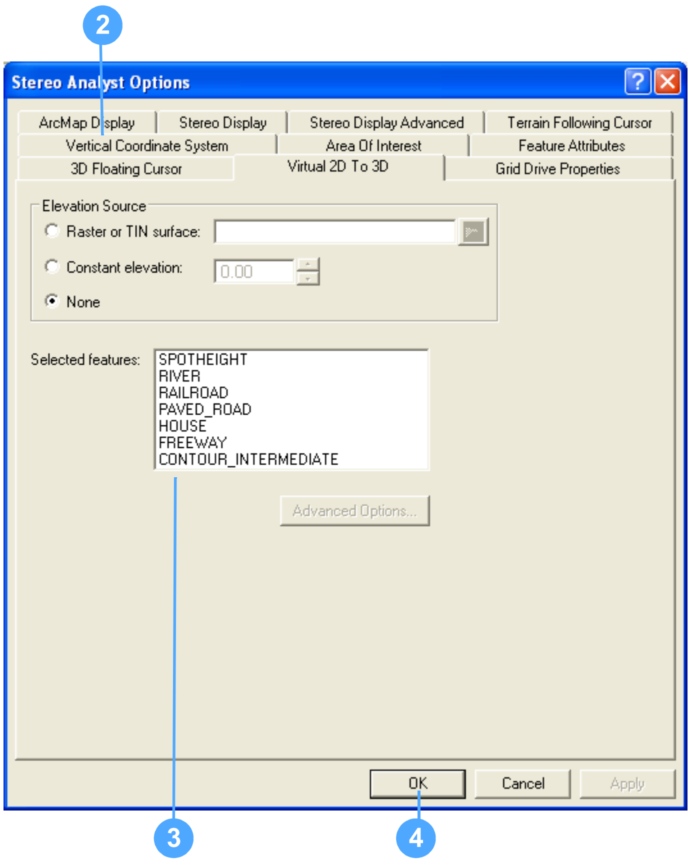
You can use the Virtual 2D to 3D tab on the Stereo Analyst Options dialog to determine whether features are 2D.

Features that are 3D are not eligible for use in virtual 2D to 3D and do not display on the Virtual 2D to 3D tab. Because this tool is only operational with 2D features; you use it here to confirm the features were converted to 2D. For more information, see **"Using Virtual 2D to 3D" on page 117**.

To confirm features are 2D, follow these steps:

1. Select **Options** from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Stereo Analyst Options dialog.

2. Click the **Virtual 2D to 3D** tab.



3. Notice that all of the features you chose for 3D to 2D conversion in the previous section of this exercise are listed in the Selected features box on this tab.

4. Click **OK** to close the Stereo Analyst Options dialog.

Converting 2D Features to 3D

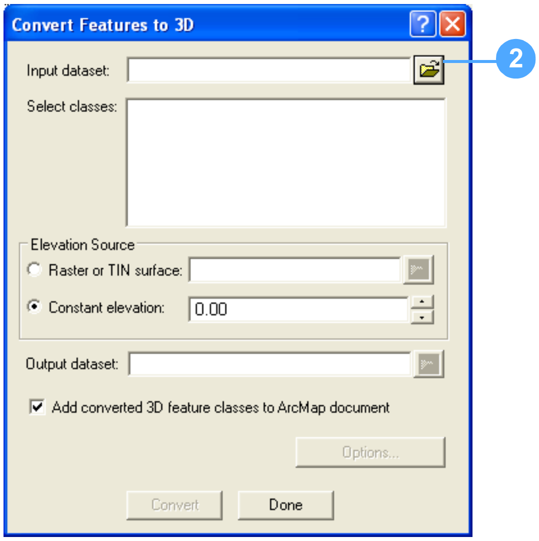
Next, you use the 2D feature dataset you just created, sampleAltdorfFME_2D.mdb, and convert it back to a 3D feature dataset using an elevation source.

To convert 2D features to 3D, follow these steps:

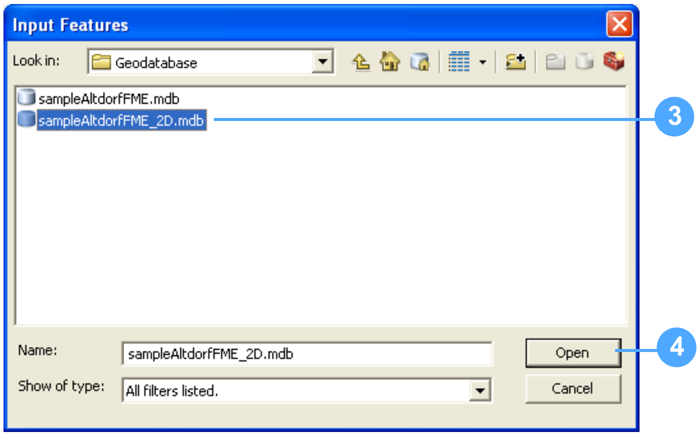
1. Select **Features to 3D** from the **Stereo Analyst** dropdown list on the Stereo Analyst toolbar to display the Convert Features to 3D dialog.

   You can define input options and modify the parameters associated with converting 2D features to 3D features in the Convert Features to 3D dialog.

2. Click the browse button for the Input dataset field, and navigate to the **\ArcTutor\StereoAnalyst\Geodatabase** folder.



3. Select the geodatabase file, **sampleAltdorfFME_2D.mdb**, that you created in the previous section of this exercise, **Exercise 3: Converting Features** on page 33.



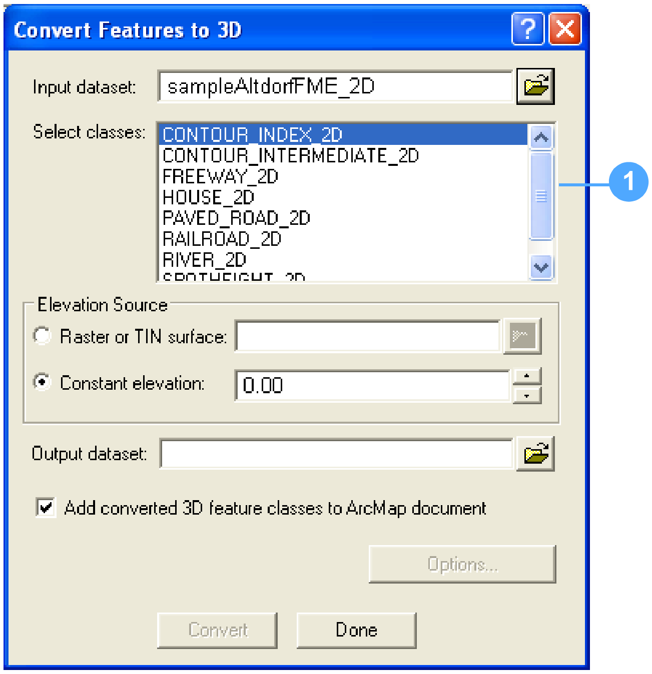
4. Click **Open** to add the feature classes in the geodatabase to the Convert Features to 3D dialog.

Selecting Feature Classes to Make 3D

By selecting a geodatabase, all the feature classes associated with the geodatabase are automatically listed in the Select classes box in the Convert Features to 3D dialog.

To select feature classes to make 3D, follow these steps:

1. Notice that all of the classes you chose to convert from 3D to 2D in the previous section of this exercise are listed in the Select Classes box and that _2D was appended to the end of each class.



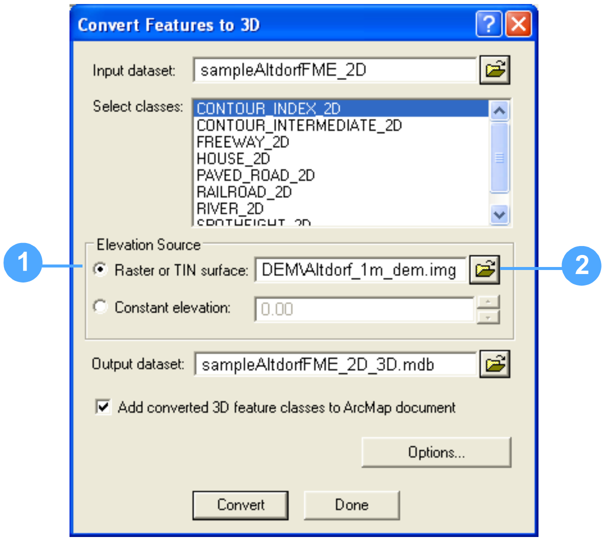
Selecting an Elevation Source

The elevation source is where Stereo Analyst for ArcGIS gets elevation information for the 2D features to convert them to 3D features.

To select an elevation source, follow these steps:

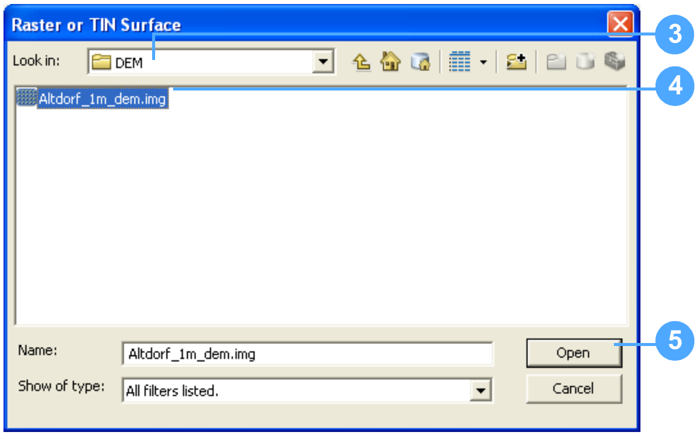
1. Click the **Raster or TIN Surface** button in the Elevation Source box.

2. Click the browse button for the Raster or TIN Surface field to display the Raster or Tin Surface dialog.



3. Navigate to the **\ArcTutor\StereoAnalyst\DEM** folder.

4. Select the **Altdorf_1m_dem.img** file.



5. Click **Open** to accept the DEM raster file as the elevation source.

Note: The accuracy of the elevation source used to convert a feature dataset to 3D impacts the quality and the amount of editing required to ensure the features reflect what is on the Earth's surface. The more an elevation source reflects the topography on the ground, the less feature editing is required.

Choosing Other Settings and Converting Features

To choose other settings and convert features, follow these steps:

1. Type a name for the output dataset in the Output Dataset field.

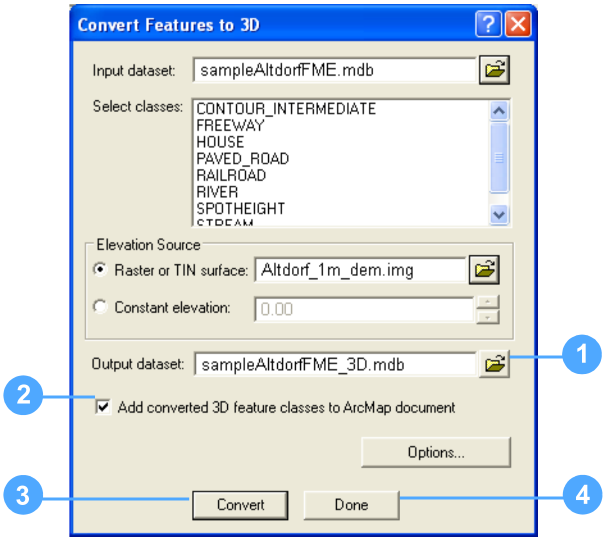
   You can specify the same name as the input dataset, but with the additional element _3D. The contents of the original dataset are not changed, and a new file is generated.

2. Notice that the Add converted 3D feature classes to ArcMap document check box is selected by default.

   This option adds the converted feature datasets to the ArcMap table of contents and data view immediately after conversion. If this box is not checked, you can add the 3D dataset to ArcMap at a later time.

3. Click **Convert** to begin the conversion process. Only the feature classes listed in the Select Classes box are converted.

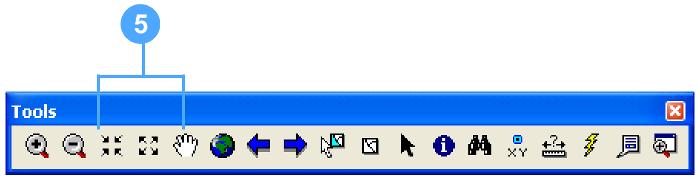
   A status bar displays at the bottom of the ArcMap window. You can view the percentage complete there as the process runs.



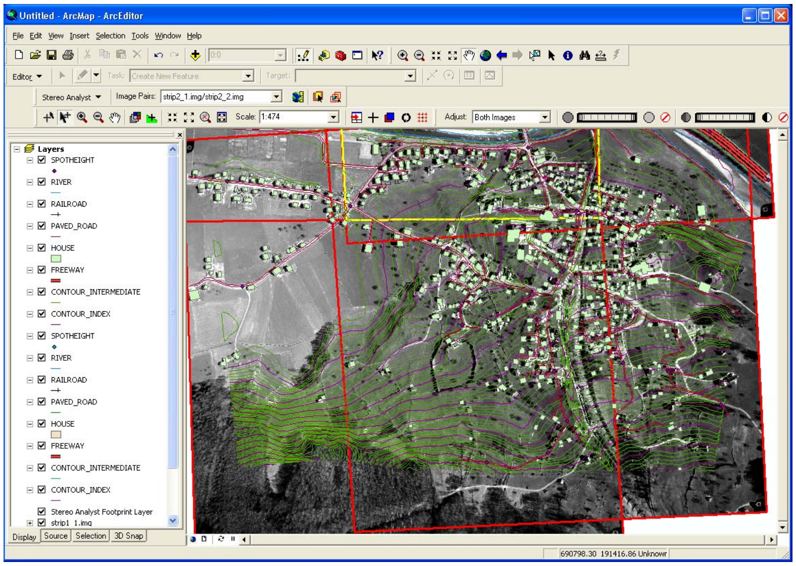
4. Click **Done** to close the Convert Features to 3D dialog when the process is complete.

   The new 3D feature classes display over the oriented images (and 2D features you created) in ArcMap.

5. Use the ArcMap Fixed Zoom In and Pan buttons on the Tools toolbar to clearly view the features in ArcMap.



You can use the Source tab in the ArcMap table of contents to confirm which feature classes are 2D feature classes, and which are 3D feature classes.



Aligning Features

The features may not entirely align with the oriented images in ArcMap. This is common because raw pixels in the oriented images have not been transformed and projected to create a new raster dataset. This process is commonly referred to as orthorectification.

Viewing the same features and oriented images in the Stereo window yields better results because Stereo Analyst for ArcGIS resamples raw pixels on the fly. To learn more about this, see **“Applying Epipolar Correction” on page 164**.

Viewing 3D Features in the Stereo Window

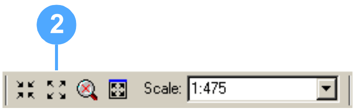
Now that you successfully updated the feature datasets using a raster DEM as your elevation source, you can view the features in the 3D representation of the area, which is created using an image pair.

To view 3D features in the Stereo window, follow these steps:

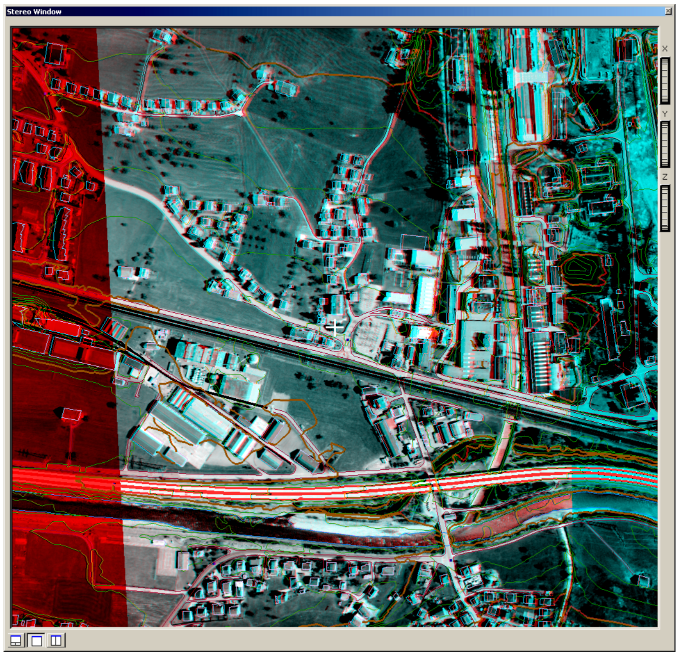
1. Click the Stereo Window button on the Stereo Analyst toolbar to display a Stereo window.

Make sure you put on the appropriate viewing glasses (anaglyph or stereo). The ArcMap display adjusts to accommodate the Stereo window, which displays the 3D feature data. If you undocked the Stereo window in the previous exercise, that undocked setting is retained.

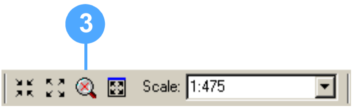
2. Click the Zoom Out By 2 button on the Stereo View toolbar until you see the extent of the raster and feature data displayed in the Stereo window.



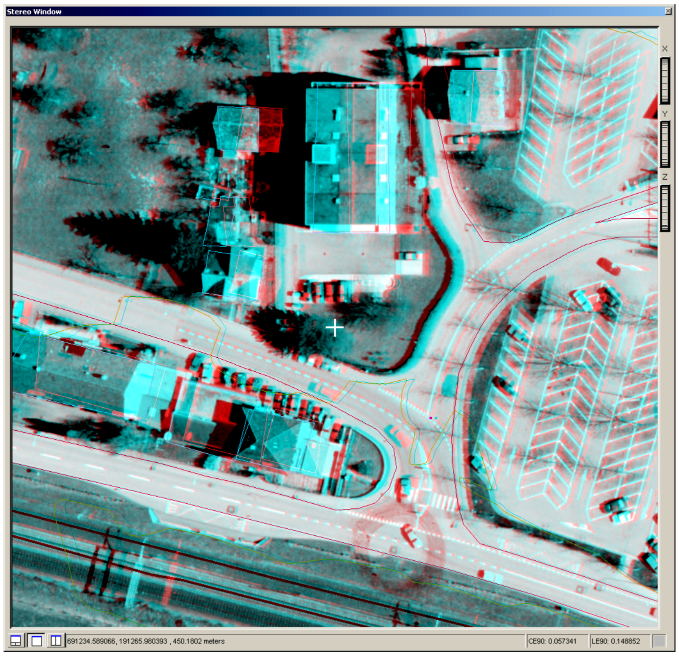
All of the features you chose in the Convert Features to 3D dialog display in the ArcMap data view and in the Stereo window.



3. Click the Default Zoom button on the Stereo View toolbar.



The oriented images display at a 1-image pixel to a 1-screen pixel resolution. This referred to as 1-to-1 zoom.



Using Tools to View Features

Stereo Analyst for ArcGIS comes with tools that let you rapidly view the data in the Stereo window. You are already familiar with the functionality of the Roam tool, so apply it again to view other portions of the image pair.

To use Stereo Analyst for ArcGIS tools to view features, follow these steps:

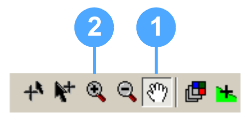
1. Click the Roam Tool button on the Stereo View toolbar, and then drag the image pair in the Stereo window to view a different area.

   Make sure you stay within the area of overlap between the left and right image of the image pair to maintain the 3D view in the Stereo window.

Remember, you can double-click when in Roam mode to enable Auto Roam mode. Double-click again to return to normal Roam mode.

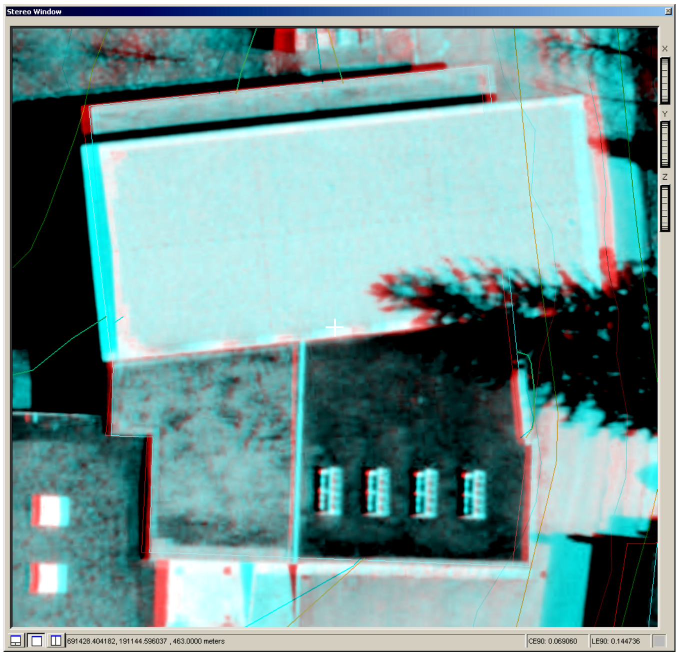
2. Click the Zoom In Tool button and click inside the Stereo window until you see a feature of interest.

You can also draw a rectangle in the Stereo window with the Zoom In tool to select an area to view.



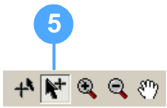
When Zoom In mode is applied, the feature that you clicked is automatically repositioned so that it displays in the center of the Stereo window. You can continue to click in the Stereo window until the feature displays at the resolution you want, which is indicated in the Scale field on the Stereo View toolbar.

3. Use the Z thumb wheel with Fixed Cursor mode to align the left and right images so that features overlap properly, if needed. Once aligned, make sure that Fixed Cursor mode is turned off.

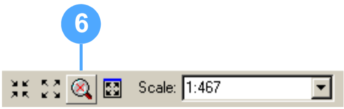


4. Click the mouse scroll wheel with the Zoom In Tool button active, and drag the mouse towards and away from you. This is another way to adjust the display, called the Continuous Zoom mode.

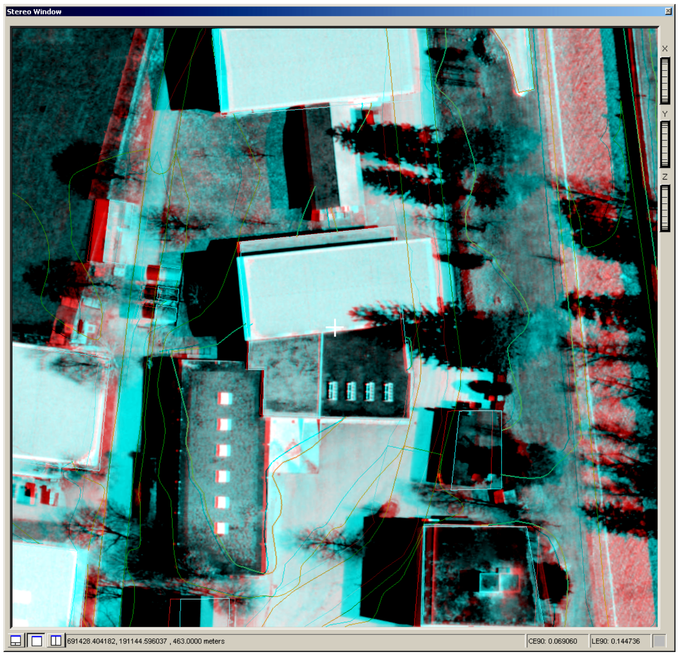
5. Click the Manually Toggle 3D floating cursor button on the Stereo View toolbar to deselect the Zoom In Tool button.



6. Click the Default Zoom button to display the oriented images at a 1-image pixel to a 1-screen pixel resolution.



The image pair displays in the Stereo window updates.



Closing the Applications

If you plan to proceed to **"Exercise 4: Collecting Features in 3D"**, perform the next series of steps. Otherwise, you can exit the ArcMap application. This closes Stereo Analyst for ArcGIS as well.

1. Hold down the **Shift** key and select all of the feature classes displayed in the ArcMap table of contents, and then right-click and select Remove.

2. Hold down the **Shift** key and select the images named **strip1_1.img** and **strip1_2.img** in the ArcMap table of contents, and then right-click and select **Remove**.

   Note: Only the image pair strip2_1.img and strip2_2.img remains in the table of contents.

What's Next?

Now that you're familiar with some of the tools used to manipulate the image pair's display in Stereo Analyst for ArcGIS, you can start collecting features.

Exercise 4: Collecting Features in 3D

To collect features in Stereo Analyst for ArcGIS, you use tools in the ArcMap editor you're already familiar with. You can use these tools to collect features in the Stereo window—the difference is you're collecting features in 3D.

Collecting features in 3D can be made easier by using the 2-Pane view of the Stereo window. This method is described in detail in this exercise.

Preparing

If you're continuing the tutorial from **"Exercise 3: Converting Features"**, proceed to **Exercise 4: Collecting Features in 3D** on page 49.

If you're starting from scratch, you should have both ArcMap and Stereo Analyst for ArcGIS running on your system. You should have an empty data view and the Stereo window, as well as the Stereo Analyst and Stereo View toolbars displayed.

Adding Images

To add images to the Stereo window, follow these steps:

1. Click the Add Data button to display the Add Data dialog and select the rasters.
2. Navigate to the **\ArcTutor\StereoAnalyst\Images** folder.
3. Hold down the **Ctrl** key and select the images named **strip2_1.img** and **strip2_2.img**.
4. Click **Add** to display the rasters in the Stereo window and in ArcMap.

   Note: If you do not like the display of the background values in ArcMap, see **Exercise 2: Adding Oriented Images** on page 18 for instructions on how to fix the display.

Enhancing Performance

If you want to enhance the performance of ArcMap, you can turn off the display of the oriented images in the ArcMap table of contents. The footprint and overlap extents remain displayed. You can also do this using the Stereo Analyst options. Select Options from the Stereo Analyst dropdown list. Click the ArcMap Display tab, click the Footprints of Oriented Images button, and then click OK.

Configuring the System Mouse

Before collecting new features, it's important to configure your input device for optimal use. An input device is the computer system's peripheral device that is used to control the 3D floating cursor in Stereo Analyst for ArcGIS. In this exercise, you use the system mouse.

Possible input devices include Immersion's SoftMouse, ABC Software Developers' Stealth 3D mouse, ITAC Systems' Mouse-Track Professional, the ERDAS TopoMouse and Handwheels EK 2000, and the standard system mouse. For more information, see the Stereo Analyst for ArcGIS help.

Setting System Mouse Properties

You must access the Devices dialog to configure the system mouse using the System Mouse Properties dialog. This dialog lets you change the settings that control mouse performance.

One of the most important settings is Axis-To-Ground, which allows you to control the sensitivity of mouse movement in X, Y, and Z (elevation). Usually, the X and Y settings of 1.00 are acceptable for digitizing. Increasing these values increases the 3D floating cursor's amount of movement in ground space in the Stereo window relative to movement of the mouse (or other digitizing device) in the X, Y, and Z directions and vice versa.

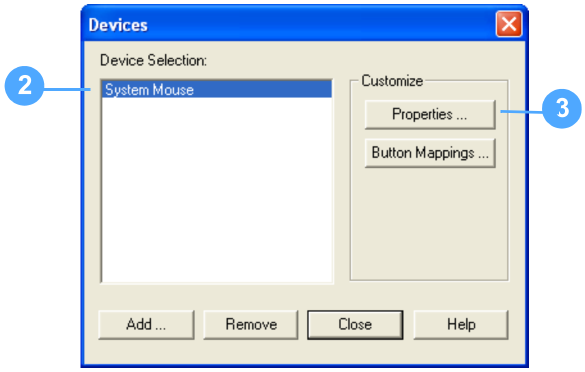
For this exercise, you alter the value for the scroll wheel (that affects Z elevation), which is 1.00 by default. This means that every movement of the scroll wheel (either up or down) results in a +/-adjustment of the elevation of the 3D floating cursor.

To set system mouse properties, follow these steps:

1. Select **Devices** from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Devices dialog.

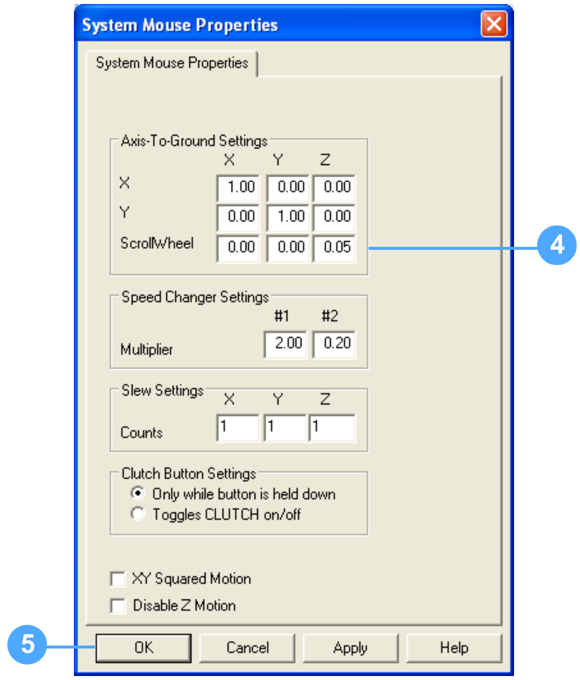
2. Select **System Mouse** in the Device Selection box.

   Note: Click the **Add** button and add the system mouse if one is not listed in the Device Selection box.



3. Click the **Properties** button to display the System Mouse Properties dialog.

4. Type the value **0.005** in the ScrollWheel field that corresponds to Z.

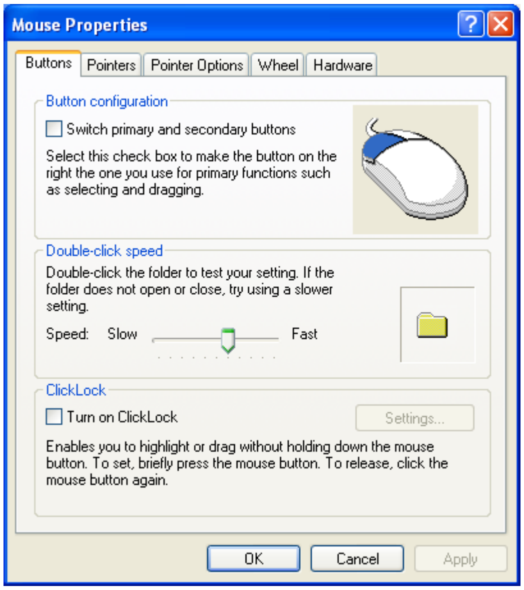


5. Click **OK** to return to the Devices dialog.

Controlling Z Movement

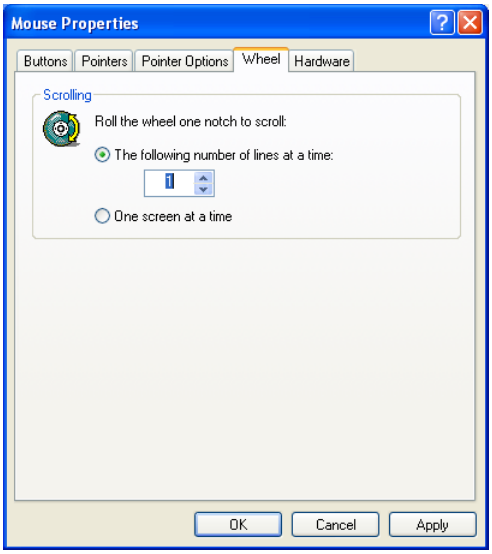
In addition to the ScrollWheel setting in the System Mouse Properties dialog, you can also control Z movement using the Mouse Properties dialog. You access this dialog through the Control Panel of your computer system. Please note that your dialog might differ from the one below depending on your computer system and mouse.

Figure 7: Mouse Properties Dialog



There are options on the Wheel tab that affect the scroll wheel of the mouse. For best results, set this value to 1 line at a time.

Figure 8: Wheel Tab



This setting equals 32 points, which is equivalent to 32 units in ground space in the Stereo window. Therefore, each click of the scroll wheel moves the 3D floating cursor up or down 32 ground units.

Mapping Buttons

You can change the mouse buttons functions to use with Stereo Analyst for ArcGIS by using the System Mouse Button Mapping dialog. It has three components:

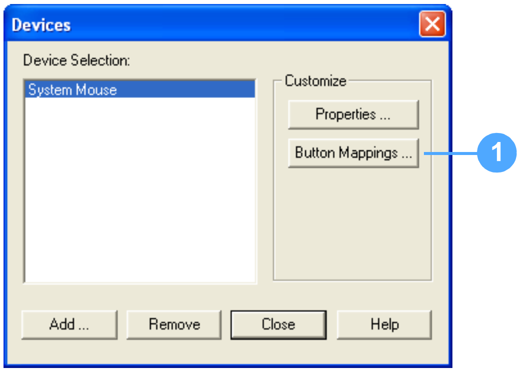
- Categories list the various ArcMap function categories.
- Commands/Buttons show the commands in each of the categories.
- Customize Button Assignment lets you view and change current button assignments. This box contains a Press/Select device button dropdown list that displays the mouse button assignments. Make a selection to display the button's function in the Currently assigned to field.

The middle mouse button (that is, the scroll wheel) remains unassigned so that it can function as the elevation control in the Stereo window.

For this exercise, you use the default settings. However, it is useful to know that you can easily change the button mappings using this dialog.

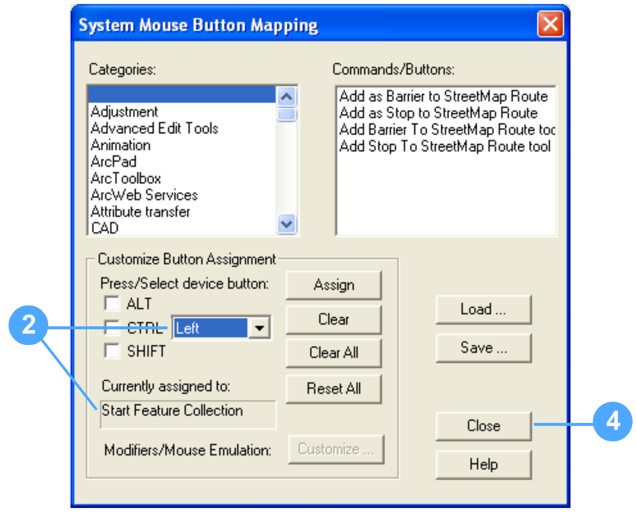
To map the system mouse buttons, follow these steps:

1. Click the **Button Mappings** button with System Mouse still selected in the Devices dialog.



2. Click the dropdown arrow in the Press/Select device button section and select **Left** when the System Mouse Button Mapping dialog opens.

You see that the Currently Assigned To field displays **Start Feature Collection**.



3. Click the dropdown arrow in the Press/Select device button and check the settings for the other mouse buttons.

4. Click **Close** to close the System Mouse Button Mapping dialog.

   You return to the Devices dialog.

5. Click **Close** to close the Devices dialog.

   Note: The default settings files for the system mouse and all other supported devices are in the \Program Files\ERDAS\ERDAS Extensions 2011\Button Mappings\StereoAnalyst directory. You can also click Reset All on the corresponding Button Mapping dialog to return to the original, default settings.

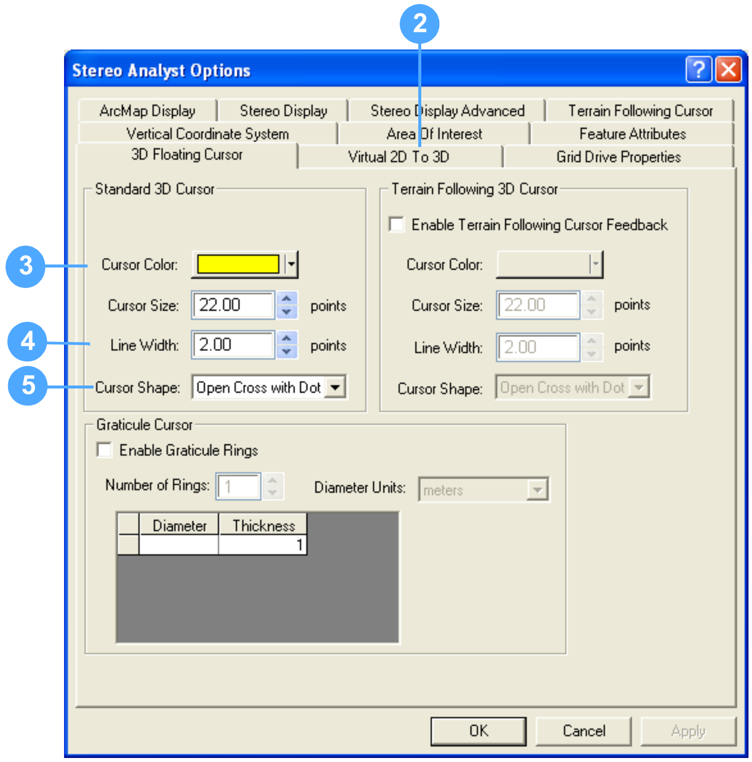
Changing the 3D Floating Cursor

You can change the way the 3D floating cursor looks in the Stereo window. This might make features easier to collect.

To change the 3D floating cursor, follow these steps:

1. Select **Options** from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Stereo Analyst Options dialog.

2. Click the **3D Floating Cursor** tab.



3. Select a color other than yellow, which is the default, for the 3D floating cursor from the Cursor Color dropdown list.

4. Click the **Line Width** up arrow to increase the line width of the 3D floating cursor, which is measured in pixel (points), to 6.00.

5. Select another 3D floating cursor shape from the list, such as Open X with Dot, from the Cursor Shape dropdown list.

   Note: For more information about 3D floating cursor shapes, see **"Selecting 3D Floating Cursor Options" on page 180**.

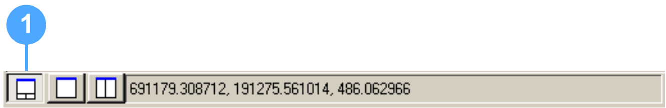
6. Click **Apply** and **OK** to close the Stereo Analyst Options dialog.

Setting up the Stereo Window

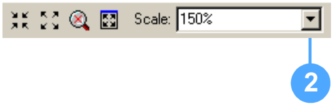
When the Stereo window is in 3-Pane view, it includes the 2-Pane view at the bottom of the Stereo window. The 2-Pane view, which shows the left and right images of the image pair, is very helpful when digitizing features to make sure that the 3D floating cursor rests on the same feature in each image.

To set up the Stereo window, follow these steps:

1. Click the 3-Pane View button at the bottom of the Stereo window if the Stereo window is not in 3-Pane view.



2. Select **150%** from the Scale dropdown list on the Stereo View toolbar.

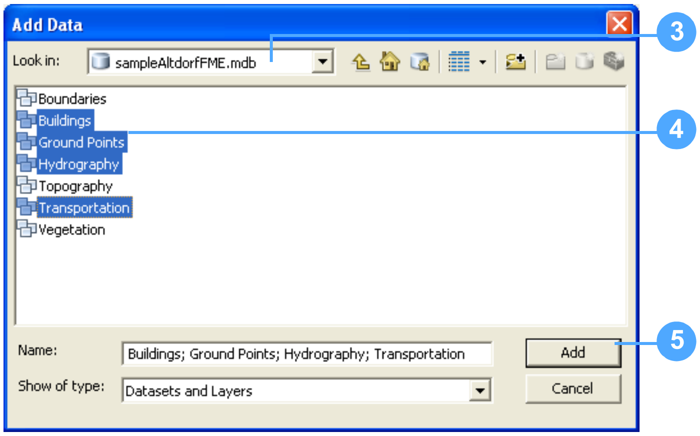


Adding Feature Classes

In this exercise, you learn some of the techniques used in the collection of features. First, you add the feature classes.

To add feature classes, follow these steps:

1. Click the Add Data button on the ArcMap toolbar to display the Add Data dialog.
2. Navigate to the **\ArcTutor\StereoAnalyst\Geodatabase** folder.
3. Double-click the **sampleAltdorfFME.mdb** file.
4. Hold down the **Ctrl** key and select the following feature datasets:



- **Buildings** – Has the layers HOUSE, HOUSE_EXTENSION, and STORAGE_TANKS.
- **Ground Points** – Has the layers FULL_CONTROL_POINT and SPOTHEIGHT.
- **Hydrography** – Has the layers DRAIN, POND, RIVER, STORM_DRAIN, and STREAM.

- **Transportation** – Has the layers FOOTPATH, FREEWAY, PAVED_ROAD, RAILROAD, and TRACK.

5. Click the **Add** button.

Displaying the Editor Toolbar

The ArcMap editing tools let you collect and edit features quickly in the Stereo window. If you don't have the Editor toolbar displayed, click the Customize menu, point to Toolbars, and select Editor to display it.

Collecting a Polygon Feature

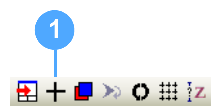
Polygon features are created by collecting a number of vertices, which are eventually closed to create a shape. For example, four connected vertices might represent a rectangular building.

Locating the Polygon Feature

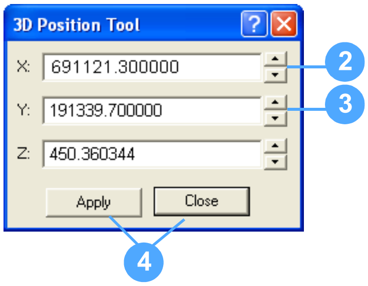
The easiest way to locate the first polygon to digitize is to use the 3D Position tool. The coordinates you enter correspond to the image pair strip2_1.img and strip2_2.img, so make sure it is active.

To locate the polygon feature, follow these steps:

1. Click the 3D Position Tool button on the Stereo View toolbar to display the 3D Position Tool dialog.



2. Type the X coordinate **691121.3** in the X field.

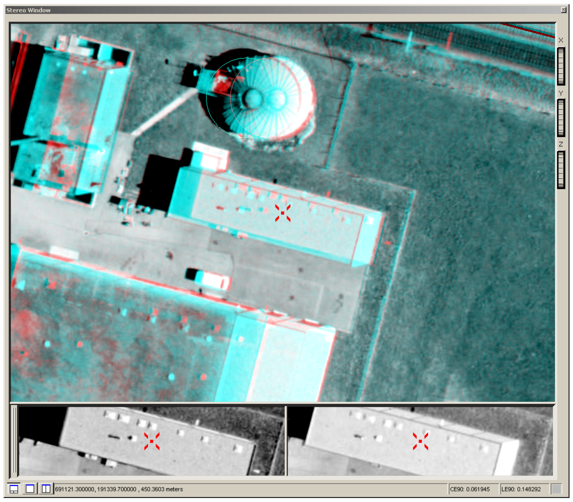


3. Type the Y coordinate **191339.7** in the Y field.

   You don't need to enter a value in the Z field.

4. Click **Apply** and **Close** to close the 3D Position Tool dialog.

The position of the 3D floating cursor adjusts to reflect the coordinates you entered in the 3D Position Tool dialog. This is the first building you digitize.



5. Click the Synchronize Geographic Displays button on the Stereo View toolbar so that the ArcMap data view approximates that of the Stereo window.

Orienting the ArcMap Display

While the location displayed in the ArcMap data view approximates that of the Stereo window, the orientation of the image pair in ArcMap can display differently from the display in the Stereo window.

To orient the ArcMap display to match the display in the Stereo window, select Options from the Stereo Analyst dropdown list on the Stereo Analyst toolbar. On the ArcMap Display tab, check the Orient ArcMap document to Image Pair when Image Pair changes check box, and then click OK.

However, if you uncheck this check box, the display in ArcMap won't return to the original rotation. To unrotate the display, use the ArcMap data frame tools.

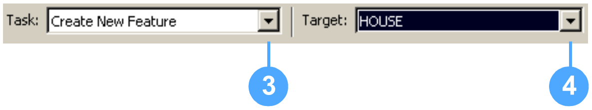
Preparing to Collect the Feature

To prepare to collect the feature, follow these steps:

1. Adjust the position of the images until the roof of the building feature overlaps in the right and left images using the Fixed Cursor Mode button and the Z thumb wheel. Make sure you deselect the Fixed Cursor Mode button when finished.

2. Select **Start Editing** from the **Editor** dropdown list on the Editor toolbar.

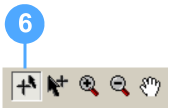
3. Make sure the Task field on the Editor toolbar displays **Create New Feature**.



4. Select **HOUSE** from the Target dropdown list.

5. Click the Sketch Tool button.

6. Click the Auto Toggle 3D Floating Cursor button on the Stereo View toolbar, and then move the cursor into the Stereo window where it immediately transitions to the 3D floating cursor.



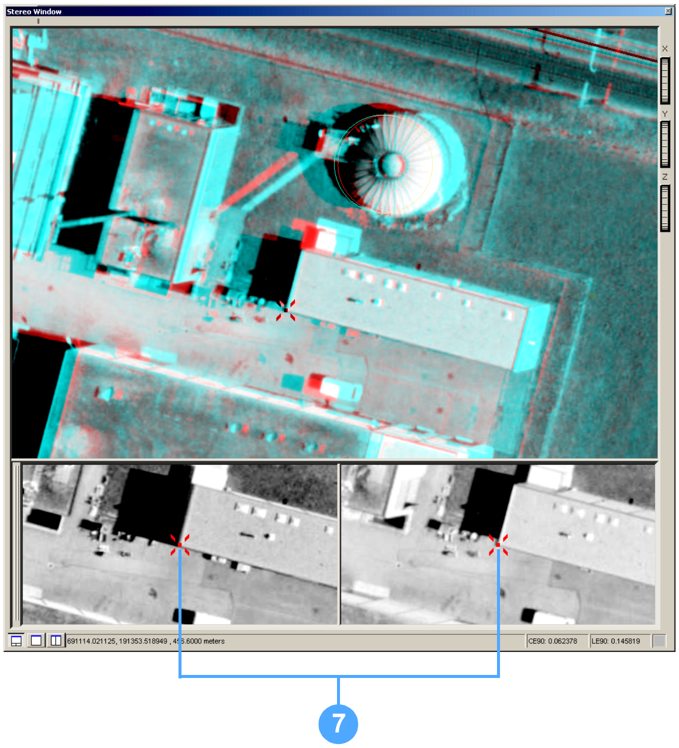
Note: When you are in Auto Toggle 3D Floating Cursor mode, it is not necessary to toggle in and out of the Stereo window (using the F3 key).

The mouse can no longer be thought of as a typical 2D mouse once in the Stereo window. It now controls the 3D floating cursor in three dimensions.

When in Auto Toggle 3D Floating Cursor mode, the images are fixed. You must adjust the elevation value using the separation of the 3D floating cursor rather than the parallax of the images.

7. Adjust the scroll wheel on the mouse up and down until the 3D floating cursor rests on the same portion of the building in the 2-Pane view (the roof of which is approximately 456 meters).

Note: If you are new to working in stereo, you might want to use the 2-Pane view frequently. It shows the individual left and right images of the image pair. When the position of the 3D floating cursor in the left pane matches the identical position in the right pane, you are at the correct X, Y, Z location.



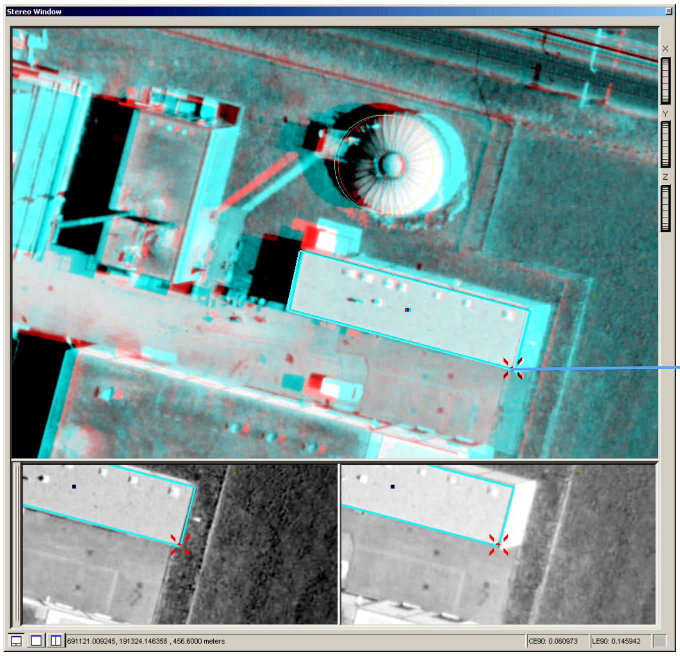
Collecting the Polygon Feature

To collect the polygon feature, follow these steps:

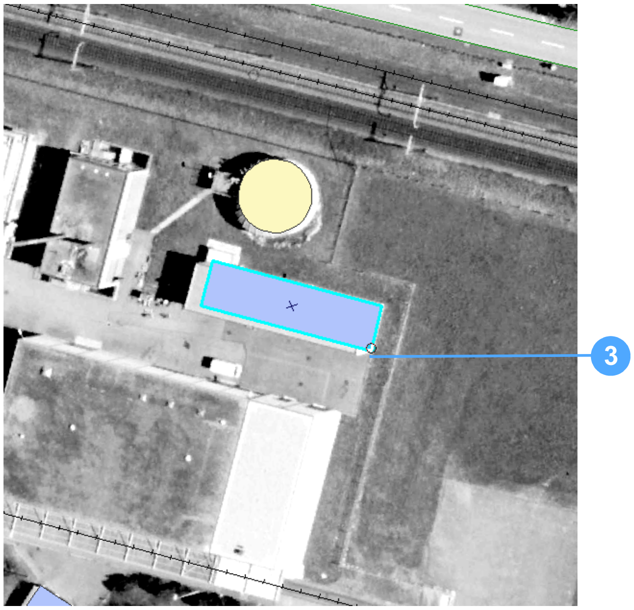
1. Click to collect the building vertices (the HOUSE layer is a polygon feature layer) around the roof's perimeter.

   Note: Always remember that you must make accurate collections in X, Y, and Z. A good strategy is to move close to the building corners, and then adjust Z with the mouse scroll wheel to get the correct X, Y, Z location.

2. Double-click to finish collecting the polygon (or press **F2** on the keyboard).



3. Examine the ArcMap display—you should now see a 2D display of the 3D feature you collected.



The ArcMap display updates in real time. Any collections made in the Stereo window are immediately reflected in the display.

Collecting Another Polygon Feature

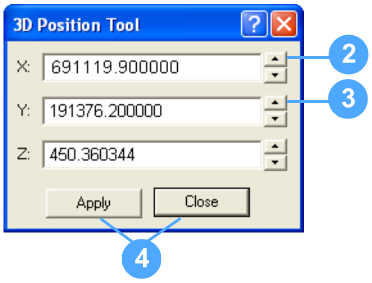
The next polygon you collect is located in the same area, but has a different elevation.

Locating the Polygon Feature

To locate the polygon feature, follow these steps:

1. Click the 3D Position Tool button on the Stereo View toolbar to display the 3D Position Tool dialog.

2. Type the X coordinate **691119.9** in the X field.



3. Type the Y coordinate **191376.2** in the Y field.

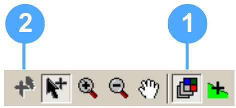
   You don't need to enter a value in the Z field.

4. Click **Apply** and **Close** to close the 3D Position Tool dialog.

Preparing to Collect the Feature

To prepare to collect the feature, follow these steps:

1. Click the Fixed Cursor Mode button on the Stereo View toolbar.



2. Notice that clicking the Fixed Cursor Mode button disables the Auto Toggle 3D Floating Cursor mode.

   Note: In Fixed Cursor mode, the 3D floating cursor does not appear to move as it does in Auto Toggle 3D Floating Cursor mode. Instead, the elevation of the 3D floating cursor is controlled by moving the images, which is also known as adjusting parallax.

3. Click in the Stereo window, and then press **F3** on the keyboard to activate the 3D floating cursor.

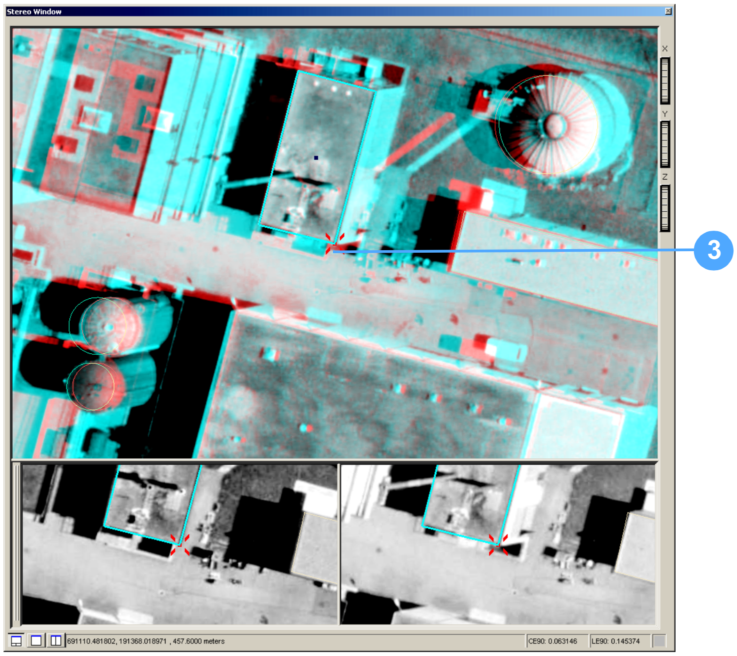
Collecting the Polygon Feature

To collect the polygon feature, follow these steps:

1. Move the scroll wheel on the mouse up and down until the roof overlaps in both the left and right image of the image pair, and the 3D floating cursor rests on the same portion of the roof in the 2-Pane view. The building's roof is approximately 457 meters.

2. Click vertices corresponding to the corners of the building.

3. Double-click to finish collecting (or press **F2** on your keyboard).



4. Collect other building features if you want.

5. Press **F3** to toggle off the 3D floating cursor.

Collecting a Polyline Feature

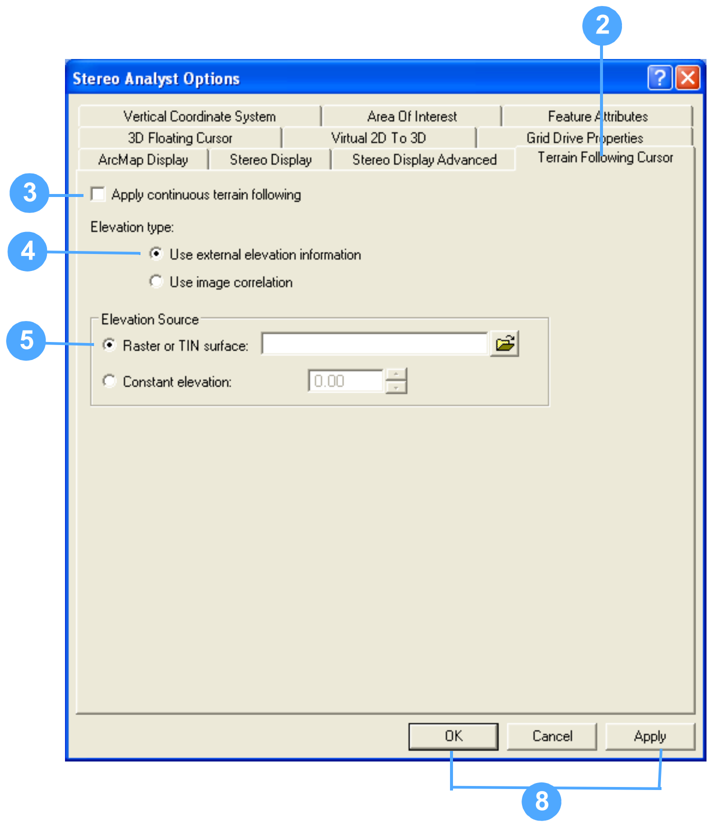
Like polygon features you collect using Stereo Analyst for ArcGIS, polyline features have an elevation component. In the next example, you use the Terrain Following mode to simplify collection of a road feature.

Setting Terrain Following Mode Options

In this portion of the exercise, you use Snap to Ground and the Terrain Following mode in conjunction with a raster elevation data source.

To set terrain following mode options, follow these steps:

1. Select **Options** from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Stereo Analyst Options dialog.



2. Click the **Terrain Following Cursor** tab.

3. Make sure the Apply continuous terrain following check box is not checked because you still want to manually navigate in Z.

4. Click the **Use External Elevation Information** button.

5. Click the **Raster or TIN Surface** button, and then click the browse button for the field to display the Raster or TIN surface dialog.

6. Navigate to **\ArcTutor\StereoAnalyst\DEM** and select the **Altdorf_1m_dem.img** raster surface.

7. Click **Open** to return to the Stereo Analyst Options dialog.

   Note: You can specify the Use image correlation setting instead, which uses a correlation algorithm to place the 3D floating cursor on the feature of interest. For more information, see **"Using Image Correlation" on page 184**.

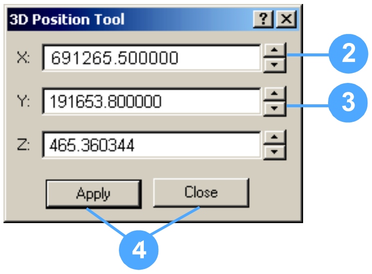
8. Click **Apply** and **OK** to close the Stereo Analyst Options dialog.

Locating the Polyline Feature

To locate the polyline feature, follow these steps:

1. Click the 3D Position Tool button on the Stereo View toolbar to display the 3D Position Tool dialog.

2. Type the X coordinate **691265.5** in the X field.



3. Type the Y coordinate **191653.8** in the Y field.

   You don't need to enter a value in the Z field.

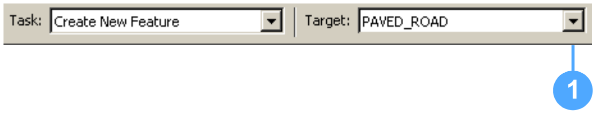
4. Click **Apply** and **Close** to close the 3D Position Tool dialog.

Collecting a Polyline Feature

In this part of the exercise, you collect a 3D line feature for the PAVED_ROAD layer. You should still be in Fixed Cursor mode, and the Manually Toggle 3D Floating Cursor mode should be active.

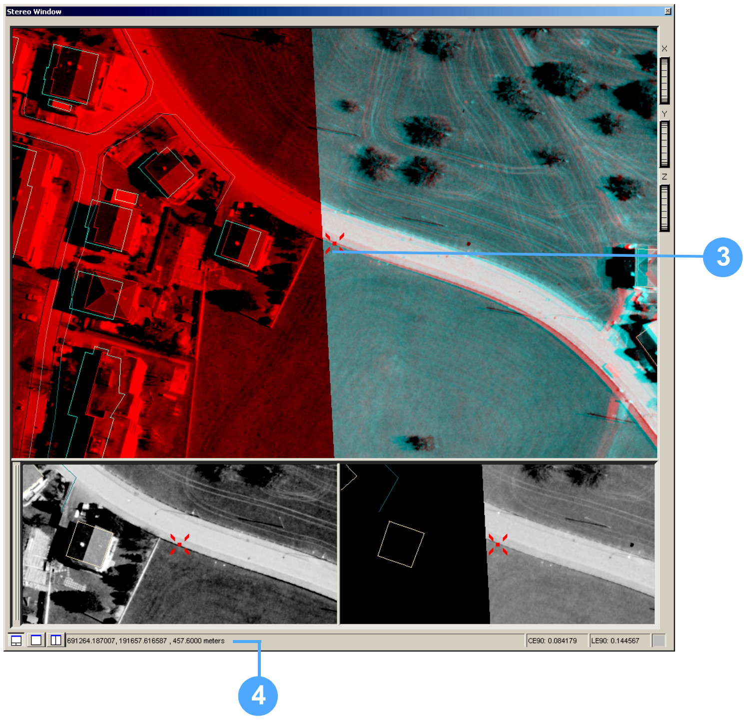
To collect a polyline feature, follow these steps:

1. Select **PAVED_ROAD** from the Target dropdown list.



2. Click in the Stereo window, and then press the **F3** key to activate the 3D floating cursor.

3. Move in X and Y to the part of the road just within the image pair overlap boundary.

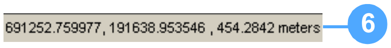


4. Notice the current elevation of the 3D floating cursor, which displays at the bottom of the Stereo window.

5. Press the **S** key on your keyboard to snap the 3D floating cursor to the ground.

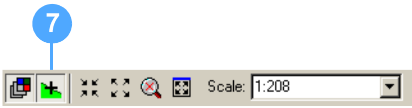
Note: Using Snap to Ground moves the elevation of the 3D floating cursor to the ground level elevation (approximately 454 meters). This elevation is obtained from the elevation data source you specified on the Terrain Following Cursor tab on the Stereo Analyst Options dialog.

6. Notice that the elevation of the area beneath the 3D floating cursor updates in the lower portion of the Stereo window.

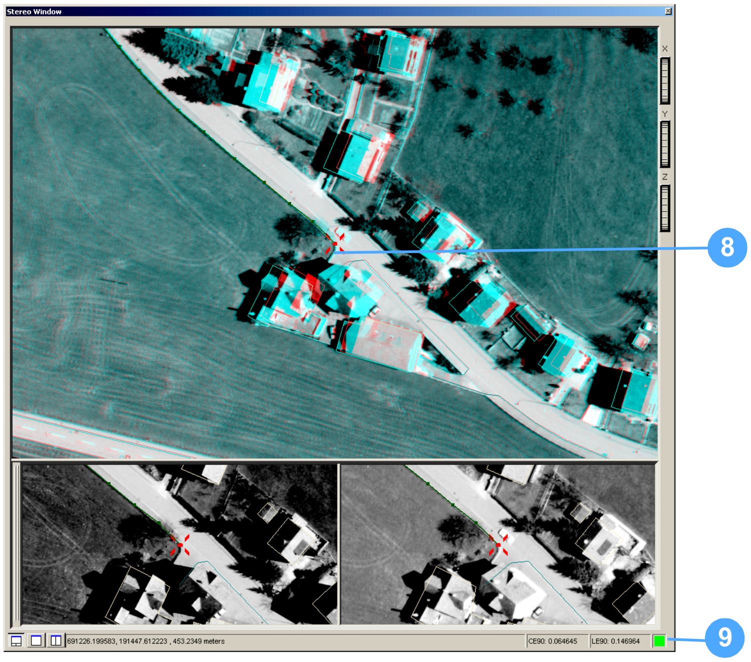


7. Click the Terrain Following Mode button on the Stereo View toolbar.

   Note: Terrain Following mode forces the 3D floating cursor to constantly acquire an elevation value from the elevation source. Using this mode is the same as constantly applying Snap to Ground. Notice that the Terrain Following mode button on the Stereo View toolbar is on.



8. Collect the vertices for the road feature until you reach the approximate coordinates X: **691225.9** and Y: **191446.9**.



9. Notice the CE90 and LE90 readings and associated color block at the bottom of the Stereo window as you digitize.

Note: A green color block indicates that the 3D floating cursor is on the ground or feature of interest; a red color block indicates that the 3D floating cursor is not resting on the feature. If the color block is red, adjust the position of the 3D floating cursor slightly until it changes to green, and then collect the next vertex. You can specify colors other than red or green using the 3D Floating Cursor tab on the Stereo Analyst Options dialog.

For more information about LE90 and CE90, see **"Checking Accuracy of 3D Information" on page 190**.

10. Double-click to finish collecting (or press F2 on the keyboard).

11. Press **F3** to toggle out of the Stereo window.

12. Click the Terrain Following Mode button on the Stereo View toolbar to toggle it off.

13. Click the Fixed Cursor Mode button to toggle it off.

14. Click the Manually Toggle 3D Floating Cursor button to toggle it off.

View the new feature in the ArcMap data view by clicking the Synchronize Geographic Displays button or by selecting the ArcMap document follows Stereo Cursor option on the ArcMap Display tab on the Stereo Analyst Options dialog.

Collecting Point Features

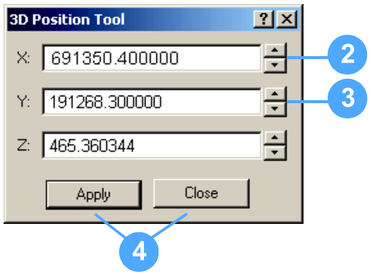
You collect point features, each of which has an X, Y, and Z coordinate, with a single click. You can use keyboard shortcuts and other tools you've learned about in the collection of point features.

Locating the Area for Point Features

To locate the area for point features, follow these steps:

1. Click the 3D Position Tool button on the Stereo View toolbar to display the 3D Position Tool dialog.

2. Type the X coordinate **691350.4** in the X field.



3. Type the Y coordinate **191268.3** in the Y field.

   You don't need to enter a value in the Z field.

4. Click **Apply** and **Close** in the 3D Position Tool dialog.

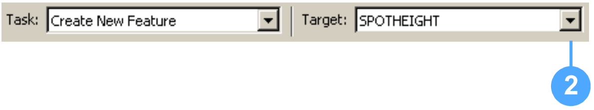
Preparing to Collect Point Features

Spot heights are point features; therefore, one click starts and completes digitizing a spot height.

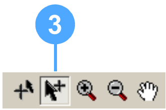
To prepare to collect point features, follow these steps:

1. Use the Fixed Cursor Mode button and the Z thumb wheel to adjust the images so that features overlap. Make sure you exit Fixed Cursor mode when you finish.

2. Select **SPOTHEIGHT** from the Target dropdown list on the Editor toolbar.



3. Make sure the Manually Toggle 3D floating cursor button is selected.



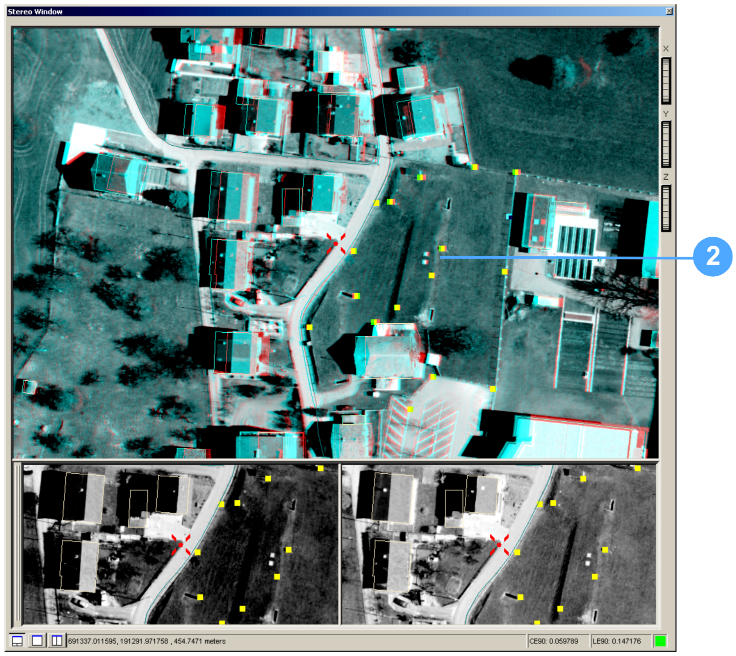
Collecting Point Features

To collect point features, follow these steps:

1. Click in the Stereo window, and then press the **F3** key to toggle on Manually Toggle 3D Floating Cursor mode.

2. Use a combination of procedures outlined in previous examples (such as Snap to Ground and Terrain Following mode) to collect individual spot heights with a single click.

3. Collect approximately 10 spot heights in the area.



4. Exit Terrain Following mode if you used it. The Terrain Following Mode button is not recessed on the Stereo View toolbar.

5. Click the Manually Toggle 3D Floating Cursor Mode button on the Stereo View toolbar to toggle it off.

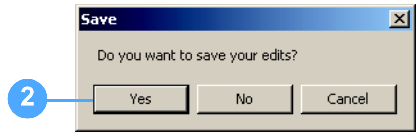
If you want to see the new features in the ArcMap data view, you can click the Synchronize Geographic Displays button on the Stereo View toolbar.

Saving Features

To save features in Stereo Analyst for ArcGIS, follow these steps:

1. Select **Stop Editing** from the Editor dropdown list.

2. Click **Yes** in the Save dialog to save your edits.



Closing the Applications

If you plan to proceed directly to **Exercise 5: Editing Existing Features** on page 71, keep the raster images and the feature datasets displayed in ArcMap and Stereo Analyst for ArcGIS. Otherwise, exit ArcMap, which also closes Stereo Analyst for ArcGIS.

What's Next?

In the final exercise, **"Exercise 5: Editing Existing Features"**, you learn how to edit individual vertices and move entire features in the Stereo window.

Exercise 5: Editing Existing Features

Feature editing in Stereo Analyst for ArcGIS differs from traditional ArcMap feature editing by operating in 3D. In Stereo Analyst for ArcGIS, you can edit existing features using a 3D digital representation of the Earth's surface (created using overlapping, oriented images) as a reference backdrop for updating the existing dataset.

While it is still possible to edit features solely in X and Y, you can no longer ignore elevation. All data collected and edited in Stereo Analyst for ArcGIS is 3D, and each vertex of every feature has an X, Y, and Z (elevation) value associated with it.

This section focuses on editing polygon features, which involves editing vertices associated with a polygon and moving an entire polygon. The same editing procedures in Stereo Analyst for ArcGIS can be used regardless of the type of feature data (point, line, or polygon).

Preparing

This exercise assumes you're using a standard computer mouse (with a scroll wheel).

If you're continuing the tutorial from **"Exercise 4: Collecting Features in 3D"**, proceed to **Exercise 5: Editing Existing Features** on page 72.

If you're starting this exercise from scratch, you should have an empty ArcMap data view and Stereo window displayed. Also, you should have the Stereo Analyst, Stereo View, and Editor toolbars displayed.

Adding Images

To add images, follow these steps:

1. Click the Add Data button to display the Add Data dialog and select the rasters.
2. Navigate to the **\ArcTutor\StereoAnalyst\Images** folder.
3. Hold down the **Ctrl** key and click the images named **strip2_1.img** and **strip2_2.img**.
4. Click **Add** to load the rasters in the Stereo window and ArcMap.

   Note: If you don't like the display of the background values in ArcMap, see **Exercise 2: Adding Oriented Images** on page 18 for instructions on how to change it.

Adding Feature Data

To add feature data, follow these steps:

1. Click the Add Data button on the ArcMap toolbar to display the Add Data dialog.
2. Navigate to the **\ArcTutor\StereoAnalyst\Geodatabase** folder.
3. Double-click the **sampleAltdorfFME.mdb** file.
4. Double-click the **Buildings** dataset. It has the following layers:
    - HOUSE
    - HOUSE_EXTENSION
    - STORAGE_TANKS
5. Hold down the **Ctrl** key and select each layer.
6. Click the **Add** button.

Adjusting a Polygon Feature

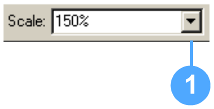
The first feature to edit is in the HOUSE feature category in image pair strip2_1.img and strip2_2.img, so make sure it is active.

Locating an Existing Polygon Feature

You use the 3D Position Tool to find the first feature quickly.

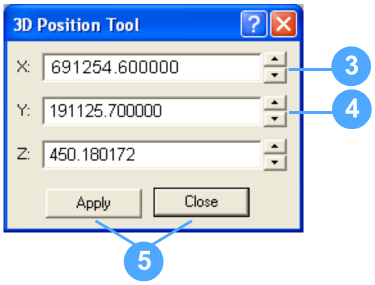
To locate an existing polygon feature, follow these steps:

1. Select **150%** from the Scale dropdown list on the Stereo View toolbar.



2. Click the 3D Position Tool button on the Stereo View toolbar to display the 3D Position Tool dialog.

3. Type the X coordinate **691254.6** in the X field.

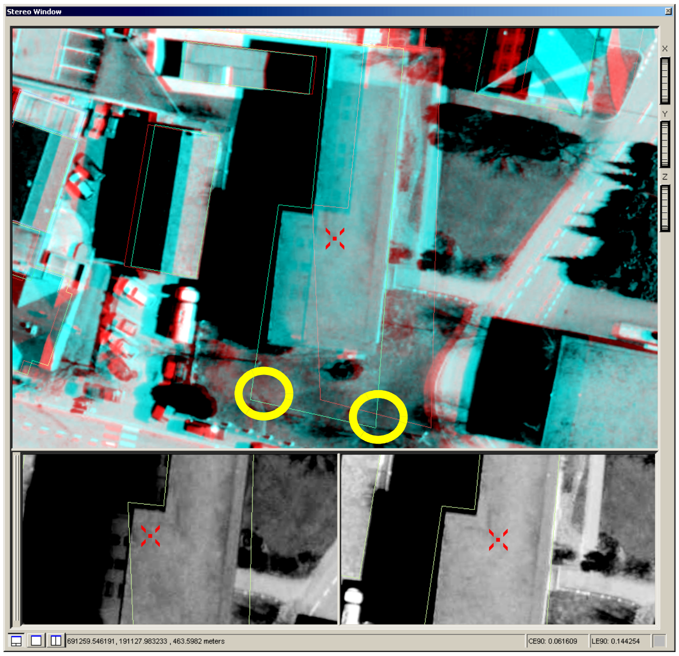


4. Type the Y coordinate **191125.7** in the Y field.

   You don't need to enter a value in the Z field.

5. Click **Apply** and **Close** to close the 3D Position Tool dialog.

   After the new coordinates are applied, the portion of the image pair shown in the Stereo window changes. Also, the 3D floating cursor moves to the coordinate location you entered. Two vertices (which are circled in yellow in the figure below) for this feature are not positioned on the corners of the building.



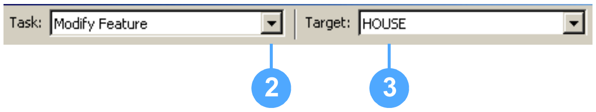
6. Click the Synchronize Geographic Displays button on the Stereo View toolbar so that the ArcMap data view approximates that in the Stereo window.

Note: To orient the ArcMap display to match the orientation of the display in the Stereo window, click the Stereo Analyst dropdown menu on the Stereo Analyst toolbar and select Options. On the ArcMap Display tab, select the Orient ArcMap document to Image Pair when Image Pair changes check box, and then click OK. You can also set the ArcMap window to follow the Stereo window, and then click OK.

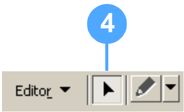
Preparing to Adjust the Polygon Feature

To prepare to adjust the polygon feature, follow these steps:

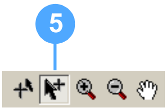
1. Select **Start Editing** from the Editor dropdown list on the Editor toolbar.
2. Select **Modify Feature** from the Task dropdown list.



3. Select **HOUSE** for the layer from the Target dropdown list.
4. Click the Edit Tool button.



5. Click the Manually Toggle 3D Floating Cursor button on the Stereo View toolbar.

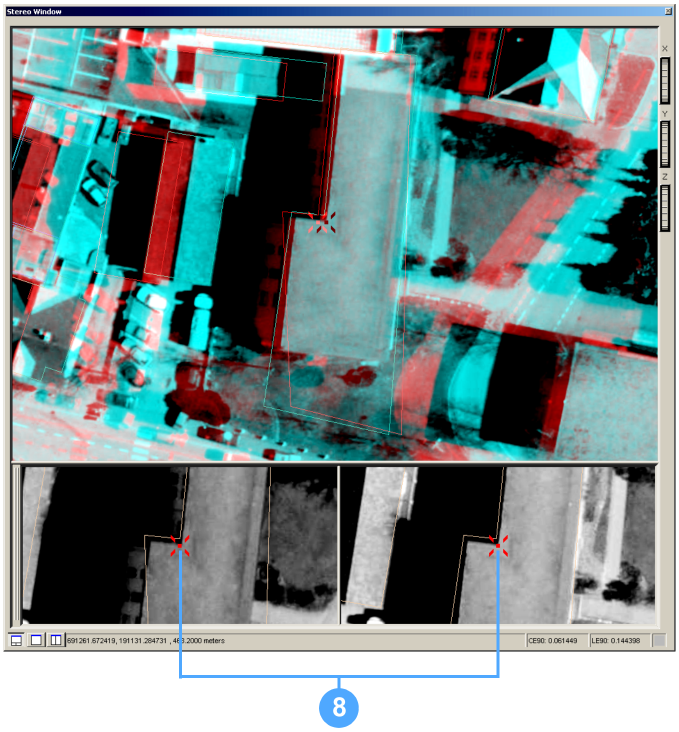


6. Click inside the Stereo window, and then press **F3** to toggle on the 3D floating cursor.

   Remember that this cursor is a 3D cursor that no longer functions as a regular 2D Windows cursor while in the Stereo window.

7. Click the Fixed Cursor Mode button to enter Fixed Cursor mode.
8. Adjust parallax so that the 3D floating cursor is at the same elevation as the roof of the building (approximately 463 meters) using the scroll wheel on your mouse.

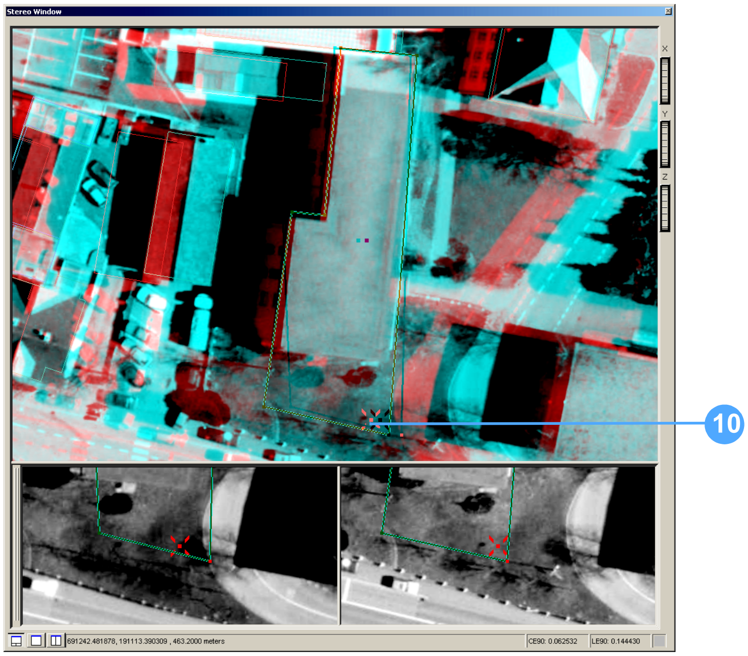
9. Click the Fixed Cursor Mode button after you remove parallax to toggle it off.



If you look at the 2-Pane view at the bottom of the Stereo window, you know you're at the correct elevation when the 3D floating cursor is in the same position in both panes.

10. Position the 3D floating cursor in the middle of the polygon when it is at the correct elevation and click.

    Notice how a dark blue square is positioned at the center of the polygon in the Stereo window, and the polygon outline color is light blue in ArcMap.



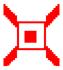
Adjusting the Vertex Position

To adjust the vertex position, follow these steps:

1. Position the 3D floating cursor over the right-most erroneous vertex.

2. Adjust the Z elevation of the 3D floating cursor to match that of the right erroneous vertex (approximately 467 meters) using the scroll wheel.

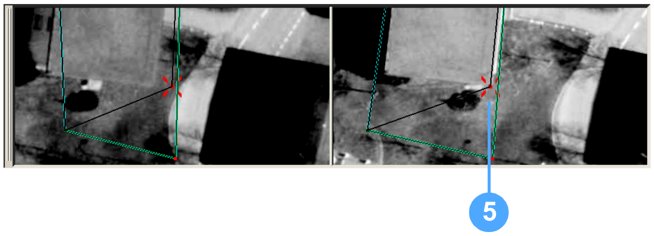
3. Notice how the 3D floating cursor changes to a squared crosshair, shown in the figure below, when you are within the snap radius of a vertex.



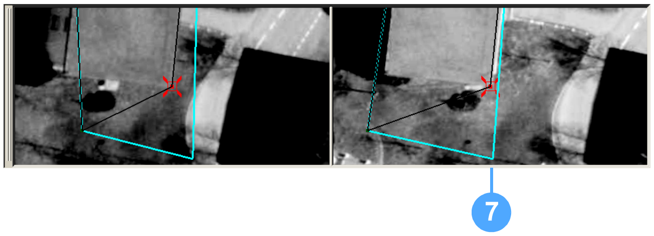
The following series of steps makes use of the 2-Pane view to ensure that the 3D floating cursor is located at the same position in both the left and right images.

4. Hold down the left mouse button in the snap radius of a vertex.

5. Move the 3D floating cursor in X and Y until its location corresponds to the appropriate corner of the building.



6. While continuing to hold down the left mouse button, use the scroll wheel on your mouse to adjust the elevation of the 3D floating cursor. The elevation of the building is approximately 463 meters.



7. Release the left mouse button when the 3D floating cursor is in the correct X, Y, and Z location.

   Notice that the original feature outline (blue) still reflects the old location, even though the vertex is in its new location.

8. Use the same steps to correct the location of the left-most erroneous vertex, which is at an incorrect elevation of approximately 470 meters.

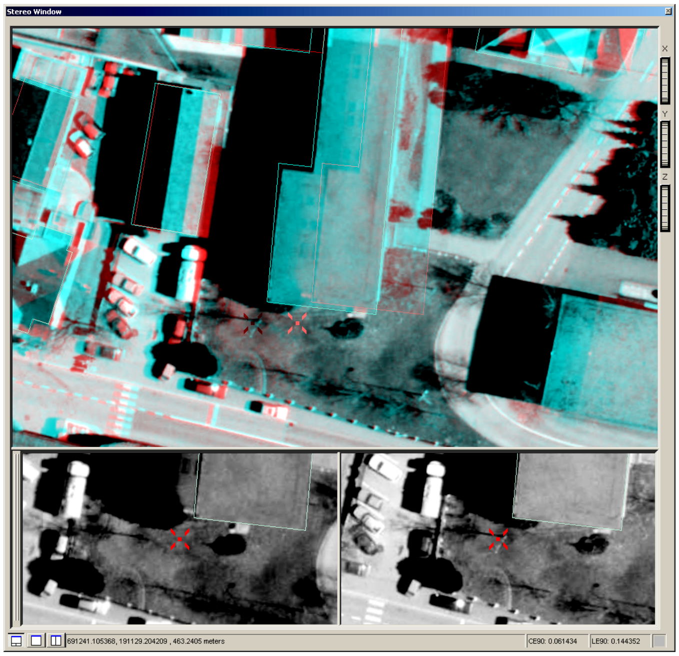
9. Right-click and select **Finish Sketch** if you are satisfied with the adjusted vertices locations.

   Notice that the polygon outlines update, and the vertices are in the correct locations.

10. Click outside the polygon to exit feature editing.

11. Click the Manually Toggle 3D Floating Cursor Mode button toolbar to toggle it off.

    When you're done, the building should look similar to the one shown in the following figure:



Moving a Polygon Feature

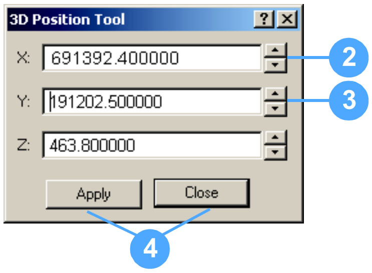
In this portion of the exercise, you learn how to move a polygon in X, Y, and Z.

Locating an Existing Polygon Feature

To locate an existing polygon feature, follow these steps:

1. Click the 3D Position Tool button on the Stereo View toolbar to display the 3D Position Tool dialog.

2. Type the X coordinate **691392.4** in the X field.

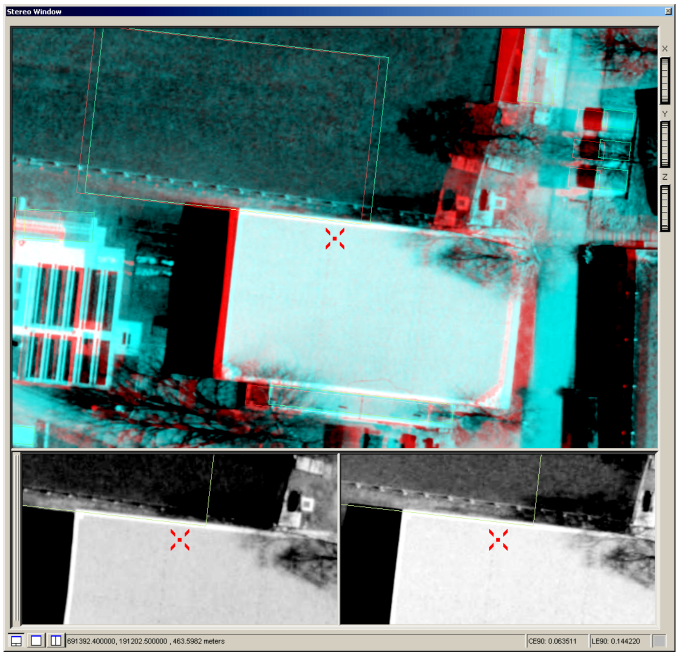


3. Type the Y coordinate **191202.5** in the Y field.

You don't need to enter a value in the Z field.

4. Click **Apply** and **Close** to close the 3D Position Tool dialog.

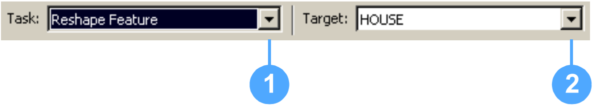
   You notice a house polygon that is incorrectly located offset from the actual building.



Preparing to Move the Polygon Feature

To prepare to move the polygon feature, follow these steps:

1. Select **Reshape Feature** from the Task dropdown list on the Editor toolbar.



2. Verify that the Target field still displays **HOUSE** as the target layer.

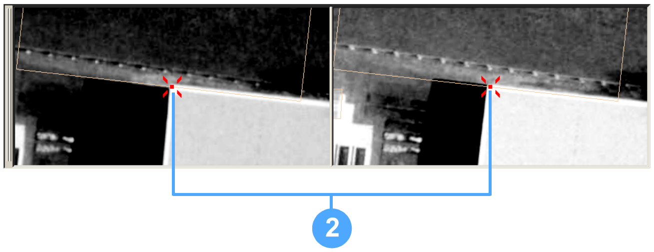
Adjusting the Polygon Position

To adjust the polygon position, follow these steps:

1. Click in the Stereo window, and then press **F3** to toggle on the Manually Toggle 3D Floating Cursor mode.

2. Adjust the position of the 3D floating cursor using the scroll wheel on your mouse so that it rests on the roof of the house polygon (approximately 461 meters).

This is easiest to accomplish at the corner of the building. You could also use the S keyboard shortcut to snap the 3D floating cursor to the roof.



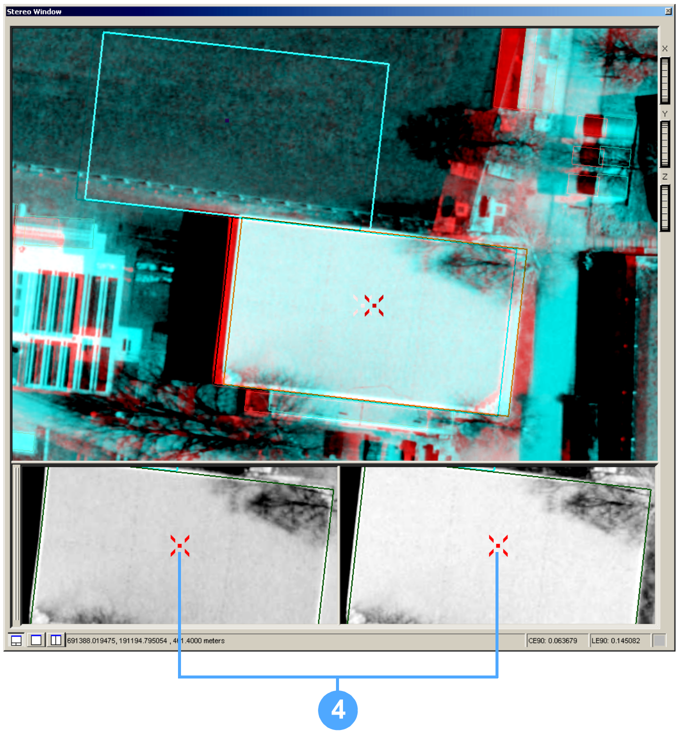
3. Click in the misplaced polygon.

The polygon outline color turns to light blue. This means that the polygon is selected.

4. Hold down the left mouse button and move the polygon to the correct building location in the X and Y direction.

Again, it is easiest to judge the correct location by looking at the corners of the building in the 2-Pane view.

Because you already adjusted the 3D floating cursor elevation to the building's roof, there is no need to make further adjustments in Z.



5. Release the left mouse button.

6. Click anywhere outside the polygon to exit the editing task after placing the polygon in its correct position.

7. Click the Manually Toggle 3D Floating Cursor Mode button on the Stereo View toolbar to toggle it off.

   If you want to see the new feature position in the ArcMap data view, click the Synchronize Geographic Displays button on the Stereo View toolbar or select the ArcMap document follows Stereo Cursor option on the ArcMap Display tab on the Stereo Analyst Options dialog.

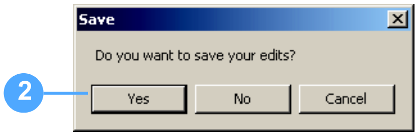
   Note: You can use the same procedure described here in **Exercise 5: Editing Existing Features** on page 78, to edit a number of polygons that are displaced by the same amount in the X, Y, or Z direction.

Saving Feature Modifications

To save feature modifications, follow these steps:

1. Select **Stop Editing** from the Editor dropdown list.

2. Click **Yes** in the Save dialog to save your edits.

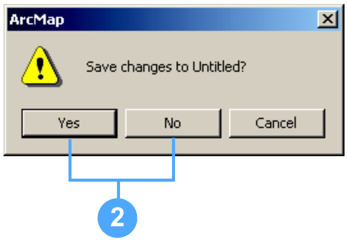


Closing the Applications

To close the application, follow these steps:

1. Select **Exit** from the File menu in the ArcMap window.

2. Click **Yes** to save your changes to an ArcMap document; otherwise, click **No**.



Both the ArcMap and Stereo Analyst for ArcGIS applications close.

What’s Next?

This tutorial introduced you to some of the basic functions you can perform using Stereo Analyst for ArcGIS. The chapters that follow go into more detail about each element of the Stereo Analyst for ArcGIS suite of tools, and include instructions on how to use them to your advantage.

Working with Oriented Images

Oriented images serve the most important role in collecting accurate and reliable information from imagery. In this chapter, you learn about oriented images: where they come from, how to create them, and how to import them into the ArcGIS environment.

IN THIS CHAPTER

Creating Oriented Images

It is helpful to look at the process used to create an oriented image to understand one.

Starting with Raw Imagery

On a day-to-day, minute-to-minute basis, our eyes record people, places, and interactions. The images our eyes record are subsequently associated with features, relationships, and processes we maintain in our brains.

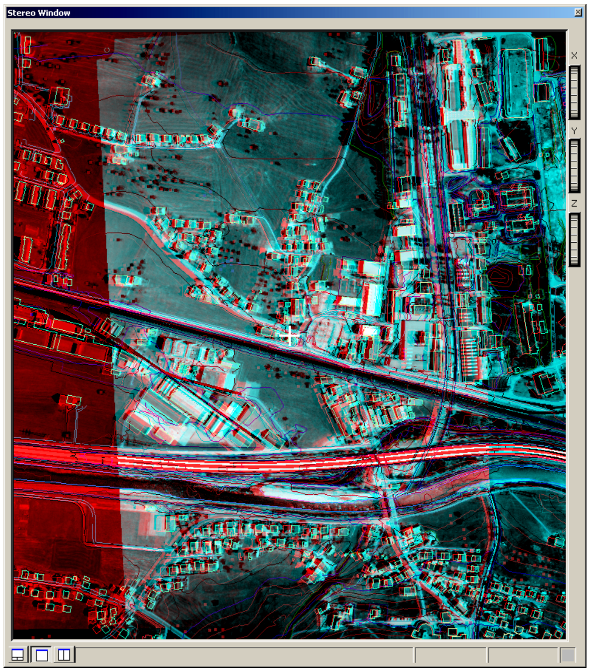
Subconsciously, we automatically associate intelligence with a feature. Once intelligence has been associated with a feature, relationships and processes between that feature and other features can be deduced. Now, apply this concept to imagery.

Two raw and overlapping images can be derived from an airborne sensor, satellite sensor, or even a hand-held digital camera. A raw image serves as a permanent record of the state of an area at the time the image was captured. Images record:

- Features such as houses, roads, rivers, schools
- Relationships between features such as distance from the post office to your office
- Processes such as the amount of water flowing in a river
- Information such as the monetary value of a forest stand

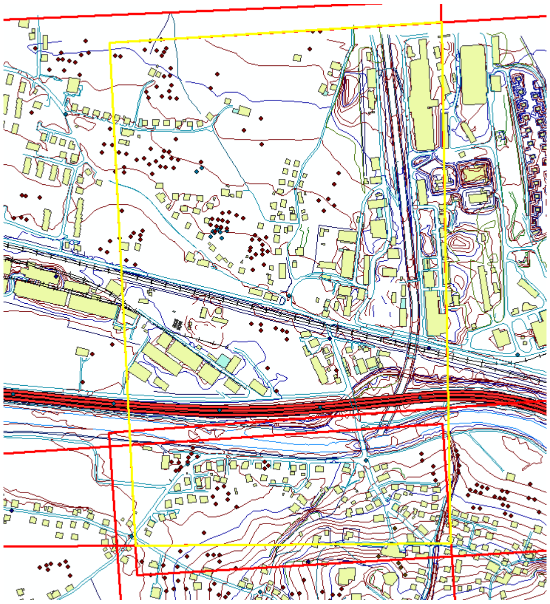
The figure below shows a Stereo window displaying features in a set of oriented images.

Figure 9: Features in Oriented Images



The figure below shows the same relative area of the previous figure with only the feature outlines displayed.

Figure 10: Feature Outlines Displayed



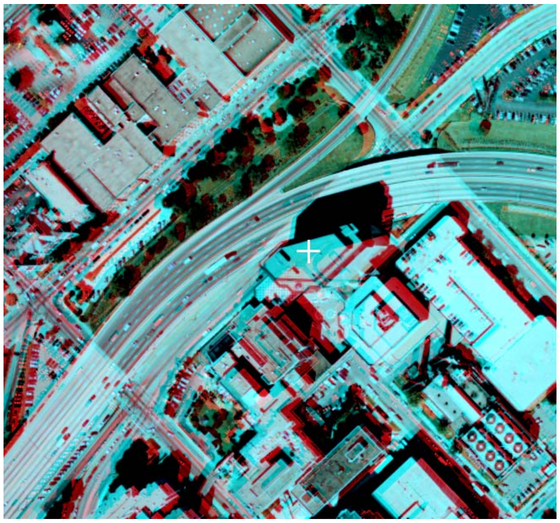
Raw imagery is an untapped resource for creating and updating all of the data used in a GIS. Stereo Analyst for ArcGIS transforms the permanent record stored in a raw image into information directly stored in the geodatabase.

This image is a TIF image.

Figure 11: TIF Image

This image is a stereo view of the area.

Figure 12: TIF Image Followed by a Stereo View



A raw image knows nothing about geography, geographical relationships, processes on the Earth's surface, scale, or how it was recorded—it's a raster with pixels in it. Essentially, it's a "dumb" image that is not GIS-ready because it knows nothing about geography.

To get accurate, valuable information from a raw image, you must process it to make it intelligent, which involves associating it with the Earth. This means defining the relationship between an image (as it existed when the image was recorded) and the Earth's surface. Once a raw image has intelligence associated with it, it is GIS-ready.

By making an image intelligent, you can collect features on the Earth's surface. When features are collected, they can be stored in multiple layers in a database, and relationships between features can be defined. Once relationships between features are defined, processes associated with features and their relationships to other features can be derived.

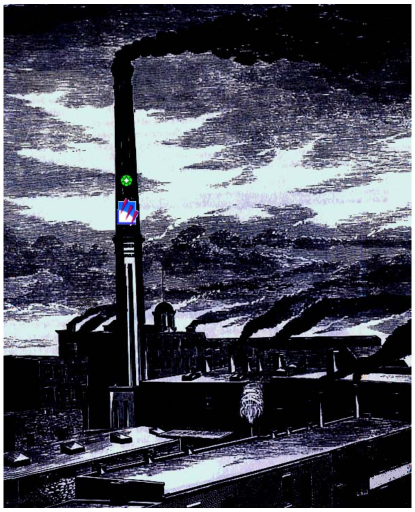
You can extract multiple levels of information from imagery, but the foundation for information extraction is in the oriented image. Prior to extracting any information from imagery, you must orient the image and make it intelligent. An intelligent image is the map of the future.

Understanding Image-to-Earth Association

An image-to-Earth association is the result of defining the 3D mathematical relationship between an image and the Earth's surface. This process is referred to as aerial triangulation (AT) and is commonly done in digital photogrammetry products such as SOCET SET and LPS. These products are factories because they provide a series of step-by-step processes that are required to transform the dumb, raw image into an intelligent, oriented image.

The factory in the image below adds information to make the image intelligent.

Figure 13: Intelligent Image



Modified from Asher and Adams, 1976

Once a raw image is transformed inside the factory, information such as projection, units, and a sensor model is available for each intelligent, oriented image. A sensor model is the 3D mathematical relationship between the sensor used to record the image, the ground, and the image itself. These are the three general variables characterized by a sensor model.

Processing inside the Factory

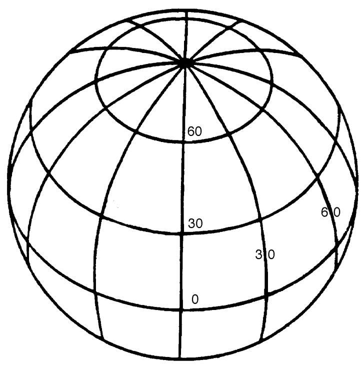
Inside the factory, the photogrammetry software adds intelligence to the raw image. This involves integrating information from a variety of sources to compute the image-to-Earth association. The following deductions can be made to better understand an oriented image.

An oriented image is defined as a raw raster image plus intelligence.

Figure 14: Raw Raster Image

Intelligence is defined as spatial reference plus a sensor model.

Figure 15: Spatial Reference



A sensor model, which is a 3D mathematical relationship, is defined by an image-to-Earth association.

Figure 16: Image-to-Earth Association

Sensor Model =

Image-to-Earth Association

The image-to-Earth association is defined as the position of the satellite at the time of image capture, plus the image, plus the image's location on the Earth.

Figure 17: Image-to-Earth Association Defined

The image-to-Earth association yields a transformation that consists of a series of coefficients describing the 3D mathematical relationship between the image, the sensor that captured it, and the ground it recorded. This process estimates the exact 3D position (X, Y, Z) and rotation (three rotation angles) of the sensor used to record the image at the time of capture. These parameters are also referred to as exterior orientation parameters.

These variables are computed by measuring 3D ground control points (GCPs) in the raw image. Before establishing the image-to-Earth association, you must define the internal characteristics associated with the sensor as reflected on the raw image. This is referred to as interior orientation and involves defining sensor properties such as focal length.

Defining an Oriented Image

Satellite images recorded and prepared by GeoEye and DigitalGlobe are referred to as oriented images. Stereo Analyst for ArcGIS can directly use overlapping oriented images provided by GeoEye and DigitalGlobe.

These oriented images contain metadata referred to as rational polynomial coefficients (RPCs). RPCs are coefficients that contain information defining the relationship between the image and the Earth's surface. Both the imagery and the metadata are most commonly stored in NITF or GeoTIFF format.

Other examples of oriented images include aerial triangulation data created by SOCET SET or LPS. SOCET SET creates project and support files that store all of the metadata required to create an oriented image. LPS block files serve as metadata storage containers used to create oriented images.

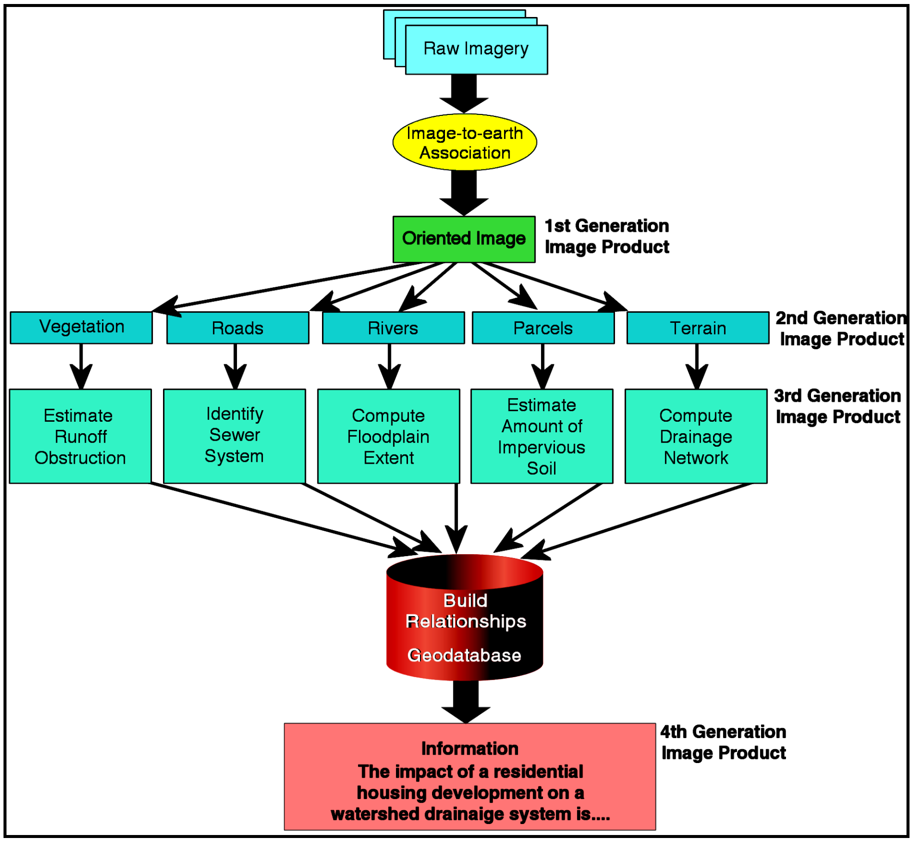
Unifying Images, Features, Relationships, Processes, and Information

A GIS serves as a container for the feature datasets that are extracted from oriented images. A GIS also maintains all of the relationships, processes, and information associated with a feature dataset.

By tracing the ancestry of spatial information, it is evident that the reliability of information in a GIS is dependent on the accuracy of feature data derived from oriented imagery.

The following example illustrates the ancestry of information derived from imagery used to assess what impact a residential housing development may have on a watershed drainage system.

Figure 18: Ancestry of Information from Imagery



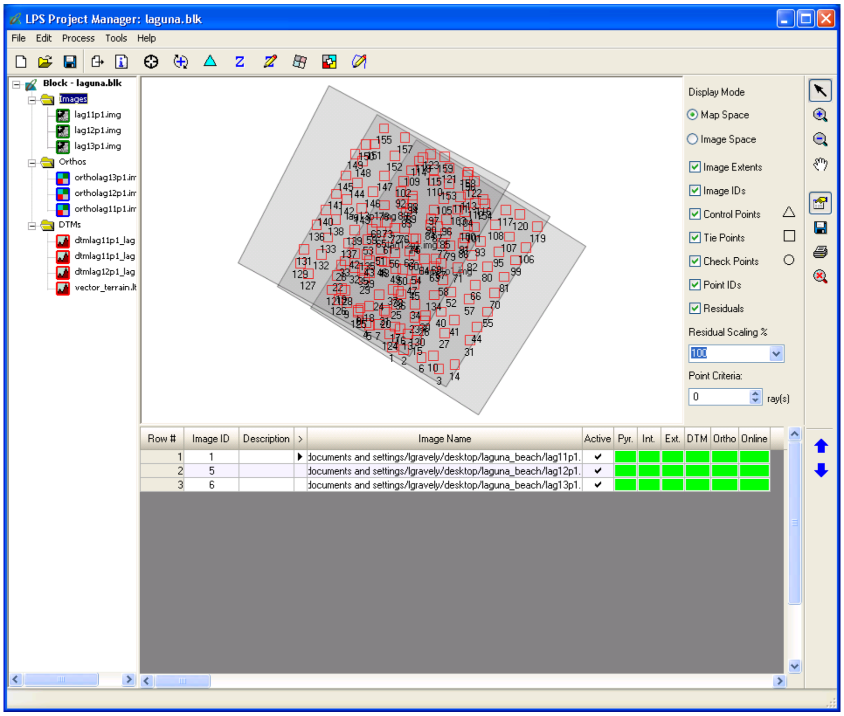
In this example, a factory is used to transform a raw image to create a GIS-ready, oriented image. Stereo Analyst for ArcGIS then uses the oriented imagery to extract all of the feature data required to assess the impact on the drainage system. This includes vegetation (location and type), roads, rivers, trees, and terrain. You can derive an additional layer of information from each feature dataset (that is, use Spatial Analyst™ to delineate a drainage system), and build relationships between multiple layers of information in the geodatabase.

ArcGIS uses these feature datasets in combination with other information layers (such as annual precipitation) to conduct hydrological analysis to assess the overall impact on water quality and quantity on the watershed of interest. Without imagery, the data required to assess the impact would not be available, and without accurate and up-to-date feature data, you cannot conduct a reliable study. This example illustrates how intelligent information relies on accurate, oriented imagery.

Using LPS to Create Oriented Images

You can think of LPS as a process-driven factory that creates oriented images and other first and second-generation data layers. These layers are stored and used in a GIS.

Figure 19: LPS Project Manager Interface



You must complete the first five steps associated with processing raw imagery to create oriented images in LPS:

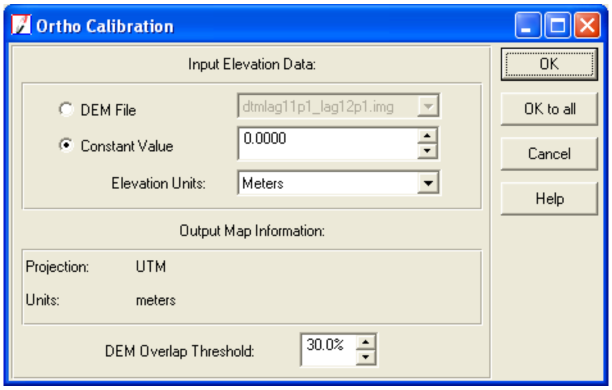
1. Adding images to your project.
2. Defining the sensor and properties associated with the sensor.
3. Measuring GCPs.
4. Performing automatic tie point collection.
5. Performing image-to-Earth association (aerial triangulation).

   Once the image-to-Earth association is completed, the information required to create an oriented image becomes available. LPS lets you create one oriented image at a time or multiple oriented images simultaneously.

   The final process in creating an oriented image involves associating the sensor model metadata with the original image. In LPS, this process is referred to as orthocalibration. The original image is not resampled or modified. LPS saves intelligent sensor model information and associates it with the original raw image.

   You can create the oriented image in LPS by clicking the Process menu, pointing to Ortho Rectification, and selecting Calibration to display the Ortho Calibration dialog.

Figure 20: Ortho Calibration Dialog



Click OK to create multiple oriented images simultaneously. At least two overlapping oriented images are required to perform feature collection and editing using Stereo Analyst for ArcGIS.

Once the oriented images are created, you can add the images directly to ArcMap for use in Stereo Analyst for ArcGIS. ArcMap automatically recognizes the images as oriented images.

Note: You can import the LPS block file in Stereo Analyst for ArcGIS, whose Import wizard turns all available images in the block file into oriented images. You import your images only once, after which you can use the Add Data button.

Using Data from LPS

Stereo Analyst for ArcGIS supports digital camera, frame camera, IKONOS, IRS-1C, QuickBird, and SPOT-oriented images created by LPS. You cannot create oriented images for terrestrial or close-range images. For more information on using LPS, see the LPS user's guide.

Using Spatial Database Engine Files

If you use the SDE converter to create an SDE raster file from a raster file calibrated in LPS, the converted file does not retain the map model.

To use SDE raster files in Stereo Analyst for ArcGIS, convert the original raster file to an SDE raster file, attach the SDE raster file to an LPS block file, and then calibrate the file. The resulting SDE raster file retains the map model, which you can use in Stereo Analyst for ArcGIS.

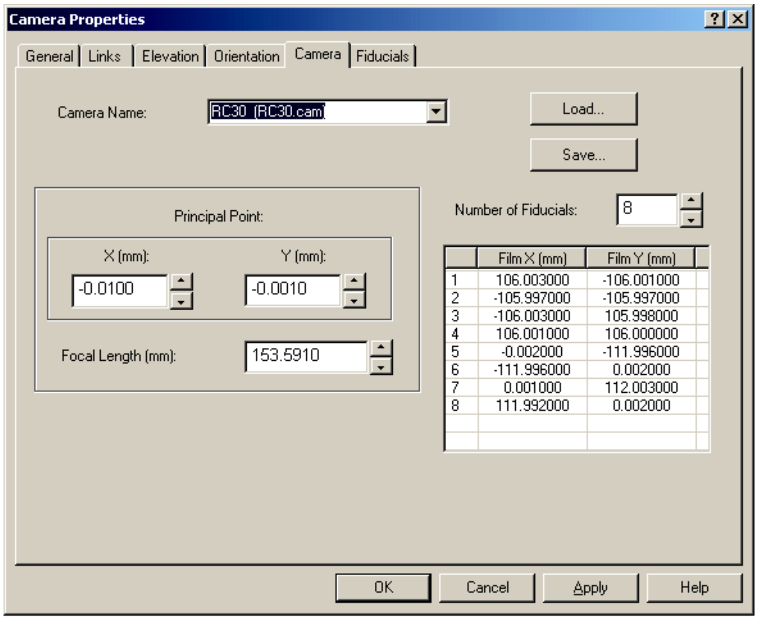
Creating Oriented Images

Another extension to ArcGIS, Image Analysis for ArcGIS, also lets you create oriented images. You can access this functionality from the GeoCorrection Properties button on the Image Analysis toolbar.

The process of creating an oriented image in Image Analysis for ArcGIS overlaps the process of creating an orthorectified image. You can use the following models: Camera, SPOT, QuickBird, and IKONOS.

Creating an oriented image in Image Analysis for ArcGIS involves associating sensor model information (metadata) to a raw image. The original raw image is not modified, but the sensor model information is added as metadata, which is required and used by Stereo Analyst for ArcGIS for accurate feature collection.

Figure 21: Camera Tab



Complete the following steps to create an oriented image using Image Analysis for ArcGIS:

1. Add a raster to ArcMap along with your reference data.

2. Select the appropriate sensor model on the Image Analysis toolbar.

3. Within the GeoCorrection properties:

   a. Define camera properties and measure fiducial marks if using aerial camera imagery.

   b. Define the elevation source.

   c. Measure links between the raw raster dataset and the reference dataset. This involves locating reference GCPs in the reference dataset and linking them to the same location in the raw image.

4. Solve and save the solution.

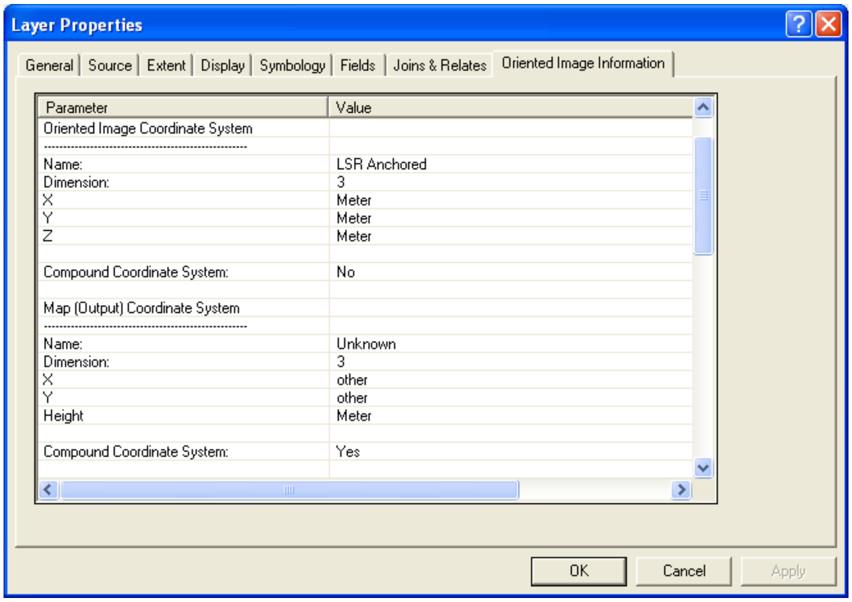
   Note: You must choose Save and not Save As. Save calibrates the image to create an oriented image.

5. Repeat **steps 1 - 4** for the next overlapping raster dataset.

Viewing Oriented Image Information

The Layer Properties dialog has an Oriented Image Information tab to facilitate the inspection of oriented image metadata. This tab is useful in inspecting the coordinate system information for oriented images that you add to the ArcMap document.

Figure 22: Oriented Image Information Tab



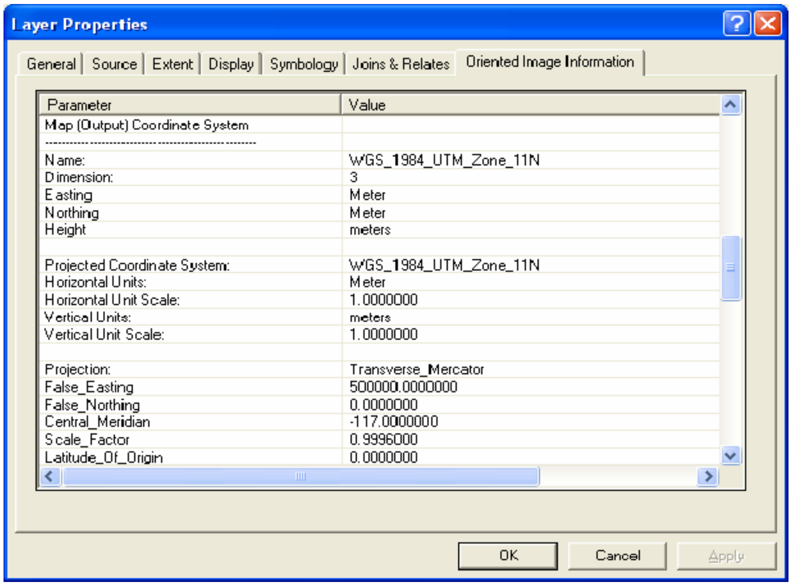
The Horizontal and Vertical Coordinate System details for the oriented image are reported in the first section on the Oriented Image Information tab.

Note: The Stereo Analyst Options dialog also defines the Vertical Coordinate System on the Vertical Coordinate System tab.

When using legacy oriented images (created prior to LPS 8.7), you should always inspect the Vertical Coordinate System definition.

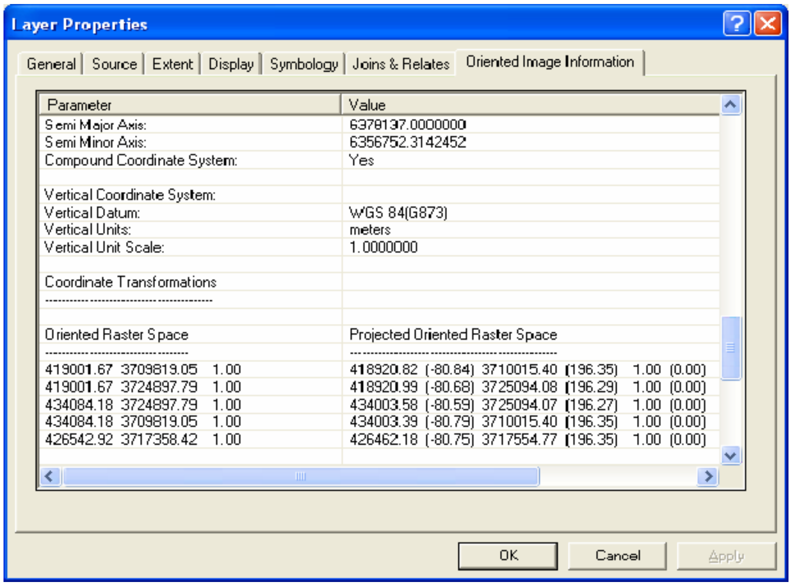
The Horizontal and Vertical Coordinate System details for the ArcMap document are reported as well.

Figure 23: Horizontal and Vertical Coordinate System Information



If used, a coordinate system transformation is also reported. The coordinates for the transformation are taken from the oriented image footprint and projected into the horizontal and vertical coordinate system currently defined for the ArcMap document.

Figure 24: Coordinate System Transformation Information



Importing Photogrammetry Projects

Photogrammetry projects and formats recognized by Stereo Analyst for ArcGIS include:

- LPS block (.blk) file
- SOCET SET project (.prj) file
- ImageStation® Automatic Triangulation (ISAT) project files
- MATCH-AT™ projects
- IKONOS data in NITF format with RPCs (metadata.txt)
- DigitalGlobe stereo files

These projects and formats are discussed in the sections that follow.

LPS Block Files

Stereo Analyst for ArcGIS supports importing LPS block files consisting of frame, digital, or satellite imagery. For a standard project, all camera or sensor information is contained in the block file structure itself and does not require repairing.

A block file, altdorf.blk, is included with the example data that comes with Stereo Analyst for ArcGIS. You can find it in the \ArcTutor\StereoAnalyst\BlockFile directory.

Reattaching Images in LPS Block Files

If the images referenced in the block file are moved from the location specifically referenced in the block file, you must reattach them using the Import Photogrammetry Project wizard. When a block file is opened in the Import wizard, the cells in the Online column appear red if the image paths are invalid. You can click in a red cell to display a dialog that lets you navigate to the named file. The Import wizard accepts the reattachment of images with a different file extension automatically, but asks you to reconfirm your selection if you attach an image with a different name to the one referenced in the project. Once it has been pointed to the location of an image, the Import wizard also scans that directory for any other remaining unattached images and attaches additional images automatically.

If the paths are valid but you want to point the Import wizard to a local copy of the images, click inside a green cell in the Online column and redirect it to your local copy.

Defining a Block File

A block file is data in a container storing all of the photogrammetric data associated with a strip or block of imagery.

Block files are binary files and have the .blk extension. They might contain information associated with one image, a strip of images that overlap or are adjacent to one another, or several strips of images. The block file contains all the dialog information associated with the block including imagery locations on your system, camera/sensor information, fiducial mark measurements, ground control point information, image measurements, projection, spheroid, and datum information.

Block Files Containing SUP Files

For block files containing support (SUP) files, you must perform a second reattach step in the Import wizard if the paths referenced in the SUP files contain invalid paths to the image files. If the interior and exterior columns are still red after reattaching the SUP file, the paths in the SUP file are invalid. Click in a red cell and point the software to any missing orientation files and the images themselves.

SOCET SET Project Files

A SOCET SET project file contains general project information associated with a photogrammetric mapping project. This file is an American Standard Code for Information Interchange (ASCII) file that is used as part of the import process. The project file contains general mapping information associated with a project such as projection, units used, and so on. The project file is what you select for import.

The project file also contains references to raw images. Each raw image used in SOCET SET has a corresponding SUP file associated with it. A support file is an ASCII file that contains the detailed photogrammetric metadata associated with a raw image.

Note: If the data paths to the images are correct in the support files, you can add the support files using the Add Data button. If the paths are broken, the Import wizard included with Stereo Analyst for ArcGIS automatically repairs the paths.

A SOCET SET project file (altdorf.prj) is included with the example data that comes with Stereo Analyst for ArcGIS. You can find it in the \ArcTutor\StereoAnalyst\SocetSet directory. If you load the project and support example data in a place other than the default, the paths are broken and require a repair.

Automatic Project and SUP File Repair

You can repair paths to images (and orientation and calibration files for ADS40 data) inside SOCET SET files by right-clicking and selecting the Repair Project option while the SOCET SET project file is selected in ArcCatalog. Because this update is performed automatically, the structure of the data on your hard drive is important. The project file must be in a parent or a sibling directory relative to the imagery and SUP files. This activates the Repair Project option and results in changes to the project and SUP files. The software automatically creates backup copies of all your SUP files as well as the project file by appending a .backup extension to the original files. If the Import wizard cannot locate the images, it launches a dialog to let you navigate to the correct location.

Once the project is repaired, you can load the SUP files in ArcMap without importing the project. The SUP files contain all the needed information to display the images properly oriented in ArcMap and Stereo Analyst for ArcGIS.

Project Localization with SOCET SET Project Files

For performance reasons, you should work with local copies of files instead of connecting and using data from a network drive. When you create a local copy of the data, the paths to the images contained in the SUP and project files might still be valid because you are connected to the network. Right-click and select the Make Paths Local option with the SOCET SET project file selected in ArcCatalog to replace those network paths with the paths to the images on your local desktop. The project file must be in a parent directory to the imagery and SUP files, and the image paths must contain UNC (that is, \\server\..) paths for this option to be available.

ISAT Project Files

Stereo Analyst for ArcGIS supports importing ISAT project files consisting of standard frame or RPC based imagery. ISAT project files are ASCII files that contain project information such as orientation, ground control points, tie points, camera information, and path specifications for each image. If the project and data have been moved from their original location, you must update the paths so the images can be oriented. You can repair the paths manually or by using a file selector in the Import wizard.

Reattaching Images in ISAT files

When an ISAT project is opened in the Import wizard, the cells in the Online column appear red if the image paths are invalid. You can click in a red cell to launch a dialog that lets you navigate to the named file. The Import wizard accepts the reattachment of images with a different file extension automatically, but asks you to reconfirm your selection if you attach an image with a different name to the one referenced in the project. Once the Import wizard has been pointed to the location of an image, it also scans that directory for any other remaining unattached images and attaches additional images automatically.

If the paths are valid but you want to point the Import wizard to a local copy of the images, click inside a green cell in the Online column and redirect it to your local copy.

If for some reason you are unable to reattach your images in the Import wizard, you can manually repair your project. All paths to the images are stored in the Photo file. You can repair paths by opening the Photo file in a text editor and carefully changing the paths. Be careful not to alter the formatting of the file. It is recommended that you create a backup prior to editing. Once the paths are correct, you can use the project file in the Import wizard.

MATCH-AT Projects

Stereo Analyst for ArcGIS supports importing MATCH-AT projects consisting of standard frame or RPC-based imagery. MATCH-AT project files are ASCII files that contain project information such as orientation, ground control points, tie points, and path specifications for each image. The camera information is contained in a CAMERA file. If the project and data have been moved from its original location, you must manually update the path specifications to the images during import.

Locating the Camera File

In addition, the Import wizard must know the location of the camera file before orienting images because it searches for the camera file in the same location as the project. If this file is missing, the Import wizard evaluates the system environment variable MATCH_DIR. This environment variable (if it exists) must point to a directory that contains a file named CAMERA. The second approach is useful if you have a camera file that contains definitions shared by a number of projects. Note that a local camera file overrides the settings in a shared file so that you can apply changes to individual projects if needed.

If the Import wizard isn’t able to determine the location of the camera file when you select a project, it lets you browse your file system to find it. In this case, the selected file is copied to the same location as the project so that you don’t have to locate the file again. You can right-click and select the Repair Project option, which becomes available when you select the project file in ArcMap. You can also copy the camera file to the project in the same manner.

Reattaching Images in MATCH-AT Projects

When a MATCH-AT project is opened in the Import wizard, the cells in the Online column appear red if the image paths are invalid. You can click in a red cell to launch a dialog that lets you navigate to the named file. The Import wizard accepts the reattachment of images with a different file extension automatically, but asks you to reconfirm your selection if you attach an image with a different name to the one referenced in the project. Once the Import wizard has been pointed to the location of an image, it also scans that directory for any other remaining unattached images and attaches additional images automatically.

If the paths are valid but you want to point the Import wizard to a local copy of the images, click inside a green cell in the Online column and redirect it to your local copy.

If for some reason you are unable to reattach your images in the Import wizard, you can manually repair your project. All paths to the images requiring orientating must be corrected in the project file. You can repair the paths by opening the project file in a text editor and carefully changing the paths. Be careful not to alter the formatting of the file. Creating a backup prior to editing is recommended. Once the paths are corrected and the camera file location is known, you can use the project file in the Import wizard.

IKONOS Files

Stereo Analyst for ArcGIS supports importing IKONOS data in NITF format or with Rational Polynomial Coefficients (RPCs). IKONOS imagery is provided by GeoEye. Typically, IKONOS stereo pairs are defined by a <po>_metadata.txt file containing references to images and RPC files. Data is usually delivered in individual bands, and must be layer-stacked prior to use. After layer-stacking the bands of data to create two single images, you must change the component and stereo mate file names of the references to the metadata.txt files to reflect the names of the two newly stacked images. You must also edit the corresponding RPC file names to match the new image names.

There are two file types available with IKONOS stereo imagery: TIFF with RPC files and NITF files. NITF files contain orientation information and do not require importing because they are already recognized as oriented images. You can load them directly using the Add Data button in ArcMap.

DigitalGlobe Stereo Files

DigitalGlobe images are supported as photogrammetry projects. There are two types of projects:

- WorldView Orbital Pushbroom Project
- WorldView RPC Project

A folder must contain the following types of files before Stereo Analyst can reorganize it as a WorldView RPC project:

- .QRP indicator files
- NTF files (assumed as RPC project)
- TIFF file with RPC metadata files

A folder must contain the following types of files before Stereo Analyst can reorganize it as a WorldView Pushbroom project:

- .QPP indicator files
- NTF files with a valid sensor model (file opened to verify)
- TIFF file with orbital Pushbroom metadata files

Stereo Analyst searches data directories and creates .qrp and .qpp files automatically. You can disable this option by changing the DigitalGlobe setting in the Stereo Analyst Preferences file. For more information about this file, see the Stereo Analyst for ArcGIS help.

When imported into ArcMap, the raster layers are loaded with the appropriate sensor model. You should always verify the sensor model on the Oriented Image Information tab of the Layer Properties dialog.

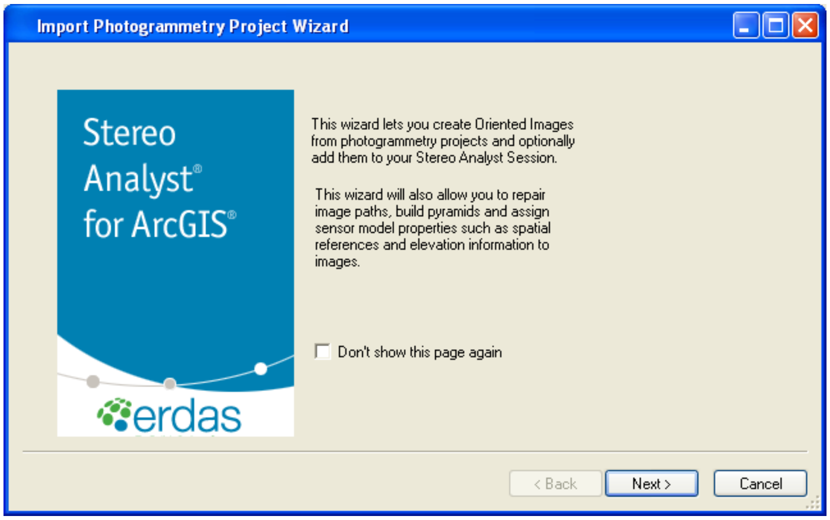
Note: If the .aux file is locked (by having the data opened in ArcMap), the import will be incorrect.

Using the Import Wizard

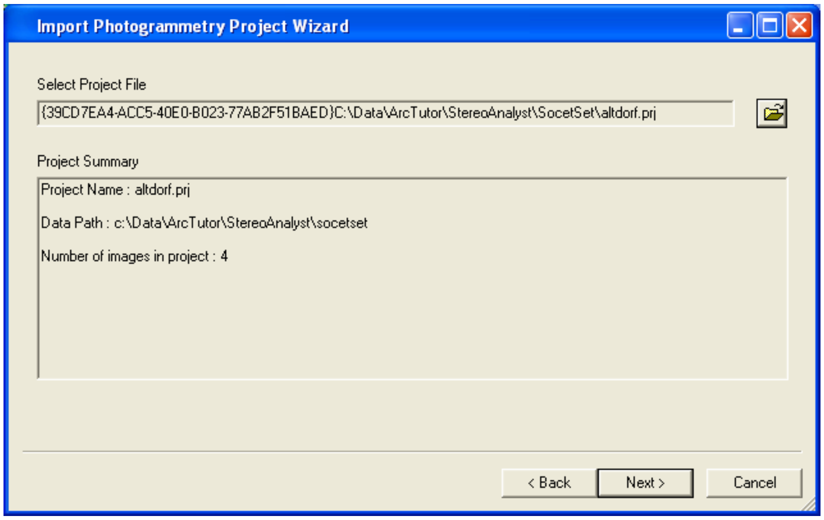
The Import Photogrammetry Project wizard provides full control of all aspects of creating oriented images from photogrammetry projects.

To use the Import Photogrammetry Project wizard, follow these steps:

1. Select **Import Project** from the Stereo Analyst dropdown list to start the wizard and display the introduction page.



2. Click **Next** to display a dialog that lets you select a photogrammetry project.



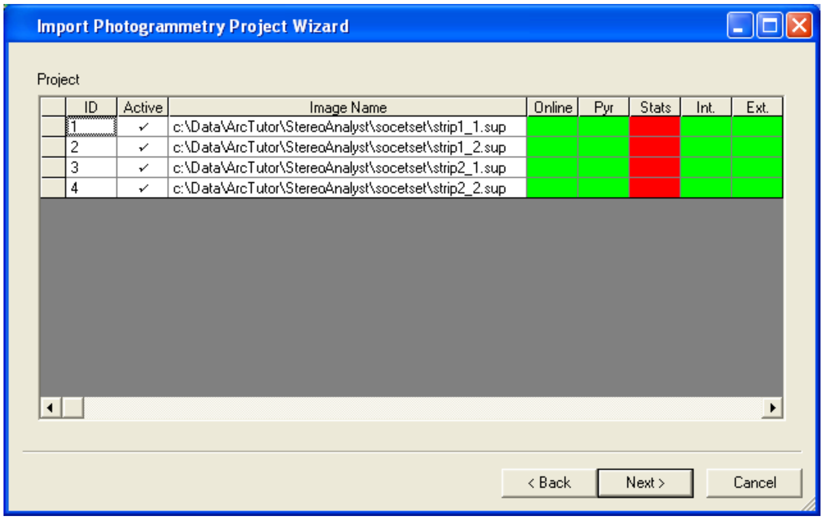
3. Click the browse button for the Select Project File field and navigate to the directory containing the file you want imported.

4. Select the file, and then click **Open**.

   A check is performed on the selected project for broken links. If found, the program attempts to automatically repair the broken links.

   Summary details about the project display in the Project Summary box.

5. Click **Next** to display a dialog containing cell arrays.



6. The main cell array indicates the data path for each image in the project. The remaining cells indicate the status of pyramid layers and whether orientations were found for each image in the project. They are as follows:

    - **ID** – Provides a numeric identifier for each image in the block. You can change the image identifier by typing inside the cell.

    - **Active** – Designates which images are going to be used. All images are active by default.

    - **Image Name** – Lists the directory path and file name for each image. When the full path to the image is specified, the corresponding Online column is green.

    - **Online** – Indicates whether the link for an image is broken. If any of the cells in the Online column are red, click inside a cell and navigate to the image location. If other images in your project are in the same directory, the program automatically repairs those links.

    - **Pry** – Indicates the presence of pyramid layers. If any of the cells in the Pyr (pyramids) column are red, click inside a cell to open a dialog that lets you specify that the program compute pyramid layers for the images. The pyramids are not computed until you finish setting up the import process, indicated by clicking the Finish button in the last wizard dialog.

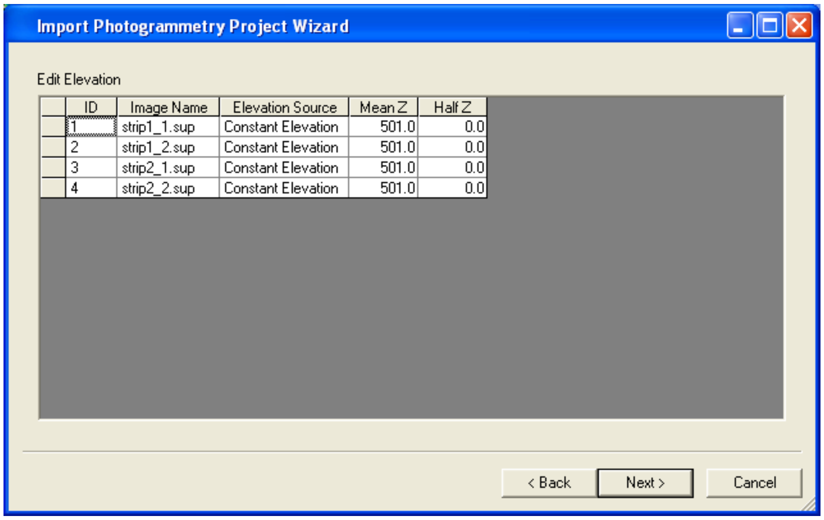
    - **Stats** – Specifies whether to calculate statistics in the Import wizard if the statistics are not available. If any of the cells in the Stats (statistics) column are red, click inside a cell to open a dialog that lets you specify that the program calculate statistics for the images. The statistics are not computed until you finish setting up the import process, indicated by clicking the Finish button in the last wizard dialog.

    - **Int.** – Indicates whether interior orientation parameters are complete.

    - **Ext.** – Indicates whether final exterior orientation parameters are complete.

7. Uncheck the appropriate cell in the Active column if you want to exclude images from the import process.

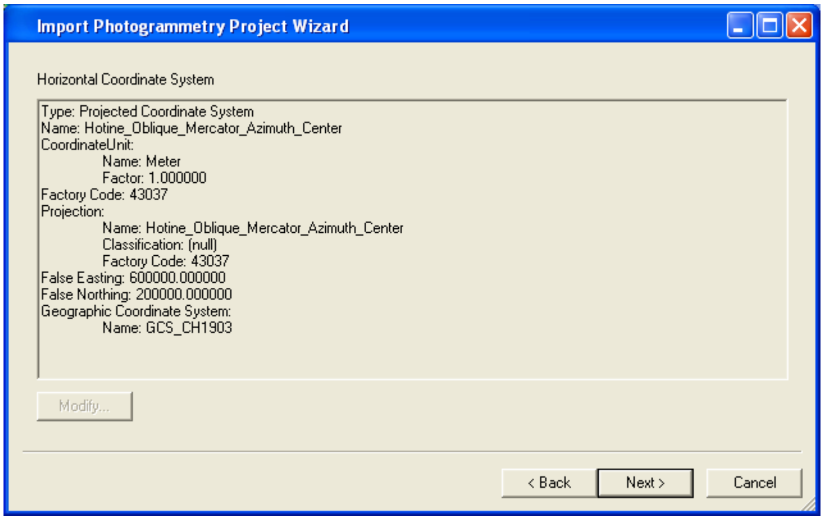
8. Click **Next** to display a dialog that lets you assign or edit the mean ground elevation (mean Z) and variation, or specify a terrain file.



The Mean Z and Half Z values together should represent the vertical range of Z values for the oriented image. The full range of Z values starts at (Mean_Z - Half_Z) and ends at (Mean_Z + Half_Z). These values are only used to improve the display of oriented images in the ArcMap document window by optimizing the reprojection of map document coordinates into oriented image coordinates and to provide a better load point for the images in the Stereo window. With an improved load point, there should be less X parallax to clear in the Stereo window when starting to work with the data. Editing these fields is optional and in no way impacts the original triangulation result.

Note: If Constant Elevation displays in the Elevation Source column, click inside a cell to display the Elevation Source Properties dialog. Next, click the Raster or TIN surface button and navigate to the directory where the terrain file is stored. Check the Apply to All Images check box if you want to list that terrain file for all images in your project. Click OK to return to the Import wizard.

9. Click **Next** to display a dialog that defines the horizontal coordinate system available in the photogrammetry project.

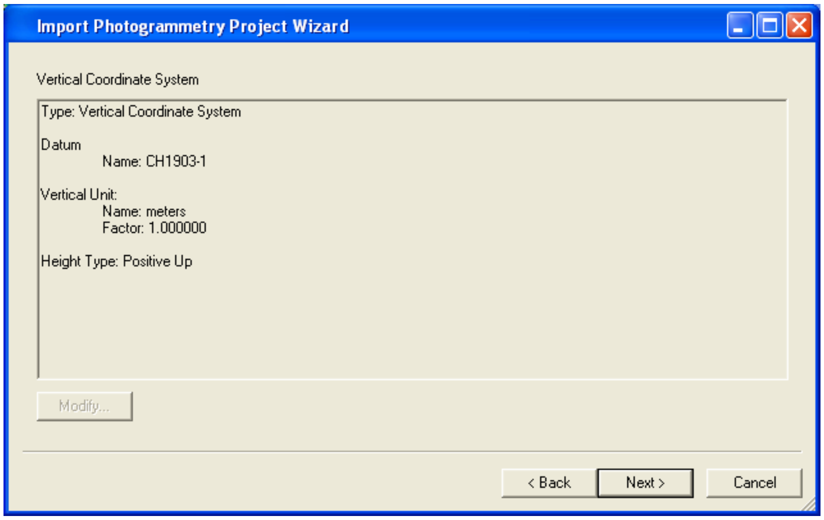


Stereo Analyst for ArcGIS provides enhanced support for coordinate systems and their transformations.

Note: Map project transformations are not possible between the oriented images and the ArcMap document without a valid coordinate system defined.

10. Click the **Modify** button and define the horizontal coordinate system if it is undefined.

11. Click **Next** to display a dialog that defines the vertical coordinate system for the oriented images.



Generally, frame photography was triangulated based on control point coordinate systems (horizontal and vertical) that were the same as those needed for features collected from the imagery. However, this situation changed due to:

a. Satellite imagery, for which orientations are based on WGS84

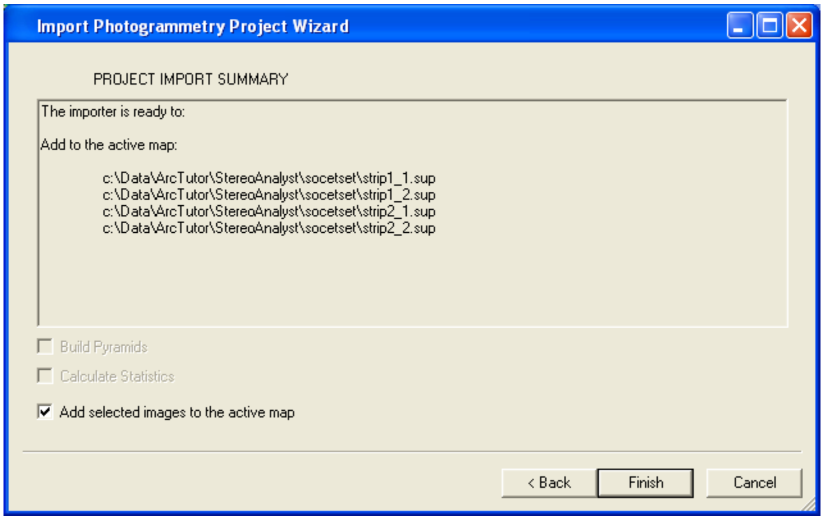
b. Digital cameras with integrated global positioning systems (GPS) and inertial navigation systems producing orientations based on the WGS84 datum

c. National Height networks remaining based on orthometric (gravity-based) heights for practical purposes

For this reason, vertical coordinate system transformations support was implemented in Stereo Analyst for ArcGIS.

12. Click the **Modify** button and define the vertical coordinate system if it is undefined.

13. Click **Next** to display a dialog that provides summary information about the processes that are performed when you click the Finish button.



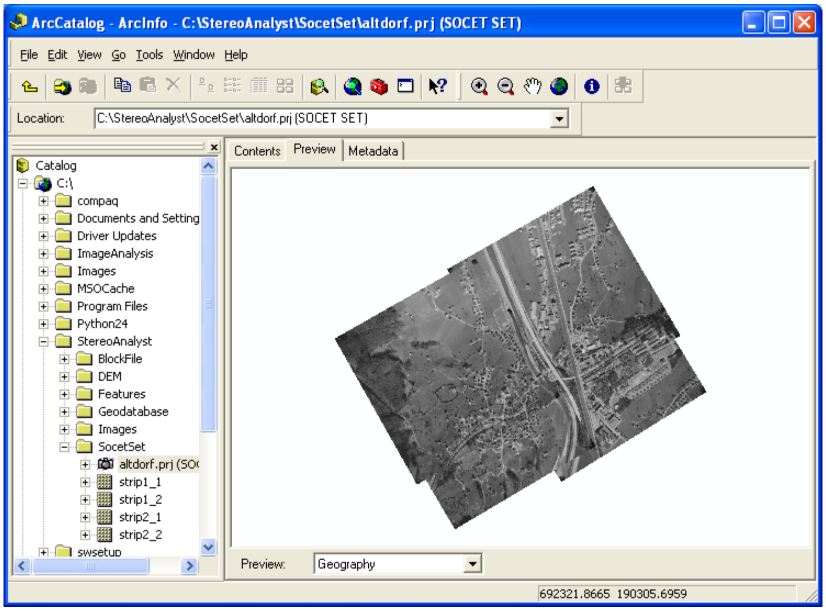
14. Click **Finish** to import the project.

Note: Please remember that once you import data using the Import wizard, it becomes an oriented image that you can load using the Add Data button in ArcMap.

Support for Photogrammetry Projects in ArcCatalog

Stereo Analyst for ArcGIS enables ArcCatalog and the Add Data button in ArcMap to recognize photogrammetry projects and display the status of project contents.

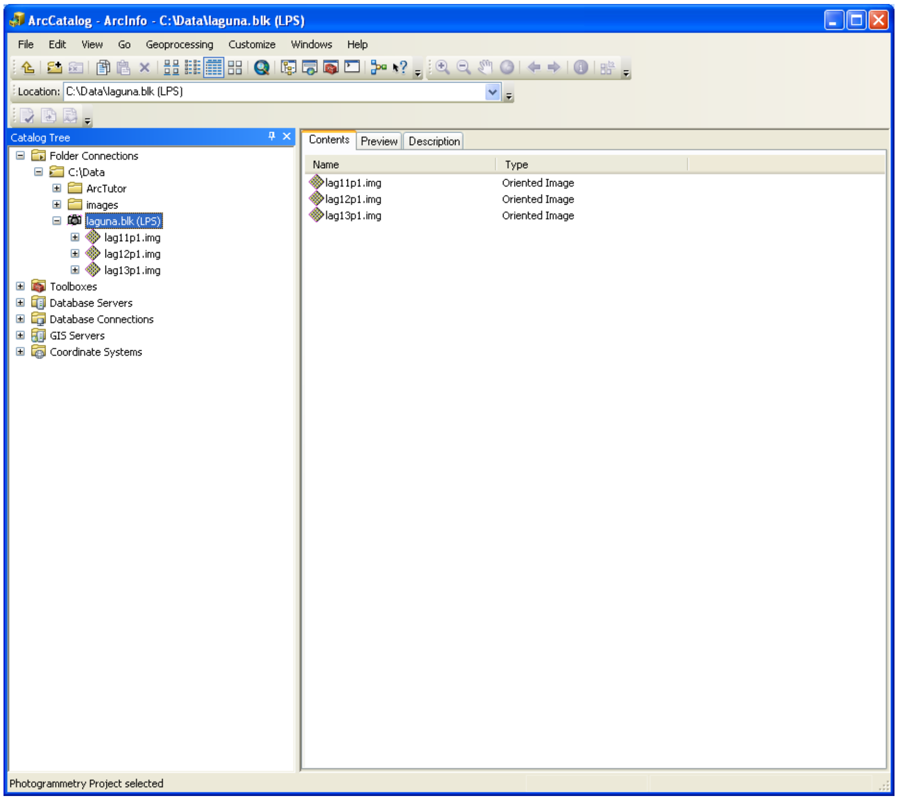
Figure 25: Photogrammetry Project in ArcCatalog



Note: Before you can preview a photogrammetry project, you must also enable the Stereo Analyst for ArcGIS extension by selecting Extensions from the Customize menu.

In addition, the Import wizard architecture provides a convenient plug-in mechanism for expanding the list of recognized photogrammetry projects. The plug-in support allows for custom development without the need for a toolkit or recompiling the software.

Figure 26: ArcCatalog Displaying LPS Block File Contents



Photogrammetry Project Contents

ArcCatalog indicates three of the four potential states of photogrammetry project contents as shown in this table.

Table 1: Photogrammetry Project Contents

lag11p1	Oriented Image	Displays as a rotated raster dataset image. This button indicates that the path to the image is correctly stored in the project file, and that the image is oriented. You can add the image directly to ArcMap using the Add Data button and view it in Stereo Analyst for ArcGIS without importing.
lag12p1	Image (not oriented)	Displays using the standard raster dataset image. This button indicates that the path to the image is correctly stored in the project file, but the image isn't oriented. You must use the Import wizard to convert the image into an oriented image.
lag13p1	Unattached Image	Displays as a standard raster dataset image with the addition of a red cross in the lower-left corner. This button indicates that the path to the image stored in the project file is incorrect and that the photogrammetry project requires repair.
lag13p1	Unattached Oriented Image	Displays as an unattached image (see Unattached Image above). It is impossible to determine if the image is oriented until the broken image path is repaired in the project file.

Photogrammetry Project Repair

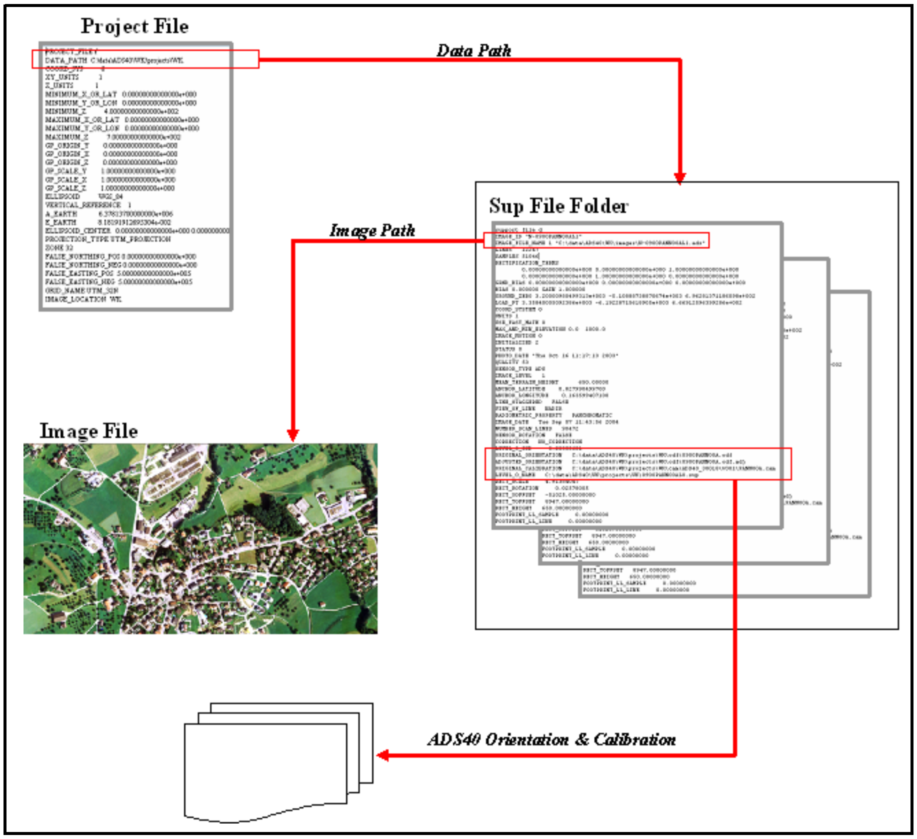
Photogrammetry projects are usually made from a collection of files that can contain information associated with one or more images (or strips of images), camera or sensor information, fiducial mark measurements, ground control point information, image measurements, projection, spheroid, and datum information. How and what information is contained in the project structure varies by format and is typically related through a common location or by data structure maintained in the project or block file. An example of such cross referencing is found in LPS block files, which explicitly reference image files by a stored path.

Once a photogrammetry project is created, the collection of files that make up the project are often copied between computers or across networks, rendering the paths stored in the project files invalid. As these projects are copied between systems, the stored file paths typically need updating to reflect the new image locations. Just as the formats of the projects vary, the methods for repairing these invalid paths vary by format. Please click the appropriate link in this topic for more information on importing your data.

The diagram on the next page illustrates the file path relationships that you can find in a photogrammetry project with imagery from the ERDAS digital airborne sensor, the ADS40. As these projects are copied between systems, the stored file paths usually need updating to reflect the new location. For SOCET SET projects, if the project file resides in a parent folder relative to all of the other support and image fields, the project repair is performed automatically. However, you must update ISAT and MATCH-AT projects manually.

This example shows the paths to data stored in the project files. All the paths to the data must be correct so that the imagery displays correctly.

Figure 27: Paths to Data Stored in Project Files

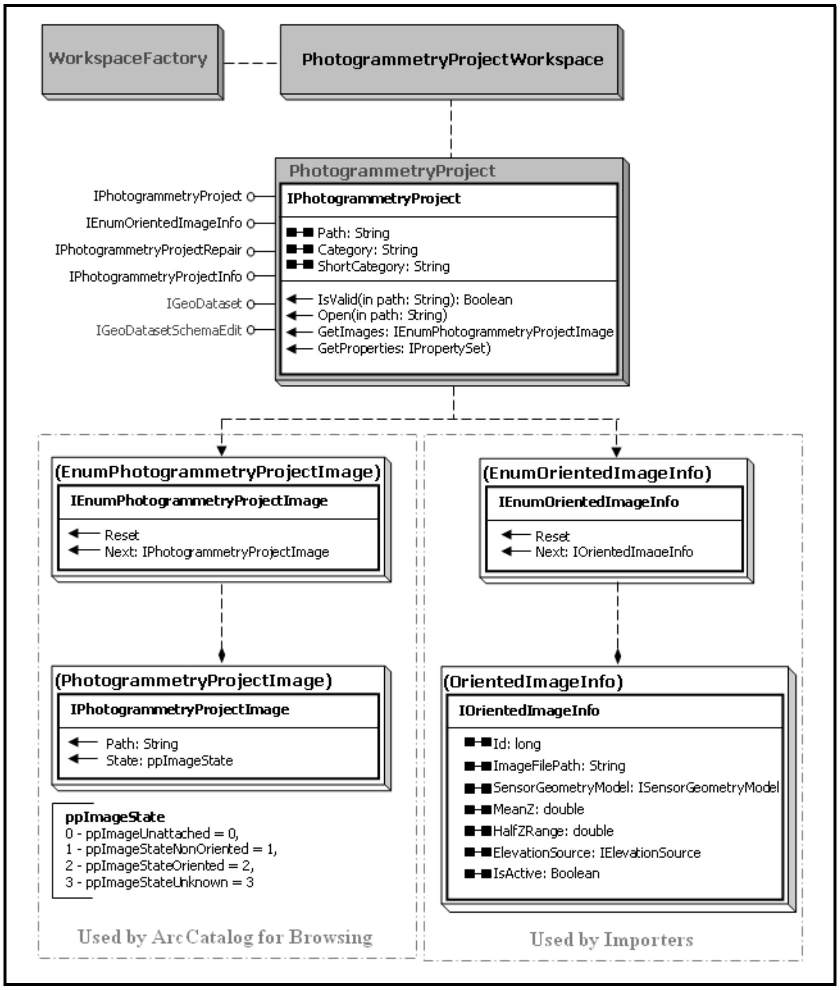


Import Wizard Plug-in Object Model (Abridged)

A custom Photogrammetry Project Object model encapsulates the knowledge of the structure of a photogrammetry project, and can open and navigate the project data structures. Internally, a list of images and orientation metadata is maintained and served through mandatory and optional interfaces implemented by the object. The Photogrammetry Project objects serve the requirements of both ArcCatalog browsing and project import.

Note: This is an abridged version. For more information, please contact ERDAS for technical support.

Figure 28: Import Wizard Plug-in Model (Abridged)



What's Next?

In the next chapter, **"Working with 3D Data" on page 115**, you learn about methods for working with 3D data. These methods include Virtual 2D to 3D, conversion of 2D feature datasets to 3D, and exporting 3D datasets to 2D datasets.

Working with 3D Data

The process of transforming a feature dataset to 3D is either virtual or physical:

- **Virtual** – This option temporarily transforms a feature dataset to 3D while working in the Stereo window. When the data updates are finished, the original feature dataset is restored, but with more accurate 2D feature data.

- **Physical** – This option transforms an existing 2D feature dataset and creates an entirely new 3D feature dataset that both supports and contains 3D data.

Regardless of which option is used, an elevation source (either a constant elevation or external elevation file) is referenced to obtain an initial Z (elevation) coordinate for a particular X, Y coordinate derived from the feature dataset. Once the Z coordinate source is provided, it is associated with each vertex in the dataset.

IN THIS CHAPTER

Comparing 3D Features and 3D Models

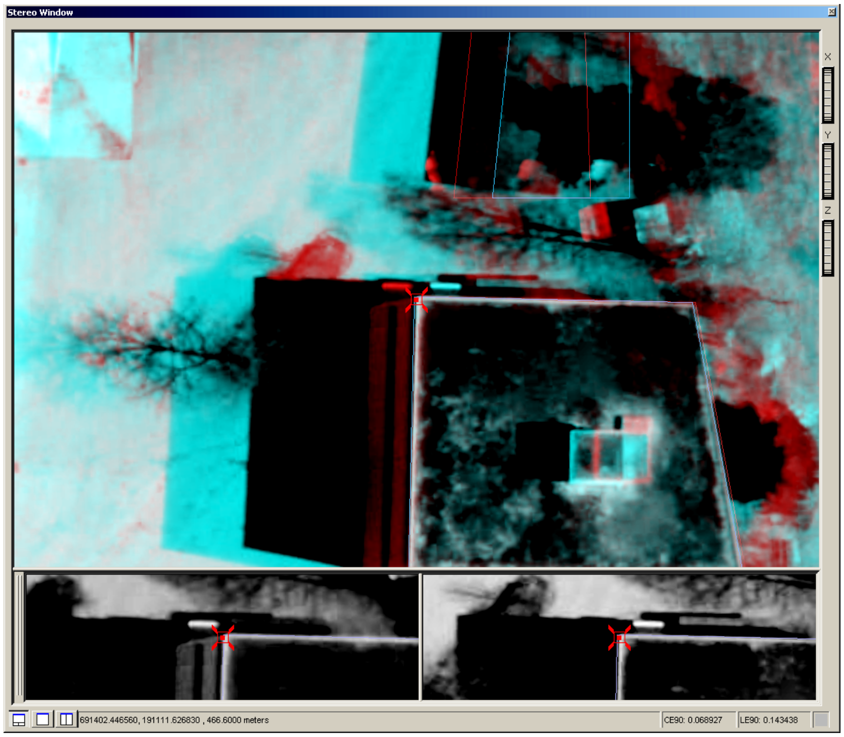
A 3D feature has 3D coordinate values associated with each vertex, but it does not have volumetric information as is the case with a 3D model. A 3D model not only has 3D coordinates in X, Y, and Z, but it also has volumetric information.

Characterizing 3D Features

A 3D feature can be a 3D point, 3D line, or a 3D polygon. A 3D feature has an X, Y, and Z coordinate associated with each vertex of that feature. The Z coordinate is the elevation value of that vertex. For example, a vertex corresponding to the corner of a house might have the X, Y, and Z coordinate values of 691402.4, 191111.6, and 466.6, respectively.

The following 3D feature has X, Y, and Z coordinates for each vertex.

Figure 29: 3D Feature with X, Y, and Z Coordinates

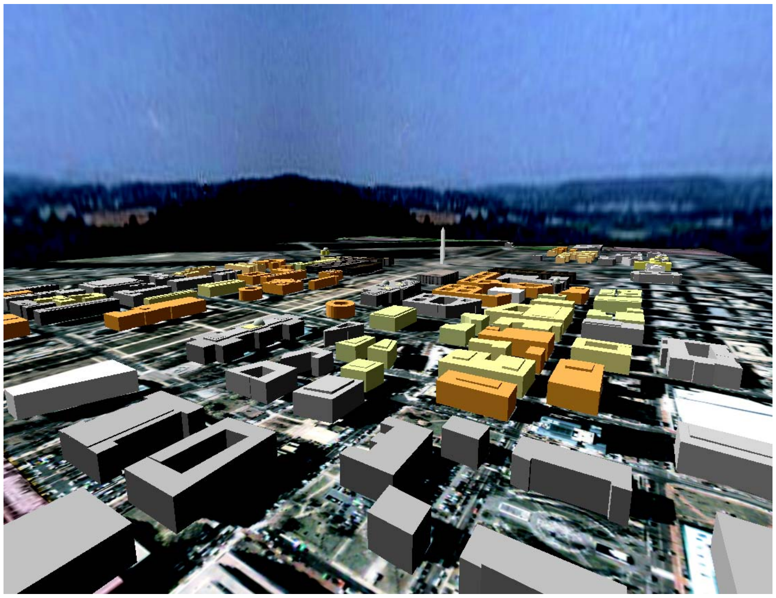


Characterizing 3D Models

A 3D model normally has a height attribute associated with the feature. For example, a 3D polygon feature can have a height attribute associated with it, and it can be used as a 3D model in 3D GIS applications.

The following is an example of a scene with many 3D building models (shown in gray, orange, and yellow).

Figure 30: 3D Model with Volumetric Information



Stereo Analyst for ArcGIS lets you collect 3D feature datasets such as 3D points, 3D lines, and 3D polygons; however, it does not let you collect 3D models.

Using Virtual 2D to 3D

Virtual 2D to 3D conversion is useful when you want to improve the accuracy of an existing feature dataset, but are not interested in capturing 3D information from the dataset. That is, you can improve the X, Y coordinate values of feature vertices.

You must use stereo feature collection and editing techniques to improve the reliability and quality of the feature dataset. As a result, the feature dataset must be superimposed on top of the 3D digital representation of the Earth's surface. The feature dataset must have 3D coordinate information associated with it before this can occur.

The virtual 2D to 3D function temporarily transforms a dataset to 3D so that it can be superimposed on the 3D digital Earth's surface displayed in the Stereo window. This is achieved by referencing a user-defined elevation source at a particular X, Y location for Z coordinate information. The X, Y location of the vertex is obtained from the original feature dataset.

The virtual 2D to 3D function does not create a new feature dataset. It references and queries an elevation source for Z coordinate information and associates that information with each vertex in the feature dataset. This virtual 2D to 3D process only occurs when the feature dataset displays in the Stereo window. Once all edits are saved, only 2D (X and Y) coordinate information is written back to the original feature dataset.

You need the following to successfully perform the virtual conversion of a dataset from 2D to 3D:

- A list of feature classes for conversion
- An elevation source such as a constant elevation value or an external elevation file

There are more advanced options that increase the accuracy of the conversion, if needed. These options include feature draping, inclusion of planar features, and a choice of how to handle incorrect elevations. For more information, see **Using Advanced Conversion Options** on page 125.

If a 3D feature dataset is added to ArcMap, it is not considered for use in Virtual 2D to 3D because it is already in 3D. In this case, use the Features to 3D utility to update elevation information. For more information, see **Using the 2D to 3D Converter** on page 121.

Understanding How it Works

Once you define an input feature dataset and an elevation source, the Z coordinate associated with a vertex node in the feature layer is assigned the elevation value located within the corresponding elevation source. The supported elevation sources include: constant elevation value, DEM, and ESRI-type triangulated irregular network (TIN) files.

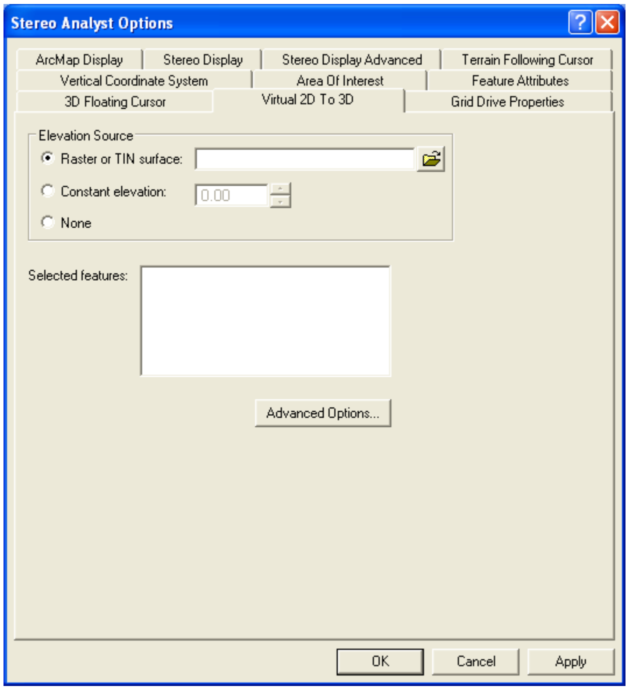
The conversion of the data to 3D is performed virtually, and your data is not actually edited. Stereo Analyst for ArcGIS uses elevation information contained in a DTM file or a constant elevation to project your feature datasets in 3D. The initialized Z value is for viewing purposes only. You can edit the feature data displayed in the Stereo window, but only X and Y information is saved.

If you want to retain the elevation information with a feature dataset, use the Features to 3D option in the Stereo Analyst dropdown list. For more information about this capability, see **Using the 2D to 3D Converter** on page 121.

Setting Virtual 2D to 3D Options

You can define the options that control the application of Virtual 2D to 3D to your data. Access these options by selecting Options from the Stereo Analyst dropdown list on the Stereo Analyst toolbar. Click the Virtual 2D to 3D tab on the Stereo Analyst Options dialog that displays. This tab lets you create temporary 3D feature data.

Figure 31: Virtual 2D to 3D Tab



Note: You can only use ESRI-type TIN files with Stereo Analyst for ArcGIS. It cannot use TIN files generated in other applications.

Setting the Elevation Source

The Elevation Source box on the Virtual 2D to 3D tab is where you define the reference elevation source used by Stereo Analyst for ArcGIS to associate a Z coordinate with each vertex of a feature in a feature class.

- **Raster or TIN Surface** – A raster surface can be an ERDAS IMAGINE .img file or a GRID file. In this case, the raster dataset is an elevation model where each pixel in the raster dataset has an elevation value associated with it.

- **Constant Elevation** – A user-defined value that approximates the elevation of the study or working area. Using a constant elevation value is less accurate than an elevation source because it might not accurately reflect the topography on the Earth’s surface.

Note: If either the Raster/TIN or Constant elevation button is clicked, 2D feature datasets are displayed, and dynamic 2D geometry is converted to 3D using the specified elevation source.

- **None** – This option disables the display of 2D feature datasets in the Stereo window. It also forces ArcMap dynamic 2D geometry (such as the selection box) displayed in the Stereo window to assume the same elevation as the 3D floating cursor.

Selecting Features

The Selected features box shows all of the current 2D feature layers in the ArcMap table of contents. If multiple feature datasets are added to ArcMap, all of the 2D feature classes associated with the feature datasets display in the list.

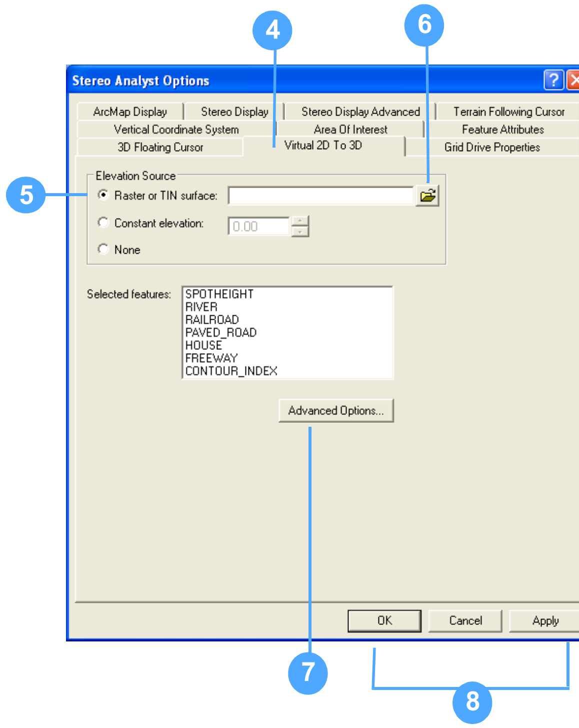
Setting Advanced Options

You can use the Advanced Options button to access the Feature to 3D Options dialog. There, you can define detailed parameters associated with the 2D to 3D conversion. This button is only activated if the Raster or TIN surface option is selected as the elevation source. For more information on the advanced options, see **Using Advanced Conversion Options** on page 125.

Using Virtual 2D to 3D

To use virtual 2D to 3D, follow these steps:

1. Add image pairs and 2D features to an empty data view.
2. Click the Stereo Window button on the Stereo Analyst toolbar.
3. Select **Options** from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Stereo Analyst Options dialog.



4. Click the **Virtual 2D to 3D** tab.

5. Click the option in the Elevation Source box that corresponds to the elevation source you want to use for virtual conversion.

6. Click the browse button for the Raster or TIN field to select a file if you selected the Raster or TIN Surface option. Type an elevation value if you selected Constant Elevation.

   Note: The 2D features you displayed in **step 1** are all listed in the Selected Features window on the Virtual 2D to 3D tab.

7. Click the **Advanced Options** button to make any additional choices you want if you're using a raster or TIN surface as the elevation source.

   Note: For more information on the advanced options for Virtual 2D to 3D, see **Using Advanced Conversion Options** on page 125.

8. Click **Apply** and **OK** to close the Stereo Analyst Options dialog.

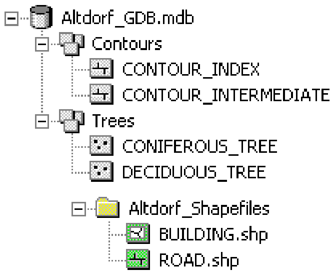
Using the 2D to 3D Converter

The Convert Features to 3D option works with the following types of input feature data:

- **Geodatabases**
- Shapefiles

The diagram below shows geodatabases, feature datasets, and feature classes converted to 3D.

Figure 32: Geodatabases, Feature Datasets, and Classes



Updating Z Values of 3D Feature Datasets

While the Convert Features to 3D dialog is most often used to add elevation information to 2D features, you can also use it to update existing 3D features with new elevation values.

The process to convert the data is the same—the only difference is the input dataset. In this case, the data is already three-dimensional. You supply a raster or ESRI TIN file, or a constant elevation to update the elevation (Z) component of each vertex of each feature.

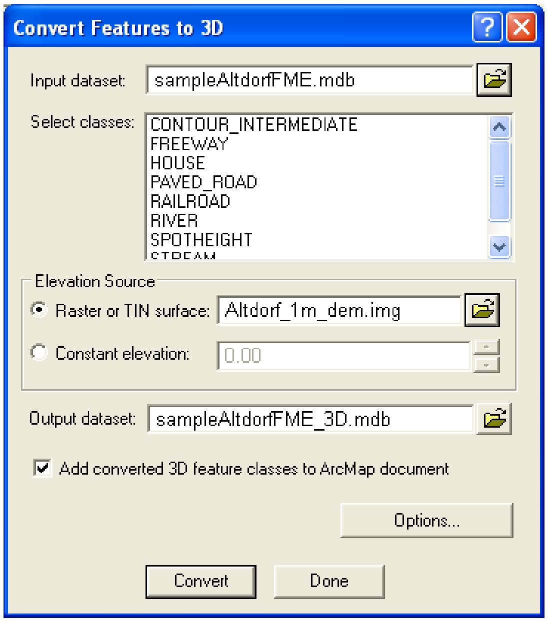
Using the Converter

Initially, you choose the 2D source that contains the feature data you want to convert to 3D. Once you select that source, eligible 2D features display in the Select Classes box. If you do not want to use all of the listed features, click a specific feature and then right-click and select Delete to remove that feature, or use Shift+Click or Shift+Ctrl to select and delete a number of features.

In the Elevation Source box, you can select your 2D data elevation from either an external raster or a ESRI TIN surface or constant elevation that you supply.

Use the Output Dataset field in the Convert Features to 3D dialog to specify a name for the output dataset. You can use the same name as the input file with a _3D designation, or a totally different name. The output dataset is placed in the same folder as the input dataset unless you use the browse button to specify a different location. You must click the Convert button to begin the conversion process. All of the features in the Select Classes box are converted. You can change these features before conversion by specifying a different input dataset.

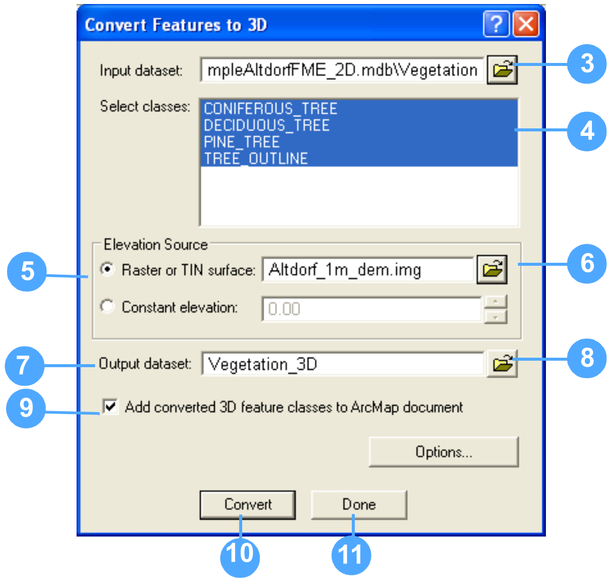
Figure 33: Convert Features to 3D Dialog



Converting 2D Features to 3D

To convert 2D features to 3D, follow these steps:

1. Start ArcMap and Stereo Analyst for ArcGIS.
2. Select **Features to 3D** from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Convert Features to 3D dialog.



3. Click the browse button for the Input Dataset field and open the 2D file.

   The classes in the input dataset populate the Select Classes box.
4. Remove any classes that you do not want from the Select Classes box by clicking a class (or use Shift+Click or Shift+Ctrl to select a number of classes), and then right-clicking and selecting **Delete**. Otherwise, all of the classes in the list are converted during the conversion process.

   Note: The first item in the Select Classes list is selected by default.
5. Click the option corresponding to the elevation source to use for conversion in the Elevation Source box.
6. Click the browse button for the Raster or TIN Surface field to select a file if you select Raster or TIN surface. Type an elevation value in the Constant Elevation field if you select Constant Elevation.
7. Type a name for the output dataset in the Output Dataset field. For more information, see **Using the 2D to 3D Converter** on page 124.
8. Click the browse button for the Output Database field and specify a location if you do not want to use the same directory as the input dataset file. By default, the output file is placed in the same directory as the input dataset.

9. Uncheck the **Add Converted 3D Feature Classes to ArcMap Document** check box if you do not want the features to display after conversion.

10. Click **Convert** to convert all of the classes in the Select Classes box.

11. Click **Done** when the status bar at the bottom of the ArcMap window indicates the process is complete.

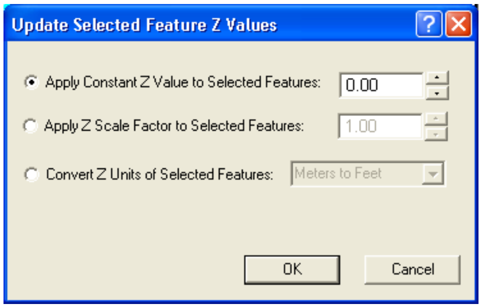
Naming the Output Dataset

You must specify a name for the output dataset in the Output Dataset field. You can use the same name as the input dataset with _3D appended to it, or you can type a different name. By default, the new file is placed in the same directory as the input dataset. If you want to place it in a different directory, click the browse button for the Output Database field and specify a different directory.

Updating Selected Feature Z Values

The Update Selected Feature Z Values dialog lets you modify elevation information for selected features using a constant elevation value, a scale factor, or a units conversion. Access this dialog by selecting Update Selection Z Values from the Stereo Analyst dropdown list on the Stereo Analyst toolbar. This option is activated only when you are in editing mode and there is a selected set of features.

Figure 34: Update Selected Feature Z Values Dialog



You can use the Update Selected Feature Z Values dialog to change the Z value of many selected features at once. Click one of the following buttons:

- **Apply Constant Z Value to Selected Features** – Lets you enter an elevation value that is applied to all of the selected features.

- **Apply Z Scale Factor to Selected Features** – Lets you enter a number to multiply each feature Z value by.

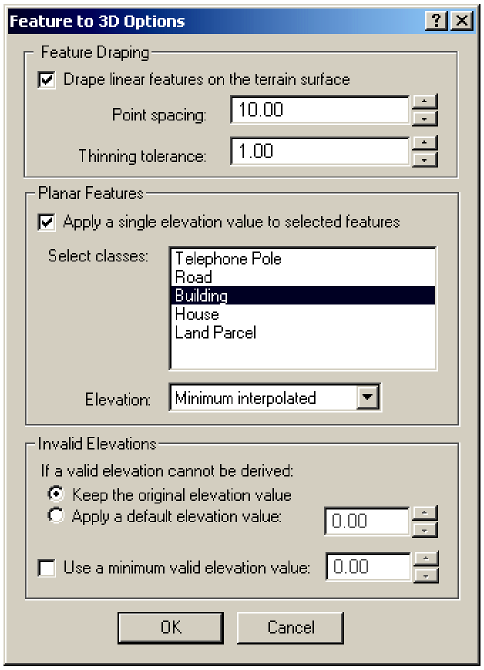
- **Convert Z Units of Selected Features** – Lets you select specific units for conversion from the dropdown list.
  - **Feet to Meters** – Converts international feet to meters using a scale factor of 0.3048.
  - **Meters to Feet** – Converts meters to international feet using a scale factor of 1/0.3048.
  - **US Feet to Meters** – Converts US survey feet to meters using a scale factor of 0.30480060960121919.
  - **Meters to US Feet** – Converts meters to US survey feet using a scale factor of 1/0.30480060960121919.

Using Advanced Conversion Options

When you convert features to 3D, you can accept the default settings in the Convert Features to 3D dialog that you learned about in **Using the 2D to 3D Converter** on page 121. Or, you can use additional settings in the processing of your data. These options are available to you whether you are using virtual 2D to 3D or are converting features to 3D and creating a new file.

The accuracy of the conversion process is increased by using accurate elevation surfaces and by defining advanced conversion parameters. These settings are available to you on the Feature to 3D Options dialog. This section describes each of those settings so you can make the most appropriate selections for your data.

Figure 35: Feature to 3D Options Dialog



Note: Advanced options are only available if you select a raster or TIN surface as an elevation source during the 3D conversion process. If you enter a constant elevation, you don't have access to the advanced options.

Using Feature Draping

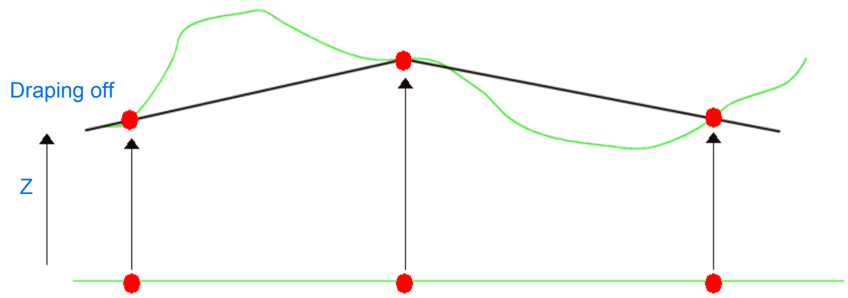
By using draping, you set the condition that the feature follows the subtle changes in elevation of the terrain surface in the height dimension. This is made possible by:

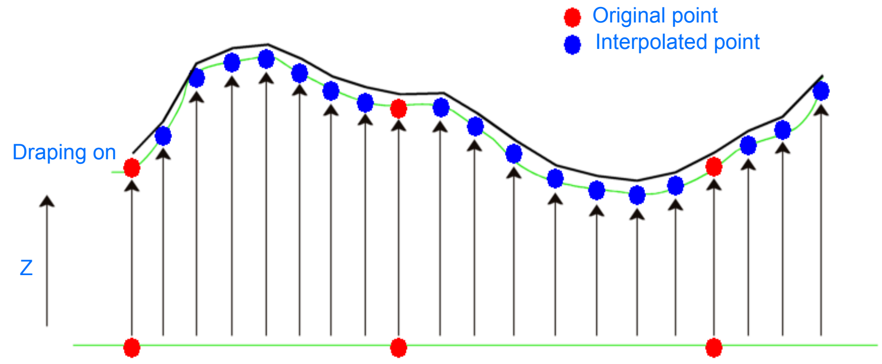
- Interpolating new vertices based on the location of existing vertices.
- Applying the elevation source used to perform the 3D conversion. If a high-resolution elevation source is used, the reliability of the newly sampled (interpolated) points is higher.

In the figure below, the points reflect the vertices associated with the features. The bottom layer is the original feature dataset assuming a zero (sea level) elevation is applied to the feature dataset. The top layer illustrates an elevation source applied to the original feature dataset.

When draping is turned on, additional vertices associated with the dataset are inserted as a function of point spacing. The feature dataset is densified to include more vertices. For more information about densifying a feature dataset to include more vertices, see **Using Advanced Conversion Options** on page 127.

Figure 36: Draping Options

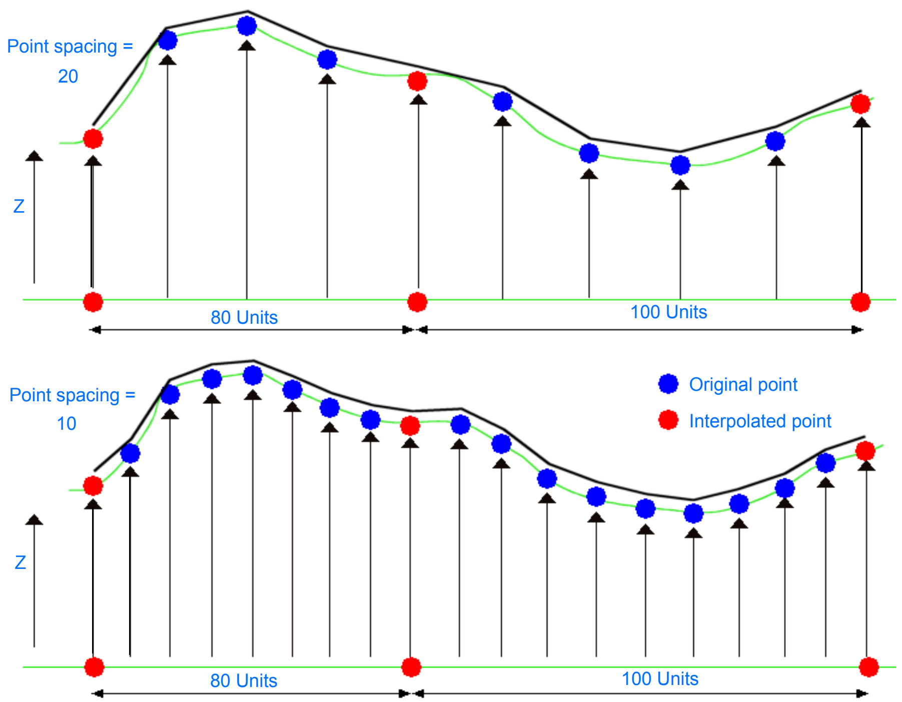

Draping off
Z


Original point
Interpolated point
Draping on
Z

Using Point Spacing

Point spacing is the distance between points used (sampled) during the interpolation process. The distance between the points is measured in the same units as the image pair displayed in the Stereo window. The distance you specify in the Point Spacing field is not exceeded when points are selected for interpolation.

Figure 37: Point Spacing Options



Using Thinning Tolerance

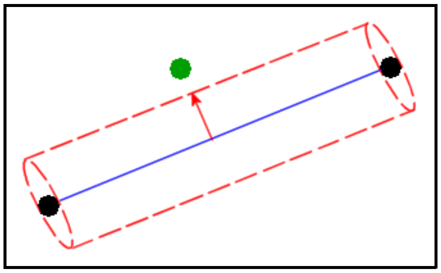
The line thinning tolerance is only active when the Drape linear features on the Terrain Surface option is active. This setting removes redundant points contained within the feature dataset based on a thinning tolerance defined by you. It's useful when the variation in topography is minimal.

By setting a thinning tolerance, Stereo Analyst for ArcGIS checks to make sure that there are no duplicate points in collinear sections. If you don't want thinning, set the value to 0.

In the following diagrams, the green circle represents the current point, the black circles represent adjacent points, and the red line terminating in an arrow represents the thinning tolerance.

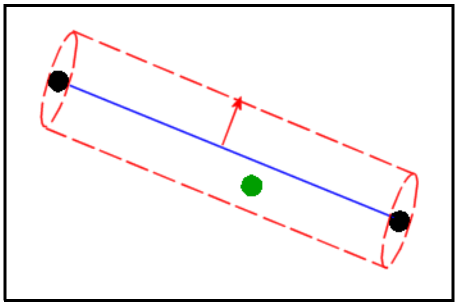
Here, the point is outside the thinning tolerance and is retained.

Figure 38: Point Outside the Thinning Tolerance



Here, the point is inside the thinning tolerance and is later eliminated.

Figure 39: Point Inside the Thinning Tolerance



Creating Planar Features

A planar feature is a feature in which all vertices associated with the feature have the same elevation. These features are commonly flat features such as building roofs.

The Planar Features box in the Feature to 3D Options dialog lets you select certain classes to which a single elevation value is applied to all features contained within that feature class. For example, if a building feature is converted to 3D, you can constrain the building polygon to be flat so that all vertices associated with the polygon have the same elevation value.

The elevation value applied to each vertex for a particular feature are determined in several ways. In the Elevation dropdown list in the Planar Features box, you can select one of the following techniques to use for computing the elevation value:

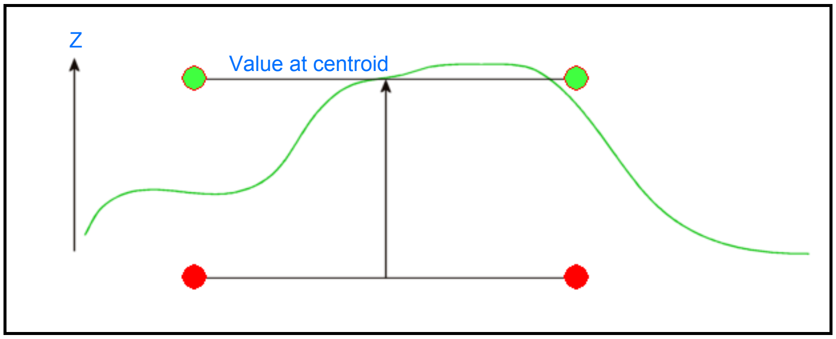
- At Centroid
- Minimum Interpolated
- Maximum Interpolated
- Average Interpolated

Each method of interpolation is described in the sections that follow. In each diagram, the points reflect the vertices associated with the features. The bottom layer, which has the red circles representing sea level elevation, is the original feature dataset assuming a zero (sea level) elevation is applied to the feature dataset.

Using the At Centroid Option

The At Centroid option takes the elevation from the physical center of the feature, the centroid. For example, in a polygon, the center pixel is used for the elevation value. The following illustration shows the At centroid option.

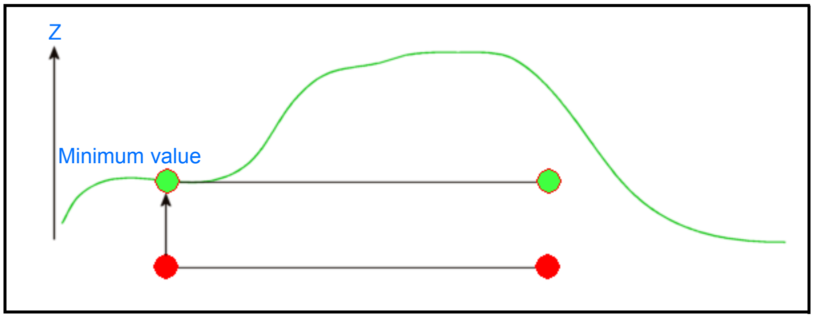
Figure 40: At Centroid Option



Using the Minimum Interpolated Option

If you select the Minimum Interpolated option, elevations are interpolated for each vertex making up the feature, and then the smallest value is used to assign the elevation value. The following illustration shows the Minimum Interpolated option.

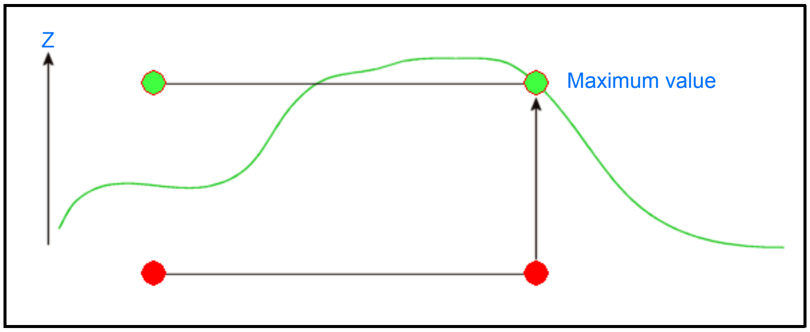
Figure 41: Minimum Interpolated Option



Using the Maximum Interpolated Option

If you select the Maximum Interpolated option, elevations are interpolated for each vertex making up the feature, and then the largest value is used to assign the elevation to the feature. The following illustration shows the Maximum Interpolated value.

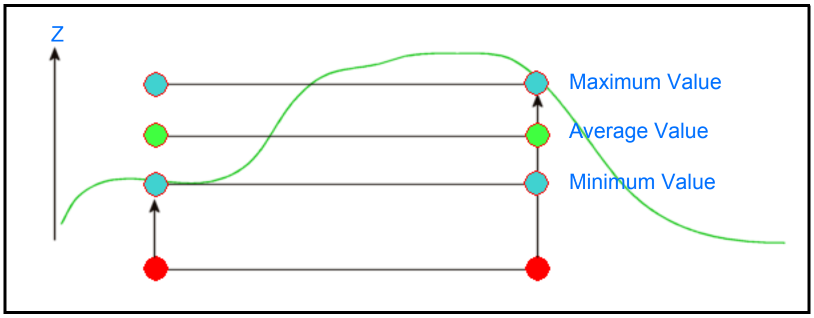
Figure 42: Maximum Interpolated Option



Using the Average Interpolated Option

If you select the Average Interpolated option, elevations are interpolated for each vertex, added, and then divided by the number of vertices, which yields an average elevation. This elevation is assigned to the feature. The following illustration shows the Average Interpolated value.

Figure 43: Average Interpolated Option



Resolving Invalid Elevations

Invalid elevations might exist during the 3D conversion and interpolation process. Stereo Analyst for ArcGIS provides several options to resolve invalid elevations during these processes in the Feature to 3D Options dialog:

- **Keep the Original Elevation Value** – This is the default. In case of an invalid elevation value, Stereo Analyst for ArcGIS uses the original elevation value if the feature is 3D. The elevation values of any questionable points are not changed.

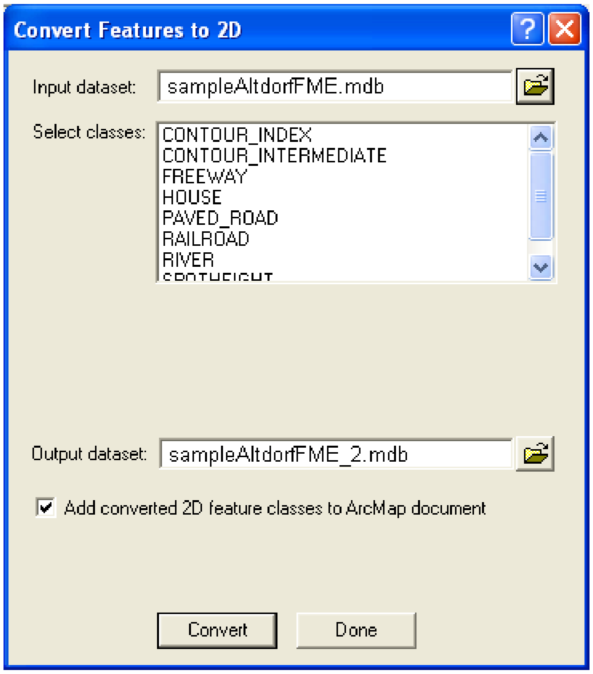
- **Apply a Default Elevation Value** – If you're familiar with the terrain in your data, you can enter an elevation value in this field to apply to all questionable points.

- **Use a Minimum Valid Elevation Value** – When you check this check box, you can enter the value of the lowest possible elevation in your data. For example, if you enter 30, invalid elevation values are assigned a value no lower than 30 map units (such as meters).

Using the 3D to 2D Converter

Stereo Analyst for ArcGIS also provides you with the ability to take your 3D feature datasets and easily convert them to 2D using the Convert Features to 2D dialog. The process is the same as the 2D to 3D converter—you select the input 3D dataset, and Stereo Analyst for ArcGIS produces a 2D dataset without the elevation (Z) component.

Figure 44: Convert Features to 2D Dialog



You must type a name for the output file in the Output Database field. You can use the name of the input file with a _2D designation at the end of it, or you can specify a totally different name. By default, the new file is placed in the same directory as the input dataset. If you want to place it in a different directory, click the browse button for the Output Database field and specify a different directory.

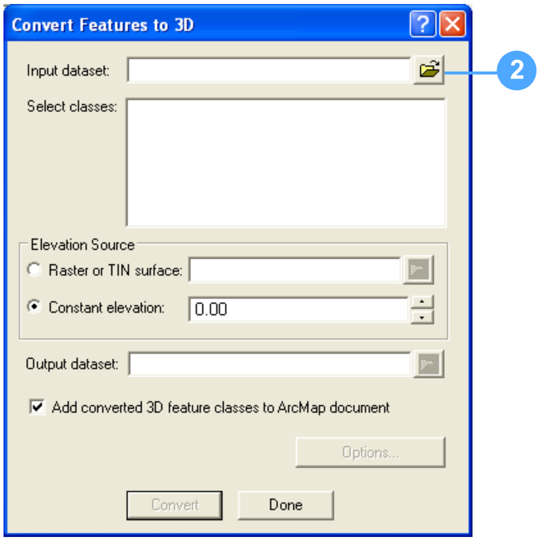
For more information on how to use this tool, see **"Converting 3D Features to 2D" on page 33**.

Applying Advanced 3D Conversion Parameters

You begin the advanced 3D conversion process by selecting the 2D feature dataset and an associated elevation source.

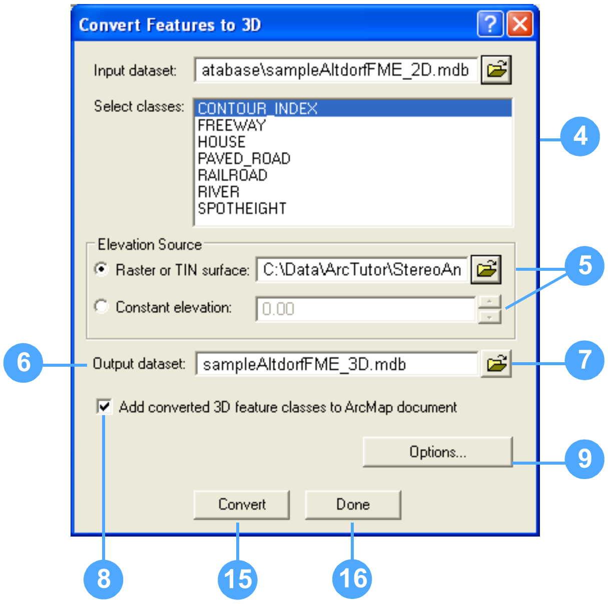
To apply advanced 3D conversion parameters, follow these steps:

1. Select **Features to 3D** from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Convert Features to 3D dialog.



2. Click the browse button for the Input Dataset field to display the Input Features dialog, and navigate to the directory that contains the 2D data.

3. Select the data file, and then click **Open** to return to the Convert Features to 3D dialog.



The classes in the input dataset populate the Select Classes box.

4. Remove any classes that you do not want from the Select Classes box by clicking a class (or use Shift+Click or Shift+Ctrl to select a number of classes), and then right-clicking and selecting **Delete**. Otherwise, all of the classes in the list are converted during the conversion process.

   Note: The first item in the Select Classes list is selected by default.

5. Click the browse button for the Raster or TIN Surface field in the Elevation Source box, and then select a raster or a TIN file to use for elevation, or enter a constant elevation for conversion in the Constant Elevation field.

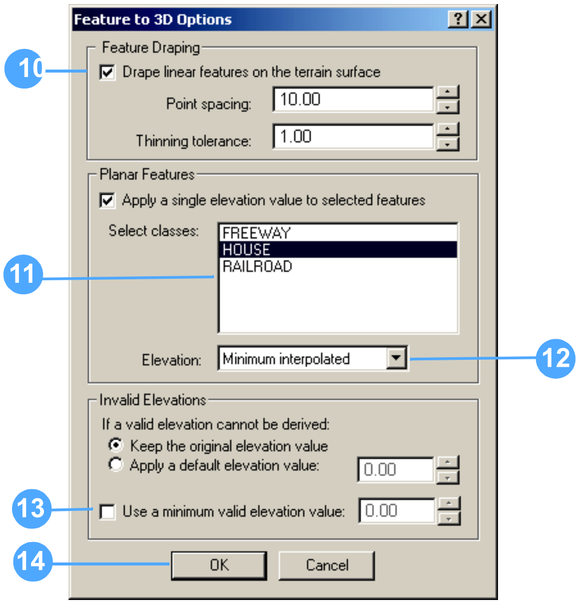
6. Type a name for the output dataset in the Output Dataset field.

   Note: You can use the same name as the input dataset with _3D appended to it.

7. Click the browse button for the Output Dataset field and specify a location if you do not want to use the same directory as the input dataset file. By default, the output file is placed in the same directory as the input dataset.

8. Keep the **Add Converted 3D Feature Classes to ArcMap Document** check box selected, which is the default.

9. Click the **Options** button to display the Feature to 3D Options dialog.



10. Check the **Drape Linear Features on the Terrain Surface** check box, and then type values in the Point Spacing and Thinning Tolerance fields.

11. Select the classes that you want to use an interpolated value in the Select Classes box.

12. Select an option to indicate how you want elevation assigned to questionable areas from the Elevation dropdown list.

13. Check the **Use a Minimum Valid Elevation Value** check box and type a minimum valid elevation value in the field if you want.

14. Click **OK** to close the Feature to 3D Options dialog and return to the Convert Features to 3D dialog.

15. Click **Convert** to start the conversion process.

16. Click **Done** when the status bar at the bottom of the ArcMap window indicates that the process is complete.

What's Next?

In the next chapter, **"Visualizing in Stereo" on page 137**, you learn how to view in stereo (3D). You do so in the Stereo window, which has three possible configurations—the 1-Pane view, the 2-Pane view, and the 3-Pane view. You also learn about the toolbars that come with Stereo Analyst for ArcGIS and how to use the tools to your advantage.

Visualizing in Stereo

Stereo Analyst for ArcGIS provides tools for you to easily view and interpret your data—you do this using typical stereo visualization methods. This chapter introduces you to those methods and gives you tips for their most effective use in Stereo Analyst for ArcGIS.

In this chapter, you learn about:

- Viewing imagery in 3D using stereo viewing techniques. These techniques include using different Stereo window view settings.
- Using tools found on the Stereo Analyst, Stereo View, and Stereo Enhancement toolbars.
- Applying various tools viewed in the Stereo window regardless of whether it's docked to or undocked from the ArcMap window.
- Using the best application of the stereo display options for your application.

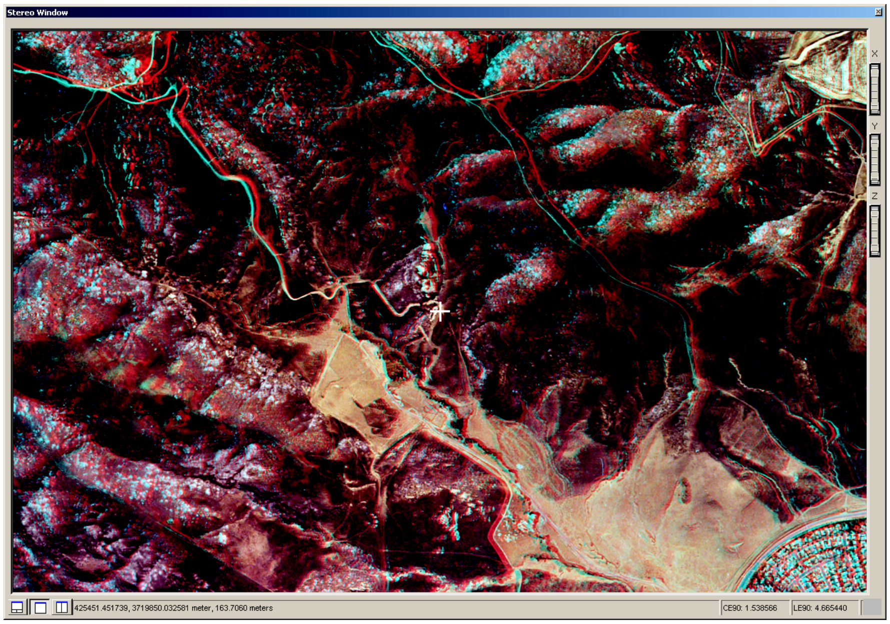
IN THIS CHAPTER

Introducing Stereo Visualization

On a daily basis, we unconsciously perceive and measure depth using our eyes. Persons using both eyes to view an object have binocular vision. Persons using one eye to view an object have monocular vision. The perception of depth through binocular vision is referred to as stereoscopic viewing.

This anaglyph image shows a 1:1 image pixel to screen pixel ratio. With red/blue glasses, the drastic elevation differences in the region are obvious.

Figure 45: Anaglyph Image



Viewing Imagery in 3D

With stereoscopic viewing, you can perceive depth information with great detail and accuracy. Stereo viewing allows the human brain to judge and perceive changes in depth and volume. In photogrammetry, stereoscopic depth perception plays a vital role in using imagery to create and view 3D representations of the Earth's surface. As a result of viewing overlapping images in stereo, geographic information can be collected to a greater accuracy. This is because a true 3D representation of the Earth's surface is used instead of the traditional monoscopic techniques that use only one image.

Stereo feature collection techniques using oriented imagery provide greater GIS data collection and update accuracy compared to other data collection and capture techniques.

The following reasons support why stereo feature collection techniques provide greater data capture reliability and quality:

- Sensor model information derived from photogrammetric block triangulation processing eliminates errors associated with the uncertainty of sensor model position and orientation. Accurate image position and orientation information (that is, sensor model information) are required for the highly accurate determination of 3D information. Sensor model information is used together with imagery to create a 3D digital representation of the Earth's surface.

- Systematic errors associated with raw photography and imagery are considered and minimized during the block triangulation process.

- The collection of 3D coordinate information using stereo viewing and feature collection techniques does not depend on a DEM as an input source. Changes and variations in depth perception are perceived and automatically transformed using the sensor model information associated with raw imagery. Therefore, DTMs containing errors are not introduced into the collected GIS data. When compared to orthorectified images (which require the use of an external elevation source), a 3D digital stereo model (DSM) created using imagery is more accurate because an elevation model is not required as input.

- Digital photogrammetric techniques used in Stereo Analyst for ArcGIS extend the perception and interpretation of depth to include the measurement and collection of accurate 2D and 3D GIS feature data.

For more information about stereoscopic viewing, see **"Understanding Stereo Viewing" on page 287**.

Using Stereo Window Views

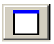
Stereo Analyst for ArcGIS provides three different Stereo window configurations for the collection of reliable GIS data using imagery.

Using the 1-Pane View

In this view, the sensor model information associated with each oriented image in an image pair is used to visually superimpose the oriented images on one another. This creates a 3D digital representation of the Earth's surface when viewed with the appropriate stereo viewing hardware.

The following image depicts a viewing in quad-buffered stereo using special hardware, such as an emitter and stereo glasses.

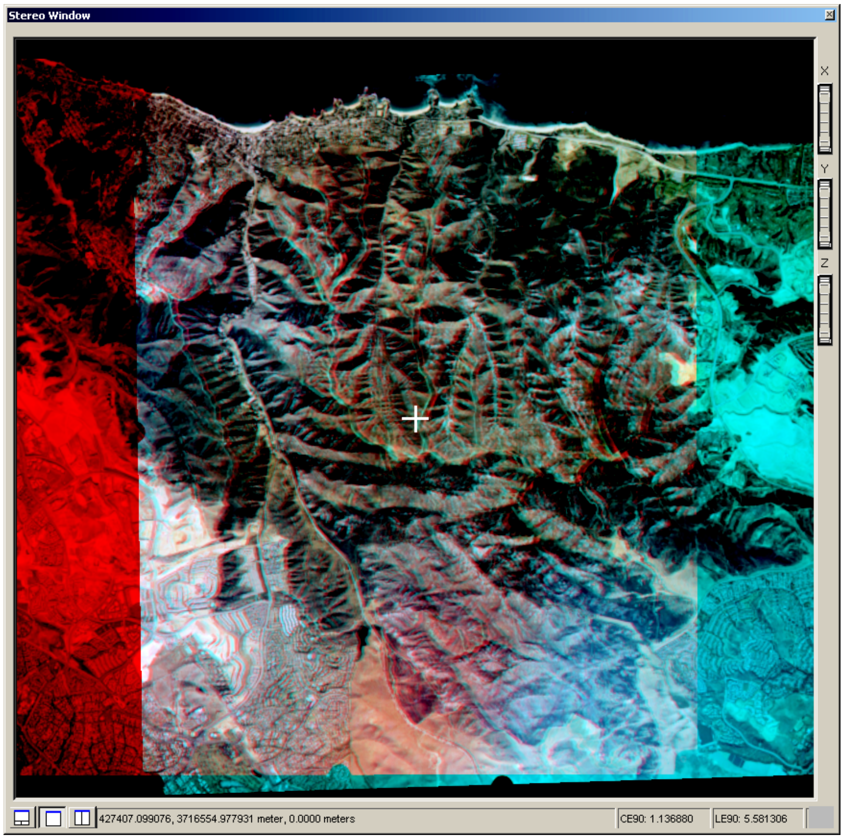
Figure 46: 1-Pane View

The 1-Pane View  button is located in the lower-left portion of the Stereo window.

If the computer graphics card does not support stereo viewing, Stereo Analyst for ArcGIS automatically reverts to anaglyph stereo mode. See the product page for Stereo Analyst for ArcGIS at http://www.erdas.com for a list of graphics cards supported for use with Stereo Analyst for ArcGIS.

In anaglyph, shown below, Stereo Analyst for ArcGIS displays the oriented images in red and green/blue to create a stereo view.

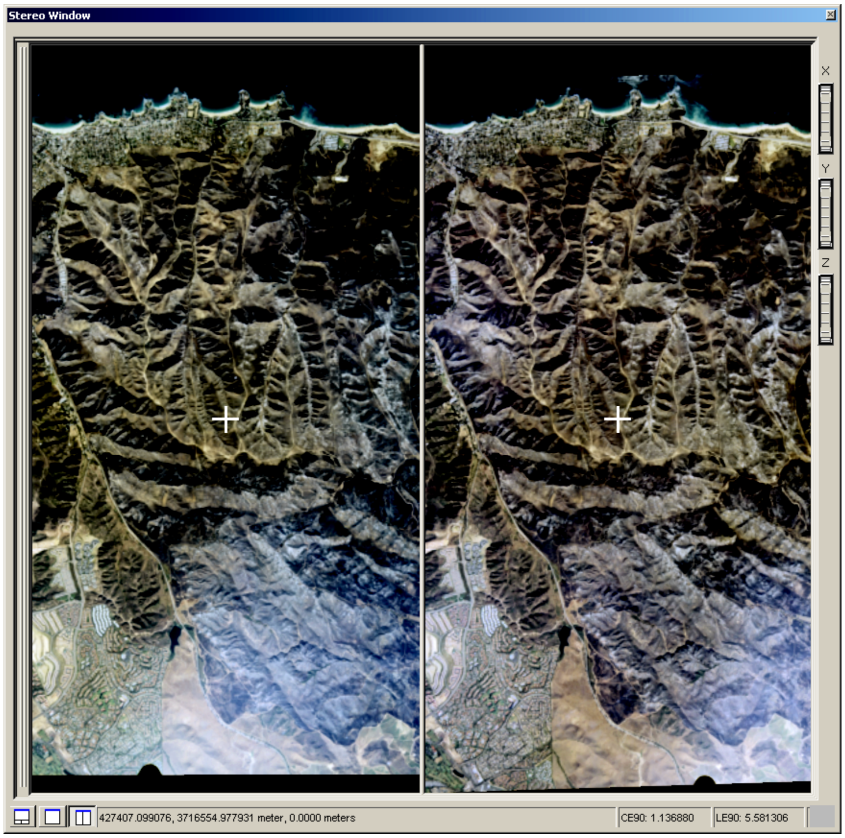
Figure 47: Anaglyph Mode



Using the 2-Pane View

In the 2-Pane view, the left and right oriented images associated with an image pair are separately displayed in the left and right mono panes of the Stereo window, respectively.

Figure 48: 2-Pane View



The 2-Pane view is useful when stereo viewing hardware is not available for stereo visualization. The 2-Pane view is also useful if you cannot properly view overlapping oriented images in stereo. In this case, positioning the 3D floating cursor on the same feature in both panes during collection lets you collect GIS data reliably and accurately.

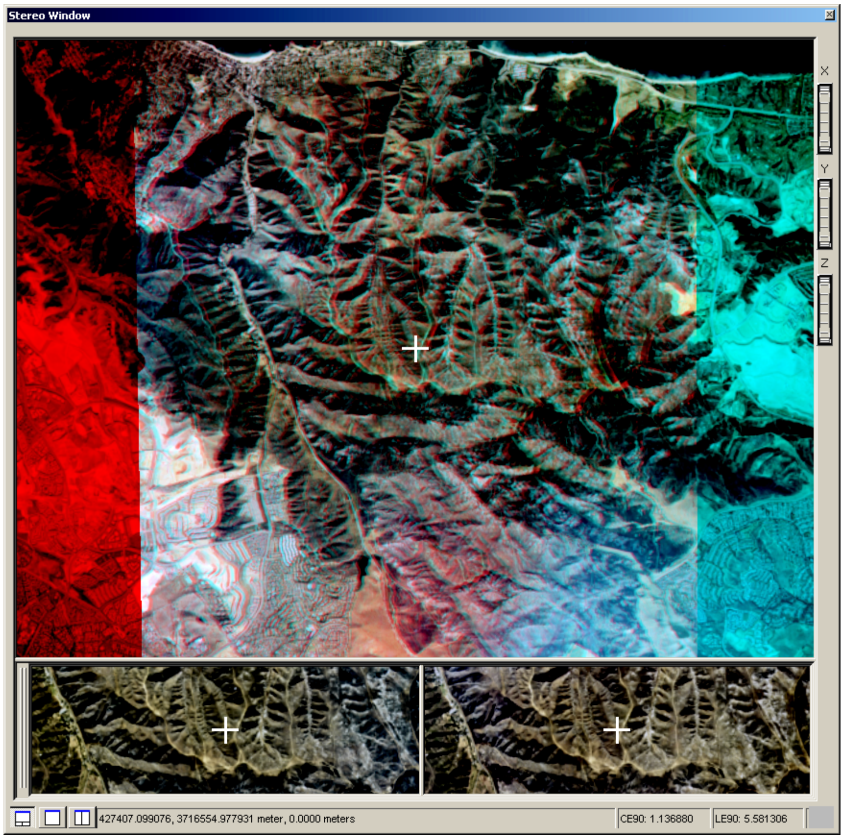
Click the 2-Pane View button in the lower-left portion of the Stereo window to activate the 2-Pane view.

Using the 3-Pane View

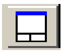
In the 3-Pane view, the 1-Pane view and the 2-Pane view are embedded in the Stereo window. This configuration was designed so you can collect feature data in the Stereo window while verifying data collected in the left and right mono panes.

In the figure below, the 3-Pane view displays the Stereo view and both mono images.

Figure 49: 3-Pane View



If the 3D floating cursor has been accurately placed on the feature being collected, it should reference the same geographic location for that feature collected in the left and right mono panes. The 3-Pane view is intended to provide a simple setup for quick quality assurance during feature collection and data update.

You can activate the 3-Pane view by clicking the 3-Pane View  button located in the lower-left portion of the Stereo window.

Switching Left and Right Images

If you need to switch the left and right images, you can do so by using the Invert Stereo Model button on the Stereo View toolbar.

The use of the Invert Stereo model is appropriate when areas of elevation appear recessed in the Stereo window and vice versa. Switching the left and right images corrects this problem.

Using Autoload Image Pairs

As you digitize features, you might encounter a feature that displays on the edge of one image pair but the remainder of the feature is located on an adjacent image pair. Use the Autoload Image Pairs button on the Stereo View toolbar to automatically jump to the adjacent image pair without having to select it from the Image Pairs dropdown list.

When this button is clicked, adjacent image pairs become active as you approach the edge of a current image pair. This is particularly useful when digitizing features in fixed cursor mode.

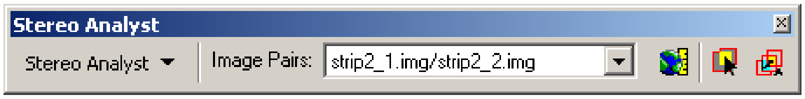
Learning about the Toolbars

Stereo Analyst for ArcGIS provides several toolbars, each with a specific function. The following sections describe the toolbars and their intended application.

Using the Stereo Analyst Toolbar

The Stereo Analyst toolbar is used to access functions and options associated with Stereo Analyst for ArcGIS.

Figure 50: Stereo Analyst Toolbar



You can use the buttons and dropdown lists on this toolbar to do the following:

- **Stereo Analyst** – Access a number of functions and the Stereo Analyst desktop help.
- **Image Pairs** – Select which image pair to display in the Stereo window.
- **Stereo Window** – Display the Stereo window.
- **Image Pair Selection Tool** – Select an image pair from the ArcMap data view or to sync the Stereo view to the ArcMap window view.
- **Autoload Image Pairs** – Automatically load image pairs based on the location of the stereo cursor.

Using the Stereo View Toolbar

The Stereo View toolbar contains a number of tools you can use to efficiently operate in the Stereo window.

Figure 51: Stereo View Toolbar

You can use the buttons and dropdown list on this toolbar to do the following:

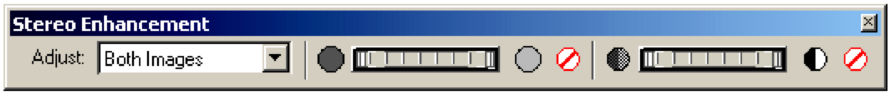
- **Auto Toggle 3D Floating Cursor** – Collect features without toggling.
- **Manually Toggle 3D Floating Cursor** – Use the F3 key to turn the 3D floating cursor on or off in the Stereo window.
- **Zoom In Tool** – Magnify by a power of 2.
- **Zoom Out Tool** – Reduce by a power of 2.
- **Roam Tool** – View a different area of the image pair in real time.
- **Fixed Cursor Mode** – Allow the cursor to remain stationary.
- **Terrain Following Mode** – Automatically place the 3D floating cursor on the ground or feature of interest.
- **Zoom In by 2** – Zoom in by a zoom ratio of 2.
- **Zoom Out by 2** – Zoom out by a zoom ratio of 2.
- **Default Zoom** – Return the display of the image pair in the view to the 1:1 display, where one image pixel equals one pixel on your computer screen.
- **Zoom to Data Extent** – Display the full extent of the image pair in the Stereo window.
- **Scale** – Select a predefined scale or type a value.
- **Synchronize Geographic Displays** – Display the same data coverage in the ArcMap data view as the Stereo window.
- **3D Position Tool** – Enter X, Y, and Z coordinates of a particular point and drive to that location.
- **Invert Stereo Model** – Display the left image of the image pair as the right image and vice versa.

- **Flip View** – Flip the stereo pair in the Stereo window 180 degrees.
- **Refresh Features Tool** – Refresh the display of features in the Stereo window.
- **Automatic Grid** - Automate collecting a regular grid.
- **Height Difference** – Measure the height, slope, and length of an object.
- **Display/Hide Features in Stereo Window** – Click to turn features on or off in the Stereo window.
- **Set Area of Interest** – Define a work area in which the features are cached into memory.
- **3D Snap** – Display a tabular view of the 3D Snap window content in a dockable window.

Using the Stereo Enhancement Toolbar

The Stereo Enhancement toolbar provides tools that let you control the contrast and brightness levels of the imagery displayed in the Stereo window.

Figure 52: Stereo Enhancement Toolbar



You can use the buttons and dropdown list on this toolbar to do the following:

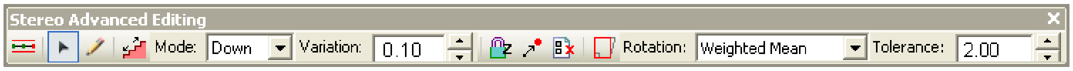
- **Adjust** – Select whether to apply enhancement to the left, right, or both images of the image pair.
- **Decrease Brightness** – Decrease the amount of light in the image pair.
- **Image Brightness Wheel** – Increase brightness by moving the wheel to the right, or decrease brightness by moving the wheel to the left.
- **Increase Brightness** – Increase the amount of light in the image pair.
- **Reset Brightness** – Reset the amount of light in the image pair to when it was originally loaded.

- **Decrease Contrast** – Decrease the apparent difference between light and dark.
- **Image Contrast Wheel** – Increase contrast by moving the wheel to the right, or decrease contrast by moving the wheel to the left.
- **Increase Contrast** – Increase the apparent difference between light and dark in the image pair.
- **Reset Contrast** – Reset the amount of difference between light and dark in the image pair to when it was originally loaded.

Using the Stereo Advanced Editing Toolbar

The Stereo Advanced Editing toolbar allows better control over the handling of Z values while you are editing features.

Figure 53: Stereo Advanced Editing Toolbar



You can use the buttons and other features on this toolbar to do the following:

- **3D Parallel Collection** – Collect offset polyline features from a single edit sketch geometry.
- **Edit Tool** – Select and edit features.
- **Sketch Tool** – Digitize a feature of interest.
- **Toggle Monotonic Mode** – Toggle Monotonic mode on or off.
- **Mode** – Increase, decrease, or keep the elevation level.
- **Variation** – Type a value indicating the amount of elevation change. You should specify a value of zero (0) for Up and Down modes to prevent automatic changes to the height of the floating cursor.
- **Toggle Lock Z Mode** – Lock or unlock the Z value to the current elevation of the floating cursor so that the Z value does not change. This tool is useful for collecting features when all vertices of the feature must be a constant value such as when collecting features for a lake.
- **Locate Feature Vertex** – Automatically move your floating cursor to the height of a nearby snap target.

Note: If the snap type is set to 2D snap, the Z value does not update. If the snap type is set to 3D snap, and the vertex is within tolerance, all X, Y, and Z values are updated.

- **Feature Attributes** – Sets up automatic features attribution after specifying an elevation source and setting up attribute field mapping. For more information, see the Stereo Analyst for ArcGIS help.
- **Toggle Squaring Mode** – Toggles Squaring mode on or off. Collecting features in the Squaring mode attempts to adjust, within the specified tolerance, each of the vertices you digitized so that they form a 90-degree angle. This simplifies the collection of buildings and other rectilinear features.
- **Rotation** – Determines the alignment of the feature:
    - **Weighted Mean** – Uses the length-weighted angle of all sides to determine the alignment.
    - **First Line** – Uses the line formed by the first two digitized vertices of a feature as alignment.
    - **Longest Line** – Uses the longest side of a feature as alignment.
    - **Active View Alignment** – Makes the squared feature sides either horizontal or vertical to the ArcMap data view.
- **Tolerance** – Specifies the greatest distance you can move a vertex to square the feature. In each of the rotation modes, the tolerance value used in squaring is measured in map units.

Opening the Stereo Window

The Stereo window is where an image pair is displayed to create a 3D digital representation of the Earth's surface. In the Stereo window, you can view your 3D features as well as update and digitize features accurately.

To open the Stereo window, follow these steps:

1. Click the ArcMap **Customize** menu, point to **Toolbars**, and select **Stereo Analyst** to display the Stereo Analyst toolbar.
2. Click the Stereo Window button on the Stereo Analyst toolbar to display the Stereo window.

Docking and Retracting the Stereo Analyst Window

You can use Stereo Analyst for ArcGIS as a part of the ArcMap window, or as a separate window by choosing whether to dock or retract it. By default, when you first open a Stereo window, it is incorporated into the ArcMap workspace. You can undock it, however, by dragging the bar at the top of the Stereo window outside the ArcMap environment. The 2-Pane view works the same way, but the bar that controls docking is on the left side.

Docking the Stereo window outside the ArcMap workspace is advantageous if a dual monitor configuration is being used for feature collection. In this scenario, the Stereo window is used as the interface for collecting and editing features while the ArcMap workspace is used as the cartographic station for feature verification, attribution, and analysis.

You can retract the Stereo window against the ArcMap window, and then reopen it when you need it. When you retract the Stereo window, you see a tab on the side of the ArcMap window. You can hover your mouse over the tab to dynamically open the Stereo window so that you can work with it. Click the Auto Hide button in the upper-right corner to pin the Stereo window open. You can close the Stereo window by clicking the Close button.

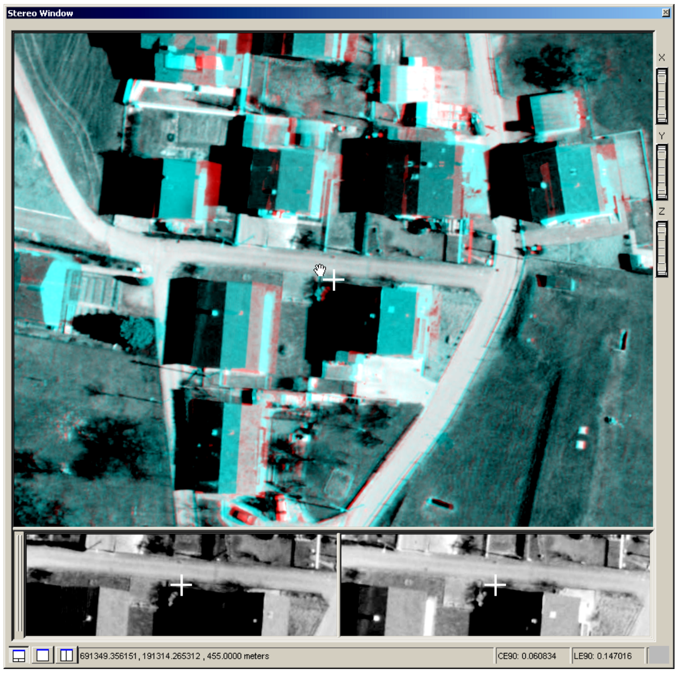
Applying Tools in the Stereo Window

Several tools designed to work in conjunction with the Stereo window are used to increase the performance and productivity of feature collection and editing.

To apply tools in the Stereo window, follow these steps:

1. Click the Add Data button on the Standard toolbar and add data to the Stereo window.

2. Click the Stereo Window button on the Stereo Analyst toolbar to display the Stereo window.



3. Click the Roam Tool button on the Stereo View toolbar.

4. Drag (your cursor looks as a hand) the image pair to a new position in the Stereo window.

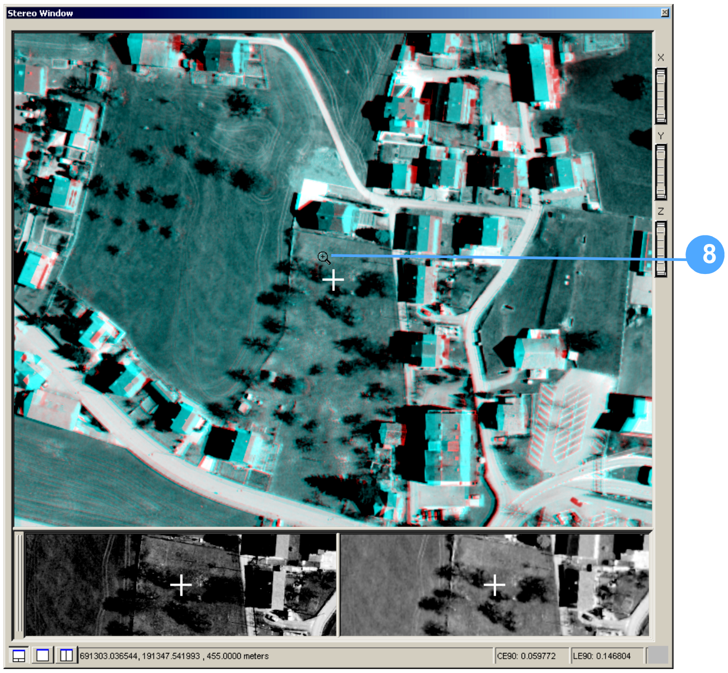
5. Double-click in the Stereo window to enter into Continuous Roam mode.

   The cursor changes from a hand to an arrow. As you change the location of your mouse, the arrow changes direction and speed accordingly.

6. Double-click in the Stereo window to exit the Continuous Roam mode.

7. Click the Zoom Out (or Zoom In) Tool button on the Stereo View toolbar.

8. Drag the scroll wheel in the Stereo window towards or away from you to activate the Continuous Zoom mode.



9. Release the scroll wheel to exit Continuous Zoom mode.

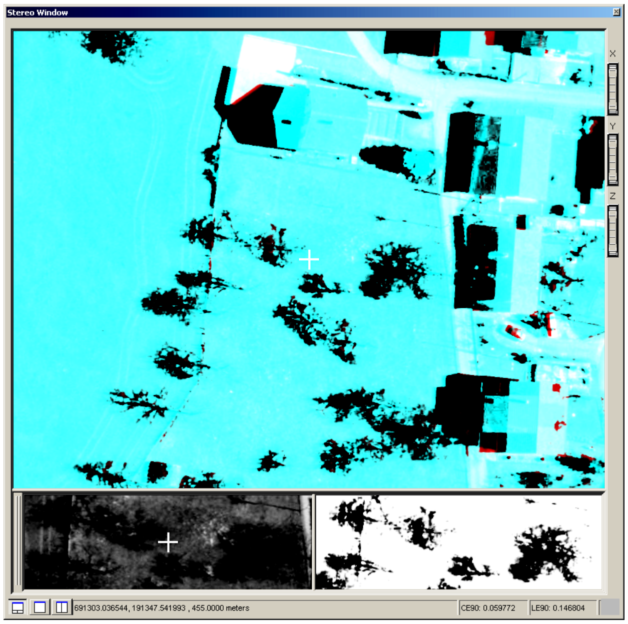
10. Click the Default Zoom button to return the display to a 1:1 default zoom.

11. Select **Right Image** from the Adjust dropdown list on the Stereo Enhancement toolbar.

12. Drag the Image Brightness Wheel button to the right to change the brightness of the right image.

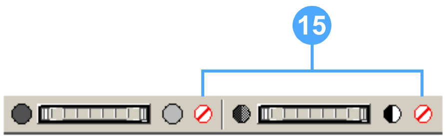
13. Drag the Image Contrast Wheel button to the right to change the contrast of the right image.

14. Observe the changes in the display.



Usually, you won't make such drastic changes to the appearance of the images in the Stereo window. If you don't like the results, you can always reset the display of the image pair to its original brightness and contrast.

15. Click the reset buttons both for brightness and contrast on the Stereo Enhancement toolbar.

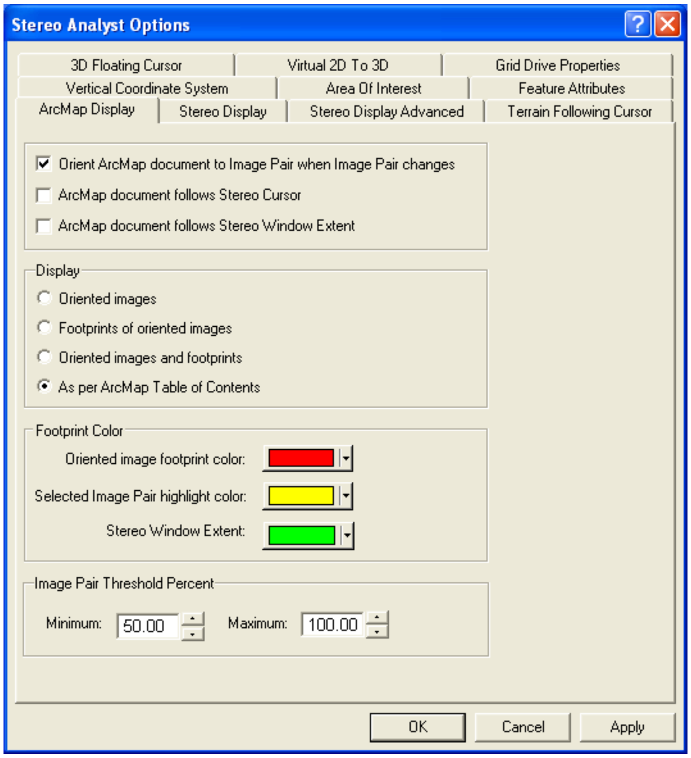


The display returns to the original settings.

Using the Stereo Window with ArcMap

There are a few advanced options you can set so that the Stereo window and ArcMap data view compliment one another during feature collection and editing. You can set these options by selecting Options on the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Stereo Analyst Options dialog. Click the ArcMap Display tab, and then choose settings that control image pair behavior in the ArcMap data view.

Figure 54: ArcMap Display Tab



Selecting Display Settings

The Stereo window and the ArcMap data view can be set to the same orientation to make visualization and feature collection easier. Stereo Analyst for ArcGIS also lets you synchronize the two displays (using the Synchronize Geographic Displays button on the Stereo View toolbar or the Image Pair Selection Tool button on the Stereo Analyst toolbar).

With both ArcMap and the Stereo window displaying data at the same resolution and rotation, you can easily locate the same feature in both applications. The orientation setting is retained if you open a different image pair in the same ArcMap session. However, if you exit ArcMap, the orientation setting must be reset when you resume your work.

Note: If you uncheck the Orient ArcMap document to Image Pair when Image Pair changes check box, the display in the ArcMap data view does not return to the original rotation. You can use the data frame tools provided by ArcMap to unrotate the image pair.

The ArcMap document follows Stereo Cursor option lets you pan the ArcMap document whenever the stereo cursor ground position is moved past the current extent of the active view.

You can use the ArcMap document follows Stereo window extent option if you want to have a zoom or pan in the Stereo window result in the same modification to the ArcMap document window.

Selecting Image Pairs

Within ArcMap, an image pair can be interactively selected and then displayed in the Stereo window using oriented image footprints.

A footprint is a graphical representation of the boundary of an individual oriented image. By default, Stereo Analyst for ArcGIS displays the footprint in red. When two images overlap, that region is again represented graphically, but in yellow. The overlap portions of two oriented images is called an image pair, but can also be referred to as a stereo pair.

If these colors do not suit your needs, you can easily change them using the dropdown arrows on the ArcMap Display tab on the Stereo Analyst Options dialog. The color changes are retained for ArcMap documents (.mxd) that you save and reopen in future Stereo Analyst for ArcGIS sessions. Similarly, the footprint and overlap colors are retained if you open a different image pair in the same ArcMap session. However, if you exit ArcMap, the default colors are reinstated when you resume your work.

Optimizing Display Performance

In cases where a mapping project uses many images (more than five) or large images (greater than 85 MB), the display of oriented images in the ArcMap data view might be slow. Rather than display each raster in ArcMap, Stereo Analyst for ArcGIS lets you display only the footprints of the oriented images. Selecting this option on the ArcMap Display tab improves the display performance in ArcMap.

Retaining Display Settings in the ArcMap Table of Contents

You can use the As per table of contents option to keep the display settings for images and vectors in the ArcMap table of contents. Images do not redisplay if you select and apply another option on the ArcMap Display tab. If an image or feature layer is unchecked on the Display tab in the ArcMap table of contents, and you save your ArcMap MXD document and then reopen it, those images remain off in the reloaded display in the ArcMap document window.

Calculating Usable Image Pairs

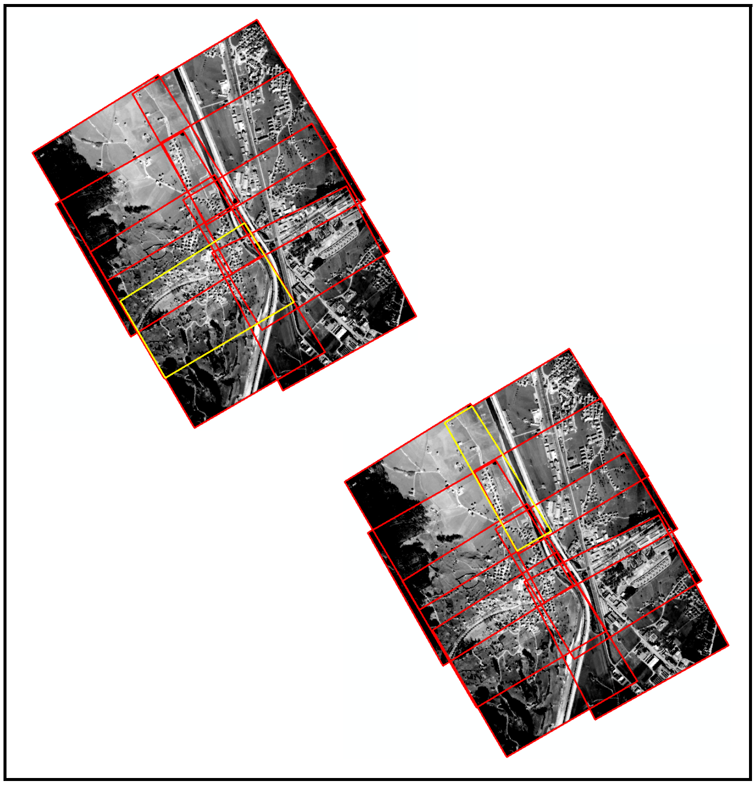
Stereo Analyst for ArcGIS automatically computes valid image pairs by determining whether two oriented images overlap. Because each oriented image contains sensor model information (3D position and orientation), Stereo Analyst for ArcGIS can determine whether the two images overlap. In cases where multiple images are used in a project, Stereo Analyst for ArcGIS might identify many image pairs, although not all of them are suitable for stereo viewing and feature collection.

During the collection of raw aerial photographs, flight plans are purposely coordinated so that resulting photographs along a strip properly overlap to create an optimum 3D digital representation of the interest area. The overlap percentage between two photographs in a strip (also referred to as endlap) is commonly 60 percent. This type of image pair is ideal for stereo viewing and feature collection.

The overlap percentage of two photographs between two strips (also referred to as sidelap) is commonly 20 percent. An image pair created from two overlapping images in adjacent strips is not ideal for stereo viewing and feature collection.

Below, the top figure shows a maximum overlap of 100 and a minimum overlap of 60. With these settings, you can choose all overlapping images. The bottom figure shows a maximum overlap of 100 and a minimum overlap of 25. With these settings, you can choose the sidelap area of image pairs. If you lower your minimum value, there are more possible image pairs from which to choose.

Figure 55: Overlap Percentages of Two Photographs



Stereo Analyst for ArcGIS computes image pairs based on an Image Pair threshold percent setting on the ArcMap Display tab. For example, if the threshold is set to 50 percent, the two images must share at least half of the same geographic area to be considered an image pair.

Depending on the type of data you use, the minimum and maximum values might be different. For example, if you are working with images that have only a 30 percent overlap, you can change the minimum threshold value to ensure that you get image pairs you can use in Stereo Analyst for ArcGIS.

Verifying and Analyzing Features

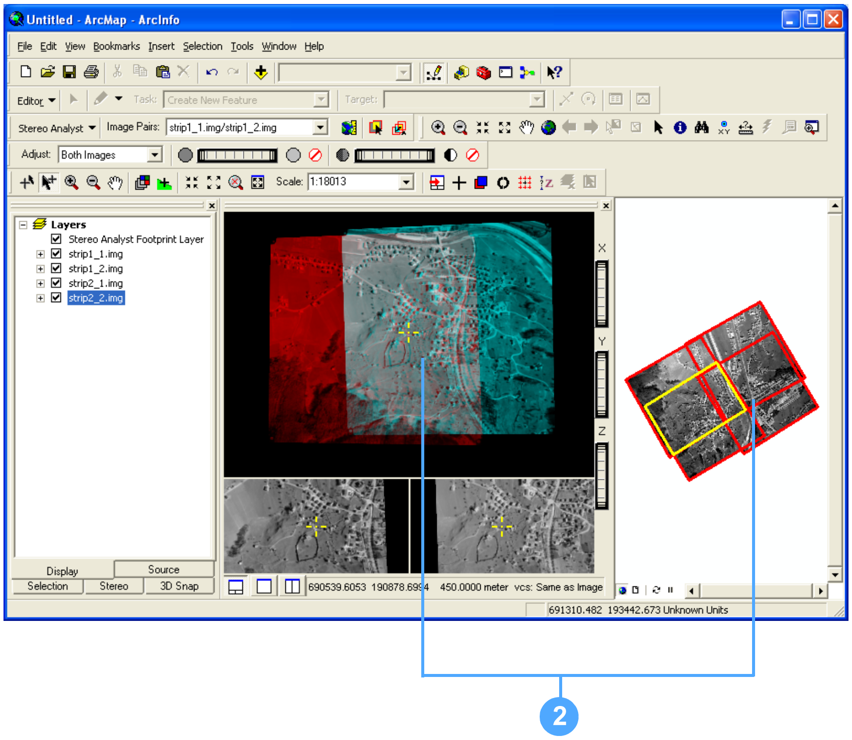
When you use the Stereo window in conjunction with ArcMap, your ability to verify and analyze collected features improves. Two important tools are Orient ArcMap document to Image Pair when Image Pair Changes and Synchronize Geographic Displays.

You should already have an image pair displayed in ArcMap and the Stereo window. This way, you can see the change in orientation more clearly.

To verify and analyze collected features in the Stereo window with ArcMap, follow these steps:

1. Click the Zoom to Data Extent button on the Stereo View toolbar to see all of the image pair in the Stereo window.

2. Note the position of the image pairs in ArcMap.



The overlap portion of the current image pair is represented by the yellow border; image footprints are represented by the red border.

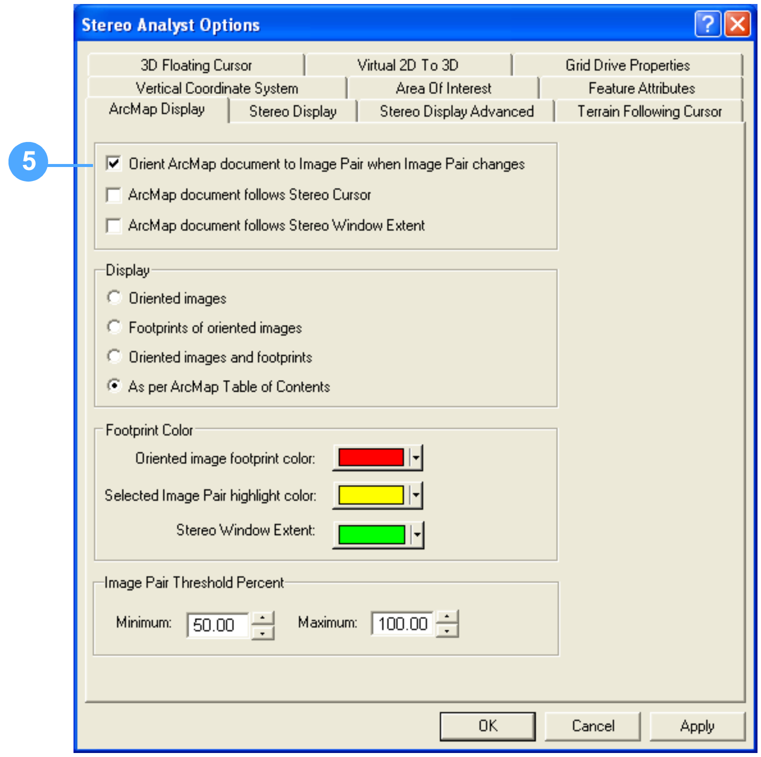
If you are working in anaglyph mode, the overlap portion of the current image pair displays in gray color, and the left and right images of the image pair display in red and blue, respectively.

If your graphics card supports quad-buffered stereo, the entire display, both overlap and nonoverlap areas, appears gray, but you can only see in stereo in the overlap area.

You can get details about your graphics card by selecting Graphics Card Information from the Stereo Analyst dropdown list.

3. Select **Options** from the **Stereo Analyst** dropdown list to display the Stereo Analyst Options dialog.

4. Click the **ArcMap Display** tab.

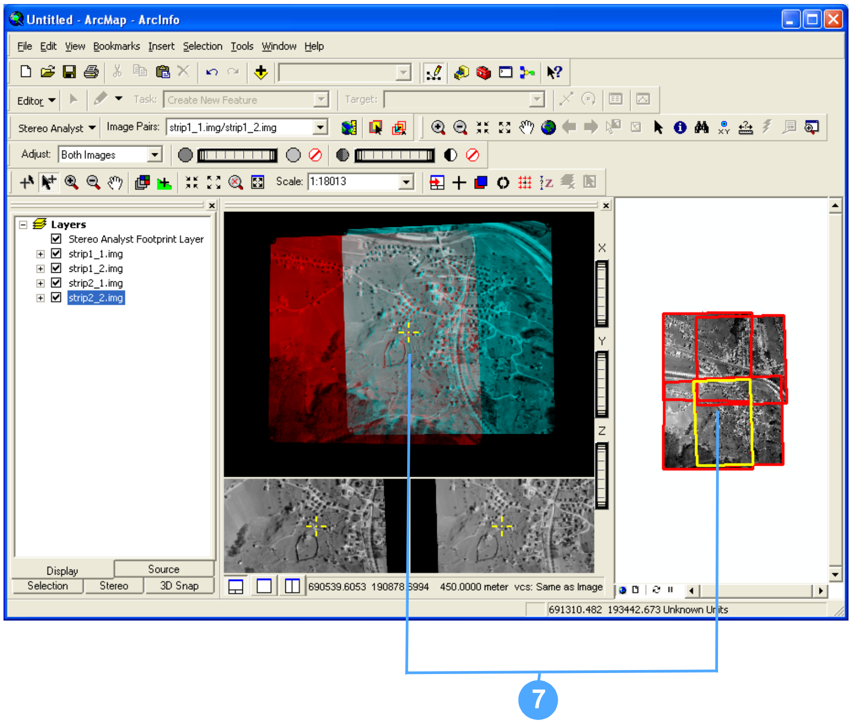


5. Check the **Orient ArcMap document to Image Pair when Image Pair Changes** check box.

   By choosing this option, you ensure that the rotation of the image pair in ArcMap matches that of the image pair displayed in the Stereo window. As a result, the orientation of the image pair in the Stereo window is used as a reference for orienting the ArcMap display. This can help you locate features in both the Stereo window and the data view.

6. Click **Apply** and **OK** to close the Stereo Analyst Options dialog.

7. Notice that the display of the image pair in ArcMap now reflects the same north-south orientation as that in the Stereo window.



You can use the Synchronize Geographic Displays button located on the Stereo View toolbar to display the image pair in the same extent in the ArcMap document window. Or, you can select the ArcMap document follows Stereo Cursor option on the ArcMap Display tab on the Stereo Analyst Options dialog. This can help you as you digitize features.

Using the Primary Stereo window in ArcMap

You can use the Stereo Display tab on the Stereo Analyst Options dialog to control the layers symbology and visibility in the Stereo window without affecting that layer's display in the ArcMap document window.

You can also use the Primary Stereo window in the ArcMap table of contents to help you control images in the Stereo Analyst for ArcGIS Stereo window. You can access the Primary Stereo window by clicking the Stereo button on the toolbar in the ArcMap table of contents. This window contains three tabs:

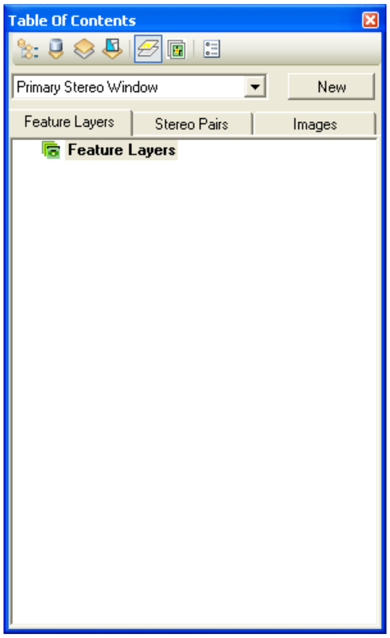
- Feature Layers
- Stereo Pairs
- Images

It also contains the New button that lets you open MultiView windows. Use the dropdown list to switch between the MultiView windows and the Stereo window. For more information, see **MultiView Windows** on page 161.

Feature Layers Tab

The Feature Layers tab is the first tab on the Primary Stereo window in the ArcMap table of contents. Feature layers are added and listed in the window as shown below.

Figure 56: Feature Layers Tab



When feature data is added to the ArcMap document window, Stereo Analyst obtains a reference to the layer, and the symbology is initially set to default to the same symbology as the ArcMap document window.

The layer names are updated automatically on the Feature Layers tab if the layer name is changed on the ArcMap Display tab.

Changing Feature Layer Visibility

The procedure for changing the feature layer in the Stereo window visibility varies depending on the status of the Use Map Layer Visibility in Stereo Window option on the Stereo Display tab in the Stereo Analyst Options dialog. If this option is on (checked), the visibility of the layers in the Stereo window is controlled from the ArcMap Display tab.

You can hide the layer in the Stereo window without affecting its display status in the ArcMap document window by clearing the Use Map Layer Visibility in Stereo Window check box. Check the check box to redisplay the layer in the Stereo window. For more information, see **Using Map Layer Visibility** on page 170.

Changing Feature Layer Display Symbology

The procedure for changing the symbology varies depending on the status of the Use Map Symbology in Stereo Window option on the Stereo Display tab in the Stereo Analyst Options dialog. If this option is on (checked), the symbology of the stereo layer is controlled from the ArcMap Display tab and its properties window. For more information, see **Using Map Symbology** on page 170.

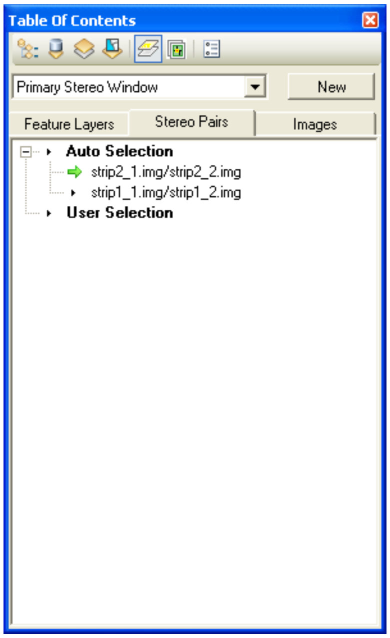
You can change the rendering properties of the feature layers in the Stereo window the same way as ArcMap layers symbology. Double-click the name of the feature layer on the Feature Layers tab to open the symbology window. Change the symbology as needed, and then click OK to apply the changes and close the window. The legend shows the changes under the layer. In addition, the Stereo window uses the new symbology and refreshes immediately.

The order of display for the stereo layers in the Stereo window can be changed by dragging and dropping a layer to a new location.

Stereo Pairs Tab

The second tab on the Primary Stereo window in the ArcMap table of contents is the Stereo Pairs tab. It lets you switch the stereo pair displayed in the window whose name is specified in the dropdown list by selecting an image pair from either the Auto Selection or User Selection list.

Figure 57: Stereo Pairs Tab



Please note the following:

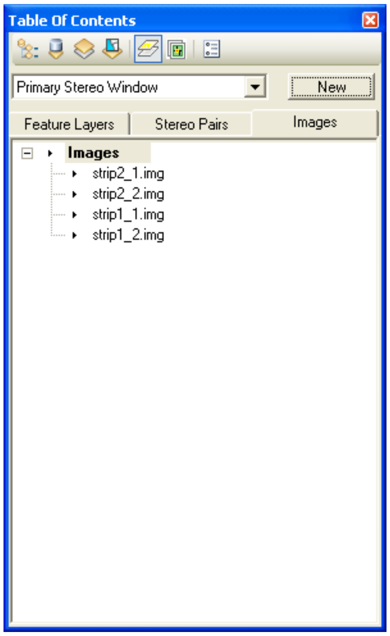
- **Auto Selection** – This list populates with valid stereo pairs automatically defined by Stereo Analyst for ArcGIS based on the overlap percentage set on the ArcMap Display tab on the Stereo Analyst Options dialog.
- **User Selection** – This list populates with stereo pairs defined by a custom API. Stereo Analyst for ArcGIS allows for the deployment of a customized image pair construction mechanism for clients with special requirements.

You can right-click Auto Selection or User Selection and then select the Refresh Image Pairs option to reconstruct the image pairs based on the valid layers currently loaded in ArcMap. This helps rebuild the image pairs after changes to the data source for image layers.

Images Tab

You can use the Images tab on the Primary Stereo window in the ArcMap table of contents to view the name of the images that are currently open in ArcMap and, therefore, available to open in a MultiView window.

Figure 58: Images Tab



MultiView Windows

Other than the dockable Stereo window, Stereo Analyst for ArcGIS lets you open additional windows called MultiView windows. These windows can be used to display an alternate stereo pair, or a single orthorectified or calibrated image to give you an alternate view of your collection area. When more than one MultiView window is open, the active window is enclosed in a red box.

You can launch a MultiView window from the Stereo tab in the ArcMap table of contents. You can load stereo pairs and images into a MultiView window using the New button in the top-right corner of the Stereo tab. Once the MultiView window opens, you can change the displayed data by clicking the different data listed on the Stereo Pairs or Images tabs.

The number of MultiView windows you can open is a preference-controlled setting that is limited by your system resources. For more information about preferences, please see the Stereo Analyst for ArcGIS Preferences file or the Stereo Analyst for ArcGIS help.

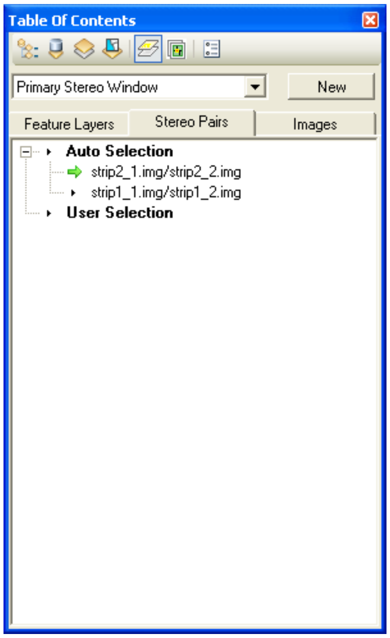
Settings that you specify in the Stereo Analyst Options dialog to control the display and movement of the Stereo window, with respect to the ArcMap document window, also apply to the display and movement of MultiView windows.

Opening multiple MultiView windows consumes additional system memory. If you open more windows than your system can handle, it might cause ArcMap to shut down unexpectedly and unsaved changes to be lost.

To open a MultiView window, follow these steps:

1. Load data into ArcMap.

2. Click the Stereo button on the toolbar in the ArcMap table of contents.



3. Click the **New** button to display the image in the MultiView window.

Note: The footprint layer shows the active image pair's intersection in highlight color for stereo windows. For a Multiview window with an orthorectified or calibrated image, the entire active image is highlighted.

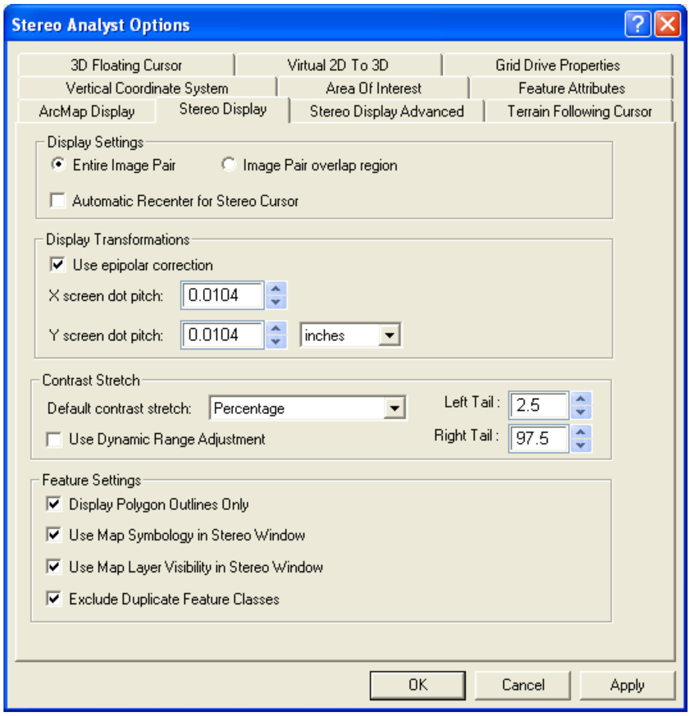
4. Click the data you want to display in a new MultiView window in either the Stereo Pairs or Images tab.

5. Make a new selection on the Stereo Pairs or Images tab to change the displayed data if you want.

Setting Stereo Display Options

Like the options you can set affecting the display of data in ArcMap, you can also set options that affect the display of oriented images in the Stereo window. You can set these options by selecting Options from the Stereo Analyst dropdown list to display the Stereo Analyst Options dialog, and then clicking the Stereo Display tab.

Figure 59: Stereo Display Tab



Choosing the Display Area

Stereo Analyst for ArcGIS displays the entire image pair in the Stereo window by default. However, you can select the Image Pair overlap Region option if you only want to see the overlap region common to the two images of an image pair. This changes the display in the Stereo window, but not the ArcMap data view.

Recentering the Stereo Cursor

The Automatic Recenter for Stereo Cursor setting automatically recenters the 3D floating cursor to the center of the Stereo window. This occurs when Fixed Cursor mode is not on and after you finish collecting or editing a feature. This option helps minimize uncertainty as to where the 3D floating cursor is located and establishes a consistent position for the 3D floating cursor while not forcing you to operate in Fixed Cursor mode.

Applying Epipolar Correction

The Use epipolar correction check box, when checked, removes Y-parallax from the image pair displayed in the Stereo window. This leaves only X-parallax, which you can adjust when the 3D floating cursor is in Fixed Cursor mode. This ensures a more accurate and visually comfortable stereo view.

For more information on Fixed Cursor mode, see **"Using Fixed Cursor Mode" on page 196**.

Using sensor model information, each oriented image in an image pair is displayed so that, when viewed in stereo, a 3D digital representation of the Earth is perceived. The images must be properly aligned to optimally perceive imagery and features in 3D using stereo viewing techniques. A feature in both the left and right image must be positioned along the epipolar line.

A feature might not always properly display along the epipolar line in both the left and right images. If the same feature in two overlapping oriented images does not display along the epipolar line, it is difficult to view the images in stereo and the accuracy of the collected feature might not be as reliable.

By selecting the Use epipolar correction option, Stereo Analyst for ArcGIS determines what correction to make to position the feature on the epipolar line for both the left and right images.

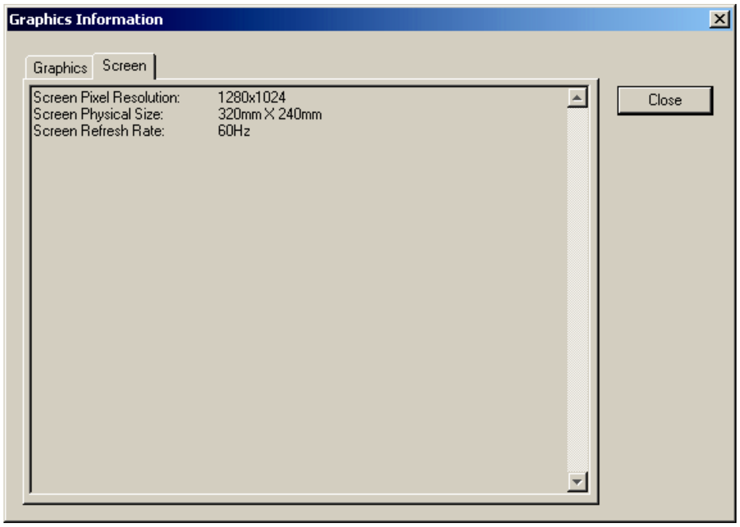
For more information, see **"Understanding the Epipolar Line" on page 296**.

Modifying Screen Dot Pitch

The screen dot pitch is the size of the pixels on the screen. The X screen dot pitch value is measured horizontally; the Y screen dot pitch is measured vertically. This value is automatically computed and is used for scaling in the Stereo window. The more accurate the screen dot pitch values are, the more accurate the scaling is in the Stereo window.

Divide the screen physical size by the screen pixel resolution for each dimension to determine the appropriate screen dot pitch size for your display. This information is found on the Screen tab on the Graphics Information dialog. You can access this tab by selecting Graphics Card Information from the Stereo Analyst dropdown list while the Stereo window is open in ArcMap.

Figure 60: Screen Tab



See the product page for Stereo Analyst for ArcGIS at http://www.erdas.com for a list of graphics cards supported for use with Stereo Analyst for ArcGIS.

The screen physical dimensions are approximate, and actual dimensions might vary due to monitor settings. If an exact measurement is required, measure the viewable area on the monitor and divide by the current screen pixel resolution.

Applying a Contrast Stretch

The range of data file values is often not the same as the range of brightness values of the display because the data file values in raster images often represent raw data (such as elevation or an amount of reflected light).

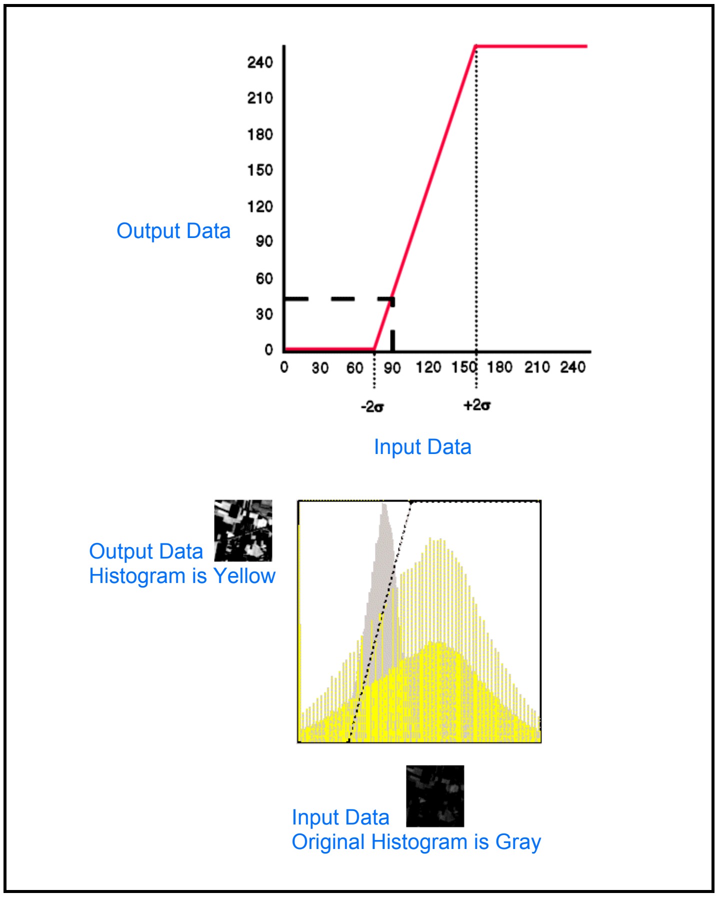
A contrast stretch, as the name implies, stretches the values of the raster image to fit the range of the display. This results in a more crisp looking image in the Stereo window.

You can choose from the following types of contrast stretches: Two Standard Deviations, Min/Max, Linear, None, Equalize, and Percentage. You learn more about these contrast stretches in the sections that follow.

Using a Two Standard Deviations Stretch

A Two Standard Deviations stretch uses the data between -2 and +2 standard deviations from the mean of the file values and stretches them to the complete range of output screen values.

Figure 61: Two Standard Deviations Stretch

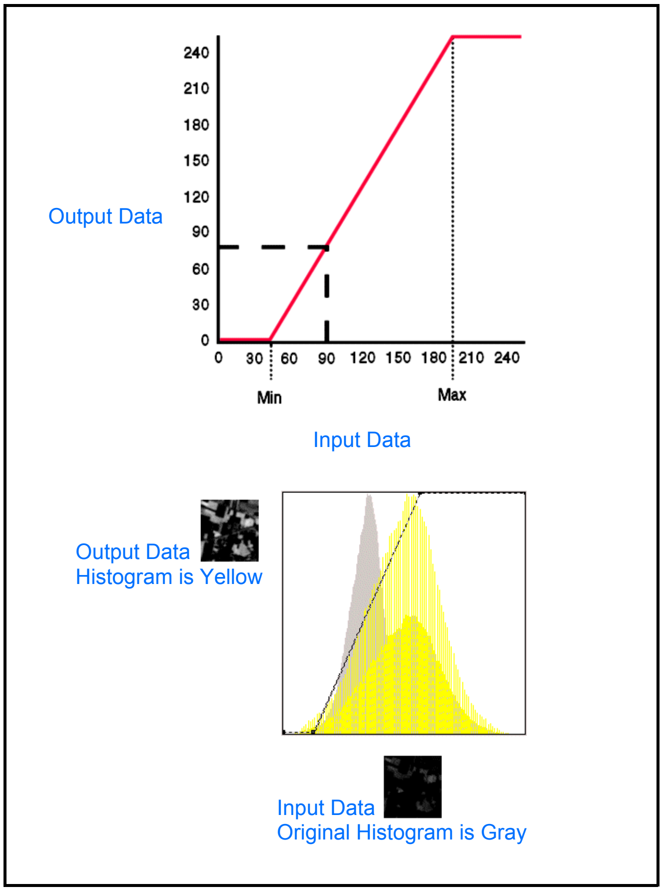


Output Data
240
210
180
150
120
90
60
30
0
0 30 60 90 120 150 180 210 240
-2σ
+2σ
Input Data
Output Data
Histogram is Yellow
Input Data
Original Histogram is Gray

Using a Min/Max Stretch

A Min/Max stretch makes the range of the data values vary linearly from the minimum statistics value to the maximum statistics value in the input direction, and from 0 to the maximum brightness value in the output direction.

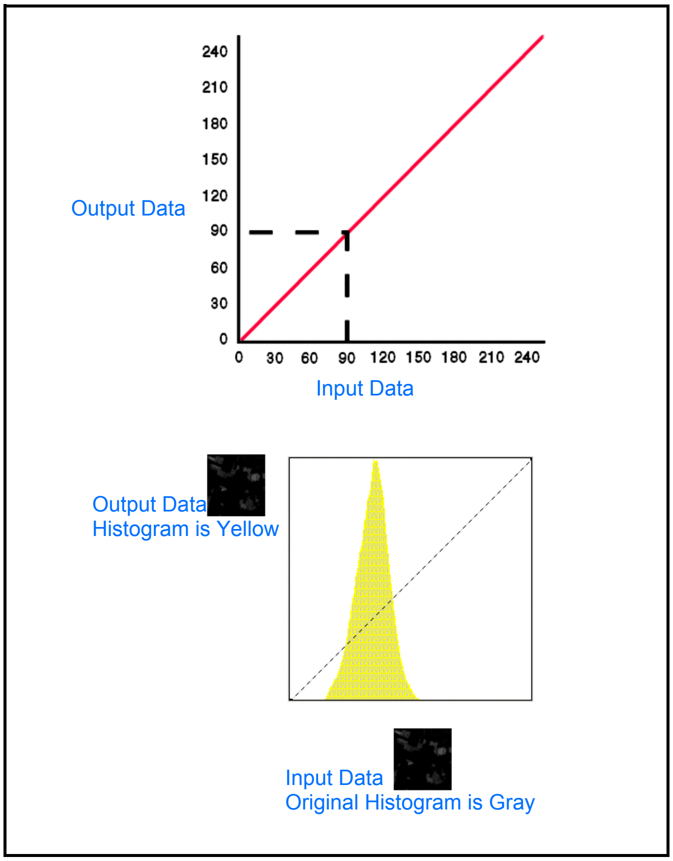
Figure 62: Min/Max Stretch



Using a Linear Stretch

A Linear stretch is a simple way to improve the visible contrast of an image. It is often necessary to contrast-stretch raw image data so that you can see it on the display.

Figure 63: Linear Stretch



In most raw data, the data file values fall within a narrow range—usually a range much narrower than the display device is capable of displaying. You can expand the range to use the total range of the display device. Note that you can only see a difference in images greater than 8 bits with this type of contrast stretch.

No Contrast Stretch

Stereo Analyst for ArcGIS lets you adjust contrast manually if you do not want it performed automatically by the program.

Equalize

This option performs a nonlinear contrast stretch that redistributes pixel values as evenly as possible over a range. The result approximates a flat histogram. Therefore, contrast is increased at the peaks of the histogram and lessened at the tails.

Percentage

You can specify percentages to clip from each side of the histogram. You can clip equal amounts from both sides, or clip different amounts from the left and right sides. This clips, or discards, the values on the extreme lower and upper ends. Type a value in both the Left Tail and Right Tail fields indicating a percentage to clip.

Using Dynamic Range Adjustment

This feature ensures brightness and contrast are automatically adjusted to the optimum as you roam the image. However, during autoroaming, the adjustment is not made until roaming pauses.

The dynamic range adjustment function is most useful with larger images to enhance features that might appear dark or washed out. This feature adjusts your range as you move around the image and locate details you might otherwise miss. This feature overrides any other contrast or brightness settings.

Displaying Polygon Outlines

If a large feature dataset is being edited, performance might decrease. One option for increasing the display speed of polygon features is displaying only the outline of polygon features and not the texture (fill) of the polygon itself. Selecting the Display Polygon Outlines Only setting displays the polygon but not the texture of the polygon. This option is only applicable to the display of polygon features in the Stereo window and not the ArcMap display.

If the Display Polygon Outlines Only check box is not checked, then all polygon features are filled, which masks the feature below it. If you are not concerned with the details of features beneath polygons (such as trees in a large area identified as a parcel of land), then filled polygons are acceptable in addition to the outlines.

The top illustration shows filled polygons representing houses. The bottom illustration shows the same polygons in the same area, but unfilled.

Figure 64: Filled and Unfilled Polygons

Using Map Symbology

The Use Map Symbology in Stereo Window option lets you keep the symbology settings in the ArcMap document window and the Stereo window the same. If you leave this option unselected, any changes to the symbology in the ArcMap Display tab does not result in a change to the symbology in the Stereo tab, which controls the symbology for the Stereo window.

Note: The actual symbology used is not always represented in the Stereo tab. Some types of complex symbologies must be generalized for display in the stereo environment.

Using Map Layer Visibility

You can control the visibility of feature data in the Stereo window through the Use Map Layer Visibility in Stereo Window option on the ArcMap Display tab. If you leave this option unselected, turning layers off in the ArcMap Display tab does not result in layers turning off in the Stereo tab, which controls the display of features in the Stereo window.

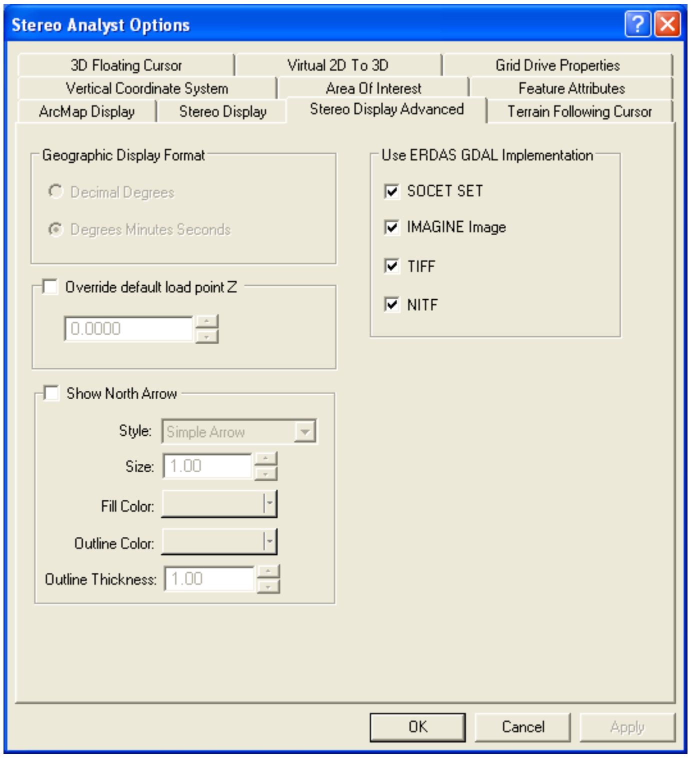
Exclude Duplicate Feature Classes

This option keeps duplicate layers from loading in the Stereo window if the same feature classes are already loaded into ArcMap. Sometimes it is necessary to load a single layer multiple times while editing for display at various scales. However, you only need to load that layer once in the Stereo window. Excluding duplicates consumes less memory, which improves performance. The excluded layers appear dimmed, and they do not have any symbology associated with them.

Setting Advanced Stereo Display Options

Stereo Analyst for ArcGIS provides the Stereo Display Advanced tab, which lets you specify advanced options for the display of the Stereo window.

Figure 65: Stereo Display Advanced Tab



Geographic Display Format

You can control the format of the display of coordinates for geographic data sets using the options in this section. Based on the option selected, coordinate information displays in decimal degrees or degrees, minutes, or seconds at the bottom of the Stereo window.

Select the Decimal Degrees option to display the entire extent of the image pair. If you want to display only the portion of the images where there is overlap, select the Degrees Minutes Seconds option.

Override Default Local Point Z

This option lets you define an initial Z to use when loading data into the Stereo window. When you enable this option, Stereo Analyst for ArcGIS uses the load point Z specified in the field instead of the mean Z from the orientation information of the images on the initial load of the data in the Stereo window. Often, the main Z value found in image tags or header information is less than accurate, which causes the data to initially display with a large amount of X parallax.

Show North Arrow

When you display the north arrow in the Stereo window, Stereo Analyst lets you select a style, display size, fill color, and outline color for the arrow. You can also specify the thickness for the line that outlines the north arrow.

Use ERDAS Raster Support

There are several raster formats with differences between the support offered by ESRI and by ERDAS. These differences can be attributed to a variant of that format, how data is stored, or the amount of data that can be read to improve the display accuracy of that file. In some cases, ERDAS lets you use ERDAS libraries to support a certain format. This ensures you the same level of format support as in the past.

Note: It is recommended that you leave the supported formatting options enabled because disabling a format results in that format's handling being delivered by ESRI.

The following formats are supported:

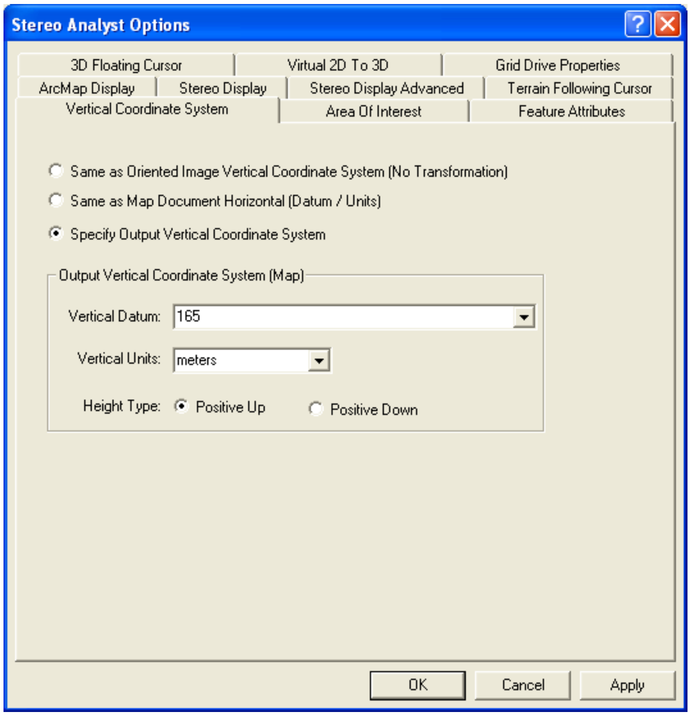
- SOCET SET
- IMAGINE Image
- TIFF
- NITF

Setting the Vertical Coordinate System Options

Stereo Analyst for ArcGIS provides a Vertical Coordinate System tab in the Stereo Analyst Options dialog. This tab lets you specify the Vertical Coordinate System for collected features.

In cases where the Vertical Coordinate System required for the target map base is different from that defined within the orientation information of stereo imagery, you can use this tab to define the target Vertical Coordinate System. Stereo Analyst for ArcGIS converts elevations acquired from the stereo imagery into the datum required for the map base.

Figure 66: Vertical Coordinate System Tab



You can select the Same as Oriented Image Vertical Coordinate System (No Transformation) option to set the vertical datum in the Stereo window to the same vertical datum and units that are specified in the oriented images. If you want to set the vertical datum for the Stereo window the same as the horizontal datum defined in the Data Frame properties in the ArcMap document window, you can specify the Same as Map Document Horizontal (Datum/Units) option.

Select the Specify Output Vertical Coordinate system option to activate the settings in the Output Vertical Coordinate System (Map) box to set an alternate vertical coordinate system from the one defined for the oriented images. All of the options in the Output Vertical Coordinate System (Map) box become active.

To specify settings for the output vertical coordinate system, follow these steps:

1. Select an option for the output vertical datum from the Vertical Datum dropdown list.
2. Select the units of measurement from the Vertical Units dropdown list.
3. Click either the **Positive Up** or **Positive Down** button to specify the height type.

What's Next?

In the next chapter, **"Applying the 3D Floating Cursor" on page 175**, you learn all about the 3D floating cursor, including how to adjust it, how to use it in conjunction with different modes, and some keyboard shortcuts.

Applying the 3D Floating Cursor

Stereo Analyst for ArcGIS creates a 3D digital representation of the Earth's surface using imagery; therefore, you cannot use a standard cursor (2D) to collect data. As a result, Stereo Analyst for ArcGIS has a 3D floating cursor that you can position in all three dimensions (X, Y, and Z). This way, the 3D floating cursor can properly rest on the feature that is being collected or edited.

The 3D floating cursor gets its name because the cursor can float on, below, or above a feature when viewing in stereo. This cursor can also be referred to as a ground point, but it is referred to as a 3D floating cursor in this document. Understanding the operation of the 3D floating cursor is very important because it collects and edits features reliably in the Stereo window.

In this chapter, you learn about using the different 3D floating cursor modes such as the Terrain Following mode. You also learn how to work with and determine the accuracy of the 3D floating cursor in the Stereo window. Plus, keyboard shortcuts are described that can help you quickly view images and collect features.

IN THIS CHAPTER

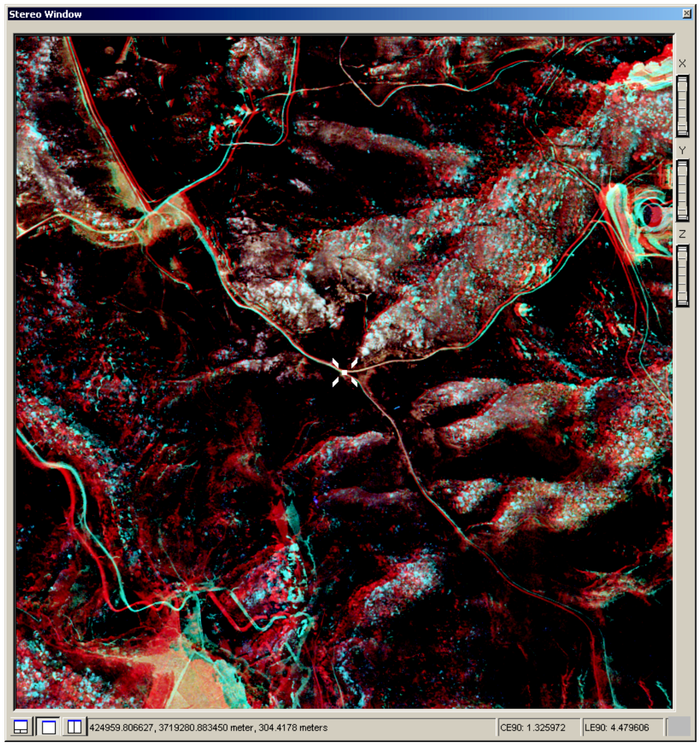
Using the 3D Floating Cursor

A 3D floating cursor consists of an independent cursor displayed for the left image and an independent cursor displayed for the right image of an image pair.

When images are not viewed in stereo, the 3D floating cursor appears to be two separate cursors that may or may not rest on the same feature. However, when viewed in stereo, the two cursors fuse to create the perception of a 3D floating cursor.

The following is an anaglyph image of an area in Laguna Beach, CA illustrating the 3D floating cursor resting on top of a mountain ridge.

Figure 67: Anaglyph Image of the 3D Floating Cursor



The left and right cursors for the left and right images reference a location. When a feature is being collected in stereo, the image position of the cursor for the left and right images must be at the exact same feature and location. If this does not occur, you cannot reliably collect the feature. For example, if a road along a rolling hill is being collected, you must adjust the elevation of the 3D floating cursor so that it rests on the surface of the road each time a point (vertex) for the road is collected.

The 3D floating cursor is the primary measuring mark used in Stereo Analyst for ArcGIS to collect and measure accurate 3D geographic information.

When collecting or editing features, you must position the 3D floating cursor on the feature being collected. While viewing in stereo, you can do this by adjusting the X, Y, and Z coordinates of the 3D floating cursor until it is at the right location. The X, Y, and Z position of the 3D floating cursor is adjusted using a digitizing device such as the system mouse, the ITAC Systems Mouse-Trak Professional, the ERDAS TopoMouse, Hand Wheels EK2000, or the Immersion SoftMouse, and Stealth 3D.

Adjusting the 3D Floating Cursor

You can adjust the position of the 3D floating cursor using a digitizing device. For example, you can move a system mouse with a scroll wheel to adjust the X and Y location. The scroll wheel can be adjusted up or down to either increase or decrease the elevation (Z) of the 3D floating cursor. Therefore, using the digitizing device, you have full control over the 3D floating cursor, and you can position it accurately and reliably in the Stereo window.

Every time the 3D floating cursor is adjusted, new 3D coordinates are computed using the sensor model information associated with each oriented image in the image pair. It is important to note that an elevation model is not required to collect reliable 3D GIS data when oriented images are used.

Note: If the 3D floating cursor is not accurately placed on the feature of interest, the accuracy of the elevation of the feature won't be correct. Manually adjusting the position of the 3D floating cursor requires your continuous attention.

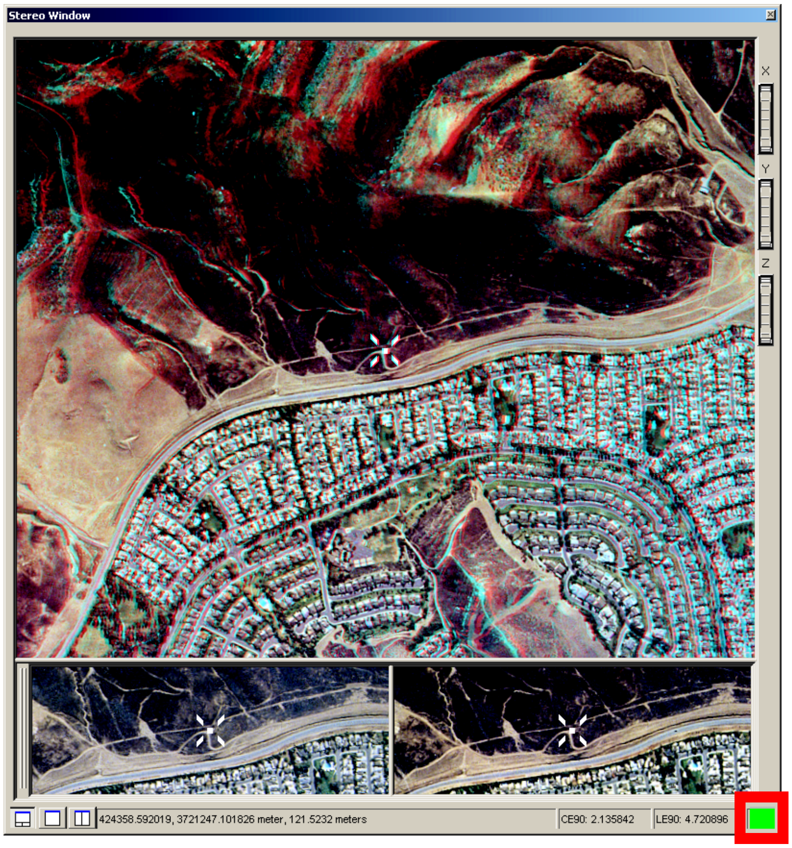
Placing the 3D Floating Cursor Automatically

Stereo Analyst for ArcGIS uses an approach referred to as Terrain Following mode to automatically adjust the position of the 3D floating cursor so that it rests on the feature of interest as the digitizing device is moved in the Stereo window. This approach uses digital image correlation techniques to accurately place the 3D floating cursor on the feature of interest.

To observe this process, use Stereo Analyst for ArcGIS with the Stereo window in the 3-Pane view and turn on Terrain Following mode. Use the digitizing device to change the location of the 3D floating cursor. While viewing in stereo, notice how the left and right image positions of the cursors are being continuously adjusted so that they reference the same geographic area (this is obvious in the 2-Pane view at the bottom of the Stereo window).

In the figure below, the correlated 3D floating cursor is indicated by the green color block in the lower-right corner of the Stereo window.

Figure 68: Green Color Block Indicating the Correlated 3D Floating Cursor

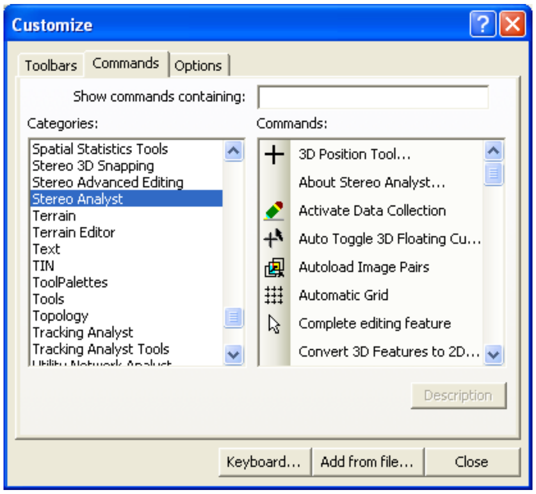


Correlation occurs automatically as the digitizing device modifies the position of the 3D floating cursor. Make sure you check the color block at the bottom right of the Stereo window. If it is green, the 3D floating cursor is accurately positioned. If it is red, the 3D floating cursor has failed to correlate and is not resting on the same feature in both the right and left images of the image pair.

Using Custom Tools

Stereo Analyst for ArcGIS provides you with custom tools for use in controlling the position of the 3D floating cursor in the Stereo window. You can access these tools by selecting Customize Mode from the Customize menu to display the Customize dialog. Click the Commands tab, and then select the Stereo Analyst category in the Categories box to see the commands. You can drag the commands to any existing toolbar. You can also use the Customize dialog to add commands that do not display on toolbars by default.

Figure 69: Commands Tab



Some notable Stereo Analyst for ArcGIS tools are described in the following table. Select Stereo Analyst in the Categories box on the Commands tab on the Customize dialog to view the entire list.

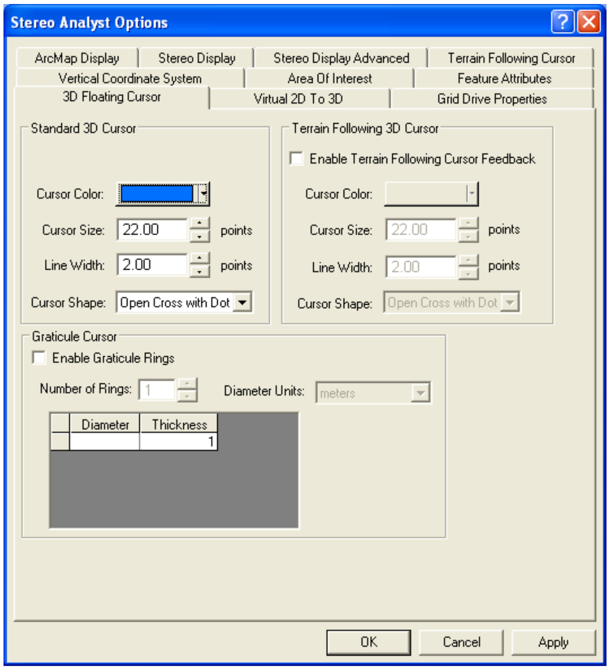
Table 1: Notable Stereo Analyst for ArcGIS Tools

Button	Description
	Click the Decrease the Elevation of the 3D Floating Cursor button to lower the 3D floating cursor by one unit, such as meters.
	Click the Increase the Elevation of the 3D Floating Cursor button to raise the 3D floating cursor by one unit, such as meters.
	Click the Recenter 3D Floating Cursor button to reposition the 3D floating cursor in the middle of the Stereo window.
	Click the Complete Editing Feature button to finish collection of a feature in the Stereo window.

Selecting 3D Floating Cursor Options

You can specify settings for the 3D floating cursor that provide optimum viewing for your application. Set these options by selecting Options from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Stereo Analyst Options dialog. Click the 3D Floating Cursor tab. You can use this tab to modify the color, size, width, and shape of the 3D floating cursor.

Figure 70: 3D Floating Cursor Tab



Adjusting 3D Floating Cursor Color

You may want a different color display for the 3D floating cursor, which is yellow by default. While viewing in quad-buffered stereo, an optimum 3D floating cursor color is red. While viewing in anaglyph, optimum 3D floating cursor colors are yellow and white.

Adjusting 3D Floating Cursor Size

When referring to the 3D floating cursor size and width, a point equals a pixel. Depending on the resolution of the images you are working with, you might find that the size needs to be larger or smaller. An optimum size is 28 points. Adjusting the size of the 3D floating cursor refers to adjusting the linear size of the entire 3D floating cursor.

Adjusting 3D Floating Cursor Line Width

Adjusting the line width of the 3D floating cursor adjusts the thickness of the lines used to construct it. One point equals one pixel.

Adjusting 3D Floating Cursor Shapes

By default, the 3D floating cursor used in the Stereo window is shaped like a cross (+). Certain 3D floating cursor shapes are better for different applications—you can change the shape quickly to see which works best for you. The following table lists the different 3D floating cursor shapes.

Table 2: 3D Floating Cursor Shapes

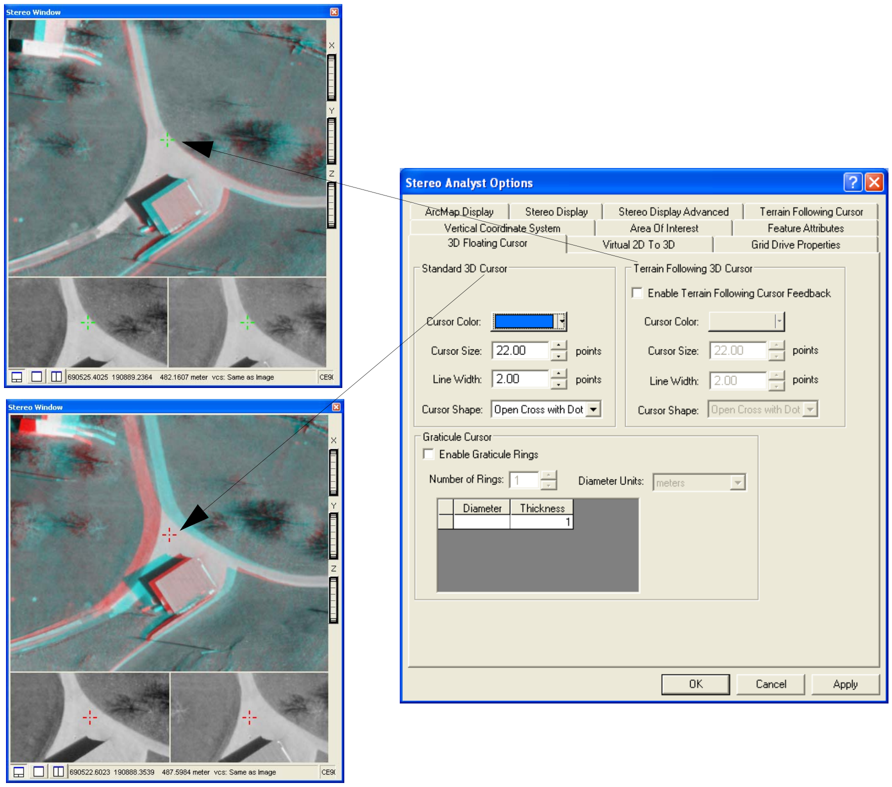
Shape	Name
	Dot
	Cross
	Open cross
	Open cross with dot
	X
	Open X
	Open X with dot

Terrain Following Cursor Graphic Feedback

A Terrain Following 3D Cursor tab on the Stereo Analyst Options dialog lets you specify different stereo cursor characteristics when the terrain following cursor (or Snap to Ground command) is successfully placed on the terrain. This enhancement helps reduce excessive eye movements previously required to determine if the cursor placement on terrain was successful.

In the figure below, the Terrain Following cursor changes color after being successfully placed on terrain.

Figure 71: Terrain Following Cursor Changes Color



Applying the 3D Floating Cursor in Arcmap

The Stereo Analyst for ArcGIS 3D floating cursor returns X, Y, and Z coordinate information to any active ArcMap tool. However, not all ArcMap tools make use of the Z coordinate.

For example, the Stereo Analyst for ArcGIS 3D floating cursor can activate hyperlinks associated with features like the cursor you see in ArcMap. Click the Hyperlink button on the Tools toolbar, and then click the feature to activate the hyperlink in which you're interested.

Using the Graticule Cursor

The 3D Floating Cursor tab also contains options that let you specify settings for defining graticule rings around a cursor. You must check the Enable Graticule Ring check box to activate the Graticule cursor.

The Number of Rings field lets you specify a value indicating the number of rings you want displayed around the Graticule cursor.

The Diameter Units dropdown list contains units of measurements you can use for defining the diameter of the rings.

The table at the bottom of the Graticule Cursor section lets you enter values indicating the diameter and thickness of each ring around the graticule circle. You must press the Enter key after entering each value.

Using the Terrain Following Mode

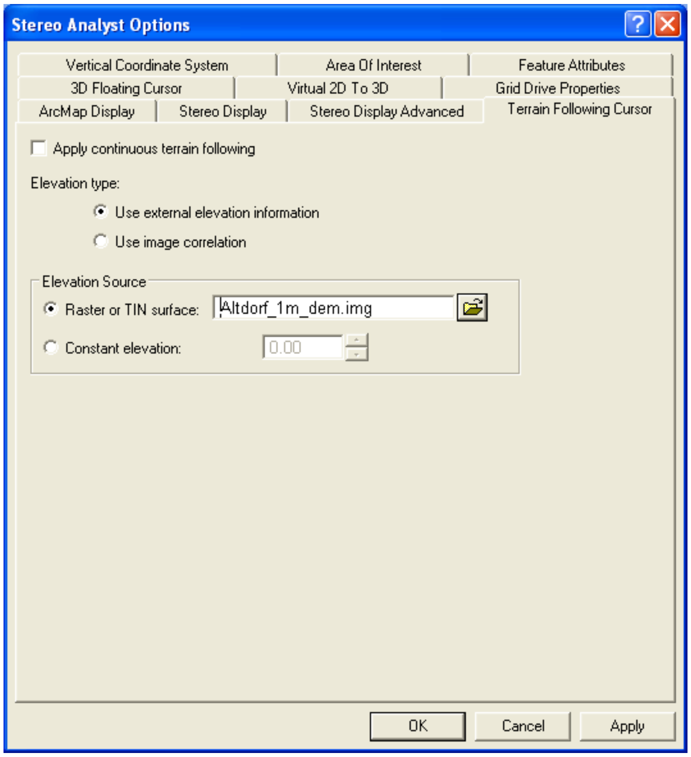
You can use the Terrain Following mode to automatically place the 3D floating cursor on the feature of interest to keep from manually adjusting its elevation every time you collect a feature. You can choose settings that control the Terrain Following mode on the Terrain Following Cursor tab on the Stereo Analyst Options dialog.

The Terrain Following mode provides two methods of operation that determine how elevation information is calculated for the 3D floating cursor. The options are either to use an external elevation source or to use image correlation.

Using External Elevation Information

This method of determining 3D floating cursor elevation is useful when a dense elevation source is available, such as LIDAR, or if the quality of the Z coordinate is not of primary importance.

Figure 72: Raster DEM File as the Elevation Source



Using a Raster or TIN Surface

One method used by the Terrain Following mode is to specify an elevation source such as a DEM or an ESRI-format TIN. In this case, Stereo Analyst for ArcGIS uses the current X, Y location of the 3D floating cursor and references the elevation source at the same X, Y location to determine the elevation value.

Using a Constant Elevation

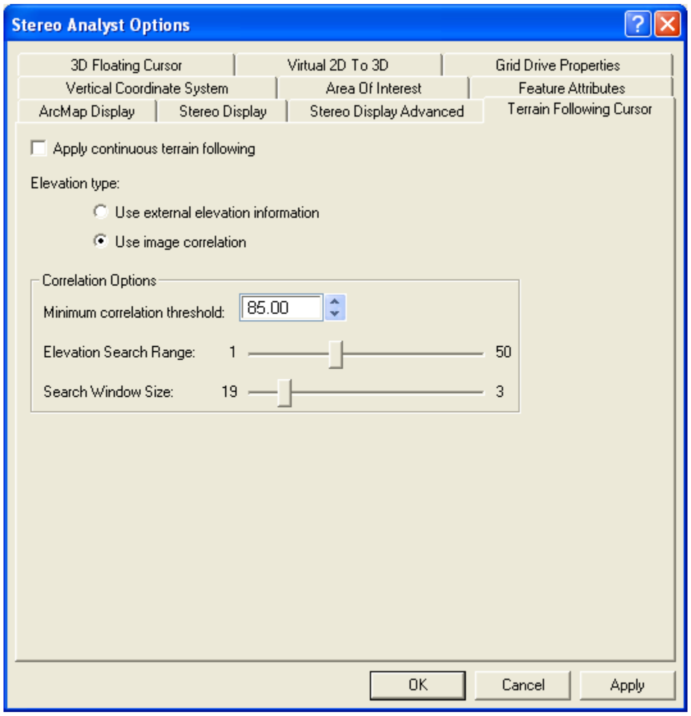
If a raster or TIN file is not available, you can select the Constant elevation option, and then enter an average elevation for the scene.

Using Image Correlation

This method works well in areas with rolling to mountainous terrain. However, it is less effective in dense urban areas with shadow or forested areas.

In the figure below, image correlation is set to 85 percent, which ensures acceptable accuracy.

Figure 73: Image Correlation Set to 85 Percent



Another method (and the default method) used by the Terrain Following mode is image correlation. In correlation, an image patch on the left image is used as a reference to search for the corresponding image patch on the right image. Once Stereo Analyst for ArcGIS finds the matching area, correlation is achieved. Using the correlated left and right image positions along with the sensor model information, Stereo Analyst for ArcGIS calculates X, Y, and Z coordinates for the 3D floating cursor.

For more information about image correlation, see **“Applying Photogrammetry” on page 299**.

Using Terrain Following with Image Correlation

With image correlation, Stereo Analyst for ArcGIS consults the images to derive 3D coordinate information. Using sensor model information and the correlated image positions of a point on the ground, 3D coordinate information is computed directly from imagery without requiring an external elevation source.

Using an external elevation source, like a DEM, the images are not consulted for elevation information. Instead, elevation information comes strictly from the DEM, which can be outdated due to construction, natural disaster, and so on since it was created.

Using the Correlation Options

Three correlation options are provided for optimizing the performance of the Terrain Following mode when image correlation is used. These include minimum correlation threshold, elevation search range, and search window size. They are located on the Terrain Following Cursor tab on the Stereo Analyst Options dialog.

Using Minimum Correlation Threshold

During the image correlation process, two image patches (one from the left image and the other from the right image) are compared, and a correlation coefficient is computed ranging in value from 0 to 100. The optimum setting for the correlation coefficient is 85.

Because the correlation process finds multiple matches for a particular point on the ground in hopes of finding the best match, you can optimize Stereo Analyst for ArcGIS to consider only statistically valid correlations. You can specify a correlation threshold value that weeds out possible false candidates while retaining good match candidates.

Selecting a low minimum correlation threshold value increases the probability of a false match, whereas increasing the correlation threshold might yield no correlation at all. A high minimum correlation threshold value is preferred in forested and urban areas (with shadows) where the probability of a false match is high. A low value is preferred in grassy areas and other areas where a specific land cover type is homogenous in the area of interest.

Using Elevation Search Range

In images with a large amount of slope, correlation can be more difficult because the relief displacement on the ground creates a parallax effect that increases with terrain variation. Similarly, if each image of the image pair is collected at a radically different angle, the matching is more computationally stressful to process. Therefore, in both instances you can set the Elevation Search Range slider bar to a higher value (to the right). This forces Stereo Analyst for ArcGIS to perform more extensive computations to ensure that the matching of points between images is correct. If the area of interest is flat with very little variation in elevation, set the Elevation Search Range slider bar to a lower value (to the left).

Using Search Window Size

In areas of low contrast, it is more difficult to locate matching points in the left and right images of the image pair. Because the image correlation process operates on the gray level values of the oriented images, Search Window Size plays a vital role in the success of image correlation. Setting the search window size to reflect the actual condition of the imagery (that is, low or high contrast) helps Stereo Analyst for ArcGIS apply rigorous methods to improve the correlation results.

Activating the Terrain Following Mode

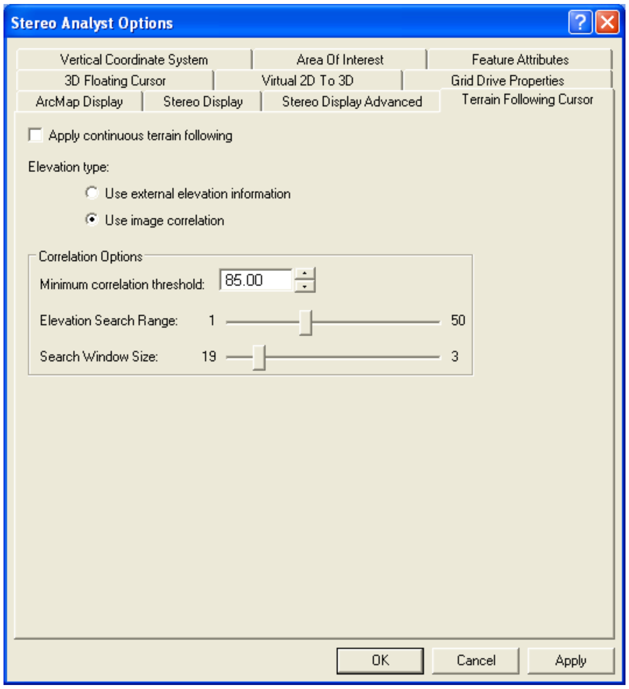
To activate the Terrain Following mode, you can do one of the following:

- Check the Apply continuous terrain following check box on the Terrain Following Cursor tab on the Stereo Analyst Options dialog.
- Click the Terrain Following Mode button on the Stereo View toolbar.
- Press the T key on your keyboard.

Applying Other Terrain Options

You can choose other settings that control the behavior of the 3D floating cursor when it is in Terrain Following mode in the Stereo window. Set these options by selecting Options from the Stereo Analyst dropdown list on the Stereo Analyst toolbar. Then, click the Terrain Following Cursor tab.

Figure 74: Terrain Following Cursor Tab


Stereo Analyst Options
Vertical Coordinate System
Area Of Interest
Feature Attributes
3D Floating Cursor
Virtual 2D To 3D
Grid Drive Properties
ArcMap Display
Stereo Display
Stereo Display Advanced
Terrain Following Cursor
Apply continuous terrain following
Elevation type:
Use external elevation information
Use image correlation
Correlation Options
Minimum correlation threshold: 85.00
Elevation Search Range: 1 50
Search Window Size: 19 3
OK
Cancel
Apply

Using Continuous Terrain Following

By clicking the Apply continuous terrain following check box, you specify that the 3D floating cursor is always in Terrain Following mode. This way, you don't have to toggle the Terrain Following mode on and off using the Terrain Following Mode button on the Stereo View toolbar.

The Terrain Following mode remains toggled on until you either uncheck the check box on the Terrain Following Cursor tab, click the recessed Terrain Following Mode  button, or press T on the keyboard to deactivate the mode.

For more information on shortcuts, see **Using Keyboard Shortcuts** on page 192.

Using Snap to Ground

An alternative to continuously operating in the Terrain Following mode is the Snap to Ground function. Snap to Ground automatically snaps the 3D floating cursor to an X, Y, Z ground position. Snap to Ground consults the Z value at the X, Y coordinate you placed the 3D floating cursor on to determine the ground elevation.

For Snap to Ground to work, you must either specify an elevation source, or use an image correlation to drive the 3D floating cursor to the ground position at a particular location. You can set these preferences on the Terrain Following Cursor tab on the Stereo Analyst Options dialog.

Snap to Ground works in both Fixed Image mode (the 3D floating cursor moves freely in the Stereo window, but the images are stationary) and Fixed Cursor mode, as well as when you are digitizing features. Note that the Snap to Ground functionality does not work in conjunction with the Terrain Following mode. This is because the 3D floating cursor is already on the ground if you're using that utility.

While the 3D floating cursor is in the Stereo window, press the S key on your keyboard to snap the 3D floating cursor to the ground. If you want to use the Snap to Ground feature while collecting features, you must apply it using the S key before collecting each vertex of the feature.

For more information about snapping in 3D, see **"Using 3D Snap" on page 201**.

Using Snap to Ground in Other Ways

Although the name implies that you can only use it to position the 3D floating cursor on the terrain, you can also use Snap to Ground to position the 3D floating cursor on top of buildings and other features.

The process is the same. First, position the 3D floating cursor over the feature of interest in the same approximate location in both the left and right image of the image pair. Then, press the S key on your keyboard.

Applying Terrain Following Mode

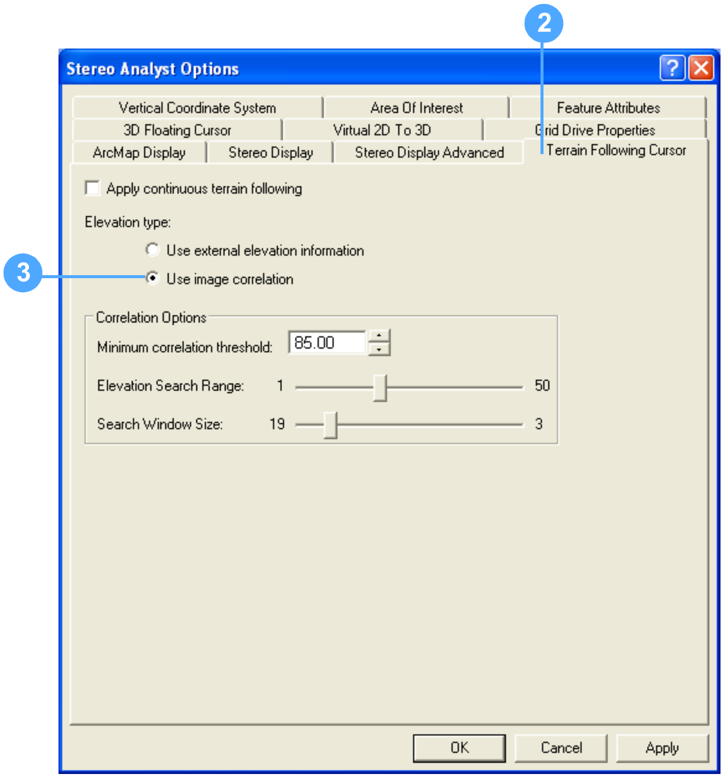
Using image correlation, the Terrain Following mode checks pixels from both images of the image pair to automatically position the 3D floating cursor to rest on a feature of interest. All you have to do is position the 3D floating cursor in the Stereo window in X and Y.

Note: Before you begin this exercise, make sure you have Stereo Analyst for ArcGIS installed, and have both ArcMap and Stereo Analyst for ArcGIS running on your computer.

To apply Terrain Following mode, follow these steps:

1. Select **Options** from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Stereo Analyst Options dialog.

2. Click the **Terrain Following Cursor** tab.



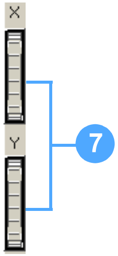
3. Click the **Use Image Correlation** button.

4. Click **OK** to close the Stereo Analyst Options dialog.

5. Click the Terrain Following Mode button on the Stereo View toolbar. When selected, it appears recessed on the toolbar.

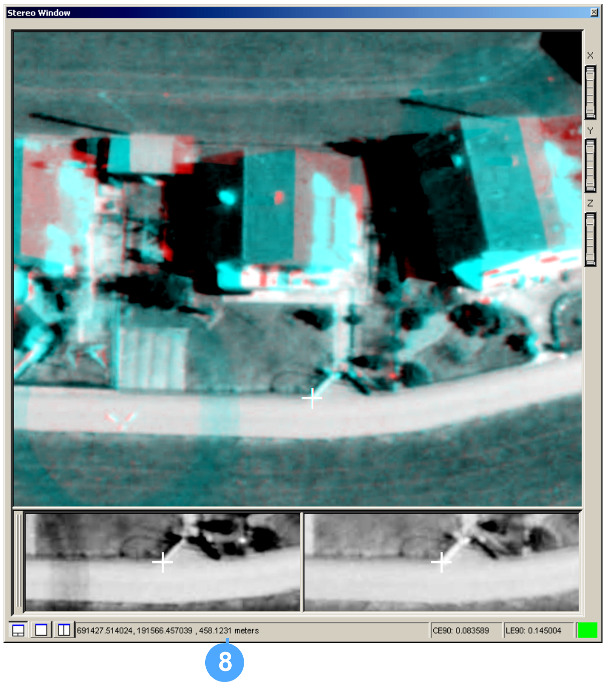
6. Click the Fixed Cursor button. When selected, it appears recessed on the toolbar.

7. Drag the **X** and **Y** thumb wheels on the Stereo window up or down to adjust the position of the image pair under the 3D floating cursor to the position you want.



You can also use the Roam Tool to move the image pair in the Stereo window.

8. View the elevation value displayed at the bottom of the Stereo window, which updates as you adjust the image pair position.



As the 3D floating cursor moves to different positions, new X, Y, and Z coordinates are automatically computed. When image correlation succeeds, a green color block displays in the lower-right corner of the Stereo window. When image correlation fails, a red color block displays in the same area.

Note: In cases where the Terrain Following mode fails to reliably position the 3D floating cursor on the feature of interest, a red color block displays in the lower-right corner of the Stereo window. See **Checking Accuracy of 3D Information** on page 190 for an explanation of the CE90 and LE90 computations.

Checking Accuracy of 3D Information

If you check the lower-right portion of the Stereo window when the 3D floating cursor is in Terrain Following mode, you see CE90 and LE90 with numerical values. These are accuracy indices that are derived from the sensor model information associated with each oriented image in an image pair.

Both CE90 and LE90 are computed based on the sensor model information that is part of the metadata associated with the oriented images. This information is derived photogrammetrically when the position and attitude of the sensor as it existed when the capture time is computed.

CE90 and LE90 provide a quality index for the current position of the 3D floating cursor. CE90 refers to circular error and LE90 refers to linear error. The 90 refers to the level of confidence in the 3D coordinates of the point. For example, an LE90 of 1.765 meters means that the current position of the 3D floating cursor is reliable to ± 1.765 meters.

The equation to compute CE90 is as follows:

$$CE90 = (\Sigma X + \Sigma Y)1.073$$

The equation to compute LE90 is as follows:

$$LE90 = \Sigma Z \times 1.646$$

In these equations, sigma (Σ) represents the standard error of the coordinate in question.

Using CE90 and LE90 While You Work

As you work in Terrain Following mode, CE90 and LE90 values are reported in the lower-right corner of the Stereo window. These values are theoretical error distribution values.

If the correlation succeeds, indicated by the green color block, the numbers indicate the standard deviation of the point feature. This color block is only active when the 3D floating cursor is in Terrain Following mode. When the color block is green, as shown below, the 3D floating cursor is correlated and is located on the same feature in both the left image and the right image of the image pair.

If the correlation fails, indicated by a red color block, the numbers are not representative of anything. When the color block is red, as shown below, the 3D floating cursor is not correlated and is not located on the same feature in both the left image and the right image of the image pair.

Using the 3D Floating Cursor

You can toggle the 3D floating cursor manually or automatically.

Toggling Manually

The Manually Toggle 3D Floating Cursor Mode button is located on the Stereo View toolbar. When this button is toggled on and you press the F3 key on the keyboard, you can freely move the 3D floating cursor and update its position in the Stereo window.

Any adjustment of the mouse's scroll wheel adjusts the elevation of the 3D floating cursor. Use the status bar at the bottom of the Stereo window to see the current elevation. Press the F3 key again to exit Manually Toggle 3D Floating Cursor mode—you see the standard Windows cursor (an arrow) displaying in the Stereo window.

You might have the 3D floating cursor manually toggled on in conjunction with Fixed Cursor Mode button. In this case, you're moving the images beneath the 3D floating cursor. Any adjustment of the mouse's scroll wheel adjusts the position of the left and right images of the image pair, which affects parallax. Aligning the image pair so that the same features overlap yields accurate elevation. Use the status bar at the bottom of the Stereo window to see the current elevation of the 3D floating cursor.

When the Manually Toggle 3D Floating Cursor Mode button is toggled off, the mouse controls a standard Windows cursor, which lets you make selections on toolbars and from menus.

You see the standard Windows cursor (an arrow) as you move it into the Stereo window. This is the best mode to use (if you don't have a special motion device like the ERDAS TopoMouse). Remember, to re-enter the Manually Toggle 3D floating cursor mode, press the F3 key on the keyboard.

Toggling Automatically

When active, the Auto Toggle 3D Floating Cursor mode eliminates the need to press the F3 key to use the 3D floating cursor in the Stereo window. Use the Auto Toggle 3D Floating Cursor button to toggle on the Auto Toggle 3D Floating Cursor mode.

When you move the 3D floating cursor inside the Stereo window, it is already active, and the standard Windows cursor does not appear. When you move the 3D floating cursor outside the Stereo window, the standard cursor reappears, which lets you select different target layers, editing modes, feature collecting and editing tools, and the like. This functionality is particularly helpful when you use the ArcMap editor to collect or edit features.

You should be aware of the following while using the Auto Toggle 3D Floating Cursor mode:

- You cannot roam over the entire image pair unless it is zoomed out to a large extent, but you can use the keyboard shortcuts X and Z to adjust the scale of the image pair displayed in the Stereo window.

- You can't use Auto Toggle 3D Floating Cursor mode in conjunction with Fixed Cursor mode, wherein the images can be adjusted to improve the stereo view. This is because the 3D floating cursor never exits the Stereo window, and therefore can never toggle off.

- You can't keep the 3D floating cursor positioned on a specific point if you need to use the mouse for normal system events (like making a selection from a menu). This is because you need to position the cursor close to a window border to exit.

Using Keyboard Shortcuts

Stereo Analyst for ArcGIS includes a number of keyboard shortcuts that let you quickly access common functions. They can save you time because it isn't necessary to move the 3D floating cursor to execute the command specified by the keyboard shortcut.

Note: There are other commands you can map to shortcut keys. To do so, select Customize Mode from the Customize menu to display the Customize dialog. Click the Commands tab and map shortcut keys from either the Stereo 3D Snapping, Stereo Advanced Editing, or Stereo Analyst categories.

Table 3: Notable Shortcut Keys

Press...	To....
F3	Toggle the 3D floating cursor on and off in the Stereo window. This switches between the Windows cursor and the 3D floating cursor when your mouse is positioned over an image. You might need to click in the Stereo window before pressing F3 to give the cursor focus.
F4	Resynchronize the ArcMap display with the display in the Stereo window. The ArcMap display is modified so that it shows the same geographic area as the Stereo window.
Shift + Z	Lock or unlock the Z value to the current elevation of the floating cursor so that the Z value does not change. This tool is useful for collecting features when all vertices of the feature must be a constant value such as when collecting features for a lake.
A	Activate the Arrow tool (the standard Windows pointer), which you can use to select buttons and options.
B	Move the 3D floating cursor to the next point if you want to skip a point during grid collection.

Table 3: Notable Shortcut Keys

Press...	To....
C	Toggle between Fixed Cursor mode and Fixed Image mode. This helps you roam about the image pair displayed in the Stereo window in Fixed Image mode and collect features in the Stereo window in Fixed Cursor mode.
H	Remove feedback graphics such as rubber band lines and sketch geometries from display in the Stereo window when held down. Ground point or snap feedback graphics remain. Feedback graphics reappear as soon as you release the H key.
I	Toggle between Fixed Image mode and Fixed Cursor mode. See the C keyboard shortcut above.
L	Move back to the current grid location if the 3D floating cursor is moved.
N	Move the 3D floating cursor back through the grid if you want to revisit a location.
R	Recenter the area of the image pair displayed so that the 3D floating cursor is in the middle of the Stereo window. This is useful when navigating the edges of the Stereo window. For more information, see **"Recentering the Stereo Cursor" on page 164**.
S	Apply Snap to Ground. This shortcut is good when you're doing feature extraction in an area where it is difficult to accurately place the 3D floating cursor on the ground. The 3D floating cursor's elevation is automatically adjusted so that it is placed on the ground or feature of interest. For more information, see **Applying Other Terrain Options** on page 187.
T	Toggle the Terrain Following mode. Use this shortcut when you want the 3D floating cursor to follow the terrain's elevation. For more information, see **Using the Terrain Following Mode** on page 183.
U	Update the current snap point to the ground point.
X	Zoom out of the area of display by 1.5 in the Stereo window.
Z	Zoom in the area of display by 1.5 in the Stereo window.

What’s Next?

In the next chapter, **“Capturing GIS Data” on page 195**, you learn about feature collecting and editing in the Stereo Analyst for ArcGIS environment. You do so using tools found in ArcMap and some new Stereo Analyst for ArcGIS tools.

Capturing GIS Data

Collecting features in Stereo Analyst for ArcGIS involves making use of the existing ArcGIS tools that you're probably already familiar with. These tools are located on the Editor toolbar, and can be applied both in ArcMap and the Stereo window. Stereo Analyst for ArcGIS also provides you with some new tools to make feature collection and editing easier in the Stereo window.

In this chapter, you learn how to:

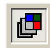
- Determine the best mode for feature collection and whether you can apply 3D Snap settings to collect adjacent 3D features.
- Define an area of interest.
- Use Advanced Editing Tools.
- Use the button mapping process for digitizing devices. For detailed information about digitizing devices, see the Stereo Analyst for ArcGIS help.

IN THIS CHAPTER

Collecting Features in Different Modes

Stereo Analyst for ArcGIS has different modes in which you can digitize features in the Stereo window. These modes are described in the following sections.

Using Fixed Cursor Mode

When the Stereo window is in Fixed Cursor mode, the 3D floating cursor is fixed in the center of the Stereo window. Adjustments you make affect the position of the left image and right image of the currently displayed image pair. When you are in Fixed Cursor mode, the Fixed Cursor Mode  button on the Stereo View toolbar appears recessed.

Using Fixed Cursor mode while collecting features is appropriate when working in the Manually Toggle 3D Floating Cursor mode and when you are using a TopoMouse. It is particularly useful when the feature you're digitizing extends beyond the Stereo window display. You can also use Fixed Cursor mode with the Autoload Image Pairs button on the Stereo Analyst toolbar. This loads any adjacent available stereo pair as you reach the edge of the current stereo pair.

Note: You cannot use the Fixed Cursor mode in conjunction with the Auto Toggle 3D Floating Cursor mode.

Using Fixed Image Mode

When the Stereo window is in Fixed Image mode, the 3D floating cursor can move, but the images are fixed. Adjustments you make affect the separation and location of the 3D floating cursor. This mode is appropriate when working with a system mouse, and works best when using the Auto Toggle 3D Floating Cursor mode. When you are in Fixed Image mode, the Fixed Cursor Mode button on the Stereo View toolbar does not appear recessed.

Using Fixed Image mode while collecting features is appropriate when the feature you're digitizing fits easily in the Stereo window. Click in the Stereo window to give the cursor focus, and then press F3 on the keyboard to apply the 3D floating cursor in the Stereo window.

Using Terrain Following Mode

As you learned in **"Using the Terrain Following Mode" on page 183**, the Terrain Following mode maintains the position of the 3D floating cursor on the ground or a feature of interest without you manually adjusting its elevation. When the Terrain Following mode is active, the Terrain Following Mode  button on the Stereo View toolbar appears recessed.

You can use the Terrain Following mode while digitizing so that the 3D floating cursor is on the feature. Make note of the CE90 and LE90 values and the red or green color block, which are located in the bottom-right corner of the Stereo window. These indicate whether the 3D floating cursor is correlated at that location to ensure accuracy as you collect features. For more information about CE90 and LE90, see **"Checking Accuracy of 3D Information" on page 190**.

Using Auto Toggle 3D Floating Cursor Mode

When you are in Auto Toggle 3D Floating Cursor mode, you can move your 3D floating cursor freely inside and outside the Stereo window without pressing the F3 key to activate the 3D floating cursor for collecting or editing features. When you are in Auto Toggle 3D Floating Cursor mode, the Auto Toggle 3D Floating Cursor Mode  button appears recessed on the Stereo View toolbar.

An advantage to using this mode is that you can change your selections on the Editor toolbar, and then move back into the Stereo window to continue your work.

Using the Stereo Window Menu

As you collect and edit features in the Stereo window, you have access to menu commands by clicking the right mouse button. These options are only available during feature collection and editing.

The options you see on the menu change depending on the mode. The tools specific to Stereo Analyst for ArcGIS are explained in the rest of this chapter. All of the other tools are documented in the book *Editing in ArcMap* and the ArcMap help.

Collecting Features in Fixed Image Mode

These steps tell you how to collect features in Fixed Image mode in the Stereo window. Fixed Image mode is best used when the feature you want to collect displays wholly in the Stereo window.

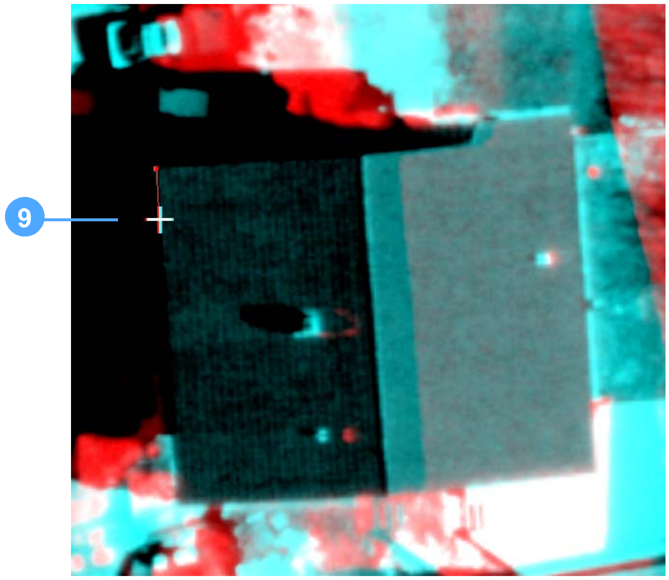
To collect features in Fixed Image mode, follow these steps:

1. Make sure your Stereo window is open and that the feature you want to collect is entirely displayed.
2. Make sure that the editing toolbar is displayed. If not, click the **Customize** menu, point to **Toolbars**, and then select **Editor**.
3. Make sure that the Fixed Cursor mode is not active on the Stereo View toolbar. (If it is active, the button appears recessed. Click to make inactive.)

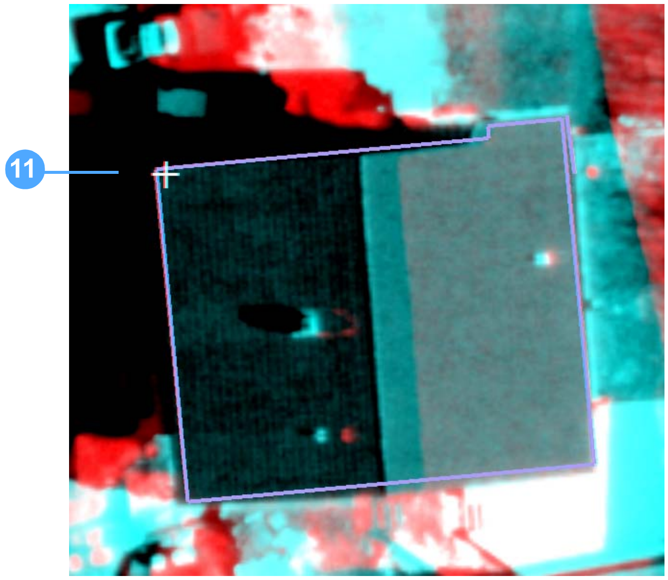
   Note: You cannot have the Fixed Cursor mode active in conjunction with the Auto Toggle 3D Floating Cursor mode.
4. Click the Auto Toggle 3D Floating Cursor button on the Stereo View toolbar.
5. Select **Start Editing** from the Editor dropdown list on the Editor toolbar.
6. Make sure that the Task field displays **Create New Feature**.
7. Select the feature class into which you want the digitized feature stored from the Target dropdown list.
8. Click the Sketch Tool button.

   Now when you move the cursor back into the Stereo window, you can digitize the feature of interest.

9. Click to collect the first vertex of the feature.



10. Continue digitizing around the perimeter of the feature by collecting corners.



11. Double-click to stop collecting the feature.

12. Select **Stop Editing** from the Editor dropdown list on the Editor toolbar.

13. Click **Yes** in the Save dialog that appears to save the feature you collected, or click **No** to discard the feature.

Collecting Features in Fixed Cursor Mode

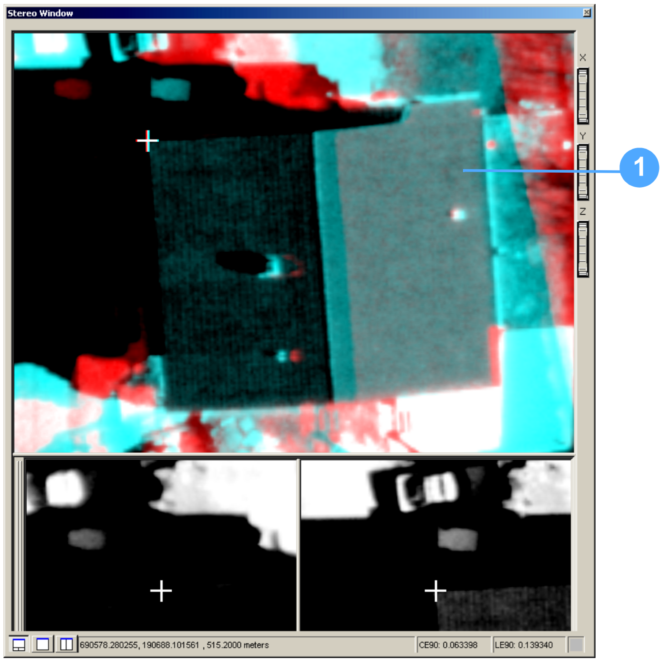
Another way to digitize features is in the Fixed Cursor mode. In this mode, the feature's position is adjusted under the 3D floating cursor. This mode is best used when the feature extends beyond the display of the Stereo window.

Note: You might encounter a feature that extends outside the Stereo window (depending on the scale at which you display the image pair). In this case, set an option so that the 3D floating cursor is recentered as you approach the extent of the Stereo window. This way, you can continue to collect a feature that initially extended beyond the Stereo window.

From the Stereo Analyst toolbar, select Options from the Stereo Analyst dropdown list. Click the Stereo Display tab, and then click Automatic Recenter for Stereo Cursor. Click Apply and OK to activate the setting. You can also use the Autoload Image Pairs button on the Stereo Analyst toolbar.

To collect features in Fixed Cursor mode, follow these steps:

1. Make sure your Stereo window is open and that the feature you want to digitize is clearly displayed with minimal parallax.



2. Make sure that the Editor toolbar is displayed. If not, click the **Customize** menu, point to **Toolbars**, and then select **Editor**.
3. Click the Manually Toggle 3D Floating Cursor button and the Fixed Cursor Mode button on the Stereo View toolbar. Both appear recessed.
4. Select **Start Editing** from the Editor dropdown list on the Editor toolbar.

5. Make sure that the Task field on the Editor toolbar displays **Create New Feature**.

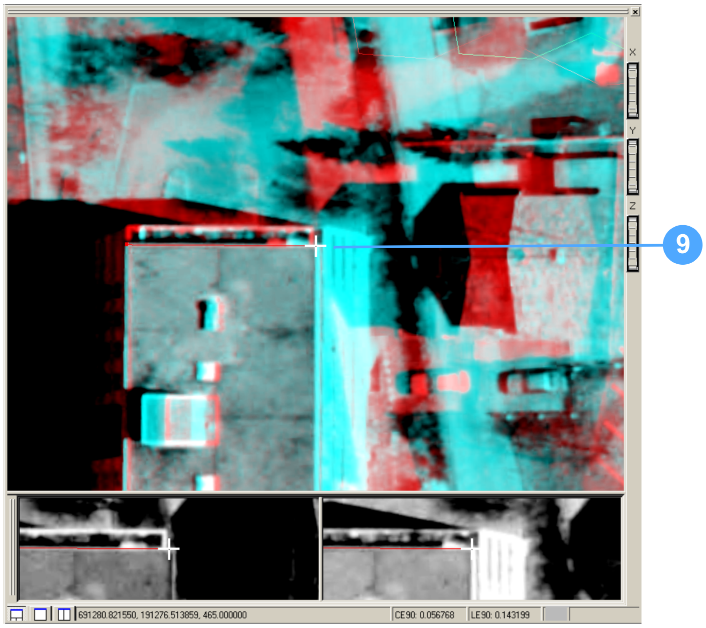
6. Select the appropriate feature class from the Target dropdown list.

7. Click the Sketch Tool button.

8. Click in the Stereo window, and then press the **F3** key to toggle on the 3D floating cursor.

   Note: You know you are in Fixed Cursor mode when the image pair changes location in the Stereo window as you move your mouse, but the 3D floating cursor remains in the center of the window.

9. Click to collect the first vertex, and then click to collect remaining vertices of the feature. When you are finished, double-click to complete the feature or press the **F2** key.



10. Press the **F3** key to toggle off Manually Toggle 3D Floating Cursor mode.

    The Arrow tool displays in the Stereo window, and the image pair no longer changes position with your mouse movement.

11. Select **Stop Editing** from the Editor dropdown list on the Editor toolbar.

12. Click **Yes** in the Save dialog that appears to save the feature you collected, or click **No** to discard the feature.

Using 3D Snap

Snapping in ArcGIS is implemented through software components known as snap agents. When using the ArcMap editor's edit sketch or editing tool to move vertices of an existing edit sketch, each movement of the pointing device results in a call to each of the active snap agents—potentially one for each feature class in the map document—to determine if a feature is within the snap tolerance. As soon as one of the snap agents reports a snap, the editor's snap cursor (a circular object that normally follows the cursor while editing) jumps to the feature that registered the snap.

Snap agents accept the XY location of the editors' cursor and assess features that are within the snap tolerance. The features that are assessed come from an in-memory cache that is maintained around the cursor location. The in-memory cache is required because performing a spatial query each time causes an unacceptable degradation in performance.

The management of the compromise between cache size and number of features served to the snap agents is a performance critical issue. This compromise is described as follows:

- You should keep the extent for the snap feature cache small to keep the number of snap candidate features to a minimum so snap agent performance and, therefore, cursor responsiveness, is not affected.
- The extent for the snap feature cache extent cannot be so small that each time the cursor moves, it is refreshed. Frequent refreshing causes the performance to degrade.
- The extent for the snap feature cache extent cannot be so large that each time it is refreshed, a noticeable delay occurs while features are loaded.

The potential performance degradation that can be caused by incorrectly configured snap feature cache manifests itself in the user interface as a "sticky" or "jumpy" cursor. A degraded snap agent performance problem causes the snap cursor (circle) to lag behind the movement of the cursor and in extreme cases, the snap cursor disappears from the display for several seconds at a time. To manage the performance of the feature cache, you must allow the cache parameters to be tuned to suit the characteristics of each individual feature class in the editing workspace.

3D Snap Feature Cache

The snapping performance of the 3D snap tools is improved through a user-configured spatially indexed feature cache.

The solution to a jumpy or sticky cursor is to operate with a feature cache that has a larger extent resulting in fewer refresh events. It is important to use this feature cache in conjunction with a spatial index that helps to minimize the features served to the snap agents for assessment. The extra cost of loading the cache is balanced against the improved performance gained through serving fewer features to the snap agents.

There are two user configurable properties for the 3D Snap feature cache. They are cache size as a percentage of the map document, and spatial index grid order. By default, the cache size is set to 33% of the map documents extent that is reassessed each time the cache is refreshed and the spatial index tile order. The tile order defaults to 2, meaning that the feature cache is divided into 2 x 2 = 4 square indexing tiles.

Importance of Database Tuning

When using enterprise or personal geodatabases, it is important that the spatial index configuration for the feature layer is tuned for optimal snap agent performance. Each time the feature cache is refreshed, a spatial query is applied to the feature class. If the spatial index parameters configured for the feature class are not optimally configured, snap agent performance degrades. This is an important consideration whether working in the Stereo window or solely in a 2D ArcMap environment. Considering these settings ensures a smooth cursor performance while editing. For more information on spatially indexing your data, see the ArcMap help.

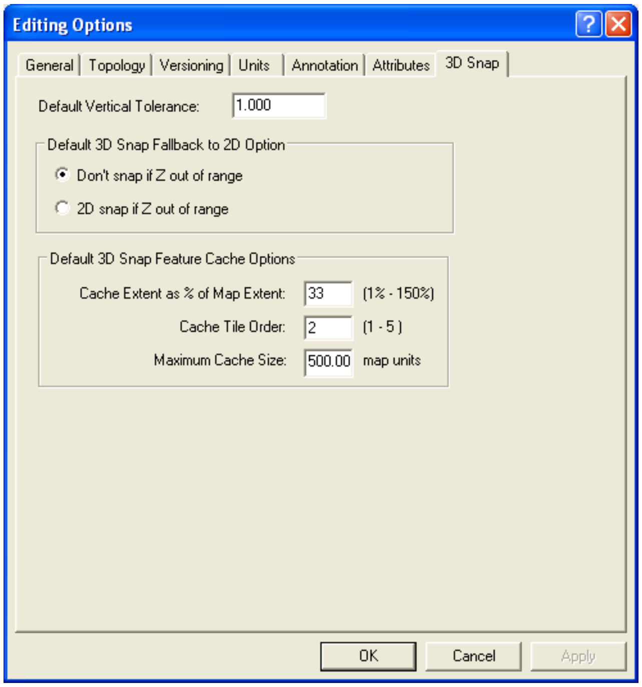
Enabling 3D Snap

You can enable 3D snapping using the Use Classic Snapping option on the General tab of the Editing Options dialog. You can open this dialog by selecting Options from the Editor dropdown list on the Editor toolbar.

3D Snap Settings

The 3D Snap tab on the Editing Options dialog lets you specify default startup options for 3D snap properties associated with the 3D snap agents. You can access this tab by selecting Options from the Editor dropdown list on the Editor toolbar.

Figure 75: 3D Snap Tab



When a new feature dataset is added to ArcMap, the new 3D snap agent obtains its startup properties from the horizontal snap properties and those set on this tab. The properties set on the 3D Snap tab can be saved and persisted in the MXD document.

Using Layer-Based 3D Snap Tools

The snap tools provide control over the snapping characteristics for each individual layer. The settings on the 3D Snap tab in the ArcMap table of contents include Snap Target and Snap Type.

You can use these snapping tools when the editor is in Start Editing mode. Snap agents are available for each 2D or 3D layer in the map document. Also, 3D snap works even if there isn't any loaded imagery, and without an active Stereo window. You only need to have the Stereo Analyst for ArcGIS extension activated and licensed to use the layer-based 3D Snap tools in ArcMap.

When you create a specific snap configuration, it is saved and persisted to layer files (*.lyr) and ArcMap Document (*.mxd) files. Thus, the setting is restored when you reopen the files in ArcMap.

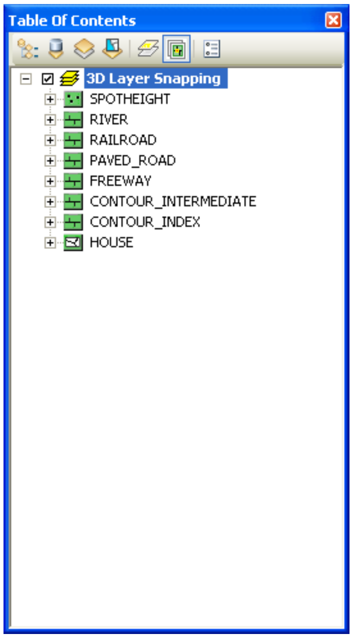
Note: You can specify settings for snapping when editing is enabled from the 3D Snap window in the ArcMap table of contents. To do so, double-click the feature class layer name in the 3D Snap window in the ArcMap table of contents or in the Layer Properties dialog.

All of the 3D snap tools are accessible on the 3D Snap tab in the ArcMap table of contents. You can also access them by clicking the 3D Snap button on the Stereo View toolbar to open the 3D Snap window.

Using the 3D Snap Window

The 3D Snap window in the ArcMap table of contents is shown in the figure below. If you cannot view the contents in this window, ensure that 3D snapping is enabled by checking the Use Classic Snapping check box on the General tab of the Editing Options dialog. Once snapping is enabled, you can also access the snapping settings by clicking the 3D Snap button on the Stereo View toolbar.

Figure 76: 3D Snap Window



Note: Making changes in the 3D Snap window changes the information that is viewable in the 3D Snap dialog. For more information on the 3D Snap dialog, see **3D Snap Dialog** on page 205.

Snap Tips

There is a setting named Show Snap Tips on the General tab on the Editing Options dialog. When it is selected, a small tip box displays to alert you when the cursor is within or outside a snapping tolerance.

Snap Target

You use the Snap Target settings in the 3D Snap window in the ArcMap table of contents to control which part of a feature the snap agent snaps to. Your options include End Snap, Vertex Snap, and Edge Snap. You can select each option individually, or use a combination of snap targets.

Snap Type

The Snap Type settings in the 3D Snap window in the ArcMap table of contents control the type of snapping. Your choices are 2D Snap, Z-only Snap, and 3D Snap. The 3D Snap option has a suboption you can select to snap in X and Y if Z is outside the tolerance value.

The 2D Snap option snaps in X and Y only. The horizontal snap tolerance exists independently of the Z snap tolerance. Initially, the horizontal tolerance defaults to the General tab on the Editing Options dialog. Change the tolerance by clicking the XY value for the layer you want to change. You can also expand the XY option to choose snapping based on pixels or map units.

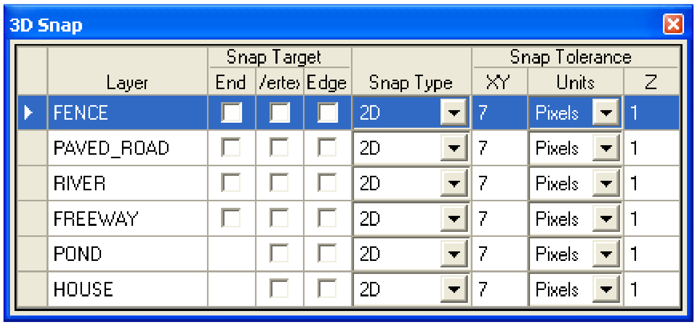
The Z-only option results in the snapped vertex inheriting the Z value of the snap target. Horizontal coordinates of the snapped vertex do not change. You set the vertical snap tolerance on the 3D Snap tab on the Editing Options dialog.

Using the 3D option, a snapped vertex inherits the full three-dimensional coordinates of the snap target. The 3D Snap option has an additional setting: 2D snap if Z out of range. When this option is selected, the snap is two-dimensional only if the height of the cursor at the snap location is above or below the Z tolerance range.

3D Snap Dialog

You can also access the 3D Snap tools by clicking the 3D Snap button on the Stereo View toolbar. This option displays a tabular view of the 3D Snap window content in a separate window.

Figure 77: 3D Snap Dialog



You can dock the 3D Snap dialog inside the ArcGIS window or let it float on your desktop. You can also expand or collapse the table columns.

The 3D Snap dialog supports making multiple selections and making changes to multiple rows when multiple rows are selected. If you want to select all of the rows in the table, click the upper-left cell next to the Layer column. Hold down the Ctrl key to change the Snap Target, Snap Type, or Snap Tolerance options.

You can also edit multiple rows for the XY and Z fields for Snap Tolerance by holding down the Ctrl key while clicking in a cell to enable the field for editing. Release the Ctrl key, edit the field, and then press Return to apply the change to all selected rows.

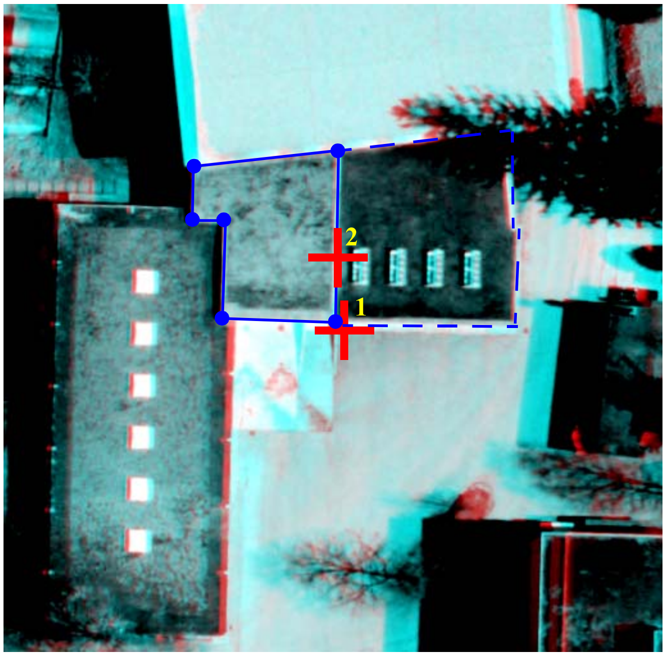
You can select a subset of rows by clicking in the upper-left cell next to the Layer column, and then dragging to select the rows you want. Or, you can use the Ctrl key to add specific rows to the selected set of rows.

Applying 3D Snap Tools

The 3D Snap functionality controls the 3D floating cursor so that it must be within a certain map unit range to snap to a feature vertex (3D Vertex Snap) in X, Y, and Z, or part of a line segment (3D Edge Snap) in Z.

The following diagram illustrates snapping. The position of the 3D floating cursor labeled 1 is within the tolerance of 1 map unit; therefore, selecting a vertex to begin the adjacent roof snaps to that vertex. However, the position of the 3D floating cursor labeled 2 is outside the 1 map unit tolerance, and is not snapped to the corner vertex.

Figure 78: 3D Floating Cursors 1 and 2

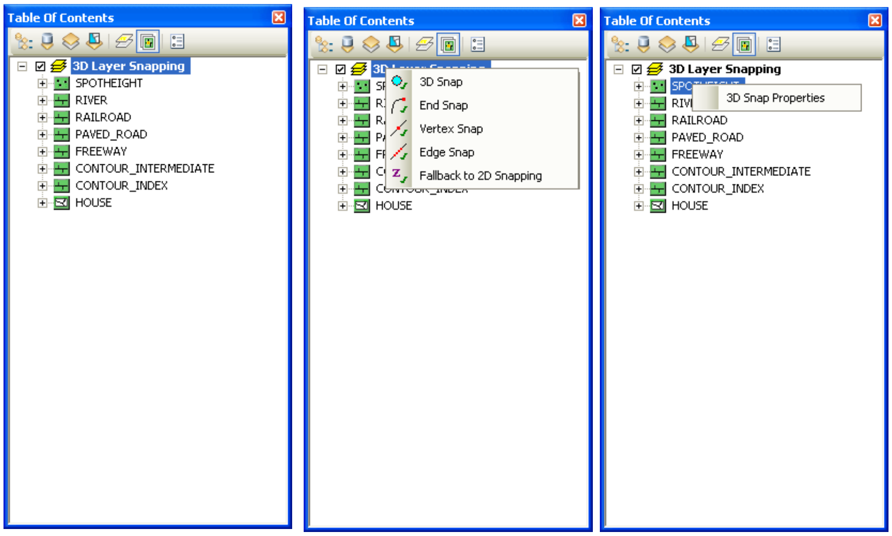


For the 3D floating cursor labeled 2 above, Stereo Analyst for ArcGIS consults the elevation out of tolerance setting on the 3D Snap tab. If you click to select the vertex at that location, either no snapping occurs, or the vertex snaps to the existing vertex but only in X and Y coordinates. The Z coordinate (elevation) is not used in snapping.

3D Snap Toggling

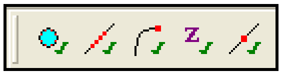
The user interface for the 3D snap contents includes a root menu item and check box to allow global toggling of the 3D snap agents. This root menu item also has a context menu that provides access to commands that toggle individual elements of the 3D snap properties.

Figure 79: 3D Snap Toggling



3D Snap Toggle Commands

Stereo Analyst for ArcGIS provides the following snap toggle commands.



They let you globally toggle the following:

- 3D Snap
- Edge Snap
- End Snap
- Fallback to 2D Snapping
- Vertex Snap

You can access these commands as follows:

- Assigning to TopoMouse buttons (default)

- Using the menu that appears when you right-click 3D Layer Snapping in the table of contents on the 3D Snap tab
- Placing the commands on a toolbar by selecting each command from the Stereo Analyst 3D Snapping category on the Commands tab on the Customize dialog

Note: If you configure the 3D snap settings for your layers in the ArcMap window, you should not use the ArcGIS standard snapping. This causes each feature to be assessed twice and, thus, slow performance.

Applying 3D Snapping

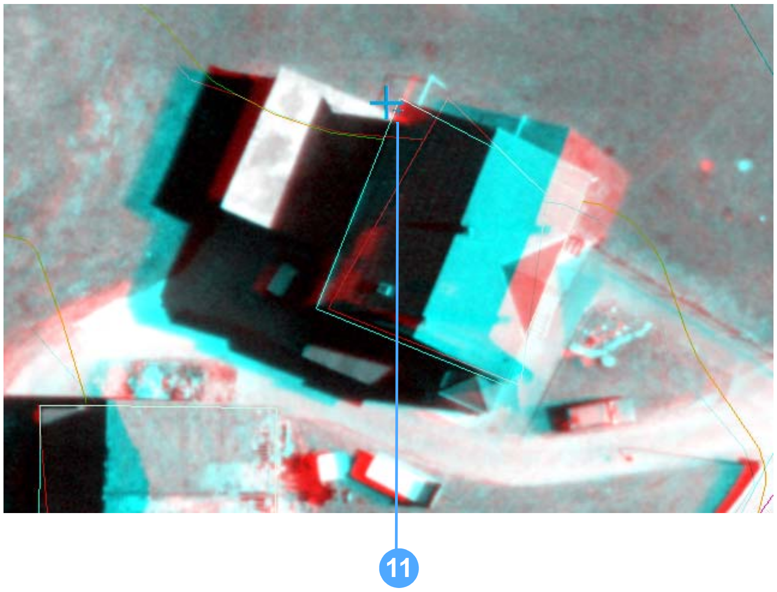
When you use 3D Snap, you are snapping to existing vertices in the X, Y, and Z direction.

To apply 3D snapping, follow these steps:

1. Make sure you have Stereo Analyst for ArcGIS running, and raster and feature data displayed in the Stereo window.
2. Select **Start Editing** from the Editor dropdown list on the Editor toolbar.
3. Ensure that 3D snapping is enabled as follows:
    a. Select **Options** from the Editor dropdown list on the Editor toolbar to open the Editing Options dialog.
    b. Make sure the **Use Classic Snapping** check box on the General tab is checked.
    c. Click **OK.**
4. Click the 3D Snap button on the toolbar in the ArcMap table of contents.
5. Expand the feature type to which you want to apply 3D snapping in the list of layers by clicking the expand button.
6. Select the options you want to use in 3D snapping.
7. Navigate in the Stereo window to the existing feature you want to snap to.
8. Make sure that the Task and Target settings are correct on the Editor toolbar.
9. Click the Sketch Tool button.
10. Position the 3D floating cursor near the existing feature.

    Notice that a second, smaller cursor displays alongside the 3D floating cursor. This shows you where the snapping is to occur.

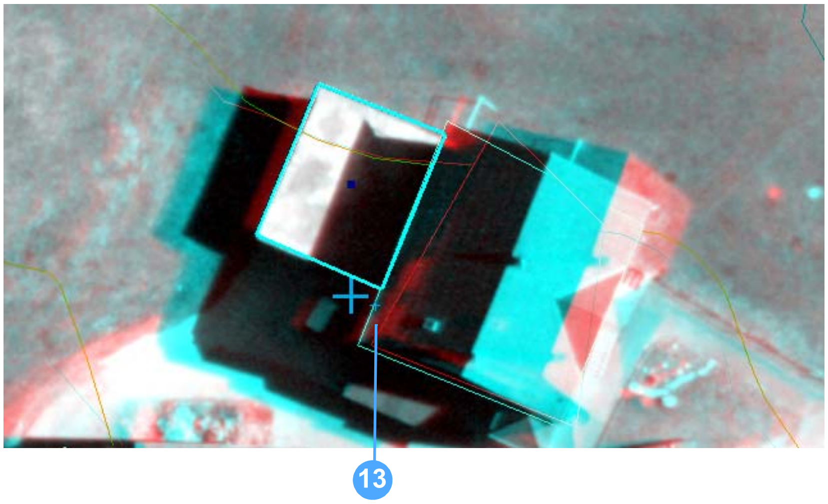
11. Click to collect the first vertex.



Notice that the vertex is automatically snapped to an edge, end, or vertex—depending on your snap target selection. In this example, the snap is to an edge.

12. Continue to digitize your feature.

13. Double-click to digitize the last vertex, or press **F2** on the keyboard, so that it also snaps to the existing feature.

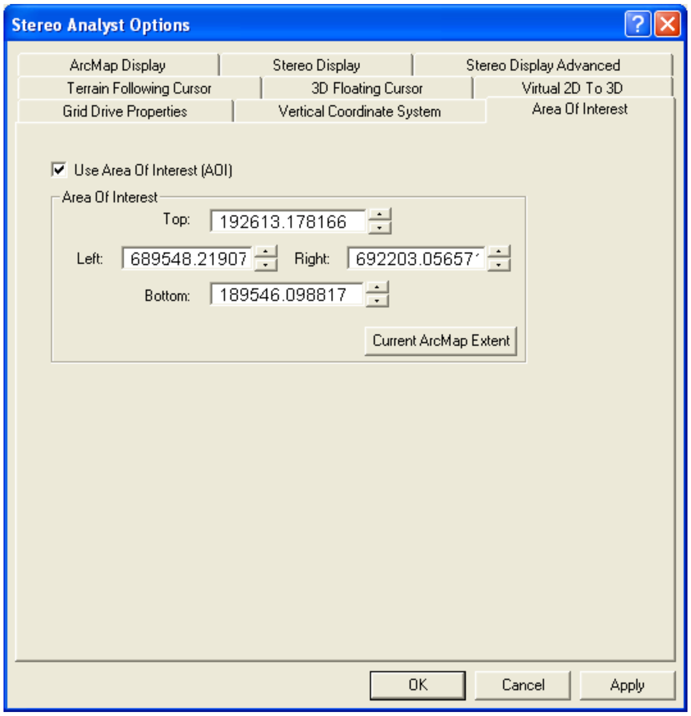


Defining an Area of Interest

You can define a region where you want to work in the Stereo window using the Use Area of Interest option. The software caches the features within the area to memory to improve performance.

Enable this option by opening the Stereo Analyst Options dialog and checking the Use Area of Interest (AOI) check box on the Area of Interest tab.

Figure 80: Area of Interest Tab



When you enable the Use Area of Interest (AOI) option, it gets the current extent from ArcMap and populates the fields. These fields let you specify coordinates for the top, left, right, and bottom boundaries for the area of interest.

Please note that you can set the area of interest graphically using the Set Area of Interest  button on the Stereo View toolbar. Be sure to enable the Use Area of Interest (AOI) check box on the Area of Interest tab first.

Click the Current ArcMap Extent button to pull the extent of the area of interest from the current extent in the ArcMap document window.

Using Advanced Editing Tools

The Stereo Advanced Editing toolbar contains editing tools that provide better control over the handling of Z values while you edit features.

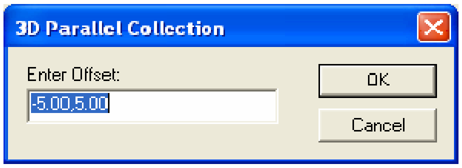
Figure 81: Stereo Advanced Editing Toolbar

The stereo advanced editing tools are described in the sections that follow.

3D Parallel Collection

The 3D Parallel Collection tool provides the capability to collect multiple offset polyline features from a single edit sketch geometry. The Z values of the parallel features are the same as those of edit sketch for each corresponding vertex. You can use the 3D Parallel Collection dialog to enter comma offset values.

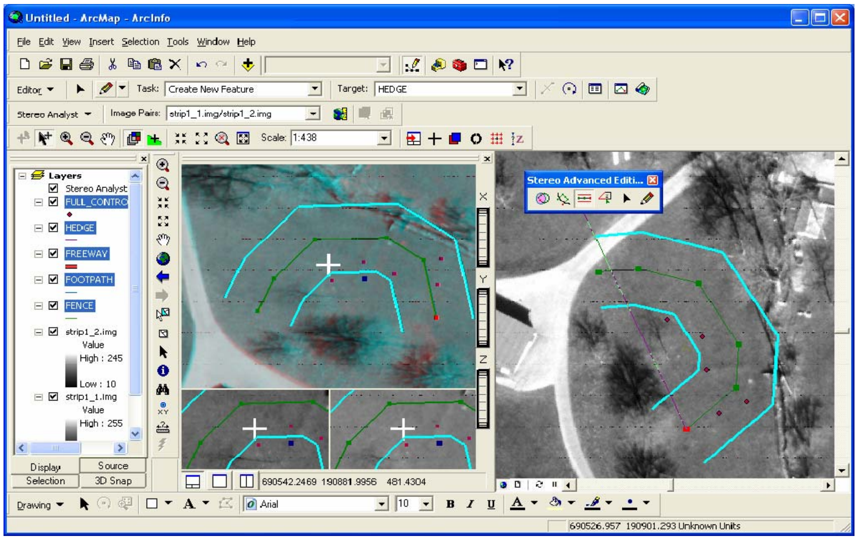
Figure 82: 3D Parallel Collection Dialog



Note: You can also use the 3D Parallel Collection dialog to enter comma offset values.

The offset values indicate whether the parallel geometries are constructed on the left or right of the edit sketch geometry, as shown in the figure below.

Figure 83: 3D Parallel Collection Tool Offset Values



Edit Tool The Edit tool lets you select and edit features.

Sketch Tool The Sketch tool lets you digitize a feature of interest.

Toggle Monotonic Mode The Monotonic mode is useful when you are collecting features to ensure that the elevations of all points composing a feature run either uphill, downhill, or at the same elevation. This mode is designed primarily for use in the collection of water drainage features so that the water flows correctly, that is, not uphill.

The Monotonic mode bases its upward (in the case that you start digitizing at the water's endpoint rather than starting point), same, or downward flow on settings set on the Stereo Advanced Editing toolbar. For more information, see **"Using the Stereo Advanced Editing Toolbar" on page 147**.

If you specify a value in the Variation field on the Stereo Advanced Editing toolbar, the program automatically adjusts the height of the floating cursor by that amount. You can make additional manual adjustments to the height of the floating cursor if the mode is set to Up or Down. However, the program prevents a reversal of the elevation change trend.

Applying Monotonic Mode

To apply Monotonic mode, follow these steps:

1. Select **Start Editing** from the Editor dropdown list on the Editor toolbar.
2. Set the Monotonic mode options on the Stereo Advanced Editing toolbar.
3. Right-click and select **Monotonic Mode** from the menu.

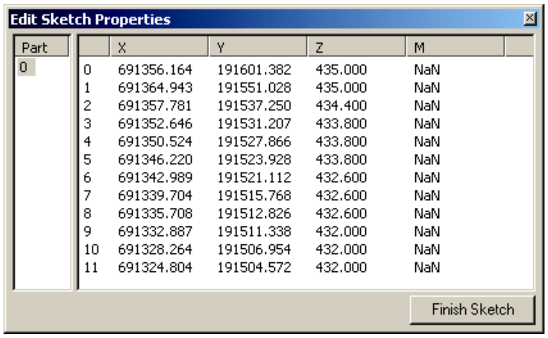
4. Click and start digitizing the first vertex of the feature.

   The program adjusts the height of the floating cursor based on the value in the Variation field.

5. Double-click to complete the feature after you finish collecting it.

6. Click the feature to select it.

7. Right-click a vertex on the feature and select **Properties** to display the Edit Sketch Properties dialog.



	X	Y	Z	M
0	691356.164	191601.382	435.000	NaN
1	691364.943	191551.028	435.000	NaN
2	691357.781	191537.250	434.400	NaN
3	691352.646	191531.207	433.800	NaN
4	691350.524	191527.866	433.800	NaN
5	691346.220	191523.928	433.800	NaN
6	691342.989	191521.112	432.600	NaN
7	691339.704	191515.768	432.600	NaN
8	691335.708	191512.826	432.600	NaN
9	691332.887	191511.338	432.000	NaN
10	691328.264	191506.954	432.000	NaN
11	691324.804	191504.572	432.000	NaN

8. Check to see that the feature collected with increasing, decreasing, or level elevation values, as appropriate.

Mode

You can increase, decrease, or keep the elevation level by selecting one of these options from the Mode dropdown list on the Stereo Advanced Editing toolbar.

Variation

The Variation field lets you specify a value indicating the amount of elevation change. You should specify a value of zero (0) for Up and Down modes to prevent automatic changes to the height of the floating cursor.

Toggle Lock Z Mode

The Toggle Lock Z Mode tool is useful for collecting features when all vertices of the feature must be a constant value such as when collecting features for a lake. It lets you lock or unlock the Z value to the current elevation of the floating cursor so that the Z value does not change.

Locate Feature Vertex

The Locate Feature Vertex tool lets you automatically move your floating cursor to the height of a nearby snap target.

Note: If the snap type is set to 2D snap, the Z value does not update. If the snap type is set to 3D snap, and the vertex is within tolerance, all X, Y, and Z values are updated.

Feature Attributes

The Feature Attributes option works in conjunction with the Stereo tab in the Layer Properties dialog to set up the automatic attribution of Height above Ground information for polygonal features. You must first specify an elevation source, then set up attribute field mapping, and lastly, enable the Automatic Features Attribution tool to set up automatic features attribution. For more information, see the Stereo Analyst for ArcGIS help.

Note: This feature is available only for polygonal features. Also, the Automatic Features Attribution tool does not correct unit differences for Z. For example, if you are using a DEM source with units of meters, you should set your Stereo window to collect values in meters. You must also set the attribute fields to accept a float value.

Note: This button becomes inactive on the Stereo Advanced Editing toolbar if an inappropriate layer is listed in the Target dropdown list on the Editor toolbar.

Toggle Squaring Mode

Squaring helps you rapidly collect features with right angles. Squaring is only for use in digitizing polylines and polygons—it is not applicable for point features.

You can change the settings for squaring by clicking the Toggle Squaring Mode button on the Stereo Advanced Editing toolbar to toggle the Squaring mode on or off, and by selecting a squaring rotation mode from the Rotation dropdown list. The squaring options are specific to Stereo Analyst for ArcGIS.

Use of squaring is most appropriate when you are digitizing features with right angles. Squaring attempts to square a feature based on the rotation method you select and the tolerance value you specify.

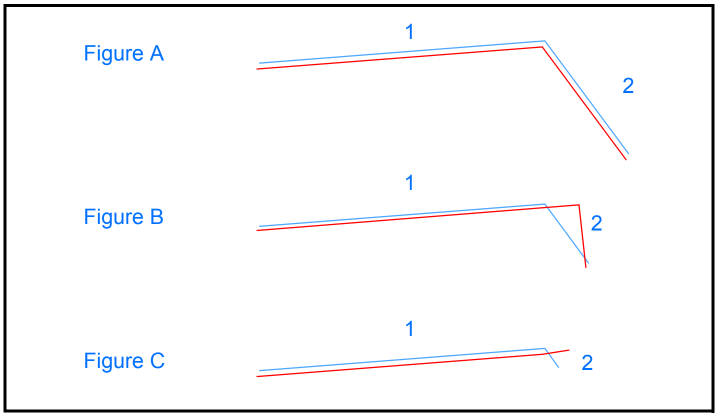
Note: The results you get from squaring are highly dependent on the tolerance setting, the rotation mode, and the order or direction of digitizing.

Squaring Polylines

Squaring polylines also considers making them straight. If greater movement of a vertex is required to make a right angle than to make the line straight, the lesser movement is taken and the line is made straight. As with squaring polygons, the vertex is not moved if movement of a vertex would be greater than the tolerance value. All vertices are preserved, allowing you to edit the line after creating it.

Below, Figure A shows the vertices outside tolerance. Figure B shows the squared polyline. Figure C shows the straightened polyline.

Figure 84: Squaring Polylines



Note: Resultant line (red) is shown slightly offset for clarity.

Configuring the Squaring Tool

To configure the Squaring tool, follow these steps:

1. Click the Toggle Squaring Mode  button on the Stereo Advanced Editing toolbar to toggle Squaring mode on.
2. Select the preferred rotation mode from the Rotation Mode dropdown list.
3. Enter a tolerance value in the Tolerance field.
4. Press **Enter**.
5. Collect features in the Stereo window as usual.

Rotation

You can choose from four methods to determine the alignment of the feature:

- **Weighted Mean** – Uses the length-weighted angle of all sides to determine the alignment.
- **First Line** – Uses the line formed by the first two digitized vertices of a feature as alignment.
- **Longest Line** – Uses the longest side of a feature as alignment.
- **Active View Alignment** – Makes the squared feature sides either horizontal or vertical to the ArcMap data view.

Using the Weighted Mean Rotation Mode

Weighted Mean is the default rotation mode used by squaring. Using the Weighted Mean rotation mode means that the length-weighted mean angle *(R)* of all sides is used to determine the alignment. Once the alignment angle is determined, the vertices are adjusted within the tolerance to square corners where possible.

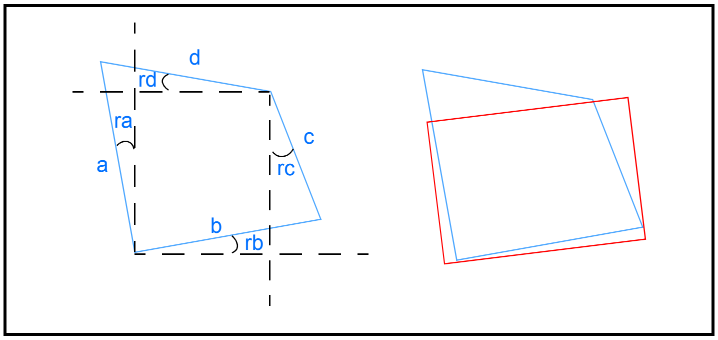
The Weighted Mean function is expressed in the following equation:

$$R = \frac{(r_a \times a) + (r_b \times b) + (r_c \times c) + (r_d \times d)}{a + b + c + d}$$

This method is good because it averages out measurement inaccuracies at all points.

The tolerance value in the following example is 3.0. The red polygon represents the result of squaring. The Weighted Mean rotation mode calculates the average rotation based on the length and angle of each segment.

Figure 85: Weighted Mean Rotation Mode



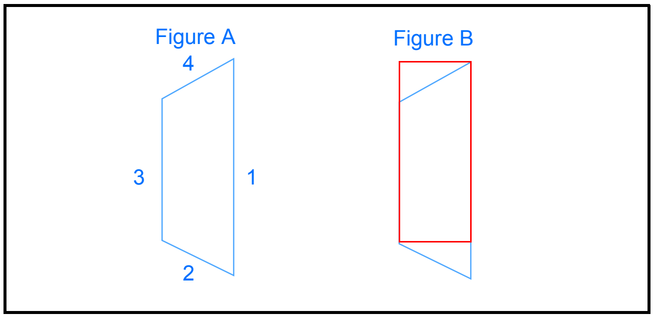
Using the First Line Rotation Mode

Using the First Line rotation mode allows the first and second vertices to form the line used to square the feature.

The tolerance value in each of the following two examples is 10.0. The red polygon represents the result of squaring. If you digitize clockwise, the First Line rotation mode uses the first line digitized as the basis for squaring.

In the figure below, Figure A shows the original polygon. Figure B shows the squared polygon.

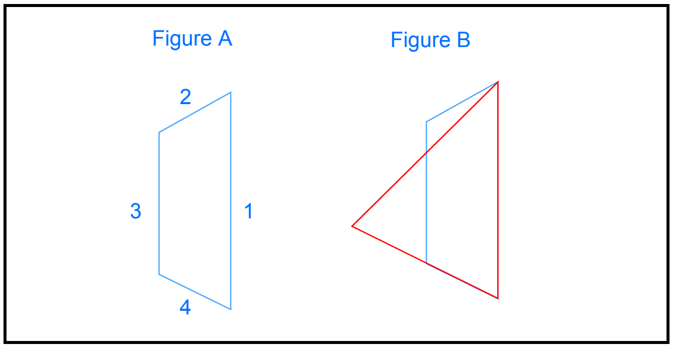
Figure 86: First Line Rotation Mode



The First Line rotation mode is sensitive to the order in which you digitize the feature vertices. If you digitize the feature in a clockwise direction, the first line is the line formed between the first two vertices. However, if you digitize the feature in a counter-clockwise direction, the first line is the line formed between the last two vertices.

In the figure below, the same line is digitized first but in the counter-clockwise direction. This can yield vastly different results.

Figure 87: Digitizing Feature in a Different Order



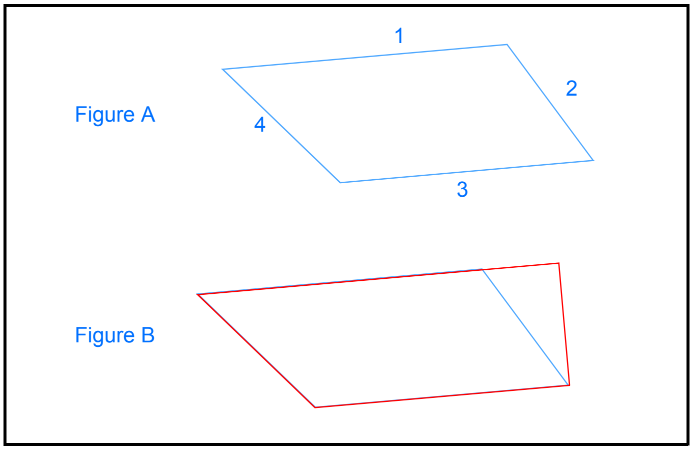
Note: When using First Line rotation mode, always digitize in a clockwise direction.

Using the Longest Line Rotation Mode

Using the Longest Line rotation mode means that the line with the greatest length is used to square the feature. In this mode, the order in which you digitize vertices does not matter.

Below, Figure A shows the original polygon. Figure B shows the squared polygon in red.

Figure 88: Longest Line Rotation Mode



Note: Segment 4 was not moved because it was not within the tolerance value.

Using the Active View Alignment Rotation Mode

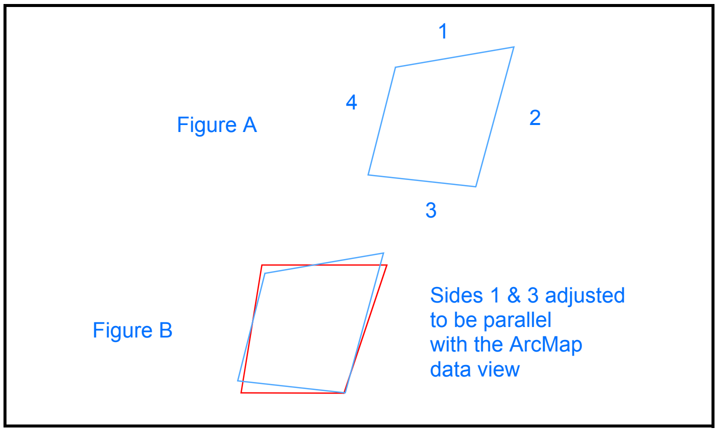
The Active View Alignment rotation mode uses the borders of the ArcMap data view to square the feature in either a horizontal or vertical direction, or both if possible.

Note: When you are using this mode, it is best to have the Orient ArcMap document to Image Pair when Image Pair Changes option on. It is located on the ArcMap Display tab on the Stereo Analyst Options dialog. For more information about this option, see **"Selecting Display Settings" on page 152**.

When the Stereo window and the ArcMap data view are oriented in the same direction, the results from this rotation mode are more consistent. That is, the final position of the feature is the same in both. Otherwise, the feature might display in a different rotation in the Stereo window and the ArcMap data view.

In the figure below, active view alignment uses the ArcMap data view boundaries as a guide.

Figure 89: Active View Alignment



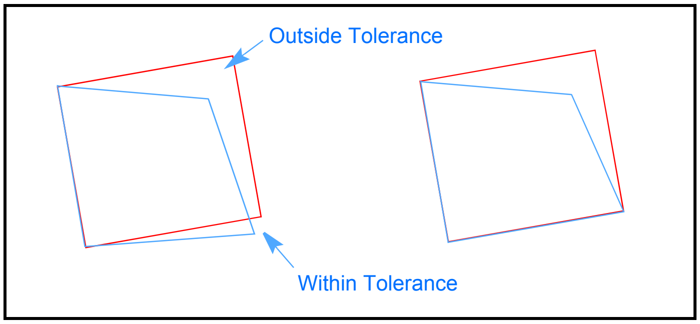
Tolerance

In each of the rotation modes, the tolerance value used in squaring is measured in map units. This tolerance value specifies the greatest distance you can move a vertex to square the feature.

A vertex is moved if it can be moved by a value that is less than or equal to the tolerance to make the feature corner square. If the vertex needs moving farther than the tolerance to make the corner square, it is not moved.

You should keep the tolerance value as small as possible. In the following illustration, the red polygon represents the ideal rectangle. One of the vertices can be moved because the distance is within the specified tolerance. The other remains in its original location.

Figure 90: Tolerance



Using the Grid Tool

The Grid tool is used in conjunction with the Grid Drive Properties tab on the Stereo Analyst Options dialog to collect points in a regular grid pattern. The Grid Drive Properties tab allows specification of grid spacing, extent, and starting location.

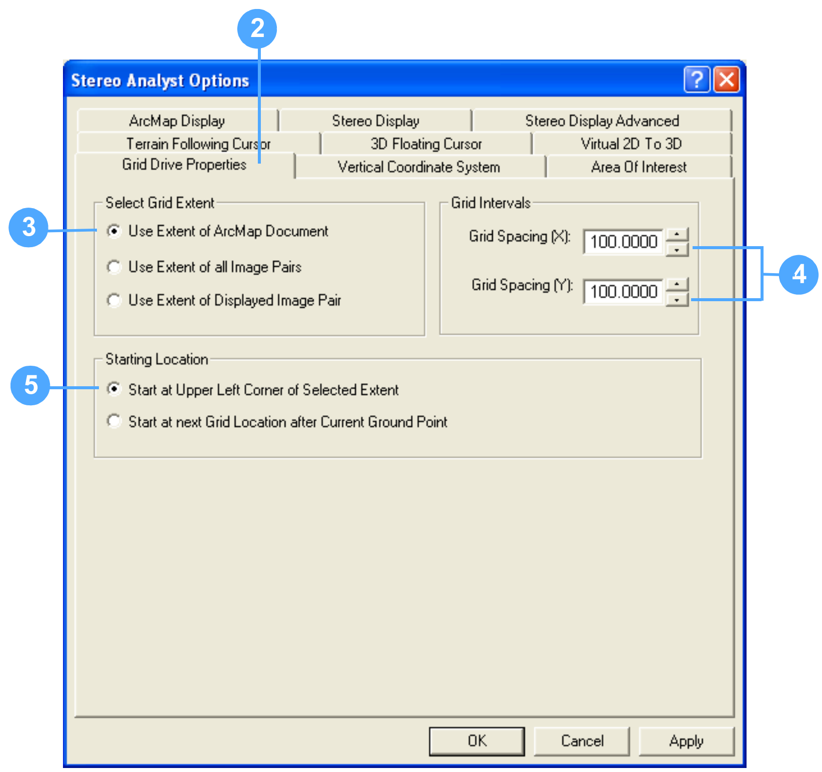
After loading images into the Stereo view and adding a feature class to ArcMap, the Grid tool moves to those locations specified in the Select Grid Extent box to collect points. The grid intervals are in the same units as the map frame. Adding a vertex or point during grid collection causes the cursor to advance to the next grid location. A snap to ground happens automatically each time a point is collected.

Note: For information on the keyboard shortcuts you can use with the Grid tool, see "Using Keyboard Shortcuts" on page 192.

To use the Grid tool, follow these steps:

1. Select **Options** from the Stereo Analyst dropdown list to display the Stereo Analyst Options dialog.

2. Click the **Grid Drive Properties** tab.



3. Click a button in the Select Grid Extent box to specify the extent you want to use.

4. Enter the grid spacing for both X and Y in the Grid Spacing fields.

5. Click a button in the Starting Location box to specify where you want to start collecting grid points.

6. Click **OK** to close the Stereo Analyst Options dialog.

Applying the Grid Tool

To apply the Grid tool, follow these steps:

1. Display or create a shapefile.
2. Select **Options** from the Stereo Analyst dropdown list to display the Stereo Analyst Options dialog.
3. Click the **Grid Drive Properties** tab.
4. Make any necessary changes.
5. Click **OK** to close the Stereo Analyst Options dialog.
6. Select **Start Editing** from the Editor dropdown list.
7. Click the Automatic Grid button on the Stereo View toolbar.
8. Collect points.
9. Select **Stop Editing** from the Editor dropdown list when you finish collecting points.

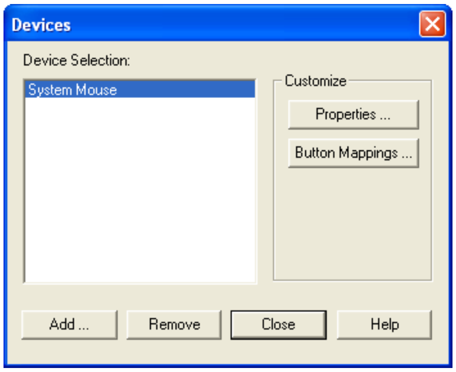
Using Digitizing Devices

You can use devices other than the standard system mouse to collect features in Stereo Analyst for ArcGIS. A list of the currently supported digitizing devices for Stereo Analyst for ArcGIS is listed in the help and on the product page for Stereo Analyst for ArcGIS at http://www.erdas.com.

Adding a Digitizing Device

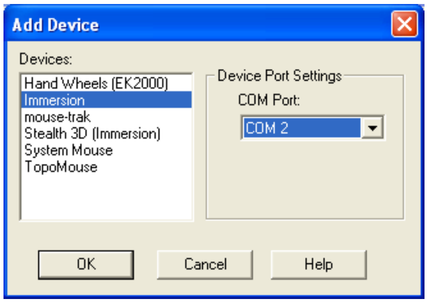
You use the Devices dialog to add a digitizing device. Select Devices from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Devices dialog. This dialog is your starting point for all device-related settings.

Figure 91: Devices Dialog



You must specify the COM port to which the digitizing device is attached in the Add Device dialog. This dialog gives you a list of the potential digitizing devices.

Figure 92: Add Device Dialog



Mapping Buttons

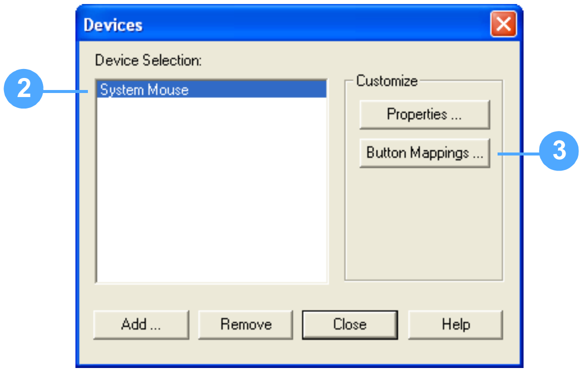
Each supported device comes with many of the buttons already mapped to common digitizing functions. However, you can change the default settings to suit your needs.

You can find a detailed list of optimum button mappings for each supported digitizing device in the Stereo Analyst for ArcGIS help.

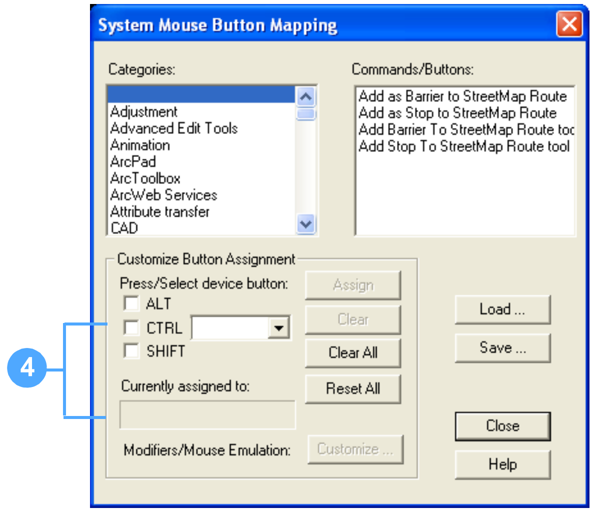
Mapping Buttons on Digitizing Devices

To map buttons on digitizing devices (in general), follow these steps:

1. Select **Devices** from the Stereo Analyst dropdown list on the Stereo Analyst toolbar to display the Devices dialog.
2. Select the digitizing device in the Device Selection box.



3. Click the **Button Mappings** button to display the device's Button Mapping dialog.



4. Click the button on the digitizing device to check a button mapping.

If you are using a multi-button digitizing device, select a mouse button from the Press/Select Device Button dropdown list.

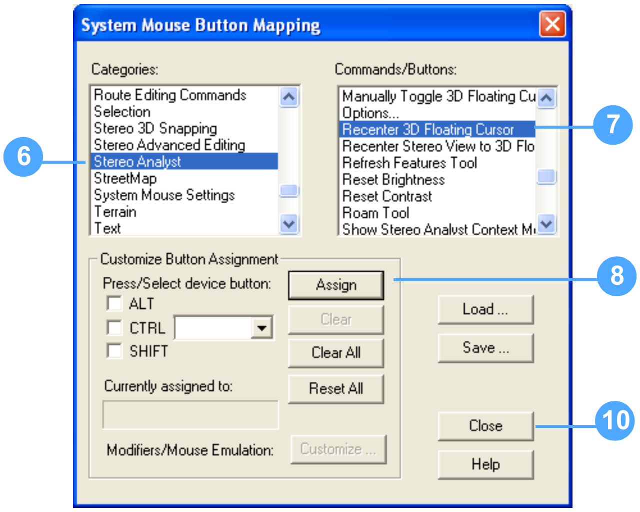
The function currently assigned to the button you press displays in the Currently assigned to field.

5. Click the button on the digitizing device to assign a new command to a button.

Note: If you are using a multi-button digitizing device, go to **step 7**.

Remember, you can use a combination of keys on some digitizing devices with the Shift button on the device. In the case of the TopoMouse, for example, that is button 4.

6. Select a function category, namely **Stereo Analyst**, from the Categories list.



Each category has its own list of commands. These commands display in the Commands/Buttons box.

7. Select the command you want to map to the selected button in the Currently Assigned To box.

8. Click the **Assign** button.

9. Repeat **steps 5 - 8** until you map all of the buttons on the device.

10. Click **Close** to close the device's Button Mapping dialog.

11. Click **Close** to close the Devices dialog.

    For more information about digitizing devices and button mapping, see the Stereo Analyst for ArcGIS help.

What's Next?

The chapter that follows tells you how to use Terrain Editor.

Understanding Terrain Editor

Terrain Editor for ArcGIS is an optional ArcGIS extension that extends Stereo Analyst for ArcGIS to provide stereo terrain editing capabilities for geodatabase terrains.

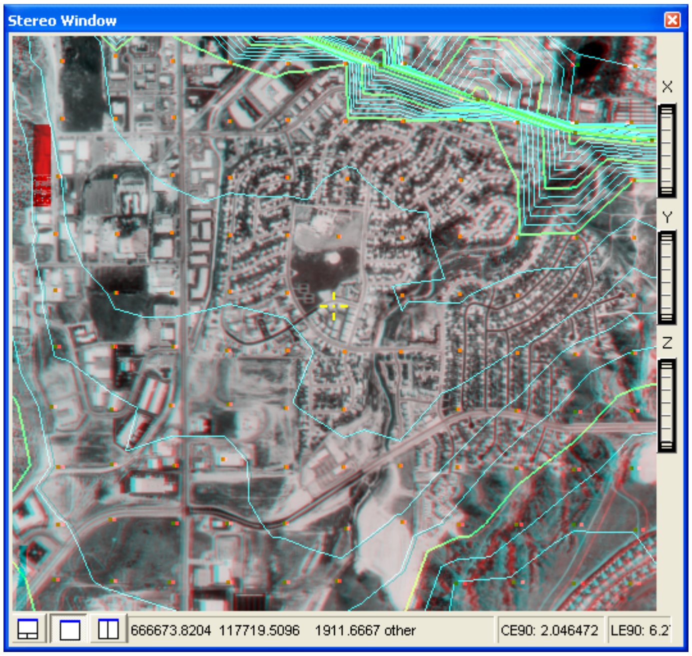
Terrain Editor for ArcGIS provides you with point, line, and area editing tools for use with the stereo environment of Stereo Analyst for ArcGIS.

IN THIS CHAPTER

Terrain Editing

The Terrain Editor for ArcGIS extension works by constructing a terrain model for each geodatabase terrain loaded. With one or more terrains loaded in the map document, Terrain Editor for ArcGIS lets you select a terrain for editing. Each feature class that participates in the terrain is editable on a layer-by-layer basis. As features are modified, the terrain is dynamically updated in the Stereo window.

Figure 93: Stereo Display with Geodatabase Terrain



Adding the Terrain Editor for ArcGIS Extension

To add the Terrain Editor for ArcGIS extension, follow these steps:

1. Select **Extensions** from the Customize menu on the ArcMap main menu to display the Extensions dialog.
2. Check the **Terrain Editor** check box to add the extension to Arcmap and activate it.
3. Click **Close** to close the Extensions dialog.

Terrain Editor Toolbars

Terrain Editor for ArcGIS provides you with several toolbars that help you use the program:

- Terrain Editor
- Terrain Area Operators
- Terrain Autocorrelation
- Terrain Bulldozer

Note: For detailed information on each of the toolbars, please see the Terrain Editor help. You can access this help file by selecting Terrain Editor Desktop Help from the Terrain Editor dropdown list on the Terrain Editor toolbar.

The Terrain Editor toolbar lets you edit points and breaklines. You can display this toolbar by clicking Customize on the ArcMap main menu, pointing to Toolbars, and selecting Terrain Editor.

Figure 94: Terrain Editor Toolbar

The Terrain Area Operators toolbar lets you quickly access the terrain area operators, and determine which features are selected, and how they are selected to modify areas of the terrain. You can display this toolbar by clicking Customize on the ArcMap main menu, pointing to Toolbars, and selecting Terrain Area Operators. Or, you can click the Terrain Area Operators Toolbar  button on the Terrain Editor toolbar.

Figure 95: Terrain Area Operators Toolbar

The Terrain Autocorrelation toolbar lets you quickly access the autocorrelation tools to generate new points to participate in the terrain. You can display this toolbar by clicking Customize on the ArcMap main menu, pointing to Toolbars, and selecting Terrain Autocorrelation. Or, you can click the Terrain Autocorrelation Toolbar  button on the Terrain Editor toolbar.

Figure 96: Terrain Autocorrelation Toolbar

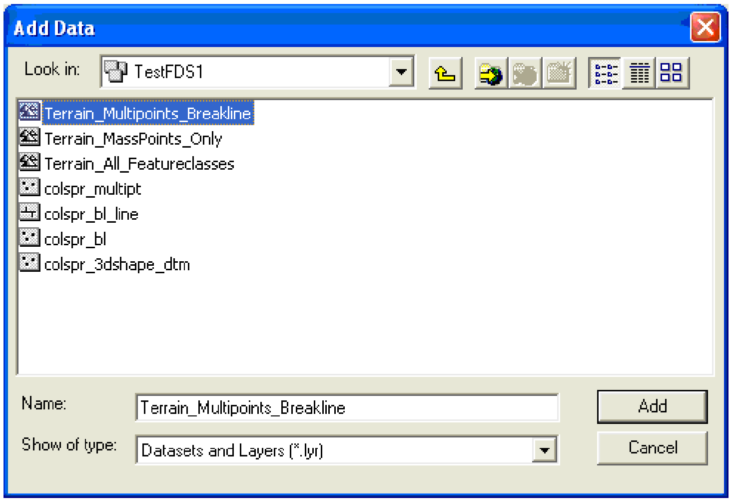
The Terrain Bulldozer toolbar lets you access the buttons and tools for building and using Terrain Bulldozer templates. You can display this toolbar by clicking Customize on the ArcMap main menu, pointing to Toolbars, and selecting Terrain Bulldozer.

Figure 97: Terrain Bulldozer Toolbar

Adding a Geodatabase Terrain

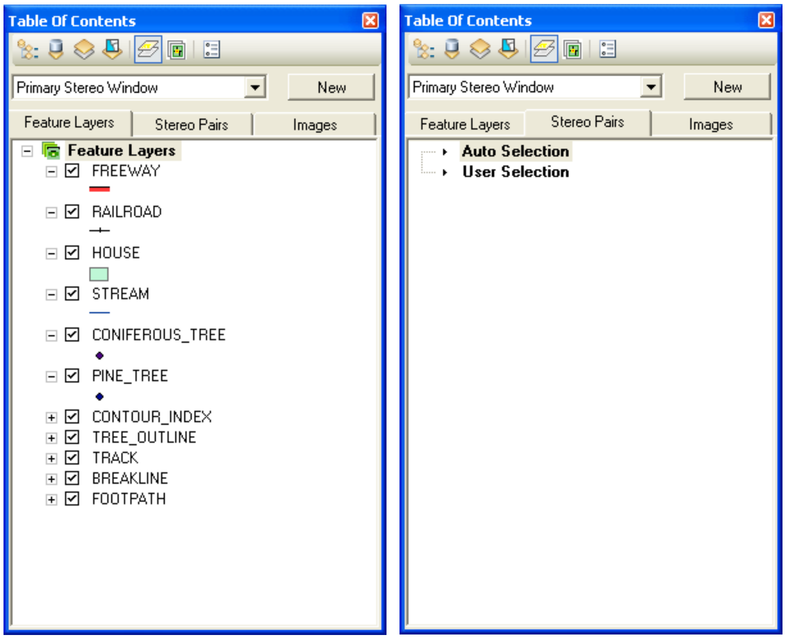
When a geodatabase terrain is added to the map document, Terrain Editor for ArcGIS obtains a reference to the terrain and constructs a terrain model based on the component feature classes of the geodatabase terrain.

Figure 98: Add Data Dialog


Add Data
Look in:
TestFDS1
Terrain_Multipoints_Breakline
Terrain_MassPoints_Only
Terrain_All_Featureclasses
colspr_multipt
colspr_bl_line
colspr_bl
colspr_3dshape_dtm
Name:
Terrain_Multipoints_Breakline
Add
Show of type:
Datasets and Layers (*.lyr)
Cancel

When a stereo pair is loaded in the Stereo window, the terrain features, points, and breaklines display in stereo along with triangles and contours. The Primary Stereo window in the ArcMap table of contents contains a tab for feature and terrain layers, and one for stereo pairs.

Figure 99: Feature Layers and Stereo Pairs Tabs



Stereo Terrain Rendering

You can access the Terrain Editor for ArcGIS rendering options using the following tabs on the Stereo Terrain Layers dialog:

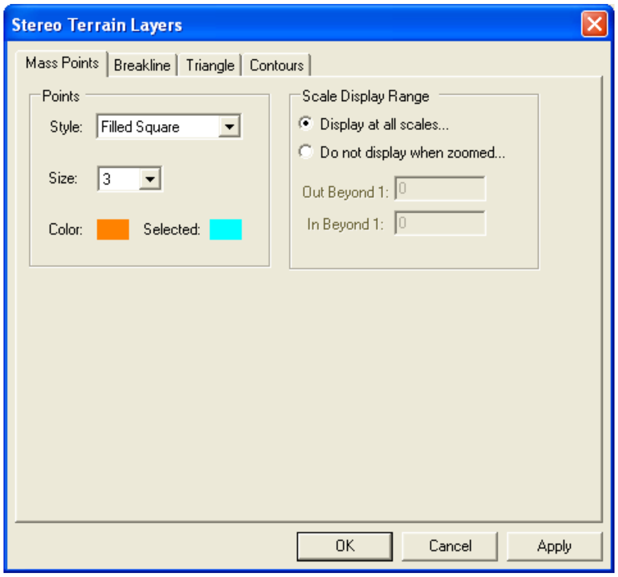
- Mass Points
- Breakline
- Triangle
- Contours

You can access these tabs by double-clicking the appropriate layer on the Stereo tab in the ArcMap table of contents. You can also access them by right-clicking the terrain layer on the Display tab in the ArcMap table of contents and selecting Properties to open the Layer Properties dialog. Click the Stereo Terrain Layers tab.

Mass Point Properties

You can use the mass point rendering properties to control the display of points data. Access the Mass Points tab by double-clicking the Points layer on the Stereo tab in the ArcMap table of contents.

Figure 100: Mass Points Tab



Points

These options let you specify the display style, size, and color of points.

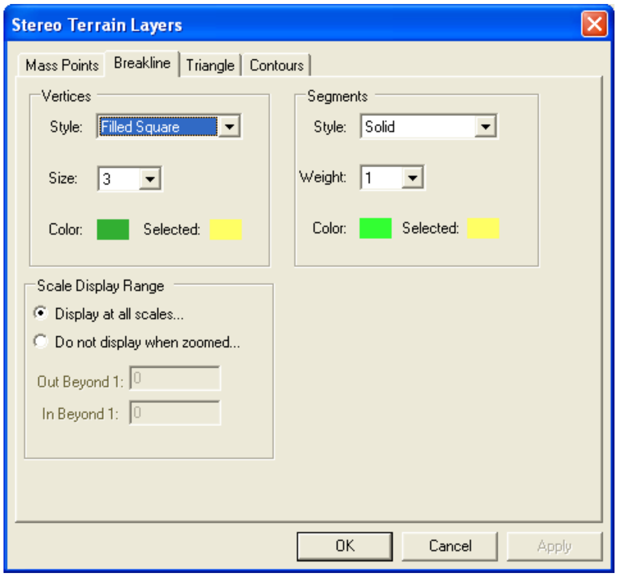
Scale Display Range

These options let you define the display range outside which point data cannot display in the Stereo window. This can be helpful in ensuring that terrain data is not edited at inappropriate scales.

Breakline Properties

You can use the breakline rendering properties to control the display of breaklines. Access the Breakline tab by double-clicking the Breaklines layer on the Stereo tab in the ArcMap table of contents.

Figure 101: Breakline Tab



Vertices

These options let you specify the display style, size, and color of vertices.

Segments

These options let you specify the display style, weight, and color of segments.

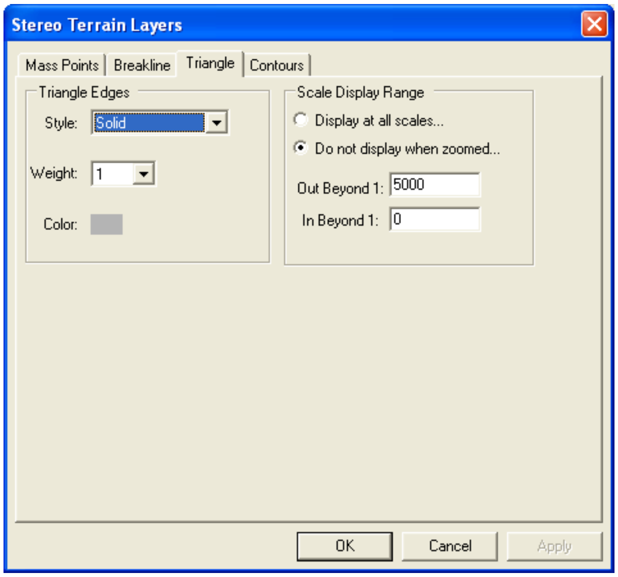
Scale Display Range

These options let you define the display range outside which breakline data does not display in the Stereo window. This can be helpful in ensuring that terrain data is not edited at inappropriate scales.

Triangle Properties

You can use the triangle rendering properties to control the display of triangles. Access the Triangle tab by double-clicking the Triangles layer on the Stereo tab in the ArcMap table of contents.

Figure 102: Triangle Tab



Triangle Edges

These options let you specify the display style, weight, and color of the edge of a triangle.

Scale Display Range

These options let you define the display range outside which triangle data cannot display in the Stereo view. This can be helpful in ensuring that terrain data is not edited at inappropriate scales.

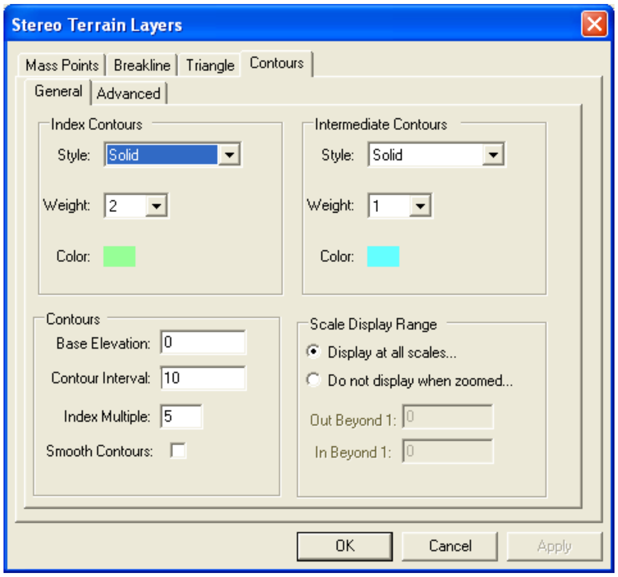
Contours Properties

You can use the contour rendering properties to control the display of contours. Access the Contours tab by double-clicking the Contours layer on the Stereo tab in the ArcMap table of contents. This tab has two subtabs: General and Advanced.

Contours – General Tab

The Contours – General tab contains options that let you specify basic settings for contours.

Figure 103: Contours – General Tab



Index Contours

These options let you specify the display style, weight, and color of index contours.

Intermediate Contours

These options let you specify the display style, weight, and color of intermediate contours.

Contours

These options let you specify the base elevation (starting point) and the interval, or height change between contours. You can also specify an index multiple, which is the number of immediate contours before another index contour, and whether to display contours with smoothing.

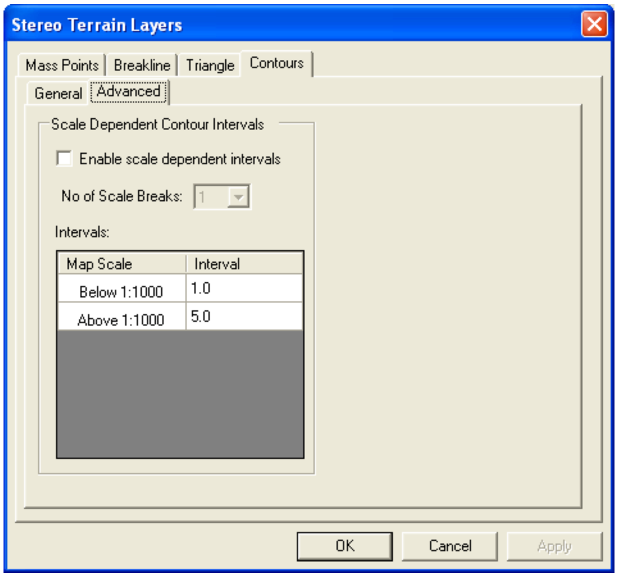
Scale Display Range

These options let you define the display range outside which contour data cannot display in the Stereo window. This can be helpful in ensuring that terrain data is not edited at inappropriate scales.

Contours – Advanced Tab

The Contours – Advanced tab lets you specify advanced settings for contours.

Figure 104: Contours – Advanced Tab



Scale Dependent Contour Intervals

When you activate the Enable scale dependent intervals check box, you can set the number of scale breaks by typing a value in the No of Scale Breaks field.

The value in the No of Scale Breaks field indicates the number of scale breaks. The Intervals table populates based on the number of scale breaks you specify. Items in the Map Scale column indicate the scale of the display in the Stereo window. You can change the value in the Interval column to specify the number of intervals of the contours for display at that scale.

Terrain Point Tools

You can use the Terrain Point tools to add or manipulate terrain points.

You can undo any action by using the Undo button on the ArcMap toolbar.

Adding a Terrain Point

To add a new terrain point, follow these steps:

1. Select **Start Terrain Editing** from the Terrain Editor dropdown list on the Terrain Editor toolbar.
2. Select the point layer from the Target dropdown list.
3. Click the Add a Terrain Point button.
4. Click in the Stereo window.
5. Press the **F3** key to enable editing in the Stereo window.
6. Click in the Stereo window where you want to add the new point.
7. Continue adding points by clicking in the Stereo window.
8. Press **F3** to exit the Stereo window.
9. Select **Save Terrain Edits** from the Terrain Editor dropdown list to save the new additions to the terrain.

Moving a Terrain Point

To move an existing terrain point, follow these steps:

1. Select **Start Terrain Editing** from the Terrain Editor dropdown list on the Terrain Editor toolbar.
2. Select **Options** from the Terrain Editor dropdown list to open the Terrain Editor Options dialog.
3. Click the **Selection** tab.
4. Type a value in the Selection Tolerance field and your selection target.
5. Click **OK** to close the Terrain Editor Options dialog.
6. Click the Move a Terrain Point button on the Terrain Editor toolbar.
7. Click in the Stereo window.
8. Press the **F3** key to enable editing in the Stereo window.

9. Move the mouse in the Stereo window near the point of interest. The point gets highlighted with the selection color. (If not highlighted, check the Selection Tolerance option.)

10. Drag the point to the location you want.

11. Repeat as needed for other points.

12. Press **F3** to exit the Stereo window.

13. Select **Save Terrain Edits** from the Terrain Editor dropdown list to save the changes to the terrain.

Deleting Points by Selected Polygon

You can delete the terrain points in any polygon that you define.

To delete points by selected polygon, follow these steps:

1. Select **Start Editing** from the Editor dropdown list on the Editor toolbar.

2. Select one or more polygons in the ArcMap document window or in the Stereo window.

3. Click the Delete Points by Selected Polygons button on the Terrain Editor toolbar.

4. Click **Yes** when a confirmation message displays to continue with the delete operation.

5. Select **Save Edits** from the Editor dropdown list to save the new additions to the terrain.

Terrain Breakline Tools

You can use the terrain breakline tools to manipulate terrain breaklines.

You can undo any action by using the Undo button on the ArcMap toolbar.

Adding a Terrain Breakline

To add a new breakline to a terrain, follow these steps:

1. Select **Start Terrain Editing** from the Terrain Editor dropdown list on the Terrain Editor toolbar.

2. Select the breakline layer from the Target dropdown list.

3. Click the Add a Terrain Breakline button.

4. Click in the Stereo window.

5. Press the **F3** key to enable editing in the Stereo window.

6. Start digitizing the breakline in the Stereo window.

7. Double-click to end the operation. The breakline is added to the terrain.

8. Press **F3** to exit the Stereo window.

9. Select **Save Terrain Edits** from the Terrain Editor dropdown list to save the new additions to the terrain.

Editing a Terrain Breakline

To edit an existing breakline in a terrain, follow these steps:

1. Select **Start Terrain Editing** from the Terrain Editor dropdown list.

2. Select the breakline layer from the Target dropdown list.

3. Click the Edit a Terrain Breakline  button on the Terrain Editor toolbar.

4. Click in the Stereo window.

5. Press the **F3** key to enable editing in the Stereo window.

6. Move your mouse near a breakline in the Stereo window and click it.

7. Drag a vertex and click where you want to place it. The vertex is moved to the new location after you double-click.

8. Continue adjusting the vertices by clicking a new location for each vertex that needs to be updated.

9. Press **F3** to exit the Stereo window.

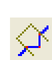
10. Select **Save Terrain Edits** from the Terrain Editor dropdown list to save the changes to the terrain.

Reshaping a Terrain Breakline

To reshape a terrain breakline, follow these steps:

1. Select **Start Terrain Editing** from the Terrain Editor dropdown list.

2. Select the breakline layer from the Target dropdown list on the Terrain Editor toolbar.

3. Click the Reshape a Terrain Breakline  button.

4. Click in the Stereo window.

5. Press the **F3** key to enable editing in the Stereo window.

6. Move your mouse near a breakline and digitize the modification needed.

7. Double-click in the Stereo window to finish editing.

   The breakline is updated to show the new shape.

8. Press **F3** to exit the Stereo window.

9. Select **Save Terrain Edits** from the Terrain Editor dropdown list to save the new additions to the terrain.

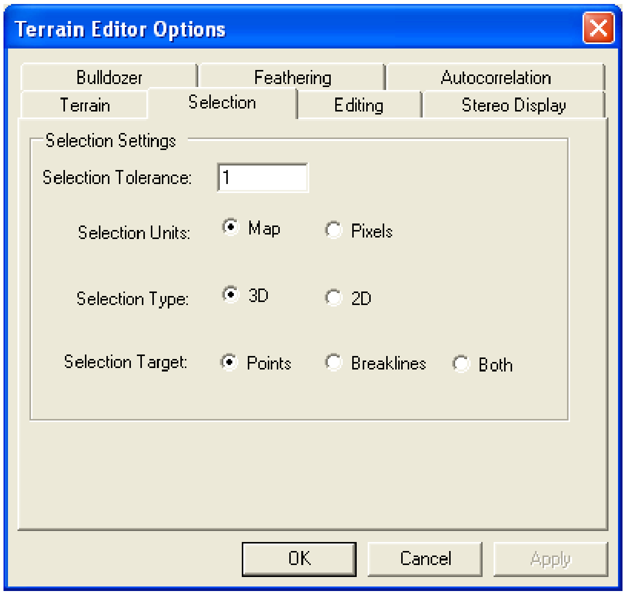
Selection Tools

Most of the terrain editing tools work on the selected mass points or breaklines. Various selection tools and options are available to efficiently select the required features of interest. You can quickly access these tools using the Terrain Editor toolbar.

Selection Settings

Before using the selection tools, set the preferences on the Selection tab in the Terrain Editor Options dialog. You can open the Terrain Editor Options dialog by selecting Options from the Terrain Editor dropdown list on the Terrain Editor toolbar. Click the Selection tab to display the Selection settings.

Figure 105: Selection Tab



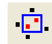
Selection tolerance refers to the distance within which the cursor must be placed to select an object in the view. The selection units can be in either map units or pixels.

For selection type, you can specify whether you are making a selection in 2D or 3D space with consideration for the feature's Z value. If 3D is selected, the floating cursor must be within range of the feature's Z value as well as within the X and Y tolerance.

Your selection target can be points, breaklines, or both. If you are only working with mass points, select Points as the selection target. Select Both if you also need breaklines during spatial selection operations.

Select Box Tool

To select features using a selection box, follow these steps:

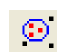
1. Select **Start Terrain Editing** from the Terrain Editor dropdown list on the Terrain Editor toolbar.
2. Click the Select Box  button.
3. Click in the Stereo window.
4. Press the **F3** key to enable editing in the Stereo window.
5. Drag a rectangle in the Stereo window.

   All the features inside the rectangle are selected and highlighted in the selection color.
6. Press the **Ctrl** key when starting another selection to add more features to the current selection.
7. Press the **Shift** key to subtract features from the current selection.
8. Press **F3** to exit the Stereo window.

Polygon Selection Tool

You can use the Polygon Selection tool to select specific features in a user-defined area.

To select specific features, follow these steps:

1. Select **Start Terrain Editing** from the Terrain Editor dropdown list on the Terrain Editor toolbar.
2. Click the Polygon Selection  button.
3. Click in the Stereo window.
4. Press the **F3** key to enable editing in the Stereo window.
5. Drag a polygon in the Stereo window to define the selection area.
6. Double-click to complete the polygon shape.

   All the features inside the polygon are selected and highlighted in the selection color.
7. Press the **Ctrl** key when starting another selection to add more features to the current selection.
8. Press the **Shift** key to subtract features from the current selection.
9. Press **F3** to exit the Stereo window.

Select Display Tool

To select all features in the currently displayed extent, follow this step:

- Click the Select Display button on the Terrain Editor toolbar to select all of the features in the current extent.

Select Features by Polygon Tool

To select features by polygon, follow these steps:

1. Click the Select Features by Polygon button.
2. Click the Selection Target dropdown list on the Terrain Area Operators toolbar and select Points, Breaklines, or Points and Breaklines to control which are selected within the defined polygon.
3. Use the other edit and area operators to modify or delete selected features.

Clear Selection Tool

To deselect all features in the currently selected extent, follow this step:

- Click the Clear Selection button on the Terrain Editor toolbar to deselect all of the features in the current extent.

Terrain Editing Area Operators

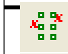
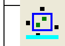
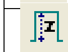
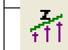
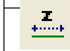
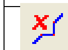
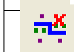
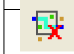
Numerous terrain operating tools are provided in Terrain Editor for ArcGIS for updating the terrain. Most of these tools work on a selected set of points. You can make the selection using the polygon or box selection tools. Access the terrain editing operators by clicking the Terrain Editing Operators button on the Terrain Editor toolbar to display the Terrain Editing Operators toolbar.

Click any of the terrain editing operator buttons listed in the following table to open a dialog for that operator.

Table 1: Terrain Editing Area Operators

Button	Name
	Selected Features
	Feathering
	Current Selection
	Show Parameters Dialog
	Delete Selected Points
	Remove Elevation Spikes
	Fit Surface to Points

Table 1: Terrain Editing Area Operators

Button	Name
	Thin Points
	Smooth Elevations and Thin Points
	Densify Points
	Bias Elevation
	Smooth Elevations
	Set Constant Z
	Delete Selected Breaklines
	Remove Breaklines Buffer Points
	Clip and Delete Selected Features

Each of the terrain editing operators are discussed in the sections that follow.

Selected Features

This operator allows the area operator tools to work on the currently selected features. If not enabled, you are expected to select features in the Stereo window.

Feathering

This operator allows feathering to continue in a nearby area after the initial task is completed. If not selected, no feathering is applied. For more information on feathering, see **Feathering** on page 256.

Current Selection

This operator either uses or clears the current selection. If selected, the selected features remain selected. If not selected, the selected features are cleared.

Show Parameters Dialog

This operator opens a parameters dialog for the selected area operator.

Delete Selected Points

This operator deletes all currently selected points. There are no parameters to set.

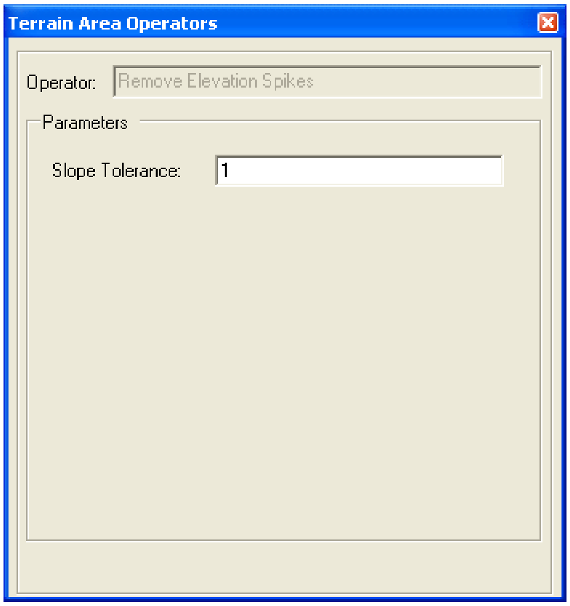
Remove Elevation Spikes

This operator works in an area to remove spiked elevation points.

Note: This operator is not available if you are currently viewing a DTM pyramid layer in the Terrain Editor Options dialog.

If you select the Remove Elevation Spikes operator, it searches each point in the area to determine whether a point is a spike. If the point is a spike, it is removed from the terrain. If you select this operator, there is an additional option to set, as shown below in the Parameters section.

Figure 106: Remove Elevation Spikes Operator



To determine whether a point is a spike, the slope of each point adjacent to the spike point must be bigger than the given threshold (tolerance). The slope is calculated as a tangent value: as a ratio of Z difference to the horizontal distance. A value of slope 1 has a 45-degree angle tilted above or below the ground. The point is removed if the slope is greater than or equal to the threshold.

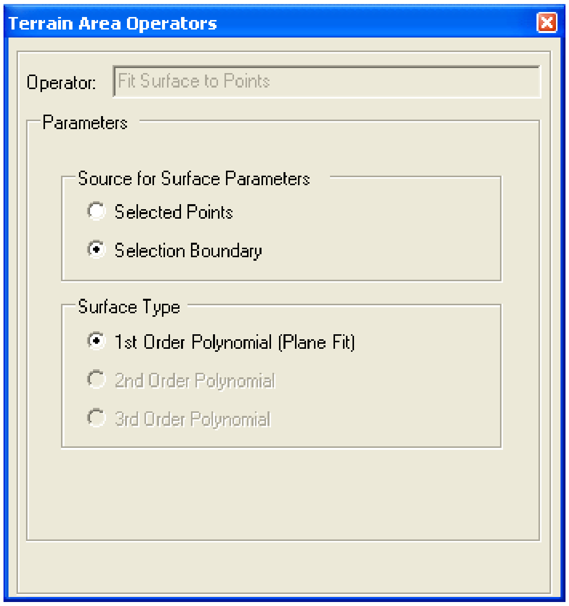
Terrain Editor for ArcGIS uses only the absolute value of the slope; therefore, the tolerance can be any positive value. A high tolerance likely removes very bad points, but might leave those slightly spiked points unchanged. A low tolerance might treat good points as spikes.

Fit Surface to Points

This operator computes new elevations for existing points in the selection based on a mathematical surface. The surface is defined by a set of data points.

Note: This operator is not available if you are currently viewing a DTM pyramid layer in the Terrain Editor Options dialog.

Figure 107: Fit Surface to Points Operator



Source for Surface Parameters

You can select the Selected Points option if all polynomial parameters are derived from the selected points. For the Selection Boundary option, the selection polygon is used to determine the plane into which the selected points are placed. In either case, a least squares method is used to find the best fitting plane.

Surface Type

There must be a minimum number of points required for a given order:

- 1st Order Polynomial = 3 points
- 2nd Order Polynomial = 6 points
- 3rd Order Polynomial = 10 points

In the following equations, x and y are ground coordinates; z is elevation; and c, c1, and c2 are values solved by least squares.

1st Order Polynomial (Plane Fit)

$$z = c + c_1x + c_2y$$

2nd Order Polynomial

$$z = c + c_1x + c_2y + c_3x^2 + c_4xy + c_5y^2$$

3rd Order Polynomial

$$z = c + c_1x + c_2y + c_3x^2 + c_4xy + c_5y^2 + c_6x^3 + c_7x^2y + c_8x^2y + c_9y^3$$

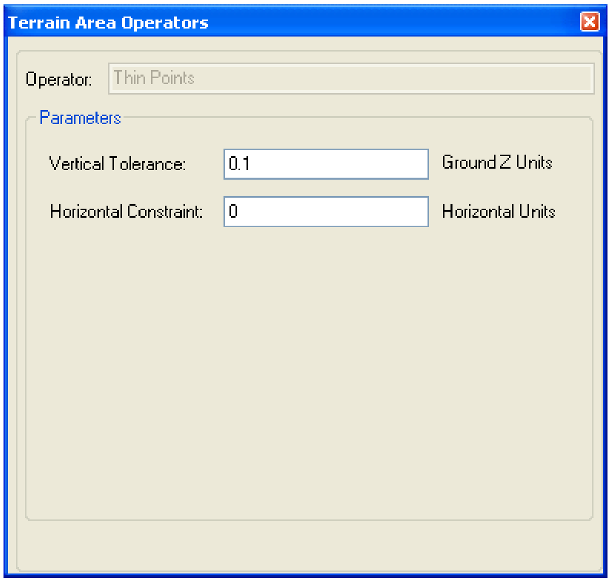
Thin Points

This operator allows the terrain points to be thinned, yet maintain a reasonable (or perhaps a slight downgrade of) overall terrain quality.

Note: This operator is not available if you are currently viewing a DTM pyramid layer in the Terrain Editor Options dialog.

The thinning tolerance defines the quality of the terrain you want to maintain. A high tolerance means lower terrain quality, and a low tolerance means higher terrain quality. The tolerance can be any positive value in the units of ground Z.

Figure 108: Thin Points Operator



Terrain Editor for ArcGIS calculates the would-be interpolated elevation of a given point if it is not inside the TIN, and then compares the value against the real elevation of the point. If the difference is smaller than the tolerance, the point is treated as redundant and is removed.

Vertical Tolerance

Type a value indicating vertical tolerance in the Vertical Tolerance field. The default value is 0.1.

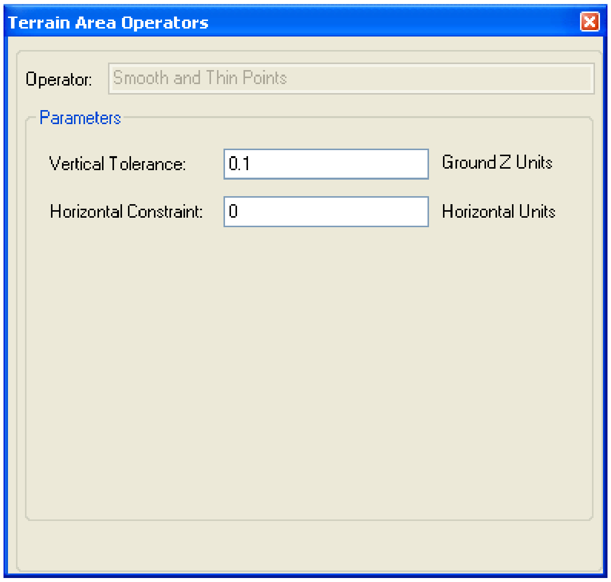
Horizontal Constraint

Type a value in units indicating the horizontal constraint in this field. The horizontal constraint controls point spacing for newly created points.

Smooth Elevations and Thin Points

This operator lets you smooth elevations and thin the points.

Figure 109: Smooth and Thin Points Operator



Vertical Tolerance

Type a value indicating vertical tolerance in the Vertical Tolerance field. The default value is 0.1.

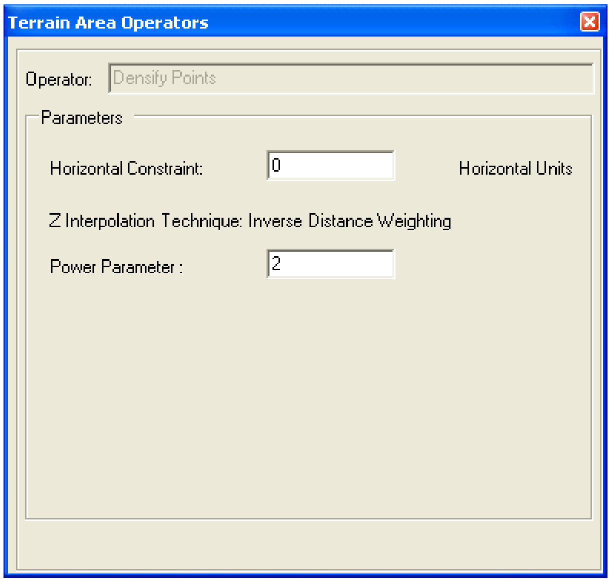
Horizontal Constraint

Type a value in units indicating the horizontal constraint in this field. The horizontal constraint controls point spacing for newly created points.

Densify Points

This operator increases the density of points in an area to make the terrain more accurately model the Earth's surface.

Figure 110: Densify Points Operator



Horizontal Constraint

Type a value in units indicating the horizontal constraint in this field. The horizontal constraint controls point spacing for newly created points.

Z Interpolation Technique: Inverse Distance Weighting

The IDW is a method for multivariate interpolation, which is the process of assigning values to unknown points using values from known points. The choice of value for p, for example, is a function of the degree of smoothing desired in the interpolation, the density and distribution of samples being interpolated, and the maximum distance over which an individual sample is allowed to influence the surrounding ones.

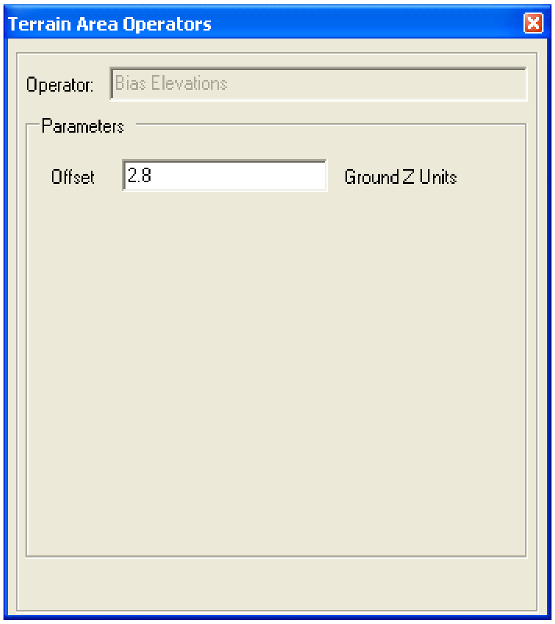
Type a value indicating the power parameter in the Power Parameter field. The power parameter in IDW controls the significance of the surrounding points upon the interpolated value. A higher power results in less influence from distant points.

Bias Elevation

This operator applies a constant offset to all elevations in the selection.

Note: This operator is not available if you are currently viewing a DTM pyramid layer in the Terrain Editor Options dialog.

Figure 111: Bias Elevation Operator



Offset

Type the amount of offset to apply to all points in the Offset field. A positive bias increases each elevation by the specified amount; a negative bias decreases each elevation by the specified amount.

Smooth Elevations

This operator adjusts existing elevations in the selection to reduce noise (high-frequency variations) on the terrain surface.

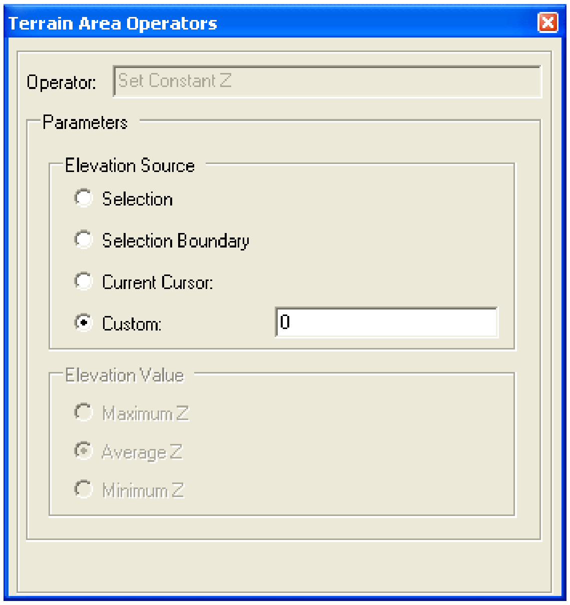
Note: This operator is not available if you are currently viewing a DTM pyramid layer in the Terrain Editor Options dialog.

Updated elevations are computed using a weighted average of the elevations of neighboring points. Elevations are weighted by horizontal distance from the point being updated. There are no parameters to set.

Set Constant Z

This operator sets all selected elevations to a constant value, which forces a horizontal surface. This is useful for modeling lakes, for example, in the terrain data set.

Figure 112: Set Constant Z Operator



Elevation Source

The options in this section specify the elevation source. The constant elevation value for the Selection option is derived from the terrain data contained in the selection, while the value for the Selection Boundary option is derived from the polygonal boundary delineating the selection.

The constant elevation value for the current cursor is derived from the current cursor elevation. You must define the custom elevation value. Enter a value in the field after you click the Custom button.

Elevation Value

The options in this section specify the maximum, average, or minimum elevation value in the specified elevation source. These elevation values are used in conjunction with both the Selection and Selection Boundary options in the Elevation Source section.

Delete Selected Breaklines

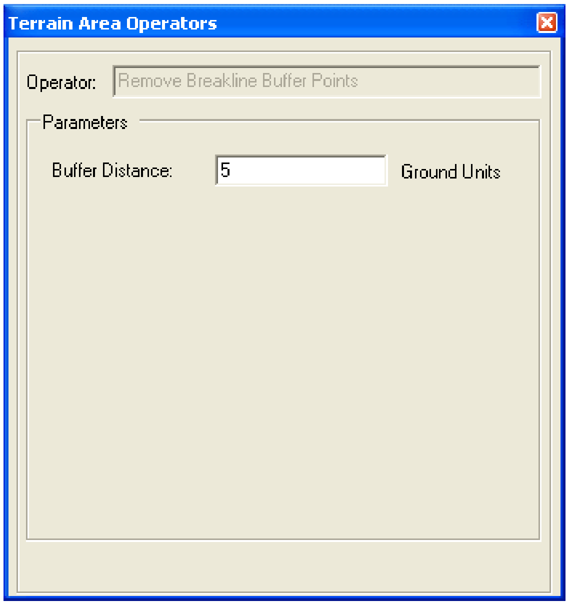
This operator removes a breakline after you select it. There are no parameters to set.

Remove Breakline Buffer Points

This operator lets you remove those mass points very close (within the buffer distance) to a breakline.

Note: This operator is not available if you are currently viewing a DTM pyramid layer in the Terrain Editor Options dialog.

Figure 113: Remove Breakline Buffer Points Operator



Buffer Distance

Type a value indicating how close a point must be to the breakline in the Buffer Distance field. The default value is 5. A buffer distance of 5 means every point within five ground units of the breakline is removed. All points beyond this buffer distance are untouched.

Breaklines are normally treated with higher precedence over existing points as one breaks the terrain, so removing the buffer points sometimes yields better and cleaner terrain.

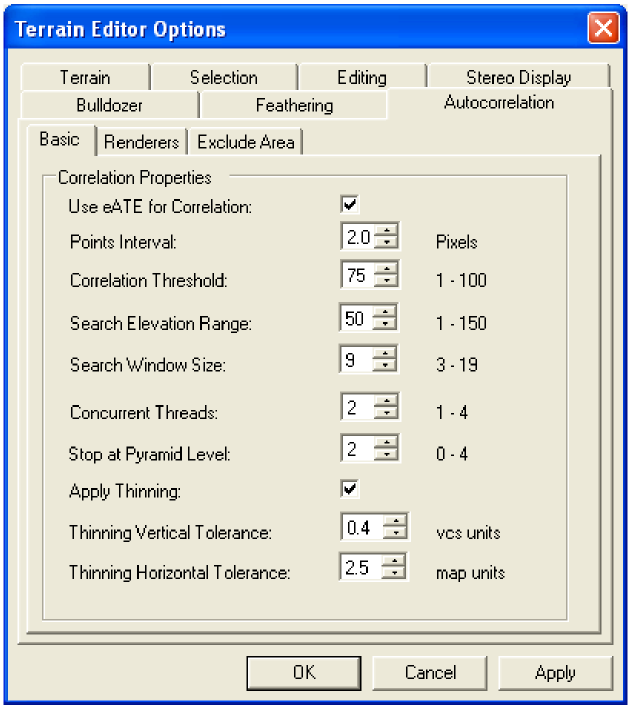
Clip and Delete Selected Features

This operator clips and deletes selected points or breaklines. There are no parameters to set.

Autocorrelation

You can set the autocorrelation options using the subtabs on the Autocorrelation tab in the Terrain Editor Options dialog.

Figure 114: Basic Tab



Using the Basic Tab

The Autocorrelation – Basic tab provides the core correlation properties. These properties are discussed in the sections that follow.

Use eATE for Correlation

This option lets you use enhanced Automatic Terrain Extraction (eATE) for correlation. If you check this check box, all of the options on the Basic tab become enabled. If you uncheck this check box, the concurrent threads, pyramid level, and thinning options become disabled, and the classic mode of autocorrelation is used.

Points Interval

This option refers to the map unit distance between autocorrelated points. The minimum limit is controlled by Terrain Editor for ArcGIS depending on the resolution of the image.

Correlation Threshold

During the image correlation process, two image patches (one from the left image and the other from the right image) are compared, and a correlation coefficient is computed ranging in value from 0 to 100. The optimum setting for the correlation coefficient is 85.

Selecting a low minimum correlation threshold value increases the probability of a false match, whereas increasing the correlation threshold might yield no correlation at all. A high minimum correlation threshold value is preferred in forested and urban areas (with shadows) where the probability of a false match is high. A low value is preferred in grassy areas and other areas where a specific land cover type is homogenous in the area of interest.

Search Elevation Range

In images with a large amount of slope, correlation can be more difficult because the relief displacement on the ground creates a parallax effect that increases with terrain variation. Similarly, if each image of the image pair is collected at a radically different angle, the matching is more computationally stressful to process. Therefore, in both instances you can set the Elevation Search Range to a higher value. This forces Terrain Editor for ArcGIS to perform more extensive computations to ensure that the matching of points between images is correct. If the area of interest is flat with very little variation in elevation, set the Elevation Search Range to a lower value.

Search Window Size

In areas of low contrast, it is more difficult to locate matching points in the left and right images of the image pair. Because the image correlation process operates on the gray level values of the oriented images, Search Window Size plays a vital role in the success of image correlation. Setting the search window size to reflect the actual condition of the imagery (that is, low or high contrast) helps Terrain Editor for ArcGIS apply rigorous methods to improve the correlation results.

Concurrent Threads

This option lets you indicate the number of distributed processing threads for this process. Each thread is assigned to a separate core in the computer, which is optimized for two threads. A quad-core computer can use a maximum of four threads for a single process, but using 100% of the CPU can severely degrade the computing performance for other processes. The default is 2.

Stop at Pyramid Level

You can use this option to indicate the level at which to stop processing pyramids. The default is 0, and this tells the correlation to process all pyramids. A higher number produces a DTM faster, but might produce a less accurate surface model.

Consider the ground sampling distance (GSD) when choosing pyramid levels because the pixel size doubles for every subsequent level you choose. If you select a pyramid level of four (pixel size = 0.5 m), the pixel size is 16 times (pixel size = 8 m) the GSD of the imagery. This can make a significant difference in the DTM extraction results and in performance.

Apply Thinning

Check this check box to allow the terrain points to be thinned, yet still maintain a reasonable (or perhaps a slight downgrade of) overall terrain quality. For a given point, the program calculates the would-be interpolated elevation of the point if the point is not inside the TIN, and then compares the value against the real elevation of the point. If the difference is smaller than the tolerance, the point is treated as redundant and is removed.

Thinning Vertical Tolerance

Type a value to indicate the quality of the terrain you want to maintain. A high tolerance means lower terrain quality, and a lower tolerance means higher terrain quality. The tolerance can be any positive value in the units of ground Z. The default is 0.1.

Thinning Horizontal Tolerance

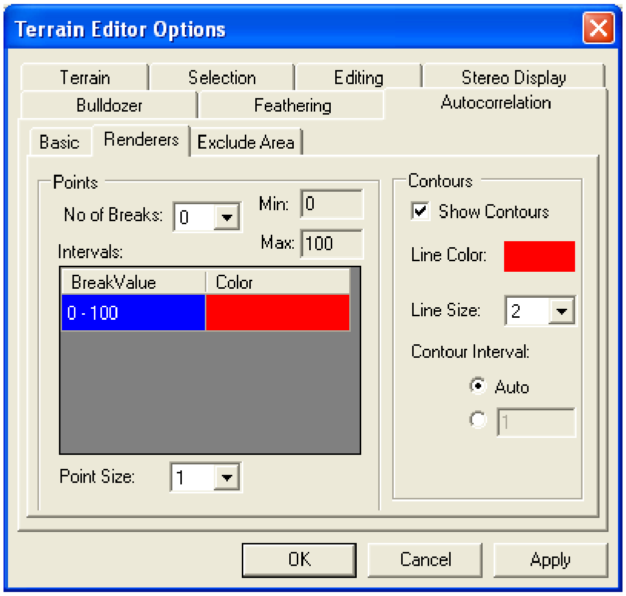
Type a value to indicate the minimum point density to maintain while thinning. If the data has a very flat terrain and you set a high vertical tolerance value, too many points are thinned unless you set the this option to control the thinning. The default is no constraint (0).

Using the Renderers Tab

The Autocorrelation – Renderers tab provides options for you to visualize the correlated points in the Stereo window. You can display all of the points in a single color or in different colors. You can also select the size of the point.

The properties on the Autocorrelation – Renderers tab are discussed in the sections that follow.

Figure 115: Renderers Tab



Points

This section contains settings that let you view information about and specify settings for the display of autocorrelated points. You can specify the number of groups you want to break the terrain points into, as well as review the minimum and maximum Z values for your autocorrelated points. You can also review the different class breaks and specify different colors for the different classes. If you want to change the size of points, type a new value in the field provided.

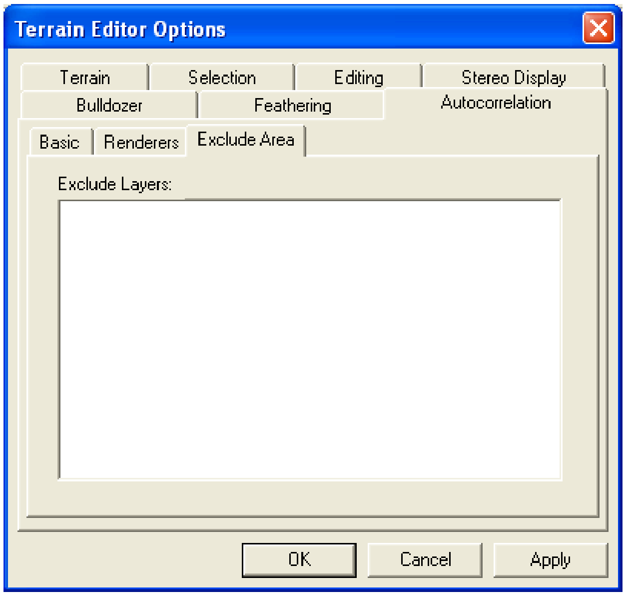
Contours

Contours are generated dynamically for the newly extracted points to assist in point quality and to eliminate spikes. You can control the display of contours using the options in this section. Specify the contour interval or allow it to be automatically selected by Terrain Editor for ArcGIS. In Auto mode, 10 contours are drawn. However, if there are spikes in the generated points, Auto mode might not be the best option. If you decide to manually specify contour intervals, be sure to enter a value in the Contour Interval field.

Using the Exclude Area Tab

The properties on the Autocorrelation – Exclude Area tab are discussed in the sections that follow.

Figure 116: Exclude Area Tab



Exclude Layers

You can use this box to specify which areas to exclude using polygon feature layers.

Generating Points Using Autocorrelation Tools

You can generate new points for the terrain using the autocorrelation tools.

To generate points using the autocorrelation tools, follow these steps:

1. Click the Add Data button and load the terrain dataset and at least one image pair into the Stereo window.
2. Specify whether there are any layers denoting polygonal areas to exclude on the Autocorrelation – Basic tab in the Terrain Editor Options dialog.
3. Select **Box** or **Polygon** from the Select By dropdown list on the Terrain Area Operators toolbar to select an area boundary for the extraction of points.
4. Click the Run Autocorrelation button on the Terrain Autocorrelation toolbar.
5. Click in the Stereo window.
6. Press the **F3** key on your keyboard to enable editing in the Stereo window.
7. Define the area for autocorrelation.
8. Delete any unnecessary points by selecting the points and clicking the Delete by Polygon button. Or, you can delete a single point by selecting the point and clicking the Delete an Autocorrelated Point button.
9. Use the Coefficient slider if you want to vary the coefficient threshold for points display.

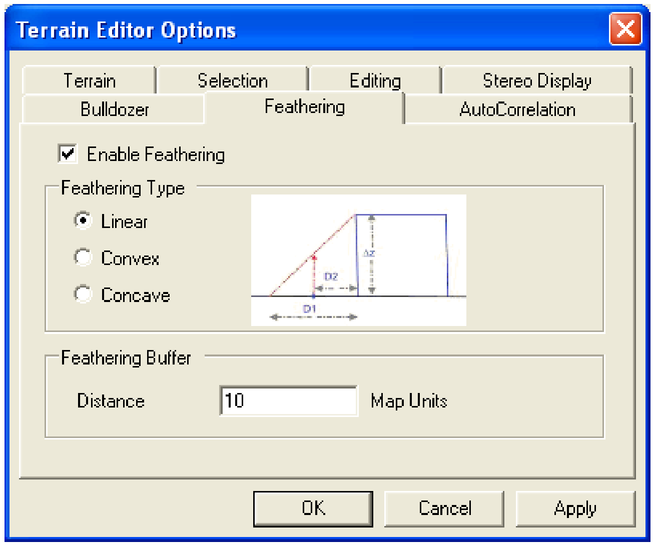
   Note: Points that are hidden by this method are not added to the terrain in subsequent steps.
10. Adjust the autocorrelation properties on the Autocorrelation –Basic tab in Terrain Editor Options dialog before rerunning the Autocorrelation tool to improve results if the new points are unacceptable.

    Note: Rerunning the Autocorrelation tool removes all previous autocorrelated points.
11. Click the Merge Visible Autocorrelated Points button to merge the points into the terrain after you finish.

Feathering

Many of the terrain editing operators support feathering, which smooths nearby points depending on the effect of the previous operation. You can enable feathering by selecting the Enable Feathering option on the Feathering tab in the Terrain Editor Options dialog.

Figure 117: Feathering Tab

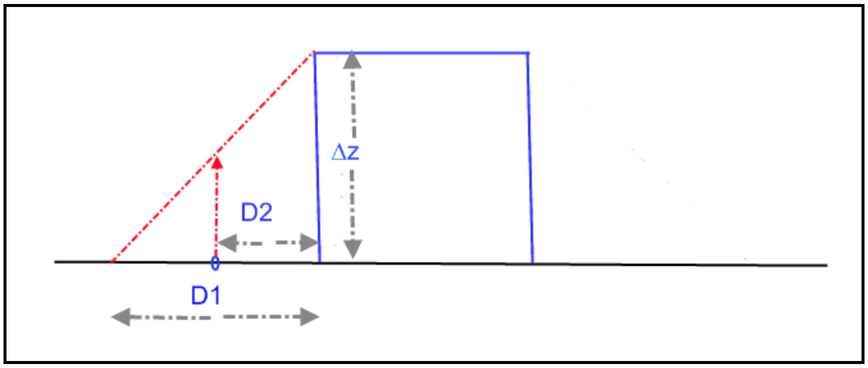


Once you set this option, you can use the Feathering  button on the Terrain Area Operators toolbar to quickly enable or disable feathering.

Feathering Logic

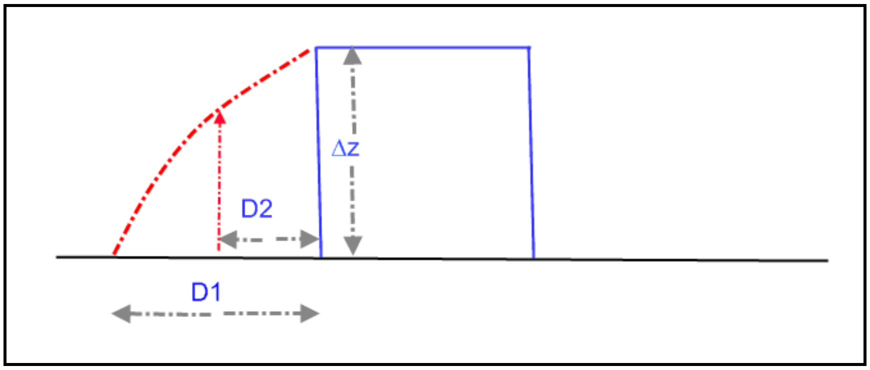
The feathering logic is as follows:

Figure 118: Linear Feathering Logic



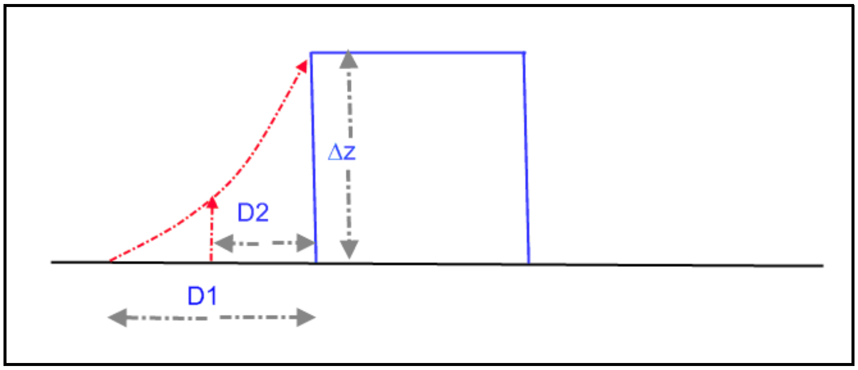
$New\ Z = Original\ Z + \Delta z * (1 - D2/D1)$

Figure 119: Convex Feathering Logic



*New Z = Original Z + Δ z * (1 - SQRT(D2 / D1))*

Figure 120: Concave Feathering Logic



*New Z = Original Z + Δ z * (1 - (D2 / D1)*(D2 / D1))*

Feathering Support

The area operators and tools that support the feathering operation are as follows:

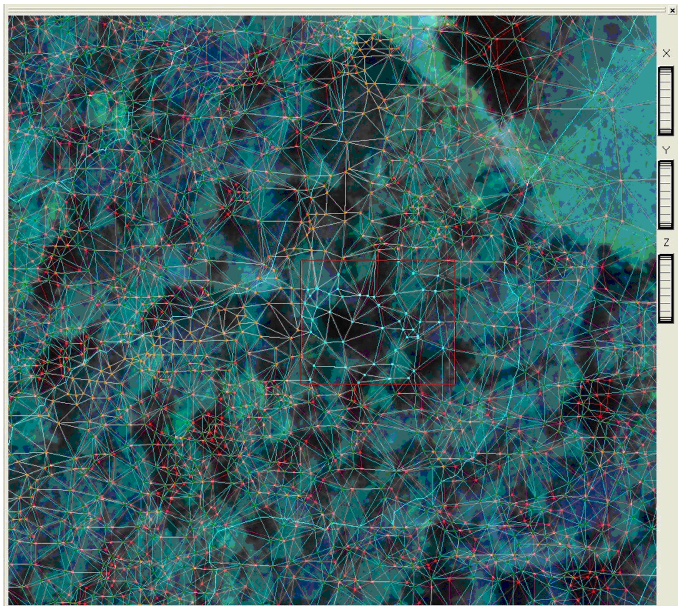
- **Bias Elevations** – For more information, see **Bias Elevation** on page 247.
- **Fit Surface to Points** – For more information, see **Fit Surface to Points** on page 243.
- **Set Constant Z** – For more information, see **Set Constant Z** on page 248.
- **Bulldozer Tool** – For more information, see **Bulldozer Tool** on page 263.

Feathering Examples

The results of various feathering settings are shown in the examples that follow.

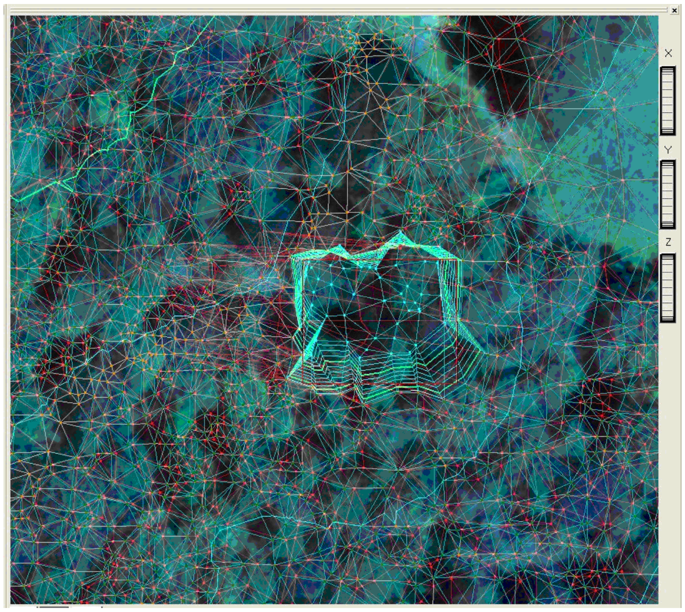
This example is the result of points selected for the bias Z operation of 100 meters with the feathering option enabled.

Figure 121: Bias Z of 100 Meters with Feathering



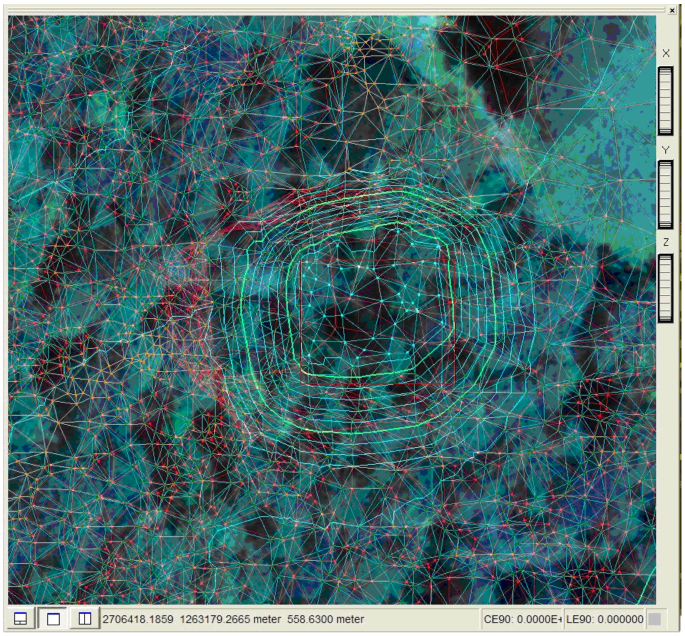
This example is the result of the bias Z operation of 100 meters without the feathering option enabled.

Figure 122: Bias Z of 100 Meters without Feathering



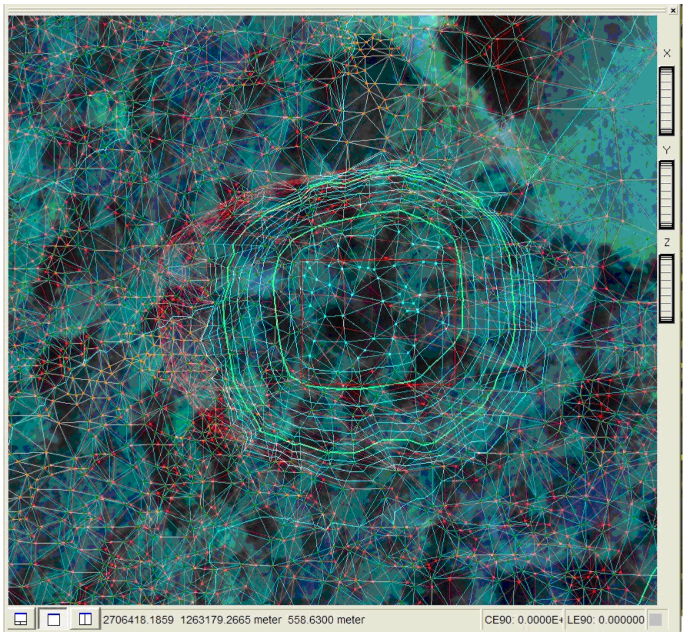
This example is the result of the bias Z operation of 100 meters with the Linear feathering option applied.

Figure 123: Bias Z of 100 meters with Linear Feathering



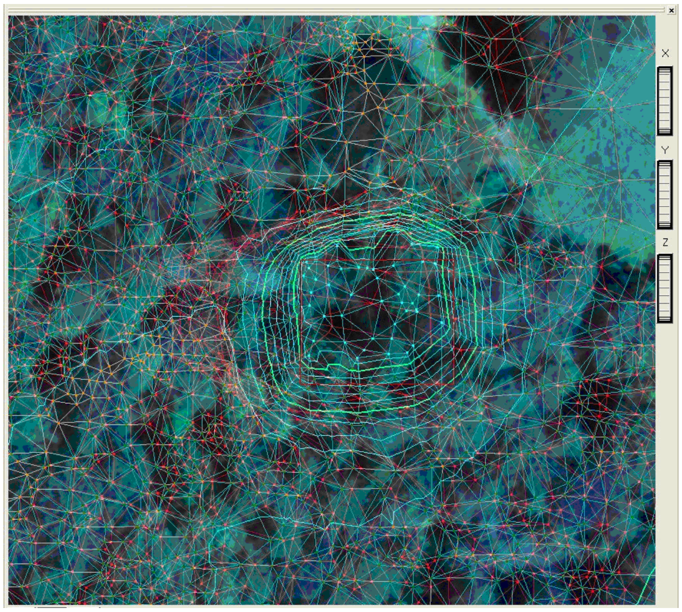
This example is the result of the bias Z operation of 100 meters with the Convex feathering option applied.

Figure 124: Bias Z of 100 Meters with Convex Feathering


X
Y
Z
2706418.1859 1263179.2665 meter 558.6300 meter
CE90: 0.0000E
LE90: 0.000000

This example is the result of the bias Z operation of 100 meters with the Concave feathering option applied.

Figure 125: Bias Z of 100 Meters with Concave Feathering



Grouping Transactions

You can group terrain editing operations so that undo and redo can be performed in a single step.

To group transactions, follow these steps:

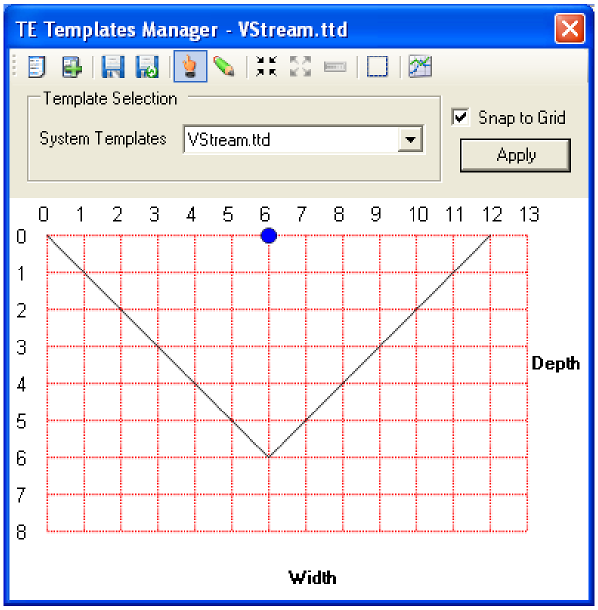
1. Select **Start Transaction** from the Terrain Editor dropdown list to start the transaction.
2. Make the terrain edits that you want.
3. Select **End Transaction** from the Terrain Editor dropdown list to complete the transaction. A single entry is made in the undo/redo stack, which combines all the individual transactions.

   Note: The Cancel Transaction command cancels the terrain editing transactions.

Templates Manager

The Templates Manager lets you create or view bulldozer templates. You can open the Templates Manager by selecting Templates Manager from the Terrain Editor dropdown list on the Terrain Editor toolbar.

Figure 126: Templates Manager



A list of system templates from the Terrain Templates folder in the product installation directory is loaded by default. You can usually find the folder in the following directory:

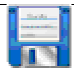
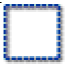
C:\Program Files\ERDAS\ERDAS\ERDAS Extensions 2011\terraintemplates

Please note the following:

- The file extension for the terrain template is .ttd (terrain template data). It is an XML file, and you can edit it manually or by using the Templates Manager.
- You can use untitled template documents for any bulldozer operation by clicking the Apply button.
- The template you select to apply to the terrain displays as a tool tip.
- If the Delete Points within X Tolerance of Breakline option is enabled in the Terrain Editor Options dialog, that rule is applied while deleting the points.

The buttons on the Templates Manager toolbar are listed in the following table.

Table 2: Templates Manager Toolbar Buttons

Button	Name	Function
	New Bulldozer Template	Create new bulldozer template file.
	Open Bulldozer Template File	Open existing template from any other location.
	Save	Save the current template file. If it is a new template, the Save dialog opens.
	Save As	Save the current template into a new file name.
	Pointer	Move the pick point or the template vertex (right-click to insert vertex).
	Draw Template Shape	Draw the template shape.
	Scale Down	Change and increase the scale of the drawing area.
	Scale Up	Change and decrease the scale of the drawing area.
	Reset Scale to 1	Change and reset the scale of the drawing area to default.
	Clear Drawing Area	Clear the drawing area.
	Digitize Template from Stereo Window	Digitize template from the Stereo window.

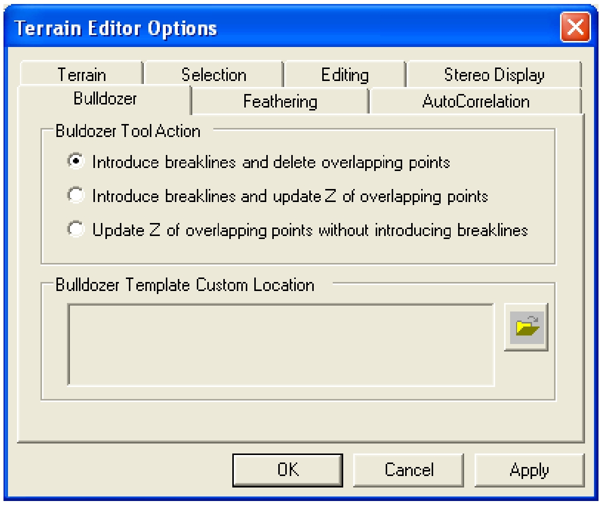
Bulldozer Tool

The Bulldozer tool alters the terrain based on a defined template along a defined line or existing breaklines. You can create a bulldozer template using the Templates Manager.

Bulldozer Tool Options

The behavior of the Bulldozer tool is based on options you define on the Bulldozer tab in the Terrain Editor Options dialog.

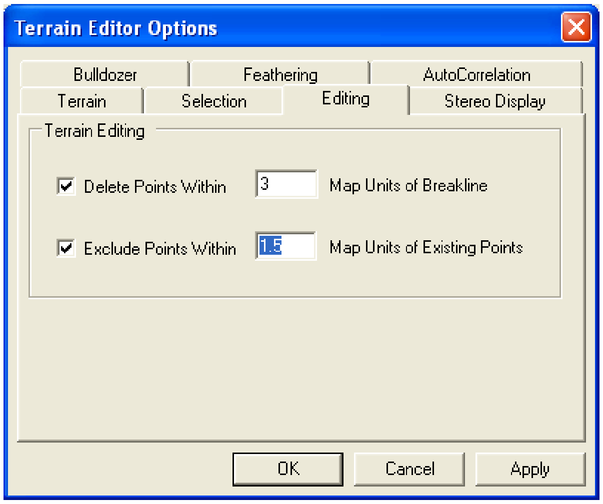
Figure 127: Bulldozer Tab



The Bulldozer tool can create breaklines, as well as delete or update the terrain points (Z).

Note: Deleted points are honored only if the Delete Points option is enabled on the Editing tab as shown below.

Figure 128: Editing Tab



You can store the template files in a location other than the standard directory location.

Applying Terrain Bulldozer to a Digitized Line

This command is similar to Terrain Bulldozer by Selected Breaklines except that it applies to the line you digitized in the Stereo window. Breaklines are created and mass points are deleted or updated within the breaklines area based on the options you specify.

To apply terrain bulldozer to a digitized line, follow these steps:

1. Create a bulldozer template file using the Templates Manager. For more information, see **Templates Manager** on page 261.
2. Select the bulldozer template file from the bulldozer Templates dropdown list on the Terrain Bulldozer toolbar.
3. Click in the Stereo window.
4. Press the **F3** key on your keyboard to enable editing in the Stereo window.
5. Start digitizing a line for the area to bulldoze.
6. Double-click to stop.

    The selected template is applied to the terrain.
7. Press **F3** to exit the Stereo window.
8. Select **Save Terrain Edits** from the Terrain Editor dropdown list on the Terrain Editor toolbar to save the new additions to the terrain.

    Note: The template does not apply if you are off the ground instead of intersecting the terrain.

Applying a Template to a Selected Breakline

This command is similar to Terrain Bulldozer by Digitizing except that it operates on the selected breaklines instead of onscreen digitization. Breaklines are created and mass points are deleted or updated within the breaklines area based on the selected breaklines. The pick point of the template is matched with the selected breaklines.

To apply a template to a selected breakline, follow these steps:

1. Create a bulldozer template file using the Templates Manager.
2. Select the bulldozer template file from the bulldozer Templates dropdown list on the Terrain Bulldozer toolbar.
3. Click in the Stereo window.
4. Press the **F3** key on your keyboard to enable editing in the Stereo window.
5. Select the breakline.

Note: Make sure the Breaklines option is selected on the Selection tab in the Terrain Editor Options dialog.

6. Press **F3** to exit the Stereo window.

7. Click the Bulldozer by Breaklines button on the Terrain Bulldozer toolbar.

8. Select **Save Terrain Edits** from the Terrain Editor dropdown list on the Terrain Editor toolbar to save the new additions to the terrain.

Creating a Template in the Stereo Window

You can initialize stereo digitization by clicking a button on the Templates Manager toolbar or the Terrain Editor toolbar. For more information on the Templates Manager, see **Templates Manager** on page 261.

Note: When digitizing form the Stereo window, snapping is not applied.

To digitize a template in the Stereo window, follow these steps:

1. Click one of the following buttons:
   - **Digitize Template from Stereo Window** – Located on the Templates Manager toolbar.
   - **Digitize Bulldozer Template** – Located on the Terrain Bulldozer toolbar.

2. Click in the Stereo window.

3. Press the **F3** key on your keyboard to enable editing in the Stereo window.

4. Start digitizing the template. You see the template being drawn dynamically in the Templates Manager window.

5. Double-click to end the template digitization.

You can also create a template using the Templates Manager or an existing template.

What's Next?

The chapters that follow explain how to capture data using imagery, how imagery is used in stereo viewing, and how imagery is used in photogrammetry. There is also a glossary of terms for your reference.

Capturing Data Using Imagery

This chapter gives you examples of how imagery is useful in collecting geographic data. This data is of primary importance for creating and maintaining a GIS. If the data and information contained within a GIS are inaccurate or outdated, the resulting analyses performed on the data do not reflect true, real-world applications and scenarios.

IN THIS CHAPTER

Collecting Data for a GIS

Since its inception and introduction, GIS was designed to represent the Earth and its associated geography. Vector data is accepted as the primary format for representing geographic information. For example, a road is represented with a line, and a parcel of land is represented using a series of lines to form a polygon.

Various approaches are employed to collect vector data used as the fundamental building blocks of a GIS. These include:

- Using a digitizing tablet to digitize features from cartographic, topographic, census, and survey maps. The resulting features are stored as vectors. Feature attribution occurs either during or after feature collection.

- Scanning and georeferencing existing hardcopy maps. The resulting images are georeferenced and then used to digitize and collect geographic information. For example, this includes scanning United States Geological Survey (USGS) 1:24,000 quad sheets and using them as the primary source for a GIS.

- Obtaining ground surveying geographic information. Ground GPS, total stations, and theodolites are commonly used for recording the 3D locations of features. The resulting information is commonly merged into a GIS and associated with existing vector datasets.

- Outsourcing photogrammetric feature collection to service bureaus. Traditional stereo plotters and digital photogrammetric workstations are used to collect highly accurate geographic information such as orthorectified imagery, DTMs, and 3D vector datasets.

- Applying remote sensing techniques, such as multispectral classification, which traditionally have been used for extracting geographic information about the Earth's surface.

Issues Collecting Gis Data

These approaches are widely accepted in the GIS industry as the primary techniques used to prepare, collect, and maintain the data contained within a GIS; however, GIS professionals throughout the world are beginning to face the following issues:

- The original sources of information used to collect GIS data are becoming obsolete and outdated. The same can be said for the GIS data collected from these sources. How can the data and information in a GIS be updated?

- The accuracy of the source data used to collect GIS data is questionable. For example, how accurate is the 1960 topographic map used to digitize contour lines?

- The amount of time required to prepare and collect GIS data from existing sources of information is great.

- The cost required to prepare and collect GIS data is high. For example, georectifying 500 photographs to map an entire county may take up to three months (which does not include collecting the GIS data). Similarly, digitizing hardcopy maps is time-consuming and costly, not to mention inaccurate.

- Most of the original sources of information used to collect GIS data provide only 2D information. For example, a building is represented with a polygon having only X and Y coordinate information. Creating a 3D GIS involves creating DTMs, digitizing contour lines, or surveying the Earth's geography to obtain 3D coordinate information. Once collected, the 3D information is merged with the 2D GIS to create a 3D GIS. Each approach is ineffective in terms of the time, cost, and accuracy associated with collecting the 3D information for a 2D GIS.

- The cost associated with outsourcing core digital mapping to specialty shops is expensive in both dollars and time. Also, performing regular GIS data updates requires additional outsourcing.

With the advent of image processing and remote sensing systems, the use of imagery for collecting geographic information has become more frequent. Imagery was first used as a reference backdrop for collecting and editing geographic information (including vectors) for a GIS. This imagery included:

- Raw photography

- Geocorrected imagery

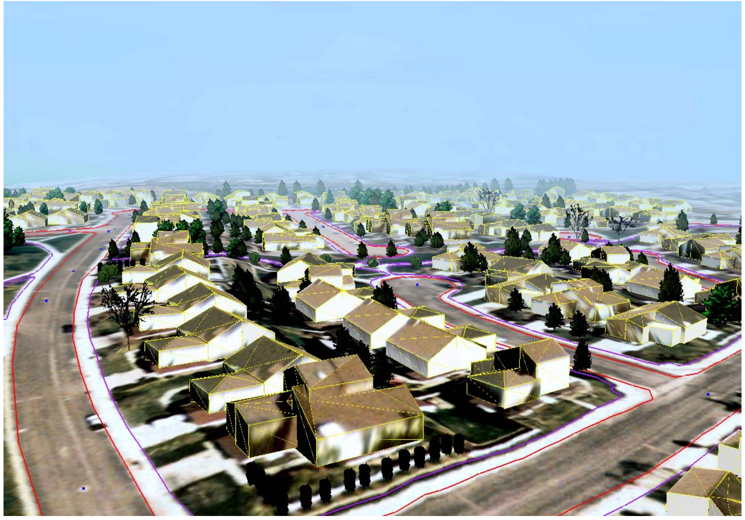
- Orthorectified imagery

Extracting 3D Information in a GIS

Each type of imagery has its advantages and disadvantages, although all are limited to the collection of geographic information in 2D. You must obtain information directly in 3D, regardless of the application, to accurately represent the Earth and its geography in a GIS. Stereo Analyst for ArcGIS provides the solution for directly collecting 3D information from stereo imagery.

The image below shows accurate 3D geographic information extracted from imagery.

Figure 129: Accurate 3D Geographic Information



Preparing Imagery for a GIS

This section describes the various techniques used to prepare imagery for a GIS. By understanding the processes and techniques associated with preparing and extracting geographic information from imagery, problems can be identified and the complete solution for collecting 3D geographic information can be provided.

Using Raw Photography

The following examples describe the common practices used for collecting geographic information from raw photographs and imagery. Raw imagery includes scanned hardcopy photography, digital camera imagery, videography, or satellite imagery that has not been processed to establish a geometric relationship between the imagery and the Earth. In this case, the images are not referenced to a geographic projection or coordinate system.

Example 1: Collecting Geographic Information from Hardcopy Photography

Hardcopy photographs are widely used by professionals in several industries as one of the primary sources of geographic information. Foresters, geologists, soil scientists, engineers, environmentalists, and urban planners routinely collect geographic information directly from hardcopy photographs. The hardcopy photographs are commonly used during fieldwork and research and are a valuable source of information.

For the interpretation of 3D and height information, an adjacent set of photographs is used with a stereoscope. While in the field, information and measurements collected on the ground are recorded directly onto the hardcopy photographs. Using the hardcopy photographs, information regarding the feature of interest is recorded both spatially (geographic coordinates) and nonspatially (text attribution).

Transferring the geographic information associated with the hardcopy photograph to a GIS involves the following steps:

- Scan the photographs
- Georeference the photograph using known GCPs
- Digitize the features recorded in the photographs using the scanned photographs as a backdrop in a GIS
- Merge and geolink the recorded tabular data with the collected features in a GIS

This procedure is repeated for each photograph.

Example 2: Collecting Geographic Information from Hardcopy Photography using a Transparency

Rather than measure and mark on photographs, a transparency is placed on top of the photographs during feature collection. In this case, a stereoscope is placed over the photographs, and a transparency is placed over the photographs. Features and information (spatial and nonspatial) are recorded directly on the transparency, and then transferred to a GIS.

The following steps are commonly used to transfer the information to a GIS:

1. Either digitally scan the entire transparency using a desktop scanner, or digitize only the collected features using a digitizing tablet.
2. Georeference the resulting image or set of digitized features to the Earth's surface. The information is georeferenced to an existing vector coverage, rectified map, rectified image, or is georeferenced using GCPs. Geographic coordinates (X and Y) are associated with each feature after geoconferencing.
3. Enter the recorded tabular (attribution) data in a GIS and merge it with the digital set of georeferenced features.

This procedure is repeated for each transparency.

Example 3: Collecting Geographic Information from Scanned Photography

By scanning the raw photography, a digital record of the area of interest becomes available and is used to collect GIS information.

The following steps are commonly used to collect GIS information from scanned photography:

1. Georeference the photograph using known GCPs.
2. Digitize the features recorded on the photographs in a GIS using the scanned photographs as a backdrop.
3. Merge and geolink the recorded tabular data with the collected features in the GIS.

This procedure is repeated for each photograph.

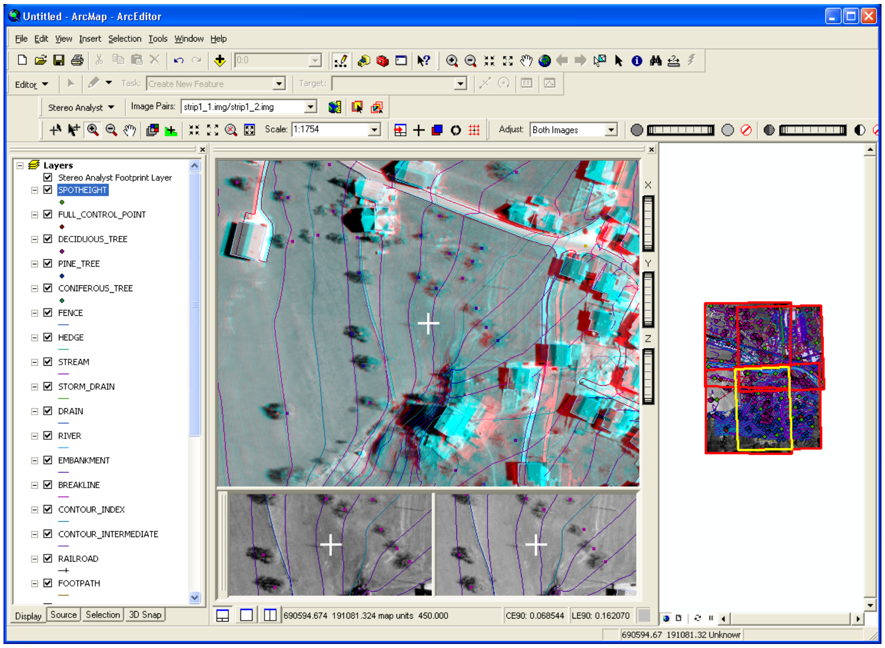
Applying Geoprocessing Techniques

Raw aerial photography and satellite imagery contain large geometric distortion caused by camera or sensor orientation error, terrain relief, Earth curvature, film and scanning distortion, and measurement errors. Measurements made on data sources that have not been rectified for the purpose of collecting geographic information are not reliable.

Geoprocessing techniques warp, stretch, and rectify imagery for use in the collection of 2D geographic information. These techniques include geocorrection and orthorectification, which establish a geometric relationship between the imagery and the ground. The resulting 2D image sources are primarily used as reference backdrops or base image maps on which to digitize geographic information.

The figure below shows spatial information collected using Stereo Analyst for ArcGIS.

Figure 130: Spatial Information



Applying Geocorrection

Conventional techniques of geometric correction (or geocorrection) such as rubber sheeting are based on approaches that do not directly account for the specific distortion or error sources associated with the imagery. These techniques have been successful in the field of remote sensing and GIS applications, especially when dealing with low resolution and narrow field of view satellite imagery such as Landsat and SPOT. General functions have the advantage of simplicity. They can provide a reasonable geometric modeling alternative when little is known about the geometric nature of the image data.

Problems

Conventional techniques generally process images one at a time. They cannot provide an integrated solution for multiple images or photographs simultaneously and efficiently. It is very difficult, if not impossible, for conventional techniques to achieve reasonable accuracy without a great number of GCPs when dealing with high-resolution imagery, images with severe systematic or nonsystematic errors, and images covering rough terrain such as mountainous areas. Image misalignment is more likely to occur when mosaicking separately rectified images. This misalignment can result in the collection of inaccurate geographic information from the rectified images. The GIS suffers as a result.

Furthermore, it is impossible for geocorrection techniques to extract 3D information from imagery. There is no way for conventional techniques to accurately derive geometric information about the sensor that captured the imagery.

Solution

Techniques used in Stereo Analyst for ArcGIS and LPS overcome all of these problems by using sophisticated techniques to account for the various types of error in the input data sources. This solution is integrated and accurate. LPS can process hundreds of images or photographs with very few GCPs, while eliminating the misalignment problem associated with creating image mosaics. In short—less time, less money, less manual effort, and more geographic fidelity is realized using the photogrammetric solution. Stereo Analyst for ArcGIS uses all of the information processed in LPS and accounts for inaccuracies during 3D feature collection, editing, and interpretation.

Orthorectification

Geocorrected aerial photography and satellite imagery have large geometric distortion that is caused by various systematic and nonsystematic factors. Photogrammetric techniques used in LPS eliminate these errors most efficiently, and create the most reliable and accurate imagery from the raw imagery. LPS is unique in terms of considering the image-forming geometry by using information between overlapping images and explicitly dealing with the third dimension, which is elevation.

Orthorectified images, or orthoimages, serve as the ideal information building blocks for collecting 2D geographic information required for a GIS. They can be used as reference image backdrops to maintain or update an existing GIS. Using digitizing tools in a GIS, features can be collected and then attributed to reflect their spatial and nonspatial characteristics. Multiple orthoimages can be mosaicked to form seamless orthoimage base maps.

Problems

Orthorectified images are limited to containing only 2D geometric information. Thus, geographic information collected from orthorectified images is georeferenced to a 2D system. Collecting 3D information directly from orthoimagery is impossible. The accuracy of orthorectified imagery is highly dependent on the accuracy of the DTM used to model the terrain effects caused by the Earth’s surface. The DTM source is an additional source of input during orthorectification. Acquiring a reliable DTM is another costly process. You can purchase high-resolution DTMs, but at a great expense.

Solution

Stereo Analyst for ArcGIS allows for the collection of 3D information—you are no longer limited to only 2D information. Using sophisticated sensor modeling techniques, a DTM is not required as an input source for collecting accurate 3D geographic information. The accuracy of the geographic information collected in Stereo Analyst for ArcGIS is higher as a result. There is no need to spend countless hours collecting DTMs and merging them with your GIS.

Using Traditional Approaches

Unfortunately, 3D geographic information cannot be directly measured or interpreted from geocorrected images, orthorectified images, raw photography, or scanned topographic or cartographic maps. The resulting geographic information collected from these sources is limited to 2D only, which consists of X and Y georeferenced coordinates. Additional processing is required to collect the additional Z (height) coordinate. The following examples explain how 3D information is normally collected for a GIS.

Example 1

The first example involves digitizing hardcopy cartographic and topographic maps and attributing the elevation of contour lines. Further interpolation of contour lines is required to create a DTM. The digitization of these sources includes either scanning the entire map or digitizing individual features from the maps.

The accuracy and reliability of the topographic or cartographic map cannot be guaranteed. As a result, any error in the map is introduced into your GIS. Additionally, the magnitude of error is increased due to the questionable scanning or digitization process.

Example 2

The second example involves merging existing DTMs with geographic information contained in a GIS.

Where did the DTMs come from? How accurate are the DTMs? If the original source of the DTM is unknown, then the quality of the DTM is also unknown. As a result, any inaccuracies are translated into your GIS.

Can you easily edit and modify problem areas in the DTM? Many times, you cannot edit the problem areas in the DTM because the original imagery is not available, or the accompanying software is not available.

Example 3

The third example involves using ground surveying techniques such as ground GPS, total stations, levels, and theodolites to capture angles, distances, slopes, and height information. You are required to geolink and merge the land surveying information with the geographic information contained in the GIS.

Ground surveying techniques are accurate, but labor intensive, costly, and time-consuming—even with new GPS technology. Also, additional work is required to merge and link the 3D information with the GIS. The process of geolinking and merging the 3D information with the GIS may introduce additional errors to your GIS.

Example 4

The fourth example involves automated DEM extraction. Using two overlapping images, a regular grid of elevation points or a dispersed number of 3D mass points (that is, a TIN) can be automatically extracted from imagery. You are then required to merge the resulting DTM with the geographic information contained in the GIS.

You are restricted to the collection of point elevation information. For example, using this approach, the slope of a line or the 3D position of a road cannot be extracted. Similarly, a polygon of a building cannot be directly collected. Many times, postediting is required to ensure the accuracy and reliability of the elevation sources. Automated DEM extraction consists of just one required step to create the elevation or 3D information source. Additional steps of DTM interpolation and editing are also required, and the additional process of merging the information with your GIS.

Example 5

The fifth example involves outsourcing photogrammetric feature collection and data capture to photogrammetric service bureaus and production shops. Using traditional stereoplotters and digital photogrammetric workstations, 3D geographic information is collected from stereo models. The 3D geographic information might include DTMs, 3D features, and spatial and nonspatial attribution ready for input in your GIS database.

Using these sophisticated and advanced tools, the procedures required for collecting 3D geographic information become costly. The use of such equipment is generally limited to highly skilled photogrammetrists.

Applying Geographic Imaging

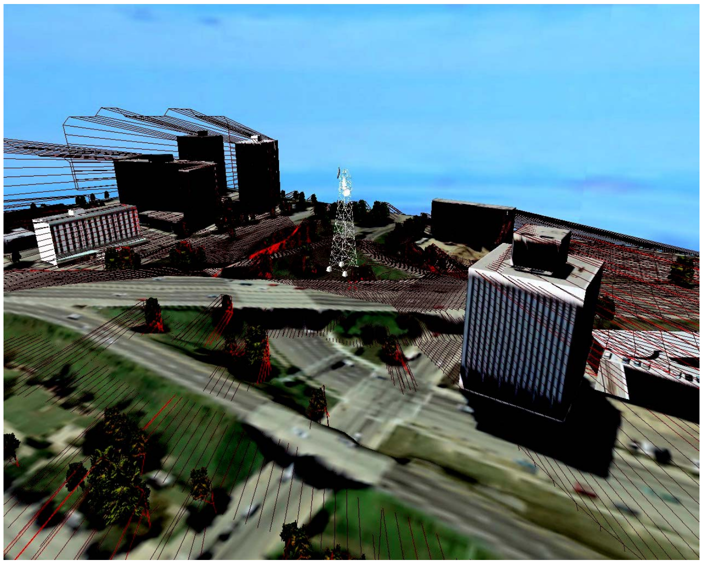
A new approach is required for collecting and maintaining geographic data and information in a GIS to preserve the investment made. The approach must provide the ability to:

- Access and use readily available, up-to-date sources of information for collecting GIS data and information.
- Collect accurate 2D and 3D GIS data from a variety of sources.
- Minimize the time and cost associated with preparing, collecting, and editing GIS data.
- Collect 3D GIS data directly from raw source data without performing additional preparation tasks.
- Integrate new sources of imagery easily for maintaining and updating data and information in a GIS.

The only solution that can address all of those issues involves the use of imagery, which provides an up-to-date, highly accurate representation of the Earth and its associated geography. You can use various types of imagery, including aerial photography, satellite imagery, digital camera imagery, videography, and 35 millimeter photography. With the advent of high-resolution satellite imagery, GIS data can be updated accurately and immediately.

Synthesizing the concepts associated with photogrammetry, remote sensing, GIS, and 3D visualization introduces a new paradigm for the future of digital mapping—one that integrates the respective technologies into a single, comprehensive environment for the accurate preparation of imagery and the collection and extraction of 3D GIS data and geographic information. This paradigm is referred to as 3D geographic imaging. These 3D geographic imaging techniques are to be used for building the 3D GIS of the future.

Figure 131: 3D Information used for GIS Analysis



3D geographic imaging is the process associated with transforming imagery into GIS data or, more importantly, information. It prevents the inclusion of inaccurate or outdated information. Sophisticated and automated techniques are used to ensure that highly accurate 3D GIS data is collected and maintained using imagery. 3D geographic imaging techniques use a direct approach to collecting accurate 3D geographic information, thereby eliminating the need to digitize from a secondary data source like hardcopy or digital maps. These new tools significantly improve the reliability of GIS data and reduce the steps and time associated with populating a GIS with accurate information.

The backbone of 3D geographic imaging is digital photogrammetry, which has established itself as the main technique for obtaining accurate 3D information from photography and imagery. Traditional photogrammetry uses specialized and expensive stereoscopic plotting equipment. Digital photogrammetry uses computer-based systems to process digital photography or imagery. With the advent of digital photogrammetry, many of the processes associated with photogrammetry are automated.

Over the last several decades, the idea of integrating photogrammetry and GIS has intimidated many people. The cost and learning curve associated with incorporating the technology into a GIS has created a chasm between photogrammetry and GIS data collection, production, and maintenance.

As a result, many GIS professionals resorted to outsourcing their digital mapping projects to specialty photogrammetric production shops. Advancements in softcopy photogrammetry, or digital photogrammetry, broke down these barriers. Digital photogrammetric techniques bridge the gap between GIS data collection and photogrammetry. This is made possible through the automated processes associated with digital photogrammetry.

For more information about photogrammetric applications, see "Applying Photogrammetry" on page 299.

Moving from Imagery to a 3D GIS

Transforming imagery into 3D GIS data involves several processes commonly associated with digital photogrammetry. The data and information required for building and maintaining a 3D GIS include orthorectified imagery, DTMs, 3D features, and the nonspatial attribute information associated with the 3D features. Through various processing steps, 3D GIS data is automatically collected and extracted from imagery.

Using Imagery

Digital photogrammetric techniques are not restricted to the type of photography and imagery used to collect accurate GIS data. Traditional applications of photogrammetry use aerial photography (commonly 9 × 9 inches in size). Technological breakthroughs in photogrammetry now allow for the use of satellite imagery, digital camera imagery, videography, and 35 millimeter camera photography.

Photographs must be scanned or digitized before using them in a digital photogrammetric system. Depending on the digital mapping project, various scanners are used to digitize photography. For highly accurate mapping projects, you must use calibrated photogrammetric scanners to scan the photography to very high precision. If high-end micron accuracy is not required, you can use more affordable desktop scanners.

Conventional photogrammetric applications, such as topographic mapping and contour line collection, use aerial photography. With the advent of digital photogrammetric systems, applications have been extended to include the processing of oblique and terrestrial photography and imagery.

Given the use of computer hardware and software for photogrammetric processing, you can use various image file formats. These include TIF, JPEG, GIF, Raw, Generic Binary, and compressed imagery, along with various software vendor-specific file formats.

Identifying Workflow

The workflow associated with creating 3D GIS data is linear. The hierarchy of processes involved with creating highly accurate geographic information can be broken down into several steps, which include:

- Define the sensor model
- Measure GCPs
- Collect tie points (automated)
- Perform bundle block adjustment (that is, aerial triangulation)
- Extract DTMs (automated)
- Orthorectify
- Collect and attribute 3D features

This workflow is generic and does not need to be repeated for every GIS data collection and maintenance project. For example, you don't need to perform a bundle block adjustment every time a 3D feature is collected from imagery.

Defining the Sensor Model

A sensor model describes the properties and characteristics associated with the camera or sensor used to capture photography and imagery. Because digital photogrammetry allows for the accurate collection of 3D information from imagery, all of the characteristics associated with the camera/sensor, the image, and the ground must be known and determined. Photogrammetric sensor modeling techniques define the specific information associated with a camera/sensor as it existed when the imagery was captured. This information includes both internal and external sensor model information.

Internal sensor model information describes the internal geometry of the sensor as it exists when the imagery is captured. For aerial photographs, this includes the focal length, lens distortion, fiducial mark coordinates, and so forth. This information is normally provided to you in the form of a calibration report. For digital cameras, this includes focal length and the pixel size of the charge-coupled device (CCD) sensor. For satellites, this includes internal satellite information such as the pixel size, the number of columns in the sensor, and so forth. If some of the internal sensor model information is not available (as in the case of historical photography), you can use sophisticated techniques to determine the internal sensor model information. This technique is normally associated with performing a bundle block adjustment and is referred to as self-calibration.

External sensor model information describes the exact position and orientation of each image as they existed when the imagery was collected. The position is defined using 3D coordinates. The orientation of an image at the time of capture is defined in terms of rotation about three axes: omega (ω), phi (φ), and kappa (κ). Over the last several years, it has been common practice to collect airborne GPS and inertial navigation system (INS) information at the time of image collection. If this information is available, you can enter the external sensor model information directly for use in photogrammetric processing. If external sensor model information is not available, most photogrammetric systems can determine the exact position and orientation of each image in a project using the bundle block adjustment approach.

Measuring GCPs

Unlike traditional georectification techniques, GCPs in digital photogrammetry have three coordinates: X, Y, and Z. The image locations of 3D GCPs are measured across multiple images. You can collect GCPs from existing vector files, orthorectified images, DTMs, and scanned topographic and cartographic maps.

GCPs serve a vital role in photogrammetry by establishing an accurate geometric relationship between the images in a project, the sensor model, and the ground. This relationship is established using the bundle block adjustment approach. Once established, you can accurately collect 3D GIS data from imagery. The number of GCPs varies from project to project. For example, if a strip of five photographs is being processed, you can use a minimum of three GCPs. Optimally, five or six GCPs are distributed throughout the overlap areas of the five photographs.

Collecting Tie Points

Tie points are commonly measured within the overlap areas of multiple images to prevent misaligned orthophoto mosaics and to ensure accurate DTMs and 3D features. A tie point is a point whose ground coordinates are not known; however, the tie point is visually recognizable in the overlap area between multiple images.

Tie point collection is the process of identifying and measuring tie points across multiple overlapping images. Tie points are used to join the images in a project so that they are positioned correctly relative to one another. Traditionally, tie points are collected manually, two images at a time. With the advent of new, sophisticated, and automated techniques, tie points are now collected automatically, saving you time and money in the preparation of 3D GIS data. Digital image matching techniques are used to automatically identify and measure tie points across multiple overlapping images.

Applying Bundle Block Adjustment

Once GCPs and tie points are collected, you can begin the process of establishing an accurate relationship between the images in a project, the camera/sensor, and the ground. This process is referred to as bundle block adjustment.

Bundle block adjustment is an essential part of processing because it determines most of the necessary information that is required to create orthophotos, DTMs, DSMs, and 3D features. The components needed to perform a bundle block adjustment might include the internal sensor model information, external sensor model information, the 3D coordinates of points, and additional parameters (AP) characterizing the sensor model. This output is commonly provided with detailed statistical reports outlining the accuracy and precision of the derived data. For example, if the accuracy of the external sensor model information is known, you can determine the accuracy of 3D GIS data collected from this source data.

Extracting DTMs

Rather than manually collecting individual 3D point positions with a GPS or using direct 3D measurements on imagery, automated techniques extract 3D representations of the Earth's surface using the overlap area of two images. This is referred to as automated DTM extraction. Digital image matching (auto-correlation) techniques are used to automatically identify and measure the positions of common ground points displaying within the overlap area of two adjacent images.

Using sensor model information determined from bundle block adjustment, the image positions of the ground points are transformed into 3D point positions. Once the automated DTM extraction process is complete, a series of evenly distributed 3D mass points is located in the geographic area of interest. The 3D mass points are then interpolated to create a TIN or a raster DEM. DTMs form the basis of many GIS applications including watershed analysis, line of sight (LOS) analysis, road and highway design, and geological bedform discrimination. DTMs are also vital for creating orthorectified images.

Orthorectifying

Orthorectification is the process of removing geometric errors inherent in photography and imagery. Using sensor model information and a DTM, errors associated with sensor orientation, topographic relief displacement, Earth curvature, and other systematic errors are removed to create accurate imagery for use in a GIS. Measurements and geographic information collected from an orthorectified image represent the corresponding measurements as if they were taken on the Earth's surface. Orthorectified images serve as the image backdrops for displaying and editing vector layers.

Collecting and Attributing 3D Features

You can collect 3D GIS data and information from a DSM. Based on sensor model information, two overlapping images comprising a DSM can be aligned, leveled, and scaled to produce a 3D stereo effect when viewed with appropriate stereo viewing hardware. A DSM allows for the interpretation, collection, and visualization of 3D geographic information from imagery. The DSM is used as the primary data source for the collection of 3D GIS data.

A 3D GIS allows for the direct collection of 3D geographic information from a DSM using a 3D floating cursor. Additional elevation data is not required. True 3D information is collected directly from imagery.

During the collection of 3D GIS data, a 3D floating cursor is displayed in the DSM while viewing the imagery in stereo. The 3D floating cursor commonly floats above, below, or rests on the Earth’s surface or object of interest. The height of the 3D floating cursor is adjusted so that it rests on the feature being collected to ensure the accuracy of 3D GIS data and that it is accurately collected.

The following figure shows accurate 3D building extracted using Stereo Analyst for ArcGIS.

Figure 132: Accurate 3D Buildings

You can use automated Terrain Following mode capabilities to automatically place the 3D floating cursor on the ground so that you do not have to manually adjust its height every time a feature is collected. For example, collect a feature in 3D using the automated Terrain Following mode with the Sketch Tool, and then collect vertices. The resulting output is 3D GIS data.

For the update and maintenance of a GIS, existing vector layers are commonly superimposed on a DSM and then reshaped to their accurate real-world positions. You can transform 2D vector layers into 3D geographic information using most 3D geographic imaging systems. During the collection of 3D GIS data, the attribute information associated with a vector layer can be edited. You can display Attribute tables with the DSM during the collection of 3D GIS data.

Interpreting the DSM during the capture of 3D GIS data allows for the collection, maintenance, and input of nonspatial information such as the type of tree and zoning designation in an urban area. Automated attribution techniques simultaneously populate a GIS during the collection of 3D features with such data as area, perimeter, and elevation. You can enter additional qualitative and quantitative attribution information associated with a feature during the collection process.

Getting 3D GIS Data from Imagery

The products resulting from using 3D geographic imaging techniques include orthorectified imagery, DTMs, DSMs, 3D features, 3D measurements, and attribute information associated with a feature. Using these primary sources of geographic information, you can collect, update, and edit additional GIS data. An increasing trend in the geocommunity involves the use of 3D data in GIS spatial modeling and analysis.

Finding 3D GIS Applications

You can use the 3D GIS data collected using 3D geographic imaging for spatial modeling, GIS analysis, and 3D visualization and simulation applications. The following examples illustrate how 3D geographic imaging techniques can be used for applications in forestry, geology, local government, water resource management, and telecommunications.

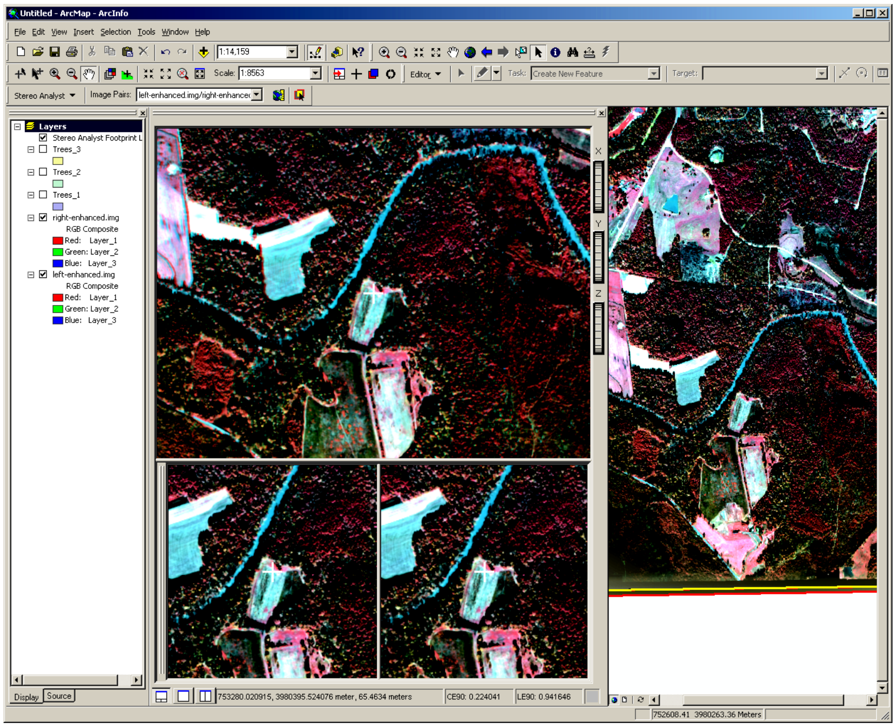
Applying 3D GIS to Forestry

For forest inventory applications, an interpreter identifies different tree stands from one another based on height, density (crown cover), species composition, and various modifiers such as slope, type of topography, and soil characteristics. Using a DSM, a forest stand is identified and measured as a 3D polygon. 3D geographic imaging techniques are used to provide the GIS data required to determine the volume of a stand. This includes using a DSM to collect tree stand height, tree crown diameter, density, and area.

Using 3D DSMs with high-resolution imagery, various tree species are identified based on height, color, texture, and crown shape. Appropriate feature codes are directly placed and georeferenced to delineate forest stand polygons. The feature code information is directly indexed to a GIS for subsequent analysis and modeling.

This image shows 3D geographic imaging techniques used in forestry applications.

Figure 133: 3D Geographic Imaging



Based on the information collected from DSMs, forestry companies use the 3D information in a GIS to determine the amount of marketable timber located within a given plot of land, the amount of timber lost due to fire or harvesting, and where problems may arise due to harvesting in unsuitable geographic areas.

Applying 3D GIS to Geology

Prior to beginning expensive exploration projects, geologists take an inventory of a geographic area using imagery as the primary source of information. DSMs are frequently used to improve the quantity and quality of geologic information that can be interpreted from imagery. Changes in topographic relief are often used in lithological mapping applications because these changes, together with the geomorphologic characteristics of the terrain, are controlled by the underlying geology.

DSMs are utilized for lithologic discrimination and geologic structure identification. Dip angles are recorded directly on a DSM to assist in identifying underlying geologic structures. By digitizing and collecting geologic information using a DSM, the resulting geologic map is in a form and projection that can be immediately used in a GIS. Together with multispectral information, high-resolution imagery produces a wealth of highly accurate 3D information for the geologist.

Applying 3D GIS to Local Government Activities

GIS sources must be timely, accurate, and cost-effective to formulate social, economic, and cultural policies. High-resolution imagery provides the primary data source for obtaining up-to-date geographic information for local government applications. Existing GIS vector layers are commonly superimposed onto DSMs for immediate update and maintenance.

DSMs created from high-resolution imagery are used for the following applications:

- Land use/land cover mapping involves the identification and categorization of urban and rural land use and land cover. Using DSMs, you can collect 3D topographic information, slope, vegetation type, soil characteristics, underlying geological information, and infrastructure information as 3D vectors.

- Land use suitability evaluation usually requires soil mapping. DSMs allow for the accurate interpretation and collection of soil type, slope, soil suitability, soil moisture, soil texture, and surface roughness. As a result, you can determine the suitability of a given infrastructure development.

- Population estimation requires accurate 3D high-resolution imagery for determining the number of units for various household types. The height of buildings is important.

- Housing quality studies require environmental information derived from DSMs including house size, lot size, building density, street width and condition, driveway presence or absence, vegetation quality, and proximity to other land use types.

- Site selection applications require the identification and inventory of various geographic information. Site selection applications include transportation route selection, sanitary landfill site selection, power plant siting, and transmission line location. Each application requires accurate 3D topographic representations, geologic inventory, soils inventory, land use, vegetation inventory, and so forth.

- Urban change detection studies use photography collected from various time periods for analyzing the extent of urban growth. Land use and land cover information are categorized for each time period, and then compared to determine the extent and nature of land use/land cover change.

Applying 3D GIS to Resource Management

DSMs are necessary for monitoring the quality, quantity, and geographic distribution of water. The 3D information collected from DSMs is used to provide descriptive and quantitative watershed information for a GIS. Various watershed characteristics are derived from DSMs including terrain type and extent, surficial geology, river or stream valley characteristics, river channel extent, river bed topography, and terraces. Individual river channel reaches can be delineated in 3D, providing an accurate representation of a river.

Rather than manually surveying 3D point information in the field, you can collect highly accurate 3D information from DSMs to estimate sediment storage, river channel width, and valley flat width. Using historical photography, you can use 3D measurements of a river channel and bank to estimate rates of bank erosion and deposition, identify channel change, and describe channel evolution and disturbance.

Applying 3D GIS to Telecommunications

The growing telecommunications industry requires accurate 3D information for various applications associated with wireless telecommunications. 3D geographic representations of buildings are required for radio engineering analysis and LOS between building rooftops in urban and rural environments. Accurate 3D building information is required to properly perform the analysis. Once the 3D data is collected, you can use it for radio coverage planning, system propagation prediction, plotting and analysis, network optimization, antenna siting, and point-to-point inspection for signal validation.

Understanding Stereo Viewing

This chapter provides you with detailed, technical information about stereo viewing and its effect on 3D stereoscopic viewing and feature collection.

IN THIS CHAPTER

Learning Principles of Stereo Viewing

On a daily basis, we unconsciously perceive and measure depth using our eyes. Persons using both eyes to view an object have binocular vision. Persons using one eye to view an object have monocular vision. The perception of depth through binocular vision is referred to as stereoscopic viewing.

Defining Stereoscopic Viewing

Using stereoscopic viewing, you can perceive depth information with great detail and accuracy. Stereo viewing allows the human brain to judge and perceive changes in depth and volume. In photogrammetry, stereoscopic depth perception plays a vital role in creating and viewing 3D representations of the Earth's surface. As a result, you can collect geographic information with greater accuracy in stereo than traditional monoscopic techniques.

Stereo feature collection techniques provide greater GIS data collection and update accuracy for the following reasons:

- Sensor model information derived from block triangulation eliminates errors associated with the uncertainty of sensor model position and orientation. Accurate image position and orientation information is required for the highly accurate determination of 3D information.
- Systematic errors associated with raw photography and imagery are considered and minimized during the block triangulation process.
- The collection of 3D coordinate information using stereo viewing techniques is not dependent on a DEM as an input source. Changes and variations in depth perception are perceived and automatically transformed using sensor model information and raw imagery. Therefore, DTMs containing errors are not introduced into the collected GIS data.

Digital photogrammetric techniques used in Stereo Analyst for ArcGIS extend the perception and interpretation of depth to include the measurement and collection of 3D information.

Understanding How Stereo Works

A true stereo effect is achieved when two overlapping images (an image pair), or photographs of a common area captured from two different vantage points, are rendered and viewed simultaneously. The stereo effect, or ability to view with measurable depth perception, is provided by a parallax effect generated from the two different acquisition points.

The stereo effect is analogous to the depth perception you achieve by looking at a feature with your two eyes. The distance between your eyes represents two vantage points like two independent photos, as in the following figures.

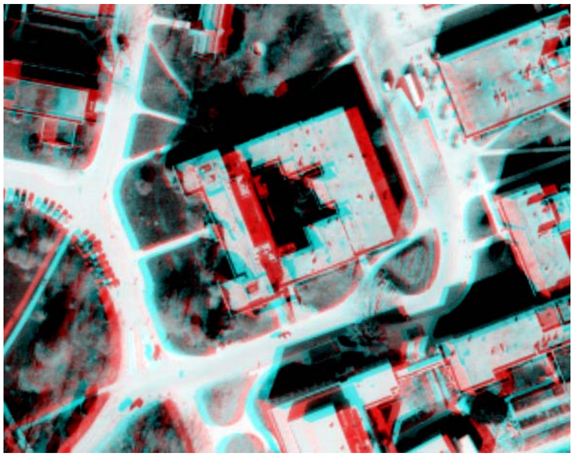
In the figure below, two overlapping photos are viewed together for 3D perception.

Figure 134: 3D Perception

The importance of using images is that by viewing the Earth's surface in stereo, you can interpret, measure, and delineate map features in 3D. The net benefit is that many map features are more interpretable and have a higher degree of accuracy in stereo than in 2D with a single image.

The following figure shows a 3D stereo view made possible using two images.

Figure 135: 3D Stereo View



When viewing the features from two perspectives, (the left photo and the right photo), the brain automatically perceives the variation in depth between different objects and features as a difference in height. For example, while viewing a building in stereo, the brain automatically compares the relative positions of the building and the ground from the two different perspectives (that is, two overlapping images).

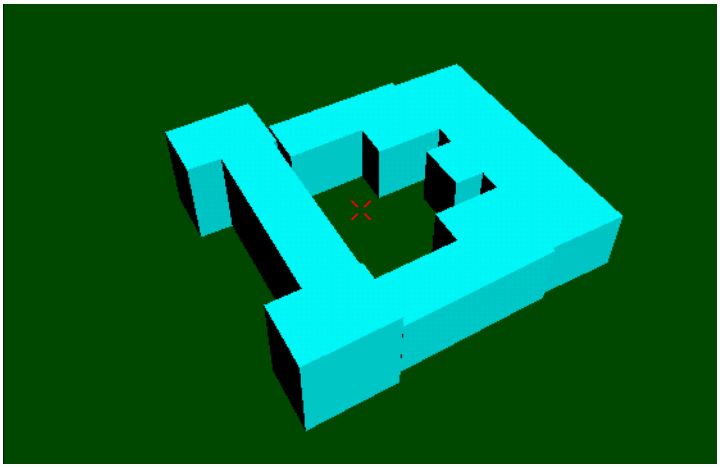
The brain also determines which is closer and which is farther: the building or the ground. Thus, as the left eye and the right eye view the overlap area of two images, depth between the top and bottom of a building is perceived automatically by the brain, and any changes in depth are due to changes in elevation.

During the stereo viewing process, the left eye concentrates on the object in the left image and the right eye concentrates on the object in the right image. As a result, a single 3D image is formed within the brain. The brain discerns height and variations in height by visually comparing the depths of various features. While the eyes move across the overlap area of the two photographs, a continuous 3D model of the Earth is formulated in the brain because the eyes continuously perceive the change in depth as a function of change in elevation.

The 3D image formed by the brain is also referred to as a stereo model. Once the stereo model is formed, you notice relief, or vertical exaggeration, in the 3D model. A digital version of a stereo model, a DSM, can be created when sensor model information is associated with the left and right images comprising an image pair. In Stereo Analyst for ArcGIS, a DSM is formed using an image pair and accurate sensor model information.

Using the stereo viewing and 3D feature collection capabilities of Stereo Analyst for ArcGIS, changes and variations in elevation perceived by the brain are translated to reflect real-world 3D information. The following figure shows an example of a 3D feature created using Stereo Analyst for ArcGIS, which is displayed in IMAGINE VirtualGIS®.

Figure 136: Illustration of a 3D Model



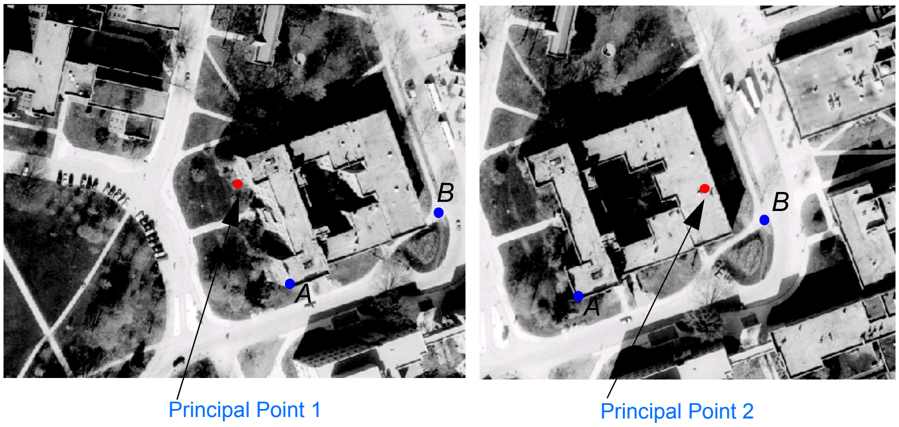
Using Stereo Models and Parallax

Stereo models provide a permanent record of 3D information pertaining to the given geographic area covered in the overlapping area of two images. Viewing a stereo model in stereo presents an abundant amount of 3D information to you. The availability of 3D information in a stereo model is made possible by the presence of what is referred to as stereoscopic parallax. There are two types of parallax: X-parallax and Y-parallax.

Correcting X-Parallax

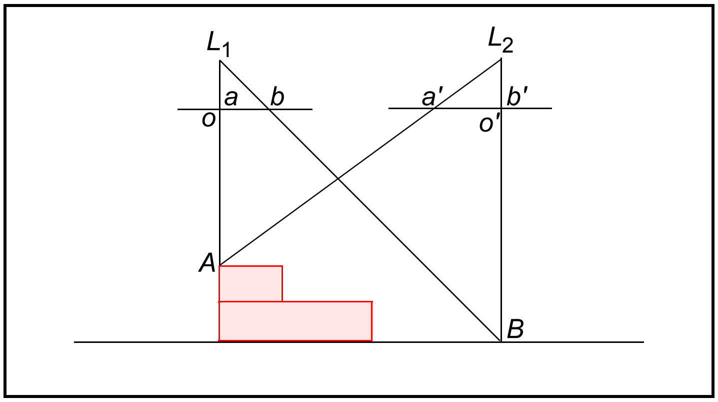
The following figures show the image positions of two ground points (A and B) displaying in the overlapping area of two images. Ground point A is located at the top of a building, and ground point B is located on the ground. The left and right images have the same features, but at different locations.

Figure 137: Image Pair Features in Different Locations



The following diagram illustrates a profile view of the image pair and the corresponding image positions of ground point A and ground point B.

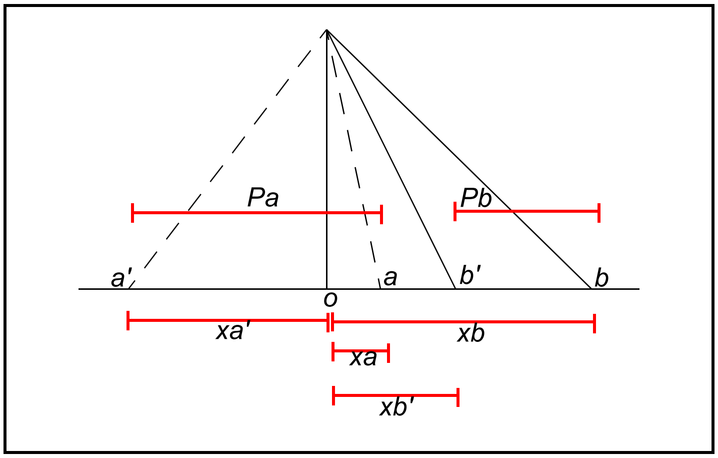
Figure 138: Profile View of an Image Pair



Ground points A and B display in the left photograph (L1) at image positions a and b, respectively. Due to the forward motion of the aircraft during photographic exposure, the same two ground points display in the right photograph (L2) at image positions *a'* and *b'*. Because ground point A is at a higher elevation, the movement of image point a to position a' on the right image is larger than the image movement of point b. This is attributed to X-parallax.

The following diagram illustrates that the parallax associated with ground point A, depicted in the illustration of profile view above. In the figure, (Pa) is larger than the parallax associated with ground point B depicted in the illustration of the profile view above (Pb).

Figure 139: Parallax Comparison between Points

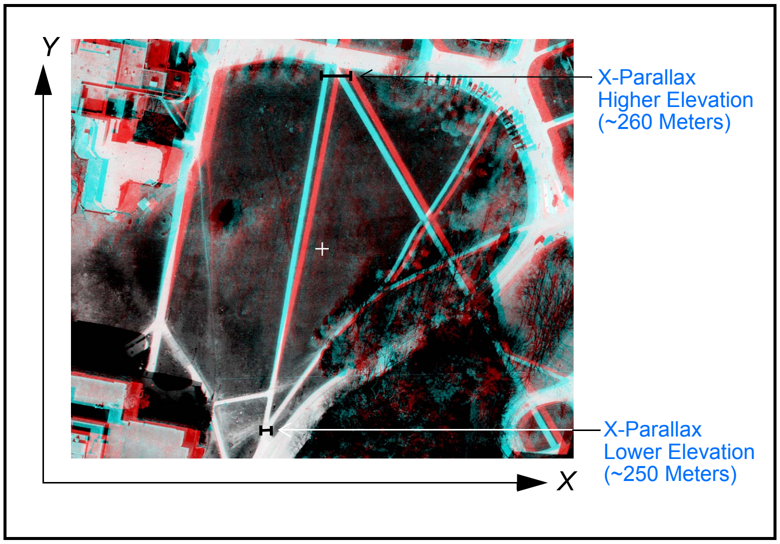


Thus, the amount of X-parallax is influenced by the elevation of a ground point. Because the degree of topographic relief varies across an image pair, the amount of X-parallax also varies. The brain perceives the variation in parallax between the ground and various features, and therefore judges the variations in elevation and height. The following figure illustrates the difference in elevation as a function of X-parallax.

Using 3D geographic imaging techniques, Stereo Analyst for ArcGIS translates and transforms the X-parallax information associated with features recorded by an image pair into quantitative height and elevation information.

The figure below shows parallax changes with increases and decreases in elevation.

Figure 140: Parallax Changes in Elevation



Correcting Y-Parallax

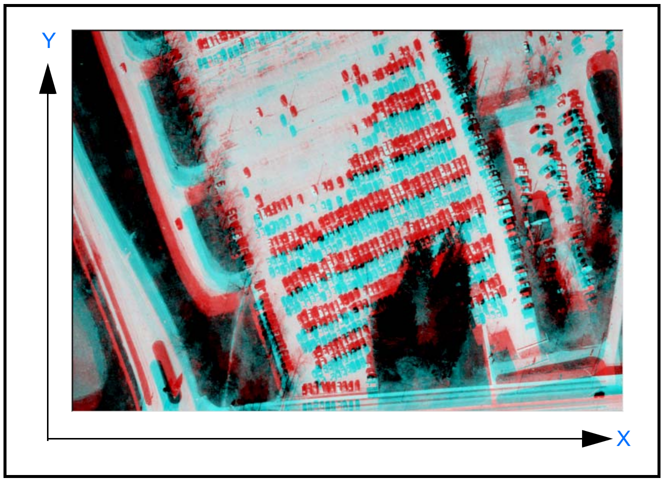
Under certain conditions, viewing a DSM is difficult. The following factors might influence the quality of stereo viewing:

- Unequal flying height between adjacent photographic exposures. This effect causes a difference in scale between the left and right images. As a result, the 3D stereo view becomes distorted.
- Flight line misalignment during photographic collection. This results in large differences in photographic orientation between two overlapping images. As a result, you experience eyestrain and discomfort while viewing the DSM.
- Erroneous sensor model information. Inaccurate sensor model information creates large differences in parallax between two images comprising a DSM.

As a result of these factors, the DSMs contain an effect referred to as Y-parallax, which introduces discomfort during stereo viewing.

The following figure displays a stereo model with a considerable amount of Y-parallax.

Figure 141: Y-Parallax Exists



The following figure displays the same stereo model without Y-parallax.

Figure 142: Y-Parallax Doesn't Exist

You must scale, translate, and rotate the images until a clear and comfortable stereo view is available to minimize Y-parallax. Scaling the stereo model involves adjusting the perceived scale of each image comprising an image pair. This is achieved by adjusting the scale (that is, relative height) of each image as required. Scaling the stereo model accounts for the differences in altitude as they existed when the left and right photographs were captured.

Translating the stereo model involves adjusting the relative X and Y positions of the left and right images to minimize X-parallax and Y-parallax. Translating the positions of the left and right images accounts for misaligned images along a flight line.

Rotating the left and right images adjusts for the large relative variation in orientation (that is, omega, phi, kappa) for them.

Note: Making these one-time adjustments imply that it is acceptable to remove errors at collection time. You cannot adjust Y-parallax directly in the stereo environment of Stereo Analyst for ArcGIS. Y-Parallax can be a symptom of an unacceptable triangulation result. You should address this issue by opening the project in a full photogrammetry package like LPS or SOCET SET and adjusting the triangulation of the images to improve the solution. Otherwise, your collection might be less accurate than required.

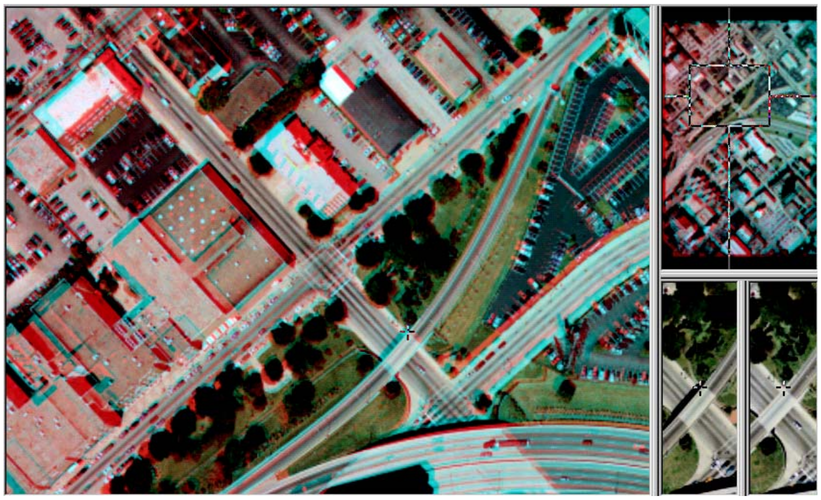
Using Scaling, Translation, and Rotation

When viewing a pair of tilted, overlapping photographs in stereo, the left and right images must be continually scaled, translated, and rotated to maintain a clear, continuous stereo model. Thus, it is your responsibility to adjust Y-parallax to create a clear stereo view. Once properly oriented, you should notice that the images are oriented parallel to the direction of flight, which was originally used to capture the photography.

When using DSMs created from sensor model information, Stereo Analyst for ArcGIS automatically rotates, scales, and translates the imagery to continually provide an optimum stereo view throughout the stereo model. Therefore, the Y-parallax is automatically accounted for. The process of automatically creating a clear stereo view is referred to as epipolar resampling on the fly. As you roam throughout a DSM, the software accounts and adjusts for Y-parallax automatically. Using OpenGL software technology, Stereo Analyst for ArcGIS automatically accounts for the tilt and rotation of the two images as they existed when the images were captured.

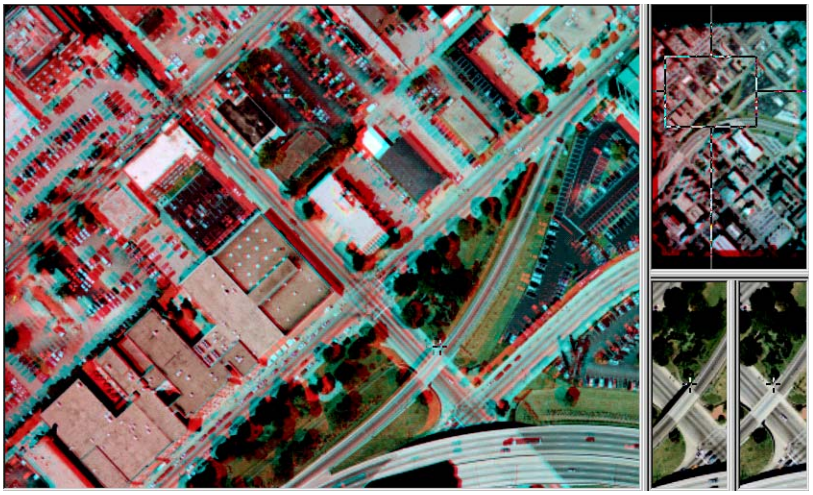
The following figure displays a DSM created without sensor model information.

Figure 143: DSM without Sensor Model Information



The following figure displays the use of epipolar resampling techniques for viewing a DSM created with sensor model information.

Figure 144: DSM with Sensor Model Information



As a result of using automatic epipolar resampling display techniques, you can collect 3D GIS data at a higher accuracy.

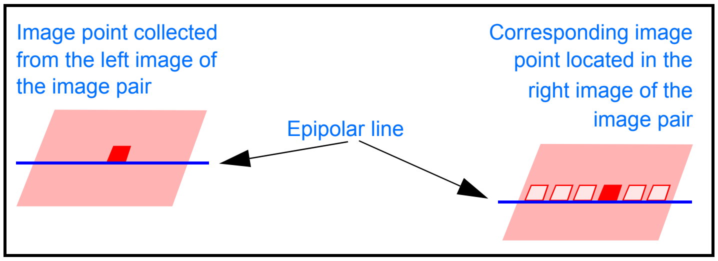
Understanding the Epipolar Line

Geometric and radiometric characteristics (derived from sensor model information and image gray values) associated with the images comprising an image pair are used to constrain the image matching process to produce highly accurate and reliable matching image point pairs.

The most common constraint, which is epipolar geometry associated with an image pair, is used to constrain the search area used to establish a pair of matching image points.

The following diagram illustrates an image point on a reference image being located along the epipolar line of an adjacent overlapping image.

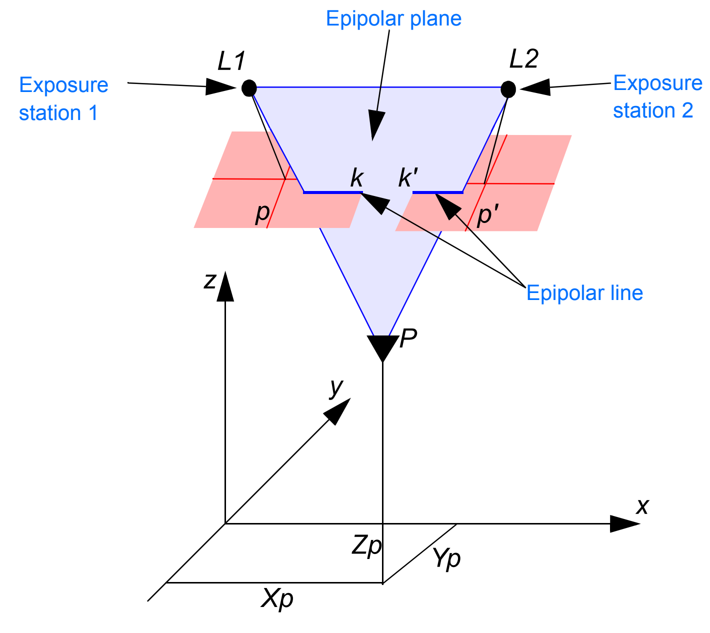
Figure 145: Matching Image Points on the Epipolar Line



The following diagram illustrates the image matching process using the epipolar plane as a geometric constraint. The figure shows the epipolar plane, which is the plane that is defined by the two exposure stations (L1 and L2), and the ground point, P. The lines pk and k'p' are the epipolar lines and are defined by the intersection of the images and the epipolar plane. Using epipolar constraint in the matching process transforms the matching problem from a two-dimensional problem to a one-dimensional problem, and is therefore beneficial because it reduces both the search area and the computation time (Wolf 1983).

The epipolar plane can be used as a geometric constraint to aid in the identification of matching points, as shown below.

Figure 146: Epipolar Plane as a Geometric Constraint



Source: Keating et al 1975

Epipolar geometry is also commonly associated with the coplanarity condition. The coplanarity condition states that the two sensor exposure stations of an image pair, any ground point, and the corresponding image position on the two images must all exist in a common plane.

The common plane is also referred to as the epipolar plane. The epipolar plane intersects the left and right images, and the lines of intersection are referred to as epipolar lines. The image positions of a ground point displaying in the left and right photos are located along the epipolar line. The searching and matching process for digital image matching occurs along a straight line (that is, the epipolar line), thus simplifying the matching process. The epipolar constraint can only be applied if the image orientation and position of each sensor are solved.

Applying Photogrammetry

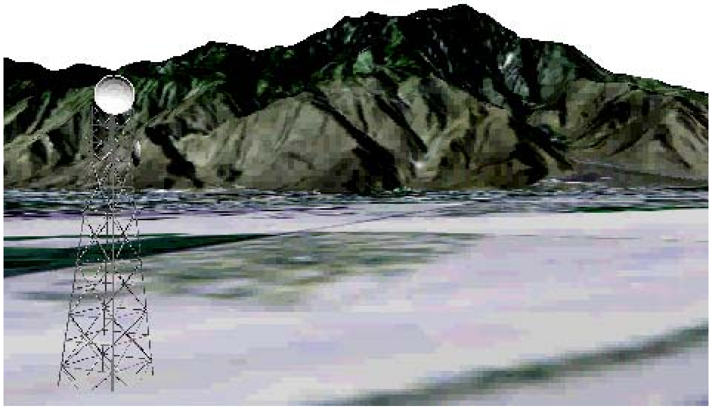
This chapter provides you with detailed, technical information about photogrammetry, which is the foundation for stereo viewing.

IN THIS CHAPTER

Learning Principles of Photogrammetry

Photogrammetric principles are used to extract topographic information from aerial photographs and imagery. The following figure illustrates rugged topography. This type of topography can be viewed in 3D using Stereo Analyst for ArcGIS.

Figure 147: 3D Topography



Understanding Photogrammetry

Photogrammetry is the “art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena” (American Society of Photogrammetry 1980).

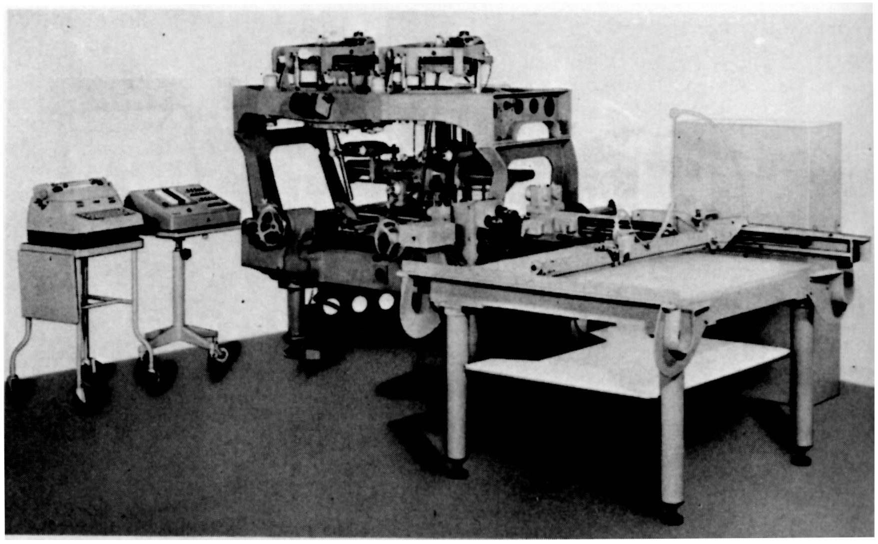
Photogrammetry was invented in 1851 by Aimé Laussedat, and has continued to develop. Over time, the development of photogrammetry has passed through the phases of plane table photogrammetry, analog photogrammetry, analytical photogrammetry, and has now entered the phase of digital photogrammetry (Konecny 1994).

The traditional, and largest, application of photogrammetry is to extract topographic and planimetric information (such as topographic maps) from aerial images. However, photogrammetric techniques have also been applied to process satellite images and close-range images to acquire topographic or nontopographic information about photographed objects. Topographic information includes spot height information, contour lines, and elevation data. Planimetric information includes the geographic location of buildings, roads, rivers, and so on.

Prior to the invention of the airplane, photographs taken on the ground were used to extract the relationship between objects using geometric principles. This was during the phase of plane table photogrammetry.

In analog photogrammetry, starting with stereo measurement in 1901, optical or mechanical instruments, such as the analog plotter, were used to reconstruct 3D geometry from two overlapping photographs. The main product during this phase was topographic maps.

Figure 148: Analog Stereo Plotter



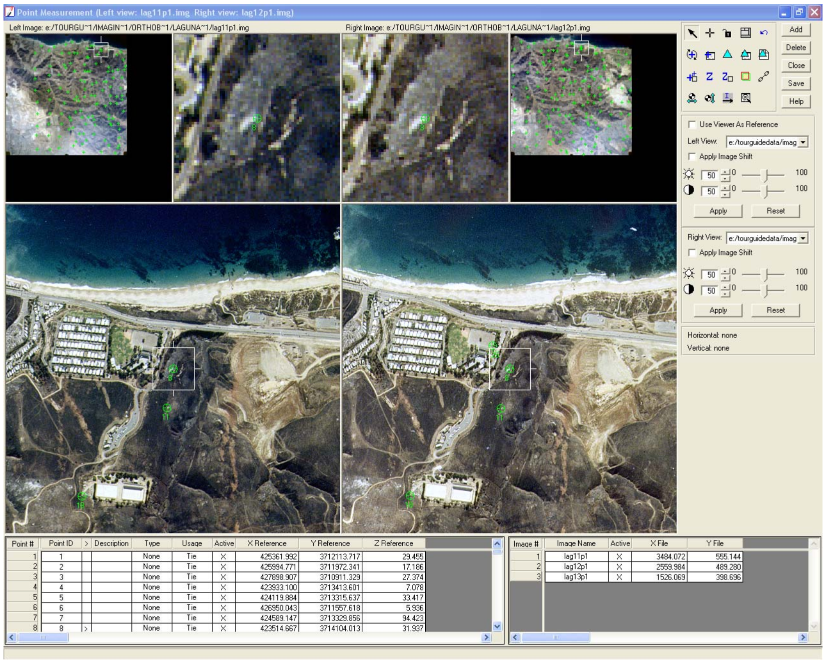
In analytical photogrammetry, the computer replaced some expensive optical and mechanical components. The resulting devices were analog/digital hybrids. Analytical aerotriangulation, analytical plotters, and orthophoto projectors were the main developments during this phase. Outputs of analytical photogrammetry can be topographic maps, but can also be digital products, such as digital maps and DEMs.

Digital photogrammetry, sometimes called softcopy photogrammetry, is photogrammetry applied to digital images that are stored and processed on a computer. Digital images can be scanned from photographs or directly captured by digital cameras. Many photogrammetric tasks can be highly automated in digital photogrammetry (such as automatic DEM extraction and digital orthophoto generation).

The output products are in digital form, such as digital maps, DEMs, and digital orthophotos saved on computer storage media. Therefore, they can be easily stored, managed, and used. With the development of digital photogrammetry, photogrammetric techniques are more closely integrated into remote sensing and GIS.

Digital photogrammetric systems employ sophisticated software to automate the tasks associated with conventional photogrammetry, thereby minimizing the extent of manual interaction required to perform photogrammetric operations. One such application is LPS, the interface of which is shown in the illustration below.

Figure 149: LPS Classic Stereo Point Measurement Tool



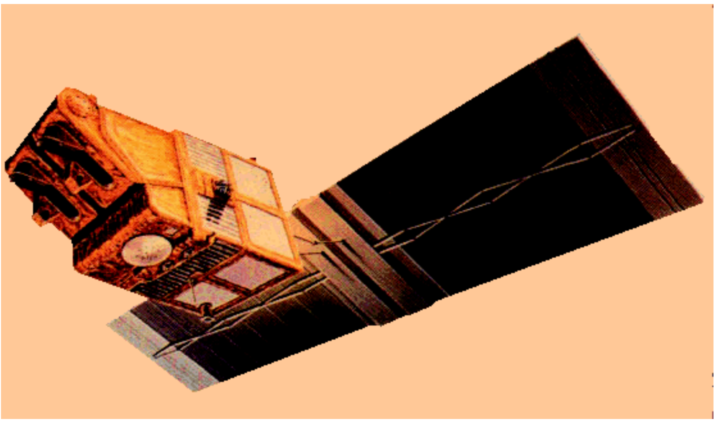
You can use photogrammetry to measure and interpret information from hardcopy photographs or images. Sometimes the process of measuring information from photography and satellite imagery is called metric photogrammetry. Interpreting information from photography and imagery is considered interpretative photogrammetry, such as identifying and discriminating between various tree types (Wolf 1983).

Identifying Photographs and Images

The types of photographs and images you can process include aerial, terrestrial, close-range, and oblique. Aerial or vertical (near vertical) photographs and images are taken from a high vantage point above the Earth’s surface. The camera axis of aerial or vertical photography is commonly directed vertically (or near vertically) down. Aerial photographs and images are commonly used for topographic and planimetric mapping projects and are commonly captured from an aircraft or satellite.

The following figure illustrates a satellite. Satellites use onboard cameras to collect high-resolution images of the Earth's surface.

Figure 150: Common Satellite



Terrestrial or ground-based photographs and images are taken with the camera stationed on or close to the Earth's surface. Terrestrial and close-range photographs and images are commonly used for applications involved with archeology, geomorphology, civil engineering, architecture, industry, and so on.

Oblique photographs and images are similar to aerial photographs and images, except the camera axis is intentionally inclined at an angle with the vertical. Oblique photographs and images are commonly used for reconnaissance and corridor mapping applications.

Digital photogrammetric systems use digitized photographs or digital images as the primary source of input. Digital imagery can be obtained from various sources, including:

- Digitizing existing hardcopy photographs
- Using digital cameras to record imagery
- Using sensors onboard satellites such as Landsat, SPOT, and IRS to record imagery

Using Terminology

This document uses the term imagery in reference to photography and imagery obtained from various sources. This includes aerial and terrestrial photography, digital and video camera imagery, 35 millimeter photography, medium to large format photography, scanned photography, and satellite imagery.

Using Photogrammetry

Raw aerial photography and satellite imagery have large geometric distortion that is caused by various systematic and nonsystematic factors. Photogrammetric processes eliminate these errors most efficiently and provide the most reliable solution for collecting geographic information from raw imagery. Photogrammetry is unique in terms of considering the image-forming geometry, utilizing information between overlapping images, and explicitly dealing with the third dimension, which is elevation.

Photogrammetric techniques allow for the collection of the following geographic data:

- 3D GIS Vectors
- DTMs (which include TINs and DEMs)
- Orthorectified Images
- DSMs
- Topographic Contours

In essence, photogrammetry produces accurate and precise geographic information from a wide range of photographs and images. Any measurement taken on a photogrammetrically processed photograph or image reflects a measurement taken on the ground. Photogrammetric tools let you accurately collect information from imagery instead of constantly going to the field to measure distances, areas, angles, and point positions on the Earth’s surface. Photogrammetric approaches for collecting geographic information save time and money, and maintain the highest accuracies.

Acquiring Images and Data

During photograph or image collection, overlapping images are exposed along a direction of flight. Most photogrammetric applications involve the use of overlapping images. By using more than one image, you can define the geometry associated with the camera/sensor, image, and ground with greater accuracy.

During the collection of imagery, each point in the flight path at which the camera exposes the film, or the sensor captures the imagery, is called an exposure station.

Figure 151: Exposure Stations in Red over Rough Terrain

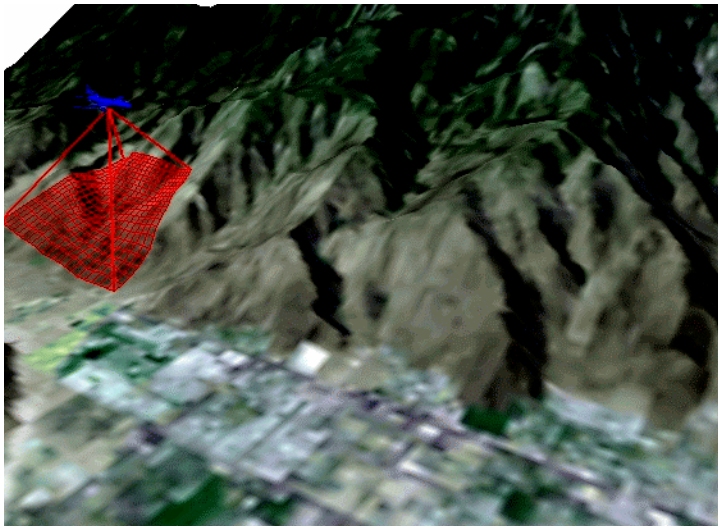
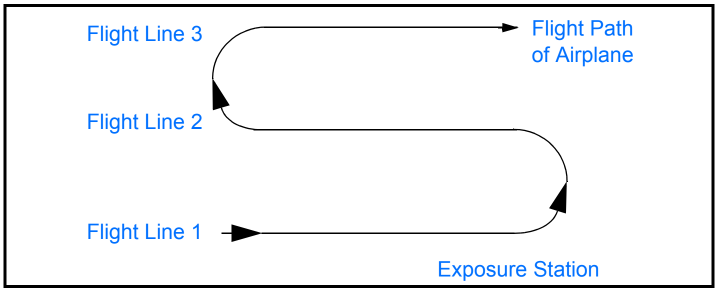


Figure 152: Exposure Stations in Blue along a Flight Path



Each photograph or image that is exposed has a corresponding image scale (SI) associated with it. The SI expresses the average ratio between a distance in the image and the same distance on the ground. It is computed as focal length divided by the flying height above the mean ground elevation. For example, with a flying height of 1000 meters and a focal length of 15 centimeters, the SI is 1:6667.

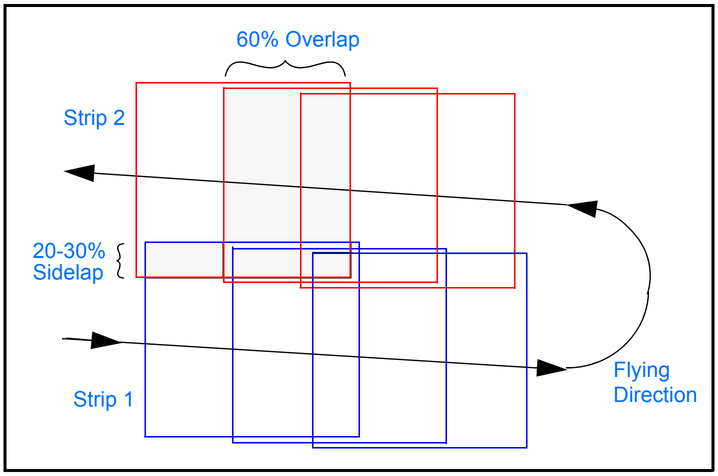
Note: The flying height above ground is used to determine SI, versus the altitude above sea level.

A strip of photographs consists of images captured along a flight line, normally with an overlap of 60 percent. All photos in the strip are assumed to be taken at approximately the same flying height and with a constant distance between exposure stations. Camera tilt relative to the vertical is assumed to be minimal.

You can combine the photographs from several flight paths to form a block of photographs. A block of photographs consists of a number of parallel strips, normally with a sidelap of 20-30 percent.

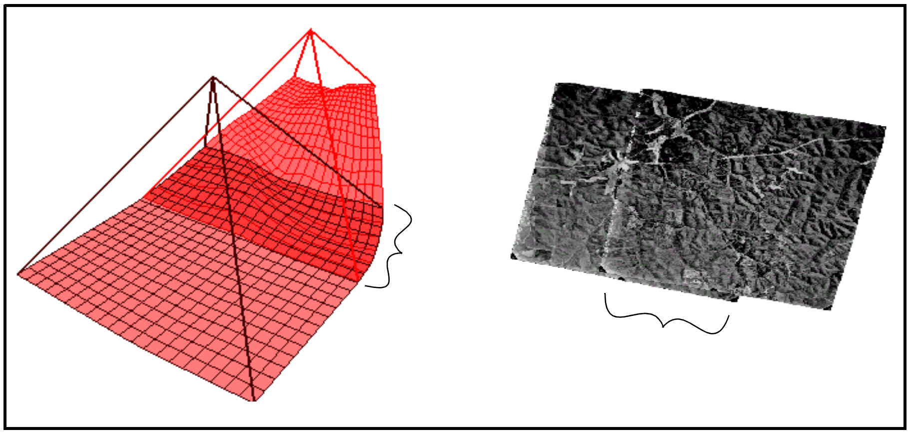
A regular block of photographs is commonly a rectangular block in which the number of photos in each strip is the same. The following illustration shows a block of 3 × 2 photographs. In cases where a nonlinear feature is being mapped (such as a river), photographic blocks are frequently irregular.

Figure 153: Regular Rectangular Block of Aerial Photos



The area of overlap is indicated by the curly brackets as shown below.

Figure 154: Two Overlapping Images



Scanning Aerial Photography

Photogrammetric scanners are special devices capable of high image quality and excellent positional accuracy. Use of this type of scanner results in geometric accuracies similar to traditional analog and analytical photogrammetric instruments. Photogrammetric scanners are necessary for digital photogrammetric applications that have high accuracy requirements.

These units usually scan only film because film is superior to paper, both in terms of image detail and geometry. These units usually have a root mean square error (RMSE) positional accuracy of 4 microns or less, and are capable of scanning at a maximum resolution of 5 to 10 microns (5 microns is equivalent to approximately 5,000 pixels per inch).

The required pixel resolution varies depending on the application. Aerial triangulation and feature collection applications often scan in the 10 to 15 micron range. Orthophoto applications often use 15 to 30 micron pixels. Color film is less sharp than panchromatic; therefore, color ortho applications often use 20 to 40 micron pixels. The optimum scanning resolution also depends on the needed photogrammetric output accuracy. Scanning at higher resolutions provides data with higher accuracy.

Using Desktop Scanners

Desktop scanners are general-purpose devices. They lack the image detail and geometric accuracy of photogrammetric-quality units, but they are much less expensive. When using a desktop scanner, you should make sure that the active area is at least 9 × 9 inches, which lets you capture the entire photo frame.

Desktop scanners are appropriate for less rigorous uses, such as digital photogrammetry in support of GIS or remote sensing applications. Calibrating these units improves geometric accuracy, but the results are still inferior to photogrammetric units. The image correlation techniques that are necessary for automatic tie point collection and elevation extraction are often sensitive to scan quality. Therefore, errors attributable to scanning errors can be introduced into GIS data that is photogrammetrically derived.

Choosing Scanning Resolutions

One of the primary factors contributing to the overall accuracy of 3D feature collection is the resolution of the imagery being used. Image resolution is commonly determined by the scanning resolution (if film photography is being used), or by the pixel resolution of the sensor.

The scanning resolution must be considered to optimize the attainable accuracy of GIS data collection. The appropriate scanning resolution is determined by balancing the accuracy requirements versus the size of the mapping project and the time required to process the project.

This table lists the scanning resolutions associated with various scales of photography.

Table 1: Photography Scanning Resolutions

	12 microns (2117 dots per inch)	16 microns (1588 dots per inch)	25 microns (1016 dots per inch)	50 microns (508 dots per inch)	85 microns (300 dots per inch)
Photo Scale 1 to	Ground Coverage (meters)	Ground Coverage (meters)	Ground Coverage (meters)	Ground Coverage (meters)	Ground Coverage (meters)
1800	0.0216	0.0288	0.045	0.09	0.153
2400	0.0288	0.0384	0.060	0.12	0.204
3000	0.0360	0.0480	0.075	0.15	0.255
3600	0.0432	0.0576	0.090	0.18	0.306
4200	0.0504	0.0672	0.105	0.21	0.357
4800	0.0576	0.0768	0.120	0.24	0.408
5400	0.0648	0.0864	0.135	0.27	0.459
6000	0.0720	0.0960	0.150	0.30	0.510
6600	0.0792	0.1056	0.165	0.33	0.561
7200	0.0864	0.1152	0.180	0.36	0.612
7800	0.0936	0.1248	0.195	0.39	0.663
8400	0.1008	0.1344	0.210	0.42	0.714
9000	0.1080	0.1440	0.225	0.45	0.765
9600	0.1152	0.1536	0.240	0.48	0.816
10800	0.1296	0.1728	0.270	0.54	0.918
12000	0.1440	0.1920	0.300	0.60	1.020
15000	0.1800	0.2400	0.375	0.75	1.275
18000	0.2160	0.2880	0.450	0.90	1.530
24000	0.2880	0.3840	0.600	1.20	2.040
30000	0.3600	0.4800	0.750	1.50	2.550

This table lists image file sizes associated with various scales of photography.

Table 2: Image File Sizes

	12 microns (2117 dots per inch)	16 microns (1588 dots per inch)	25 microns (1016 dots per inch)	50 microns (508 dots per inch)	85 microns (300 dots per inch)
Photo Scale 1 to	Ground Coverage (meters)	Ground Coverage (meters)	Ground Coverage (meters)	Ground Coverage (meters)	Ground Coverage (meters)
40000	0.4800	0.6400	1.000	2.00	3.400
50000	0.6000	0.8000	1.250	2.50	4.250
60000	0.7200	0.9600	1.500	3.00	5.100
B/W File Size (MB)	363	204	84	21	7
Color File Size (MB)	1089	612	252	63	21

Note: The Ground Coverage column refers to the ground coverage per pixel. Thus, a 1:40000 scale black-and-white photograph scanned at 25 microns (1016 dots per inch) has a ground coverage per pixel of 1 meter × 1 meter. The resulting file size is approximately 85 MB, assuming a square 9 × 9 inch photograph.

Understanding Coordinate Systems

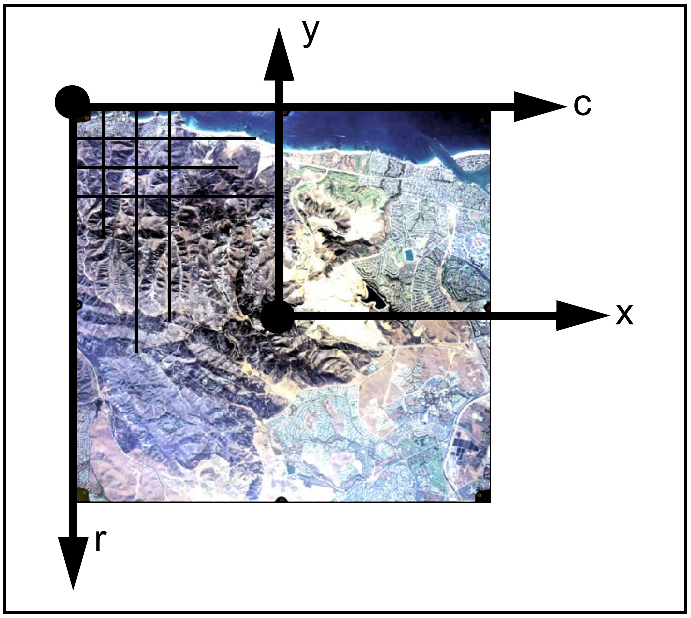
Conceptually, photogrammetry involves establishing the relationship between the camera or sensor used to capture the imagery, the imagery itself, and the ground. You must define each of the three variables associated with the relationship with respect to a coordinate space and coordinate system to understand and define this relationship.

Applying a Pixel Coordinate System

The file coordinates of a digital image are defined in a pixel coordinate system. A pixel coordinate system is usually a coordinate system with its origin in the upper-left corner of the image, the x-axis pointing to the right, the y-axis pointing downward, and the units in pixels, as shown by axes c and r in the following illustration. These file coordinates (c, r) can also be thought of as the pixel column and row numbers, respectively.

This illustration shows the origin of the image coordinate system (x, y) and the origin of the pixel coordinate system (c, r).

Figure 155: Origin of Image and Pixel Coordinate Systems



Applying an Image Coordinate System

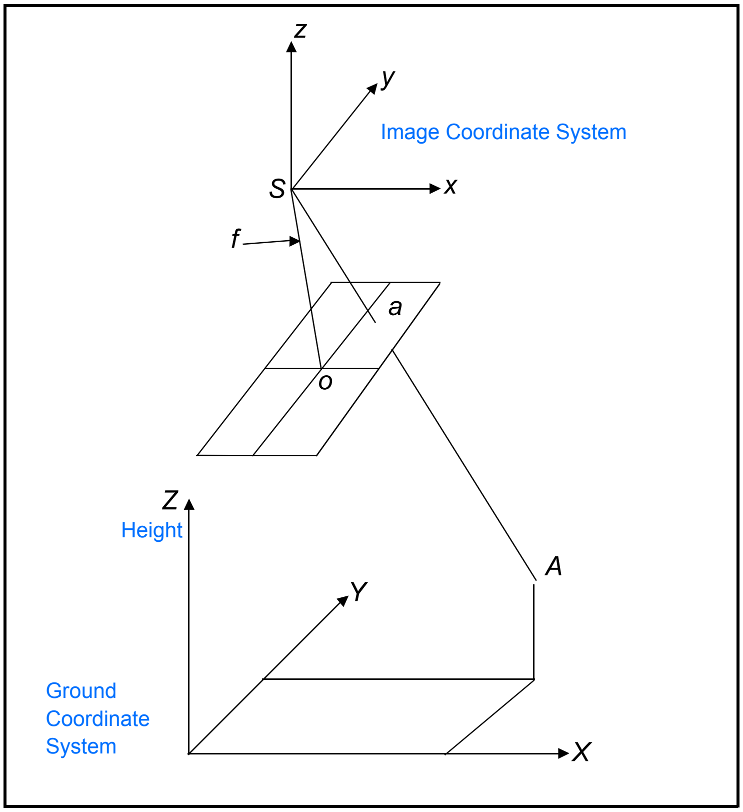
An image coordinate system or an image plane coordinate system is usually defined as a 2D coordinate system occurring on the image plane with its origin at the image center. The origin of the image coordinate system is also referred to as the principal point. On aerial photographs, the principal point is defined as the intersection of opposite fiducial marks as illustrated by axes x and y as in the previous diagram.

Image coordinates are used to describe positions on the film plane. Image coordinate units are usually millimeters or microns.

Applying an Image Space Coordinate System

An image space coordinate system (see the following illustration) is identical to image coordinates, except that it adds a third axis (z). The origin of the image space coordinate system is defined at the perspective center S as shown in the following illustration.

Figure 156: Image and Ground Space Coordinate Systems



The perspective center is commonly the lens of the camera as it existed when the photograph was captured. Its x-axis and y-axis are parallel to the x-axis and y-axis in the image plane coordinate system. The z-axis is the optical axis; therefore, the z value of an image point in the image space coordinate system is usually equal to the focal length of the camera (*f*). Image space coordinates are used to describe positions inside the camera, and usually use units in millimeters or microns. This coordinate system is referenced as image space coordinates (x, y, z) in this chapter.

Applying the Ground Coordinate System

A ground coordinate system is usually defined as a 3D coordinate system that utilizes a known geographic map projection. Ground coordinates (X, Y, Z) are usually expressed in feet or meters. The Z value is elevation above mean sea level for a given vertical datum. This coordinate system is referenced as ground coordinates (X, Y, Z) in this chapter.

Applying the Geocentric and Topocentric Coordinate Systems

Most photogrammetric applications account for the Earth's curvature in their calculations. This is done by adding a correction value or by computing geometry in a coordinate system that includes curvature. Two such systems are the geocentric coordinate system and the topocentric coordinate system:

- A geocentric coordinate system has its origin at the center of the Earth ellipsoid. The Z-axis equals the rotational axis of the Earth, and the X-axis passes through the Greenwich meridian. The Y-axis is perpendicular to both the Z-axis and X-axis, so as to create a three-dimensional coordinate system that follows the right hand rule.

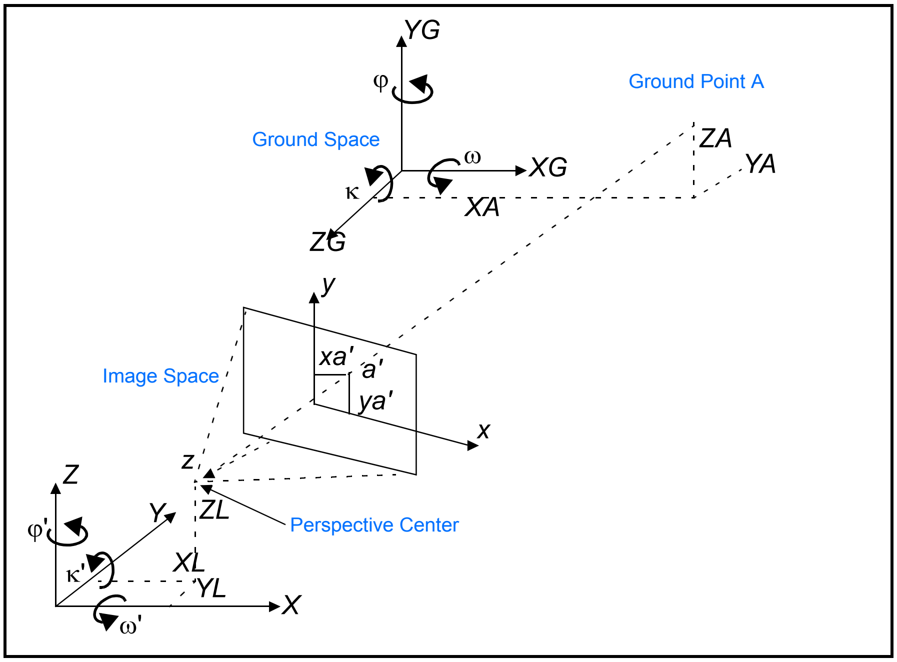
- A topocentric coordinate system has its origin at the center of the image projected on the Earth ellipsoid. The three perpendicular coordinate axes are defined on a tangential plane at this center point. The plane is called the reference plane or the local datum. The X-axis is oriented eastward, the Y-axis northward, and the Z-axis is vertical to the reference plane (up).

The remainder of this chapter does not explicitly reference geocentric or topocentric coordinates. Basic photogrammetric principles are presented without adding this additional level of complexity.

Using Terrestrial Photography

Photogrammetric applications associated with terrestrial or ground-based images utilize slightly different image and ground space coordinate systems. The following figure illustrates the two coordinate systems associated with image space and ground space.

Figure 157: Terrestrial Photography Components



The image and ground space coordinate systems are right-handed coordinate systems. Most terrestrial applications use a ground space coordinate system defined using a localized Cartesian coordinate system.

The image space coordinate system directs the z-axis toward the imaged object and the y-axis directed north up. The image x-axis is similar to that used in aerial applications. The XL, YL, and ZL coordinates define the position of the perspective center as it existed at the time of image capture. The coordinates of ground point A (XA, YA, and ZA) are defined within the ground space coordinate system (XG, YG, and ZG).

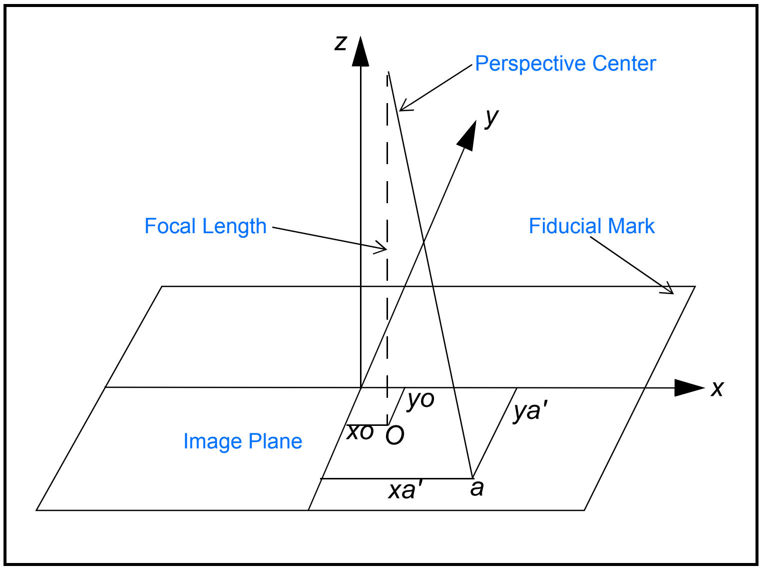
With this definition, three rotation angles ω (omega), φ (phi), and κ (kappa) define the orientation of the image. You can also use the ground (X, Y, Z) coordinate system to directly define GCPs. Thus, GCPs do not need transforming. The definition of rotation angles ω', φ', and κ' is different, as shown in **Figure 157** on page 312.

Understanding interior Orientation

Interior orientation defines the internal geometry of a camera or sensor as it existed at the time of image capture. The variables associated with image space are obtained during the process of defining interior orientation. Interior orientation is primarily used to transform the image pixel coordinate system or other image coordinate measurement systems to the image space coordinate system.

The following figure illustrates the variables associated with the internal geometry of an image captured from an aerial camera, where O represents the principal point and *a* represents an image point.

Figure 158: Components of Internal Geometry


z
Perspective Center
y
Focal Length
Fiducial Mark
x
yo
ya'
xo
O
Image Plane
xa'
a

The internal geometry of a camera is defined by specifying the following variables:

- **Principal Point**
- Focal Length
- Fiducial Marks
- Lens Distortion

Defining Principal Point and Focal Length

The principal point is mathematically defined as the intersection of the perpendicular line through the perspective center of the image plane. The length from the principal point to the perspective center is called the focal length (Wang 1990).

The image plane is commonly referred to as the focal plane. For wide-angle aerial cameras, the focal length is approximately 152 millimeters, or 6 inches. For some digital cameras, the focal length is 28 millimeters. Prior to conducting photogrammetric projects, the focal length of a metric camera is accurately determined (calibrated) in a laboratory environment.

The optical definition of principal point is the image position where the optical axis intersects the image plane. In the laboratory, this is calibrated in two forms: principal point of autocollimation and principal point of symmetry, which you can see in the camera calibration report. Most applications prefer to use the principal point of symmetry because it can best compensate for any lens distortion.

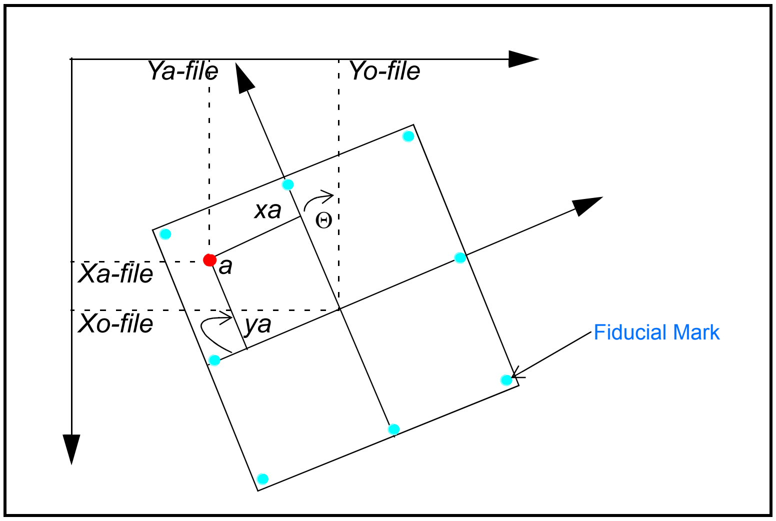
Defining Fiducial Marks

As stated previously, one of the steps associated with calculating interior orientation involves determining the image position of the principal point for each image in the project. Therefore, the image positions of the fiducial marks are measured on the image, and then compared to the calibrated coordinates of each fiducial mark.

The measured image coordinates of the fiducial marks are referenced to a pixel or file coordinate system because the image space coordinate system has not yet been defined for each image. The pixel coordinate system has an x coordinate (column) and a y coordinate (row). The origin of the pixel coordinate system is the upper-left corner of the image having a row and column value of 0 and 0, respectively.

The following diagram illustrates the difference between the pixel coordinate system and the image space coordinate system.

Figure 159: Pixel Versus Image Space Coordinate System



Using a 2D affine transformation, the relationship between the pixel coordinate system and the image space coordinate system is defined. You can use the following 2D affine transformation equations to determine the coefficients required to transform pixel coordinate measurements to the corresponding image coordinate values:

$$x = a_1 + a_2 X + a_3 Y$$

$$y = b_1 + b_2 X + b_3 Y$$

The x and y image coordinates associated with the calibrated fiducial marks and the X and Y pixel coordinates of the measured fiducial marks are used to determine six affine transformation coefficients. The resulting six coefficients are then used to transform each set of row (y) and column (x) pixel coordinates to image coordinates.

The quality of the 2D affine transformation is represented using an RMSE. The RMSE represents the degree of correspondence between the calibrated fiducial mark coordinates and their respective measured image coordinate values. Large RMSEs indicate poor correspondence. This is attributed to film deformation, poor scanning quality, out-of-date calibration information, or image mismeasurement.

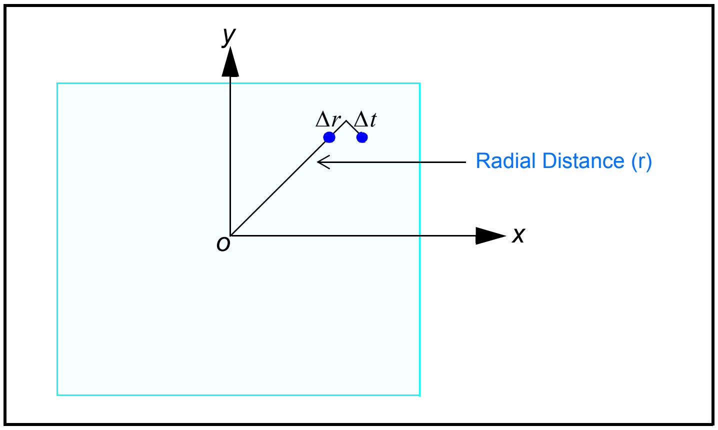
The affine transformation also defines the translation between the origin of the pixel coordinate system and the image coordinate system (xo-file and yo-file). Additionally, the affine transformation takes into consideration the rotation of the image coordinate system by considering angle Θ (theta). A scanned image of an aerial photograph is normally rotated due to the scanning procedure.

The degree of variation between the x-axis and y-axis is referred to as nonorthogonality. The 2D affine transformation also considers the extent of nonorthogonality. The scale difference between the x-axis and the y-axis is also considered using the affine transformation.

Defining Lens Distortion

Lens distortion deteriorates the positional accuracy of image points located on the image plane. Two types of radial lens distortion exist: radial lens distortion and tangential lens distortion. Lens distortion occurs when light rays passing through the lens are bent, thereby changing direction and intersecting the image plane at positions deviant from the norm. The following diagram illustrates the difference between radial and tangential lens distortion.

Figure 160: Radial versus Tangential Lens Distortion



Radial lens distortion causes imaged points distort along radial lines from the principal point *o*. The effect of radial lens distortion is represented as Δr. Radial lens distortion is also commonly referred to as symmetric lens distortion.

Tangential lens distortion occurs at right angles to the radial lines from the principal point. The effect of tangential lens distortion is represented as Δt. Because tangential lens distortion is much smaller in magnitude than radial lens distortion, it is considered negligible. The effects of lens distortion are commonly determined in a laboratory during the camera calibration procedure.

Understanding Exterior Orientation

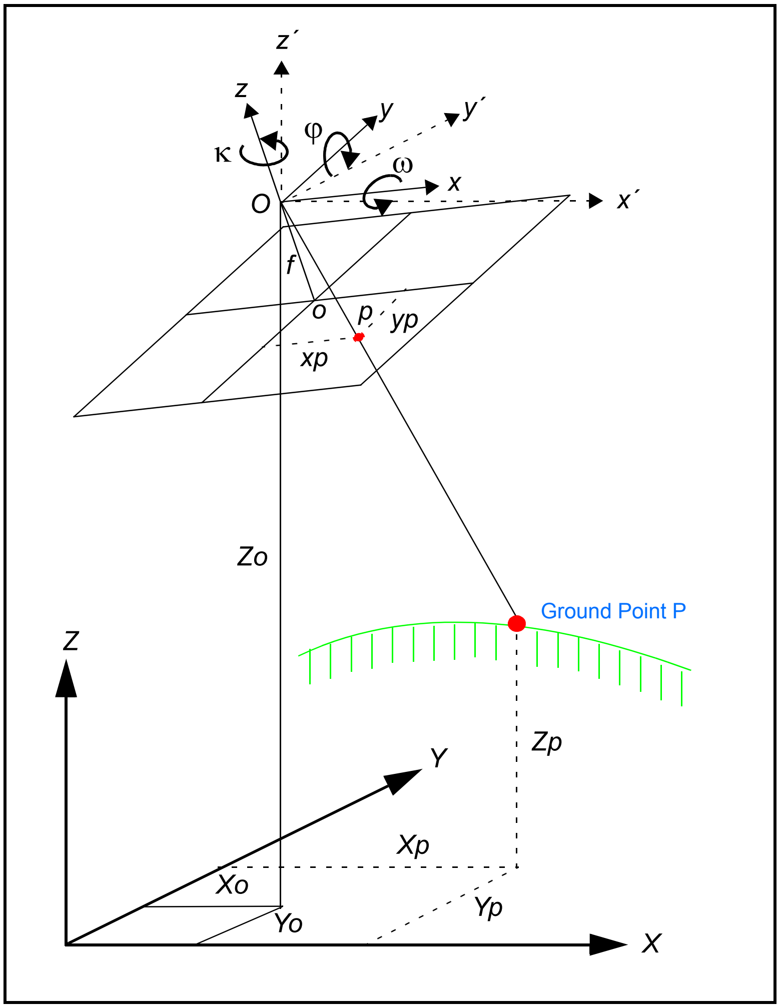
Exterior orientation defines the position and angular orientation of the camera that captured an image. The variables defining the position and orientation of an image are referred to as the elements of exterior orientation. The elements of exterior orientation define the characteristics associated with an image at the time of exposure or capture.

The positional elements of exterior orientation include X_o, Y_o, and Z_o. They define the position of the perspective center (O) with respect to the ground space coordinate system (X, Y, and Z). Z_o is commonly referred to as the height of the camera above sea level, which is commonly defined by a datum.

The angular or rotational elements of exterior orientation describe the relationship between the ground space coordinate system (X, Y, and Z) and the image space coordinate system (x, y, and z). Three rotation angles are commonly used to define angular orientation. They are omega (ω), phi (φ), and kappa (κ).

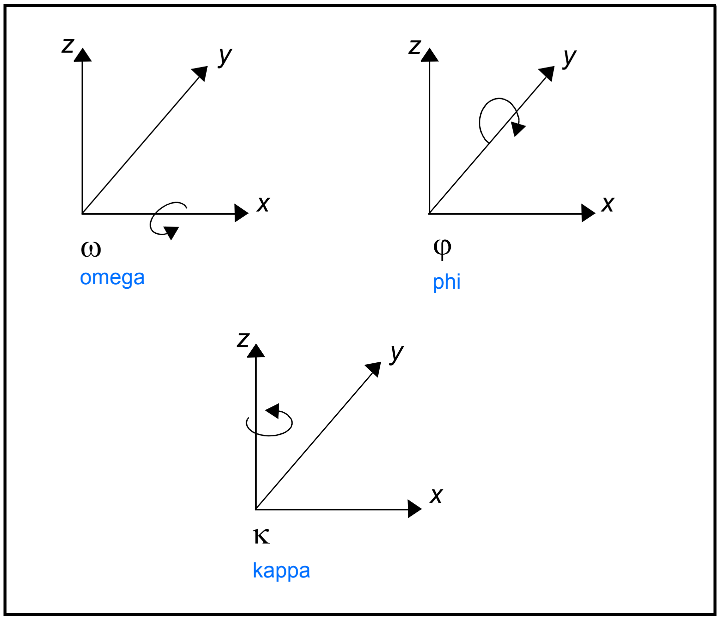
The following figure illustrates the elements of exterior orientation.

Figure 161: Elements of Exterior Orientation


z´
z
y
y´
φ
κ
ω
x
O
x´
f
o
p
yp
xp
Zo
Ground Point P
Z
Zp
Y
Xp
Xo
Yo
Yp
X

The following figure illustrates the individual angles (ω, φ, and κ) of exterior orientation. Angles omega, phi, and kappa correspond to X, Y, and Z axes.

Figure 162: Angles of Exterior Orientation



Omega is a rotation about the photographic x-axis, phi is a rotation about the photographic y-axis, and kappa is a rotation about the photographic z-axis, which are defined as being positive if they are counterclockwise when viewed from the positive end of their respective axis. Different conventions are used to define the order and direction of the three rotation angles (Wang 1990).

The International Society of Photogrammetry and Remote Sensing (ISPRS) recommends the use of the ω, φ, κ convention. The photographic z-axis is equivalent to the optical axis (focal length). The *x′*, *y′*, and *z′* coordinates are parallel to the ground space coordinate system.

Using the three rotation angles, the relationship between the image space coordinate system (x, y, and z) and ground space coordinate system (X, Y, and Z or x', y', and z') can be determined. A 3 × 3 matrix defining the relationship between the two systems is used. This is referred to as the orientation or rotation matrix, M. The rotation matrix can be defined as follows:

$$M = \begin{bmatrix} m_{11} & m_{12} & m_{13} \\ m_{21} & m_{22} & m_{23} \\ m_{31} & m_{32} & m_{33} \end{bmatrix}$$

The rotation matrix is derived by applying a sequential rotation of omega about the x-axis, phi about the y-axis, and kappa about the z-axis.

Defining the Collinearity Equation

The following section defines the relationship between the camera or sensor, the image, and the ground. Most photogrammetric tools utilize the following formulas in one form or another.

With reference to **Figure 161** on page 317, image vector *a* can be defined as the vector from the exposure station *O* to the image point *p*. A ground space or object space vector *A* can be defined as the vector from the exposure station *O* to the ground point *P*. The image vector and ground vector are collinear, inferring that a line extending from the exposure station to the image point and to the ground is linear.

The image vector and ground vector are only collinear if one is a scalar multiple of the other. Therefore, the following statement can be made:

$$a = kA$$

where *k* is a scalar multiple. The image and ground vectors must be within the same coordinate system. Therefore, image vector *a* is comprised of the following components:

$$a = \begin{bmatrix} x_p - x_o \\ y_p - y_o \\ -f \end{bmatrix}$$

where x_o and y_o represent the image coordinates of the principal point. Similarly, the ground vector can be formulated as follows:

$$A = \begin{bmatrix} X_p - X_o \\ Y_p - Y_o \\ Z_p - Z_o \end{bmatrix}$$

The ground vector must be multiplied by the rotation matrix *M* for the image and ground vectors to be within the same coordinate system. The following equation can be formulated:

$$a = kMA$$

where

$$\begin{bmatrix} x_p - x_o \\ y_p - y_o \\ -f \end{bmatrix} = kM \begin{bmatrix} X_p - X_o \\ Y_p - Y_o \\ Z_p - Z_o \end{bmatrix}$$

The previous equation defines the relationship between the perspective center of the camera/sensor exposure station and ground point *P* displaying on an image with an image point location of *p*. This equation forms the basis of the collinearity condition that is used in most photogrammetric operations. The collinearity condition specifies that the exposure station of the image, ground point, and its corresponding image point location must all fall along a straight line, thereby being collinear.

Two equations comprise the collinearity condition:

$$x_p - x_o = -f\left[\frac{m_{11}(X_p - X_{o_1}) + m_{12}(Y_p - Y_{o_1}) + m_{13}(Z_p - Z_{o_1})}{m_{31}(X_p - X_{o_1}) + m_{32}(Y_p - Y_{o_1}) + m_{33}(Z_p - Z_{o_1})}\right]$$

$$y_p - y_o = -f\left[\frac{m_{21}(X_p - X_{o_1}) + m_{22}(Y_p - Y_{o_1}) + m_{23}(Z_p - Z_{o_1})}{m_{31}(X_p - X_{o_1}) + m_{32}(Y_p - Y_{o_1}) + m_{33}(Z_p - Z_{o_1})}\right]$$

One set of equations can be formulated for each ground point displaying on an image. The collinearity condition is commonly used to define the relationship between the camera/sensor, the image, and the ground.

Using Digital Mapping Solutions

Digital photogrammetry is used for many applications including orthorectification, automated elevation extraction, image pair creation, stereo feature collection, highly accurate 3D point determination, and GCP extension.

A relationship between the camera/sensor, the images in a project, and the ground must be defined before starting any of these tasks. The following variables are used to define the relationship:

- Exterior Orientation Parameters
- Interior Orientation Parameters
- Camera or Sensor Model Information

Well-known obstacles in photogrammetry include defining the interior and exterior orientation parameters for each image in a project using a minimum number of GCPs. Due to the costs and labor intensive procedures associated with collecting ground control, most photogrammetric applications do not have an abundant number of GCPs. Additionally, the exterior orientation parameters associated with an image are normally unknown.

Depending on the input data provided, photogrammetric techniques such as space resection, space forward intersection, and bundle block adjustment are used to define variables required to perform orthorectification, automated DEM extraction, image pair creation, highly accurate point determination, and control point extension.

Understanding Space Resection

Space resection is a technique commonly used to determine the exterior orientation parameters associated with one image or many images based on known GCPs. Space resection uses the collinearity condition. Space resection using the collinearity condition specifies that, for any image, the exposure station, the ground point, and its corresponding image point must be positioned along a straight line.

If a minimum number of three GCPs is known in the X, Y, and Z direction, you can use space resection techniques to determine the six exterior orientation parameters associated with an image. Space resection assumes that camera information is available.

Space resection is commonly used to perform single frame orthorectification where one image is processed at a time. If multiple images are used, space resection techniques require a minimum of three GCPs for each image being processed.

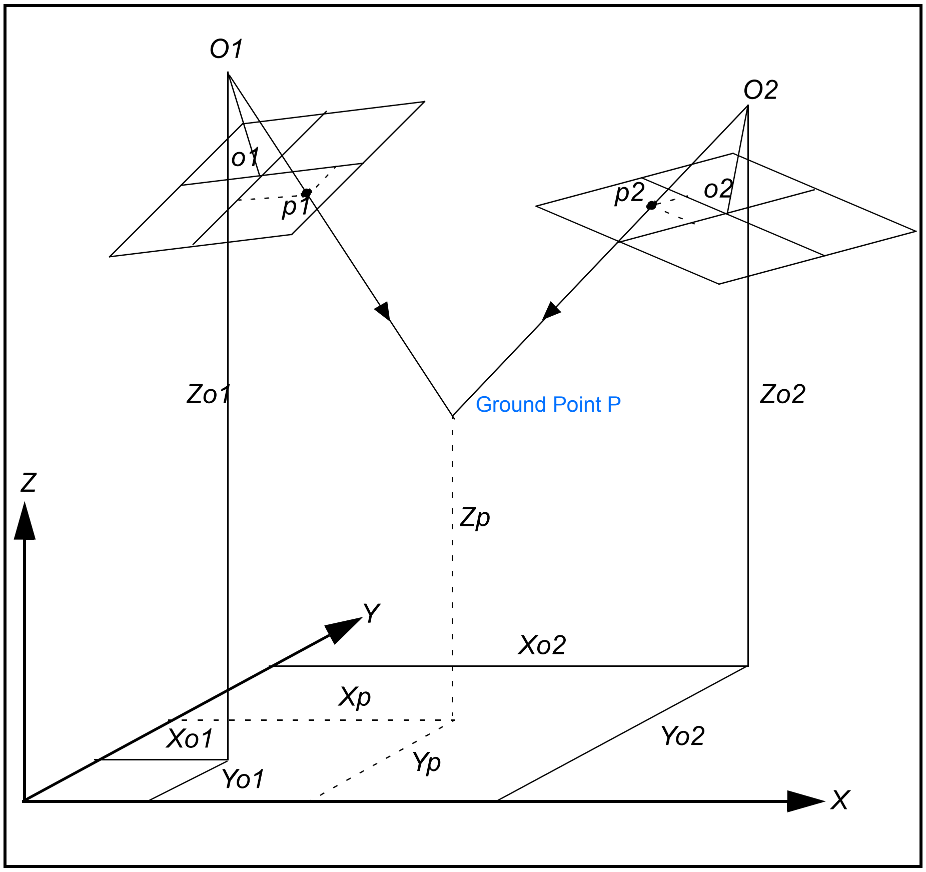
Using their collinearity condition, the positions of the exterior orientation parameters are computed. Light rays originating from at least three GCPs intersect through the image plane through the image positions of the GCPs and resect at the perspective center of the camera or sensor. Using least squares adjustment techniques, the most probable positions of exterior orientation are computed. You can apply space resection techniques to one or multiple images.

Understanding Space Forward Intersection

Space forward intersection is a technique that is commonly used to determine the ground coordinates X, Y, and Z of points that display in overlapping areas of two or more images based on known interior orientation and exterior orientation parameters. The collinearity condition is enforced, which states that the corresponding light rays from the two exposure stations pass through the corresponding image points on the two images and intersect at the same ground point.

The following diagram illustrates the concept associated with space forward intersection.

Figure 163: Space Forward Intersection



Space forward intersection techniques assume that the exterior orientation parameters associated with the images are known. Using the collinearity equations, the exterior orientation parameters along with the image coordinate measurements of point p_1 on Image 1 and point p_2 on Image 2 are entered to compute the Xp, Yp, and Zp coordinates of ground point *P*.

Space forward intersection techniques are also used for applications associated with collecting GCPs, cadastral mapping using airborne surveying techniques, and highly accurate point determination.

Understanding Bundle Block Adjustment

For mapping projects having more than two images, the use of space intersection and space resection techniques is limited. This is attributed to the lack of information required to perform these tasks. For example, it is fairly uncommon for the exterior orientation parameters to be highly accurate for each photograph or image in a project because these values are generated photogrammetrically. Airborne GPS and INS techniques normally provide initial approximations to exterior orientation, but the final values for these parameters must be adjusted to attain higher accuracies.

Similarly, rarely are there enough accurate GCPs for a project of thirty or more images to perform space resection (that is, a minimum of 90 is required). If there are enough GCPs, the time required to identify and measure all of the points is costly.

The costs associated with block triangulation and orthorectification are largely dependent on the number of GCPs used. Fewer GCPs are collected and used to minimize the costs of a mapping project. An approach known as bundle block adjustment is used to ensure that high accuracies are attained.

A bundle block adjustment is best defined by examining the individual words in the term. A bundled solution is computed including the exterior orientation parameters of each image in a block and the X, Y, and Z coordinates of tie points and adjusted GCPs. A block of images contained in a project is simultaneously processed in one solution. The statistical technique least squares adjustment is used to estimate the bundled solution for the entire block while also minimizing and distributing error.

Block Triangulation

Block triangulation is the process of defining the mathematical relationship between the images contained within a block, the camera or sensor model, and the ground. Once the relationship is defined, accurate imagery and geographic information concerning the Earth's surface is created and collected in 3D.

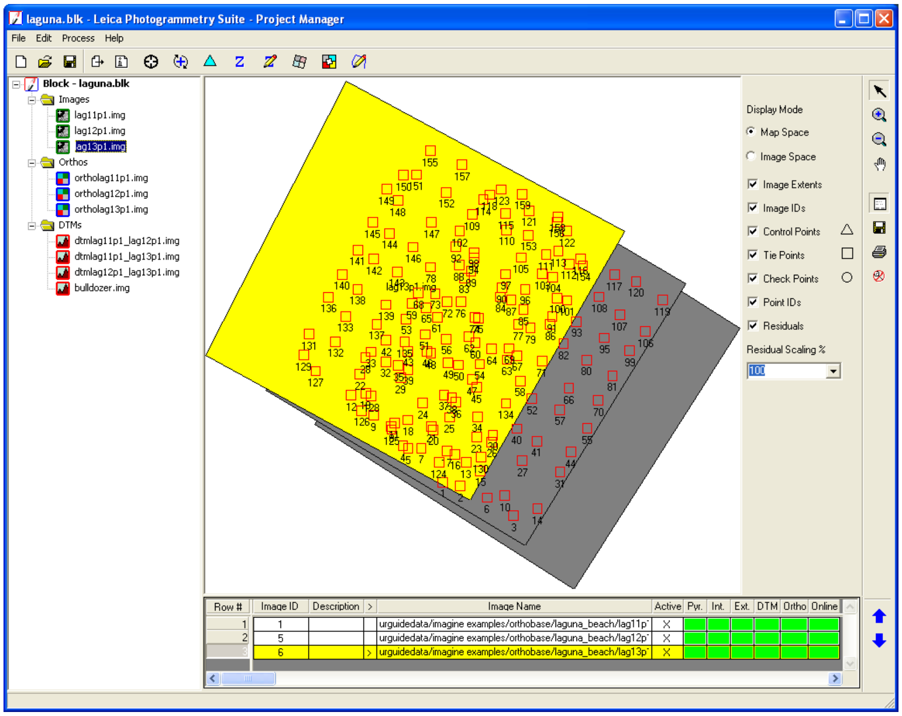
When processing frame camera, digital camera, videography, and nonmetric camera imagery, block triangulation is commonly referred to as aerial triangulation (AT). When processing imagery collected with a pushbroom sensor, block triangulation is commonly referred to as triangulation.

There are several models for block triangulation. The common models used in photogrammetry are block triangulation with the strip method, the independent model method, and the bundle method. Among them, the bundle block adjustment is the most rigorous, considering the minimization and distribution of errors. Bundle block adjustment uses the collinearity condition as the basis for formulating the relationship between image space and ground space.

Bundle Block Adjustment Illustrated

To understand the concepts associated with bundle block adjustment, the following diagram illustrates ten images with multiple GCPs whose X, Y, and Z coordinates are known. Additionally, six tie points are available. The LPS Graphic Status Display dialog illustrates the photogrammetric configuration.

Figure 164: Photogrammetric Configuration



The photogrammetric block configuration displays in the graphic status display area of the main LPS Project Manager workspace.

References

The following references were used in the creation of this book.

American Society of Photogrammetry. 1980. *Photogrammetric Engineering and Remote Sensing,* XLVI:10:1249.

Asher & Adams. 1976. *Asher & Adams' Pictorial Album of American Industry: 1876.* New York: Rutledge Books.

Free On-Line Dictionary of Computing. "American Standard Code for Information Interchange from FOLDOC: American Standard Code for Information Interchange." 24 Oct. 1999 <http://foldoc.doc.ic.ac.uk/foldoc>.

International Society for Photogrammetry and Remote Sensing. "ISPRS—The Society." 29 May 2000 <http://www.isprs.org/society.html>.

Keating, T. J., P. R. Wolf, and F. L. Scarpace. 1975. "An Improved Method of Digital Image Correlation," *Photogrammetric Engineering and Remote Sensing* 41, no. 8 (1975): 993.

Konecny, G. 1994. "New Trends in Technology, and their Application: Photogrammetry and Remote Sensing—From Analog to Digital." Paper presented at Thirteenth United Nations Regional Cartographic Conference for Asia and the Pacific, Beijing, China, May 1994.

Merriam-Webster OnLine Dictionary. "algorithm." 07 Feb. 2001 <http://www.m-w.com/>.

Merriam-Webster OnLine Dictionary. "ellipsoid." 29 May 2000 <http://www.m-w.com/>.

Merriam-Webster OnLine Dictionary. "monotonic." 28 Feb. 2003 <http://www.m-w.com/>.

National Oceanic and Atmospheric Administration. "Inertial Navigation System: Inertial Navigation System (INS)." 29 Mar. 2001 <http://www.csc.noaa.gov/crs/tcm/ins.html>.

Natural Resources Canada. "Carto Corner - Glossary of Cartographic Terms: Cartesian coordinate system." 13 Jul. 2001 <http://www.atlas.gc.ca/english/carto/cartglos.html#4>.

Natural Resources Canada. "Carto Corner - Glossary of Cartographic Terms: coordinate system." 13 Jul. 2001 <http://www.atlas.gc.ca/english/carto/cartglos.html#4>.

Natural Resources Canada. “Carto Corner - Glossary of Cartographic Terms: GPS, Global Positioning System.” 13 Jul. 2001 <http://www.atlas.gc.ca/english/carto/cartoglos.html#4>.

Natural Resources Canada. “Carto Corner - Glossary of Cartographic Terms: parallax.” 13 Jul. 2001 <http://www.atlas.gc.ca/english/carto/cartoglos.html#4>.

Wang, Z. 1990. *Principles of photogrammetry (with Remote Sensing)*. Beijing, China: Press of Wuhan Technical University of Surveying and Mapping, and Publishing House of Surveying and Mapping.

Wolf, Paul R. 1983. *Elements of Photogrammetry.* New York: McGraw-Hill, Inc.

Wolf, Paul R., and Bon A. Dewitt. 2000. *Elements of Photogrammetry with Applications in GIS.* 3rd ed. New York: McGraw-Hill, Inc.

Glossary

Terms

additional parameter

In block triangulation, additional parameters characterize systematic error in the block of images and observations, such as lens distortion.

aerial photographs

Photographs taken from positions above the Earth captured by aircraft. Photographs are used for planimetric mapping projects.

aerial triangulation

The process of establishing a mathematical relationship between images, a camera or sensor model, and the ground. The information derived is necessary for orthorectification, DEM generation, and image pair creation. This term is used when processing frame camera, digital camera, videography, and nonmetric camera imagery.

affine transformation

A 2D plane-to-plane transformation that uses six parameters to account for rotation, translation, scale, and nonorthogonality between the planes. Defines the relationship between two coordinate systems such as a pixel and an image space coordinate system.

airborne GPS

A technique used to provide initial approximations of exterior orientation, which defines the position and orientation associated with an image as they existed during image capture. GPS provides the X, Y, and Z coordinates of the exposure station. See also **global positioning system**.

algorithm

"A procedure for solving a mathematical problem (as of finding the greatest common divisor) in a finite number of steps that frequently involves repetition of an operation” (Merriam-Webster OnLine Dictionary 2001).

American Standard Code for Information Interchange

A “basis of character sets...to convey some control codes, space, numbers, most basic punctuation, and unaccented letters
a–z and A–Z” (Free On-Line Dictionary of Computing 1999).

anaglyph

A 3D image composed of two oriented or nonoriented image pairs. Viewing an anaglyph requires a pair of red/blue glasses. These glasses isolate your vision into two distinct parts corresponding with the left and right images of an image pair. This produces a 3D effect with vertical information.

analog photogrammetry

A technique in which optical or mechanical instruments such as analog plotters are used to reconstruct 3D geometry from two overlapping photographs.

analytical photogrammetry

A technique in which the computer replaces some expensive optical and mechanical components by substituting analog measurement and calculation with mathematical computation.

AP

See **additional parameter**.

ASCII

See **American Standard Code for Information Interchange**.

AT

See **aerial trianglulation**.

attribute

A piece of information about a feature, such as its length, location, name, and so on.

attribute table

A collection of attributes in tabular format.

attribution

Attribute data associated with a feature.

auto-correlation

A technique used to identify and measure the image positions appearing in the overlap of two adjacent images in a block file.

automated terrain following

Automatically places the 3D floating cursor on the ground so that you don't have to manually edit the height of it. The X-parallax is adjusted using image correlation techniques to determine the image coordinate positions of a feature displaying on both the left and right image of an image pair.

binocular vision

Vision using two eyes. See also **stereoscopic viewing**.

block file

A term used to describe and characterize all of the information associated with a photogrammetric mapping project, such as projection, spheroid, and datum; imagery; camera or sensor model information; GCPs; and geometric relationship between imagery and the ground. A block file is a binary file.

block footprint

A graphical representation of the extent of images in a block file. The images are not presented as raster images. Rather, they are displayed as vector outlines that depict the amount of overlap between images in the block file.

block of photographs

A series of photographs formed by the combined exposures of a flight. For example, a traditional frame camera block might consist of a number of parallel strips with a sidelap of 20–30 percent and an overlap of 60 percent.

block triangulation

The process of establishing a mathematical relationship between images, the camera or sensor model, and the ground. The information derived is necessary for orthorectification, DEM generation, and image pair creation.

bundle

The unit of photogrammetric triangulation after each point measured in an image is connected with the perspective center by a straight light ray. There is one bundle of light rays for each image.

bundle block adjustment

A mathematical technique (triangulation) that determines the position and orientation of each image as they existed at the time of image capture, determines the ground coordinates measured on overlap areas of multiple images, and minimizes the error associated with the imagery, image measurements, and GCPs. This is essentially a simultaneous triangulation performed on all observations.

calibration report

In aerial photography, the manufacturer of the camera specifies the interior orientation of each camera in the form of a certificate or report. Information includes focal length, principal point offset, radial lens distortion data, and fiducial mark coordinates.

Cartesian coordinate system

"A coordinate system consisting of intersecting straight lines called axes, in which the lines intersect at a common origin. Usually it is a 2-dimensional surface in which a' x, y' coordinate defines each point location on the surface. The 'x' coordinate refers to the horizontal distance and the 'y' to vertical distance. Coordinates can be either positive or negative, depending on their relative position from the origin. In a 3-dimensional space, the system can also include a 'z' coordinate, representing height or depth. The relative measurement of distance, direction and area are constant throughout the surface of the system" (Natural Resources Canada 2001).

CCD

See charge-coupled device.

centroid

The point whose coordinates are the averages of the corresponding coordinates of the vertices of the polygon.

charge-coupled device

A device in a digital camera that contains an array of cells that record the intensity associated with a ground feature or object.

coefficient

One number in a matrix, or a constant in a polynomial expression.

collinearity

A nonlinear mathematical model that photogrammetric triangulation is based upon. Collinearity equations describe the relationship among image coordinates, ground coordinates, and orientation parameters.

collinearity condition

The condition that specifies that the exposure station, ground point, and its corresponding image point location must all be positioned along a straight line.

contrast stretch

The process of reassigning a range of values to another range, usually employing a linear function. Contrast stretching is often used in displaying continuous raster layers because the range of data file values is commonly much narrower than the range of brightness values available to the display device.

control point

A point with known coordinates in a coordinate system, expressed in the units (such as meters, feet, pixels, film units) of the specified coordinate system.

control point extension

The process of converting tie points to control points. This technique requires the manual measurement of ground points on photos of overlapping areas. The ground coordinates associated with GCPs are then determined using photogrammetric techniques.

coordinate system

"A system, based on mathematical rules, used to measure horizontal and vertical distance on a surface, in order to identify the location of points by means of unique sets of numerical or angular values" (Natural Resources Canada 2001).

coplanarity condition

This is used to calculate relative orientation. It uses an iterative least squares adjustment to estimate five parameters (B_y, B_z, omega, phi, and kappa). The parameters explain the difference in position and rotation between two images making up the image pair.

correlation

Regions of separate images are matched for the purposes of tie point or mass point collection.

correlation coefficient

Represents the measure of similarity between a set of image points displaying within the overlapping portions of an image pair. A large correlation coefficient (0.80-1.0) statistically indicates that the set of image points is more similar than a set of image points with a low correlation coefficient value (less than 0.50).

correlation threshold

A value used in image matching to determine whether to accept or discard match points. The threshold is an absolute value threshold ranging from 0.100 to 1.000.

cross-strips

Strips of image data that run perpendicular to strips collected along the flight line.

datum

"A datum is a system of reference for specifying the horizontal and vertical spatial positions of points" (Wolf and Dewitt 2000). See also **reference plane.**

DEM

See **digital elevation model**.

digital elevation model

Continuous raster layers in which data file values represent elevation.

digital image matching

The process of matching features common to two or more images for the purpose of generating a 3D representation of the Earth. Also known as auto-correlation.

digital orthophoto

An aerial photo or satellite scene that has been transformed by the orthogonal projection, yielding a map that is free of most significant geometric distortions.

digital photogrammetry

Photogrammetry as applied to digital images that are stored and processed on a computer. Digital images are scanned from photographs or directly captured by digital cameras.

digital stereo model

Stereo models that use imaging techniques of digital photogrammetry that can be viewed on desktop applications.

digital terrain model

A discrete expression of topography in a data array, consisting of a group of planimetric coordinates (C, Y) and the elevations of the ground points and breaklines.

digitizing

Any process that converts nondigital data into numeric data, usually to be stored on a computer. The creation of vector data from hardcopy materials or raster images. The data is traced using a digitizer keypad on a digitizing tablet, or a mouse on a display device.

direction of flight

The direction in which the craft is moving (such as east to west). Images in a strip are captured along the aircraft or satellite's direction of flight. Images overlap in the same manner as the direction of flight.

draping

See **feature draping**.

DSM

See **digital stereo model**.

DTM

See **digital terrain model**.

elements of exterior orientation

Variables that define the position and orientation of a sensor as it obtained an image. It is the position of the perspective center with respect to the ground space coordinate system.

elevation source

Data, such as a DEM or TIN, that supplies the Z component of a feature or scene. An elevation source enables stereo viewing and 3D feature extraction.

ellipsoid

"A surface all plane sections of which are ellipses or circles" (Merriam-Webster OnLine Dictionary 2000).

endlap

The area common to two images in a strip of photos taken along the flight path. Another term for overlap. See also **overlap.**

epipolar line

The line traced on each image representing the intersection of the epipolar plane with the image plane.

epipolar plane

The plane, in space, containing a ground point and both exposure stations.

exposure station

During image acquisition, each point in the flight path at which the camera exposes the film. The exposure station has elements that define its position and rotation: X, Y, Z, omega, phi, and kappa.

exterior orientation

External sensor model information that describes the exact position and orientation of each image as they existed when the imagery was collected. The image's position is defined as having 3D coordinates, and the orientation is defined as having three rotations that include omega, phi, and kappa.

exterior orientation parameters

The perspective center's ground coordinates in a specified map projection and three rotation angles around the coordinate axes.

feature collection

The process of identifying, delineating, and labeling various types of natural and human-made phenomena from remotely sensed images.

feature draping

A condition that occurs when the feature follows the subtle changes in elevation of the terrain surface in the height dimension.

feature extraction

The process of studying and locating areas and objects on the ground and deriving useful information from images.

fiducial mark

Four or eight reference markers fixed on the frame of an aerial metric camera and visible in each exposure. Fiducials are used to compute the transformation from pixel coordinates to image coordinates.

Fixed Cursor mode

A mode in which the 3D floating cursor remains at a constant position while the image pair is repositioned in the display.

Fixed Image mode

A mode in which the image pair remains at a constant position while the 3D floating cursor moves freely in the display.

flight line

One of, typically, consecutive lines flown by an airplane consisting of exposure stations. A strip of photographs is captured along a flight line.

flight path

The path of an airplane including, typically, multiple flight lines with multiple exposure stations where the camera exposes the film. Photographs from several flight paths can be combined to form a block of photographs.

focal length

The distance between the optical center of the lens and where the optical axis intersects the image plane. Focal length of a camera is determined in a laboratory environment.

focal plane

The plane of the film or scanner used in obtaining an aerial photo.

footprint

An outline corresponding to an image or image pair. Used to visualize areas of overlap between image pairs.

GCP

See **ground control point**.

geocentric

A coordinate system with its origin at the center of the Earth ellipsoid. The Z-axis equals the rotational axis of the Earth, the X-axis passes through the Greenwich meridian, and the Y-axis is perpendicular to both the Z-axis and the X-axis so as to create a 3D coordinate system that follows the right-hand rule.

geocorrect

A method of establishing a geometric relationship between imagery and the ground. Geocorrection does not use many GCPs, and is therefore not as accurate as orthocorrection or orthorectification. See also **orthorectification**.

geographic information systems

A unique system designed for a particular application that stores, enhances, combines, and analyzes layers of geographic data to produce interpretable information. A GIS might include computer images, hardcopy maps, statistical data, and any other data needed for a study, as well as computer software and human knowledge. GISs are used for solving complex geographic planning and management problems. A GIS consists of spatial data stored in a relational database with associated ancillary information.

geolink

A method of establishing a relationship between attribute data and the features to which they pertain.

GIS

See **geographic information system**.

GIS-ready image

Imagery that has information about the relationship between the image (as it existed when the image was recorded) and the Earth's surface.

global positioning system

"A surveying method that uses a set of 24 satellites in geostationary position high above the Earth. Specially designed GPS receivers, when positioned at a point on Earth, can measure the distance from that point to three or more orbiting satellites. The coordinates of the point are determined through the geometric calculations of triangulation. GPS provides accurate geodetic data for any point on Earth" (Natural Resources Canada 2001).

GPS

See **global positioning system.**

ground control point

An easily identifiable point for which the ground coordinates of the map coordinate system are known.

ground coordinate system

A 3D coordinate system that utilizes a known map projection. Ground coordinates (X, Y, and Z) are usually expressed in feet or meters.

ground point

Another term for the 3D floating cursor.

ground space

Events and variables associated with the objects being photographed or imaged, including the reference coordinate system.

image

A picture or representation of an object or scene on paper or a display screen. Remotely sensed images are digital representations of the Earth.

image center

The center of an aerial photo or satellite scene.

image pair

Two overlapping oriented images. A set of two remotely sensed images that overlap, providing a 3D view of the terrain in the overlap area.

image scale

Expresses the ratio between a distance in the image and the same distance on the ground.

image space

Events and variables associated with the camera or sensor as it acquired the images. The area between perspective center and the image.

image space coordinate system

A coordinate system composed of the image coordinate system with the addition of a Z axis defined along the focal axis.

image-to-Earth association

The 3D mathematical relationship between an image and the Earth's surface.

inertial navigation system

A technique that provides initial approximations to exterior orientation. This data is provided by a device or instrument. The instrument collects data about the altitude of the airplane in which it is located. The information it collects includes pitch (tilting forward and backward), roll (tilting sideways), and heading (the direction of flight) (National Oceanic and Atmospheric Administration 2001). See also **omega, phi, kappa.**

INS

See **inertial navigation system**.

interior orientation

Describes the internal geometry of a camera such as the focal length, principal point, lens distortion, and fiducial mark coordinates for aerial photographs.

International Society of Photogrammetry and Remote Sensing

An organization “devoted to the development of international cooperation for the advancement of photogrammetry and remote sensing and their application” (ISPRS 2000). For more information, visit the Web site <http://www.isprs.org>.

ISPRS

See **International Society of Photogrammetry and Remote Sensing**.

kappa

In a rotation system, kappa is positive rotation around the Z-axis.

least squares adjustment

A technique by which the most probable values are computed for a measured or indirectly determined quantity based upon a set of observations. It is based on the mathematical laws of probability and provides a systematic method for computing unique values of coordinates and other elements in photogrammetry based on a large number of redundancy measurements of different kinds and weights.

lens distortion

Caused by the instability of the camera lens at the time of data capture. Lens distortion makes the positional accuracy of the image points less reliable.

line of sight (LOS)

The area that can be viewed along a straight line without obstructions.

LOS

See **line of sight.**

map coordinate system

A map coordinate system that expresses location on the Earth’s surface using a particular map projection such as Universal Transverse Mercator, State Plane, or Polyconic.

mass points

Points whose 3D coordinates are known (X, Y, and Z), and are used in creating a DEM or DTM. See also **digital elevation model** and **digital terrain model.**

metadata

A more highly organized or comprehensive level of data. Metadata files often contain lists of data files and auxiliary files such as header files, attribute files, and transform files. Metadata can be thought of as data about data.

metric photogrammetry

The process of measuring information from photography and satellite imagery.

mono

A view in which there is only one image. There are no two images to create an image pair. You cannot see in 3D using a mono view.

monocular vision

Vision using one eye.

monotonic

“Having the property either of never increasing or of never decreasing as the values of the independent variable or the subscripts of the terms increase” (Merriam-Webster OnLine Dictionary 2003).

mosaicking

The process of piecing together images, side-by-side, to create a larger image.

nadir

The area on the ground directly beneath a scanner’s detectors.

near vertical aerial photographs

Photographs taken from vertical or near vertical positions above the Earth captured by aircraft. Photographs are used for planimetric mapping projects.

node

An element of a line or polygon, or the element of a point that has specific coordinates in X, Y, and in the case of 3D data, Z.

nonoriented image pair

An image pair made up of two overlapping photographs or images that have not been photogrammetrically processed. Neither the interior nor the exterior orientation, defining the internal geometry of the camera or the sensor as well as its position during image capture, has been defined. You can collect measurements from a nonoriented image pair; however, the measurements are in pixels and 2D.

nonorthogonality

The deviation from perpendicularity between orthogonally defined axes.

oblique photographs

Photographs captured by an aircraft or satellite deliberately offset at an angle.

omega

In a rotation system, omega is rotation around the X-axis.

omega, phi, kappa

A rotation system that defines the orientation of a camera/sensor as it acquired an image. Omega, phi, kappa is used most commonly, where omega is positive rotation around the X-axis, phi is a positive rotation around the Y-axis, and kappa is a positive rotation around the Z-axis. This rotation system follows the right-hand rule.

optical axis

“The line joining the centers of curvature of the spherical surfaces of the lens” (Wolf and Dewitt 2000).

orientation

The position of the camera or satellite as it captured the image. Usually represented by six coordinates: X, Y, Z, omega, phi, and kappa.

oriented image

A first generation data product derived from imagery with a sensor model and spatial reference. Combining multiple oriented images allows for the creation of DTMs and collection of 3D features.

oriented image pair

An image pair with known interior (camera or sensor internal geometry) and exterior (camera or sensor position and orientation) orientation. The Y-parallax of an oriented image pair has been improved. Additionally, an oriented image pair has geometric and geographic information concerning the Earth’s surface and a ground coordinate system. Features and measurements taken from an oriented image pair have X, Y, and Z coordinates.

orthocalibration

A form of calibration that corrects for terrain displacement and can be used if a DEM of the study area is available. Unlike orthorectification, this method depends on a transformation matrix to resample on the fly thus leaving the image file (data) unaffected.

orthocorrection

A form of geometric correction that uses a DEM and sensor position information to correct distortions resulting from Earth curvature and the like. See also **orthorectification**.

orthorectification

The process of lessening geometric errors inherent within photography and imagery caused by terrain displacement, lens distortion, and the like. Then, the photography or imagery is resampled to a specified resolution. Also called orthoresampling.

overlap

In a traditional frame camera, when two images overlap, they share a common area. For example, in a strip of photographs taken along the flight path, adjacent images typically overlap by 60 percent. This measurement is sometimes called endlap. See also **sidelap**.

parallax

"The apparent angular displacement of an object as seen in an aerial photograph with respect to a point of reference or coordinate system. Parallax is caused by a difference in altitude or point of observation" (Natural Resources Canada 2001).

perspective center

(1) The optical center of a camera lens. (2) A point in the image coordinate system defined by the x and y coordinates of the principal point and the focal length of the sensor. (3) After triangulation, a point in the ground coordinate system that defines the sensor's position relative to the ground.

phi

In a rotation system, phi is rotation around the Y-axis.

photogrammetric scanners

Special devices capable of high image quality and excellent positional accuracy. Use of this type of scanner results in geometric accuracy similar to traditional analog and analytical photogrammetric instruments.

photogrammetry

The "art, science and technology of obtaining reliable information about physical objects and the environment through the process of recording, measuring, and interpreting photographic images and patterns of electromagnetic radiant imagery and other phenomena" (American Society of Photogrammetry 1980).

pixel

Abbreviated from picture element. The smallest part of a picture (image).

planar

A constant elevation value (Z) is applied to each vertex of a feature.

plane table photogrammetry

Prior to the invention of the airplane, photographs taken on the ground were used to extract the geometric relationships between objects.

point

(1) A feature that has X, Y, and (sometimes) Z coordinates. A point can represent a feature such as a telephone pole. You can also collect multiple points to create a DEM or TIN. (2) In the case of defining the size of the 3D floating cursor used in the Stereo window, a point equals a pixel.

point spacing

The distance between points sampled in terrain interpolation.

polygon

A set of closed line segments defining an area, composed of multiple vertices. Polygons can be used to represent features such as buildings, and can contain elevation values.

principal point

The point in the image plane onto which the perspective center is projected.

principal point of autocollimation

Part of the definition of principal point, the image position where the optical axis intersects the image plane. The principal point of autocollimation is near the principal point (Wolf 1983).

principal point of symmetry

Part of the definition of principal point, the principal point of symmetry can best compensate for lens distortion. “The point about which [distortions] are symmetrical” (Wolf 1983).

project file

A SOCET SET file containing the information required to restore the current state of a work. All necessary files, settings, and preferences are stored in the project file.

projection

The manner in which the spherical surface of the Earth is represented on a flat (2D) surface.

pushbroom

A scanner in which all scanning parts are fixed and scanning is accomplished by the forward motion of the scanner.

pyramid layer

An image layer that is successively reduced by a power of two and resampled. Pyramid layers allow large images to display faster at any resolution.

radial lens distortion

Imaged points are distorted along radial lines from the principal point. Also referred to as symmetric lens distortion.

rational polynomial coefficients

Coefficients, generally supplied by the data provider, that detail the position of a satellite at the time of image capture.

raw image

An image that does not have any projection associated with it. Raw images serve as a record of features, relationships between features, processes, and information.

reference coordinate system

A system that defines the geometric characteristics associated with events occurring in object space.

reference plane

In a topocentric coordinate system, the tangential plane at the center of the image on the Earth ellipsoid, on which the three perpendicular coordinate axes are defined.

regular block of photos

A rectangular block in which the number of photos in each strip is the same. This includes a single strip or a single image pair.

rendering

Drawing an image in a view at the scale indicated by the zoom in or zoom out factor.

resample

The process of extrapolating data file values for the pixels in a new grid when the image is rescaled or rotated.

right-hand rule

A convention in 3D coordinate systems (X, Y, Z) that determines the location of the positive Z-axis. If you place your right-hand fingers on the positive X-axis and curl your fingers toward the positive Y-axis, the direction your thumb is pointing is the positive Z-axis direction.

RMSE

See **root mean square error**.

root mean square error

Used to measure how well a specific, calculated solution fits the original data. For each observation of a phenomena, a variation can be computed between the actual observation and a calculated value. (The method of obtaining a calculated value is application-specific.) Each variation is then squared. The sum of these squared values is divided by the number of observations and then the square root is taken. This is the RMSE value.

rotation matrix

A three-by-three matrix used in the aerial triangulation functional model. Determines the relationship between the image space coordinate system and the ground space coordinate system.

rubber sheeting

A 2D rectification technique (to correct nonlinear distortions) that involves the application of a nonlinear rectification (second order or higher).

screen dot pitch

Screen dot pitch is the size of the pixels on the screen—measured horizontally in X and vertically in Y. The more accurate the screen dot pitch values are, the more accurate scale representations are on the screen.

self-calibration

A technique used in bundle block adjustment to determine internal sensor model information.

sensor

A device that gathers energy, converts it to a digital value, and presents it in a form suitable for obtaining information about the environment.

sensor model

A model describing the 3D relationship between a sensor, raw image, and the Earth's surface. A sensor model is required to create an oriented image, an image pair, a stereo model, and for the collection of 3D features. A sensor model makes an image oriented and photogrammetrically aware.

SI

See **image scale**.

sidelap

In a block of photographs consisting of a number of parallel strips, the sidelap is measured between the strips and is usually 20–30 percent in traditional frame camera photos. Sidelap is measured perpendicular to flight path.

single frame orthorectification

Orthorectification of one image at a time using the space resection technique. A minimum of three GCPs is required for each image.

softcopy photogrammetry

See **digital photogrammetry**.

space forward intersection

A technique used to determine the ground coordinates X, Y, and Z of points that display in the overlapping areas of two or more images based on known interior orientation and exterior orientation parameters.

space intersection

A technique used to determine the ground coordinates X, Y, and Z of points that display in the overlapping areas of two images, based on the collinearity condition. See also **collinearity condition**.

space resection

A technique used to determine the exterior orientation parameters associated with one image or many images, based on the collinearity condition.

spatial reference

A coordinate or other means by which a location can be specified.

spot height

In feature collection, a point feature collected primarily for its Z, or elevation, value. A spot height feature also contains X and Y coordinate values.

stereo

A mode of visualizing wherein two images are used to derive elevation information.

stereo model

The overlapping portion of an image pair. A 3D image formed by the brain as a result of changes in depth perception and parallactic angles. See also **image pair**.

stereo pair

A pair of images of the same area taken from slightly different angles. See also **oriented image pair**.

stereo scene

Composed of two images of the same area acquired on different days from different orbits—one taken east of the vertical and the other taken west of the nadir.

stereoscopic parallax

"The change in position of an image from one photograph to the next caused by the aircraft's motion" (Wolf 1983). Makes viewing of 3D data possible, composed of X-parallax and Y-parallax. See also **X-parallax**, **Y-parallax**.

stereoscopic viewing

Vision using two eyes. Also referred to as binocular vision.

strip of images/photographs

In traditional frame camera photography, consists of images captured along a flight line, normally with an overlap of 60 percent for stereo coverage. All photos in the strip are assumed to be taken at approximately the same flying height and with a constant distance between exposure stations. Camera tilt relative to the vertical is assumed to be minimal. See also **cross-strips**.

support file

A SOCET SET file containing photogrammetric metadata associated with an image in a project file.

tangential lens distortion

Distortion that occurs at right angles to the radial lines from the principal point.

Terrain Following mode

A mode in which the 3D floating cursor follows the elevation of the terrain displayed in the Stereo window. This is accomplished either by using an external elevation source, such as a DEM, or image correlation techniques.

thinning tolerance

A measure that prevents duplicate points within a certain distance in terrain interpolation (such as 5 meters).

threshold

Threshold is used during image correlation as a measure of probability that a point is the same in both the left image and the right image of an image pair. A high threshold value increases the probability of a correct match, but may take longer to process. Setting a low threshold increases the probability of a false match.

tie point

A point. Its ground coordinates are not known, yet it can be recognized visually in the overlap or sidelap area between two images.

TIN

See **triangulated irregular network**.

topocentric coordinate system

A coordinate system that has its origin at the center of the image on the Earth ellipsoid. The three perpendicular coordinate axes are defined on a tangential plane at this center point. The X-axis is oriented eastward, the Y-axis northward, and the Z-axis is vertical to the reference plane (up).

transformation

A series of coefficients describing the 3D mathematical relationship between an image, the sensor that captured it, and the ground it recorded.

triangulated irregular network

A specific representation of DTM in which elevation points can occur at irregular intervals forming triangles.

triangulation

Process of establishing the geometry of the camera or sensor relative to objects on the Earth's surface. See also aerial triangulation.

vector

A point, line, or polygon. A vector is a one-dimensional matrix, having either one row (1 by j) or one column (i by 1). Vectors typically represent objects such as road networks, buildings, and geographic features such as contour lines.

vertex

A component of a feature, typically made up of three axes: X, Y, and (sometimes) Z. The Z component corresponds to the elevation of the vertex. A feature can be composed of only one vertex (such as a point as in a TIN) or many vertices (such as a polyline or polygon).

vertical exaggeration

The effect perceived when a DSM is created and viewed. Vertical exaggeration is also referred to as relief exaggeration, and is the evidence of height differences in the stereo model.

vertices

More than one vertex, each with X, Y, and (sometimes) Z components.

X-parallax

The difference in position of a common ground point appearing on two overlapping images, which is a function of elevation. X-parallax is measured horizontally.

Y-parallax

The difference in position of a common ground point displaying on two overlapping images, which is caused by differences in camera position and rotation between two images. Y-parallax is measured vertically.

Z

The vertical (height) component of a vertex, 3D floating cursor, or feature in a given coordinate system.

Z-axis

In the image space coordinate system, the Z-axis is the optical axis. The image space coordinate system directs the Z-axis toward the imaged object. In object space, the Z-axis is orthogonal to the X and Y axes and is directed out of the Earth's surface.

Numerics

2D

Images or photos in X and Y coordinates only. There is no vertical element (Z) to 2D images. Viewed in mono, 2D images are good for qualitative analysis.

3D

Images or photos in X, Y, and Z (vertical) coordinates. Viewed in stereo, 3D images approximate true Earth features.

3D feature

A feature that has vertex coordinates in X, Y, and Z. The Z component is the elevation of a particular vertex.

3D floating cursor

This cursor is apparent when you have a DSM (that is, two images of approximately the same area) displayed. The 3D floating cursor's position is determined by the amount of X-parallax evident in the DSM and your positioning of it on the ground or feature of interest. You adjust the position of the 3D floating cursor using the keyboard and the system mouse. See also **X-parallax**.

3D model

This model has vertex coordinates in X, Y, and Z, where the Z coordinate indicates elevation. A 3D model displays in 3D (that is, a volumetric object).

Symbols

****.blk***

An LPS block file. A block file can contain only one image, but usually contains two or more images with approximately 60 percent overlap. Block files can be viewed in 3D using Stereo Analyst for ArcGIS.

.img

An ERDAS IMAGINE image file. An .img file uses the hierarchical file format (HFA) structure to store many types of information in addition to the image data. For example, the .img format stores information about the file, sensor, layers, statistics, projection, and so on.

.prj

A SOCET SET project file, which contains sensor position and projection information about images in the project.

.sup

A SOCET SET support file, which contains geometric information about the image it supports.

κ

Kappa. An angle used to define angular orientation. Kappa is rotation about the Z-axis.

ω

Omega. An angle used to define angular orientation. Omega is rotation about the X-axis.

φ

Phi. An angle used to define angular rotation. Phi is rotation about the Y-axis.

Index

A

B

C

D

G

M

N

O

P

T

U

V

W