

Review

Stereo Feature Collection Software for GIS: From 2-D to 3-D Databases

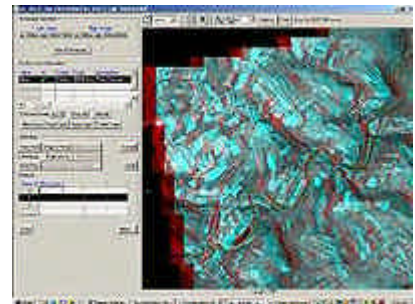
by Kyle Bohnenstiehl

Viewing aerial and satellite imagery using stereoscopic vision has been a common practice for over 30 years. Many of us at one time or another have used binocular stereoscopes and a pair of aerial photographs to see in 3-D, often times with an accompanying "Wow!". Today, digital imagery can be viewed stereoscopically with an equally dramatic effect and the added benefit of head-up digitizing and stereo mensuration. This article will describe the theory behind stereoscopic vision, the necessary hardware, software and imagery inputs, and what can be accomplished by a modern, stereo viewing system. Before reading this article, I would strongly recommend that you read [Create Accurate Orthophotos with Photogrammetry](#) (April 2001 GISVision) and [Purchasing Photogrammetry Software](#) (February 2002 GISVision) to fully understand the theory, software and data sources that are used in photogrammetry and stereo viewing.

Uses of Stereo Viewing Software

The main uses that GIS users will find for stereo viewing software are the following:

1. Editing contour and point elevation data generated by DEM extraction tools for stereo aerial and satellite imagery. Autocorrelation techniques used to generate DEM's automatically from stereo imagery are not perfect and may either omit important topographic features or may place them in the wrong X, Y, Z coordinate space. Stereo viewers provide vector editing capability much like any other GIS software, except that every feature vertex has a Z value in the vertical datum of the digital stereo model (DSM). One common application is to take 3-D contours, overlay them in the stereo viewer and edit them to more accurately represent the true surface. Contours that represent stream channels can be digitized, lakes made to appear flat, curbs and gutters added, and other important topographic breaklines added. Erroneous contour values will appear to float or be submerged below the terrain and these can be edited easily by moving their vertex Z values up or down. Some people prefer to work with a set of mass points and to remove, add or edit points where necessary, and then generate a TIN, DEM or set of contours from those points. It is important to have the vector features edited in the same horizontal and vertical coordinate system as the DSM.
2. Generating or updating vector information by head-up digitizing from a DSM. As we use our GIS data more and more to create virtual worlds, fly-thru's and other 3-D simulations, the accuracy and positioning of GIS vector data becomes more important. Digitizing roads, utility lines, buildings and other infrastructure in a stereo editor produces the most spatially accurate data. Digitizing in 3-D requires that a set of features be defined (building types, road types, utility classes, etc), a set of attributes be assigned to each set of features, and a symbology set be applied. As each vector is digitized, a Z value is assigned to each vertex. ERDAS Stereo Analyst allows you to manually clean up the Z values to square up buildings up and to verify if any erroneous Z values were collected. Once the 3-D information is collected, standard GIS software can be used to further edit attribute information.
3. Viewing imagery in stereo for intelligence gathering and reconnaissance purposes. Finally, stereo viewing allows for enhanced photo interpretation because features have an added dimension. Military intelligence analysts have long been aware of the value of stereo imagery for photo interpretation. GIS users that do regulatory enforcement work and monitoring of environmental sites will be able to leverage the added benefits of stereo viewing. An important part of this activity is measuring the length, area, volume, and elevation of objects visible in the imagery through the process of stereo mensuration. These measurements are very accurate and allow a great amount of information to be collected very quickly about objects located anywhere



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in the world.

Stereo Feature Collection Software for GIS: From 2D to 3-D Databases Continued...

The Human Side of Stereo Viewing

Most of us have the capability to perceive and measure depth with our own two eyes using binocular vision, which is known as stereoscopic viewing. Much like listening to music in stereo, viewing imagery and vector data using stereoscopic vision opens up a vast new world of perception and information content to us. The interrelationship between features and the real world becomes clearer, photo interpretation becomes more accurate and complete, and spatial accuracy is increased. Amazingly, your brain actually synthesizes the information from the left and right eye (delivered by your monitor and controlled by the eyewear you are using) to create the perception of seeing in 3-D.

The stereo effect is achieved only when two images with two different perspectives are overlapped (digitally, in the context of this article), rendered by the software, and viewed relatively simultaneously. A cycle of 60 times per second/per eye is a good rate. Digital depth perception is created by parallax, or the shift of the camera from one image to the next, much the way the distance between your eyes is sufficient to generate parallax for depth perception. Your brain is constantly developing a stereo model of the world around you in real-time, a feat that we could only hope to mimic using a computer and software. However, by knowing the position where an image was acquired and the focal length of the camera or sensor, the software can create a stereo model that can be perceived by our brains.

Depth perception by the brain is achieved by measuring the distance from the left eye to an object and from the right eye to the same object. The closer an object is to one eye than the other allows the brain to develop a measure of parallax and to perceive the distance. The same concept applies to aerial photography and satellite imagery, where a point is measured in two images (with file pixel coordinates) to calculate the parallax and the stereo editing software calculates the elevation (using some complex math and camera calibration information). This feature matching can be done automatically using digital autocorrelation (terrain following cursor), or manually by adjusting the location of the cursor in each image until it is in the same location in the perceived stereo image.

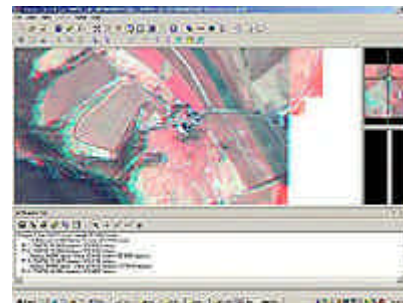
Digital Stereo Models

For the purposes of this article we will assume that stereo viewing will be accomplished using digital aerial or satellite imagery that comes from a sensor with known camera calibration information. While it is possible to manually drag and drop digital images on top of one another in the software and view them in stereo, it is impossible to perform mensuration activities on them. Ideally for aerial imagery there will be 60% overlap from one image to the next.

The [Quickbird](#) and [Ikonos](#) satellites are capable of providing up to 99% overlap between stereo pairs and the new [SPOT 5](#) satellite should provide at least 60% overlap. For each image in a digital stereo model(DSM) we must know the position of each image at the time of exposure. For aerial photos this is the camera perspective center point (X,Y,Z) in ground coordinates and for the Ikonos and Quickbird satellites it is expressed in a Rational Polynomial Coefficients header type file in geodetic Lat/Long coordinates. Another required parameter is the attitude of the aircraft or satellite, defined by the omega, phi and kappa angles that describe the roll, pitch and heading. Once again, for high resolution satellites, this is contained in the RPC file. Finally, a camera calibration report that defines the sensor focal length, either physically or synthetically, and the principal point of the aerial photo is required

Figure 1

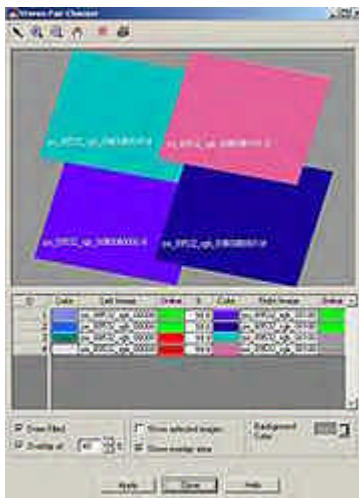
PCI Geomatica Stereo Viewer provides a simple, easy to use interface for digitizing vector features like the river shown here in green. (anaglyph red and blue glasses required to view figures in stereo)



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Figure 2

ERDAS Stereo Analyst allows users to interactively measure point X, Y, Z coordinates, line length and vertice X, Y, and Z coordinates, and polygon areas, average height and vertice X, Y, and Z coordinates.



[Click to enlarge...](#)

Figure 3

ERDAS Stereo Analyst allows users to choose the DSM they would like to view. There are 4 Ikonos DSM's in this view showing over 99% overlap per pair.

same would apply with [PCI Geomatica 8.2](#) where you would use an OrthoEngine block directly in the stereo viewer.

High resolution satellite imagery from Quickbird and Ikonos is much easier to use because the number of images is fewer for a given area and there is sufficient georeferencing information contained in the RPC header file to allow you to get to work without supplemental GPS ground control. Further accuracy refinements to the RPC file can be done in an aerial triangulation software like Imagine Orthobase or PCI OrthoEngine before importing the imagery into a stereo editor.

Hardware and Software Considerations

Stereo viewing is most likely the most computationally intensive activity that GIS users will undertake. Each image in a DSM could be as large as 1.0 Gb, although pyramid layers and reduced resolution data sets can be utilized when not zoomed in. Obviously, the fastest computer you can afford is ideal. A minimum of 512 MB of RAM and EIDE/Ultra ATA drives will help, but 1 GB of RAM and Ultra SCSI 2 15,000 RPM harddrives will really get things moving.

The stereo graphics display card is the most important piece of hardware and most require 100% INTEL compatible chipsets. There are three types of stereo graphics card interfaces in common use today: PCI (the oldest and slowest type), AGP 2,3, 4x Pro, and AGP Pro 50 (which is unique to Pentium IV motherboards). When configuring your system, verify the type of port that you have and the compatibility with your motherboard, operating system and stereo viewing software. The most common stereo graphics cards in the photogrammetry and GIS worlds are made by [3-D Labs](#). The highest end Wildcat 5110 and 6110 boards can cost upwards of \$2500. The lower end GVX1, GVX420 and GVX1 Pro will only cost around \$500. This is truly a case of you get what you pay for, not so much in terms of rendering quality but rendering speed. Large size DSM's may take over 30 seconds to render every time you pan or zoom with the slower cards, making the digitizing of features very frustrating. At a minimum, 32MB of graphics card RAM is required for effective rendering. One feature unique to true stereo graphics cards is the 3-pin mini stereo connector on the back of the card where you plug in the stereo eyewear. This port sends a signal that syncs the left and right eye shutters on the glasses to render the stereo view to your brain.

Another piece of hardware that is required is the stereo eyewear. There are several types of systems

to set up a metric stereo model.

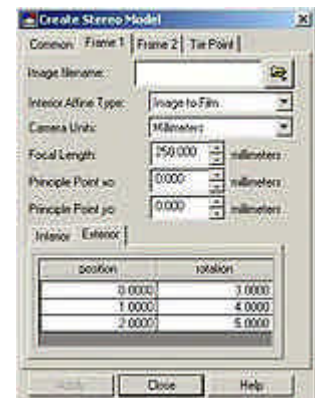
For most users of stereo viewing software, I would recommend having your aerial photo contractor or photogrammetry technicians provide you with following deliverables.

The raw aerial imagery in TIFF format on CD or DVD

The exterior orientations in the ground coordinates you will require your 3-D GIS data to be collected in. Be sure to specify the vertical datum you require in either feet or meters. The angle measurements will always be in degrees.

A camera calibration report or at a minimum the focal length and principal point locations.

Given this information, you should be able to reconstruct the DSM. A better approach is to have the original "Block Adjustment File" from the aerial triangulation/block adjustment software that you can import directly into the stereo viewing software. In the case of [ERDAS Imagine 8.5](#), you would take an Orthobase 8.5 block and open it directly in ERDAS Stereo Analyst 1.2, only having to reset the file paths if they have changed. The



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Figure 4

In ERDAS Stereo Analyst, users can add the interior and exterior orientation information for two images to generate a DSM quickly using only one tie point.

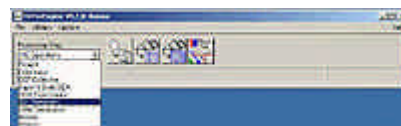
available at present that include LCD shutter glasses, polarized screens that fit over your monitor, and LCD shutters that fit over your screen. [Stereographics Corporation](#) has the full range of these products. I like the Crystal Eyes LCD shutter product that they make given its low cost (around \$179) and ease of installation. It is available in a wireless solution that enables several users to view the monitor at the same time. If you absolutely want the lowest cost stereo viewing hardware, most stereo editors will render color anaglyph images on the screen. All you need to view these images with are a pair of the red and blue lens paper glasses. You can project these color anaglyph images to an entire room through an LCD projector, hand out the glasses to your audience and do some amazing presentations. You also can do screen captures to use in presentation software. No special graphics cards are required to render these images but the red-blue anaglyph glasses are.

Comparison of ERDAS Stereo Analyst and PCI OrthoEngine Stereo Feature Module

For GIS users, ERDAS Stereo Analyst or PCI OrthoEngine are probably the most affordable stereo packages available that provide a full range capabilities. I will summarize a few key features of each package below.

PCI OrthoEngine Stereo Viewer: This package is a module that is buried in the OrthoEngine suite of software. I was unable to find a way to run it as a standalone module so you must create a full block within OrthoEngine. You can import the exterior orientations and camera calibration in from another package, but essentially you are creating a full OrthoEngine block. What I like best about this package is the ease of use of the editor. There are only a few commands to master and it is easy to generate new vector files and add attributes. There is a good choice of file formats available for export. It is also possible to work with ASTER and Radarsat satellite data, in addition to Ikonos, Quickbird, and the standard aerial cameras. Weaknesses include the lack of a terrain following cursor (one that always follows the ground while digitizing), no capability to edit vertex Z values after digitizing, and no ancillary windows that display the collected vector data in a 3-D perspective view or the location of the Z cursor on each individual frame in the DSM (helpful for moving the cursor down to ground level).

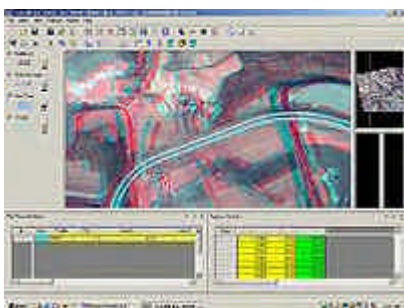
ERDAS Stereo Analyst 1.2 is a powerful stereo editor that allows for the collection of stereo data using relative and absolute DSM's generated from manually overlapping the images, from imported exterior orientation information, from Ikonos stereo pairs with RPC files, or from Imagine Orthobase 8.5 block triangulation files. Stereo Analyst 1.2 can be run from within ArcView as an extension, as a standalone module, or as part of Imagine 8.5 . The biggest advantages to Stereo Analyst are its cost (around \$3000), a full set of terrain following cursor tools, an extensive set of predefined features classes with symbology, a 3-D feature viewer window that lets you view the position of all 3-D features that have been collected, and the ability to edit the Z values of vertices to create truly cubed buildings. Other nice tools include parallel line digitizing tools for roads and rivers, right angle digitizing for buildings, and 3-D extend tools that drop rooflines to the ground to create true 3-D buildings. You can also import in shapefiles or ASCII data into the editor window. Overall, this product is a great value and one that any serious GIS shop should consider owning.



Click to enlarge...

Figure 5

PCI OrthoEngine provides a full suite of aerial triangulation, DEM extraction, and stereo viewing tools that provides functionality with the widest variety of sensors of any package on the market.



Click to enlarge...

Figure 6

Kyle Bohnenstiehl has been involved in remote sensing, GPS and GIS for over 10 years and is currently a remote sensing scientist with the Department of Interior. His work has taken him throughout the Andes of South America and the desert Southwest where he has worked with tribes, NGO's, government and private sector groups to create innovative solutions using the latest geotechnology. He can be reached at Kyle@nagis.com

*ERDAS Stereo Analyst 1.2
provides excellent digitizing tools
and a powerful interface for
capturing 3-D ASCII and Shapefile
data.*

