



ArcGIS™ 3D Analyst™ :
***Three-Dimensional Visualization, Topographic Analysis,
and Surface Creation***

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ArcGIS 3D Analyst: Three-Dimensional Visualization, Topographic Analysis, and Surface Creation

An ESRI White Paper

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ArcGIS 3D Analyst: Three-Dimensional Visualization, Topographic Analysis, and Surface Creation

ArcGIS 3D Analyst

ESRI® ArcGIS™ 3D Analyst™ is an ArcGIS extension that provides advanced tools for three-dimensional visualization, analysis, and surface generation. 3D Analyst includes sophisticated tools for three-dimensional modeling and analysis such as viewshed and line-of-sight analyses, spot height interpolation, profiling, steepest path determination, and contouring. In addition, users can perform surface area and volumetric calculations, slope, aspect, and hillshade. 3D Analyst also provides a rich suite of tools for interactive perspective viewing. Geographic information system (GIS) users already use maps to examine the spatial relationships in their data; now the user can see the effect that mountains, valleys, building profiles, and other three-dimensional objects have on these relationships. Whether the user is planning to build a new school, evaluating subsurface hazardous materials dispersion, or performing dramatic fly-through simulations, 3D Analyst is the solution for interactive perspective viewing and advanced three-dimensional modeling and analysis.



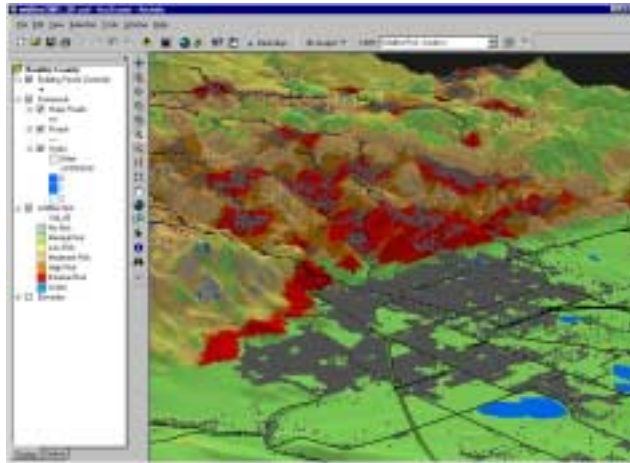
Powerful Visual Displays for Examining Real-World Phenomena



Terrain Analysis for Tasks Such as Visualizing Trends, Identifying Suitable Locations, and Deriving the Steepest Path on an Elevation Surface

Who Uses 3D Analyst

Any GIS user who needs a better spatial understanding of vector or raster data can use ArcGIS 3D Analyst. 3D Analyst enables users to examine the visual impact of building new structures; analyze atmospheric, surface, and subsurface pollution dispersion; visualize the income distribution in their community; and much more. With advanced raster–vector analysis and interactive three-dimensional analysis and visualization, almost any organization can benefit by analyzing its geographic area of interest with 3D Analyst. From analyzing three-dimensional surfaces of air pollution to identifying population distributions, 3D Analyst bridges the gap between a simple map on a computer and real-world visualization and analysis. Some of the various industries that utilize 3D Analyst include agriculture production, exploration geology, meteorology, hydrology, archaeology, forestry, health care, mining, real estate, park services, city governments, retail chains, and many others.



Local government agencies utilize 3D Analyst to accurately represent real-world fire danger for fire mitigation in local communities.

What's New in 3D Analyst 8.1

ArcGIS 3D Analyst 8.1 introduces many new features that include a world-renowned customization environment and integration into the ArcGIS interface; the user also has a variety of powerful tools for raster–vector analysis. The three-dimensional viewing interface ArcScene™ introduces an entirely new realm of three-dimensional visualization and analysis.

At version 8.1 many new features have been added to the existing functionality of ArcView® 3D Analyst.

- Integrated with ArcMap™ for ArcView, ArcEditor™, and ArcInfo™.
- ArcTIN™ and ArcView 3D Analyst are incorporated into one package.
- ArcScene viewing application for three-dimensional visualization.
- New symbology options.
- Displays personal and multiuser geodatabase data.
- High-resolution imagery.
- Advanced navigation tools.
- Great developer tools.
- Interactive contour and steepest path tools in three dimensions.
- Interactive perspective controls.
- ActiveX® scene viewer for use with other applications.

- GeoVRML export.
- Reclassifies for raster analysis.
- Converts rasters to features.
- Converts triangulated irregular networks (TINs) to features.
- New interpolation methods.
- On-the-fly TIN and raster projection.
- Animated rotations.
- Image catalogs.
- New scene export formats (.emf, .bmp, .eps, .tif, .pdf, .jpg, .cgm).

Surface Analysis

With ArcGIS 3D Analyst users can derive useful information such as hillshade, contour, slope, view-shed, or aspect maps. These topographic surfaces give you the power to effectively relate your data to real-world elevation and analyze how these varied surfaces will affect the data in question. By combining the terrain maps with the data in question, a more realistic depiction of the area is presented, which leads to accurate analysis for issues such as the location of a new school or road. The user can make use of the transparency feature in ArcMap to mold these data sets into one effective and highly visual map of the area. The user can then see where elevation and other terrain fluctuations may play a role in the spatial problem at hand.

■ Slope

Slope identifies the slope, or maximum rate of change, from each cell to its neighbors. An output slope raster data set can be calculated as either a percentage of slope (for example, 10% slope) or a degree of slope (for example, 45-degree slope). A GIS analyst might use the slope feature to assess areas that will be most susceptible to runoff from floods.

■ Aspect

Aspect identifies the steepest downslope direction from each cell to its neighbors. The value of the output raster data set represents the compass direction of the aspect: 0 is true north, a 90-degree aspect is to the east, and so forth. Aspect is important when determining the solar exposure of an area. Aspect can help identify areas of optimal plant growth and much more.

■ Hillshade

Hillshade is used to determine the hypothetical illumination of a surface for either analysis or graphical display. For analysis, hillshade can be used to determine the length of time and intensity of the sun in a given location. For graphical display, hillshade can greatly enhance the relief of a surface.

■ Contour

The contour function produces an output polyline data set. The value of each line represents all contiguous locations with the same height, magnitude, or concentration of whatever the values on the input data set represent. The function does not connect cell centers; it interpolates a line that represents locations with the same magnitude. Creating contours is an effective way to identify which locations have the same value. Contours are also useful for surface representation because they allow the

user to simultaneously visualize flat and steep areas for analyzing the distance between contours. The user can also identify ridges and valleys.

■ **Curvature (directional flow of angles)**

Curvature measures the slope of the surface at each cell. It calculates the second derivative of the input surface raster data set—the slope of the slope. The result of the curvature function can be used to describe the physical characteristics of a surface such as the erosion and runoff processes within a landscape. The slope identifies the overall rate of downward movement, and aspect defines the direction of flow. The profile curvature is the shape of the surface in the direction of the slope. The planform curvature defines the shape of the surface perpendicular to the direction of the slope.

■ **Area and Volume**

Calculate the three-dimensional surface area of a terrain, or assess the volume between the surface and a reference plane at a specific height.

■ **Profile**

Create profile graphs to see and measure height along selected lines. Profile graphs are used for tasks such as evaluating the difficulty of mountain trails or assessing a corridor for rail lines.

■ **Steepest Path**

Calculate a line that follows the steepest downhill direction on a surface.

Visibility Analysis

ArcGIS 3D Analyst allows the analyst to determine visibility on a surface from point to point along a given line of sight or across the entire surface in a view shed. The shape of a terrain surface can dramatically affect what parts of the surface can be seen at any given point. What is visible from a location is an important element in determining the value of real estate, the location of telecommunication towers, or the placement of military forces.

■ **View Shed**

View shed identifies either how many of the observation points specified on the input observation raster data set can be seen from each cell or which cell locations can be seen from each observation point. A fire mitigation expert might use this feature to identify areas that will be optimal for a new fire tower.

■ **Line of Sight**

Examine visibility from one point to another across a given surface. This can be useful for determining the optimal location of a fire tower or any new development.

Surface Creation

Typically, it is not possible or economically feasible to collect data points for every value within the area of interest. Therefore, an accurate, continuous surface creation is a must for predicting these values. 3D Analyst introduces a set of spatial interpolation functions, allowing the user to generate results for areas of missing data. For example, users can

use global positioning system (GPS) points to interpolate an elevation surface. 3D Analyst can also create TINs for high-precision modeling of small areas.

Interpolation

Interpolation is the process of predicting values at locations where data has not been observed using other data that has been collected.

3D Analyst includes the following interpolation methods:

■ **Spline**

Spline estimates values using a mathematical function that minimizes overall surface curvature, resulting in a smooth surface that passes exactly through the input points.

■ **Inverse Distance Weighted**

Inverse Distance Weighted (IDW) estimates cell values by averaging the values of sample data points in the vicinity of each cell. The closer a point is to the center of the cell being estimated, the more influence, or weight, it has in the averaging process. This method assumes that the variable being mapped decreases in influence with distance from its sampled location.

■ **Natural Neighbors**

Like IDW, this interpolation method is a weighted-average interpolation method. However, instead of finding an interpolated point's value using all of the input points weighted by their distance, Natural Neighbors interpolation creates a Delauney Triangulation of the input points, selects the closest nodes that form a convex hull around the interpolation point, and then weights their values by proportionate area.

■ **Kriging (Ordinary, Universal)**

Kriging is based on statistical models that include autocorrelation (the statistical relationship among the measured points). The two methods included give the user the power to produce a prediction surface as well as identify the certainty or accuracy of the predictions.

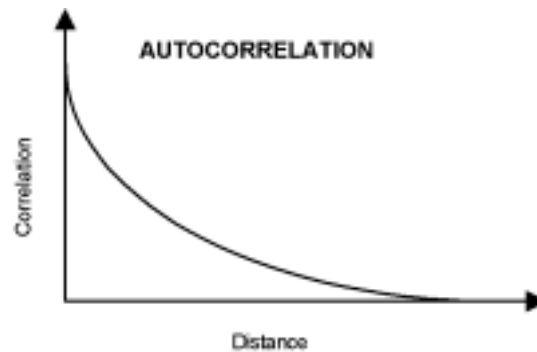
● **Ordinary Kriging**

Ordinary kriging is the most general and widely used of the kriging methods. It assumes that the constant mean of all the user's data measurements is unknown. This is a reasonable assumption unless there is some scientific reason to reject this assumption.

● **Universal Kriging**

Universal kriging is used when the analyst is aware of an overriding trend in the data (e.g., a prevailing wind), and it can be modeled by a deterministic function, a polynomial. This polynomial is subtracted from the original measured points, and the autocorrelation is modeled from the random errors. Once the model is fit to the random errors, before making a prediction, the polynomial is added back to the predictions to give the analyst meaningful results. Universal kriging should only be used when the user knows there is a trend in the data and can give a

scientific justification to describe it.



As distance increases the correlation between measurements will decrease.

◆ Semivariogram Models

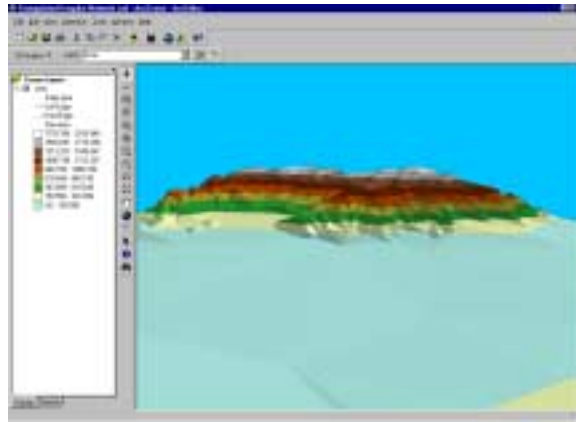
3D Analyst provides a variety of semivariogram models to model the empirical semivariogram and ultimately optimize the created surface with better statistical accuracy. The semivariogram is essentially the variogram divided by two. The variogram is the variance of the difference between two variables at two locations. The variogram generally increases with distance. The appropriate model is chosen based on the spatial autocorrelation and prior knowledge of the phenomenon. 3D Analyst includes the following functions for modeling the empirical semivariogram: circular, spherical, exponential, Gaussian, and linear.

◆ Variance of Prediction Surface

3D Analyst also allows the user to create a variance of prediction surface. This aids the analyst in identifying areas with large amounts of data error. The variance of prediction map quantifies the statistical uncertainty of each prediction for each cell location on the output kriging prediction surface. One will notice that locations near the sample points generally have lower variance (or error) than those farther away, indicating that the larger the variance, the greater the uncertainty for the prediction.

Triangulated Irregular Networks

A TIN is another type of an object used to represent a surface. A TIN partitions a surface into a set of contiguous, nonoverlapping triangles. 3D Analyst gives users the power to create TINs from any combination of point, line, and polygon feature types, as well as grids. Data that has no height information but is still important in defining a surface (such as a study area boundary) can also be used in creating a TIN.



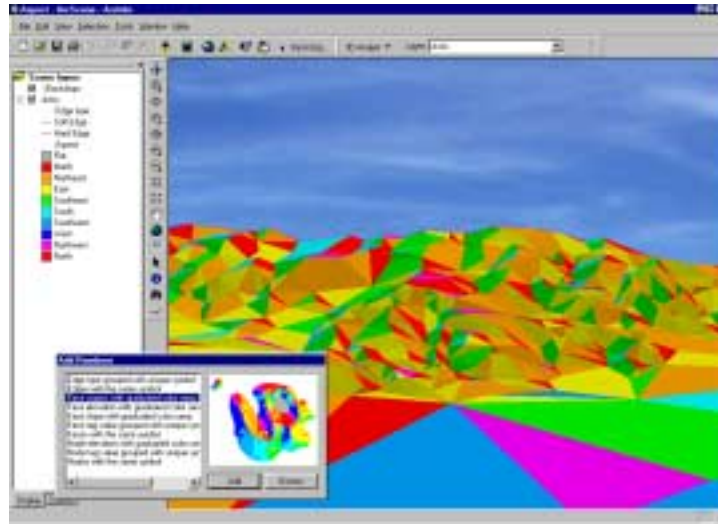
TIN displayed in ArcScene.

Some sources of data with z values include

- Digitized cartographic sources—contours and spot heights
- Remote accessing sources—spot heights and break lines derived from aerial photography, satellite imagery, radar, or lasers
- Engineering sources—survey, computer-aided design (CAD), and GPS
- Environmental sources—weather stations, wells
- Geologic sources—boreholes

TINs are typically used for high-precision modeling of smaller areas, such as in engineering applications, where they are useful because they allow calculations of planimetric area, surface area, and volume.

With 3D Analyst users can now display TINs as slope, aspect, node elevation, and similar edges, as well as many others, through the TIN symbology options.



Represent TINs with a variety of symbology options, such as aspect, for more in-depth analysis of the geographic region of interest.

Reclassification

The ArcGIS 3D Analyst reclassify command can be used for any given phenomenon to better visualize the importance of certain features. Reclassifying the raster allows the user to assign values of preference, sensitivity, priority, or some similar criteria to a raster. This may be done on a single raster (a raster of soil type may be assigned values of 1–10 that represent degree of susceptibility to erosion) or with several rasters to create a common scale of values.

Some of the most common reasons for reclassifying rasters include the following:

- Replace values based on new information.
- Classify certain values together for display.
- Classify certain values together for conversion to vector format for analysis.
- Reclassify values to a common scale.
- Set specific values to NoData or to set NoData cells to a value.

Three-Dimensional Visualization

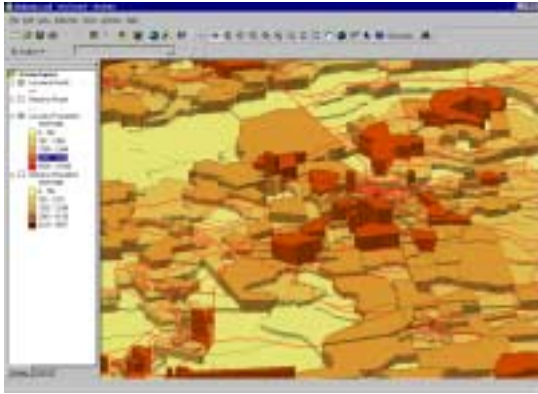
ArcGIS 3D Analyst provides a rich suite of methods for interactive perspective viewing including pan and zoom, rotate, tilt, and fly-through simulations. The high-quality, realistic three-dimensional scenes the user creates using 3D Analyst are easily turned into stunning animation sequences that make the presentation of the analysis even more compelling.

Displaying data in three dimensions displays patterns that are not evident in two dimensions. Interpreting contour lines or shading is not necessary; three-dimensional visualization can actually show how steep a slope is. Displaying other forms of data, such as population, in three dimensions can dramatize the situation beyond what is possible in two dimensions.

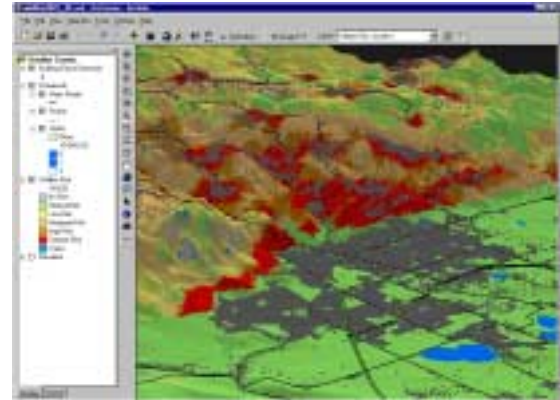
ArcScene

ArcGIS 3D Analyst adds a specialized three-dimensional viewing application, ArcScene, to the desktop. ArcScene lets the analyst make perspective view scenes in which users can navigate and interact with their GIS data. The user can drape raster and vector data over surfaces and extrude features from vector data sources to create lines, walls, and

solids. The user can also use the 3D Analyst tools in ArcScene to create and analyze surfaces.



Three-Dimensional View of the Population Distribution in a Section of Louisiana



Three-Dimensional View of Fire Risk and Elevation Within Boulder County

■ Interactive Three-Dimensional Data

Three-dimensional data can be viewed interactively in the ArcScene Viewer. The data can be viewed from any angle by rotating and tilting the object in the viewer. The user also has control over zooming in and out, panning, and flying forward or backward.

■ Control of Light Source

The user can set the azimuth and altitude of the light source, as well as the amount of contrast, used in rendering the illumination of the scene. The illumination properties for a scene apply to all of the aerial features (including extruded polygon and line features) in a scene. The user can also control whether individual layers are shaded by turning shading on or off on the Rendering tab of the layer's Properties dialog.

- Azimuth—the direction from which a light source illuminates
- Altitude—the height measured in degrees above the horizon from which a light source shines on the scene
- Contrast—the amount of shading applied to a surface

■ Shading

Shading illuminates a theme to add a sense of depth and realism. Changing the position of the light source is easy, and shading can be turned on or off.

■ Viewing Two-Dimensional Images or Vectors in Three Dimensions

The three-dimensional viewing environment can temporarily convert any two-dimensional ArcGIS data, including CAD, shapefiles, and ArcInfo coverages, to three dimensions on the fly. In this way, two-dimensional features can be viewed in

perspective without the need to create three-dimensional data sets. 3D Analyst can also drape a variety of image data sources (satellite images, aerial photographs, scanned images) onto surface features, adding visual texture and content to three-dimensional mapping applications.

The height or *z* source is selected from

- Surface—The height is calculated based on values in a grid or TIN.
- Attribute—A selection is made from a list of numeric fields in the theme.
- Constant—A value is provided as a constant *z* value.

Two-dimensional data can also be converted into three-dimensional data, if desired.

■ **Extruding Two Dimensions by Attribute or Function**

Extrusion changes the form of a feature in the 3D Scene Viewer. Points turn into vertical lines, lines turn into vertical walls, and polygons turn into three-dimensional blocks. There are two properties for extruding feature themes: (1) an expression or value that defines how far the features should be extruded and (2) the method that defines how the features will be extruded.

■ **Offsetting Three-Dimensional Data**

3D Analyst allows the user to incorporate offsets either to separate themes with similar base heights for a more accurate visual display or when the only height attribute for a theme is relative to a surface that is used to provide the base heights (e.g., height of utility lines above terrain). Values greater than 0.0 raise the height above the base heights; values less than 0.0 lower it.

■ **Multiple Surface Support**

More than one surface can be displayed at a time in the 3D Scene Viewer. Along with the support of offsets, displaying multiple surfaces is a good way to compare surfaces or what is happening between them. For example, a user may want to display an elevation surface in combination with a bathymetric surface to visualize shoreline trends.

■ **Scene and Z-Factor Exaggeration**

Vertical exaggeration refers to increasing or decreasing the height in a scene. It is common to increase the height of terrain models in which the horizontal extent is much larger than the vertical extent. The value specified for exaggeration will multiply heights for all themes.

Supported Data Types	ArcGIS 3D Analyst supports three primary types for modeling features in three dimensions: grids, TINs, and three-dimensional data.
TIN	A triangulated irregular network is a data structure that represents a continuous surface through a series of irregularly spaced points with values that describe the surface at that point (e.g., an elevation). From these points, a network of linked triangles forms the surface.
Grid	A grid is a geographical representation of the world as an array of equally sized square cells arranged in rows and columns. Each grid cell is referenced by its geographic x,y location.
Three-Dimensional Vector Data	Three-dimensional vector data is a vector data source (shp, CAD, GOB, etc.) that has associated z values stored within its geometry.
Exporting Data	<ul style="list-style-type: none"> ■ Export Snapshot in 3D Scene Viewer A snapshot displayed in the 3D Scene Viewer can be taken and exported into several image formats including JPEG and Windows bit map. ■ Data Export 3D Analyst includes a variety of file types to export the 3D Scene for visualization in other software programs. The 3D Scene can also be viewed in three-dimensions outside the application by using the VRML Export. ■ VRML Export With VRML Export users can export three-dimensional scenes to an exchange format for three-dimensional data called VRML. Because VRML browsers and plug-ins are inexpensive and widely available, the three-dimensional virtual worlds that users make from existing geographic data will be accessible to a wide audience. When a scene is exported, one main file is created that references a series of other files. A separate file is made for each theme that has its display turned on. An additional file is added if the scene contains graphics.
Querying Three-Dimensional Data	Sometimes just looking at three-dimensional data is not enough. The analyst often needs to query data or derive new data to solve problems. ArcGIS 3D Analyst lets the analyst explore the data on a map or in a scene and get the information needed. By simply clicking on surfaces or features the user can find out what they are. When the analyst clicks to get information about a TIN, the user can find out the elevation, slope, and aspect of the point. If the TIN feature has a tag value, it will be shown as well. When users click a raster surface, they can see the elevation value at the point. When users click a feature, they can see all of the attributes of the feature.
Data Integration	ArcGIS 3D Analyst integrates the user's data-enabling interaction between data of many different types. For example, images, elevation models, and other raster surfaces can be represented with CAD data and vector data. This brings spatial analysis to an entirely new level by giving the analyst the flexibility to do all of the analysis with one environment. 3D Analyst lets the user do integrated raster–vector theme analysis such as aggregating properties of a raster data theme based on an overlaid vector data theme. For

instance, regional or national maps showing the mean or the maximum precipitation for states or counties could be created by overlaying state or county boundary lines on a raster precipitation map.

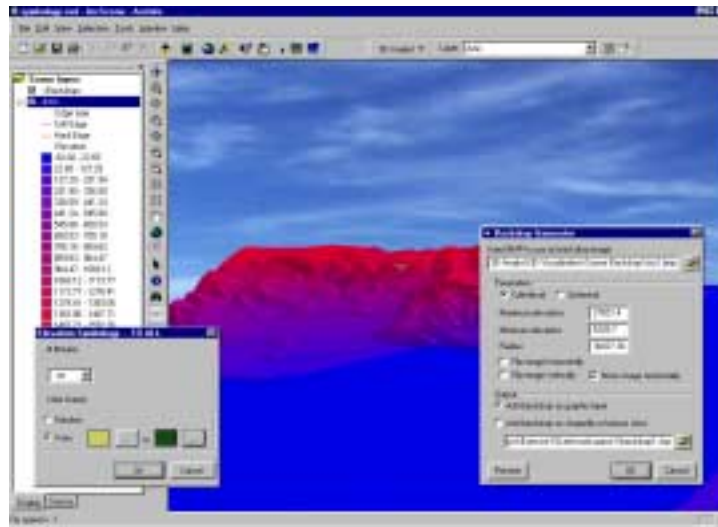
Customization

ArcGIS 3D Analyst has the ability to create custom tools for three-dimensional display and analysis and to incorporate these tools directly into the ArcGIS interface with any Component Object Model (COM)-compliant development environment.

New customization features never before seen in 3D Analyst are as follows:

- Customize the interface with the drag-and-drop and menu-driven tools.
- Create custom models and user interfaces.
- Add your own analysis functions.
- Use your own .dll or .exe.
- Support for new formats.

For more technical information, downloads, and developer scripts, please visit ArcObjects™ online at <http://arconline.esri.com/arcobjectsonline>.



Create custom tools for dynamic visual backdrops, unique symbology classifications, automation, additional graphic parameters, and much more.

Conclusion

ArcGIS 3D Analyst is an ArcGIS extension that provides advanced tools for three-dimensional visualization, analysis, and surface generation. 3D Analyst integrates a wide variety of terrain and visualization analysis tools within a dynamic three-dimensional environment. With 3D Analyst, the user can create exceptional raster and vector three-dimensional data sets for visualizing the data in an entirely realistic fashion. 3D Analyst also includes a variety of surface creation options either through interpolation for predicting the occurrence of a phenomenon or the triangulated irregular network for elevation surfaces. 3D Analyst now includes a sophisticated customization environment through Visual Basic for Applications so that users can create unique tools specific to their GIS analysis. Ultimately, 3D Analyst gives the GIS user the freedom to bridge the gap between static two-dimensional features and realistic three-dimensional modeling and analysis.