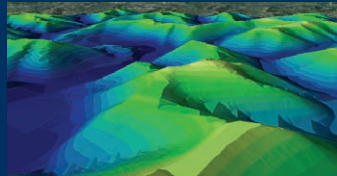
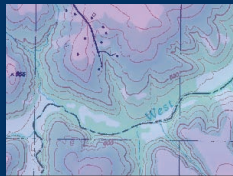




# introduction to 3D data

MODELING WITH ARCGIS® 3D ANALYST™ AND GOOGLE EARTH™



K. HEATHER KENNEDY



# Introduction to 3D Data



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Modeling with ArcGIS®  
3D Analyst™ and  
Google Earth™

**K. Heather Kennedy**



**WILEY**

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# Preface

*Introduction to 3D Data* teaches GIS specialists, analysts, and technicians how to use ESRI's ArcGIS 3D Analyst to model and analyze three-dimensional geographical surfaces, create 3D data, and produce displays ranging from topographically realistic maps to 3D scenes and spherical earthlike views. The book is organized into 10 chapters, each focusing on one data type or software interface (ArcCatalog, ArcScene, ArcGlobe, or Google Earth). There are 39 step-by-step project exercises, with plain-language discussions throughout of pertinent data structures and software mechanics. My goal was to create a friendly, engaging atmosphere that strikes a balance between reference-like tutorials that just tell you what to do but not why, and academic tomes that celebrate theory without suggesting any real-world application. After going through these exercises, you will know exactly what 3D Analyst can do, and you will remember the situations in which you applied particular techniques and created particular types of data.

Some readers will recognize material from my previous book, *Data in Three Dimensions: A Guide to ArcGIS 3D Analyst* (Onword Press, 2004), which covered 3D Analyst for ArcGIS 8.x. *Introduction to 3D Data* is updated and expanded for ArcGIS 9.3 and covers new data formats, such as Terrains, multipatch features, and KML. Google Earth is also addressed, but 3D Analyst remains the focus since its strength is GIS data creation and analysis, while Google Earth is mostly for display.

You will need to have ArcView installed to do the exercises in this book, and you will need a concurrent 3D Analyst license. Most of the exercises can be done using version 9.1 or 9.2, but some require 9.3. You will also need to have Google Earth installed.

The sample data on the support website at [www.wiley.com/college/kennedy](http://www.wiley.com/college/kennedy) is only for tutorial use. The data has been altered and so is not reliable for purposes other than illustrative or educational. The datasets are not to be sold, copied (except for personal use), or distributed.



# Acknowledgments

For providing the datasets used in this book, I'd like to thank Kent Anness and Rusty Anderson at Kentucky WRIS GIS, Ryan Freedman at Lakes Environmental Software and WebGIS.com, Jason Stoker at EROS, the North Carolina Floodplain Mapping Program via the USGS "CLICK" website, John Kelly at the SLO Datafinder, and Carol Schuldt of the Kennedy Library at Cal Poly, San Luis Obispo. I'd also like to thank Jim Harper, Dan Magers, Nancy Cintron, and Jeri Freedman of John Wiley & Sons, Josh Lazarus, and Lynda Gregory. I'd like to thank my husband, Tom McMurdo, for his never-ending support and for doing my chores while I wrote nights and weekends. Finally, I'd like to thank my dad, Michael Kennedy, author of many GIS books, including *Introducing Geographic Information Systems with ArcGIS*, Second Edition (Wiley & Sons, 2009) for his encouragement and support, and for his infectious enthusiasm that makes GIS fun.



# Introduction to 3D Data





## CHAPTER 1

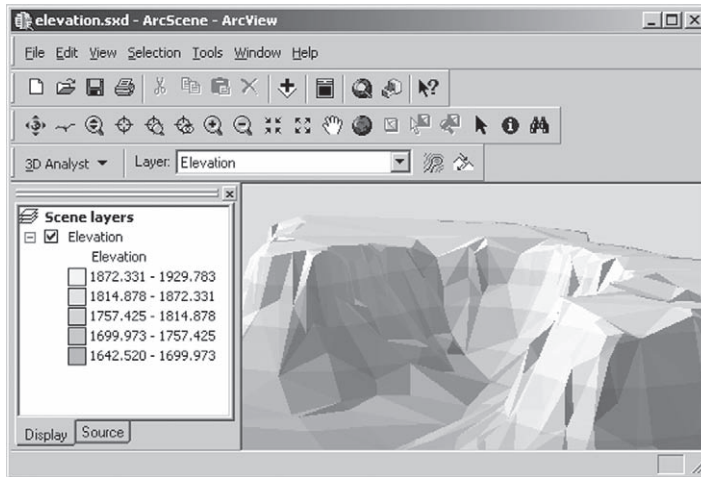
# Introduction to 3D Data: Modeling with ArcGIS 3D Analyst and Google Earth

*Introduction to 3D Data* is a self-study tutorial workbook that teaches you how to create data and maps with ESRI's 3D Analyst software, and to integrate them with Google Earth.

The datasets for all of the exercises in the book are provided online at [www.wiley.com/college/kennedy](http://www.wiley.com/college/kennedy). You must already have ArcGIS 3D Analyst installed to use this tutorial, as the book does not come with any trial software. Most of the 3D Analyst exercises can be done with versions 9.1 or 9.2 of ArcView, ArcEditor, or ArcInfo; some exercises require 9.3. Google Earth is free.

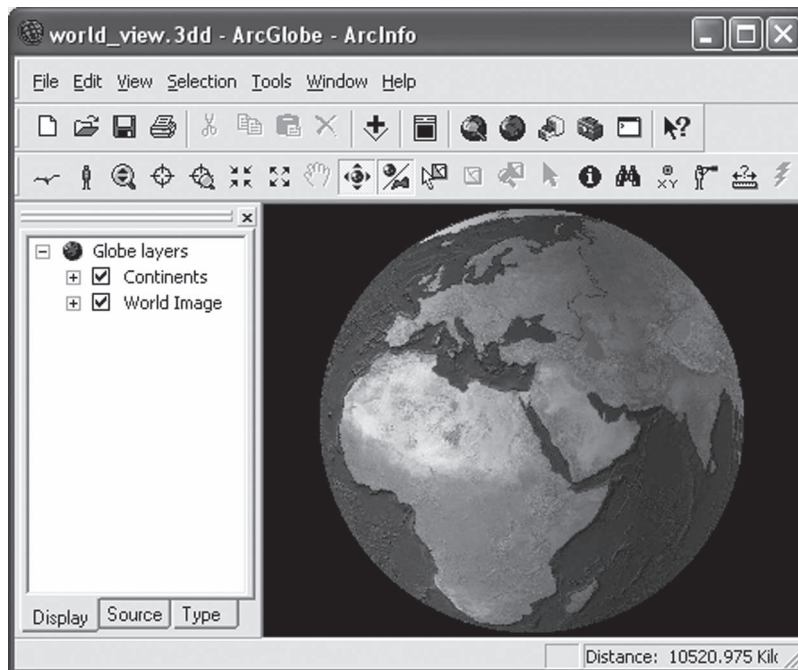
This book is designed for people who are already familiar with ESRI products, particularly ArcMap and ArcCatalog, but who would like to understand the ins and outs of the three-dimensional modeling environment. While you can do the exercises in any order, you should work through early chapters first, since instructions in later chapters are somewhat abbreviated.

3D Analyst is designed primarily to create surface elevation data and display it in three dimensions. It provides additional analysis functions such as viewshed, surface area, and volume calculation. Its original interface, ArcScene, presents data in three-dimensional space.



**ArcScene models data in three-dimensional space**

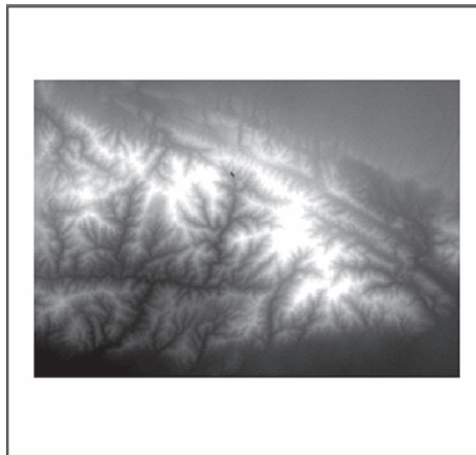
In version 9.0 ESRI added ArcGlobe to the package, which allows you to view large datasets in a global format.



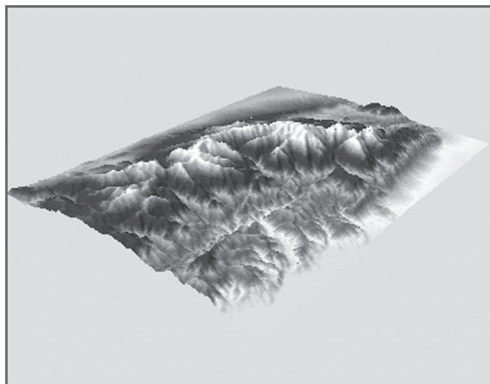
**ArcGlobe models data on the earth**

Increasingly, however, GIS users and the general public expect to be able to view maps interactively, on the web, for free. This is thanks largely to Google Earth, which has revolutionized the way we view spatial information. ArcGIS 3D Analyst has the power to create and analyze geographic data, but Google Earth has the speed and intuitive interface that makes it a staple for displaying maps and sharing spatial information.

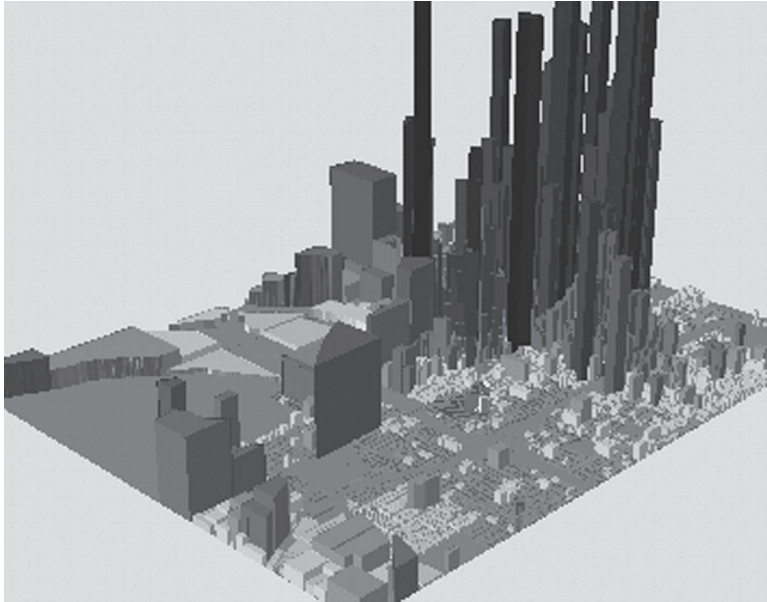
With 3D Analyst, you can create TIN (Triangulated Irregular Network) and raster surface models from any vector elevation data such as contour lines, GPS points, or survey points. In ArcScene and ArcGlobe, you can drape images and vector features over surfaces, fly through your GIS data in 3D perspective, and make movies of your flights. You can extrude 2D points, lines, and polygons into lines, walls, and solids, and you can create multipatch “true 3D” features. You can calculate slope, aspect, hillshade, volume, and surface area; create contour lines, and determine visibility from any point on a surface. You can also determine lines of sight, create profile graphs of a surface, and digitize 3D features and graphics.



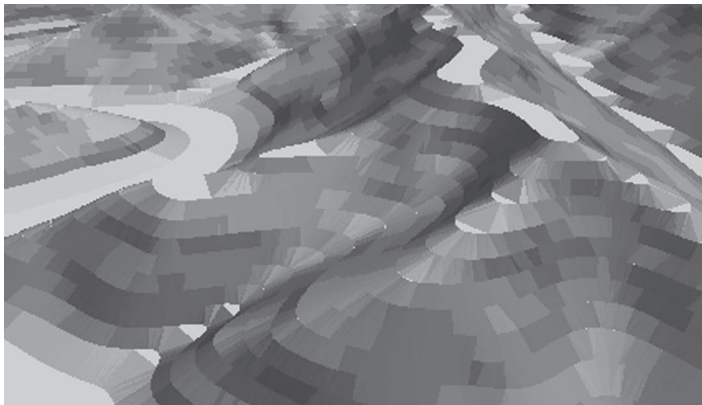
**An elevation raster in ArcMap**



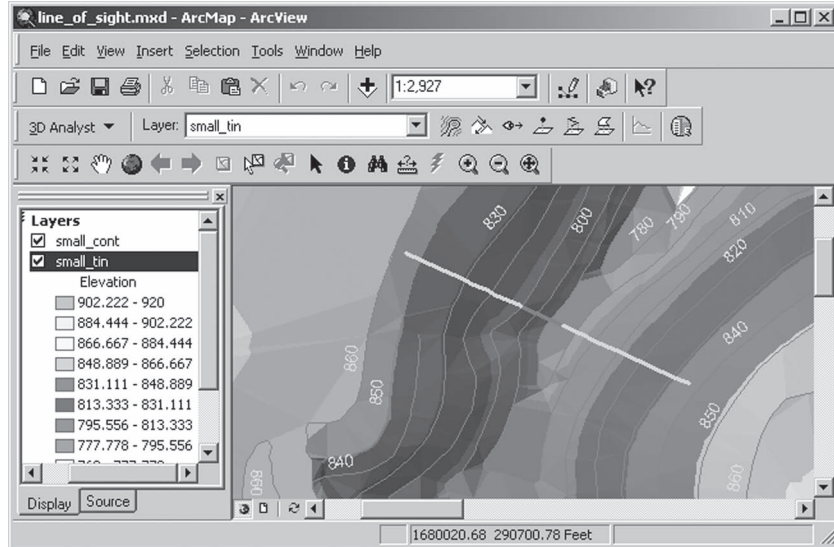
**The same elevation raster in ArcScene**



**Parcels colored and extruded by land value**



**A TIN created from contour lines with faces symbolized by slope**

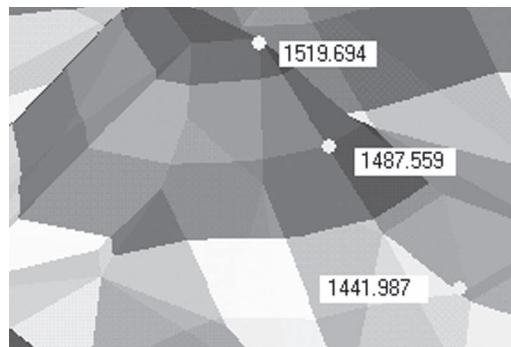


A line of sight drawn in ArcMap

## 3D Data Overview

### *X, Y, and Z Values*

All geographical data contains horizontal  $x,y$  coordinate values. To work in three dimensions, you need data that contains  $z$  values as well. For each  $x,y$  location stored in a 3D dataset, a  $z$  value is stored that represents an attribute other than that location's horizontal position. In a terrain model, the  $z$  value represents elevation, or height about sea level.



Three locations on the surface of a TIN, each labeled with their elevation ( $z$ ) values in feet

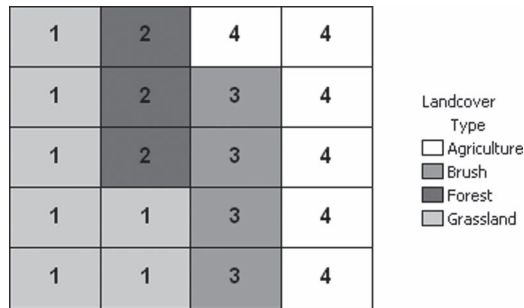
# Chapter 1

3D Analyst works primarily with raster, TIN, and 3D vector feature data. Rasters and TINs are used to model surfaces, not just of terrain but of any phenomenon that varies continuously across an area, such as precipitation, chemical concentration, pollution dispersion, noise levels, population distribution, or soil pH.

## Rasters

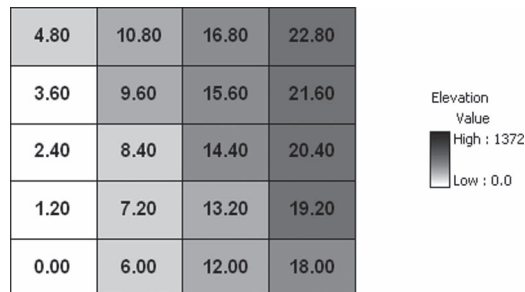
A raster represents a surface as a rectangular grid of evenly spaced square cells. Each cell is the same size and has a unique row and column address. A cell can represent a square kilometer, a square meter, or a square centimeter. The smaller the cells, the more detailed the raster, and the larger the file space taken up by the grid.

Since the grid is uniform, its horizontal (x,y) coordinates don't need to be stored in each cell. Instead they are calculated from the x,y location of the lower-left cell in the grid. Each cell does, however, hold its own z value that represents a quantity or a category of phenomena such as elevation, crop yield, or reflected light.



**Cells in a landuse grid. All cells with the same value are symbolized by the same color**

While landuse could also be represented by discrete vector polygons, vector data cannot represent values that change gradually, or continuously, over an area.



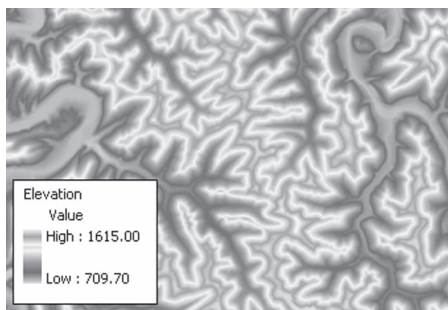
**Cell in a continuous grid, symbolized by value range**

Raster data is often divided into two categories: image and thematic. In an image, the surface phenomenon is the reflection or emission of light, or some other band in the electromagnetic spectrum, and can be measured by camera or satellite.



**An aerial photograph. Cells in this raster represent light reflected from the earth's surface**

When a phenomenon such as light is measured by a camera or a satellite, each cell's value represents the light and color at that point on the surface. A thematic raster, however, represents a category or quantity of a phenomenon such as elevation, pollution, population, rainfall, or noise. Since readings cannot be taken at every location, samples are taken instead, and a surface model is made. The model approximates the surface by interpolating the values between the sample points.



**A thematic raster of elevation values. A few of the cells represent samples actually taken, but most of the values have been interpolated**

3D Analyst uses the z value stored in each cell to display the raster in 3D. Elevation values are commonly shown, but any numeric cell value can be illustrated in three dimensions. Even though images and many

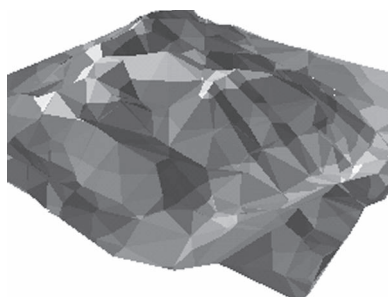
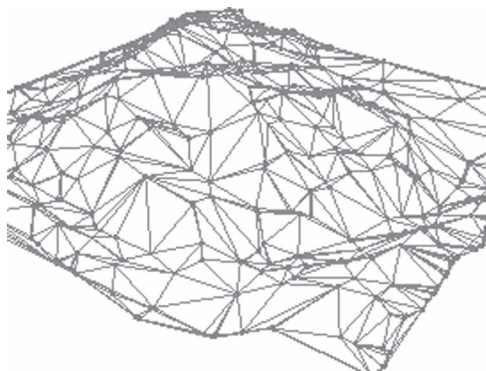
## Chapter 1

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thematic rasters don't contain elevation values, you can still display them in 3D by draping them over a 3D surface model with the same geographic extent.

### **TINs**

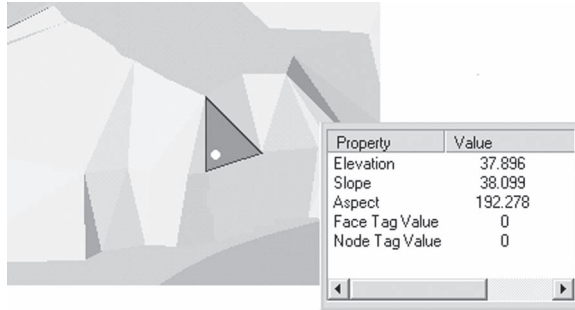
A Triangulated Irregular Network (TIN) represents a surface as a set of irregularly located points, joined by lines to form a network of contiguous, non-overlapping triangles that vary in size and proportion. Each triangle node stores an x, y, and z value.



**The structure of a TIN. Top: only the TIN edges and nodes are shown. Bottom: the TIN's triangles (faces) are colored to represent elevation**

Like rasters, the values in a TIN are interpolated from sample points. The sample points form the triangle nodes, and the interpolation (or triangulation, as it's generally called) consists of connecting the nodes by lines. Once the TIN is built, the elevation of any location on a TIN surface can be estimated using the x, y, and z values of the bounding triangle's vertices. The slope and aspect for each triangle face is also calculated.





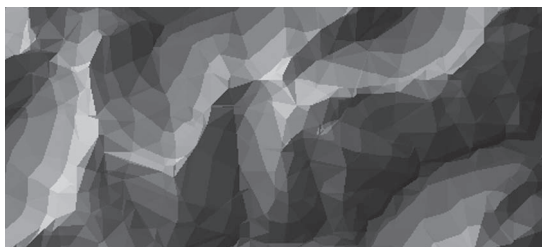
**When you identify any point on the face of a TIN, the node x, y, z values are used to interpolate the elevation at that point. The node values are also used to calculate the slope and aspect of each triangle face**

Because the nodes can be placed irregularly over the surface, TINs can show greater detail where a surface is highly varied or where you want more accuracy. A TIN is only as good as the initial sample points taken; mountainous areas need many more samples per square unit than flat areas do in order to create an accurate terrain model.

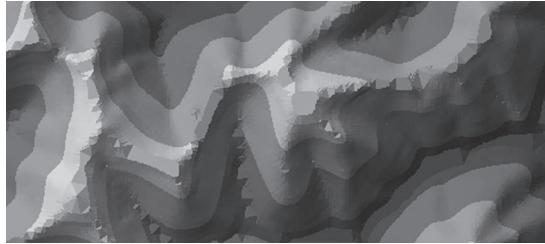
TIN models are less widely available than raster surface models; they take longer to build and require much more disk space. They are typically used for precise modeling of small areas.

## ***Terrain Datasets***

A terrain dataset represents a surface in the same way that a TIN does, but uses a different storage system. Elevation measurements collected by LiDAR or SONAR are typically used to create a terrain because they can result in millions of mass points. This enables the creation of a very accurate surface, but also makes for a large file size. Terrain datasets get around this by separating the TIN representations into multiple levels of resolution, called pyramids, for faster drawing of large datasets. At smaller scales, a coarser TIN representation is drawn; at larger scales, more detailed features are shown.



**In a lower-resolution pyramid of a terrain dataset, fewer triangles are calculated during display. This pyramid level would normally be drawn at a smaller scale in ArcMap**

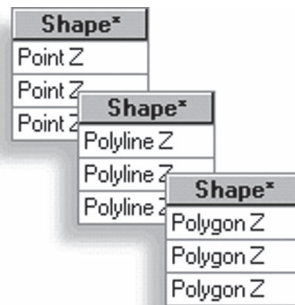


**In the finest resolution pyramid, all triangulations are represented in the terrain dataset. This pyramid level would normally be drawn at a large scale in ArcMap**

## 3D Features

3D vector features, like their 2D counterparts, represent objects or clearly bordered areas such as buildings, land parcels, roads, power poles, and wells. Often, the z values in 3D features are used to represent an attribute other than height. For example, you might create a scene that shows city points extruded into 3D columns based on their population.

Like TINs, 3D features store z values along with x, y coordinates as part of their geometry. A point has one z value; lines and polygons have one z value for each vertex in the shape. You can identify 3D feature classes by looking at the Shape field in their attribute tables.



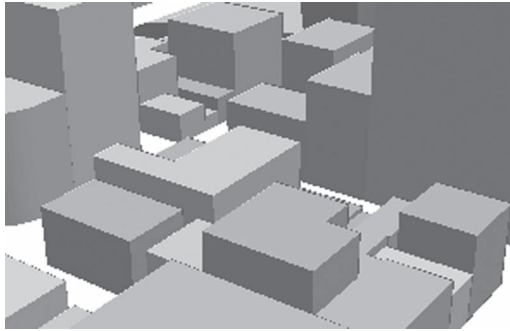
**A 3D feature class shows a Z value in its Shape field**

## 2.5-Dimensional and 3-Dimensional Data

Generally, when we talk about 3D data, we mean 2.5 D data. Rasters, TINs, and terrains are surfaces that store exactly one z value for each x, y value pair. Also, when we turn points, lines, or polygons into solids, we're really just extruding 2D coordinates by a set of specified values.

True 3D geometric structures are represented in 3D Analyst by multipatch features. Multipatches are made of planar 3D rings and triangles stitched together to model objects like spheres, trees, rooftops, or buildings with overhanging features.

Software programs like Sketchup (Google's free 3D modeling software), 3ds Max, OpenFlight, and VRML 2.0 can create models that 3D Analyst can import into a geodatabase and use as symbols. They can also be used as graphics in ArcScene or ArcGlobe, without committing them into a geodatabase.



**3D features extruded from 2D polygons. Each x,y vertex has one companion z value**

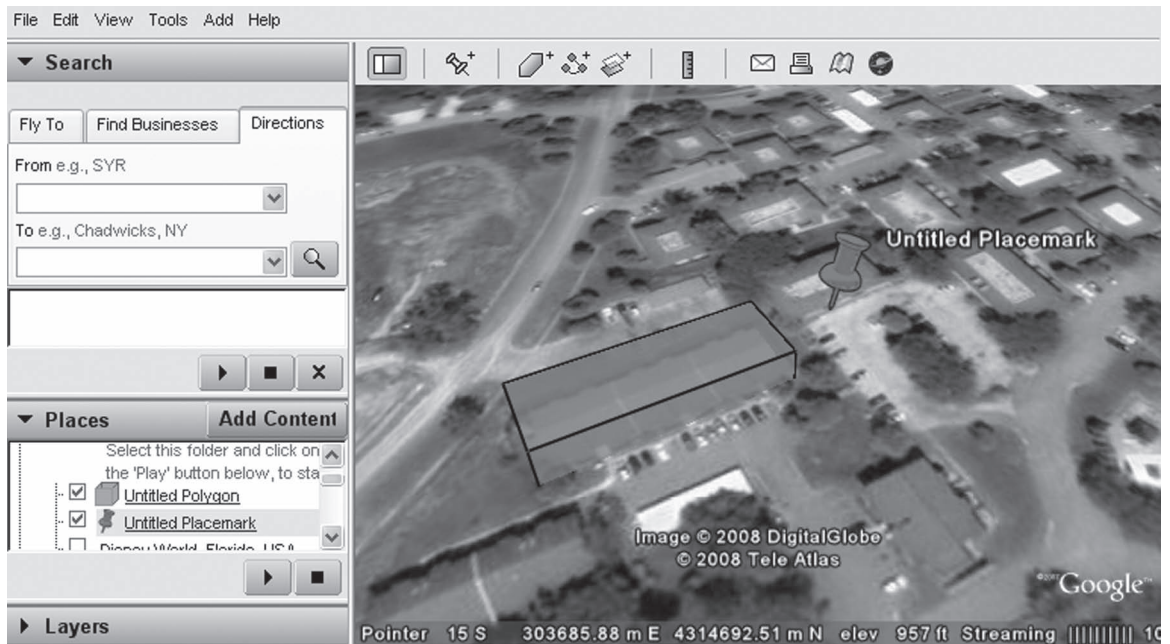


**Multipatch (true 3D) features can handle multiple z values per x,y vertex, permitting realistic representations of features that include overhangs or textures**

## KML

KML is Google Earth's file format for displaying 3D data. You may be used to seeing the most common form of KML document in Google Earth and Google Maps: the Placemark. This is similar to a point feature class in ArcGIS in that it represents a geographically referenced point on the earth. It differs completely, of course, in the file structure and instructions used for rendering. KML is a tag-based structure similar to HTML and XML that can be created or altered in any text editor. Generally, though, you will create 3D features directly in Google Earth, or import files created in Sketchup into Google Earth.

Besides Placemarks, KML allows you to create or place polygons, lines, and raster image overlays in Google Earth.



**A Placemark and a Polygon created in Google Earth. The KML code for the Placemark object is shown below:**

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```

Now that you've had an introduction to 3D data structures, you're ready to learn how to use 3D Analyst.

## Load the Tutorial Data

The next two exercises will teach you how to work with 3D data in ArcCatalog. Before you can do any exercises, however, you need to load the 3D Analyst tutorial data and add the ArcScene, ArcGlobe, ArcCatalog, and ArcMap program icons to your desktop.

Visit the support website for the book to download the tutorial data at [www.wiley.com/college/kennedy](http://www.wiley.com/college/kennedy). Click on the cover for *Introduction to 3D Data: Modeling with ArcGIS 3D Analyst and Google Earth*. On the next page click the link for the Student Companion Site on the right side of the page and follow the links for the 3DDATA.zip archive. Download the zip file to your desktop and extract the archive to the drive of your choice using a program such as WinZip or 7-Zip (freely available at [www.7-zip.org](http://www.7-zip.org)). If you have the disk space, I recommend that you copy it directly under your C: drive, so that the full pathname reads "C:\3DDATA."

Once the contents of the 3DDATA.zip archive are copied to your hard drive, you can delete the zip file as you won't need it again.

### ***Add the Program Icons to Your Desktop***

Note: ArcGIS 3D Analyst must be installed before you can create shortcuts to it on your desktop. If you have not installed the software, please see the ArcGIS 3D Analyst installation guide.

1. On the taskbar of your desktop, click the Start menu. Move your cursor to Programs, then ArcGIS, and right-click on ArcScene.
2. Choose Send to . . . , and then click Desktop (Create Shortcut). A shortcut to ArcScene is added to your desktop. (This procedure is for Windows XP; if you're running Windows 2000, NT, or Vista, it may be a little different.)
3. Use the same procedure to add the ArcGlobe icon to your desktop. If you don't already have desktop icons for ArcCatalog and ArcMap, you should add them as well.