ArcGIS Tools for Professional Cartography

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ABSTRACT

ArcGIS is professional Geographic Information Systems (GIS) software produced by Environmental Systems Research Institute (ESRI), Inc. of the United States of America. This software facilitates map design by giving users the ability to easily layout maps for printing, embedding in other documents, or electronic publishing.

This paper explores a sample of the different tools available in ArcGIS 9 for the purpose of creating professional maps. These tools are not only present as interactive cartographic tools in ArcMap but also as geoprocessing tools in ArcToolbox that can be utilized for automation of cartographic enhancement.

Some examples of what can be done include using geoprocessing tools to enhance the visibility of contour labels or the non ambiguous display of overlapping linear symbology; using tools, which were originally designed for analysis tasks, to enhance the figure-ground of the land-water masses; creating generalized renditions of features for use in smaller scale maps; processing raster data in ArcMap, ArcToolbox, and the Spatial Analyst extension to provide cartographically suitable three-dimensional (3D) background for the map to enhance visualization of the terrain; and tools for labeling and annotation, including the use of both the Standard and the Maplex label engines.

INTRODUCTION

Computer assisted cartography has reached an advanced stage with all the research and development efforts placed in the production of such an advanced and sophisticated GIS software represented by the ArcGIS 9 software with all its extensions.

ArcGIS 9 is available in three different license levels depending on how much and what type of functionalities the organization needs. These licenses are: ArcView 9, ArcEditor 9, and ArcInfo 9. Any of these licenses has two major applications: ArcMap and ArcCatalog. It also comes with a dockable ArcToolbox module which can be invoked in either of the two applications. ArcToolbox has a comprehensive set of geoprocessing tools. ArcCatalog is an application with a graphic user interface to view and manage GIS data. ArcMap is an application with a graphic user interface to display, query, edit, analyze, and map the data.

ArcGIS 9 comes with several tools that can be used for cartographic purposes. This is essential as the end product of any GIS analysis is usually a map. The following topics will discuss the different tools that are available in this software to create professional cartographic products.

CARTOGRAPHIC TOOLS AVAILABLE IN ArcMap

There is a wide list of cartographic tools embedded in ArcGIS in different parts of the interface. Most appear on toolbars, and the remainder appear either within a dialog or in ArcToolbox. Figure 1 shows the general list of these tools. This list is not all the available cartographic tools in ArcMap.
The **Symbol Levels** concept

Many GIS databases comprise of street data that are represented as center lines, i.e. the streets were digitized as line features instead of polygon features. The cartographer will have difficult time and perhaps it would cost a lot of money to acquire polygonal data for the streets in order to display the streets by their different Street types (example: an interstate highway, a local street, an on/off ramp, etc....).

The cartographer can use the capabilities in ArcMap to simulate polygonal representation of the street using cased line symbolization. The first thing the cartographer can do is to use multi-layered wide symbology with the top layer colored based on the street type. Then he/she would use the Symbol Levels concept to manage the way these different color coded streets would merge or cross over or under other streets.

Figure 2 shows the different street-type data layers under the *Redlands roads* data frame in ArcMap’s Table of Contents (TOC). All six data layers have been symbolized with a two-layer symbol: the bottom symbol layer is a wide black line and the top symbol layer is a thinner colored line. The combination of the two symbol layers represents a black-casing exterior and a color-coded interior. Notice, that each of the six symbols vary in size, depending on the street type; thus simulating various sizes of rights of way. This information can come from a field in the feature attribute table of the streets feature class or shapefile. Remember, one can do all this with simply a linear feature class representing the street centerlines.

Figure 3 shows the result of using the Symbol Levels tool in ArcMap. This is the result of multiple operations involving: rearranging the layers in ArcMap’s TOC, rearranging the layers in the Symbol Layers dialog box in Figure 4, and turning on or off the checkboxes next to the layers in both the Join and or the Merge columns in the Symbol Layers dialog box in Figure 4.

![Figure 2: Six layers symbolized differently in ArcMap’s TOC.](image1.png)

![Figure 3: The result of using the Symbol Levels tool in ArcMap.](image2.png)

![Figure 4: Portion of the Symbol Levels tool’s dialog box.](image3.png)

![Symbol|Layer Name|Label|Join|Merge](image4.png)
The Variable-depth masking concept

Variable-depth masking is a drawing technique for hiding parts of one or more layers. Masking is usually done around important features. First, the cartographer will create a polygon layer that supplies the areas defining the mask. Then he/she specifies which target layers are to be masked. The drawing process clips the content of the target layers within the areas of the masks.

There are three geoprocessing tools to produce common kinds of masking polygons. Figure 5 shows a portion of the ArcToolbox where these tools are located. These tools are only available with an ArcInfo license. These tools respect symbolization (e.g., font size, line thickness). To create masks for text the cartographer must have annotation. Labels cannot be masked. For maximum performance, the mask should be the simplest possible.

- Cartography Tools
  - Masking Tools toolset
    - Cul-De-Sac Masks tool
    - Feature Outline Masks tool
    - Intersecting Layers Masks tool

Figure 5: Portion of the ArcToolbox geoprocessing tools showing the cartographic Masking tools

1. Cul-De-Sac Masks

This tool is used to resolve the problem of creating rounded line ends when using the round end caps property for thick lines in order to smooth their connections. Rather than having lines end with a rounded end cap, the end of the line can be masked using the polygon feature class created with this tool. Figure 6 shows an example of how this tool works.

Figure 6: How the Cul-De-Sac Masks tool works to enhance the quality of thickened line symbology.

2. Feature Outline Masks

This tool is used to create masking polygons at a specified distance and shape around the symbolized features in the input layer. This is useful to mask the contour lines under the annotations of the contour values without erasing underlying hillshading, or to mask street network under the city marker symbol. Figure 7 shows an example of how this tool works.

Figure 7: How the Feature Outline Masks tool works to enhance the legibility of the contour annotation.

3. Intersecting Layers Masks

This tool is used to create masking polygons at a specified shape and size at the intersections of symbolized input layers. This is useful to mask the lines of the river layer under the lines of the roads layer. Figure 8 shows an example of
how this tool works as applied to masking the boundary symbol along the road symbol where the two features are in coincidence.

![Figure 8: How the Intersecting Layers Masks tool works to enhance the legibility of overlapping line symbology.](image)

**Improving figure-ground using Analysis tools to create a vignette**

Although the Multiple Ring Buffer tool was originally created for use as an analysis tool, however, it can be very useful for cartographic purposes. In Figure 9, the Proximity toolset of the Analysis Tools in ArcToolbox was used to create the five ring buffer for South America. With the choice of an appropriate color ramp, the five buffers gradually changed color from white near the shore to the blue of the ocean creating a coastal vignette. This created an enhanced figure-ground for the land mass as well as adding more aesthetic quality to the final map product.

![Figure 9: Using an ArcGIS analysis tool to enhance the figure-ground effect of a mapped area.](image)

**On-the-fly clipping tools**

Sometimes the cartographer needs to show a clipped area of a certain region, but does not want to physically create data stored on disk for this clipped area. In ArcMap, one of the properties of the data frame is to clip on-the-fly using a selected pre-drawn graphical shape. In Figure 10, a circular graphic was used to clip on-the-fly an area in a city. This procedure clips all the displayed layers even the text. Notice that two other clipping options are available on the same interface.
Generalization tools

There are several generalization tools in ArcGIS that can assist in creating generalized versions of the data for producing maps at specified reduced scales. These tools are found under the geoprocessing tools in ArcToolbox. These tools are available for both generalizing vector and raster data. Some of these tools require a workstation ArcInfo license or the Spatial Analyst extension. Figure 11 shows some examples of generalization techniques available in ArcGIS [Lee, 2003].

Utilizing the ArcGIS Spatial Analyst extension tools for 3D visualization

ArcGIS with its Spatial Analyst extension offers special techniques done mostly by using Map Algebra expressions to enhance the 3D visualization of the terrain in maps. The following paragraphs discuss four different 3D visualization techniques.

1. Special shading

You can superimpose raster data on top of other raster data (e.g., hillshade). The superimposed image can be symbolized with accentuated colors and placed with a suitable transparency on top of the hillshade, creating a dramatic and aesthetic rendition of reality. This technique can be employed using the core ArcGIS software; no need for the ArcGIS Spatial Analyst extension nor the use of any Map Algebra functions. Observe this transparent effect of the layer draped on top of the hillshade in Figure 12A.
2. Multi-directional, oblique-weighted shaded relief

This method was proposed by Robert Mark of the United States Geological Survey [Mark, 1992]. He experimented with the display of raster data to enhance its 3D rendition. He wrote an algorithm that emphasizes oblique illumination on all surfaces. His method combines computer-generated shaded-relief images illuminated from 225, 270, 315, and 360 degrees azimuths, each 30 degrees above the horizon. He used weights that were calculated for each image, on a cell-by-cell basis, as well as a generalized aspect map with smoothed 1000-meter cells. His technique highly enhances the details that are obliterated in the traditional hillshading technique in the shaded portion of the image. All the Map Algebra statements involved in this method can be employed in the ArcGIS Spatial Analyst extension. Observe the details in the shaded area of the hillshade in Figure 12A.

3. Swiss style hillshading technique

This method was proposed by David Barnes of ESRI [Barnes, 2002]. He combined ArcGIS Spatial Analyst functions and a special display technique. The Spatial Analyst Map Algebra functions include the use of the Focal Statistics Neighborhood tool from ArcToolbox whereby a circular neighborhood is utilized to calculate median values for every cell that is being processed based on the type of neighborhood. Observe the enhanced cartography in Figure 12B using this technique

4. Adding texture

Painting the relief with landscape patterns derived from imagery or photographs can create an effective method of portrayal in maps to better understand the landscape for decision making activities. This method was proposed by Jeff S. Nighbert of the United States Bureau of Land Management (BLM) [Nighbert, 2001]. He devised a special method to add a visual texture to the painted relief, by decreasing the elevation values, in the elevation layer, where trees were cleared for ski runs, by a distance equal to the average height of the cleared trees from the mountain forests. Similar effect can be induced at the locations of water bodies in that surface. All the Map Algebra statements involved in this method can be employed in the ArcGIS Spatial Analyst extension. Observe the enhanced texture in Figure 12C.

![Special shading](imageA.png) ![Swiss hillshading](imageB.png) ![Adding texture](imageC.png)

Figure 12: Special techniques in ArcMap for 3-D visualization using raster data.

Labeling and annotation for professional cartography using ArcMap

In ArcMap there are two labeling engines: the Standard Label Engine and the Maplex Label Engine. The latter requires the ArcGIS Maplex extension and has more rules that one can set to create and facilitate better name placement on maps. Figure 13 shows a decision making roadmap to assist the user of the software as to what path to use in labeling or annotating the map.
Figure 13: A decision making roadmap to assist the user of ArcMap as to what path to use in labeling or annotating the map. GDB stands for the geodatabase data model of ArcGIS. FC stands for feature classes. GP stands for geoprocessing tools in ArcGIS. CAD stands for computer-aided design data formats.

ArcMap uses default settings for dynamic labeling when one first starts labeling. Although the software has some good fixed labeling defaults, some labels might not be positioned correctly where they should. Both the Standard label Engine or the Maplex Label Engine can help the cartographer by offering stricter rules that he/she can set to enhance the quality of the labels and dramatically reduce the label placement problems. Figure 14 shows an example of two choices that one has with the Maplex extension to automatically resolve ambiguous labeling on linear features.

Figure 14: An example of two choices in the Maplex extension to resolve ambiguous labeling on linear features.

Regardless of the Label Engine used, the labels will remain dynamic until one converts them into annotation. This freezes them for the scale of map publication and for a chosen viewing distance. At this time the cartographer can manually finalize the placement of the annotation features. The ArcMap user has a choice to save the annotation in a map annotation group where the annotations are stored in the map document, or store the annotation as an annotation feature class in a geodatabase. Thus, the ArcMap user has a lot of flexibility in creating useful and faster reading maps using text sizes that are legible at the scale of map publication and satisfying the required viewing distance for the map use.

One of the advantages of the Maplex extension is the use of abbreviation dictionaries. This feature in the software should be set before labeling. Then the software will use this dictionary, and based on the users three pre-set rules, will apply the abbreviations. This saves the cartographer a lot of time and effort; minimizing the post-processing or editing of the map labels.

For other examples on labels and annotations using ArcMap see the paper entitled: Professional Labeling and Text Annotation Techniques with ArcMap [Murad-al-shaikh, 2005].

CONCLUSION

Computer assisted cartography has reached an advanced stage. Many previously time consuming operations in cartography have been greatly simplified. GIS software has played an important role in these cartographic improvements. ArcGIS 9 produced by ESRI, Inc. offers cartographic tools that definitely make a difference in the life
of a contemporary cartographer. ESRI, Inc. has strong database-driven cartography capabilities and has a vigorous development program in this area, as described in [Hardy and Kressmann, 2005].

REFERENCES


BIOGRAPHY

Mr. Murad-al-shaikh has over 30 years of experience in the educational field in a variety of disciplines ranging from civil engineering, cartography, and Geographic Information Systems (GIS). He joined Environmental Systems Research Institute (ESRI), Inc. in 1993 as a Senior Instructor and teaches both introductory and advanced courses focusing on ESRI technology. Mr. Murad-al-shaikh received his B.Sc. in Civil Engineering in 1969 from Al-Hikma University in Baghdad, Iraq, a certificate in Educational Technology from Huddersfield Polytechnic in England in 1979, and his M.S. in Cartography from the University of Wisconsin-Madison, USA in 1983.

While as a senior instructor in ESRI’s Educational Services group, Mr. Murad-al-shaikh has been involved in designing, authoring, and conducting training courses for ESRI software users. Mr. Murad-al-shaikh has trained users at universities, companies, and government agencies both in the United State of America and abroad. He is the course manager, co-author, and author of several instructor-led courses at ESRI. His recently published ESRI’s course is *Cartography with ArcGIS*. He has participated in enhancing several ESRI courses to better communicate cartographic and GIS concepts with his graphics capabilities.

Between 1970 and 1993, Mr. Murad-al-shaikh worked as an Assistant Professor at the Institute of Technology in Baghdad, Iraq. Since 1983, he was responsible for the instruction of cartography and remote sensing courses at various levels at that location. Mr. Murad-al-shaikh also taught various cartography and remote sensing courses on a part-time basis in the graduate and undergraduate programs at the Geography Department of the University of Baghdad, Iraq. He was the first cartographer to introduce GIS concepts as part of the curriculum in both institutions he was teaching at in Iraq in the mid 1980s.

Since 1996, Mr. Murad-al-shaikh has been teaching *GIS cartography* courses within the GIS certification programs of five local colleges and universities in Southern California, USA.

Mr. Murad-al-shaikh has written thirteen text and reference books in civil engineering, calligraphy, educational technology, cartography, GIS, and remote sensing. He also has published several papers on calligraphy, cartography, remote sensing and GIS.