Cartographic Visualization with ArcGIS

In the education, research and advisory services environment of our institute (ITC, the Netherlands) we have come across quite a few wrong ideas of what ESRI’s new ArcGIS really is about. ArcGIS is not simply another software package. On the contrary, it is a family of GIS software products with the same architecture and a common (Windows) user interface. However, it has different "levels of functionality" which may be employed according to the specific GIS needs and requirements of the users and their organizations. The big advantage is, of course, that users do not have to familiarize themselves with new software and a new interface as soon as they need more functionality. ESRI facilitates differences and possible changes in user needs by applying a flexible and "floating" license concept with the installation of the ArcGIS desktop.

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License Manager, but only one hardware key), ArcView has exactly the same functionality but is extended by ArcGIS in providing access to multi-user editing, advanced analysis and spatial database and Internet services (the latter not only for dissemination purposes, but also to access data in e.g. the Geography Network). ArcView 8.1 may be customized at different levels. It includes, for instance, Visual Basic for Applications.

ArcGIS Licensing

ArcEditor 8.1 is neither the same nor the successor of ArcEdit. It is a completely new software product with the same functionality as ArcView 8.1 but with the additional power to edit features in a multi-user geodatabase or (ArcInfo) coverage. And next to all this, ArcInfo 8.1 has more advanced geo-processing functionalities, as expressed by the maximum number of ArcToolbox functions referred to above. It should be noted that ArcInfo 8.1 in fact consists of ArcInfo Desktop, with only menus and wizards, as well as the complete "old" ArcInfo Workstation, with the same interface as ArcInfo 7.

ArcGIS Extensions

There are six new ArcGIS extensions that add functionality to ArcView, ArcEditor or ArcInfo. Functionally wise, these extensions do not differ when called upon by either ArcView or ArcEditor or ArcInfo. The Spatial Analyst extension combines the capabilities of the extension we already knew of the former versions of ArcView with those of ArcGRID. The extension can be used for surface creation, raster analysis and grid algebra. 3D Analyst is for 3D visualization and analysis and combines the capabilities of the old 3D Analyst extension of ArcView and ArcTIN. 3D Analyst includes the new three-dimensional viewing application ArcScene. Geostatistical Analyst is a new extension for advanced surface interpolation, modelling and exploratory...
ESRI's ArcGIS 8.1

Spatial data analysis. The new ArcPress extension is a PostScript-based Raster Image Processor (RIP) for printing and exporting of maps with improved colour output control. StreetMap is for street display and geo-coding (at the moment, for the USA only) and the MrSID Encoder produces smaller-sized MrSID images from geo-referenced input images up to 500 MB and mosaics MrSID images. Other new ArcGIS extensions are on their way (e.g. Survey Analyst, Network Analyst, Tracking Analyst, Business Analyst, Maplex, etc.). Finally, ArcSDE and ArcIMS are the fully integrated application services on the ArcGIS platform. ArcIMS adds Inter- and Intranet functionality to ArcGIS and ArcSDE is the interface for storage and management of a multi-user geo-database in a DBMS. Together, these application services make possible a mutual integration of Internet, Intranet and local geo-data and also allow for their dissemination.

System Requirements

The ArcGIS desktop products run on Windows NT4 (SP 6a or higher), Windows 2000 (SPs) and Windows XP. The minimum system requirements are a Pentium 450 MHz with 128 MB RAM, but a Pentium 650 MHz or higher with 256 MB RAM (available) and more than 1 GB disk space (without data) is strongly recommended (and perhaps even necessary, as we have discovered). These requirements are one of the reasons why ESRI will continue the support of ArcView 3.x for the time being. After all, for running ArcView 3.x all you need is a Pentium with 32 MB and Windows 95/98. Besides, the stand-alone version of ArcView 8.1 is somewhat more expensive than ArcView 3.x, and another reason why users may want to continue working with 3.x is that a customization with Avenue scripts cannot be transferred to the 8.1 environment.

ArcCatalog

In view of the expertise of the authors, the rest of this concise review of comprehensive software will emphasize the cartographic visualization aspects of the ArcGIS desktop applications, usually in comparison with ArcView 3.x, the most "cartographic" predecessor. Therefore, we will not deal any further with the working of ArcToolbox, nor with many other standard GIS functionalities and the new 'geo-database' object-oriented vector data model that increases interoperability. Instead, we will concentrate on the cartographic functionalities of ArcMap. But, before doing so, first a few words should be devoted to ArcCatalog. For ArcCatalog is a very useful management tool to connect to data sources (be they e.g. on the local hard disk, on the Intranet or the Internet) and to pre-view the data. It is more than just the 'Windows Explorer' of ArcGIS, if only because of the options to incorporate and edit meta data. In addition, ArcCatalog does not only provide cartographic and tabular previews of the data, but also offers some basic functionality to explore, query and edit the data on the basis of these previews. For example, in the map preview it is possible to "identify" singular objects in a similar way as in ArcView 3.x. Furthermore, the user may edit a table preview by adding or deleting fields. A disadvantage is that the user is not able to add or change values for a field. Another functionality is the calculation of statistics and the production of a frequency distribution for a field. ArcCatalog also offers useful search functionality: a user may search by geographic location and within the metadata. Searching based on geographic location is possible by drawing a box around the area of interest, by selecting a location from a drop-down list, by specifying geographic coordinates in text boxes or starting from a user-defined map. One important thing that is missing in the main menu of ArcCatalog is an "undo" function. For example, after deleting a file in the catalog tree it is not possible any longer to reverse this action. Therefore, users have to take great care when organizing files in GIS folders.

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Cartographic Digitizing and Editing in ArcMap

In ArcMap, new cartographic features may be created and existing ones edited, similar to ArcView 3.x but with many new functionalities. Users need no longer be dependent on buying cartographic datasets but may create or edit their own. Input of various data formats is possible, or use can be made of digitizing tablets that support the Wintab driver. Compared to the possibilities offered by ArcView 3.x, the new snapping interface and facilities make digitizing more comfortable. Examples are vector snapping capabilities like snapping to reference layers with different priorities and selecting snapping types like: snapping to vertices, edges or the end of a line. Placing functionalities are extended with construction tools like placing vertices at intersections of two distances from two other points, or at the implied intersection of two segments. Lines can be placed at different angles, distances or deflections and parallel or perpendicular to other segments. For on-screen digitizing raster images may be geo-referenced in ArcMap. First, second and third order transformations are supported, but it is a pity that raster tracing is not. However, segments may be traced, with or without offset. To maintain relationships while editing a dataset with different layers in which features share common boundaries or points, there is a possibility to snap to vertices, edges or endpoints of features that are situated in other layers than the current editing layer. In ArcMap, features from different data sources that share common boundaries or points may now also be integrated, using a specific function.

Thumbnail views in ArcCatalog of the data in a database. From ArcCatalog, ArcMap may be launched directly.
Projections and Coordinate Transformations

 Whereas in ArcView 3.x the emphasis was on the map projection, in ArcGIS the emphasis is on the coordinate system. The map projection is just one component in a layer’s coordinate system. ArcGIS supports a huge number of coordinate systems: around 1500 international, continental and national map coordinate systems and more than 300 different datum systems have been defined. In ArcView 3.x a shapefile may only be displayed in different projections as long as the source shapefile is defined as geographic (or unprojected) with units set to decimal degrees. If you want to display a projected shape file in a different projection, first you must permanently change the projection by creating a new shape file using the Projection Utility extension. However, this utility is rather slow and only supports a limited number of coordinate systems. Therefore, it is good that in ArcMap it is possible to re-project already projected data directly (“on-the-fly”), whereby data can be in any coordinate system. For existing shapefiles you will need to define a projection file using ArcCatalog or ArcToolbox so that ArcMap knows the projection of your data. Furthermore, while in ArcView 3.x the Warp extension can be used to geo-reference grids, ArcMap offers a similar function that is faster, more user-friendly and more extensive. If there is enough coordinate system information, layers in an ArcMap data frame are aligned by an on-the-fly re-projection of both vector and raster layers. In such a way a raster may be combined with several vector layers in one map without the need of resampling the raster image. If there is not enough coordinate information one can add the missing information, or, in the case of a raster, one can supply a set of control points and link the raster image to the map coordinates of the data frame by means of a two-dimensional correction model. Supported models are linear equations, and second and third order polynomial equations. Orthophoto correction models are not supported. There is a raster resampling capability to permanently re-project the raster image.

New Possibilities for Cartographic Visualization in ArcMap

Cartographic visualization in a GIS environment need not always be directed towards the production of maps for presentation. Such a GIS environment may also allow for direct exploration and analysis of the geo-data through map and other graphic displays. In this respect, dynamics, multiple representation, dynamic linking and interaction with maps are among the key concepts. Some new possibilities for exploratory and analytical visualization may be found in the ArcGIS extensions 3D Analyst and Geostatistical Analyst in particular. But it is also very well possible to interact with map displays in various ways in the standard ArcMap environment. As before, it is possible to pan and zoom, to click map features to get more detailed information and to experiment with e.g. ways of representation and different data classifications. One interesting new interaction possibility is to rotate the whole map image (leaving the map text in the correct, horizontal position). Within a ‘Map document’ (the ArcGIS concept that replaces the ArcView 3.x ‘Project’), it is not possible anymore to have more than one ‘Data frame’ (cf. ‘View’ in 3.x) open at the same time, so as to be able to compare different visualizations in data view directly. This comparison of multiple representations must be done in layout view that now allows (unlike ArcView 3.x) interaction with the data as well.

In ArcMap, features in layers may be symbolized with the help of many standard symbol sets that are directly accessible. Regrettably, the symbols are arranged according to map themes ("transportation", "weather", etc.) and not according to the visual variables applied. The latter would help a user to also select effective symbols in other application areas. However, there are more and more user-friendly possibilities now to design new symbols (e.g. in the ‘Symbol Property Editor’). The symbols designed may also be stored in a symbol library (called ‘Style’ in ArcMap) for use in later map displays.

In addition to the ‘Legend types’ of ArcView 3.x, ArcMap offers some new standard thematic map types and ways to adjust them. There is, for instance, a new option (‘Unique values, many fields’) to represent more than one nominal data field in the attribute table at the same time (by e.g. colour with a pattern overlay). Also, there is more variation possible in the application of the map type ‘Chart’: pie graphs and bar graphs may take on different shapes and a third type of chart, the ‘stacked’ bar graph, has been added. And
there are two ways now of generating proportional point symbol maps: ‘Graduated symbols’ (with the data automatically grouped into classes) and ‘Proportional symbols’ (as many symbol sizes as there are data values).

Although this increased variation in standard thematic mapping methods may be considered an improvement, there are still a number of minor cartographic objections against the ways these map types are constructed by default. For instance, in proportional symbol maps, the maximum value in the legend does not correspond to the maximum data value and polygons with an excluded data value (e.g. 0) are not drawn anymore. But the individual symbol sizes are correctly proportional now to the data values. As in ArcView 3.x this is still not the case in the graduated symbol maps: there, the symbol sizes are not proportion-al to the mid-class data values because ArcMap offers a default symbol size for both the minimum and the maximum value possible in ArcView 3.x. You now have many more options for defining how you want your labels to appear in the map. ArcMap offers somewhat better and more default colour schemes for the representation of nominal, categorical data and better default graded series for the representation of relative quantitative (‘normalized’), interval or ordinal data. The default graded series in ArcView 3.x, for instance, always contained colours that were too dominant and thus created a wrong impression. But still, the flexibility in colour selection offered by ArcMap may also often lead to problems and it would be desirable to offer the colours to the users in ways, which are more directly related to the purpose of the map displays (e.g. by means of Ostwald colour circles). In ArcMap, standard colours are defined as RGB-values. In case printed map output is desired, colour definition in the CMYK-system is supported as well with possible export to PostScript colour separates. Presentation maps with titles, legend, scale bars, etc. may still be made in the ‘layout view’, e.g. on the basis of various map templates. Next to formats as BMP, EPS, TIFF, PDF, JPG, CGM, an ArcMap layout view can also be exported to a vector file (in “Enhanced Meta Format”) that may be edited in a graphic design software package. This makes it possible, for instance, to move individual features in the map in order to improve its legibility without disturbing the geographical data structure that forms the basis of ArcGIS.

An interactive histogram may be used to set the class limits.

at the same time, irrespective of the data range. A real improvement with respect to the representation of quantitative data (also by means of ‘Graduated colors’, i.e. choropleth maps) is the provision of a visual tool (a histogram of the data) to be used in interactive data classification. Interesting new cartographic design options that are offered by ArcMap are the direct availability of an overview/location map, an interactive moving magnifying glass that allows you to zoom into parts of the map display, whereas the surroundings remain represented at the same scale, and the possibility to make a layer transparent. Also the labelling functions (automatic name placement and map text design) are really improved compared to what was possible in ArcView 3.x. You now have many more options for defining how you want your labels to appear in the map. ArcMap offers somewhat better and more default colour schemes for the representation of nominal, categorical data and better default graded series for the representation of relative quantitative (‘normalized’), interval or ordinal data. The default graded series in ArcView 3.x, for instance, always contained colours that were too dominant and thus created a wrong impression. But still, the flexibility in colour selection offered by ArcMap may also often lead to problems and it would be desirable to offer the colours to the users in ways, which are more directly related to the purpose of the purpose of the map displays (e.g. by means of Ostwald colour circles). In ArcMap, standard colours are defined as RGB-values. In case printed map output is desired, colour definition in the CMYK-system is supported as well with possible export to PostScript colour separates. Presentation maps with titles, legend, scale bars, etc. may still be made in the ‘layout view’, e.g. on the basis of various map templates. Next to formats as BMP, EPS, TIFF, PDF, JPG, CGM, an ArcMap layout view can also be exported to a vector file (in “Enhanced Meta Format”) that may be edited in a graphic design software package. This makes it possible, for instance, to move individual features in the map in order to improve its legibility without disturbing the geographical data structure that forms the basis of ArcGIS.

Conclusion

ArcView 3.x and ArcMap in version 8.1 definitely are among the best software solutions for creating various thematic map types in a GIS environment. Since the initial release of ArcView 1.0, we have seen that more and better cartographic functionality has been added to the successive software products. And also ArcGIS is now offering to the user many new and useful tools for the interactive cartographic visualization of geographic data. The increased flexibility in using these tools may poten-

tially lead to obtaining a better insight into and overview of these data. At the same time, however, this great flexibility may result into wrong interpretations as a consequence of the fact that existing cartographic knowledge is not yet optimally applied and that users (who may want this) are not yet always properly guided through the cartographic visualization process. It is hoped that more cartographic user guidance and an appropriate implementation of even more already existing cartographic knowledge will be considered in new releases, so that this may lead to a more effective use of GIS through cartographic and other visualizations.

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