GIS by ESRI™

ESRI® White Paper Series
February 1996

- **ARC NETWORK™**
- **ARC COGO™**
- **ARC GRID™**
- **ARC TIN™**
- **ArcPress™**
- **ArcScan™**
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ARC/INFO® Extensions

Optional Software for Specific Applications

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ARC/INFO EXTENSIONS

An ESRI White Paper

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ARC/INFO EXTENSIONS

An ESRI White Paper

ARC/INFO® software is the leading geographic information system (GIS) available today. ARC/INFO provides robust tools for users to access, visualize, and query both geographic and tabular data to support better analysis and decision making. ARC/INFO offers a complete GIS solution for the automation, management, display, and high-quality output of geographic and associated multimedia data, whether users are working on an individual project on a desktop computer or an enterprisewide application in a large networked organization.

Environmental Systems Research Institute, Inc. (ESRI), offers a number of fully integrated optional software packages that extend the ARC/INFO data model to support specific applications. This white paper describes extensions for

- Network modeling and analysis (ARC NETWORK)
- Coordinate geometry applications (ARC COGO)
- Raster geoprocessing (ARC GRID)
- Surface modeling and terrain analysis (ARC TIN)
- Graphics metafile rasterization (ArcPress)
- Scan digitizing and scanning data entry (ArcScan)
- Display speed acceleration (ArcExpress)
- Comprehensive spatial data management (ArcStorm)

ARC NETWORK

Introduction

The movement of people, the transportation and distribution of goods and services, the delivery of resources and energy, and the communication of information all occur through definable network systems. Networks form the infrastructure of the modern world. The form, capacity, and efficiency of these networks have a substantial impact on our standard of living and affect our perception of the world around us. The ARC NETWORK™ extensions facilitate the modeling of spatial networks. With ARC NETWORK, efficient paths and travel sequences can be determined. The allocation of resources can be computed and spatial interactions estimated.

ARC NETWORK provides tools to find paths—the shortest or minimum *impedance* path through a network. Included also is tours—a heuristic procedure to what is commonly called the *traveling salesman problem,* finding the most efficient path to a series of locations. Allocation functions assign portions of the network to a resource supply location. Tracing tools provide a means to determine whether one location in a network is connected to another. Spatial interaction commands estimate the potential for interactions between populations and centers of attraction. Distance matrix calculations allow you to calculate distances between sets of origins and destinations. Location-allocation determines site locations and assigns demand to sites.

ARC NETWORK is fully integrated with the feature selection, display, and query capabilities provided by ARCPLOT™ software. ARC NETWORK takes full advantage of the route-system data model and the dynamic segmentation functions in ARCPLOT for the display and analysis of results.

Pathfinding

A fundamental problem addressed by network analysis is finding a shortest or least-cost manner in which to visit a series of locations in a network. The cost may be determined by any attribute of the network components that is expressed in numeric terms. For example, distance or travel time may be used to compute the shortest path in a transportation network, or a combination of factors may be used to calculate a monetary cost value.

In ARC/INFO, networks are represented with line coverages. *Stops*, or the locations to be visited, may be specified in an INFO file or may be selected interactively. The shortest path is computed and saved as a *route* in a *route-system* that can be graphically displayed using the route display commands in ARCPLOT. The ARC NETWORK commands PATH and TOUR are used for finding minimum paths.

Allocation

Assigning portions of a network to a location based on predetermined criteria is referred to as *allocation*. The ALLOCATE command assigns areas of the network to be served by a facility. In ARC NETWORK, allocation is based on supply, demand, and impedance.

Tracing

The TRACE command determines which portions of the network are connected. For example, an electrical company may need to know which facilities on the power network are serving a particular customer, or a hydrologist may wish to determine all tributaries upstream of a point on a river.

The result of TRACE is a selected set of connected arcs. The TRACE command will operate on arcs in a network coverage and across tile boundaries in a map library layer.

Spatial Interaction

The spatial interaction commands are used to model the accessibility of a location and the interactions that occur between locations based on the costs of travel and communication.

The spatial interaction commands use a technique known as *gravity modeling* which has been widely applied to problems in economics, geography, engineering, and the social sciences. The underlying assumption of this method is that the interaction between nearby places is more than that between faraway places and that the interaction can be increased if the destination is made more attractive.

These tools can be applied to such problems as evaluating the location of a proposed shopping center in terms of the number of consumers living in proximity to it, or finding out how accessible existing amenities will be to the residents of a proposed new subdivision.

Distance Matrix

A distance matrix is useful in many transportation planning models and applications. For

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Calculation

all pairs of locations specified, the network, Euclidean, and Manhattan distances can be calculated.

For more information, see NODEDISTANCE Command.

Location-Allocation

Location-allocation is used to simultaneously determine the location of facilities and the allocation of demand to facilities.

For more information, see the Location-Allocation Concepts Guide.

ARC COGO

This section describes the ARC/INFO extensions for capturing survey data by plan entry and conversions from other sources. Special commands, macros, and a menu system have been written to help meet the needs of survey data automation.

ARC COGO™ software includes tools for

- Conversion of data from survey field data collectors
- Conversion of data from CAD packages
- Traverse data entry and adjustment
- Construction of new features
- Reports and listings

ARC COGO is designed primarily for capturing survey data. Many of its operations can be used in applications requiring accurate coordinate geometry (COGO) for data entry and manipulation.

Capturing Survey Data

ARC COGO is a collection of tools that can be used to automate survey data originating from a variety of sources and formats. ARC COGO can be operated using a pulldown menu that prompts you for required information and leads you through each operation. These menus and supporting ARC Macro Language (AML™) macros can be modified to suit your particular needs.

Conversion from Field Collectors

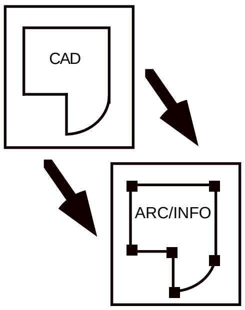
One of the more popular means of collecting data for surveying and engineering applications is by an electronic field data collector connected to an electronic theodolite or total station. Observed direction and distance information is automatically recorded in the data collector. "Raw" observations (raw or unadjusted directions and distances) can be transferred from the data collector to a personal computer and saved as an ASCII file for further calculation of coordinate data.

In order to handle the wide variety of electronic field data collector formats, ARC/INFO provides a conversion program (FDCONVERT in ARC) to convert data collector raw observation files (ASCII format) into ESRI® Generic Fielddata Format files. The generic data can then be converted to a COGO arc coverage using FIELDDATA, a program in ARC that accepts as input the ESRI Generic Fielddata Format.

Conversion of Data

COGO arc coverages can be created from survey and engineering COGO data from CAD

from CAD Packages



program packages. COGO arc coverages can also be created by calculating and saving COGO attributes for two-point lines and curves.

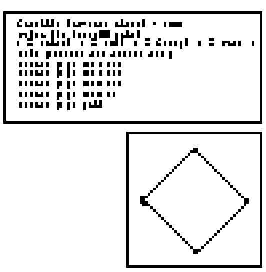
In order to handle the wide variety of CAD programs, ARC/INFO provides three conversion programs in ARC (DXFARC, IGDSARC, and IGESARC) to convert CAD data format files into ARC/INFO coverages (see the ARC command references for more information on these conversion programs). COGO attribute data for two-point lines and curves are calculated from the ARC/INFO coverage and then added to items in the AAT by the ARC COGO conversion program in ARC. Once the COGO attribute data are added to the arc coverage, they can then be utilized by ARC COGO.

CAD Data Formats

There are three CAD data formats currently supported by ARC/INFO used for conversion into arc coverages:

- DXF   AutoCAD ASCII Drawing Exchange File
- IGDS   Intergraph Binary Interactive Graphic Design Software File
- IGES   Initial Graphics Exchange Specification ASCII File (version 3.0 uncompressed)

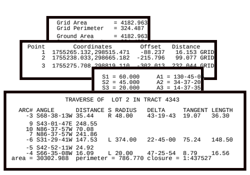
Traverse Entry



Plans are generally recorded as a series of traverses that can be adjusted as needed. Straight courses as well as tangent and nontangent curves can be entered using any desired units of measurement and format for directions and distances. After traversing the perimeter of a plan, you can correct dimension errors, compute and adjust closure for traverses, and identify drafting errors in the original plan. Other features in a plan, such as cul-de-sacs and street centerlines, can be entered by traversing or using construction operations that create parallel lines and fillet curves.

Plans may be automated using an arbitrary set of points in any planimetric coordinate system. However, using control points with known coordinates will ease the task of fitting together adjacent plans and provide the means to connect survey plan data with other types of data in your database.

Reports and Calculation Listings



In addition to the inverse reporting facility and the LOTAREA command in ARC, the following reporting facilities have been added to the Version 7 release:

- Report areas of selected lines in either ground or grid coordinate systems
- Report offsets and angles (polar or field) in either ground or grid coordinate systems
- Solve and report missing parameters for curve and triangle solutions
- Report legal areas for selected polygons in ARCPLOT and draw them using chosen symbology

Types of Features

Points and lines are the primary types of features used to represent survey data. Area

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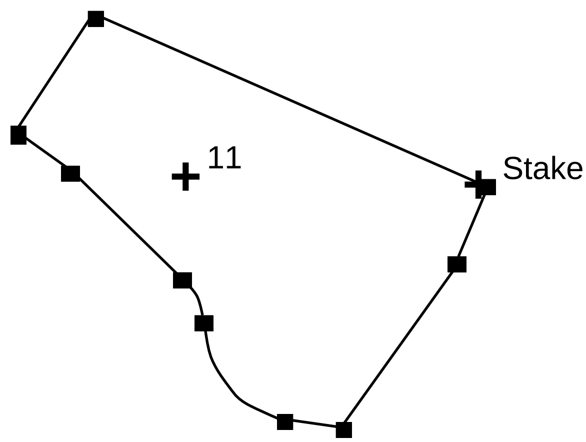
Captured features, or polygons, can be derived from line features for preparing area calculations and reports.

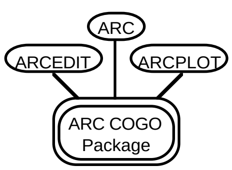
Points

Any type of reference or control point, such as a monument, can be represented by a point feature. The position of a point (its x,y coordinates) may be referred to by typing in the actual coordinates or by using the name for that point. For example, "Stake" can be used to refer to the position of the COGO point shown in the figure below.



The ARC COGO Package

The ARC COGO package is implemented as a number of commands, AMLs, and a menu interface. It includes



- ARC commands to convert survey field collector data into ARC/INFO coverages
- ARC commands to convert CAD data into ARC/INFO coverages
- ARCEDIT™ commands, AMLs, and a menu system for entering survey plans, constructing features, and generating reports
- The capability to generate area reports in ARCPLOT and attach legal areas to polygons in a coverage

You can use a combination of ARC COGO and other ARC/INFO commands for all of your coverage digitizing and editing tasks. For example, applications that do not require highly accurate data entry, or in cases where the accuracy of the source data is questionable, you may decide to quickly digitize features. Reliable data can be accurately entered by traversing or constructing features, and less accurate data digitized. After digitizing arcs, attributes can be added to the attribute table to be used for annotation and constructing other features.

Some of the functionality provided by ARC COGO can be applied to needs other than entering survey plans. A good example is the ARC COGO command PROPORTION, which proportions arcs into a desired number of segments or segments of a specific length. This capability is not part of the standard ARCEDIT program.

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ARC GRID

This section provides an overview of the ARC GRID™ software, the raster geoprocessing extensions for ARC/INFO.

ARC GRID is a raster- or cell-based geoprocessing toolbox that is integrated with ARC/INFO. ARC GRID provides tools for both simple and complex grid-cell analyses. It represents space from a locational perspective (dividing space into discrete units called cells) and can accurately portray continuous surfaces. The commands and functions of ARC GRID have been designed to optimize these representations; such a design allows for greater analytical capabilities. In conjunction with the other spatial representations and tools available in ARC/INFO, ARC GRID provides a powerful environment in which to explore spatial problems.

ARC GRID Software's Relationship with ARC/INFO

Geographic information and features are exceedingly complex. A single data-storage scheme simply cannot represent all geographic phenomena. Consequently, the ARC/INFO vector, grid, network, and TIN data structures were each devised to produce a highly specialized type of representation that each of the others cannot accurately achieve. Accompanying these storage technologies are sets of tools that have been developed to specifically take advantage of the data storage. The sets of tools can derive information from base data that could not easily be derived by any other technology. The more information you have about a problem, the more readily you can make effective decisions.

Even more important, when the technologies are integrated with one another, as they are in ARC/INFO, they create a synergy. Information passed from one technology to another generates additional insights into a problem. You can derive information from multiple, integrated technologies that you could not when using only one. As you uncover each new piece of information and pass it on to the next technology for further processing, you more clearly understand the issues associated with a problem. The power that results from integrating the technologies is much greater than the sum of the parts.

ARC GRID: An Overview

ARC GRID is a raster- or cell-based geoprocessing system integrated with ARC/INFO. Like all extensions to the ARC/INFO data model, ARC GRID uses a georelational model for geographic data. The model used in ARC GRID, however, differs from the other modules because it is based on a combined raster-based (grid-cell) spatial model and a relational attribute model. In ARC GRID, the inherent power of the grid-modeling structure is coupled with the capabilities of a relational database that manages all attributes associated with the cell values. A grid is similar to an ARC/INFO coverage. Data belonging to different themes are stored as separate grids. Each categorical grid has an associated value attribute table (VAT) that is stored in the INFO relational database. The VAT of a grid is similar to the polygon attribute table (PAT) of a coverage.

Because ARC GRID is integrated with ARC/INFO, you can use many of the capabilities that are common between modules. The attributes stored in the VAT are managed by the INFO database management system and by existing tools in ARC/INFO that have been developed for vector data. ARC GRID uses the graphic environments of ARCPLOT and ARCEDIT software for all visual display of grids. ARC Macro Language can be used as a macro facility and to control the user environment. Metafiles and plotter drivers that have been developed for IMAGE INTEGRATOR™ software are fully integrated with the ARC GRID software.

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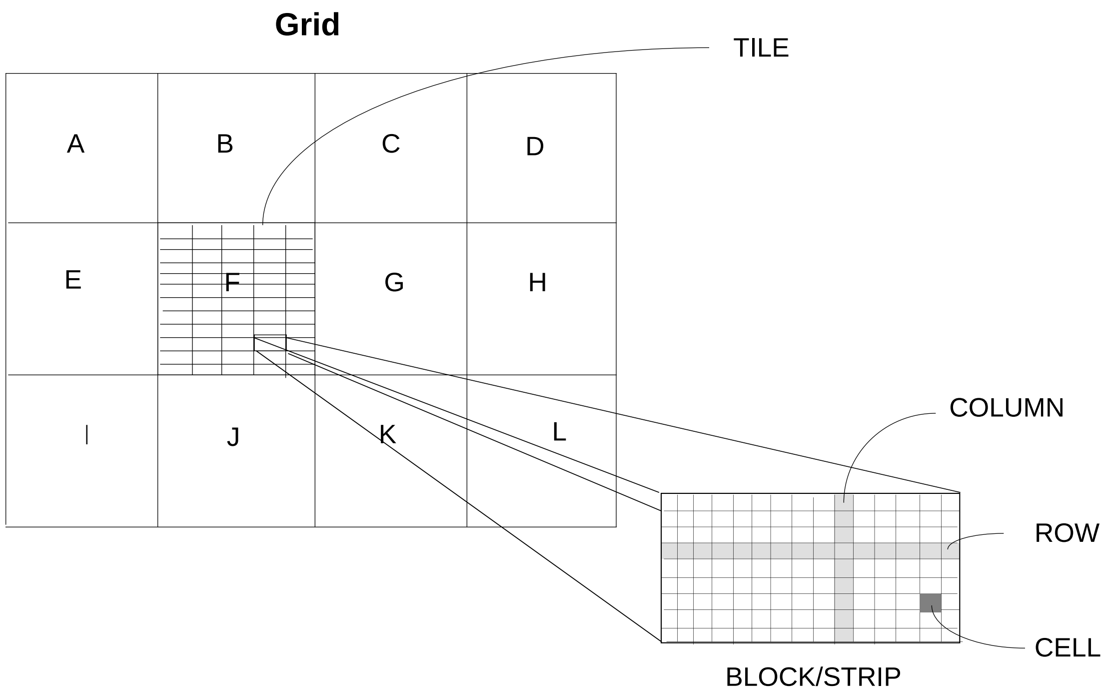
ARC GRID Data Structure

ARC GRID is based on a hierarchical tile-block structure. A grid is first divided into uniform square units called *tiles*. Each tile represents an actual portion of geographic space. A tile is divided into *blocks*. Because there are more blocks on the y-axis than on the x-axis, a block is always rectangular. A block is made up of *cells* arranged in a Cartesian matrix consisting of rows and columns. Cells are square.



The tile-block structure allows ARC GRID to support random access to data—rapid retrieval of information maintained from any subsection of a grid, regardless of the size of the database. The tile, block, and row-column hierarchical divisions of grid data form the spatial indexing of ARC GRID data. The indexing allows ARC GRID to access data from anywhere in a grid quickly, regardless of the size of the grid. Spatial indexing provides a map that the ARC GRID system can follow to find and retrieve data. The system first determines which tile the desired data are in, then the block, and finally the actual row and column.

ARC GRID data are accessible seamlessly. The tile structure is for spatial indexing; it does not divide data into discontinuous map sheets. In most practical cases, all data for a grid reside in a single tile, but sometimes more than one tile may be used for data storage. ARC GRID automatically keeps track of the tiles and the data's position with multiple tiles.

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ARC GRID compresses data using an adaptive run-length encoding scheme that automatically optimizes database size. ARC GRID automatically compresses individual blocks or strips of data. It first tests each group of data to determine the optimal compression technique, either cell-by-cell or run-length code, and then stores it in that manner. Spatial indexing and compression techniques are applied separately to each grid in a database.

The adaptive compression techniques allow for the efficient use of a wider variety of tools providing more flexibility when performing spatial analysis. Most compression techniques perform some spatial functions quickly, but others very slowly. The adaptive run-length code performs well for all types of spatial analysis: per cell (local), per neighborhood (focal), per zone (zonal), and per layer (global). One of the principal strengths of ARC GRID is that it provides the maximum amount of flexibility for performing spatial analysis.

Even though analytical flexibility is the priority for ARC GRID, fast processing speeds have been achieved through run-length code processing without expansion. ARC GRID does not expand the run-length code to perform operations within or between grids and per-cell functions. Direct processing of the run-length code greatly improves performance. The commands that process compressed data directly include all of the operators, local functions, and DOCELL loop.

ARC GRID allows you to store and transparently process grids at different resolutions within the same database. If two or more input grids in an expression are at different resolutions, ARC GRID automatically resamples them (using the nearest-neighbor resampling technique) to the coarsest resolution unless specified otherwise before processing. Processing grids at different resolutions causes no reduction in speed.

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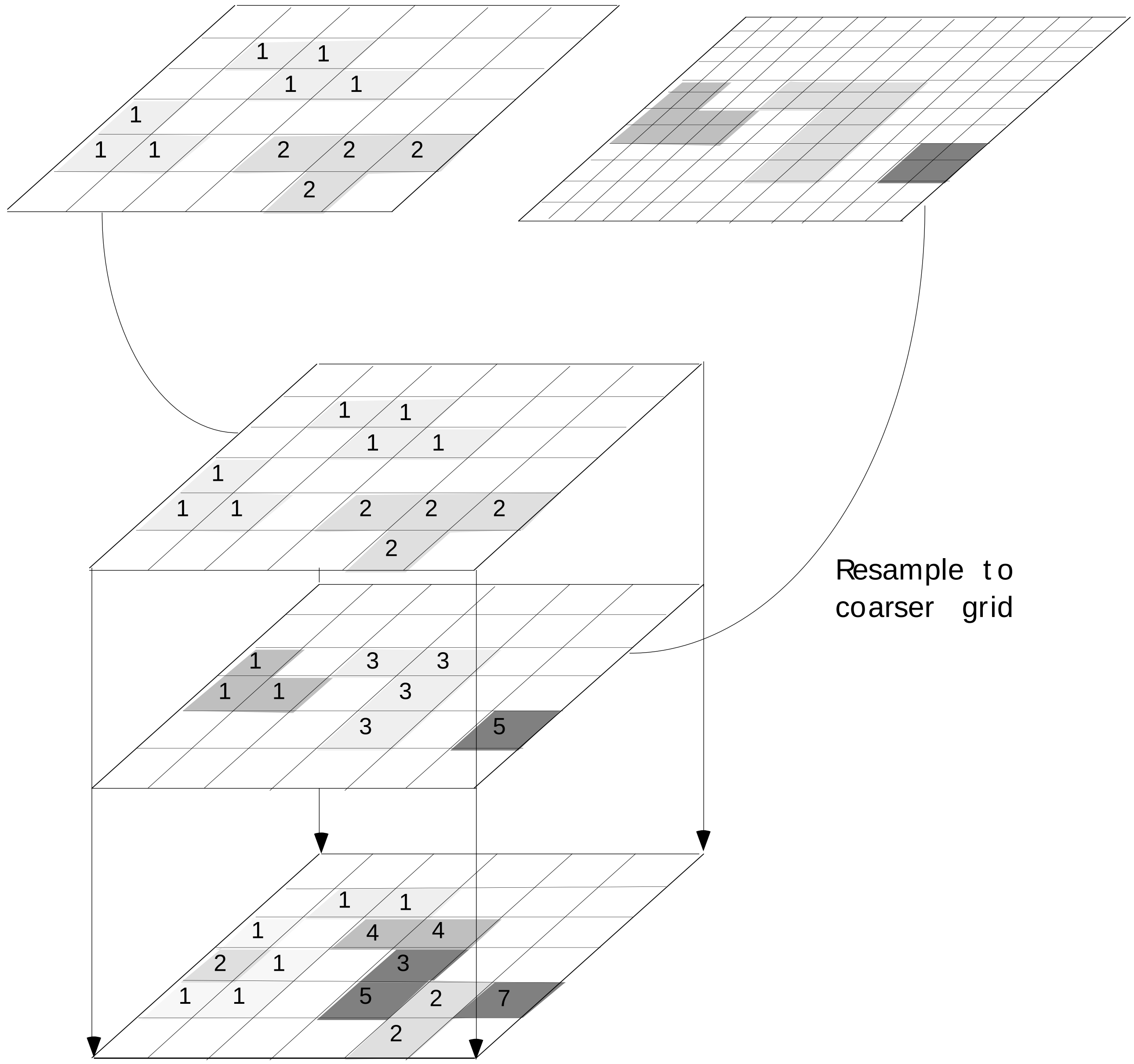

ARC GRID automatically optimizes spatial indexing and compression, making them transparent to the user. Much of ARC GRID software's internal processing and storage operations—storing the data on disk, selecting compression techniques, determining the size of the blocks for spatial indexing, window snapping, resampling, and so on—are hidden from the end user. ARC GRID automatically optimizes each of the operations while you work easily with the grids, unencumbered by the computer structure. ARC GRID has been designed to allow the computer to optimize the storage techniques. With ARC GRID, you are better able to maintain a natural view of the world.

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ARC GRID Map Algebra Language

ARC GRID is based on map algebra concepts. Map algebra is a data manipulation language designed specifically for geographic cell-based systems. The algebra is a high-level computational language for describing cartographic spatial analysis using gridded maps. ARC GRID utilizes the map algebra spatial language so you can order your thoughts efficiently, verbalize clearly with other users and, most important, communicate effectively with the software.

Through the spatial language, ARC GRID furnishes functions specially designed to process data and information in the grid-cell format. Because ARC GRID is based on a locational model, its spatial analysis capabilities allow you to perform cartographic modeling tasks that cannot be performed with any other geographic technology. The types of processing can be broken into three categories: operators, functions, and statements.

A full suite of operators are available for processing of cell-based data in ARC GRID. Operators complete computation on one or more input data sets. ARC GRID supports the following operators:

- Arithmetic (plus, minus, multiply, etc.)
- Boolean (TRUE or FALSE)
- Relational (greater than, less than, equal to, etc.)
- Bitwise (binary left shift, right shift, complement, etc.)
- Combinatorial (overlay of grids while carrying attributes)
- Logical (contained within a set, etc.)
- Accumulative (sum, divide, multiply, etc., all values within a grid)
- Assignment (output equals)

Analysis with ARC GRID

ARC GRID can perform simple queries to complex modeling. The set of ARC GRID tools and the map algebra language can solve a wide range of spatial problems. Single, existing operators and functions will solve simple queries and display problems. To resolve more complex problems, the ARC GRID spatial language allows you to combine multiple operators and functions into a single expression.

ARC GRID allows you to customize the user environment to meet specialized end user needs. All of the AML menu- and user-environment customizing tools are available to the user of ARC GRID.

ARC GRID provides tools for controlling the analysis environment that allow you to specify the cells of the input grids to process and the resolution at which to process them. Once defined, the parameters for an environment are used by future analysis functions on all grids. The three most significant parameters are the window, mask, and cell size.

- The window allows you to identify spatial limits for future analysis and processing. Usually a subset of the spatial extent of a study area, the window defines the subarea of interest.

- The mask further defines the cells within a window that will be considered when processing. After a mask is set, processing will ignore all cells that do not meet the desired attribute or spatial parameters within the window.

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- The cell size dictates the size of the cells on the output grids. When no cell size is specified, the default size is set to the resolution of the coarsest of the input grids.

Setting these three parameters does not affect processing speeds. All resampling occurs dynamically.

The Problems ARC GRID Can Solve

ARC GRID can be used in a multitude of applications, including land use planning, market research, disease control, and famine relief. Because a cell-based structure divides the world into individual locations that it then describes, this technology best addresses locational problems. These include problems where the location and its surroundings are as important, if not more important, than the feature makeup. Vector structures better address problems in which an object is of greater concern than the location of the object. Cell-based and vector structures applied together can address most types of problems better than either can alone.

ARC TIN

Introduction

ARC TIN™ software is the surface modeling extension package used to create, store, analyze, and display surface information in the ARC/INFO GIS software environment. The acronym TIN stands for Triangulated Irregular Network—a set of adjacent, nonoverlapping triangles computed from irregularly spaced points with x,y coordinates and z values. The TIN data model stores the topological relationship between triangles and their adjacent neighbors (i.e., which points define each triangle and which triangles are adjacent to each other). This data structure allows for the efficient generation of surface models for the analysis and display of terrain and other types of surfaces. The ARC TIN extension package consists of specialized ARC and ARCPLOT commands and AML macros that are completely integrated with the entire ARC/INFO GIS environment.

Surface Models as Data Abstractions

The ARC TIN extension package supports two data models for representing surfaces: TINs and lattices. Both data structures are digital abstractions or approximations of a surface in the real world. The TIN data structure is based on irregularly spaced point, line, and polygon data interpreted as mass points and breaklines. The lattice data structure is an array of regularly spaced sample points. ARC TIN provides a suite of software tools for surface analysis and display of these geographic data models.

TIN Data Sources

TIN surface models can be created from a wide variety of data sources. A TIN surface can be created from one or more of the following sources:

- ARC/INFO point, line, and polygon coverages
- Contour maps
- Stereoplotter data
- Randomly distributed points in ASCII files
- Breakline data in ASCII files
- Lattices
- Existing TINs

For example, you can input a line coverage containing isolines representing contours and a point coverage containing surface values for peaks and pits. These data can be supplemented with a polygon breakline coverage containing one or more irregularly shaped polygons, with or without surface elevations, to define the limits of your study area or holes inside the surface model.

Lattice Data Sources

The ARC TIN extension package also supports regularly spaced surface data through its complementary lattice data structure. Lattices can be constructed from any of the following sources:

- USGS DEMs
- SPOT DEMs in TAME format
- TINs
- Point coverages containing randomly distributed points
- ASCII files containing randomly distributed points
- ASCII files containing regularly spaced data
- Single Variable Files (SVF)
- Images
- ARC/INFO grids

Surface Analysis Capabilities

Once a surface model has been created, it can be analyzed or displayed in perspective and panoramic views. A TIN surface model can be easily converted to lattice, and vice versa. Surface models can also be converted to any of the other data models supported by ARC/INFO for additional GIS processing.

ARC TIN software's surface modeling capabilities include the following:

- Interpolation of surface z values
- Generation of contours
- Calculation of slope, aspect, surface area, and surface length
- Generation of Thiessen proximal polygons
- Volumetric and cut–fill analysis
- Extraction of important surface features
- Generation of profiles over one or more surfaces
- Determination of intervisibility between two points
- Sophisticated visibility analysis
- Analytical hillshading

Planimetric Display Capabilities

ARC TIN software's surface display capabilities are incorporated in the ARCPLOT display environment. The ARC TIN two-dimensional planimetric display capabilities include the following:

- Drawing of TIN triangles, nodes, hulls, and edges classified by edge type

- Shading of TIN triangles based on slope, aspect, and surface z values

- Labeling of TIN nodes and triangles based on surface z values, slope, aspect, and z value ranges

- Drawing of lattice mesh points and labeling mesh points with their z value or other related text

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- Display of contours at specified intervals
- Display of viewsheds from specified observation points
- Interpolation of surface values by pointing at the planimetric display or surface view
- Display of hill-shaded surfaces based on a specified sun position
- Composite displays of surfaces shaded for elevation gain and sun illumination

Surface Viewing Capabilities

ARC TIN also allows the generation of sophisticated perspective and panoramic views of TIN and lattice surface models in ARCPLOT. You have complete control over the surface viewing environment including the following:

- Specification of the portion of the surface to be viewed.
- Drawing of one or more surface views on the same graphics page.
- Drawing of stacked surface views.
- Precise orientation of the surface view by specifying the location of the observer and target with absolute coordinates, relative angles, or by pointing at the planimetric display or a surface view.
- Both the observer and target can be either inside or outside the surface model.
- Specification of field of view angles and distances.
- Choice of either perspective or panoramic surface views.
- Ability to zoom in on a particular area of interest inside the model.
- Control of the level of detail by setting the surface resolution.
- Control of the degree of vertical exaggeration.

Surface Drapes

Once a surface view has been generated, you can use ARC TIN to drape the view with one or more ARC/INFO geographic data models including the following:

- Meshes of lines or grids, at specified intervals
- Point, line, or polygon coverages
- Single points
- Graphics files
- Images
- Grids
- Contour lines
- Hill-shaded views
- Views shaded by elevation change and sun illumination angles

Importance of the Third Dimension

As you can see, ARC TIN has many powerful and useful tools for analysis and surface display. These tools can generate new information and insights about your study area that are not otherwise possible with two-dimensional analysis tools alone. Surface views have a very high information content and can be a powerful vehicle for conveying geographic information to audiences of all levels.

ArcPress

ArcPress™ software is a graphics metafile rasterizer for map output and printing that offers many benefits for digital cartography. If you use ARC/INFO or ArcView® software for UNIX and have a raster printer, ArcPress can greatly increase the speed, efficiency, and quality of your GIS output operations by providing the following:

- Improved support for industry standard and minimally configured devices
- Faster throughput especially for large and complex vector/raster metafiles
- Cost savings—no need for extra RAM on your plotter, increased productivity
- Higher quality—better color control, more consistent imaging
- Multiple input and output options—support for many standard formats

Originally conceived as an extension to ARC/INFO, ArcPress also works well for users of ArcView for UNIX. Users have discovered that ArcPress also works as a stand-alone package, to help speed output from CAD or other graphics systems.

ArcPress represents a real value for GIS users and quickly pays for itself by reducing plotting time, increasing the quality and consistency of GIS output, and saving the cost of additional RAM for the printer.

How Does ArcPress Work?

ArcPress converts standard graphic or ARC/INFO metafiles to a bit map format ready for rendering on an output device. ArcPress translates the standard formats to device-specific formats, allowing you to off-load the rasterization process from your plotter to your workstation CPU. ArcPress rasterizes graphics files more efficiently than most output devices by using the memory and processing resources of your host computer.

Supported Input/ Output Formats

ArcPress handles EPS Levels 1 and 2, CGM, and ARC/INFO metafiles (1039 plot files, 1040 graphics files, and map compositions) for input. ArcPress outputs bit map files ready for printing on

- Desktop printers: PCL, PCLC (PCL3, PCL5)
- Ink-jet printers: RTL, CCRF-Interleave
- Electrostatic Plotters: CCRF, RGI, VRF

Standard bit map interchange formats include BMP, PCX, portable bit map formats, TIFF 3 and 4, and RAW (BIP) files that can be drawn in an ARCPLOT session.

What Makes ArcPress Different from Other Rasterizers?

- Support for multiple input and output formats including ESRI metafiles
- Multiple device support (electrostatic plotters, ink-jet, and desktop printers)
- Integration with GIS functions
- ArcTools, X Windows, or command-line interface

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- Integration and plot queuing within the ARC/INFO plot system
- Several output options (paneling, multicopies, rotation, scaling, color correction, saturation, and more)

ArcScan

Geographic information systems require accurate digital geographic data. Traditional methods of automating vector spatial data include three alternatives: contracting with a service bureau, in-house table digitizing, or COGO data entry. Users now have an alternative to existing methods for creating vector databases—an option called scanning data entry. This new choice in data automation, scanning data entry, is affordable; uses mature, reliable technology; can be implemented with existing staff; is integrated with existing GIS software and databases; and offers an array of capabilities adaptable to a wide range of user requirements.

Scanning data entry technology offers a variety of tools for manipulating raster data and for converting raster data to vector data. A thorough evaluation of project needs and available data sources will determine the tool or tools that work best for you. This section describes the ArcScan™ extensions, ESRI's scanning data entry and integrated data editing/data management technology within ARC/INFO.

ArcScan is a set of software tools that support data automation using scan digitizing. These tools permit GIS applications to automate vector databases using scanned raster data sets as input. ArcScan is an extension to ARC/INFO and is fully integrated with the ARC/INFO software environment. The ArcTools™ ArcScan menu system provides an easy-to-use interface for raster editing and interactive vectorization. ArcScan includes a *Users Guide* and *Command Reference* that describe ArcScan capabilities to users.

ArcScan Capabilities

ArcScan users can create ARC/INFO coverages by extracting line features from scanned monochrome document images. This is done using interactive, automated line-following software within ARCEDIT. Examples of linear features that can be extracted and added to a coverage include street lines, utility lines, contour lines, parcel boundaries, and soil polygon boundaries. This technique for digitizing features is simpler, more accurate, and often faster than traditional manual and heads-up digitizing.

ArcScan provides tools for editing monochrome, grayscale, and pseudo-color single-band imagery within ARCEDIT.

ArcScan provides a powerful and efficient set of tools in ARC/INFO for importing, correcting, editing, plotting, and exporting scanned raster images. ArcScan supports industry-standard raster data formats and can accept data from many types of scanners.

ArcScan Components

ArcScan functional components include raster database construction tools, raster pre-processing tools, integrated raster-to-vector editing tools, and an interactive raster-to-vector conversion tool. ArcScan soft-copy and hard-copy raster display is provided using standard ARC/INFO display functionality. ArcScan tools work with the highly efficient ARC/INFO grid raster data format.

Raster Database Construction Tools

Scanned raster images in a variety of standard formats (e.g., TIFF, RLC, SunRASTER) and compressions (e.g., Run Length Compressed, CCITT Group III, CCITT Group IV)

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can be converted to and from compressed grids using the IMAGEGRID and GRIDIMAGE conversion tools. The GRIDMERGE tool can be used to build a raster database from georeferenced input grid raster data sets. The ArcScan conversion tools transfer runs of data directly, rapidly converting large scanned monochrome documents.

Geometric Correction and Noise Removal Tools

The ArcScan raster preprocessing tools prepare raster data sets for additional processing. A set of geometric correction tools can be used to correct orientation errors during scanning, distortions in the source document, and georeferencing. These tools perform the following operations:

- Rotate a grid by a multiple of 90 degrees. Commonly used when documents are scanned sideways.
- Flip the contents of a grid from top to bottom. Commonly used when documents are scanned upside down.
- Mirror the contents of a grid from left to right. Commonly used with translucent documents that are scanned wrong side up.
- Correct a skewed document by converting a user-specified parallelogram on the input document to a rectangle on the output document. A common distortion encountered in scan digitizing is a skew caused by paper feed that is not perfectly aligned.
- Apply a warping transformation to georeference a grid to real-world coordinates.

The following noise cleanup tools can be applied to either the entire image or a selected image area:

- Remove specks of black noise from a scanned image. Most scanned documents will show speckling to varying degrees.
- Apply a majority rule filter to a scanned image. Commonly used to correct dropout in noisy scanned lines.

Integrated Raster–Vector Editing Tools

Grids can be edited in conjunction with coverages. The ARC/INFO software environment supports editing monochrome, grayscale, and pseudo-color raster data. Users can edit multiple grids during an ARCEDIT session. ARCEDIT supports full pan and zoom display in map coordinate space of both raster and vector data. A multilevel undo capability provides the user with a "safety net" during raster editing. The user can concurrently edit both raster and vector data. The editing tools include

- **Filling Tools:** Fill the interiors of user-defined boxes, circles, and polygons. Fill a connected entity of pixels by pointing to any pixel in the entity.
- **Drawing Tools:** Rasterize the boundaries of user-defined boxes, circles, and polygons.
- **Pixel Editing Tools:** Set and query the value of individual pixels by pointing to the screen.

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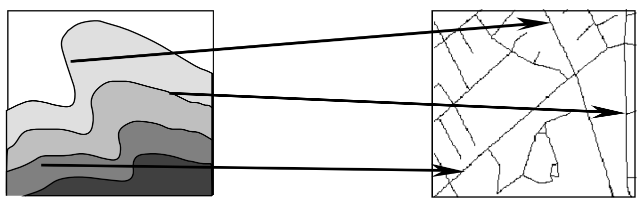
- **Brush Tools:** Change the value of pixels in the grid by dragging a brush on the screen.
- **Rasterization Tools:** Rasterize the selected set of arcs into the edit grid.
- **Selection Tools:** Select all cells within a box, circle, or polygon.
- **Geometric Operations:** Move, rotate, flip, and mirror the selected region.
- **Filtering Operations:** Despeckle, smooth, or enhance the selected region.
- **Georeferencing Tools:** These tools allow a user to interactively position and rescale the edit grid in map coordinate space, deskew the edit grid, and warp the edit grid using a link coverage created in ARCEDIT. Georeferencing is accomplished by identifying common points in the raster data set and in real-world coordinates.

The mouse is used to register the image to real-world coordinates.



Interactive Vectorization Tools

With ArcScan you can extract the centerlines of linear features from a raster document with optimized user intervention. Interactive raster-to-vector conversion using an automated line-following, or line-tracing, tool is especially useful for selective raster-to-vector conversion from a raster data set with multiple data layers. The ArcScan line tracer, because of its high degree of user control, can also vectorize complex and difficult data. With the line tracer tool you can efficiently produce high-quality vector output. The trace tool performs automatic intersection straightening and automatic line generalization based on user parameters.

The ArcScan Tracing Tool works in the ARCEDIT environment.

The trace tool snaps to the center of a raster line. Tracing begins at that point, stopping at junctions to obtain user input. The user interacts with the tracer using the mouse or keyboard, and controls the direction taken by the tracer at the junction. Tracer features include the ability to jump gaps, the ability to snap to the center of a heavy raster line, and smart retrace. Built-in junction memory prevents retrace of explored paths, offering improved line tracing efficiency. Line following can be done with user interaction, or in fully automatic mode, all connected line work within a defined area can be vectorized without operator intervention. The line tracer can work from bi-tonal ARC/INFO grid or RLC raster data.

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ArcScan provides automatic cleanup of line intersections guided by user set parameters.

Because the line tracer is built into ARCEDIT, you can interleave manual digitizing with line following, enabling more productive processing of noisy data. You can use a menu interface for heads-up digitizing to tag features with attribute data shown in the raster document. The line trace tool works with the multiple windowing capability of ARCEDIT. ArcScan automatically moves a close-up view of the tracing activity, following the tracing activity even as it moves out of view.

ArcExpress

Introduction

The ArcExpress™ extensions to ARC/INFO GIS software enhance ARC/INFO software's display speed on X Windows-based workstations and are useful in interactively investigating large, complex databases.

What Is ArcExpress?

ArcExpress is a software subsystem that enables rapid display and navigation of ARC/INFO data sets on X Windows-based workstations. It is available for ARC/INFO Version 7 and higher and supports display of most feature classes. With ArcExpress, panning, zooming, and redrawing operations occur within seconds, better supporting interactive applications and leaving more free time for data analysis. ArcExpress also provides the capability to add and remove coverages as needed, which further enhances display performance. In addition, all current ARC/INFO functionality is fully compatible with the ArcExpress software subsystem.

General Description

ArcExpress was designed to greatly improve the display performance of the ARCPLOT and ARCEDIT subsystems. The display speed is tightly coupled with the amount of data to be displayed. Current ARC/INFO display performance (without ArcExpress enhancements) is a result of software clipping, scaling, and symbolization of graphic data, all done during the display process. ArcExpress utilizes a setup phase in which clipping, scaling, and symbolization are all handled via a capture module and results are managed with a memory-resident display list. Subsequent data display functions use this precomputed information to improve display times substantially faster than conventional ARCPLOT and ARCEDIT commands.

ArcExpress can greatly improve display speed when using ARC/INFO. ArcExpress stores all of the data required for the graphic image in the workstation memory. You will obtain maximum benefit from the product when the graphic image fits into the available memory.

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Operational Description

All ArcExpress commands are contained within ARCPLOT and are accessible in ARCEDIT by using the ARCPLOT command. The performance of existing commands and functions of ARCPLOT and ARCEDIT have not been modified in any way. The graphic view displayed by ArcExpress commands is in the same screen coordinate system as if it were drawn with ARCPLOT and ARCEDIT commands. This allows existing ARCPLOT and ARCEDIT commands that utilize screen and cursor coordinates to operate correctly. All ArcExpress commands can be executed interactively or from AML programs and menus. ArcExpress works with both regular and library coverages. Imagery and grids are not supported by ArcExpress in the initial release.

When to Use ArcExpress

ArcExpress is most useful when the user wishes to interactively examine complex data sets and search for detail at various zoom/scale factors. A typical example of this might be when exploring a detailed database that contains information about a major city's various utility lines and traffic routes.

Limitations

The operating system may swap out the ARC process to disk when other applications are running, which can result in occasionally slower display speeds. Also, if the graphic image is so large as to exceed the available memory, it will not be captured.

ArcStorm

Overview

Providing multiple users concurrent access to a continuous spatial database is a challenging aspect of GIS software development. The ARC/INFO LIBRARIAN™ subsystem manages large geographic databases by partitioning the data into tiles. When one user checks out a tile, other users are prevented from modifying data in that tile. Although this method works well for many applications, it can be cumbersome when different users want simultaneous access to data in the same tile.

In response, ESRI has developed ArcStorm™ (Arc Storage Manager) as an optional ARC/INFO extension. Key components include feature-level transaction management, unified transactions between spatial and tabular data in a commercial Relational Database Management System (RDBMS), a seamless appearance for distributed data across a network, archiving changes made to the database, and a client/server architecture.

What Is ArcStorm?

ArcStorm is a storage facility and transaction manager for spatial information. ArcStorm is a feature-oriented, continuous geographic database that can be closely integrated with the same relational database systems supported by ARC/INFO's DATABASE INTEGRATOR™ (such as Oracle, INGRES, INFORMIX, and SYBASE).

ArcStorm Features

ArcStorm offers the following features:

- Feature-level transactions. ArcStorm manages data at the feature level. This means that if you only want to edit one feature, you can do that without preventing other users from editing data in the same area.

- Unified transactions (spatial and aspatial). ArcStorm coordinates the changes to feature (spatial) data and their corresponding external RDBMS (aspatial) data so that the database remains consistent.

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- Persistent locks on related records in external database management systems (DBMSs). Once an ArcStorm lock is placed on a row in an external RDBMS table, that row is locked until the transaction is ended.
- Recovery mechanism. In the event a failure of some sort occurs (system failure, RDBMS failure, power outage, etc.), ArcStorm has a recovery mechanism that will return the database to its last consistent state.
- Schema integrity always maintained. Only the ArcStorm Database Administrator may modify the schema of the database.
- Data archiving. ArcStorm has a facility for maintaining the history information for the database. Changes to data are written to history records that can be reconstructed or viewed.
- Client/Server architecture. ArcStorm is built with a client/server architecture meaning it can be the data server for many clients, not just ARC/INFO.
- A data definition language. ArcStorm allows only the database administrator (DBA) to create libraries and layers and to include external attribute tables in the database.
- ARC/INFO LIBRARIAN conversion tools. There are tools for putting an ARC/INFO LIBRARIAN library into an ArcStorm database.
- Direct browse access for clients (ArcView® Version 2, ARC/INFO Version 7.0). ArcStorm servers are not required to display or query the data.
- Transactional access for ARC/INFO Version 7.0 (ARCEDIT, ARCPLOT). Transactional access is required to make copies of data or to modify data.

The ArcStorm Database

A database is an organized collection of information. An ArcStorm database is a collection of libraries containing spatial data (coverages) and (optionally) RDBMS tables containing attributes.

An ArcStorm database is implemented within the operating system and external RDBMSs. The directory $ARCHOME/arcstorm contains a list of all the available ArcStorm databases. Each database file contains the location of the database's "root" directory, the server node name, and database ID number. The root directory is named the same as the ArcStorm database (e.g., USGS_DB). Under the database's root directory are directories for each library and a directory containing transaction information.

Client/Server Architecture

ArcStorm uses a client/server architecture. The ArcStorm servers are a set of programs that control all transactional access to the ArcStorm database, thus ensuring data integrity and security. They run in the background, with one master server per database. The ArcStorm Application Program Interface (API) is a small set of subroutines that provide transactional access to the ArcStorm database. These server programs supply data requested by client programs such as ARCEDIT™ by way of the API. Server programs run on the server node.

ArcStorm Applications

As an ARC/INFO user, you should consider ArcStorm as a data manager for your data if

- Data must be managed and organized. ArcStorm databases can handle any volume of data efficiently.
- General systemwide access to data is desired. Data may be accessed from anywhere on a system or network without having to know the physical location of the database.
- Database has to be maintained over a long period of time. ArcStorm provides a self-sustaining, organizational framework that persists through system, personnel, and administrative changes.
- Individual spatial feature locking is required. Rather than lock a lot of features that you do not intend to edit (e.g., an entire tile's worth of data), you can select, lock, and check out data at the feature level.
- Data archiving is required. It may occasionally be necessary to go back to a version of the database as it existed at a given point in time. ArcStorm provides the ability to record the history of the database and to reconstruct the database for a given point in time.
- Persistent locks on, and long transaction support for, related DBMS table rows is required. If a user selects a feature (e.g., an arc) for update, then the feature, as well as its related rows in an RDBMS, are marked as locked. They will remain locked until the user ends the transaction.
- Coordinated commits between long (spatial) transactions and short (RDBMS) transactions is required. When a user puts data back into the ArcStorm database, both the feature insert **and** the RDBMS record insert must complete successfully or the insert will abort and any changes made will be rolled back.
- System failure recovery mechanism is needed. In the event of a system failure, a recovery mechanism ensures that the database is returned to a consistent state when the system comes back on-line.
- Distributing data across a network is required. Many data sets are too large to fit on one physical disk. ArcStorm allows data to be distributed.

You may not need to use ArcStorm if

- Data consistency is not critical. In some applications, slight variations in attribute table item definitions may be acceptable. ArcStorm requires exact attribute consistency.
- Concurrency management is not an issue. Multiple users will not be accessing or updating the data at the same time.

- All you need is a simple, single coverage. The time required to implement an ArcStorm database on your data may not be worth the effort.

What Is the Difference between ArcStorm and ARC/INFO LIBRARIAN?

Prior to ArcStorm, ARC/INFO LIBRARIAN was the only way to organize and manage ARC/INFO data. Even though ARC/INFO LIBRARIAN and ArcStorm have some of the same database concepts, ArcStorm has a number of advantages over ARC/INFO LIBRARIAN and is the better spatial data manager. There are, however, a number of users who will not want to convert from ARC/INFO LIBRARIAN to ArcStorm because ARC/INFO LIBRARIAN currently meets their needs. This is not a problem because ARC/INFO LIBRARIAN will be supported for some time to come. For those users who want to convert their Map Library to an ArcStorm database, there are conversion tools to make the transition easier.

As with ARC/INFO LIBRARIAN, effective administration of ArcStorm requires some understanding of ARC/INFO, your operating system and, if used, your RDBMS. ArcStorm uses only those data structures provided by ARC/INFO, the operating system, and the RDBMS (again, if used). Spatial data managed by ArcStorm are in UNIX coverage format. Security is provided by the operating system's security as well as whatever security the RDBMS offers.

ARCPLOT commands can be used to query and display ArcStorm data by specifying the database, library, and layer name. This is very similar to how ARC/INFO LIBRARIAN data are displayed and queried in ARCPLOT. AML programs and menus can be used to make ArcStorm data part of an application tailored to your needs. Several AML functions provide access to ArcStorm libraries, layers, and external attributes. A tailored system can use the AML menu capability to access ArcStorm data in concert with access to other coverages and attribute tables in RDBMSs. ArcView also provides display and query capabilities with ArcStorm data.

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