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# Why is ArcGIS an Improvement?

By Antonio Lopez

Unlike other versions of Environmental Systems Research Institute (ESRI)'s Geographic Information Systems (GIS) software, ArcGIS 8 is an integrated Geographic Information System using object-oriented and traditional file-based data models together with a set of tools used to create and work with geographic data. The ArcGIS suite of GIS software consists of three applications.

- ArcCatalog (for data management)
- ArcMap (for mapping and data manipulation)
- ArcTool Box (for spatial data editing and processing)

These three applications are the core components of the suite of GIS software called ArcGIS. Three licenses of ArcGIS can be purchased and additional software components and extensions can be added to the core software. The three licenses available for the core software are listed below.

- ArcView
- ArcEditor
- ArcInfo

The number of tools available to the user for editing and analysis depends on the license. ArcView and ArcEditor have a limited number of tools. The ArcInfo license, however, increases the number of tools available to provide high-end functionality. The differences between these licenses will be further discussed later in the article.

### What Geographic Data Models are Used in ArcGIS?

ArcGIS uses a geographic data model that represents spatial information as objects, features, rasters, and other data types. It integrates two GIS data models, the traditional file-based model and an object-oriented relational model called a geodatabase. ArcGIS is designed to give users the option of using traditional file-based datasets or utilizing the robustness and flexibility of the geodatabase.

ESRI's file-based models include spatial data structures used by previous versions of their software, such as coverages, shapefiles, grids, images, and triangulated irregular networks (TINs). The object relational geographic data model used by ArcGIS, however, can be used to manage previously existing geographic datasets in a database management system (DBMS) by taking advantage of the many benefits of object-oriented relational database management system (OO RDBMS) technology. These significant changes in how the data is conceptualized and managed constitute a noteworthy improvement in this version of the software.

The object-based design affords geodatabases with several advantages, including the implementation of data integrity rules and behavior. These two features provide data modelers with greater flexibility in designing databases. This ultimately allows for the development of more realistic geographic models that simulate the "real world". These technological developments are significantly different from older versions of their software, which were based on older procedural technology. Moreover, the way data is stored has significantly improved. Raster data types, for example, are stored using a unified means for managing all raster data formats, including multi-band images, grids, and compressed raster formats.

The object-oriented geodatabase model represents geographic information using standard relational database technology rather than files. This model supports the storage and management of geographic information in tables residing in an OO RDBMS, such as Access or Oracle. The system encapsulates the geometry of a geographic feature by storing it as a Binary Long Object (BLOB) in a record's field. The field storing the BLOB is called the called the *shape* field.

Because geodatabases adhere to the Open GIS Consortium (OpenGIS or OGC), geodatabases can be implemented using spatial data types used by other GIS software vendors such as Oracle. While Oracle does not produce software with full GIS functionality, their Oracle Spatial product stores spatial data in an object-oriented relational environment. It can be used to warehouse enterprise wide spatial databases (see "Collaborating for the Better Good: ITS Teams Up with New York City Transit"(915K PDF) in the Fall 2002 issue of *Connect*) such as the NYCMAP (see "GIS on the World Wide Web" in the Summer 1998 issue of *Connect*) and can reside as middleware between a functional GIS and an attribute Oracle data-warehouse.

The conceptualization of geographic features as "objects" has resulted in a more realistic GIS view of the world. Geographic objects relate to other objects, have behavior, and adhere to specified rules. In the geodatabase, geographic features are no longer solely related to one another through geometry. Instead, schema diagrams define how objects relate to one another and behavior can be given to these objects using programming code such as Visual Basic, Java, or C++. Features in traditional file-based spatial datasets, on the other hand, related to one another solely in geometric space. Through an object schema diagram and programming code, however, the relationship of geographic objects takes on another dimension. These geographic objects now relate to each other not only in geometric space but also by relationships defined in schematic diagrams, rules specified by database designers, and behavior added to objects through programming code. These changes have revolutionized how geographic models in a GIS environment are conceptualized and implemented.

## How is Topology Implemented in ArcGIS?

Topology in a GIS environment is different from the field of mathematics that studies the properties of figures or solids that are not normally affected by changes in size or shape. In GIS, topology defines how geographic objects relate to one another in geographic space through an explicit data structure. This data structure was created by ESRI with the implementation of ArcInfo coverage file-based geographic data format. In the ArcGIS environment, however, topology is defined using a set of integrated rules that describe the behavior of spatially integrated geographic features and feature classes. In the geodatabase, a topology is expressed as a series of integrity rules along with key properties and exceptions to those topological rules. Establishing topological rules is a fundamental part of the geodatabase design. This requires that the user define the feature classes that participate in a topological and shared geometric environment. The shared feature classes are organized into common feature datasets, and the topological rules that govern geometric behavior of the features are defined. For example, a database developer can define rules for entering topological data in a regional rail network geodatabase. Furthermore, Geographic objects belonging to a class called *tracks* can be subdivided into subclasses such as subway track and commuter-rail track subclasses. Rules can be established that do not allow tracks belonging to the subway and commuter rail subclasses to physically connect. By establishing such rules, data integrity is assured.

Since the geodatabase data model builds on the spatial concepts used in ArcInfo coverages and ArcView shapefiles, new functionality has been added by extending the coverage and shapefile models with support for advanced geometry (3D coordinates, measures, and true curves), complex networks, and relationships among feature classes, planar topology, and other object-oriented features.

## What are ArcMap, ArcCatalog, and ArcToolbox?

### ArcMap

ArcMap is the central application in ArcGIS used for map-based tasks such as cartography, geographic analysis, and editing spatial features. ArcMap offers different ways to view a map, a geographic data view and a layout view. The *data view* is similar to the view in ArcView 3.x. It contains a view of the geographic layers and a legend containing *dataframes* (i.e., a set of layers). The *layout view*, on the other hand, consists of dataframes with a series of layers and map elements such as legends, scale bars, north arrows, and others. Unlike ArcView 3.x, the layout contains a live link to the dataframes in the data view. This link allows the user to make edits directly on the screen. While the interface is a significant improvement from the previous version of ArcView and ArcInfo, a shortcoming is that a user can only create one *layout*, now called a *map document*. In the previous version of ArcView, a user could create several layouts, each containing a cartographic product.

#### ArcCatalog

The ArcCatalog application is used to organize and manage the GIS data. It includes tools for browsing and finding geographic information, recording, viewing, and managing metadata, viewing datasets, and defining the schema structure of the object-based geographic datasets.

#### ArcToolbox

ArcToolbox is a simple application containing many GIS tools used for geoprocessing. There are two versions of ArcToolbox: the complete ArcToolbox that comes with ArcInfo, and a lighter version that comes with ArcView and ArcEditor.

### How do ArcMap, ArcCatalog, and ArcEditor Work Together?

When ArcMap, ArcCatalog, and ArcEditor are combined, they perform all the GIS tasks available with whichever license of ArcGIS is being used (ArcView, ArcEditor, and ArcInfo). For example, a map document can be searched for and found in ArcCatalog, opened in ArcMap, and edited and enhanced in ArcMap using tools available through ArcEditor. Data can also be searched for through direct database connections in Access, SQL, Oracle, and other relational database management systems using OLE DB or ODBC (Object Database Connection Technology). Once the data is found, the user can drag and drop data from ArcCatalog onto tools in ArcToolbox. When new geographic information is created using all three applications, the user can document metadata (information on data) for the resulting datasets in ArcCatalog. Recording information describing data and its sources is always a good idea!

### What Are the Differences Between ArcView, ArcEditor, and ArcInfo?

As previously mentioned, three licenses of ArcGIS are available: ArcView, ArcEditor, and ArcInfo. The ArcView license provides mapping and analysis tools along with a simple editing and geoprocessing. The ArcEditor license includes advanced editing capabilities for shapefiles and geodatabases in addition to all the features available in ArcView. The ArcInfo license further adds functionality to ArcEditor by extending the number of tools available for editing and geoprocessing. The interface for all three licenses consists of ArcMap, ArcEditor, and ArcCatalog.

To avoid confusion, it is important to note that the ArcEditor license and the ArcEditor component of the interface are separate entities even though they have the same name. In other words, ArcEditor is the name of one of the three components of the ArcGIS interface (ArcMap, ArcEditor, and ArcToolbox) in addition to one of the three licenses (ArcView, ArcEditor, and ArcInfo). The ArcInfo license of ArcGIS is available through the ITS Social Science, Statistics, and Mapping Group.

### What Changes in the Software Industry Lead to the Development of ArcGIS?

The *software industrial revolution* describes the current era, when software is complied out of reusable object components creating vast libraries of such components. This is made possible through the development of object-oriented techniques that allow software to be built out of other objects. Systems analysis in the object-oriented world is achieved by analyzing objects in the environment and those events that interact with those objects. These techniques have been combined with other software technologies. Early object-oriented techniques were primarily concerned with writing code in languages like Smalltalk and C++. The combination of these object-oriented methods with other technologies such as GIS has revolutionized the spatial modeling techniques used by GIS analysts.

Smallworld (http://www.gepower.com/networksolutions/) developed the first object-oriented Geographic Information System. Smallworld products are most popular in Europe among utility companies who take full advantage of its ability to handle multi-transactions. In New York City, the Department of City Planning, Con Edison Communications, and the CARSI Lab of the City University of New York at Hunter College are some of its users. ESRI's first step towards implementing a complete object-oriented GIS was successfully achieved with ArcView 3.x. This version of the software can be referred to as a hybrid GIS that used the traditional GIS layer view of the world and a limited object-oriented scripting language for application development. While Avenue (ArcView 3.x's scripting language) was built using C++, feature class definition was not possible, limiting users to the object model provided by ESRI. This, however, has changed with the fully object-oriented high-end ArcGIS.

At a programming code level, prior to the advent of object-oriented technology, previous versions of the software were based on procedural technology. Object-oriented technology, however, has revolutionized how GIS technology conceptualizes, stores, and manages geographic information. The change in the underlying programming code used to develop ArcGIS has resulted in an enhanced interface and data model.

### Object-Oriented Technology

Since ArcGIS is fully object-oriented, it maintains the features of the technology on which it was built. The basis of object-oriented technology consists of the concepts and methods listed below.

- **Abstraction** is the extraction of essential details about an object or group of objects while ignoring unessential details.

- **Encapsulation** is a method of packaging information that hides unessential information and makes necessary information visible.
- **Classes and Subclasses** are sets of entities that share the same conceptual basis. An object is an instance of a class.
- **Inheritance** is a relationship between classes where one class is the parent of another class.
- **Polymorphism** is the ability to redefine *methods* for *derived classes*. For example, given a base class *shape*, polymorphism enables the programmer to define different *circumference* methods for any number of derived classes, such as circles, and rectangles. No matter what shape an object is, applying the circumference method to it will return the correct results.

A proper description of object-oriented theory is beyond the scope of this article. Nonetheless, it also greatly improves how databases are stored and managed. The following are some of the advantages in implementing ArcGIS:

- Centralized datasets in a relational database management system and other improvements in data design and storage
- Schematic Diagrams and Case Tools are used for database design and building
- Topology is better implemented with schema diagrams, rules, and behavior
- Improved Data Integrity

From a software engineering perspective, the concepts of abstraction and encapsulation can be employed using programming languages such as Java or C++. Through these languages, well-defined *classes* provide a modular decomposition technique and any other advantages experienced through reusable software components. Using the object-oriented method of *inheritance*, together with encapsulation, abstraction, and polymorphism, software engineers will avoid rewriting the same code repeatedly and wasting time by introducing inconsistencies and errors. ArcGIS will become more sophisticated with time by building new components to the existing software.

### What is the Bottom Line?

ArcGIS is a system with the capacity of implementing a more robust geographic model and flexible interface for data editing, data automation, mapping, data management, geographic analysis, and metadata management. The geodatabase allows for complex models that more accurately simulate the world. Through relationships, rules, and behavior, the software has the ability of better resembling "real world" objects and scenarios. Moreover, the implementation of rules improves data integrity. Users are also given the flexibility of using both file-based and geodatabase datasets, facilitating the migration of data from traditional formats to a geodatabase. This is particularly important to long-time users of ESRI products, who have made considerable investments in implementing older versions of the software and have large amounts of data stored in file-based formats. ArcGIS is a much-improved system whose functionality will continue to expand as software components are added to the core system using object-oriented techniques.

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### Author Biography

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