# MOVING TOWARDS NEW TECHNOLOGY FOR GENERALIZATION
**(For the 4th Workshop on Progress in Automate Map Generalization, ICA)**

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## Abstract

In pursuing GIS-based map generalization, a set of most requested generalization tools has been added to ESRI's ArcInfo system in recent years. These tools derive reduced data sets from a master database, with less complexity and detail, to satisfy the output scales and other requirements. With the coverage data model used in the "classic" ArcInfo (now called Workstation ArcInfo), features are processed through commands. Based on parameters and options, some changes take place and new results are produced. Our main practices include defining generalization rules, creating algorithms and procedures, facilitating post-processes, and supporting user's requests and benchmarks, which have prepared us to meet new challenges.

The new generation of GIS software, such as ArcGIS 8.1 produced by ESRI, has adopted object-oriented technology and data model. Geographic features can now be defined and stored as objects with intelligence, including their natural behaviors and relationships to other objects. This means an object can behave differently as the map scale changes. It can show different appearances according to scale range, or it can be given certain generalization methods that are automatically applied and produce generalized results on the fly.

This paper briefly reviews our experience in the past, gives an overview on ArcGIS, and presents the ideas for new development in ArcGIS. Our ultimate goal is to provide the users with powerful and flexible generalization tools that help them to derive datasets and produce maps efficiently from a unified and scalable geodatabase.

### Experiences with Coverage Data Model

In Workstation ArcInfo, the coverage data model is used to define geographic information. Features are collected as topologically related points, lines, and polygons with generic behavior, combined with attribute tables. To add special types of behavior, one has to implement customization programs written in the Arc Macro Language (AML). To make a generalization step happen, one needs to provide input coverage and parameters. In such environment, features are passively following instructions.

Developing computer-assisted generalization solutions within the Workstation ArcInfo in the past few years has involved the derivation of procedures (atools or customized AML programs combined with necessary interactive steps) using existing functions (commands) to solve certain generalization problems and the creation of new functions specialized for other generalization tasks (Lee, 2000). In the practice of deriving procedures, the logic and strategies of solving the problem were laid out and then translated into a series of steps in a logical sequence.

When no procedures could be found to solve certain generalization problems, new programs were developed and added to the system. These new tools, favoring large to medium scale applications, include simplification of linear features or polygon boundaries without creating topological errors, simplification of building footprints with flag on potential conflicts, and collapse dual-line features to centerlines. Generalization quality and status are usually recorded for these processes and reflected in outputs, which facilitate post-editing and QC processes. Figure 1 below shows a few of the generalization functions in Workstation ArcInfo.

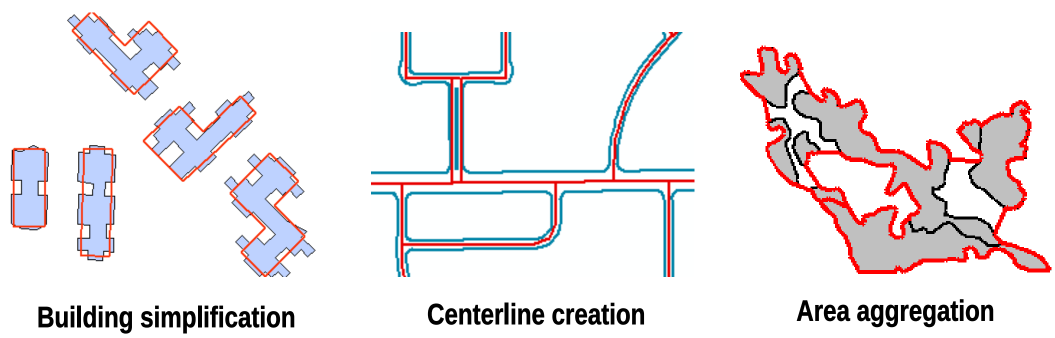


**Figure 1 Example generalization functions in Workstation ArcInfo**

As post-processes, one procedure (FINDCONFLICT, an atool in Arc) was derived to detect spatial conflicts among simplified buildings; two sample scripts were created to allow interactive editing of the simplified buildings and collapsed centerlines. In all generalization tools, a one-to-one or one-to-many feature relationship between input and output is always maintained for attribute transfer or other data integration.

## Overview of ArcGIS

With an entirely new architecture and user environment, ArcGIS, the object-oriented product, marks a major breakthrough in the evolution of ESRI software (ESRI, 2000). ArcGIS 8.1 embraces the functionality that GIS professionals expect and presents the first release of a complete, unified, scalable, and integrated system for geographic data creation, management, integration, and analysis.

### The Unified and Scalable System

The ArcGIS Desktop product family (ArcView, ArcEditor, and ArcInfo) is a unification of the traditional ArcView and ArcInfo environments. At the 8.1 release, users will see a common architecture, the same underlying executables and user interface, common extension model, and single development environment for ArcGIS Desktop and extensions (ESRI, 2000).

ArcGIS, consisting of ArcGIS Desktop, the extensions, ArcSDE, and ArcIMS, is designed to be scalable (ESRI, 2001a). The system can be deployed in every organization, from an individual desktop to a globally distributed network of multi-users (Figure 2).

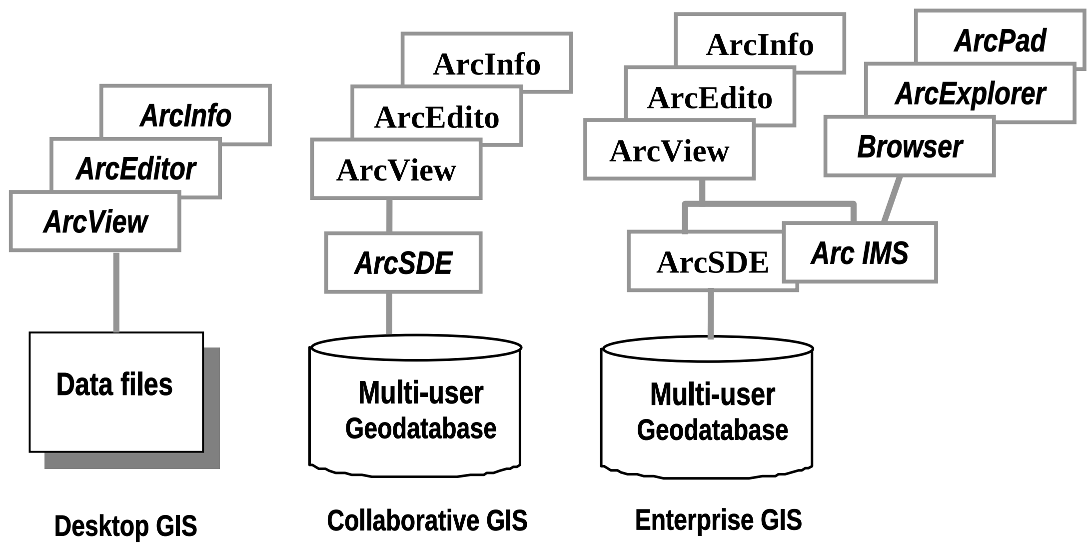


**Figure 2 ArcGIS is scalable.**

ArcView 8.1 is the entry point into ArcGIS and provides core mapping and GIS functionality. It provides data visualization, query, analysis, and integration capabilities along with the ability to create and edit simple geographic features and produce high-quality cartography. Additional functionality is enabled with dramatically increased usability and interoperability as you move from ArcView to ArcEditor to ArcInfo. All ArcGIS 8.1 extensions (Spatial Analyst, 3D Analyst, Geostatistical Analyst, ArcPress, StreetMap, and MrSID Encoder) operate with the entire line of ArcGIS Desktop.

ArcSDE 8.1 adds database services to the ArcGIS family. It is the gateway for storing and managing a multi-user geodatabase stored in a database management system (DBMS). By allowing joint multi-user editing and providing transacted views of a geodatabase, ArcSDE plays a fundamental role in collaborative GIS systems.

ArcIMS adds Internet mapping services to an ArcGIS system. All ArcGIS desktop clients (ArcInfo, ArcEditor, ArcView, ArcExplorer, and ArcIMS Viewer) can dynamically stream vector data across the Web from an ArcIMS server. These new layer types can be symbolized, mapped, queried, edited, and analyzed just like local data. They can also be saved locally for later use. This ability to access and publish geographic information across the globe is changing the use, scope, and impact of GIS.

## COM-Based ArcObjects

ArcGIS Desktop is built with an intuitive Windows user interface; and the open programming environment makes the full capability of ArcGIS accessible to all. The collection of COM (component object model)-based ArcGIS components is known as ArcObjects, which is the development platform (ESRI, 2001b). All existing ArcGIS Desktop applications, such as ArcMap and ArcCatalog in ArcView, are created using ArcObjects. You can find many ways to extend the existing ArcGIS capabilities or build more extensions and custom applications using the built-in Microsoft Visual Basic for Applications (VBA) scripting capabilities or a COM-compliant programming language.

## The Geodatabase

Building a geographic database is modeling of the real world. The data structure and the information stored in the database directly affect the analysis and decision-making in GIS and mapping applications. For generalization, it is especially important to know, other than the locations and shapes of features, the spatial relationships among them and how they should be managed according to scale changes (Lee, 1996).

The geodatabase model, an object-oriented data model created with ArcGIS, supports a topologically integrated feature classes and extends the traditional coverage model with support for complex networks, relationships among feature classes, and other object-oriented features. As a generic model for geographic information, the geodatabase model can be used to define and work with a wide variety of user- or application-specific models (MacDonald, 1999). Geographic features can now be defined and stored as objects with intelligence, including their natural behaviors and relationships to other objects. As a researcher pointed out (João, 1998), a data model for generalization is only effective if it stores spatial relationships among features.

To allow modeling the real world more naturally, a geodatabase provides a framework for features to have geometry, attributes, spatial reference, relationships, domains and validation rules, topology, and custom behaviors (Zeiler, 1999). Simple or standard behaviors of features are built-in and can be implemented by choosing a feature type and topological association, setting up relationships, and specifying attribute domains and validation rules. More complex and specialized behaviors of features for advanced applications can be realized through custom features.

# Integration of Generalization

The integration of generalization tools into ArcGIS is underway with the ultimate goals to support database generalization and cartographic generalization from geodatabases. The ArcObjects component library will be extended to include a set of generalization functions, that is, generalization operators, measuring and analysis methods, visualization tools, and so on. User-interfaces will be created in geodatabase management, editing, and map layout environments to access these functions for map production.

Two basic approaches, the passive operator-driven approach and the active feature-reacting approach, will be supported. They both are necessary and applicable for database generalization and cartographic generalization, as distinguished by researchers (Weibel and Jones, 1998).

**Operator-Driven Approach**

Before the entire generalization task can be fully automated with completely satisfactory results, the passive operator-driven approach will remain a tradition in many organizations. This approach follows the logic of map compilation with computer-assisted tools; the user selects features, sets parameters and processing orders, and edits the result if necessary.

To support this approach, a menu-driven interface will be created to allow users to access geodatabases, specify or select features to be generalized, choose one or more generalization operators to apply, set parameters by fixed values or interactively using sliders, and interactively editing the results (resolving remaining conflicts and improving cartographic quality), with the assistance of measuring and visualization tools. The parameters and sequences can be saved and reused. Since a feature in ArcGIS can be smart enough to follow generalization rules (implemented as its behavior), it will be able to “cooperate” with the given instructions; therefore the generalization analysis and decision-making will be more effective and the results closer to satisfaction. For example, if buildings are to be aggregated (given a distance tolerance), they may end up crossing some roads. If the buildings have built-in methods that prevent them from crossing roads in aggregation at certain scale range, you will not have the problem.

**Feature-Reacting Approach**

This approach takes advantage of the object-oriented data model in which a geographic feature with built-in properties and methods will react and change appearances according to output and display resolutions or map scales. A feature can be given multiple representations, each corresponds a scale range, and methods to generalize itself in different situations. For example buildings can be shown as polygons with detailed footprints at a very large scale, combined into an urban area at mid-range scales, shown as a point to indicate the city location at small scales, and excluded at very small scales. This approach will be helpful not only for map compilation, but also more importantly for dynamic applications, such as internet mapping and wireless communications.

Finding the nearest pharmacy, obtaining driving directions, notifying emergency service providers of your precise location, and the like - these are all location services that will utilize GIS technology to operate effectively and economically (Koeppel, 2000). ArcGIS technology has laid the foundation to serve this marketplace. ArcIMS, designed specifically for the Web, provides a diverse set of mapping, location analysis, and routing capabilities for location service developers. ArcPad, the new mobile GIS, operates both stand-alone (GIS data is loaded on a mobile device) as well as in a “wireless" communication mode as a client to ArcIMS. It allows workers in the field to use geographic (locational) information directly to communicate their locations in real time and to access large databases for data collection and analysis.

The location-based requests on the web or in a wireless communication need to be answered instantly with descriptions and effectively generalized maps. On-demand map generalization may share similar nature as map compilation in terms of fitting the output scales and purposes, but the result is expected to be complete (not with a queue of unresolved cases), readable, and repeatable. This would force the generalization rules to be rather simple and decisive. In case of a conflict, a resolution has to be reached without human interactions and rooms for corrections. This is a change from the traditional thinking.

## Conclusions

As GIS technology is advancing, geographic features or objects are being given new life. They become equipped with intelligence and aware of relationships. This makes it easier to further automate the processes that used to be complicated and difficult, such as generalization. Our experiences in the past have prepared us with in-depth knowledge and understanding about digital map generalization, including the rules, the algorithms and techniques, the priorities, and the issues in production. ArcGIS is the right system to integrate generalization capabilities and to support advanced GIS and cartography.

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