Analyzing the Earth With Geographic Information Systems

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What is GIS?

Geographic information systems (GIS) provide a technology and method to analyze *spatial data*, or information about the Earth. The earth's climate, natural hazards, population, geology, vegetation, soils, land use, and other characteristics can be analyzed in a GIS using computerized maps, aerial photographs, satellite images, databases, and graphs. By analyzing phenomena about the Earth's hydrosphere, lithosphere, atmosphere, and biosphere, a GIS helps people understand patterns, linkages, and trends about our planet.

The "G" part of GIS is some representation of the Earth—a scanned topographic map, aerial photograph, satellite image, routes in a watershed, slopes, fault lines, surficial geology, or a variety of other themes and ways to represent those themes in two or three dimensions. The "I" part of GIS is the Information about the features on the map. This information is usually stored in one or more tables in a relational database. It could be whether a stream is perennial or intermittent, the name of a cave, the elevation of a contour line, or other attribute. The power of a GIS is in the "S" part—the System that allows the data user to analyze both the representation and the attributes of the Earth simultaneously.

GIS is more than just computer software. GIS is a *system*, and is usually considered as comprised of the software, hardware, spatial data, methods, and people that make daily decisions using GIS tools. Since the 1960s, GIS has quietly transformed decision-making in universities, government, and industry by bringing digital spatial data sets and geographic analysis to desktop computers. *Geographic Information Sciences* include Geographic Information *Systems* as well as the disciplines of geography (examining the patterns of the Earth's people and physical environment), cartography (mapmaking), geodesy (the science of measuring and surveying the Earth), and remote sensing (studying the Earth from space).

Because most issues and problems in our world have a spatial component, GIS and associated technologies are fundamental to sound decision-making. GIS is used in conjunction with Global Positioning Systems (GPS) for mapping everything from cave locations to fire towers. GPS, once used mostly by organizations such as the USGS for creating accurate topographic maps, have increased in accuracy and become affordable to the caver and general public, spreading from government agencies into vehicles and cellular telephones. Increasingly, non-scientists are relying on GIS and GPS technologies for everything from siting retail site locations to real estate sales to setting insurance rates, spawning a related industry called *Location-Based Services.* In addition, private companies have combined government-generated spatial data with handy GPS utilities to create computer mapping software, such as *Topo* by National Geographic, that allows even nonscientists to plan and create tracks and trails.

GIS is used in three major ways in education at the elementary, secondary, and university level. First, teaching *about* GIS dominates at the university level, where courses in methods and theory of GIS are taught in geography, engineering, business, environmental studies, geology, and in other disciplines. Every major university and most community colleges in the USA host a GIS program. Second, teaching *with* GIS is emphasized at the elementary and secondary level, where GIS is increasingly used to teach concepts and skills in earth science, geography, chemistry, biological science, history, and mathematics courses. Finally, GIS is used as a fundamental research tool in all institutes of higher education in geography, demography, geology, and other disciplines.

GIS Applications in Caves and Karst

Caves contain a wealth of information on natural resources, water resources, and human history. Cave data is relevant to how watersheds work, global climate change, waste disposal, groundwater supply and contamination, petroleum recovery, medical investigations, minerals, biology, paleontology, archaeology, geology, and even Martian exploration. Because caves are complex *systems*, understanding, protecting, and managing them can be enhanced through the use of another system, the GIS. Because of the unique underground, three-dimensional nature of caves, GIS applications in speleology had to wait for the arrival of specialized 3D applications and increased computer processing speed. However, increasing need for cave protection and identification has hastened GIS development over recent years.

GIS has been recently used, for example, in a Kentucky sinkhole digitization effort, and for proposing new routes for Interstate 66 within the state. In Timpanogos Cave National Monument, GIS has been used to identify rockfall hazards to visitors, to create a virtual tour of the cave and valley, and to make a three-dimensional model of the cave itself through surveyed coordinates, COMPASS software by Fountainware, and the CaveTools extension of ArcView GIS. Additional applications of GIS cave science and protection can be found on: www.esri.com/industries/cavekarst/

GIS Tools for Caves and Karst

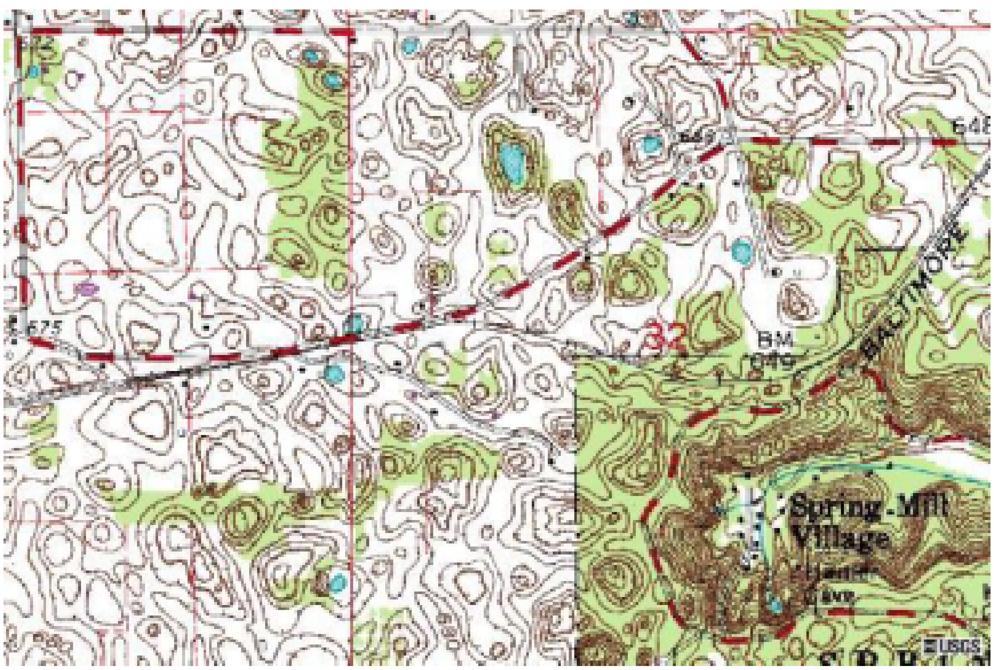
Several specialized tools exist, particularly for those who use ESRI GIS software, some of which are free. CaveTools is a free ArcView GIS extension that provides tools to convert COMPASS Plot Files into 2D or 3D ESRI map files. CaveTools also includes tools to register cave survey data from any source to known locations, such as GPS locations. COMPASS is a cave survey software package designed to edit, process, analyze and view cave survey data. With COMPASS, users can enter and revise survey data, generate cave statistics, close loops, view plots from various angles on the screen and create 3D and passage wall maps. ArcView GIS users can convert

COMPASS Plot Files to ESRI Shapefiles using the CaveTools for ArcView GIS extension, and can directly output 2D and 3D AutoCAD DXF files that can be directly read by ArcView via a CAD Reader extension. Walls is an integrated set of tools designed to help cave surveyors organize their data and prepare maps for publication. Walls is suited for complex projects, includes a geographical calculator for coordinate conversions and declination calculations, can import SMAPS (SEF), COMPASS, and CML data files, and can export SEF, annotated maps as metafiles, and 3D VRML models. Also, several types of shapefiles can be generated directly for use with ArcView GIS and other ESRI software. WinKarst is software for cave surveying, processing and visualization. Using WinKarst a user can maintain survey data, generate statistics, close loops and import and export data in several formats. WinKarst handles geographic coordinates, projections, and automatically calculates magnetic declination. Users can export 2D and 3D DXF files that can be directly read by ArcView, or comma delimited text for import into Access.

Data Sets for GIS

The US Geological Survey, the US Census Bureau, and other federal agencies have been producing digital map data since the 1970s. The USGS, for example, uses these data sets within a GIS environment to analyze urban growth, investigate the downstream effects of abandoned mine lands, to create flood models, and in other investigations. Private companies have taken these base data sets to use in a wide variety of services, including popular web mapping services such as ***www.mapquest.com***.

Base spatial data includes scanned topographic maps, digital raster graphics (DRGs), usually in TIFF format.

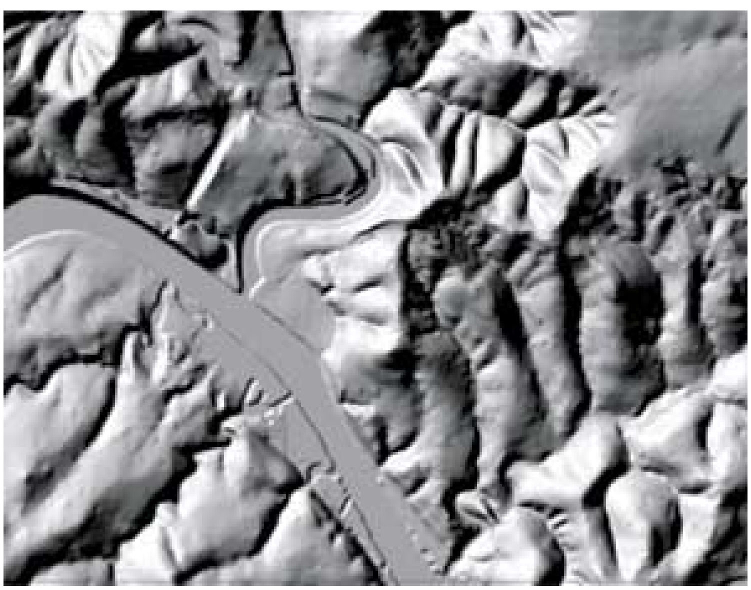


DRG showing karst topography near Orleans, Indiana.

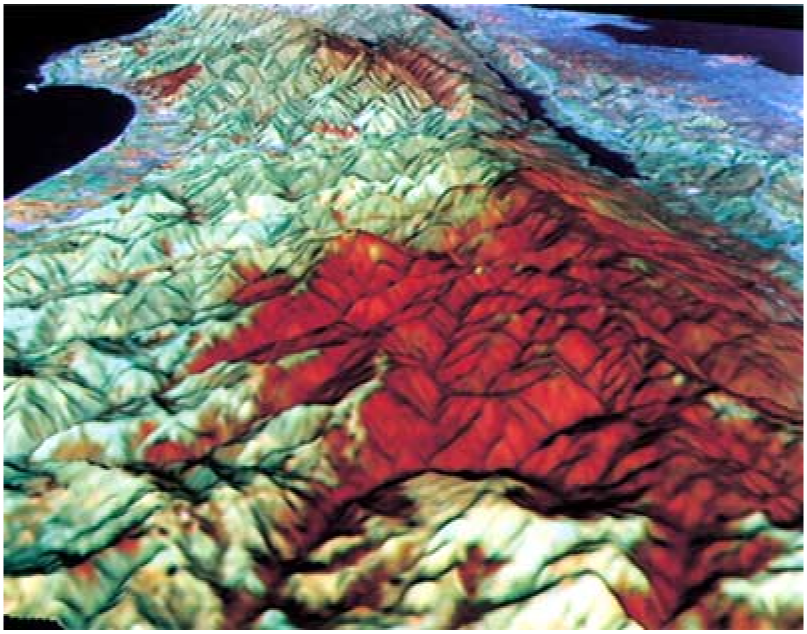
Digital orthophotoquads, or DOQs, are scanned, corrected aerial photographs at resolutions as fine as 1 meter.

Digital Orthophotoquad (DOQ) for same area near Orleans, Indiana.

Digital Elevation Models (DEMs) and the related National Elevation Dataset are three-dimensional models of the earth, made from topographic maps.



Digital Elevation Model in the Texas Hill Country, Austin.


Perspective view made from a Digital Elevation Model for San Mateo County, California.

Land use and land cover data is another useful, nationwide, free data set, compiled from satellite imagery for up to 30 land cover classes. The National Hydrography Dataset (NHD) provides streamflow and watershed data for the country, and Digital Line Graphs (DLGs) are comprised of roads, boundaries, survey markers, contour lines, and other data layers.

Data from a variety of satellites such as Landsat (operated by the USGS and NASA), IKONOS (operated by Space Imaging), and QuickBird (operated by Digital Globe) are just a few of the expanding array of imagery available to examine the Earth. The US Census Bureau's TIGER files are road and other files that can be combined with Census data for population and housing analysis on a neighborhood level. The Natural Resources Conservation Service produces digital soils data, while the USGS National Geologic Maps Database provides an index of geologic maps, some of which are in digital form.

Many of these data sets can be found on such national sites as seamless.usgs.gov, geographynetwork.com, ***www.geodata.gov***, though statewide GIS data portals, and through data vendors such ***www.gisdatadepot.com***. A fuller description of the data sets available and how to obtain them is on: rockyweb.cr.usgs.gov/public/outreach/gisguidelines.html.

GIS Education: Taking the Next Step

Many avenues exist for finding out more about using GIS, including conferences, web sites, books, online tutorials, journals, and online courses.

Starting Points

Good starting points for learning more about GIS can be found on ESRI's sites ***www.gis.com*** and ***www.gisday.com***, and the USGS site ***erg.usgs.gov/isb/pubs/gis_poster/*** . Of particular interest to cavers will be the Cave and Karst News on ESRI's ***www.esri.com*** site. Online mapping, driven by GIS software, is becoming more and more common and is an excellent way to learn how spatial data can be examined. Spend time browsing through USGS online aerial photographs and topographic maps on ***www.terraserver-usa.com***, the National Atlas on ***www.nationalatlas.gov***, real-time wildfire mapping on ***www.geomac.gov***, for example, for the look-and-feel of standalone GIS. Also, since all communities use GIS, speaking with someone in your city or county open space, parks, planning, land use, public works, or zoning department is often the best way of all to begin learning more about GIS.

Software

Manufacturers of GIS software include *ArcView*, by Environmental Systems Research Institute (ESRI): ***www.esri.com***, *Idrisi*, by Clark Labs at Clark University: ***www.clarklabs.org***, *GeoMedia*, by Intergraph Corporation: ***www.ingr.com***, *MapInfo*, by MapInfo Corporation: ***www.mapinfo.com***, and *Maptitude*, by Caliper Corporation: ***www.caliper.com***.

Conferences

ESRI hosts a conference in GIS each summer in California that attracts over 11,000 people from around the world. In addition, most states host an annual GIS conference as well, as do the professional societies mentioned above. The conference proceedings are an excellent way of learning about what people are doing with GIS.

Training

In addition to taking courses at your local community college or university, a variety of online options are available. ESRI operates an affordable online series of courses on campus.esri.com. The USGS Rocky Mountain Mapping Center hosts online GIS lessons with downloadable data on rockyweb.cr.usgs.gov/outreach.

Literature

Over 21,000 entries exist in the on-line GIS bibliography available at campus.esri.com under the "library" heading. The University of Maine maintains a list of GIS-related journals on:
http://www.library.umaine.edu/sec/guides/gisjournals.htm, and another list of online GIS Journals exists on: http://www.gisdevelopment.net/publications/journal/ and **http://www.gisnet.com/notebook/giszine.htm.** These journals include application journals such as *Geospatial Solutions* and *GeoWorld,* exclusively online magazines, such as *Spatial News* and *Directions Magazine,* as well as research oriented journals

such as the International Journal of GIS. Most of the print journals host at least part of their content online. Books about GIS include “how to” books such as *Getting To Know ArcGIS* (ESRI Press) as well as books on GIS theory and applications, such as *Geographic Information Systems and Science* (Wiley).

Professional Societies

Professional societies provide job opportunities, networking, and training for learning about GIS. Organizations that are involved in GIS include the Association of American Geographers (AAG), www.aag.org, the American Congress on Surveying and Mapping (ACSM), www.survmap.org, the American Society for Photogrammetry and Remote Sensing (ASPRS), www.asprs.org, the Geographic Information and Technology Association (GITA), www.gita.org, and the Urban and Regional Information Systems Association (URISA), www.urisa.org.   Other organizations concerned with GIS are the University Consortium for Geographic Information Science (www.ucgis.org), and the Federal Geographic Data Committee (www.fgdc.gov).