Spatial Analysis 7.

Applications and software

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Abstract

In this module the typical applications of Geographical Information Systems will be introduced, and we would like to prove the flexibility GIS and the potentials for multiple use of GIS.

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Chapter 7. Applications and software

1. 7.1 Introduction

What is GIS? From the previous modules, you already know the answer. GIS used for everything and everywhere where earlier maps were applied. But the digital database, of course, much more able to do.

In this module our aim is to synthesize the lessons learned in the previous modules, to classify the applications, and to prove the flexibility and the multiple uses of GIS.

In the previous modules spatial operations were demonstrated through ESRI ArcGIS Desktop. This module will widen your knowledge. It will introduce you to the ESRI software environment, as a whole. ESRI was one of the GIS pioneers. Its early mission was to organize and analyze geographic information to support land planners and land resource managers in making well-informed environmental decisions. These projects consisted of site or regional land studies resulting in maps that geographically delineated constraints and opportunities for development. Esri staff applied the principles of integrated landscape analysis developed and implemented in the 1960s by Ian McHarg using manual mapping and map overlay techniques.

There are many other software packages like Intergraph Geomedia, AutoCAD Map 3D, Mapinfo Professional etc., unfortunately we have no time to deal with only one other software. It is Idrisi Taiga. Idrisi is developed by Clark Labs, based within the world-renowned Graduate School of Geography at Clark University. Clark Labs is well known for pioneering advancements in areas such as decision support, uncertainty management, classifier development, change and time series analysis, and dynamic modeling.

After learning of the module you will be able to:

• explain the typical applications of GIS,

• describe the GIS software functionality,

• discuss the links between the applications,

• give orientation for the selection of a GIS software.

2. 7.2 GIS application areas

GIS within the last 40 years has made remarkable development, are widely used in many areas, resource surveys, environmental assessment, disaster prediction, land management, urban planning, post and telecommunications, transportation, military police, water electricity, public facilities management, agriculture, forestry animal husbandry, statistics, commerce, finance etc[1].

This subchapter will give a classification of the typical GIS application areas. Let us start with an overview.

Visualization Application

Digital terrain model as a basis for the establishment of city, regional, or large construction projects, a famous scenic spots of the three-dimensional visualization model, multiple angles view, can be widely used in publicity, urban and regional planning, large-scale project management and simulation, tourism and other fields.

Cadastral Application and Land Management

Cadastre deals with a systematic classification and valuation of land, under the control of the government, by means of maps of parcels drafted on the basis of land surveys and recorded according to parcels in a land register. Cadastral applications involves the nature of land use changes, changes in contour plots, cadastre-owned power relations have changed, and many other elements, using GIS technology can be efficient, high-quality completion of these tasks.

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[1] http://www.gis-mapping.org/basics/gis-application.html

Fig.7.1. Multipurpose cadastre (Source: Esri)

GIS is used in agriculture and forestry sector to deal with a variety of agricultural and forestry resources (such as land, forests, grasslands) distribution, classification, statistics, graphics and other issues. Real estate development and sales process, also can take advantage of GIS capabilities in decision-making and analysis.

Spatial Planning

Spatial planning is an advanced GIS application. For example, in a large-scale urban infrastructure construction, how to ensure that the proportion of green space and a reasonable distribution, how to ensure that schools, public facilities, sports facilities, services, facilities, etc. to have the largest coverage (urban resource allocation problem) and so on.

Environmental Management and Modeling

Regional ecological planning, environmental status quo assessment, environmental impact assessment, pollutant reduction allocation decision support, environment and regional sustainable development, decision support, environmental protection facilities management, environmental planning.

Facilities Management

The above and below ground infrastructure (telecommunications, water supply, road transport, natural gas pipelines, sewage facilities, electricity facilities, etc.) is widely distributed in the country, and these facilities clearly have a geo-referenced feature. Their management, statistics, summary use of GIS can be completed, and can greatly improve efficiency.

Site Selection

According to the characteristics of the regional geographical environment, considering the allocation of resources, market potential, traffic conditions, terrain characteristics, environmental impact and other factors, in choosing the best location within the region, is a typical GIS applications, fully embodies the GIS spatial analysis function.

Resource Allocation

The goal is in such applications to ensure the most rational allocation of resources and maximize the effectiveness. GIS is used in various utility services,

Business and Marketing

The establishment of commercial facilities to fully consider their market potential. For example, the establishment of large shopping malls shopping centers if you do not take into account the distribution of the other, waiting for the building of the regional distribution and number of the surrounding neighborhood, once completed may not be able to achieve the desired marketing and service side.

Disaster mitigation in the distribution of goods across the country, energy security, food supply to institutions, and so on.

GIS can

- create beautiful, informative map displays,

- enhance reports and presentations with maps,

- find geographic patterns that cannot be seen in database tables,

- answer geographic questions that impact business operations,

- share spatial data with the organization and its partners.
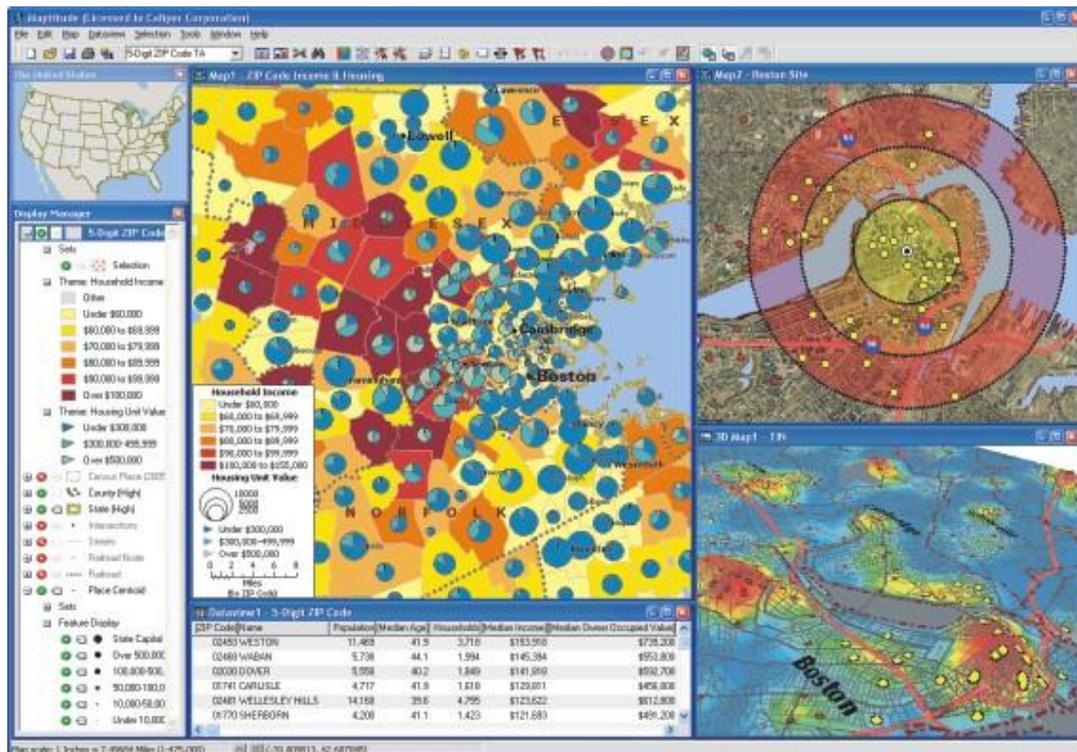
Fig. 7.2. Business GIS (Source: Maptitude)

Emergency Response

Able to resolve in the event of floods, war, nuclear accidents and other major natural or man-made disasters, to arrange the best evacuation routes, and equipped with the appropriate transport measures and support facilities.

Scientific Applications

Terrain analysis, watershed analysis, land use studies, economic geography studies, spatial decision support, spatial statistical analysis, and mapping and so can make use of GIS software to complete.

Network Analysis

The establishment of transport networks, underground pipeline network of computer models to study the traffic flow, traffic to deal with emergencies underground pipelines (burst pipes, circuit), etc. emergency. Police and medical aid selection of the best path, vehicle navigation, etc. are all examples of GIS network analysis applications.

Distributed Geographic Information Application

With the network and Internet technology development, running on the Intranet or Internet environments GIS application types, the objective is to achieve a distributed geographic information storage and information sharing, and remote space navigation.

3. 7.3 Types of GIS applications

The second part of the chapter gives an overview of typical GIS applications by their native role in the IT environment. We will start with the most simple inventory systems and go through step-by-step to the advanced monitoring, decision support planning and modeling systems. The applications have fuzzy boundaries, there are many overlaps and there is a trend also moving from simple to more complex systems.

3.1. 7.3.1 Processes and tasks

General purpose GISs essentially perform six processes or tasks[2].

- Input

- Data Manipulation

- Data Management

- Query

- Spatial Analysis

- Visualization

Input

Before geographic data can be used in a GIS it must be converted into a suitable digital format. The process of converting data from analogue paper maps into computer files is called digitizing. Modern GIS technology has the capability to automate this process fully for large projects; smaller jobs may require some manual digitizing.

Today many types of spatial data already exist in GIS-compatible formats. These data can be obtained from data suppliers and loaded directly into a GIS.

Manipulation

It is likely that data types required for a particular GIS project will need to be transformed or manipulated in some way to make them compatible with your system. For example, spatial information is available at different scales (street centerline files might be available at a scale of 1:100,000; postal codes at 1:10,000; and census boundaries at 1:50,000). Before these can be overlaid and integrated they must be transformed to the same scale. This could be a temporary transformation for display purposes or a permanent one required for analysis. There are many other examples of data manipulation that are routinely performed in GIS. These include projection changes, data aggregation (for example, to convert sales territories for census building blocks), and generalization (weeding out unnecessary data).

Management

For small GIS projects it may be sufficient to store spatial information as computer files. There comes a point, however, when data volumes become large and the number of users of the data becomes more than a few, that it is best to use a database management system (DBMS) to help store, organize, and manage data. A DBMS is nothing more than computer software to manage a database–an integrated collection of data.

There are many different designs of DBMS, but in GIS the relational design has found most favor. In the relational design, data are stored conceptually as a collection of tables. Common fields in different tables are used to link them together. This surprisingly simple design has been so widely used mainly because of its flexibility and very wide deployment in applications both within and without GIS.

Query

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[2] http://www.rst2.edu/ties/gentools/gis_task.html

Once you have a functioning GIS containing your spatial information, you can begin to ask questions such as:

• Where are all the sites suitable for building new houses?

• What is the dominant soil type for oak forest?

• If I build a new highway here how will traffic be affected?

Both simple and sophisticated queries utilizing more than one data layer can provide timely information to analysts and managers alike.

Analysis

GIS systems really come into their own when they are used to analyze spatial data. The processes of spatial analysis (often called spatial analysis or geoprocessing) uses the geographic properties of features to look for patterns and trends, and to undertake "what if" scenarios. Modern GISs have many powerful analytical tools, but two are especially important.

Proximity Analysis

GISs are often used to answer such questions as

• What is the total number of customers within 10 km of this store?

• What proportion of the different land use categories within 5000 m of the stream?

To answer such questions, GIS technology uses a process called buffering to determine the proximity relationship between features.

Overlay Analysis

The integration of different data layers involves a process called overlay. At its simplest, this could be a visual operation, but analytical operations require one or more data layers to be joined physically. This overlay, or spatial join, can integrate data on soils, slope, and vegetation, or land ownership with tax assessment.

Visualization

For many types of spatial operation the end result is best visualized as a map or graph. Maps are very efficient at storing and communicating spatial information. While cartographers have created maps for millennia, GIS provides new and exciting tools to extend the art and science of cartography.

3.2. 7.3.2 Inventory systems

The inventory systems focus on data input, data management, data maintenance, simple query and visualization tools. These types of systems have week spatial analysis functions.

In the following four typical examples will be presented.

For the registration of the ownership of real estate property, the assessment of land use in many countries land registry systems are used. This system forms the basis of the other land parcel-based system in the new information society (e.g. local governments, or utility companies). It is the core element of the spatial data infrastructure.

Fig.7.3. TAKARNET is connecting land offices in Hungary (Source: www.takarnet.hu)

Another example could be the register of monuments, cultural heritages. In the database we can store an easily accessible way not only the maps, but the images of the monuments, facades, drawings and orthophotos.

The online NC OneMap GIS Inventory[3], launched in 2006, aims to attract more government participation. As a component of the NC OneMap Program, the statewide inventory seeks to include all 100 North Carolina counties and every municipality that creates GIS data for their jurisdiction. The NC OneMap GIS Inventory offers an online catalog of GIS data produced by government agencies (and others) as well as a Who's Who in GIS in our state. The inventory can be updated at any time.

The NSGIC Inventory[4] is produced by the National States Geographic Information Council (NSGIC) as a tool for states and their partners. Its primary purpose is to track data availability and the status of geographic information system implementation in state and local governments to aid the planning and building of Spatial Data Infrastructures. The Random access metadata for online nationwide assessments (Ramona) database is a critical component of the GIS Inventory.
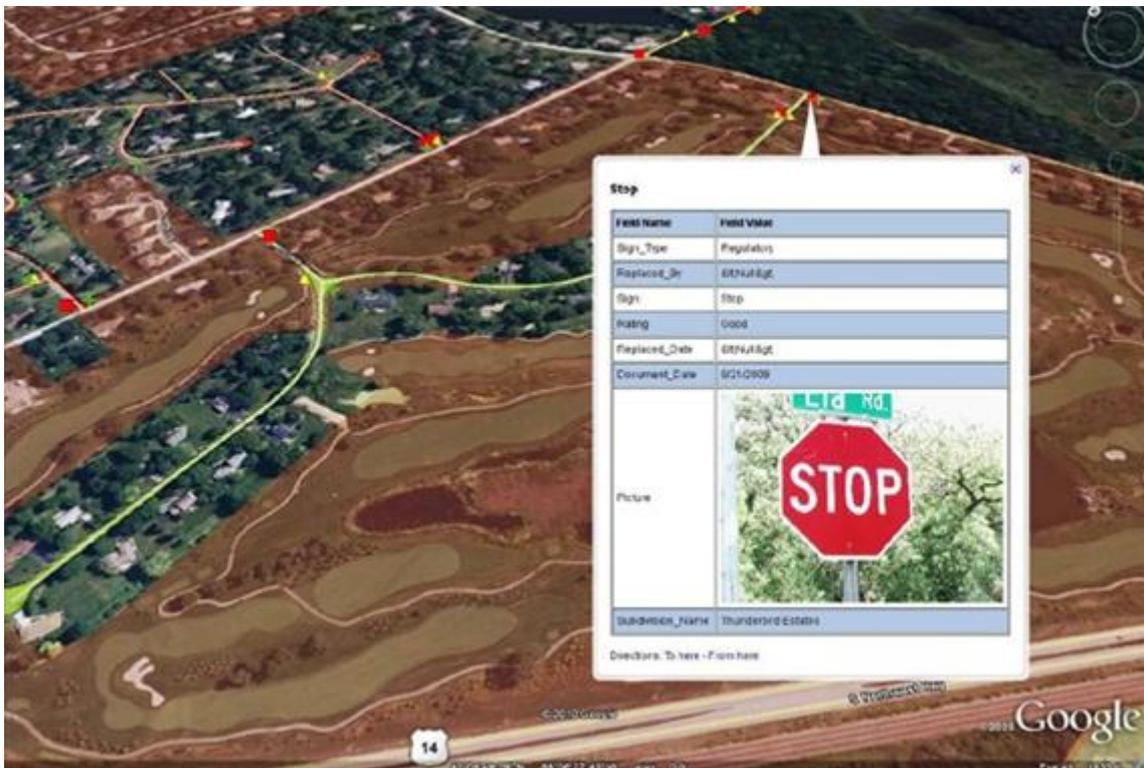

Fig.7.4. Inventory of roadway signage (Source: Regalus)

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[3] Source: http://www.nconemap.com/Default.aspx?tabid=288
[4] Source: http://www.gisinventory.net/

Palatine Township Road District (PTRD) used GIS inventory services to implement a GIS infrastructure in order to meet Federal mandates, PTRD not only implemented a maintenance and inventory program for their roadway signage, but also added documentation for other infrastructure assets such as pavement and storm sewers. The field data collected included photos of roadway signage and critical pavement areas along with storm sewer size, type and location. Once field data was compiled along with office data, a complete infrastructure database was created. Based on this, they were able to take advantage of current aerial imagery and view pertinent information within the Google Earth environment.

3.3. 7.3.3 Query systems

Spatial querying and selection is the ability to find spatial features based on spatial or non-spatial properties using certain rules. A query system enables query construction with a query builder and displays results in a configurable window, and gives a set of classes and interfaces for making extensible queries and rendering results.

The query systems are based on an existing database, focus on advanced search, queries and visualization tools. These types of systems usually have week spatial analysis functions.

You can measure the coordinates of the objects on the screen, measure the distance between the objects or determine the area covered by a set of objects.

In general SQL (Structured Query Language) is used for discovery of the contents of the database. You can use this to select a set of data. For example, may be selected and listed the land owners in a specific area with the parcels larger than 1000 sqm. In the selection mathematical and statistical operations could be carried out. You can calculate the sum of the total area or display the area distribution. The results can be visualized as text or graphically.

A GIS user can also query features based on their location in relation to other ones-what is near what, how many are in that one, how close is this to that, and so on. For example, which towns have natural parks within their borders?

The following figure is an example of a water supply GIS query for Chitraban in Pune (India). You can click on the image to see an enlarged view. You can see the primary water supply for each household in the slum, which houses have their own connection.
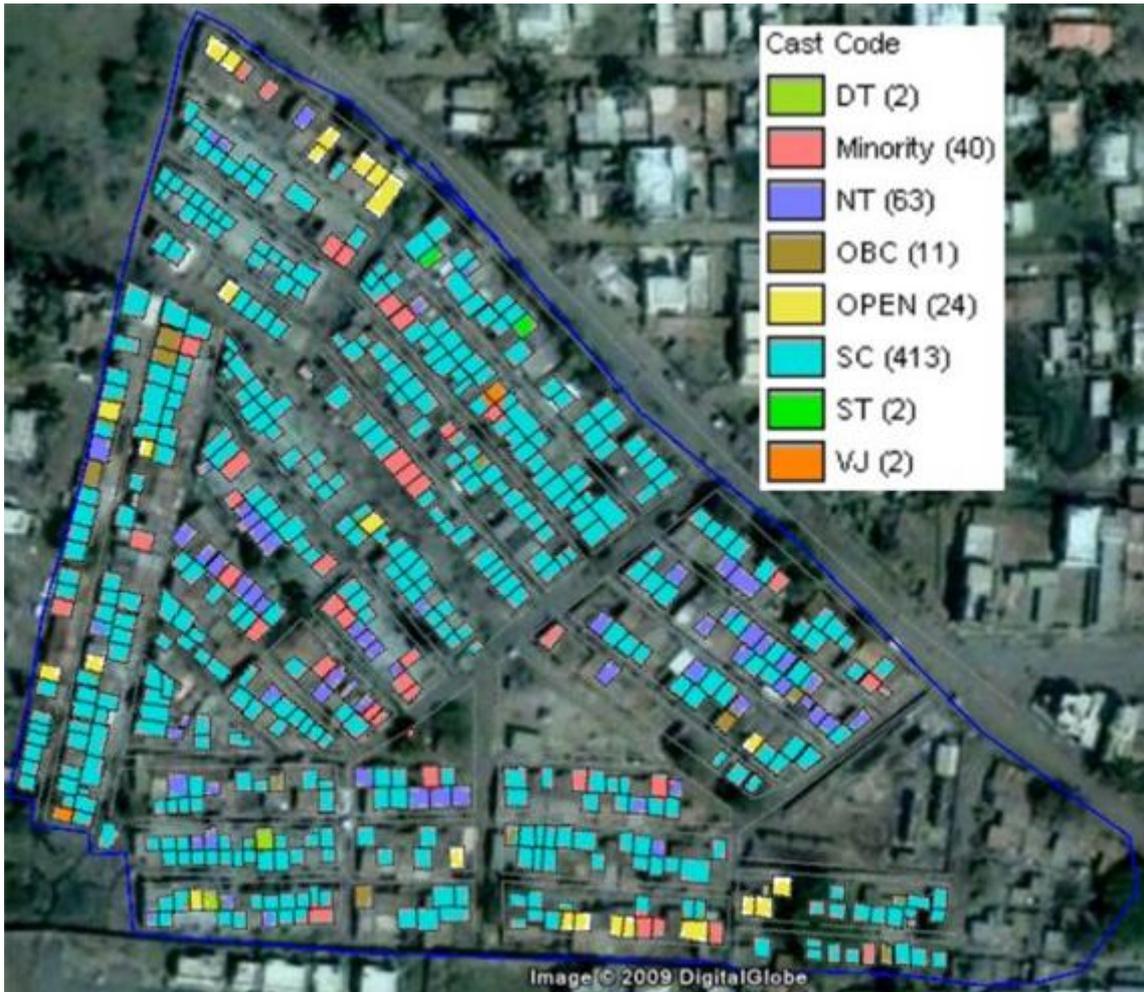
Fig.7.5. GIS query system for Chitraban in Pune (India).

3.4. 7.3.4 Analysis system

The analysis systems focus on sophisticated query, advanced analysis and visualization tools. The analysis system is based on the primary database; it is an active information production process. While in the query systems the information is depending on the human interpretation, here the GIS produce directly „machine readable" information.

Using the analysis software you can understand the geographic context of your data, allowing you to see relationships and identify patterns in new ways. The software helps organizations make better decisions and solve problems faster.

With the analysis software you can build new geographic data sets quickly and easily; create publication-quality maps; manage your file, database, and Internet data resources; customize the user interface around the tasks that you need to accomplish.

With spatial analysis systems, you can

• find suitable locations,

• calculate the accumulated cost of traveling from one point to another,

• perform land-use analysis,

• predict fire risk,

• analyze transportation corridors,

- determine pollution levels,

- perform crop yield analysis,

- determine erosion potential,

- perform demographic analysis,

- conduct risk assessments,

- model and visualize crime patterns.

Modern spatial analysis focuses on computer based techniques because of the large amount of data, the power of modern statistical and geographic information science software, and the complexity of the computational modeling. Spatial analytic techniques have been developed in geography, biology, epidemiology, sociology, demography, statistics, geoinformatics, computer science, mathematics, and scientific modeling.

3.5. 7.3.5 Spatial decision support systems

In the last decades Spatial Decision Support Systems (SDSS) developed in parallel with the concept of Decision Support Systems (DSS). An SDSS is an interactive, computer-based system designed to support a user or group of users in achieving a higher efficiency of decision making while solving a semi-structured spatial problem.

SDSS is designed for example to assist the spatial planner with guidance in making land use decisions, when deciding where to build a new airport many contrasting criteria, such as noise pollution vs. employment prospects or the knock on effect on transportation links, which make the decision problematic. A SDSS which models decisions could be used to help identify the most effective decision path.

A spatial decision support system typically consists of the integration GIS+DSS components. In more detail that means:

- A database management system - This system holds and handles also the spatial data.

- Potential decision models that can be used to forecast the possible outcomes of decisions.

- An interface to aid the user's interaction with the computer system and to assist in analysis of outcomes.
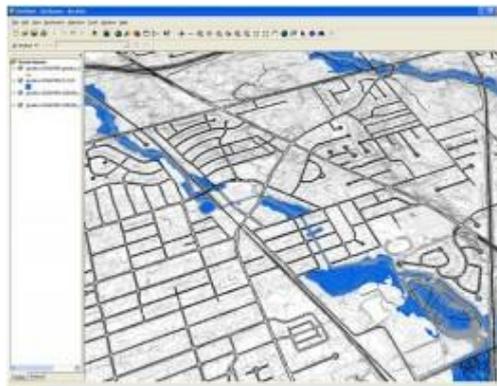

Fig.7.6. SDSS in flooding (Source: ESRI)

3.6. 7.3.6 Modeling systems

The objects, events or processes could be modeled by this type of systems. As a result of the simulation or modeling a spatial object, we get closer to the understanding of the substance of the phenomenon; you will be able to answer regarding „What if...?" questions. The modeling system has the ability to operate a well defined model on the selected geographical area, able to predict the effects. By analyzing differences between the model and the reality we are able to refine the model. Assuming a geographical event, the system is able to examine how changes, damage occur in the environment.

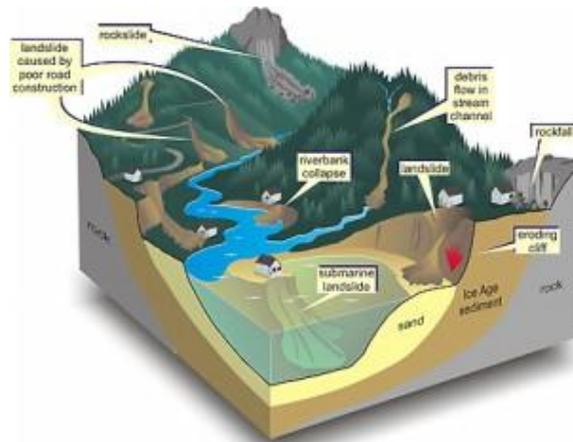The following figure illustrates a complex modeling problems of nature.

Fig.7.7. Complex modelling of natural processes (Source:
http://www.satimagingcorp.com/svc/natural_hazards.html)

3.7. 7.3.7 Monitoring systems

In the monitoring system samples taken at intervals in the course of a natural or artificial processes for spatial analysis. The monitoring system reveals the trends in time; this helps the user, that decisions taken in time, for example, the environmental monitoring system.

Fig.7.8. Gulf of Mexico oil spill monitoring (Source: http://www.enterprise-dashboard.com/2009/06/26/gis-dashboards/)

4. 7.4 GIS software

GIS software encompasses a broad range of applications, all of which involve the use of some combination of digital maps and georeferenced data. GIS software can be sorted into different categories. This chapter is dealing with two notable GIS software packages, namely ArcGIS and Idrisi.

4.1. 7.4.1 GIS software categories

As far as it was mentioned earlier in this module, before any spatial analysis can take place the data need to be derived from field work, maps or satellite imagery, or acquired from data providers. Hence, data need to be created and - in case something has changed - edited, and then stored. If data are obtained from other sources

they need to be viewed and eventually integrated (conflation) with existing data. To answer particular questions the data are queried and analyzed. However, some specific analysis tasks may require a data transformation and manipulation before any analysis can take place. The query and analysis results can finally be displayed on a map.

Different types of GIS software exist with different functionality, as not every GIS user needs to carry out all of the above tasks. The main software categories are as follows

• Desktop GIS usually serve all GIS tasks and are sometimes classified into three functionality categories: GIS Viewer, GIS Editor, and GIS Analyst.

• Mobile GIS are mainly used for field data collection.

• Spatial Database Management Systems (DBMS) are mainly used to store the data, but often also provide (limited) analysis and data manipulation functionality.

• WebMap Servers are used to distribute maps and data over the internet1. Similarly, WebGIS Clients are used for data display and to access analysis and query functionality from Server GIS over the internet or intranet.

• Libraries and Extensions provide additional (analysis) functionality that is not part of the basic GIS software, for instance functions for network and terrain analysis, or functions to read specific data formats.

4.2. 7.4.2 ArcGIS

ArcGIS is a system that lets you easily author data, maps, globes, and models on the desktop and serve them out for use on a desktop, in a browser, or in the field via mobile devices, depending on the needs of your organization. If you are a developer, ArcGIS gives you tools for building your own applications. The source of the following introduction is http://www.esri.com/products/index.html.

4.2.1. 7.4.2.1 ArcGIS Desktop
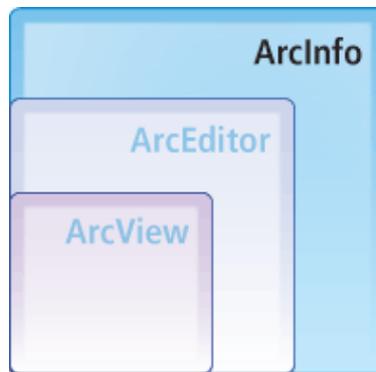
Fig.7.9. ArcGIS Desktop

ArcView is geographic information system software for visualizing, managing, creating, and analyzing geographic data. Using ArcView, you can understand the geographic context of your data, allowing you to see relationships and identify patterns in new ways.

With ArcView, you can

• Author maps and interact with your data by generating reports and charts and printing and embedding your maps in other documents and applications.

• Save time using map templates to create consistent style in your maps.

• Build process models, scripts, and workflows to visualize and analyze your data.

• Read, import, and manage more than 70 different data types and formats including demographics, facilities, CAD drawings, imagery, Web services, multimedia, and metadata.

- Communicate more efficiently by printing, publishing, and sharing your GIS data and dynamic content with others.

- Use tools such as Find, Identify, Measure, and Hyperlink to discover information not available when working with static paper maps.

- Make better decisions and solve problems faster.

ArcEditor is a powerful GIS desktop system for editing and managing geographic data. It includes all the functionality of ArcView along with additional advanced editing tools to ensure the quality of your data. ArcEditor supports single-user and multiuser editing, allowing you to disconnect from the database and edit in the field.

With ArcEditor, you can

- Allow multiple users to simultaneously modify and edit data.

- Build and maintain spatial relationships between features using topology rules and a process called validation.

- Support multiple workflows, manage work order processing, and implement QA procedures for validating edits.

- Monitor the database over time and evaluate what-if scenarios.

- Perform raster-to-vector conversion and create data from scanned maps.

ArcInfo is the most complete desktop GIS. It includes all the functionality of ArcEditor and ArcView and adds advanced spatial analysis, extensive data manipulation, and high-end cartography tools. Organizations use the power of ArcInfo every day to create, edit, and analyze their data in order to make better decisions, faster. ArcInfo is the de facto standard for GIS.

With ArcInfo, you can

- Perform advanced GIS data analysis and modeling.

- Take advantage of tools designed for overlay analysis, proximity analysis, surface analysis, and raster processing and conversion.

- Publish and convert data in many formats.

- Create and manage personal geodatabases, multiuser geodatabases, and feature datasets.

- Use high-end cartography tools to generate professional-quality, publication-ready maps.

- Design customized symbols and place sophisticated annotation and labels on your maps.

Extension products let you add more capabilities to ArcGIS Desktop. These specialized tools allow you to perform extended tasks such as raster geoprocessing, three-dimensional analysis, and map publishing. Some extensions are listed below

- ArcGIS 3D Analyst analyzes data in a realistic perspective.

- ArcGIS Geostatistical Analyst has advanced statistical tools to investigate data.

- ArcGIS Network Analyst performs sophisticated routing, closest facility, and service area analysis.

- ArcGIS Schematics represents and helps to understand networks to shorten decision cycles.

- ArcGIS Spatial Analyst derives answers from data using advanced spatial analysis.

- ArcGIS Tracking Analyst reveals and analyzes time-based patterns and trends.

ArcReader is a free, easy-to-use desktop mapping application that allows users to view, explore, and print maps and globes. Anyone with ArcReader can view high-quality interactive maps authored by a high-level ArcGIS Desktop product and published with the ArcGIS Publisher extension.

With ArcReader, you can

• View, navigate, and print published ArcGIS maps using ArcReader (.pmf files).

• Deploy your GIS data to novices and professionals alike.

• Zoom, pan, and switch between map and page layout views.

• Communicate more efficiently with the ability to graphically mark up maps.

• Print published map and globe documents including all layer symbology and cartographic map elements on any supported printer.

• Create custom ArcReader applications and embed ArcReader capabilities into existing applications.

4.2.2. 7.4.2.2 ArcGIS server

ArcGIS Server software gives the ability to create, manage, and distribute GIS services over the Web to support desktop, mobile and Web mapping applications. It simplifies access to GIS services for GIS professionals, mobile workers, as well as knowledge workers without any GIS experience. With ArcGIS Server, the users stay in control of your content through centralized management of spatial data, including imagery.

In addition, ArcGIS Server provides users with a scalable GIS server platform that can be deployed on a single machine to support small workgroups, or it can distributed across multiple servers for supporting enterprise applications. You can also deploy ArcGIS Server on Cloud infrastructure.

4.2.3. 7.4.2.3 ArcPad

ArcPad is mobile field mapping and data collection software designed for GIS professionals. It includes advanced GIS and GPS capabilities for capturing, editing, and displaying geographic information quickly and efficiently. Critical data can be checked in and out of a multi-user or personal geodatabase and shared across the organization. ArcPad is part of an enterprise GIS solution and integrates directly with ArcGIS Desktop and ArcGIS Server.

Fig.7.10. Collecting utility data using ArcPad (Source: ESRI, Trimble)

4.3. 7.4.3 IDRISI

IDRISI software is developed by Clark Labs (Clark University, Worcester, USA) (www.clarklabs.org).

The IDRISI software includes a comprehensive suite of image processing tools, making it an excellent choice for land cover mapping applications with remotely-sensed data. Tools are provided for image restoration, enhancement, classification and transformation. Special techniques are included for soft classification and hyperspectral image analysis. IDRISI also provides a host of machine learning tools. With the Taiga Edition, segment-based classification has been added.

Types of analysis available with IDRISI:

• Inventory and baseline land resource

• mapping

• Land change and time series analysis

• Agricultural monitoring

• Natural resource monitoring

• Satellite image processing

• Error assessment and uncertainty

4.3.1. 7.4.3.1 GIS Analysis

At the very heart of GIS is the ability to perform analyses based on geographic location. IDRISI provides a range of powerful tools for the exploration of our rapidly changing world--traditional tools for the day-to-day needs of the GIS professional as well as advanced procedures for complex analysis.

For the most fundamental of GIS operations, database query, IDRISI supports the ability to query features in map layers and also provides a wide range of tools for analyzing a spatial database of raster and vector data. For raster data, facilities exist to query irregular subregions of images and report basic statistics as well as profiles over space and time, histograms, and tabulations of area and perimeter. Queries can also be constructed as relational statements using the basic overlay and reclassification routines provided. For vector databases, an integrated relational database management tool called Database Workshop can be used to enter attribute data, calculate new field values as a function of existing fields, and construct database queries. Database Workshop allows for the full integration and linking of vector data with ancillary tabular database files employing full SQL capabilities.

Derivative mapping is one of the most dramatic features of a GIS, the ability to construct new data layers as a function of existing layers (such as developing a map of soil erosion as a mathematical function of layers indicating slope, rainfall intensity, soil K factor, etc.). IDRISI provides a full suite of mathematical and relational modeling tools for this activity, allowing models to be entered as equations, with map layers as variables.

With respect to distance and geographic context, important factors in the analysis of interactions over space, IDRISI provides an especially rich set of operations, including Euclidian and cost distance functions (the latter incorporating the concept of frictions), procedures for the aggregation and disaggregation of directional forces and frictions, a least-cost path procedure, and spatial allocation routines. IDRISI also includes facilities for the analysis of patterns and textures in the local vicinity of features, and the analysis of local context through filtering and aggregation of contiguous groups.

Further, an entire suite of tools exists for employing statistics, primarily aimed at the description of spatial characteristics. These include point distribution measures, simple and multiple image regression, logistical and multinomial logistical regression, autocorrelation procedures, pattern and texture measures, polynomial trend surface analysis and spatial sampling, and random generation procedures for support of Monte Carlo Simulation.

4.3.2. 7.4.3.2 Image Processing

Of major significance are the tools that IDRISI provides for the processing of remotely-sensed images. IDRISI accommodates all major imagery formats, including satellite-borne multispectral imagery and hyperspectral data.

IDRISI includes restoration procedures that allow for both the radiometric and geometric correction of images, permitting the integration of high quality images with other georeferenced data. Tools are also provided for atmospheric correction, destriping and mosaicing. Image enhancement techniques in IDRISI include contrast adjustment, panchromatic merging, noise removal (using both convolutional filters and Fourier analysis) and various filtering operations (such as edge enhancement).

An extensive set of transformation procedures is provided, including Principal Components analysis, Canonical Components analysis, color space transformations and procedures for the calculation of vegetation indices.

For image classification, the IDRISI software is unsurpassed, offering the widest range of classifiers in the industry. IDRISI includes unsupervised classifiers which employ clustering techniques to find characteristic land cover reflectance patterns, as well as supervised classifiers, which use examples of land cover types provided by the analyst to search for statistically similar characteristics in the imagery.

IDRISI provides the traditional hard classifiers as well as innovative soft classifiers. Where hard classifiers identify the most likely land cover class using procedures such as a Bayesian Maximum Likelihood evaluation of evidence, soft classifiers expose the inherent uncertainties in the classification process. The reasons for this vary but include the determination of proportions of various land covers in mixed pixels. These are often called fuzzy classification techniques but in IDRISI, they incorporate mathematical bases in Bayesian and Dempster-Shafer weight-of evidence procedures as well as Fuzzy Sets.

Recent classifiers in the IDRISI tool set are geared towards advanced exploration and include Machine Learning, Neural Network and Classification Tree analyses. Specifically provided are the Multi-Layer Perceptron, Kohenon's Self-Organizing Feature Map, and Fuzzy ARTMAP neural network classifiers; Classification Tree Analysis; K-Means; and k-Nearest Neighbor.

IDRISI also includes a suite of tools to support segment-based classification. Segmentation is a process by which pixels are grouped into segments that share a homogenous spectral similarity. Segment-based classification is an approach that classifies a remotely-sensed image based on these image segments.

4.3.3. 7.4.3.3 Surface Analysis

A distinctive component of IDRISI is its wide range of surface analysis tools. These tools support the manipulation of imagery over continuous space to identify patterns, trends, and topological features.

IDRISI provides a variety of surface generation, interpolation and analysis routines. Given a developed digital elevation model, surface characteristics such as slope gradient, aspect (slope orientation), illumination (hill shading), and curvature can easily be calculated. Interpolation procedures include inverse distance weighting, triangulated irregular network (TIN) modeling, Thiessen polygons, trend surface mapping and geostatistics.

IDRISI also allows you to delineate watersheds and viewsheds (areas visible from one or more designated sites on a surface), determine surface runoff and flow patterns, evaluate sedimentation and model soil erosion. Traditional distance and buffer analysis tools include cost distance and pathway analyses. Surface analysis modeling tools are provided for random image generation, image sampling, and image filtering.

Change and Time Series Analysis

Change and Time Series analysis identifies and quantifies change and its impacts. IDRISI includes an extensive set of tools for measuring change at both the local and global scales, including tools for pairwise image comparison, multiple image comparison, and predictive modeling and assessment.

IDRISI's distinctive image comparison tools include image differencing, image rationing, regression differencing, change vector analysis, and qualitative data analysis. Multiple image comparison techniques look at trends and anomalies across multiple images (time series) and include tools for time series analysis using Principal Components analysis, time series Fourier analysis, spatial/temporal correlation and image profiling over time.

A suite of tools is also provided for predictive land cover change modeling as well as the assessment of those predictions, utilizing knowledge of past changes. These tools include Markov Chain Analysis, Cellular Automata, logistical regression and multinomial logistical regression, GEOMOD, and Artificial Neural Networks.

IDRISI includes two vertical applications for the analysis of change and time series as well. The Land Change Modeler provides tools for the assessment of land cover change, the identification of driving forces of change, and the use of that information to predict future scenarios. The Earth Trends Modeler provides tools for the observation, exploration and analysis of image time series data and is particularly relevant for climate change work.

4.3.4. 7.4.3.4 Modeling

IDRISI's modeling tools unleash the power of raster analysis by allowing users to easily develop their own models through existing functionality or to create their own tools and procedures to work within the IDRISI environment.

The Image Calculator, an interactive mathematical modeling tool, provides a simple calculator-like interface for constructing algebraic and logical formulas with map layers as variables. The Macro Modeler, another graphical modeling tool, exposes all of IDRISI's GIS modules as objects that can be linked, dynamically and with feedbacks, with map layers in an algorithmic chain.

For the most demanding of algorithmic modeling applications, or for the development of stand-alone modules as add-ons to IDRISI, a scripting language such as Python or a full programming language such as C++, Delphi or Visual Basic can be used to access IDRISI through the industry-standard COM object model interface.

IDRISI also includes two vertical applications for modeling. The Earth Trends Modeler provides a coordinated suite of data mining tools for the extraction of trends and underlying determinants of variability from image time series data. The Land Change Modeler provides a range of tools for modeling land cover change and its impacts on biodiversity.

4.3.5. 7.4.3.5 Decision Support and Uncertainty Management

IDRISI is widely known for the character of its decision support tools for effective resource allocation, including cutting-edge techniques for multi-criteria evaluation, multi-objective land allocation modeling, and suitability mapping. IDRISI also provides a consensus-seeking procedure for weighting criteria, fuzzy standardization, and an extensive set of criteria aggregation procedures based on Weighted Linear Combination and Ordered Weighted Averaging.

IDRISI consists of the most extensive set of tools for uncertainty management in the industry. These include error propagation through Monte Carlo Simulation, the evaluation of decision risk as a result of propagated error, calculation and aggregation of Fuzzy Sets, and the aggregation of indirect evidence to support a weight-of-evidence conclusion using both Bayesian and Dempster-Shafer approaches. IDRISI includes a soft reclassification procedure that allows one to map the probability of a location being above or below a threshold (such as sea level rise) as well as an implementation of spatial prior probabilities for Maximum Likelihood classification.

5. 7.5 Summary

In this module our aim was to synthesize the lessons learned in the previous modules, to classify the applications, and to prove the flexibility and the multiple uses of GIS.

After learning of the module you are be able to:

• explain the typical applications of GIS,

• describe the GIS software functionality,

• discuss the links between the applications,

• give orientation for the selection of a GIS software.

Review questions

1. Give an overview of the typical GIS application areas.

2. Explain the characteristics of the inventory systems.

3. Introduce the typical applications and benefits of the query systems.

4. Give explanation of the analysis systems.

5. Introduce the spatial decision support systems?

6. Give an overview of modeling GIS applications.

7. What is the essence of the monitoring GIS applications?

8. Introduce ArcGIS software family.

9. Introduce Idrisi software package.

Bibliography:

Márkus B.: *Térinformatika II.,* NyME GEO jegyzet, Székesfehérvár, 2009

Websites of GIS companies