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Geographical Information Systems

Spatial Reasoning & Geomatics Engineering

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Preface

"Truth lies within a little and certain compass,
but error is immense"
St. John, Henry, Viscount Bolingbroke (1678-1751),
The Columbia Encyclopedia, 6th ed., 2001

A geographical information system (GIS) is a computer-based information system that enables capturing, modeling, manipulation, retrieval, analysis and presentation of geographically referenced data.

The study of GIS has emerged in the last decade as an exciting multi-disciplinary subject, spanning such areas as topography & cartography, computing (computer graphics, databases), geography, photogrammetry, image processing and the environmental sciences. In particularly, the last few years have been a proliferation of GIS, employed by a wide range of users.

The growing interest in GIS reflects the fact that so much of information needed for management and decision making in government, local authorities and commerce is spatially referenced, yet conventional information technology (database systems) developed for commercial purposes is poorly suited to answering apparently simple queries framed in *space* and in *time*.

The treatment in this text book is unashamedly biased towards the computational aspects of GIS. Within information technology and computing science, GIS is a special interest of fields such as computer graphics, databases, geometric transformations, digital mapping, systems engineering and computational geometry, being not only a challenging application area but also providing open research issues for these disciplines.

The emphasis here is on understanding principles and techniques for representing, processing and visualizing spatial data in GIS application environments. The book provides a brief summary of applications of GIS and describes many of the techniques for data analysis, retrieval and graphical display that are to be found in scientific and commercial GIS applications.

This book is mainly intended for readers and students on undergraduate and master-level programmes - from computing or geomatics engineering background - who wish to learn about the issues that GIS engenders for information technology. It should also however be of considerable value to professionals using and implementing GIS in government, local authorities, industry and commerce.

Regarding the use of this text in teaching, coverage of all material presented here would be expected to extend over at least two academic semesters. It is anticipated that for teaching purposes the book will be used in combination with practical classes which provide experience of using a GIS environment (software package) to apply the methods described here. Practical exercises are also provided within the NCGIA Core Curriculum in GIS (www.NCGIA.org).

Βασικός στόχος του βιβλίου είναι η ανάπτυξη ικανοτήτων των φοιτητών έτσι ώστε να είναι σε θέση –αργότερα στον επαγγελματικό τους βίο– να κωδικοποιούν, σε ενιαίο λογισμικό περιβάλλον, τη **Γεωμετρία** (*Θέσεις* και *Τοπολογία*), τα **Θέματα** (*Χαρακτηριστικά* και *Ιδιότητες*) και το **Χρόνο** (*Διαχρονικές Μεταβολές*).

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Several research centers have assisted by providing visiting research scholarship to the author. In particular thanks are due to: The National Center for Geographic Information and Analysis (NCGIA at Santa Barbara, CA) and The University of Melbourne: Dept. of Geomatics and Center of GIS & Modelling (VIC, Australia).

Finally, many thanks are also due to the Ziti Editions production group people for their patient and professionalism.

Copyright Notes

Dr. Athanassios D. Styliadis

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Part **A**

Geographical Information Science Overview & Fundamentals

Chapter 1

Overview of GIS

"The first Law of Geography: Everything is related to evetything else, but near things are more related than distant things"

Prof. Emeritus Waldo Tobler (1930 - ...)
Univ. of California / Geography, Santa Barbara

1.1 Introduction

Geographic Information System (GIS) is a computer based information system used to represent digitally and analyse the geographic features present on the Earth' surface and the events (non-spatial attributes linked to the geography under study) that taking place on it. The meaning to *represent digitally* is to convert analog (smooth line) into a digital form (line segment).

"Every object present on the Earth can be geo-referenced", is the fundamental key of associating any database to GIS. Here, term 'database' is a collection of information about things and their relationship to each other, and 'geo-referencing' refers to the location of a *layer* or *coverage* in space defined by the co-ordinate referencing system.

Work on GIS began in late 1950s, but first GIS software came only in late 1970s from the lab of the ESRI. Canada was the pioneer in the development of GIS as a result of innovations dating back to early 1960s. Much of the credit for the early development of GIS goes to Roger Tomilson. Evolution of GIS has transformed and revolutionized the ways in which planners, engineers, managers etc. conduct the database management and analysis.

Some Interesting Links:

1. **Geographical Information Systems**
   http://www.usgs.gov/research/gis/title.html
   An Introduction to GIS by U.S Geological Survey
2. **An Introduction to GIS with Idrisi for Windows 2000**
   http://vulture.geog.ubc.ca/tutorials/idrisi/#_Toc408753068
3. **What is GIS?**
   http://www.geog.ubc.ca/courses/klink/gis.notes/ncgia/u01.html
   A complete compilation of information on GIS

4. **GIS guide to Good Practice**
   http://ads.ahds.ac.uk/project/goodguides/gis/sect21.html
   A brief introduction to GIS and Archaeology
5. **Geographical Information Systems**
   http://www.utexas.edu/depts/grg/gcraft/notes/intro/intro.htm#Appli
   Geographical Information Systems as an Integrating Technology : Context, Concepts and Definitions
6. **Introduction to GIS**
   http://www.du.edu/~shick/geog2250/notes/INTROGIS.HTM
   A list of Introduction to GIS, relevant technologies, capabilities, applications of GIS, etc
7. **Introduction to GIS**
   http://www.gisrg.com/introgis.htm
   An Introduction to GIS using Maps
8. **An Introduction to GIS in Real Estate**
   http://www.castleconsulting.com/95anintr.html
   Gil Castle's final draft of the real estate column appearing in Real Estate Issues, August 1995
9. **An Introduction to GIS**
   http://www.kingston.ac.uk/geog/gis/intro.htm
   An Introduction to GIS and Geospatial Data, Overview, Glossary and Acronyms by Kingston Centre for GIS, Kingston University
10. **A Brief Introduction to GIS Technology**
   http://www.inforain.org/applegate/HTML_FIL/GIS.htm
   Enhancing Community Capacity to use Spatial Information

Geographic information comprises of data about the surface, sub-surface, and atmosphere of the earth, its interpretations and explanations applied to those data, and an organizational framework for understanding the information. Commonly, geographic information is considered as that which comes from maps, but the concept embraces any type of information, which may be positioned, on or relative to the earth (Fig. 1.1). It may be acquired through direct measurement, remote sensors, in situ observations; defined through survey or legal description; interpreted from data analysis or simulation.

Geographic information obtains meaning from both spatial and non-spatial aspects of the data, i.e. *"where"* and *"what"*.

The availability of computerized geographic data has led to profound changes in how we use and understand information about the earth. Mapmaking in its traditional form has evolved into systems for enabling user-directed views of selected information. Cartographic principles are essential for the successful automation of geographic information –the concepts of abstraction, classification, delineation, and interpretation is equally applicable to a computerized system. Other mapmaking con-

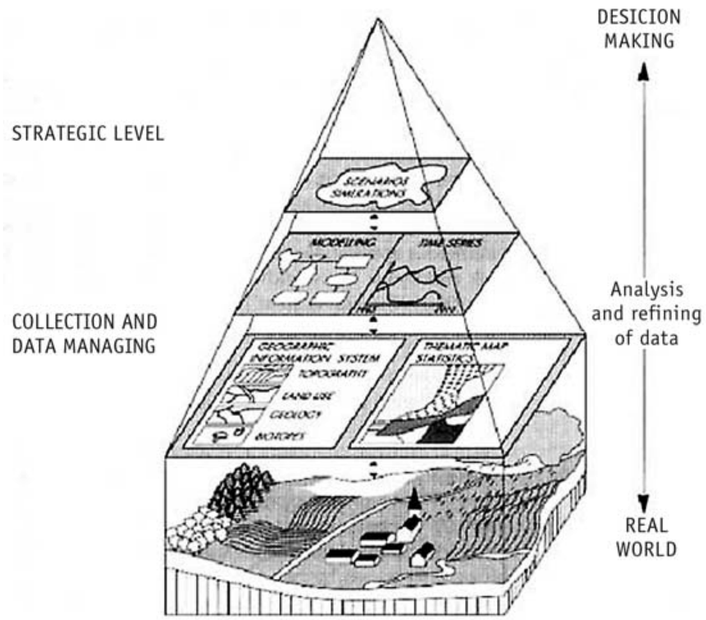


Figure 1.1: *By use of geographic information systems, a "simplified" world can be brought into the computer. GISs are in the process of filling the upper half of the pyramid. Other realms of geographic information have also been transformed*

cepts such as projection and symbology have taken new forms. Although earlier systems for computerizing geographic data focussed on faithful automation of the components of map sheets, such as a geometric shape with a label, newer approaches consider the underlying problem of effectively modeling real-world conditions, such as a bounded area associated with its description. The forthcoming sections of this chapter provide clarity of the entire geographic information System.

What is GIS?

GIS is an acronym for:

∑ Geographic Information Systems (US)
∑ Geographical Information Systems (UK, Australia/New Zealand, Canada)
∑ Geographic Information Science (Academia)

An understanding of what Geographic Information Systems represent may be helped by considering the component parts of the term separately.

Geographic...

This term is used because GIS tend to deal primarily with 'geographic' or 'spatial' features. These objects can be referenced or related to a specific location in space. The objects may be physical, cultural or economic in nature. Features on a map for instance are pictorial representations of spatial objects in the real

world. Symbols, colors and line styles are used to represent the different spatial features on the two-dimensional map.

Computer technology has been able to assist in this mapping process through the development of automated cartography and computer aided design. Computer programs can now accomplish in minutes and hours tasks which previously took days or weeks for cartographers and draughtsmen to complete.

...Information...

This represents the large volumes of data, which are usually handled within a GIS. All real world objects have their own particular set of characteristics or descriptive attributes. This non-spatial alphanumeric data plus locational information needs to be stored and managed for all spatial features of interest.

Conventionally maintained as paper files, computer technology has enabled much more efficient handling and management of information within automated database management systems.

...Systems...

This term is used to represent the systems approach taken by GIS, whereby complex environments are broken down into their component parts for ease of understanding and handling but are considered to form an integrated whole. Computer technology has aided and even necessitated this approach so that most information systems are now computer based.

Computer systems are becoming vital for the storage and manipulation of the increasing volumes of data, the handling of complex spatial algorithms and the integration of data of different scales, projections and formats. All of which are essential to GIS.

Therefore, Geographic Information System (GIS) is a computer based information system used to digitally represent and analyse the geographic features present on the Earth' surface and the events (non-spatial attributes linked to the geography under study) that taking place on it.

A GIS is typically made up of a variety of information systems like Cartographic Display System, Map Digitising System, Database Management System, Geographic Analysis System, Image Processing System, Statistical Analysis System and Decision Support System (Fig. 1.2). In many ways, learning GIS involves learning to think - learning to think about patterns, about space, and about processes that act in space.

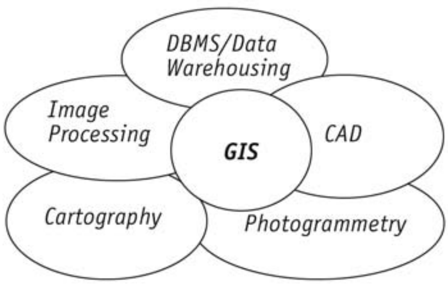


Figure 1.2: *GIS and Related Disciplines*

1.2 Historical Roots: Milestones in GIS

Map Overlays

- Thematic maps developed in the last century
- The roots of GIS can be traced to the development of hand drawn overlays
- Manning 1912 - Overlay interpretation of land data
- Düsseldorf 1912 - time-series change overlays
- Jacquline Tyrwhitt - *"Surveys for Planning"* - first explicit discussion of the overlay technique. Four data maps are combined and analyzed into one map entitled "Land Characteristics".
- Ian McHarg, 1969 - *"Design with Nature"*

Early Computer Developments

- 1958 - 61: University of Washington, Department of Geography, research on advanced statistical methods, rudimentary computer programming, computer cartography
- mid 1960s: Harvard Laboratory for Computer Graphics and Spatial Analysis
  - established to develop general-purpose mapping software
  - had major influence on the development of GIS until early 1980s, still continues at smaller scale
  - software was widely distributed and helped to build the application base for GIS
  - many pioneers of newer GIS "grew up" at the Harvard lab
  - Dana Tomlin, Donna Peuquet, Duane Marble, Hugh Calkins
  - The Harvard packages included SYMAP (1964), SYMVU (late 60s), GRID (late 1960s), ODYSSEY (mid 1970s)
- mid 1960s: Canada Geographic Information System (CGIS)
  - often cited as the first GIS developed under the direction of Roger Tomlinson
  - its purpose was to analyze the data collected by the Canada Land Inventory (CLI) and to produce statistics to be used in developing land management plans for large areas of rural Canada
  - CGIS still highly regarded in late 1970s, early 1980s as centre of technological excellence despite its aging database
  - attempts were made to adapt the system to new data and new functionality (e.g. networking capability), however, this was too late to compete with the new vendor products of 1980s
  - pioneered many key GIS concepts which are still in use today
- late 1960s: U.S. Bureau of the Census
  - need for a comprehensive approach to census geography
  - 1970 was the first geocoded census

  - Dual Independent Map Encoding (DIME) files were the major component of the geocoding approach
  - DIME files were very widely distributed and used as the basis for numerous applications
  - 1969: Environmental Systems Research Institute (ESRI) founded by Jack Dangermond
  - based on ideas developed at Harvard and elsewhere
- early 1980s release of ARC/INFO by ESRI
  - successful implementation of CGIS idea of separate attribute and locational information
  - successful marriage of standard relational database management system (INFO) to handle attribute tables with specialized software to handle objects stored as arcs (ARC)
- late 1970s: MAP - Map Analysis Package developed by Dana Tomlin and Joseph Berry
  - Grid based analytical package
  - led to development of many raster based systems including IDRISI
- 1977 study for Fish and Wildlife Service identified fifty-four operational geographical information systems that could perform more than one task.
- 1980's:
  - Intergraph's CADD and mapping software
  - MOSS Bureau of Land Management (BLM)
  - GRASS Army Corps of Engineers, National Park Service (NPS)
  - SPANS Tydac, Inc. - extensively used by Environment Canada and Parks Canada
- 1990's: GIS/CAD client software
- 2000's: Web GIS, Internet Mapping GIS Solutions (MapObjects, etc.)

1.3 Defining GIS

GIS is an information system designed to work with data referenced by spatial / geographical coordinates. In other words, GIS is both a database system with specific capabilities for spatially referenced data, as well as, a set of operations for working with these data. It may also be considered as a higher order *"smart map"*.

"Every object present on the Earth can be geo-referenced", is the fundamental key of associating any database to GIS. Here, term 'database' is a collection of information about things and their relationship to each other, and 'geo-referencing' refers to the

location of a layer or coverage in space defined by the co-ordinate referencing system.

GIS technology integrates common database operations such as **query** and **statistical analysis** with the unique **visualization** and **geographic analysis** benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies. (ESRI - Fig. 1.3).

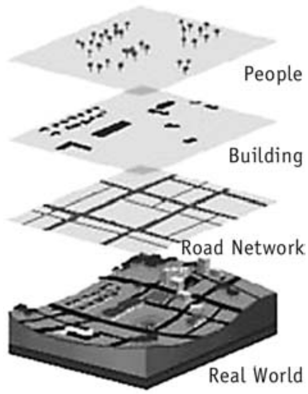


Figure 1.3: *The Real World Consists of Many Geographies which can be represented as a related datalayer.*

A typical GIS can be understood by the help of various definitions given below:

- A geographic information system (GIS) is a computer-based tool for mapping and analyzing things that exist and events that happen on Earth.
- Burrough in 1986 defined GIS as: *"Set of tools for collecting, storing, retrieving at will, transforming and displaying spatial data from the real world for a particular set of purposes"* .
- Arnoff in 1989 defines GIS as: *"a computer based system that provides four sets of capabilities to handle geo-referenced data:*
    1. *data input*
    2. *data management (data storage and retrieval)*
    3. *manipulation and analysis*
    4. *data output".*

Hence GIS is looked upon as a tool to assist in decision-making and management of attributes that needs to be analysed spatially.

Some Interesting Links:

1. **What is GIS?**
   http://www.gis.com/whatisgis/index.html
   Geographical Information Systems Definition by GIS.Com
2. **A revised definition of GIS**
   http://www.wiley.com/college/chrisman/define.html
   For the purpose of Exploring Geographical Information Systems
3. **Geographical Information Systems**
   http://www.usgs.gov/research/gis/title.html
   U.S Geological Survey's definition of Geographical information Systems
4. **GIS**
   http://gis-www.larc.nasa.gov/qat/gisdefinition.html
   Definition of GIS, Potential Links, and Products

5. **Definition of GIS**
   http://www.stile.lboro.ac.uk/~gydrw/STILE/t0050001.html
   David Walker's Resource Information
6. **What is a GIS?**
   http://www.esri.com/library/gis/abtgis/what_gis.html
   Geographical Information Systems as defined by ESRI
7. **Definition of GIS**
   http://faculty.washington.edu/chrisman/G460/NewDef.html
   A revised definition of Geographic Information System given by Chrisman
8. **Definitions of GIS**
   http://members.rediff.com/gisindia/def.htm
   Compiled by Kenneth E. Foote and Margaret Lynch, The Geographer's Craft Project, Department of Geography, University of Texas at Austin.
9. **Geographical Information Systems: Definition**
   http://gisdasc.kgs.ukans.edu/dasc/gis.html
   Definition of Geographical Information Systems by Data Access and Support Center, State of Kansas
10. **GIS - A Definition**
    http://www.esricanada.com/k-12/gis/definition.html
    ESRI Canada definition of GIS
11. **Definition of GIS: The Manager's Perspective**
    http://www.geom.unimelb.edu.au/research/publications/IPW/DGISMP.htm
    Paper presented at the International Workshop on Dynamic and Multi-Dimensional GIS held at Hong Kong, 25-26th August 1997
12. **What is a GIS?**
    http://www.nww.usace.army.mil/html/gis/definition.htm
    U.S Army Corps of Engineers definition of Geographical Information Systems
13. **GIS: Definition**
    http://www.nwgis.com/gisdefn.htm
    Definition of GIS by the Northwest GIS Services Inc.

1.4 GIS Philosophy

The proliferation of GIS is explained by its unique ability to assimilate data from widely divergent sources, to analyse trends over time, and to spatially evaluate impacts caused by development.

For an experienced analyst, GIS is an extension one's own analytical thinking. The system has no in-built solutions for any spatial problems; it depends upon the analyst.

The importance of different factors of GIS in decreasing order is as under:

- Spatial Analysis
- Database
- Software
- Hardware

GIS involves complete understanding about patterns, space, and processes or methodology needed to approach a problem. It is a tool acting as a means to attain certain objective quickly and efficiently. Its applicability is realized when the user fully understands the overall spatial concept under which a particular GIS is established and analyses his specific application in the light of those established parameters.

Before the GIS implementation is considered the objectives, both immediate and long term, have to be considered. Since the effectiveness and efficiency (i.e. benefit against cost) of the GIS will depend largely on the quality of initial field data captured, organizational design has to be decided upon to maintain this data continuously. This initial data capture is most important.

Some Interesting Links:

- **Philosophy of GIS**
  http://www.unigis.org/resources/Abstracts96.htm
  Msc Abstracts, 1996 UNIGIS U.K
- **Philosophy of GIS**
  http://www.ngdc.noaa.gov/seg/eco/gedb/html/task.htm
  An article by NOAA National Data Centers, NGDCA
- **Philosophy of GIS**
  http://www.island.net/~kiles/jf_ar.htm
  Original version of the invited article published in the December 1994 Journal of Forestry, which was a special edition devoted to Forest Inventory.
- **Implementing GIS in Middle East (Lebanon)**
  http://www.gisqatar.org.qa/conf97/links/i2.html
  Implementing GIS in Lebanon - A Case Study by Jacques Ekmekji, Director GIS Services Division/Associate Khatib & Alami - Consolidated Engineering Company Beirut - Lebanon

1.5 GIS Advantages

The Geographic Information System has been an effective tool for implementation and monitoring of municipal infrastructure. The use of GIS has been in vogue primarily due to the advantage mentioned below:

- Planning of project
- Make better decisions
- Visual Analysis
- Improve Organizational Integration

Planning of Project

Advantage of GIS is often found in detailed planning of project having a large spatial component, where analysis of the problem is a pre requisite at the start of the project. Thematic maps generation is possible on one or more than one base maps, example: the generation of a land use map on the basis of a soil composition, vegetation and topography. The unique combination of certain features facilitates the creation of such thematic maps. With the various modules within GIS it is possible to calculate surface, length, width and distance.

Making Decisions

The adage "better information leads to better decisions" is as true for GIS as it is for other information systems. A GIS, however, is not an automated decision making system but a tool to query, analyze, and map data in support of the decision making process. GIS technology has been used to assist in tasks such as presenting information at planning inquiries, helping resolve territorial disputes, and siting pylons in such a way as to minimize visual intrusion.

Visual Analysis

Digital Terrain Modeling (DTM) is an important utility of GIS. Using DTM/3D modeling, landscape can be better visualized, leading to a better understanding of certain relations in the landscape. Many relevant calculations, such as (potential) lakes and water volumes, soil erosion volume (Example: landslides), quantities of earth to be moved (channels, dams, roads, embankments, land leveling) and hydrological modeling becomes easier.

Not only in the previously mentioned fields but also in the social sciences GIS can prove extremely useful. Besides the process of formulating scenarios for an Environmental Impact Assessment, GIS can be a valuable tool for sociologists to analyze administrative data such as population distribution, market localization and other related features.

Improving Organizational Integration

Many organizations that have implemented a GIS have found that one of its main benefits is improved management of their own organization and resources. Because GIS has the ability to link data sets together by geography, it facilitates interdepartmental information sharing and communication. By creating a shared database one department can benefit from the work of another—data can be collected once and used many times.

As communication increases among individuals and departments, redundancy is reduced, productivity is enhanced, and overall organizational efficiency is improved. Thus, in a utility company the customer and infrastructure databases can be inte-

grated so that when there is planned maintenance, affected people can be informed by computer-generated letters.

Some Interesting Links:

∑ **Geographical Information Systems**
http://www.skyclean.org/gis.html
Advantages of GIS over Manual Methods

∑ **The GeoData Institute**
http://www.geodata.soton.ac.uk/Booklet.html
The GIS Awarness Booklet by University of Southampton

1.6 GIS Functionality: Answers

Till now GIS has been described in two ways:

1. Through the formal definitions, and
2. Through technology's ability to carry out spatial operations, by linking data sets together (Gouglidis *et al*., 2002).

However, there is another way to describe GIS by listing the type of questions the technology can (or should be able to) answer: *Location, Condition, Trends, Patterns, Modeling, Aspatial Questions, Spatial Questions.*

There are five type of questions that a sophisticated GIS can answer:

Locations

–What is at … ?

The first of these questions seeks to find out what exists at a particular location. A location can be described in many ways, depending upon the type of information needed.

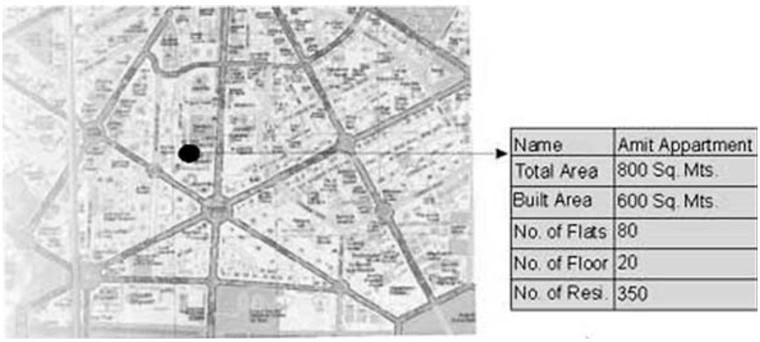


Figure 1.4: *A typical residential appartment query*

For example, for a residential apartment, a municipal government employee needs information regarding the number of residents, total area, total built area, number of flats, etc. (Fig. 1.4).

Conditions

–Where is it ... ?

The second question is the converse of the first and requires spatial data to answer. Instead of identifying what exists at a given location, one may wish to find location(s) where certain conditions are satisfied (e.g., in a given area where are apartments having more than three floors?) (Fig. 1.5).

Figure 1.5: *The residential apartments having more than 3 floors*

Trends

–What has changed since ... ?

The third question is the extension of both the first two and seeks to find the differences (e.g. in land use) over time.

1995 **2000**

How much land has been used for construction since 1995?

Patterns

–What spatial patterns exist ... ?

This question is more sophisticated. One might ask this question to determine what kind of patterns exists that provide potential for vehicular accidents. It might be just as important to know how many places that do not fit the pattern and where they are located (Fig. 1.6).

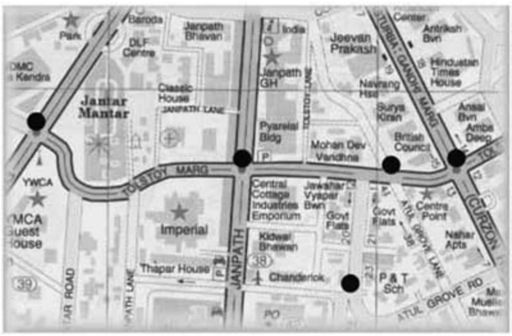


Figure 1.6: *What kind of patterns exists that provide potential for vehicular accidents?*

Modeling

–What if ... ?

"What if..." questions are posed to determine what happens, for example, if a new road is added to a network or if a toxic substance seeps into the local ground water supply (Fig. 1.7).

Figure 1.7: *What happens, if a new road is added to a network?*

Answering this type of question requires both geographic and other information (as well as specific models). GIS permits spatial operation.

Aspatial Questions

"What is the number of people having monthly salary only 800 € " is an aspatial question –the answer to which does not require the stored value of latitude and longitude; nor does it describe where the places are in relation with each other.

Spatial Questions

"How many people work with GIS in the major business centres of Northern Greece" or *"Which business centres lie within 10 Kms of each other?",* or *"What is the shortest route passing through all these centres".* These are spatial questions that can only be answered using latitude and longitude data and other information such as the radius of earth. Geographic Information Systems can answer such questions!

1.7 GIS Necessity

Many professionals, such as foresters, urban planners, and geologists, have recognized the importance of spatial dimensions in organising & analysing information. Whether a discipline is concerned with the very practical aspects of business, or is concerned with purely academic research, GIS can introduce a perspective, which can provide valuable insights.

∑ 70% of the information has geographic location as it's denominator making spatial analysis an essential tool.

∑ Ability to assimilate divergent sources of data both spatial and non-spatial (attribute data).

∑ Visualization Impact

∑ Analytical Capability

∑ Sharing of Information

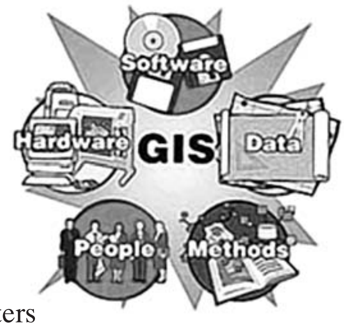
Some Interesting Links:

1. **GIS -The Need of Quality**
   http://www.gisdevelopment.net/tutorials/tuman006.htm
   An article by Richard Markham and David Rix
2. **GIS Development Guide: Needs Assesment**
   http://msuinfo.ur.msstate.edu/mcu_memo/pdfs/memo24-01.pdf
   An article by New York Bhate Archives

Factors aiding the rise of GIS

- Revolution in Information Technology.
  - Computer Technology
  - Remote Sensing
  - Computer Graphics / CAD
  - Data Bases /RDBMS
  - Digital Photogrammetry
  - Global Positioning Systems (GPS)
  - Communication Technology
  - Internet/Web Technologies
- Rapidly declining cost of Computer Hardware, and at the same time, exponential growth of operational speed of computers.
- Enhanced functionality of software and their user-friendliness.
- Visualizing impact of GIS corroborating the Chinese proverb *"a picture is worth a thousand words"*.
- Geographical feature and data describing it are part of our everyday lives and some facet of Geography influences most of our everyday decisions.

1.8 GIS Components



GIS constitutes of the following five key components:

Hardware

It consists of the computer system on which the GIS software will run. The choice of hardware system range from 400 MHz Personal Computers to Super Computers having capability in Tera FLOPS.

The computer forms the backbone of the GIS hardware through which gets it's input using a Scanner or a digitizer board. Scanner converts a picture into a digital image for further processing. The output of scanner can be stored in many formats e.g. TIFF, BMP, JPG etc. A digitizer board is flat board used for vectorisation of a given map objects. Printers and plotters are the most common output devices for a GIS hardware setup.

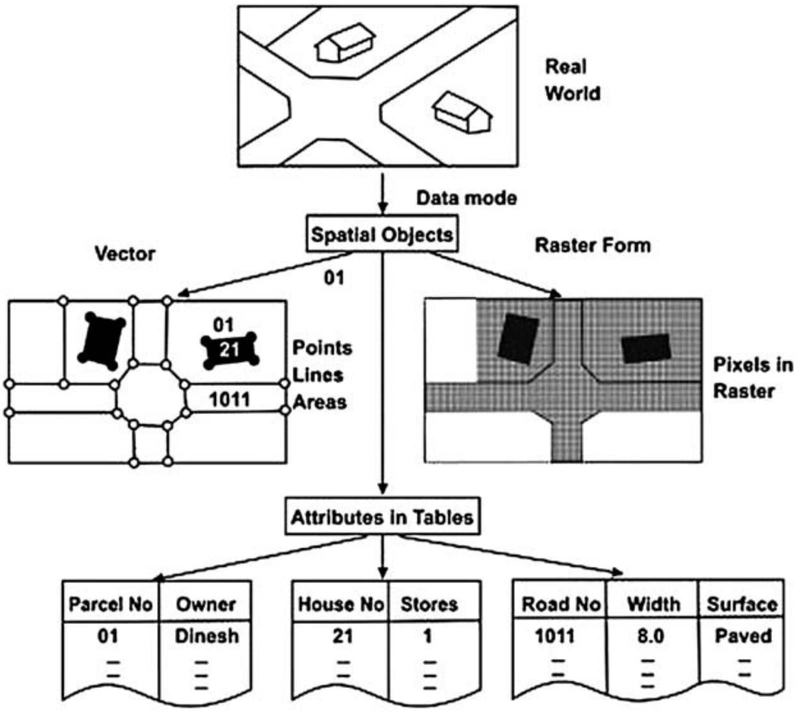
Software

GIS software provides the functions and tools needed to store, analyze, and display geographic information. GIS softwares in use are ArcView, ILWIS, MapInfo, ARC/INFO, AutoCAD Map, etc. A detailed list of GIS softwares available in the market can be found using Web search engines, like Google. The software available can be said to be application specific. When the low cost GIS work is to be carried out desktop GIS is the

suitable option. It is easy to use and supports many GIS feature. If the user intends to carry out extensive analysis on GIS, ARC/Info is the preferred option. For the people using AutoCAD and willing to step into GIS, AutoCAD Map is a good option.

Data

Geographic data and related *tabular data* can be collected by the organisation or purchased from a commercial data provider. The *digital map* forms the basic data input for GIS. Tabular data related to the map objects can also be attached to the digital data. A GIS will integrate spatial data with other data resources and can even use a DBMS, used by most organization to maintain their data, to manage spatial data.



People

Most definition of GIS focuses on the hardware, software, data and analysis components. However, no GIS exists in isolation from the organisational context, and there must always be people to plan, implement and operate the system as well as make decisions based on the output. GIS projects range from small research applications where one user is responsible for design and implementation and output, to international corporate distributed systems, where teams of staff interact with the GIS in many different ways.

GIS users range from technical specialists who design and maintain the system to those who use it to help them perform their everyday work. The people who useGIS can be broadly classified into two classes. The CAD/GIS operator, whose work is to vectorise the map objects. The use of this vectorised data to perform query, analysis or any other work is the responsibility of a GIS engineer/user.

Methods

And above all a successful GIS operates according to a well-designed plan and business rules, which are the models and operating practices unique to each organization. There are various techniques used for map creation and further usage for any project. The map creation can either be automated raster to vector creator or it can be manually vectorised using the scanned images. The source of these digital maps can be either map prepared by any survey agency or satellite imagery.

Some Interesting Links:

∑ **Components of GIS**
www.ESRI.com/library/gis/abtgis/comp_gis.html
A working GIS integrates five key components - ESRI

∑ **Components of GIS**
corpweb.semcor.com/gis/about/components.html
by Semcor Information Systems and Services

1.9 GIS Applications

Computerized mapping and spatial analysis have been developed simultaneously in several related fields. The present status would not have been achieved without close interaction between various fields such as utility networks, cadastral mapping, topographic mapping, thematic cartography, surveying, photogrammetry, remote sensing, image processing, computer science, rural and urban planning, earth sciences, geography, computer graphics, CAD and Internet/Web technologies.

The GIS technology is rapidly becoming a standard tool for **management of natural resources**. The effective use of large spatial data volumes is dependent upon the existence of an efficient geographic handling and processing system to transform this data into usable information.

The GIS technology is used **to assist decision-makers** by indicating various alternatives in development and conservation planning and by modelling the potential outcomes of a series of scenarios. It should be noted that any task begins and ends with the real world. Data are collected about the real world. Of necessity, the product is an abstraction; it is not possible (and not desired) to handle every last detail. After the data are analysed, information is compiled for decision-makers.

Based on this information, actions are taken and plans implemented in the real world.

Major Areas of Applications

- *Different streams of planning*
  Urban planning, transportation planning, architectural conservation planning, urban design planning.
- *Street Network Based Application*
  It is an address-matched application, vehicle routing and scheduling location and site selection and disaster planning.
- *Natural Resource Based Application*
  Management and environmental impact analysis of wild and scenic recreational resources, flood plain, wetlands, ground water and forests. Wild life habitat study and migration route planning.
- *View Shed Analysis*
  Hazardous or toxic factories sitting and ground water modelling.
- *Land Parcel Based*
  Zoning, sub-division plans review, land acquisition, nature quality management and maintenance etc.
- *Facilities Management (FM)*
  Water supply management, sewer lines management and planning, tracking energy use.

Some Interesting Links:

- **Application of GIS to Fisheries Science**
  http://web.orst.edu/~malavear/
  Recent Trends, Methodological Problems and Challenges by Maria Yolanda Malavear
- **GIS and Public Health**
  http://www-dccps.ims.nci.nih.gov/LIBCSP/ms8156/maintext.html
  Mapping the Future - An article by Thomas B. Richards, Charles M. Croner, Gerard Rushton and Carol K. Brown from The Long Island Breast Cancer Study Project, National Cancer Institute.
- **Defining Hazard Areas using GIS**
  http://www.dca.state.fl.us/brm/LMS_pt1/lms_pt_1_defining_haz_areas.htm
  LMS Part1 - Vulnerability Assessment
- **GIS and Archaeology**
  http://www2.una.edu/geography/classes/ge424/students/kmodlin/Archeology.HTML
  Application og GIS in the Field of Archeology - Executive Summary by Kelley Modlin and Jamie Sharp

- **Application of GIS**
  http://www.uow.edu.au/science/geosciences/ugrad/lectnotes/geos339/L21.htm
  Application of GIS for Coastal Zone Management
- **GIS and Multimodal Investment Analysis**
  http://www.ctre.iastate.edu/Research/multimod/phase1/III.htm
  The Application of GIS to Multimodal Investment Analysis by Center for Transportation Research and Education
- **Spatial Analysis of Crime using GIS-Based Data**
  http://www.cs.cmu.edu/~olli/dissertation.html
  Weighted Spatial Adaptive Filtering and Chaotic Cellular Forecasting with Applications to Street Level Drug Markets
- **GIS and Telecommunication**
  http://www.laserscan.com/papers/telecomgis.htm
  GIS - A Major Aid to Telecommunications Planning
- **GIS and Land Cadastre**
  http://www.odyssey.maine.edu/gisweb/spatdb/egis/eg94194.html
  The use of GIS Technology in Digital Land Cadastre by Martin Puhar, Ales Suntar and Edvard Mivsek
- **Risky Business and GIS**
  http://www.geoplace.com/bg/1999/0999/999rbus.asp
  GIS helps Insurers make more informed risk-based decisions - An article by Keith Reid in Business Geographics
- **GIS for RIDGE Research**
  http://dusk.geo.orst.edu/ridge.html
  An article by Dawn J. Wright published in RIDGE Events, 1994
- **Environmental Projects using GIS**
  http://www.iceis.mcnc.org/projects/GIS/
  North Carolina Supercomputing Center Environmental Programs
- **Application of GIS**
  http://www.esri.com/library/userconf/proc96/TO300/PAP289/P289.HTM
  Interactive Application Of GIS during the Vision Wildfire at Point Reyes National Seashore
- **GIS and Electrical Distribution**
  http://www.odyssey.maine.edu/gisweb/spatdb/egis/eg94210.html
  Application of GIS Technology in Electrical Distribution Network Optimization -An article by Davor Skrlec, Slavko Krajcar, Snjezana Blagajac
- **GIS and Forest Fire**
  http://www.metla.fi/conf/iufro95abs/d4pap126.htm
  Application of GIS in Forest Fire Prevention - An article by Perestrello de Vasconcelos, Maria J., Caetano, Mario S., Pereira, Joseé M.C.

- **Application of GIS in various fields**
  http://centrin.net.id/~agul/gis_apl.html

Contributing Disciplines & Technologies

- GIS is a convergence of various technological fields and traditional disciplines
- GIS has been called an "enabling technology" because of the potential it offers for the wide variety of disciplines which must deal with spatial data
- Each related field provides some of the techniques which make up GIS
- Many of these related fields emphasize data collection - GIS brings them together by emphasizing integration, modeling and analysis
- As the integrating field, GIS often claims to be the science of spatial information

Geography

- Broadly concerned with understanding the world and man's place in it
- Long tradition in spatial analysis
- Provides techniques for conducting spatial analysis and a spatial perspective on research

Cartography

- Concerned with the display of spatial information
- Currently the main source of input data for GIS is maps
- Provides long tradition in the design of maps which is an important form of output from GIS
- Computer cartography (also called *"digital cartography"* or/and *"automated cartography"*) provides methods for digital representation and manipulation of cartographic features and methods of visualization

Remote Sensing

- Images from space and the air are major source of geographical data
- Remote sensing includes techniques for data acquisition and processing anywhere on the globe at low cost, consistent update potential
- Many image analysis systems contain sophisticated analytical functions
- Interpreted data from a remote sensing system can be merged with other data layers in a GIS

Digital Photogrammetry

- Using aerial photographs and techniques for making accurate measurements from them, Photogrammetry is the source of most data on topography (ground

surface elevations) used for input to GIS

Geomatics (Geomatics Engineering)

- Geomatics is the synergy of multiple disciplines, namely GIS, computer graphics, CAD, remote sensing, image processing, GPS, cartography, databases, statistics, artificial intelligence, digital photogrammetry and other geo-related sciences.
- With advancements in information technology (RDBMS), Geomatics has emerged as a discipline dealing with spatial and non-spatial information, their methods of acquisition, organisation, classification, analysis, management, display and dissemination, as well as, the infrastructure necessary for the optimal use of this information.

Surveying

- Provides high quality data on positions of land boundaries, buildings, etc.

Geodesy

- Source of high accuracy positional control for GIS

Statistics

- Many models built using GIS are statistical in nature, many statistical techniques used for analysis
- Statistics is important in understanding issues of error and uncertainty in GIS data

Operations Research

- Many applications of GIS require use of optimizing techniques for decision-making

Computer Science/Information Technology

- Computer-aided design (CAD) provides software and techniques for data input, display, visualization and representation, particularly in three dimensions (3-D CAD)
- Advances in computer graphics provide hardware, software for handling and displaying graphic objects, techniques of visualization
- Database management systems (DBMS) contribute methods for representing data in digital form, procedures for system design and handling large volumes of data, particularly access and update
- Artificial intelligence (AI) and Neural Networks (NN) uses the computer to make choices based on available data in a way that is seen to emulate human intelligence and decision-making - computer can act as an "expert" in such functions as designing maps, generalizing map features
- Although GIS has yet to take full advantage of AI and NN, AI already provides methods and techniques for system design

Mathematics

∑ Several branches of mathematics, especially *geometry* and *graph theory,* are used in GIS system design and analysis of spatial data

Road Engineering - Urban Development

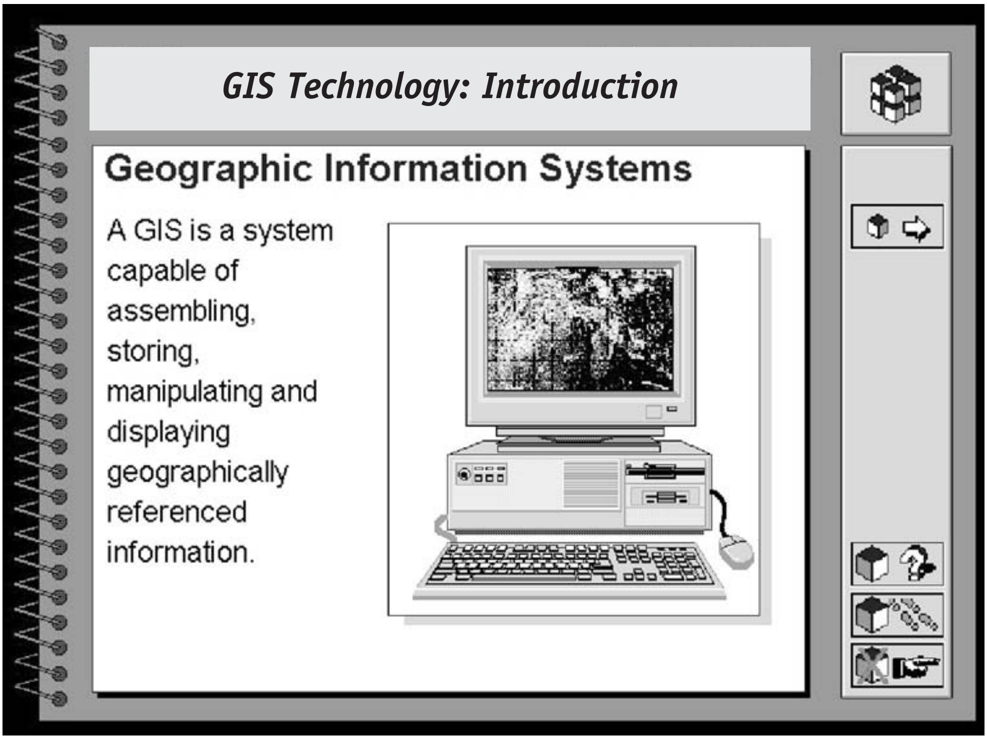
∑ GIS has many applications in transportation and urban engineering

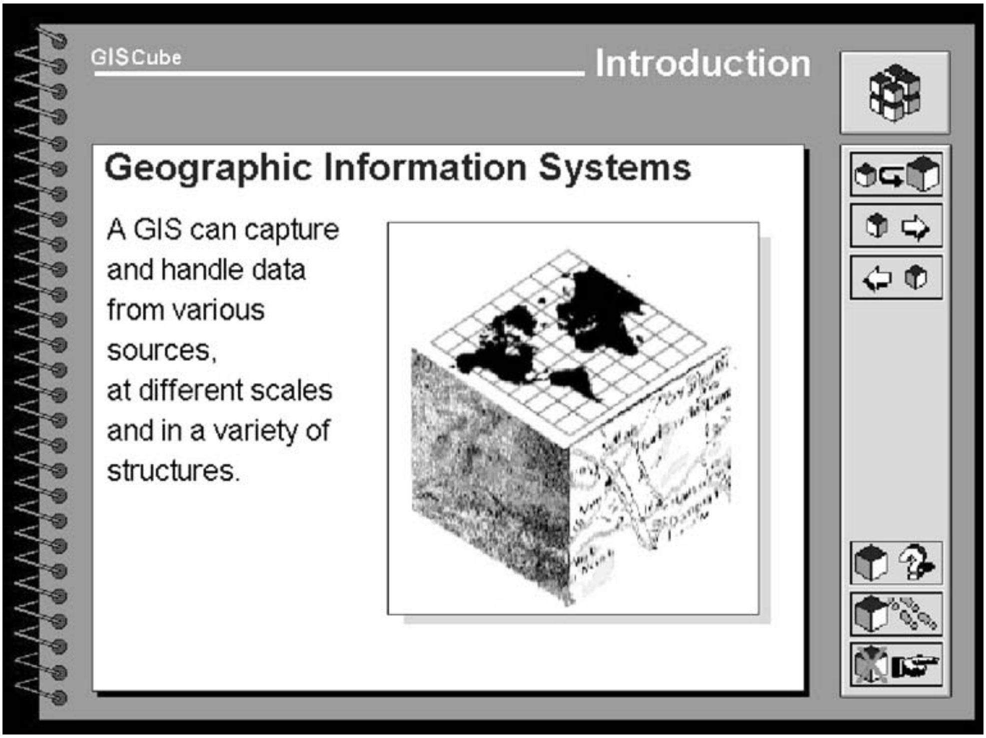
1.10 Conclusions

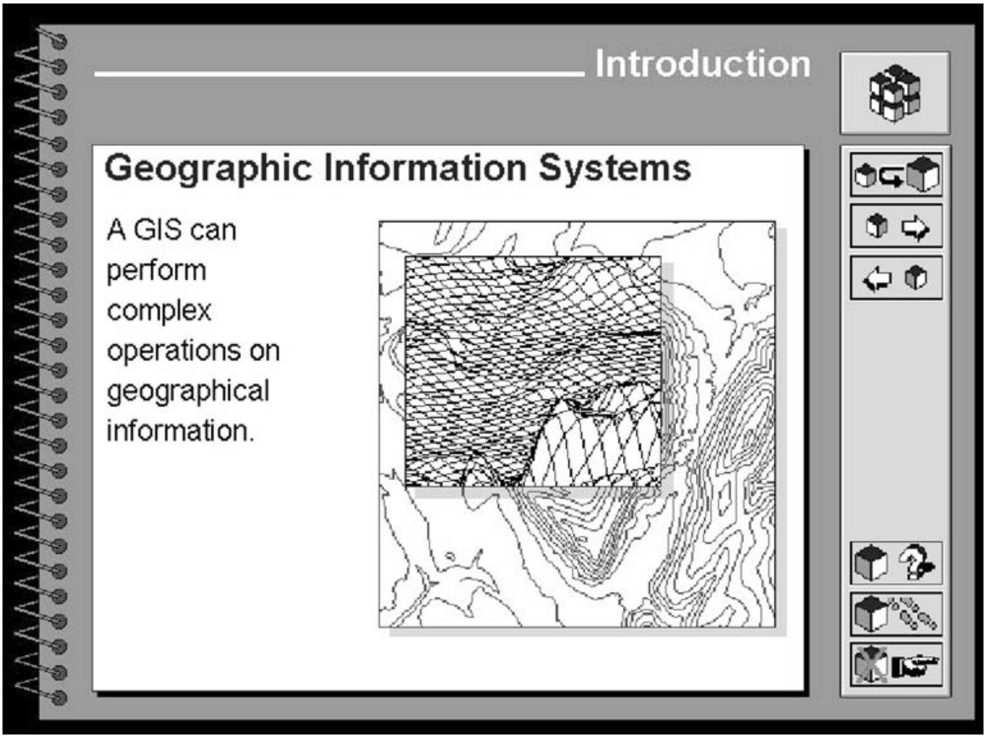
GIS technology has now become a very powerful and acceptable tool for the management and analysis of spatial data.

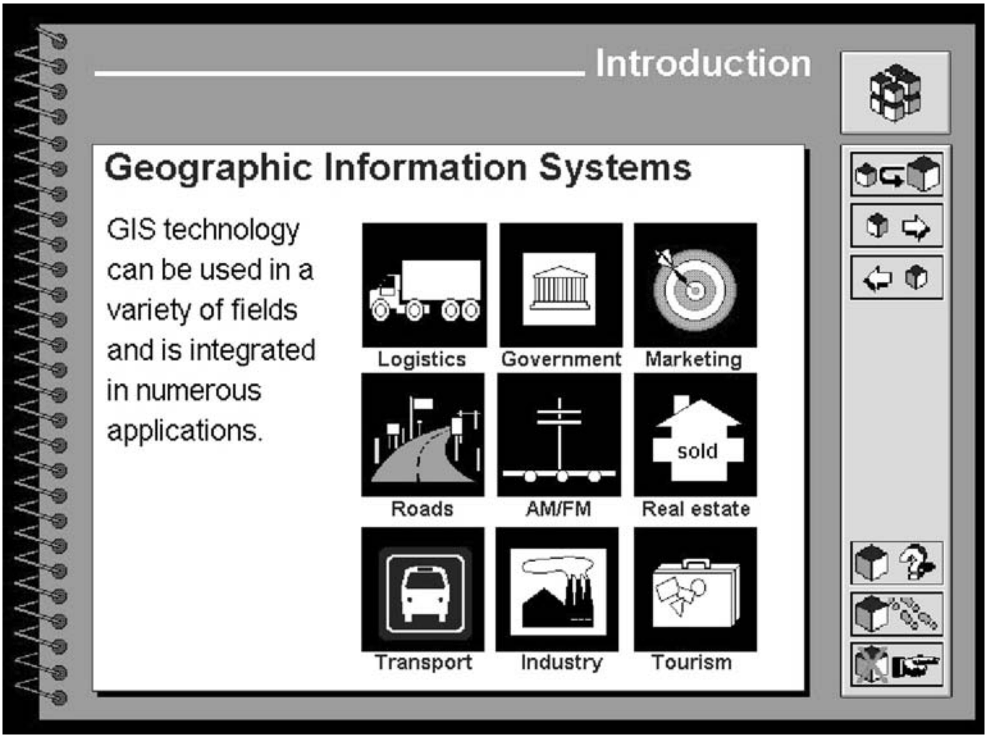
With the advance of related technologies like CAD, RDBMS, digital photogrammetry, remote sensing, GPS and surveying, more rapid and precise analysis of data has been highly demanded, which naturally has to be complemented by the geographic information technology.

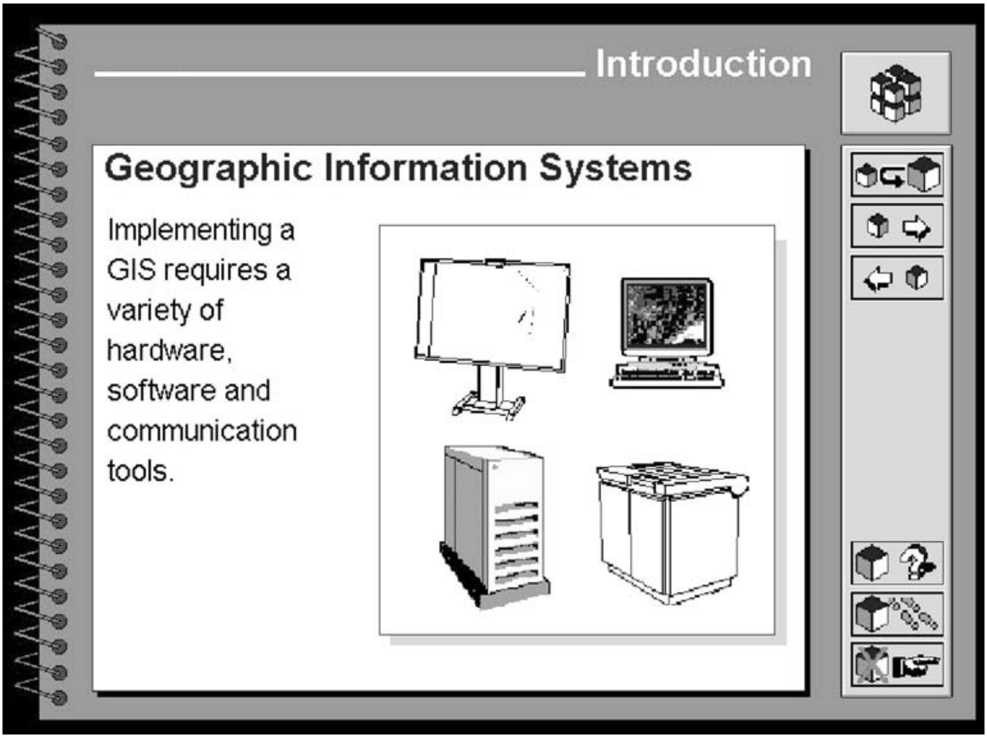
1.11 GIS Technology: Introduction (e-Learning Multimedia GIS)

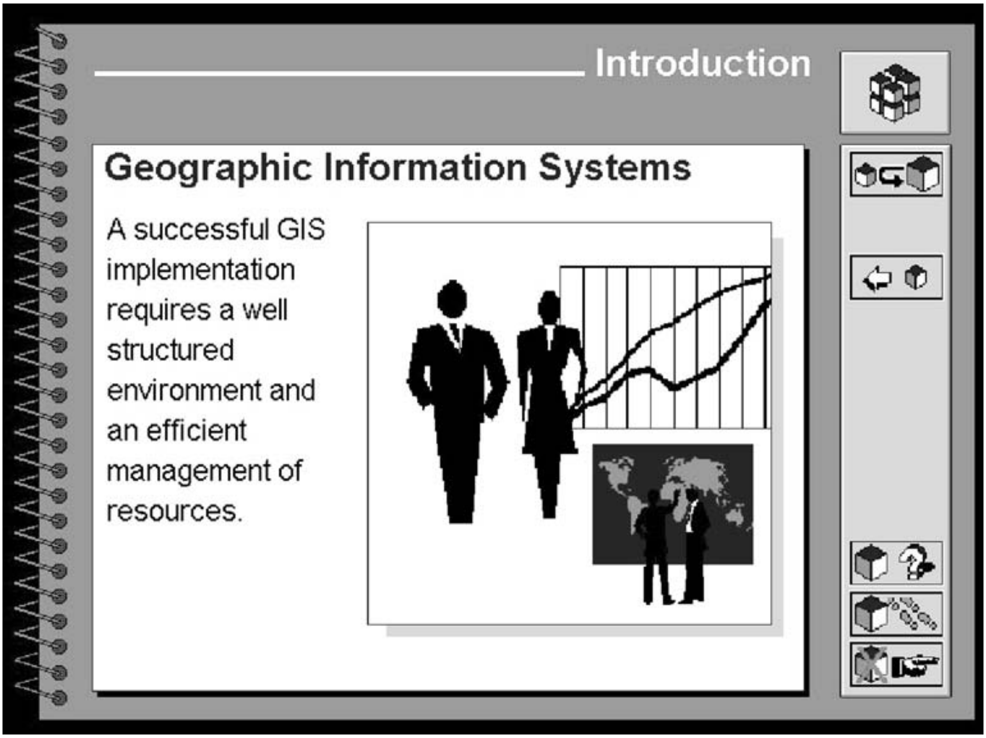



GISCube
Introduction
Geographic Information Systems
A GIS can capture and handle data from various sources, at different scales and in a variety of structures.

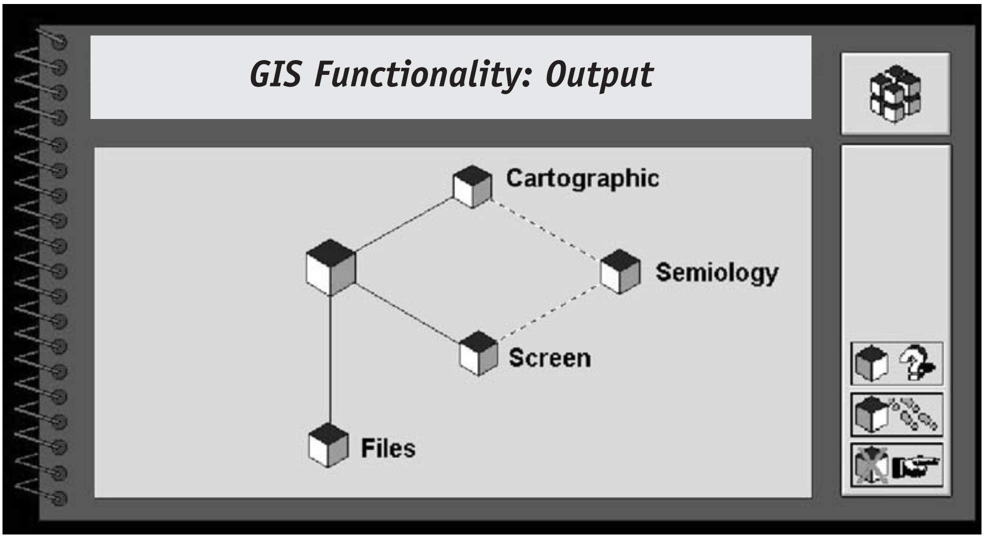

Introduction
Geographic Information Systems
A GIS can perform complex operations on geographical information.

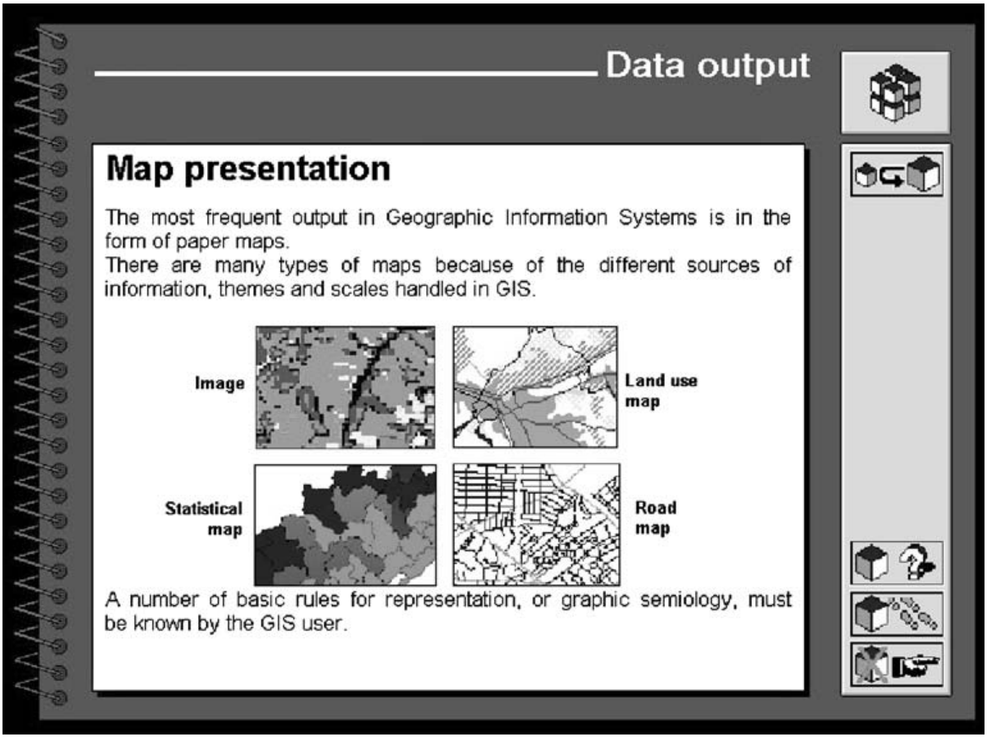

Introduction
Geographic Information Systems
GIS technology can be used in a variety of fields and is integrated in numerous applications.
Logistics
Government
Marketing
Roads
AM/FM
sold
Real estate
Transport
Industry
Tourism

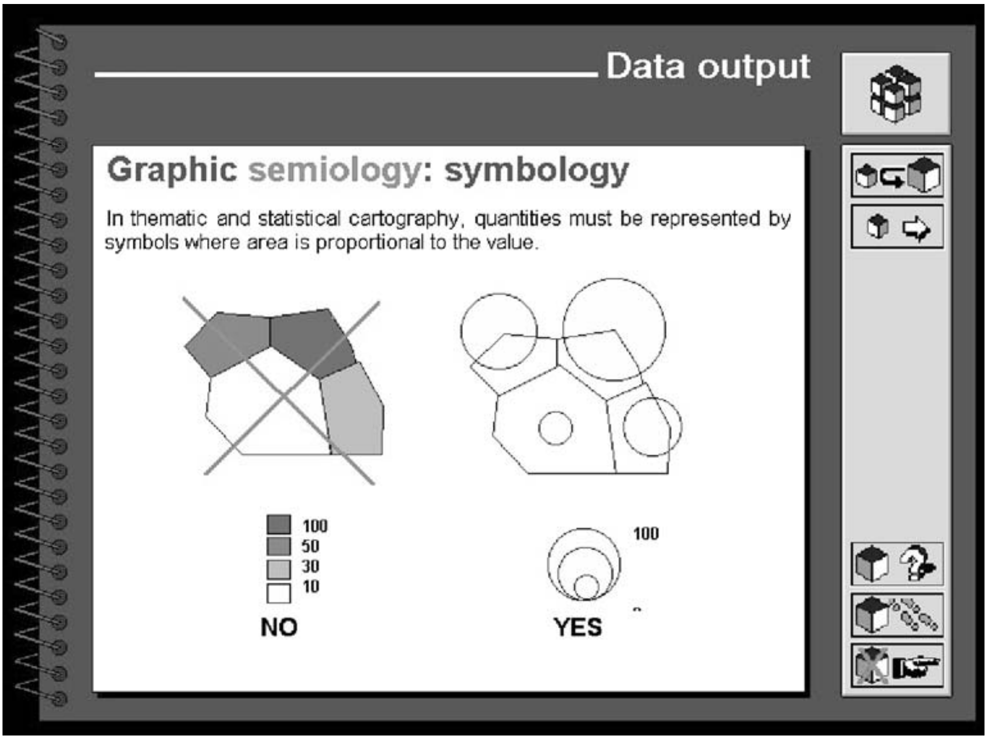

Introduction
Geographic Information Systems
Implementing a GIS requires a variety of hardware, software and communication tools.

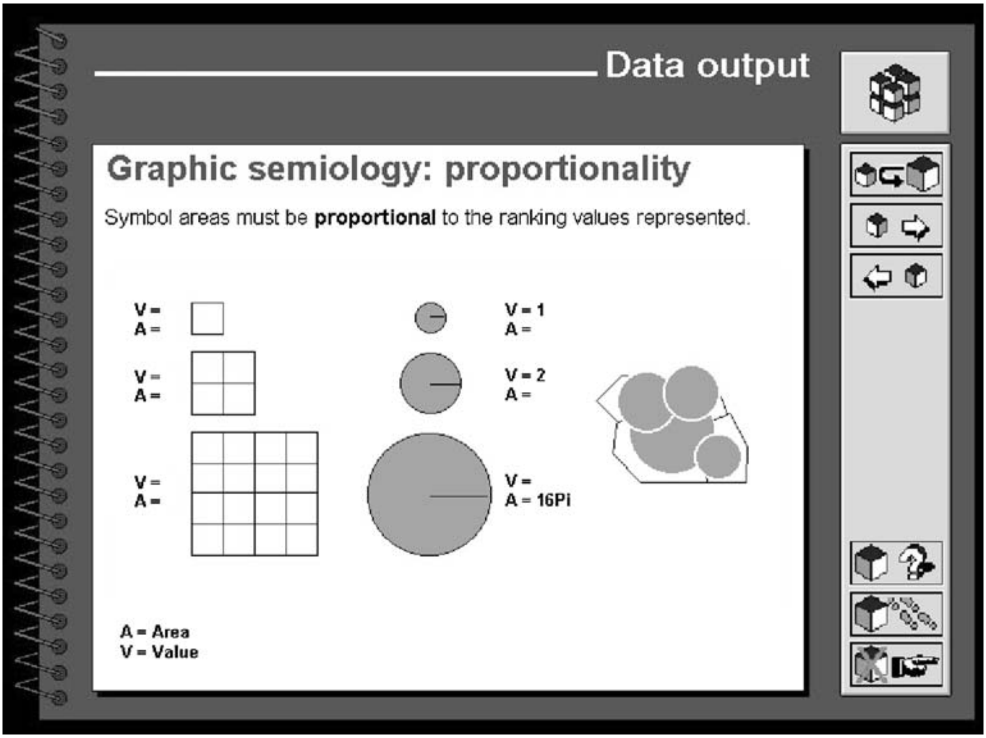


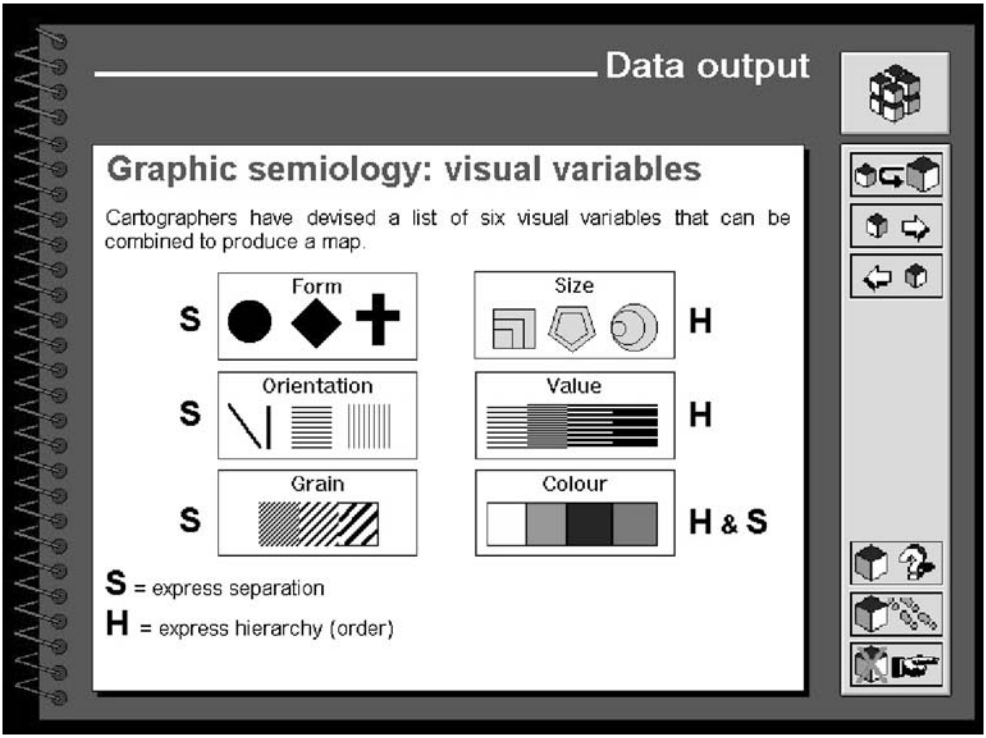
1.12 GIS Functionality: Output
(e-Learning Multimedia GIS)

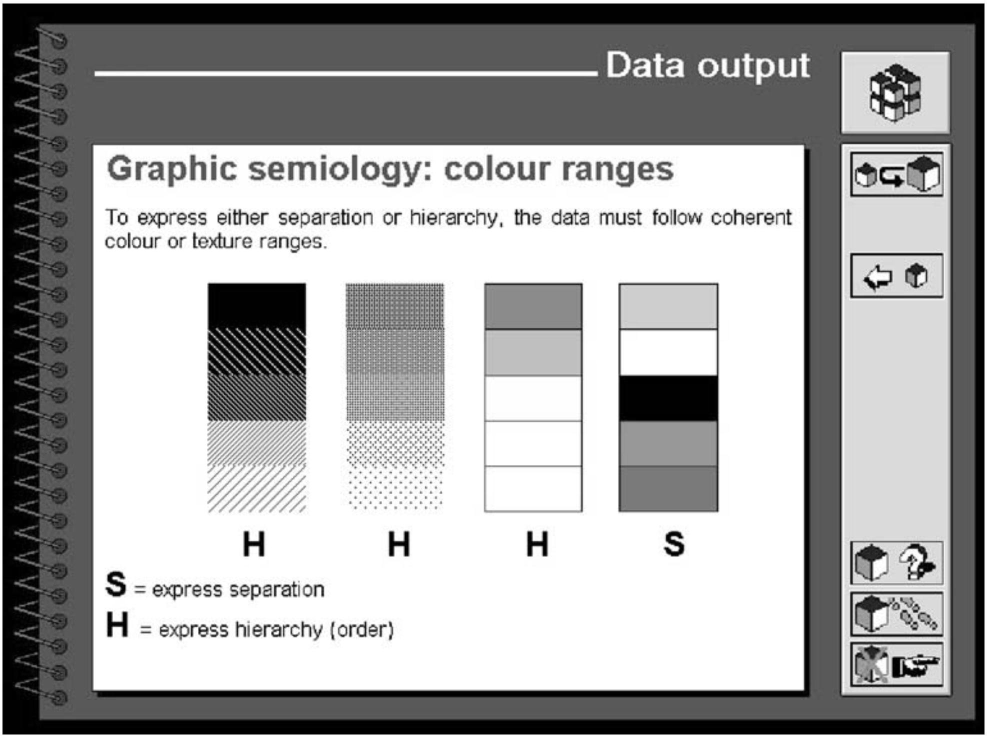


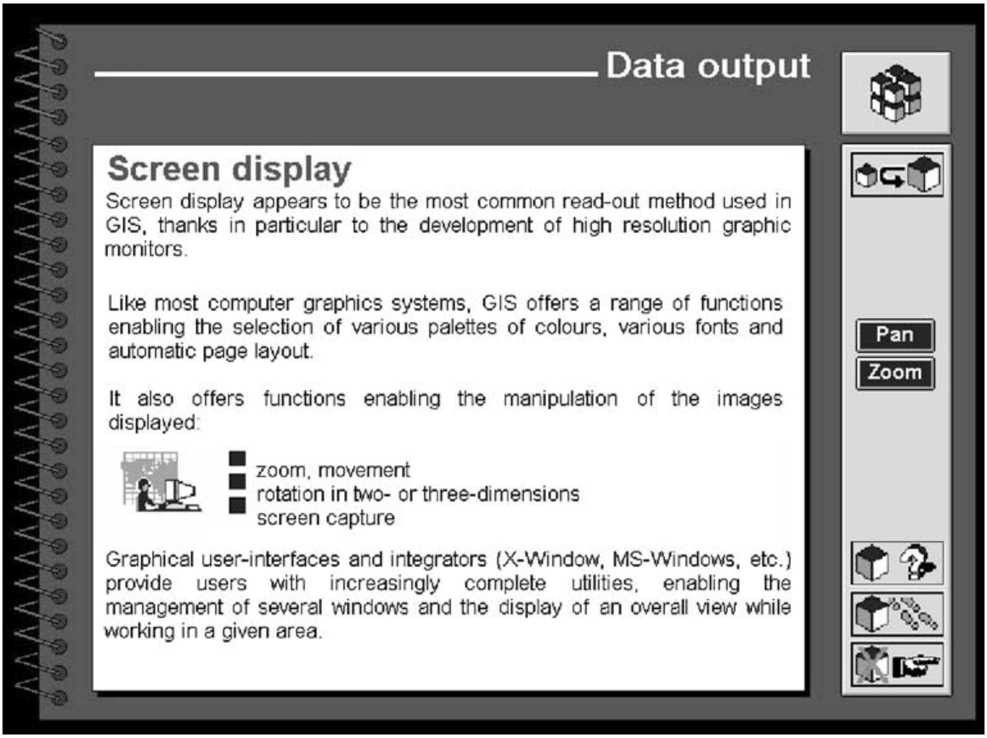

Data output
Map presentation
The most frequent output in Geographic Information Systems is in the form of paper maps.
There are many types of maps because of the different sources of information, themes and scales handled in GIS.
Image
Land use map
Statistical map
Road map
A number of basic rules for representation, or graphic semiology, must be known by the GIS user.

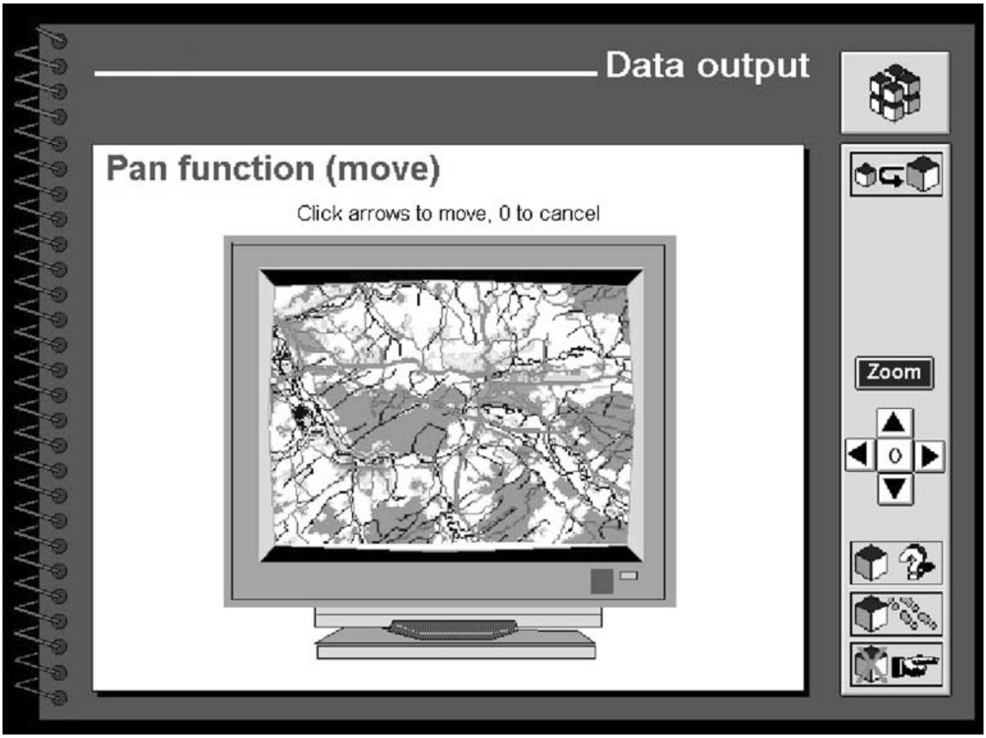

Data output
Graphic semiology: symbology
In thematic and statistical cartography, quantities must be represented by symbols where area is proportional to the value.
100
50
30
10
NO
100
YES

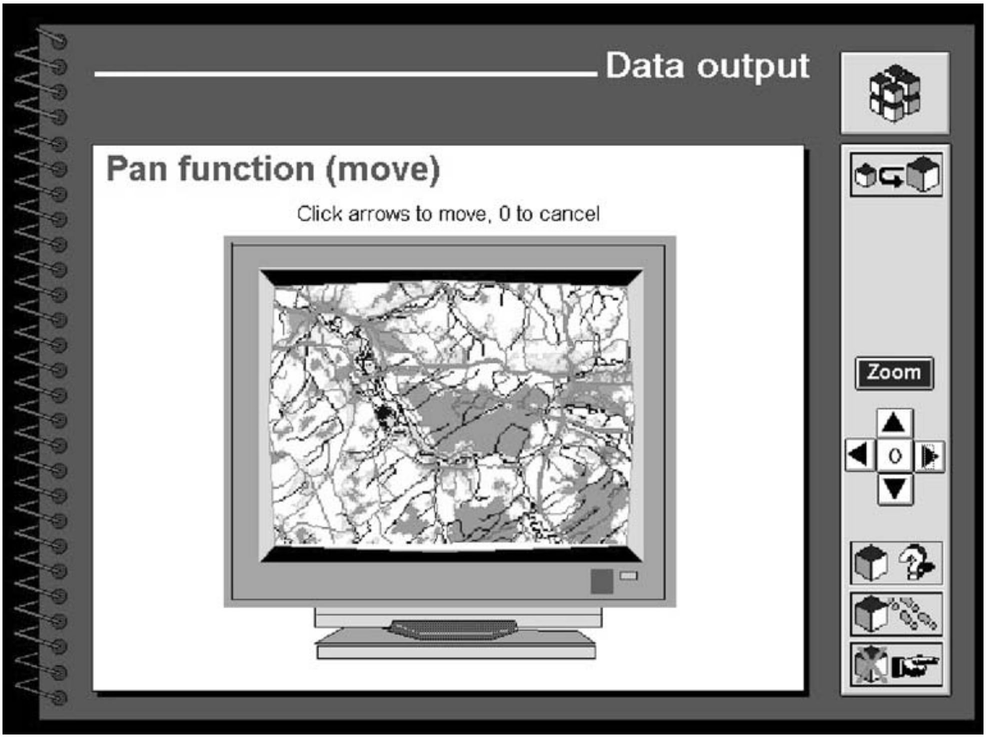

Data output
Graphic semiology: proportionality
Symbol areas must be **proportional** to the ranking values represented.
V =
A =
V =
A =
V =
A =
V = 1
A =
V = 2
A =
V =
A = 16Pi
A = Area
V = Value

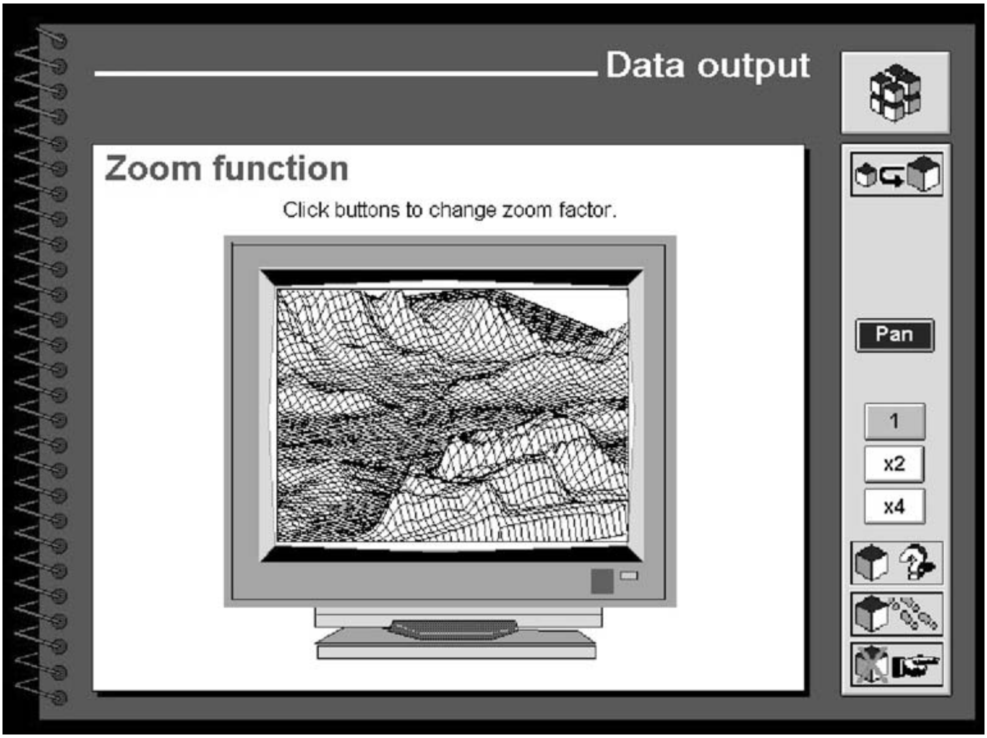

Data output
Graphic semiology: visual variables
Cartographers have devised a list of six visual variables that can be combined to produce a map.
S
Form
Size
H
S
Orientation
Value
H
S
Grain
Colour
H & S
S = express separation
H = express hierarchy (order)

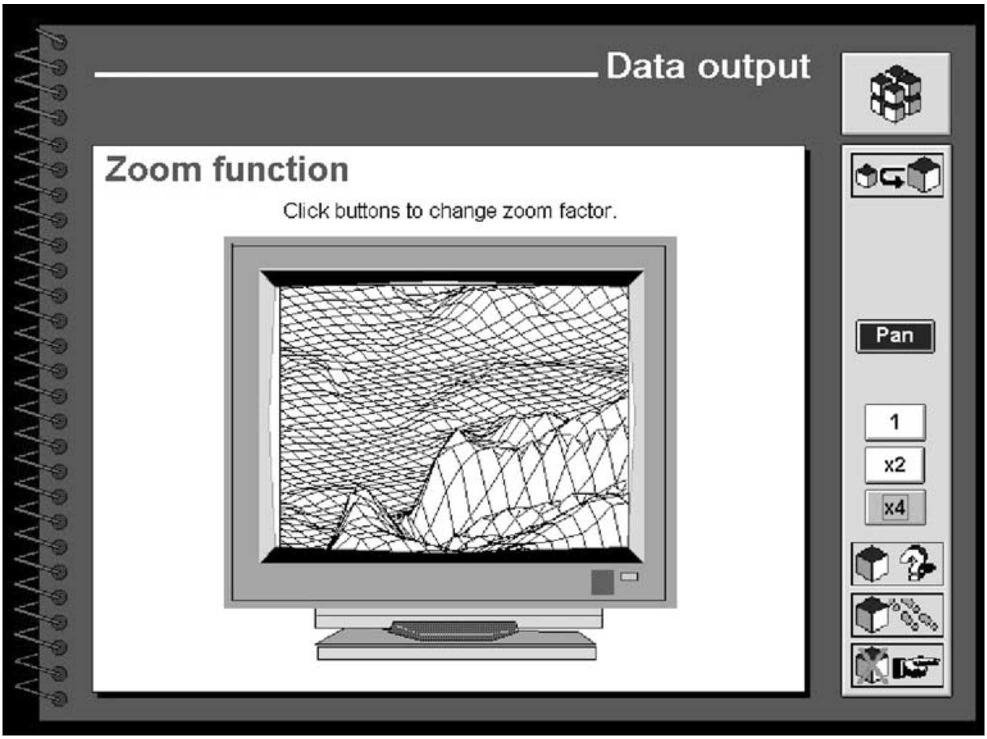

Data output
Graphic semiology: colour ranges
To express either separation or hierarchy, the data must follow coherent colour or texture ranges.
H H H S
S = express separation
H = express hierarchy (order)

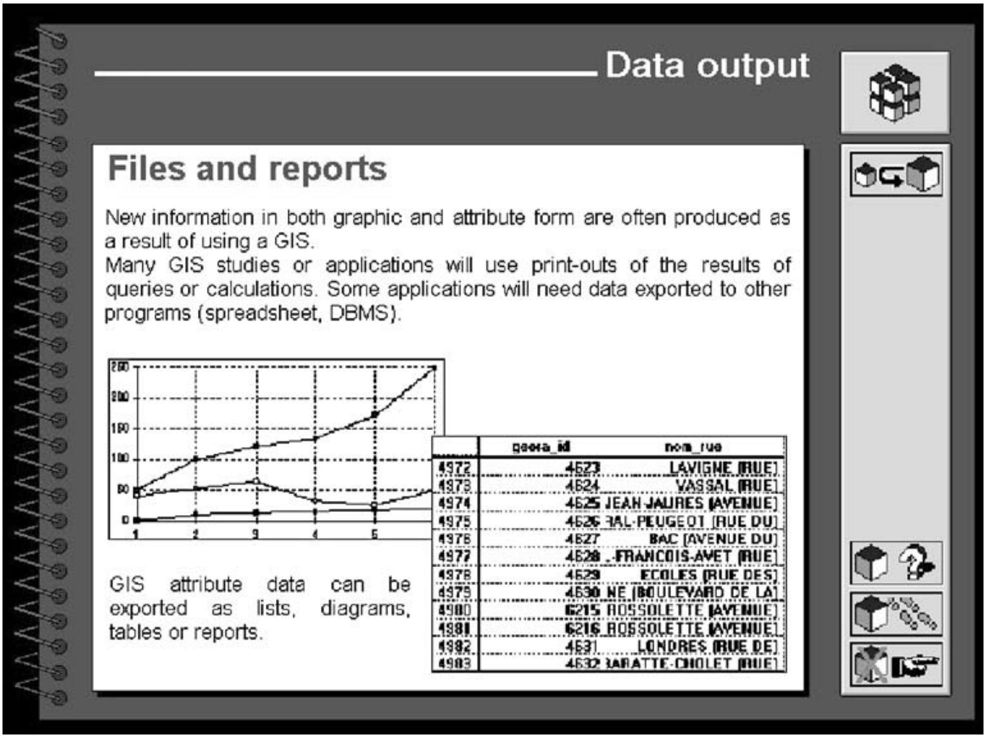

Data output
Screen display
Screen display appears to be the most common read-out method used in GIS, thanks in particular to the development of high resolution graphic monitors.
Like most computer graphics systems, GIS offers a range of functions enabling the selection of various palettes of colours, various fonts and automatic page layout.
It also offers functions enabling the manipulation of the images displayed:
zoom, movement
rotation in two- or three-dimensions
screen capture
Graphical user-interfaces and integrators (X-Window, MS-Windows, etc.) provide users with increasingly complete utilities, enabling the management of several windows and the display of an overall view while working in a given area.
Pan
Zoom


Data output
Pan function (move)
Click arrows to move, 0 to cancel
Zoom
0


Data output
Pan function (move)
Click arrows to move, 0 to cancel
Zoom
0


Data output
Zoom function
Click buttons to change zoom factor.
Pan
1
x2
x4


Data output
Zoom function
Click buttons to change zoom factor.
Pan
1
x2
x4



1.13 Additional Readings

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Σ **Burrough, P.A.** (1986). *Principles of Geographical Information Systems for Land Resource Assessment.* Clarendon Press, Oxford.

Σ **Chrisman, N.R.** (1997). *Exploring Geographic Information Systems.* Wiley, New York.

Σ **DeMers, M.N.** (1997). *Fundamentals of Geographic Information Systems.* Wiley, New York.

Σ **Gouglidis, A.** and **A.-D. Dritsas** (2002). *Graphical Information Systems.* TEI of Thessaloniki / Dept. of Information Technology (Project Dissertation).

Σ **Heywood, I.** *et al.* (1998). *An Introduction to Geographical Information Systems.* Longman, New York.

Σ **Tobler, W.** (2002). *Global Spatial Analysis.* University of California, Geography Dept., Santa Barbara (www.geog.ucsb.edu/~tobler)

Σ **Tobler, W.** (1970). *An Expirement in Geo-Coding.* University of California, Geography Dept., Santa Barbara (www.geog.ucsb.edu/~tobler)

Σ **Worboys, M.F.** (1997). *GIS – A Computing Perspective.* Taylor & Francis, London.