Title
Unit 02 - Maps and Map Analysis

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UNIT 2 - MAPS AND MAP ANALYSIS

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Compiled with assistance from David Rhind, Birkbeck College, University of London

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For Information that Supplements the Contents of this Unit:

- Cartographic Communication (Foote and Crum/Geographer's Craft) -- Elements of effective cartographic design.
- Cartography/Maps (U of Western Ontario)
- Fundamental of Cartography (NAIS) -- Illustrated and described: Map projections; tables showing properties of projections.
- Map Projection Overview (Dana/Geographer's Craft)
- Thematic and Base Map images of Canada (NAIS) -- Thematic maps (e.g. ethnic diversity, satellite image); Base maps (e.g. Canada base map series, world).
- What Does Analytical Cartography have to do with GIS? (Chrisman/U of Washington) -- GIS definitions; schools of thought about maps and mapping.

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This unit explores the map analysis roots of GIS. We have placed it early in the sequence as we feel the issues discussed here determine to a large extent how GIS users presently view the role of GIS and it should help to put later lectures into perspective. Illustrate this unit with several examples of different kinds of maps from your map collection.

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A. INTRODUCTION

- maps are the main source of data for GIS
- the traditions of cartography are fundamentally important to GIS
- GIS has roots in the analysis of information on maps, and overcomes many of the limitations of manual analysis
- this unit is about cartography and its relationship to GIS - how does GIS differ from cartography, particularly automated cartography, which uses computers to make maps?

B. WHAT IS A MAP?

Definition

- according to the International Cartographic Association, a map is:
  - a representation, normally to scale and on a flat medium, of a selection of material or abstract features on, or in relation to, the surface of the Earth

Maps show more than the Earth's surface

- the term "map" is often used in mathematics to convey the notion of transferring information from one form to another, just as cartographers transfer information from the surface of the Earth to a sheet of paper

- the term "map" is used loosely to refer to any visual display of information, particularly if it is abstract, generalized or schematic

Cartographic abstraction

- production of a map requires:
    - selection of the few features in the real world to include
    - classification of selected features into groups (i.e. bridges, churches, railways)
    - simplification of jagged lines like coastlines
    - exaggeration of features to be included that are to small to show at the scale of the map
    - symbolization to represent the different classes of features chosen

Types of maps

- in practice we normally think of two types of map:
- topographic map - a reference tool, showing the outlines of selected natural and man-made features of the Earth
    - often acts as a frame for other information
    - "Topography" refers to the shape of the surface, represented by contours and/or shading, but topographic maps also show roads and other prominent features
- thematic map - a tool to communicate geographical concepts such as the distribution of population densities, climate, movement of goods, land use etc.

Thematic maps in GIS

- several types of thematic map are important in GIS:
- a choropleth map uses reporting zones such as counties or census tracts to show data such as average incomes, percent female, or rates of mortality
    - the boundaries of the zones are established independently of the data, and may be used to report many different sets of data
- an area class map shows zones of constant attributes, such as vegetation, soil type, or forest species
    - the boundaries are different for each map as they are determined by the variation of the attribute being mapped, e.g. breaks of soil type may occur independently of breaks of vegetation
- an isopleth map shows an imaginary surface by means of lines joining points of equal value, "isolines" (e.g. contours on a topographic map)
    - used for phenomena which vary smoothly across the map, such as temperature, pressure, rainfall or population density

Line maps versus photo maps

- an important distinction for GIS is between a line map and a photo map
- a line map shows features by conventional symbols or by boundaries
- a photo map is derived from a photographic image taken from the air
    - features are interpreted by the eye as it views the map
    - certain features may be identified by overprinting labels

photomaps are relatively cheap to make but are rarely completely free of distortions

Characteristics of maps

- maps are often stylized, generalized or abstracted, requiring careful interpretation
- usually out of date
- show only a static situation - one slice in time
- often highly elegant/artistic
- easy to use to answer certain types of questions:
  - how do I get there from here?
  - what is at this point?
- difficult or time-consuming to answer other types:
  - what is the area of this lake?
  - what places can I see from this TV tower?
  - what does that thematic map show at the point I'm interested in on this topographic map?

The concept of scale

- the scale of a map is the ratio between distances on the map and corresponding distances in the real world
  - if a map has a scale of 1:50,000, then 1 cm on the map equals 50,000 cm or 0.5 km on the Earth's surface
- the use of the terms "small scale" and "large scale" is often confused, so it is important to be consistent
  - a large scale map shows great detail, small features
    - representative fraction is large, e.g. 1/10,000
  - a small scale map shows only large features
    - representative fraction is small, e.g. 1/250,000
- the scale controls not only how features are shown, but what features are shown
  - a 1:2,500 map will show individual houses and lamp posts while a 1:100,000 will not
- different scales are used in different countries
  - in the US, 1:100,000 is the largest scale at which complete coverage of the continental states exists, but there is limited coverage at 1:62,500 and 1:24,000
  - in the UK, there is complete coverage at much larger scales (1:1,250 to 1:10,000)

Map projections

- the Earth's surface is curved but as it must be shown on a flat sheet, some distortion is inevitable
  - distortion is least for when the map only shows small areas, and greatest when a map attempts to show the entire surface of the Earth
- a projection is a method by which the curved surface of the earth is represented on a flat surface
  - it involves the use of mathematical transformations between the location of places on the earth and their projected locations on the plane

numerous projections have been invented, and arguments continue about which is best for which purposes

- projections can be identified by the distortions which they avoid - in general a projection can belong to only one of these classes:
    - equal area projections preserve the area of features by assigning them an area on the map which is proportional to their area on the earth - these are useful for applications which require measuring area, and are popular in GIS
    - conformal projections preserve the shape of small features, and show directions (bearings) correctly - they are useful for navigation
    - equidistant projections preserve distances to places from one or two points

C. WHAT ARE MAPS USED FOR?

- traditionally, maps are used as aids to navigation, as reference documents, and as wall decorations
- maps have four roles today:

Data display

- maps provide useful ways of displaying information in a meaningful way
    - in practice, the cost of making and printing a map is high, so its contents are often a compromise between different needs

Data stores

- as a means of storing data, maps can be very efficient, high density stores
    - a typical 1:50,000 map might have 1,000 place names on it
        - the distances between all possible pairs of these 1,000 places would run to (1,000 x 999 / 2) or 499,500 numbers if stored in a table instead of scaled off the map when needed
    - the information printed on the typical 1:50,000 topographic map sheet in the UK requires 25 million bytes of storage when it is converted to digital form, equivalent to one standard computer tape, or 10 full-length novels
        - the information on all British topographic maps would require 150 gigabytes (150x109 bytes)

Spatial indexes

- a map can show the boundaries of areas (e.g. land use zones, soil or rock types) and identify each area with a label
    - a separate manual with corresponding entries may provide greater detail about each area

Data analysis tool

- maps are used in analysis to:
    - make or test hypotheses, such as the identification of cancer clusters
    - examine the relationship between two distributions using simple transparent overlays

D. THE USE OF MAPS FOR INVENTORY AND ANALYSIS

- the following examples demonstrate how maps have been used for sophisticated applications in inventory and analysis, and point out some limitations

Measuring land use change

- example, two major land use surveys were carried out in the UK, in the late 1930s by Sir Dudley Stamp and in the 1960s by Professor Alice Coleman
  - the results were published as maps
  - in order to compare changes in land use between 1930s and 1960s, the area of each land use type was measured using a hand planimeter and counting overlaid dots
- despite interest in measuring the amount of change of land use through time, particularly from agricultural to

  urban, few results were produced using this method because the traditional techniques are slow and tedious, and because of the difficulty of overlaying or working from very different map sources

Landscape architecture

- Ian McHarg pioneered the use of transparent map overlays for planning locations of highways, transmission corridors and other facilities in environmentally sensitive areas (McHarg, 1969)
- despite the popularity of this technique and numerous applications, this method remains cumbersome and imprecise

E. AUTOMATED AND COMPUTER-ASSISTED CARTOGRAPHY

Changeover to computer mapping

- personalities were critically important in the 1960s and early 1970s - individual interests determined the direction and focus of research and development in computer cartography (see Rhind, 1988)
- impetus for change began in two communities:

  1. scientists wishing to make maps quickly to see the results of modeling, or to display data from large archives already in digital form, e.g. census tables

     - quality was not a major concern
     - SYMAP was the first significant package for this purpose, released by the Harvard Lab in 1967

  2. cartographers seeking to reduce the cost and time of map production and editing

     - hardware costs limited interest in this technology prior to 1980 to the major mapping agencies

    - the costs of computing have dropped dramatically, by an order of magnitude every six years
        - what costs $1 to compute in 1989 would have cost $10 in 1983 and $100,000 in 1959
        - the development of the microcomputer and the launch of the IBM PC in 1983 have had enormous influence
    - an early belief that the entire map-making process could be automated diminished by 1975 because of difficulties of generalization and design
        - has resurfaced in the context of Expert Systems where the computer chooses the proper techniques based on characteristics of the data, scale, map purpose, etc.
- today, far more maps are made by computer than by hand
    - now few mapmakers are trained cartographers
- also, it is now clear that once created, digital data can serve purposes other than map-making, so it has additional value

Advantages of computer cartography

- lower cost for simple maps, faster production
- greater flexibility in output - easy scale or projection change - maps can be tailored to user needs
- other uses for digital data

Disadvantages of computer cartography

- relatively few full-scale systems have been shown to be truly cost-effective in practice, despite early promise
- high capital cost, though this is now much reduced
- computer methods do not ensure production of maps of high quality
    - there is a perceived loss of regard for the "cartographic tradition" with the consequent production of "cartojunk"

GIS and Computer Cartography

- computer cartography has a primary goal of producing maps
    - systems have advanced tools for map layout, placement of labels, large symbol and font libraries, interfaces for expensive, high quality output devices
- however, it is not an analytical tool
    - therefore, unlike data for GIS, cartographic data does not need to be stored in ways which allow, for example, analysis of relationships between different themes such as population density and housing prices or the routing of flows along connecting highway or river segments

F. GIS COMPARED TO MAPS

Data stores

- spatial data stored in digital format in a GIS allows for rapid access for traditional as well as innovative purposes

- nature of maps creates difficulties when used as sources for digital data
  - most GIS take no account of differences between datasets derived from maps at different scales
  - idiosyncrasies (e.g. generalization procedures) in maps become "locked in" to the data derived from them
  - such errors often become apparent only during later processing of digital data derived from them
- however, maps still remain an excellent way of compiling spatial information, e.g. field survey
  - maps can be designed to be easy to convert to digital form, e.g. by the use of different colors which have distinct signatures when scanned by electronic sensors
- as well maps can be produced by GISs as cheap, high density stores of information for the end user
  - however, consistent, accurate retrieval of data from maps is difficult
  - only limited amounts of data can be shown due to constraints of the paper medium

Data indexes

- this function can be performed much better by a good GIS due to the ability to provide multiple and efficient cross-referencing and searching

Data analysis tools

- GIS is a powerful tool for map analysis
  - traditional impediments to the accurate and rapid measurement of area or to map overlay no longer exist
  - many new techniques in spatial analysis are becoming available

Data display tools

- electronic display offers significant advantages over the paper map
  - ability to browse across an area without interruption by map sheet boundaries
  - ability to zoom and change scale freely
  - potential for the animation of time dependent data
  - display in "3 dimensions" (perspective views), with "real-time" rotation of viewing angle
  - potential for continuous scales of intensity and the use of color and shading independent of the constraints of the printing process, ability to change colors as required for interpretation
- one of a kind, special purpose products are possible and inexpensive

REFERENCES

Dobson, J.E., 1983. "Automated geography," Professional Geographer 35:135-43. Compares the potential of digital and conventional map use. See also the set of discussions published in the next issue.

Goodchild, M.F., 1988. "Stepping over the line: technological constraints and the new cartography," American Cartographer 15:311-9. Argues that cartography's traditions are derived from its reliance on pen and paper, and looks at how these constraints are removed by automation.

McHarg, I.L., 1969. Design With Nature, Doubleday, New York. The definitive work on the use of map analysis in landscape architecture.

Rhind, D.W., 1988. "Personality as a factor in the development of a discipline: the example of computer- assisted cartography," American Cartographer 15:277-90. Examines the history of the digital revolution in cartography and the effect of key personalities.

Tobler, W.R., 1959. "Automation and cartography," Geographical Review 49:526-34. An early perspective and prophesy.

Tomlinson, R.F., 1988. "The impact of the transition from analogue to digital cartographic representation," American Cartographer 15:249-62. An overview from a pioneer of GIS.

EXAM AND DISCUSSION QUESTIONS

1. What steps can be taken to minimize the effects of generalization and error in digital data obtained from maps?

2. "In a computer environment, there is no longer any useful distinction between topographic and thematic maps". Is this true?

3. Using a planimeter, determine the length of time it would take you to measure areas of different shapes and sizes. With these results, estimate the cost of analyzing the Canada Land Inventory using planimetry, assuming that the inventory is shown on 2,000 map sheets, and that there are on average 1,000 areas to be measured on each sheet. (Calculations of this nature were the basis for the cost/benefit study which justified the development of the Canada Geographic Information System in the mid 1960s.)

4. The papers by Tomlinson, Rhind and Goodchild referenced above are published in a special issue of the American Cartographer devoted to the so-called digital revolution in cartography. Compare the different perspectives presented by the authors in the special issue. What might account for the different perspectives the various authors have taken?

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