13 Geovisualization

OVERVIEW

- Using techniques of geovisualization, GIS provides a far richer and more flexible medium for portraying attribute distributions than the paper mapping which is covered in Chapter 12.
- First, through techniques of spatial query, it allows users to explore, synthesize, present (communicate), and analyze the meaning of any given representation.
- Second, it facilitates transformation of representations using techniques such as cartograms and dasymetric mapping.
- Third, GIS-based geovisualization allows the user to interact with the real world from a distance, through interaction with and even immersion in artificial worlds.
- Together, these functions broaden the user base of GIS, and have implications for public participation in GIS (PPGIS).

LEARNING OBJECTIVES

After studying this chapter, students will understand:

- **How GIS facilitates visual communication.**
- **The ways in which good user interfaces can help to resolve spatial queries.**
- **Some of the ways in which GIS-based representations may be transformed.**
- **How 3-D geovisualization and virtual worlds can improve our understanding of the world.**

KEY WORDS AND CONCEPTS

Geovisualization, cartographic transformation, cartograms, dasymetric maps, scientific visualization (ViSC), PPGIS

OUTLINE

CHAPTER OUTLINE

13.1 Introduction: Uses, Users, Messages, and Media

- Effective decision support through GIS requires that computer-held representations (discussed in Chapters 3 and 6) are readily interpretable in the minds of users who need them to make decisions.
- Critiques of GIS have suggested that digital maps and virtual Earths present a privileged' or "God's Eye" view of the world because the selectivity inherent in the representation
    - predates the GIS age: it is evident in the early motivations for creating maps
    - Web mapping and digital spatial data infrastructures expose politically sensitive issues and, in the era of VGI, are still explicitly contested as a consequence
- Geovisualization entails multiple representations of large and complex datasets, on the fly.
    - Different from cartography and map production (see Chapter 12) in that it typically uses an interactive computer environment for data exploration
- Historically, the paper map was the only available interface between the mapmaker and the user
    - it was not possible to differentiate between the needs of different users
    - Application Box 13.1 describes the OpenStreetMap project and "tag wars" occurring as a result of the contested geography of Cyprus.
- Geovisualization builds on the established tenets of map production and display.

    - It is the creation and use of visual representations to facilitate thinking, understanding, and knowledge construction about human and physical environments, at geographic scales of measurement.
    - It is a research-led field that integrates approaches from visualization in scientific computing (ViSC), cartography, image analysis, information visualization, exploratory data analysis (EDA), as well as GIS.
    - Its motivation is to develop theories, methods, and tools for visual exploration, analysis, synthesis, and presentation of geospatial data.

13.2 Geovisualization, Spatial Query, and User Interaction

13.2.1 Overview

- Fundamental to effective geovisualization is an understanding of how human cognition shapes GIS usage, how people think about space and time, and how spatial environments might be better represented using computers and digital data.
- Four principal purposes of geovisualization are explanation, synthesis, presentation and analysis
- The most straightforward way in which reformulation and evaluation of a representation of the real world can take place is through posing *spatial queries*
- These questions are articulated through the GUI paradigm called a WIMP interface, based upon **W**indows, **I**cons, **M**enus and **P**ointers
- The familiar actions of pointing, clicking, and dragging windows and icons are the most common ways of interrogating a geographic database and summarizing results in map and tabular form.

13.2.2 Spatial Query Online and the Geoweb

- Spatial query functions are also central to many Internet GIS applications
    - For many users, spatial query is the end objective of a GIS application
    - In other applications, spatial query is a precursor to more advanced spatial analysis
- Web 2.0 has enabled bidirectional collaboration between web sites and has important implications for geovisualization
    - Applications Box 13.2 describes an online mapping portal

13.3 Geovisualization and Interactive Transformation

13.3.1 Overview

- The term ‘transformation’ is used here in the cartographic sense of taking one vector space (the real world) and transforming it into another (the geovisualization).
- Table 13.1 gives examples of coordinate and cartographic transformations

13.3.2 Cartograms

- Cartograms are maps that lack planimetric correctness, and distort area or distance in the interests of some specific objective.
- The usual objective is to reveal patterns that might not be readily apparent from a conventional map or, more generally, to promote legibility.
- Thus, the integrity of the spatial object, in terms of areal extent, location, contiguity, geometry, and/or topology, is made subservient to an emphasis upon attribute values or particular aspects of spatial relations.
- One of the best known linear cartograms is the London Underground map, devised in 1933 by Harry Beck to fulfil the specific purpose of helping travelers to navigate across the network.
- Figure 13.11 presents an equal population cartogram that ensures that every area is drawn approximately in proportion to its population

13.3.3 Re-modeling spatial distributions as dasymetric maps

- Dasymetric mapping intersects two datasets to obtain more precise estimates of a spatial distribution.
- Examples of this technique are described and illustrated in Figures 13.12 and 13.13
- It is important to remain aware that the visualization of reality is only as good as the assumptions that are used to create it.
- Inference of land use from land cover, in particular, is an uncertain and error-prone process, and there is a developing literature on best practice for the classification of land use using land cover information and classifying different (e.g., domestic versus non-domestic) land uses.

13.4 Participation, Interaction, and Immersion

13.4.1 Public Participation in GIS (PPGIS)

Geovisualization has a range of uses in PPGIS, including:

- Making the growing complexity of land-use planning intelligible
- Transforming the planning profession through use of new tools for community design and decision making.
- Unlocking the potential of the digital data
- Helping communities shift land-use decisions from being more proactive and less reactive.
- Improving community education about local environments
- Improving the feed of information between public and government in emergency planning and management

13.4.2 Interaction and 3-D Representation

- Three dimensional representations may be used to reveal aspects of data that are not easily observable in two dimensions
- The third dimension can also be used to represent built form
    - Popular in globe offerings from Microsoft and Google and often simple to augment through free software such as Google Sketchup
- Virtual models of cities provides a valuable forum for planning through consultation on a range of environmental and economic development issues
    - Biographical Box 13.3 describes the Virtual Kyoto (Japan) project

13.4.3 Hand-Held Computing and Augmented Reality

- These are discussed, along with some of the geovisualization conventions they entail, in Sections 7.6.4 and 11.3.

13.4.4 Scientific Visualization (ViSC) and Virtual Reality

- Visualization in Scientific Computing (ViSC) provides new and more sophisticated ways of visualizing and interacting with the world than conventional mapping alone.
    - Involves wide range of computer devices in different settings
- New computer technologies can be used to partially or wholly immerse users in artificial worlds.
- The advent of immersive and semi-immersive systems has important implications for participation by a broad user base since they allow:
    - Users to access virtual environments and select different views of phenomena.
    - Real-time fly-throughs.
    - Repositioning or rearrangement of the objects that make up virtual scenes.
    - Users to be represented graphically as avatars

- Engagement with avatars connected at different remote locations, in a networked virtual world.
    - The development, using avatars, of new kinds of representation and modeling.
- The linkage of networked virtual worlds with virtual reality (VR) systems.

13.5 Consolidation

- Geovisualization can make a powerful contribution to decision making and can be used to simulate changes to reality
    - the limitations of human cognition mean that it necessarily provides a further selective filter on the reality that it seeks to represent.

ESSAY TOPICS

1. For any one application known to you, describe how modern geovisualization has led to new insights or efficiencies.
2. Identify and describe the major drivers of the move to geovisualization as a means of analyzing data.
3. What are the three functional dimensions of geovizualization recognized by MacEachren et al (2000)? Locate some examples known to you in the cube space created by these dimensions.
4. 'All analysis involves transformation'. To what extent is this idea illustrated by geovizualization?
5. A neglected aspect of geovisualization is the impact of the way that we chose to project our geography. Develop, with examples, a case for regarding projection as a very basic graphic variable.
6. What do you understand by the term dasymetric mapping, and why may it offer improvements on conventional choropleth displays? Illustrate your answer with examples.
7. Distinguish between desktop, semi-immersive and immersive virtual reality and describe at least one application of each in GIS
8. Is the development of public participation in GIS frustrated principally by technical, social, educational, or economic impediments? Give reasons for your answer.
9. One of the objectives of many virtual reality applications in geography is to create photorealistic scenes from an original digital representation. Under what circumstances and in which types of application might this actually reduce the viewer's understanding? (see Fisher and Unwin, 2002)

10. Can geovisualization help us handle uncertainty in the results of geographic information analysis?

MULTIPLE CHOICE QUESTIONS (MCQ)

The emphasis in the chapter on conceptual materials does not readily generate simple MCQs, but here is a collection of five possible questions:

1. The geovisualization process can be broken down into a series of steps. Order these into their logical sequence, and number them starting with ‘1’ through to ‘6’:
    a. Analysis
    b. Measurement and representation
    c. Feedback
    d. Conception
    e. Real world
    f. Exploration

2. Write one sentence descriptions of the basis of the following geovisualization techniques:
    a. Linear cartogram …………………………
    b. Equal population cartogram …………………………
    c. Parallel co-ordinates plot …………………………
    d. Area cartogram …………………………

3. Rank the following sources of information in order of their probable suitability for producing a map of the true population densities of an area (Answer 1 to 4, with 1 as the most suitable):
    a. Land use classified from aerial photography
    b. Low resolution imagery classified by an unsupervised process
    c. Point pattern of ZIP or Post Code reference points
4. Expand the following acronyms used in geovisualization work:
    a. ViSC ………………………
    b. EDA ………………………
    c. WIMP ………………………
    d. PPGIS ………………………

ACTIVITIES

1. There is a number of highly graphic websites that describe geovisualization research. One of the best is that developed by the GeoVISTA Center at Penn State University (see Box 13.3) at www.geovista.psu.edu. From the wealth of materials at this site, we suggest that you navigate to the 'software demos' section and examine the effectiveness of any or all of the following advanced visualization tools:
    a. Scatter plot matrices
    b. Dynamic parallel co-ordinates plots
    c. Simulation applied to spatial statistics (advanced)
    d. Temporal legends

2. Why not also download and examine the geovisualization environment called GeoVISTA Studio? The system is well-documented. A suitable topic for discussion is to assess the important ways that it differs from a standard GIS. Alternatively, compare and contrast the Penn. State approach with that of Wood's Landserf system (see Activity 6).

3. Visualizing health data. Organize the class into teams, and ask each to develop and describe the methods they would use to visualize the pattern of incidence of a rare disease such as TB or cancer across a large city. In doing this, attention needs to be drawn to the nature of the available disease data, which can be assumed to be some form of ZIP or Post Code, and the baseline population at risk data, which should be assumed to be from a standard decennial census of population. One approach, using the regular GIS method of kernel density estimation is outlined at www.agocg.ac.uk/wshop/sosci/atkinson.htm .

4. A classroom discussion. Ask the class to read the famous paper by J. Brian Harley (1989) Deconstructing the map, Cartographica, 26(2): 1-20. First summarize Harley's arguments and then discuss their merits. How do you think that Harley would have 'deconstructed' current geovisualization activity?

5. One of the best free geovisualization systems yet produced is that written over the past decade by Jo Wood, of the City University, London, England GIS group. His system can be downloaded from www.soi.city.ac.uk/~jwo/landserf and then used to experiment with a number of geovisualizations. Although originally developed for morphometric analysis of terrain from DEM data, it is now a very serious, if specialized, GIS. Even if you do not

download the system, visit the image gallery at the website to explore some of its geovisualization capabilities.

6. Visit www.ncgia.ucsb.edu/projects/Cartogram_Central/gallery.html and examine the example cartograms, then attempt a classification of the various types that have been recognized. Whilst at the site, follow the link to www.mapresso.com to see an animation of Dorling's circle growing algorithm for cartogram construction. MAPresso also has code to create continuous choropleth maps. Other examples of Dorling's (collaborative) work can be viewed at www.worldmapper.org.

FURTHER READING

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Dorling D. and Thomas B. 2004 *People and Places: a 2001 Census Atlas of the UK*. Bristol, UK: Policy Press.

Hearnshaw H.M. and Unwin DJ. (eds) 1994 *Visualization in Geographical Information Systems*, Wiley: London

Readings on scientific visualization in GIS. The visually stunning cover of this book was produced by Jo Wood, using the GRASS system

MacEachren A. 1995 *How Maps Work: Representation, Visualization and Design*. New York: Guilford Press.

MacEachren A.M., Gahegan M., Pike W., Brewer I., Cai G., Lengerich E., and Hardisty F. 2004 'Geovisualization for knowledge construction and decisionsupport'. *Computer Graphics and Applications* **24**(1), 13–17.

Raubal M. 2009. Cognitive engineering for geographic information science. *Geography Compass* 3: 1–18.

Tufte E.R 2001 *The Visual Display of Quantitative Information* (2nd edn). Cheshire, CT: Graphics Press.

Unwin D. and Fisher P. 2002 *Virtual Reality in Geography*, Wiley: London

An edited collection of early experiments with virtual reality in geography. The essay by Mark Gillings makes a case against photo-realism in archaeological applications.

RELATED READING

Longley P.A., Goodchild M.F., Maguire D.J. and Rhind D.W. (eds) 2005 *Geographical Information Systems: Principles, Techniques, Management and Applications* (abridged edition). Hoboken, NJ: Wiley.
28 Interacting with GIS, M J Egenhofer and W Kuhn. pp. 401–12.
52 Managing public discourse: towards the augmentation of GIS with multimedia, M J Shiffer, pp. 723–732.

ONLINE RESOURCES

ESRI Virtual Campus course, *Turning Data into Information* by Paul Longley, Michael Goodchild, David Maguire, and David Rhind (campus.esri.com)

Module 2: Cartography, Map Production, and Geovisualization
Section 13.2, Module 2: Cartography, Map Production, and Geovisualization
 Unit: Scientific visualization,
 Sub-unit: Purposes of visualization
 Sub-unit: Internet GIS as a site selection tool

Section 13.2.2, Module 2: Cartography, Map Production, and Geovisualization, Unit: Scientific visualization,
 Sub-unit: Interacting with representations on the Internet

Section 13.3, Module 2: Cartography, Map Production, and Geovisualization, Unit: Advanced methods for improving visualizations
 Unit: Representing attributes and spatial objects
 Sub-unit: Representing spatial objects

Section 13.4.1, Module 2: Cartography, Map Production, and Geovisualization, Unit: Scientific visualization

Section 13.4.2, Module 2: Cartography, Map Production, and Geovisualization, Unit: Scientific visualization
 Sub-unit: Interacting with representations to support decisions