2 A gallery of applications

OVERVIEW

The chapter gives a flavor of the breadth and depth of real-world GIS implementations. It considers:

- How GIS affects our everyday lives;
- How GIS applications have developed, and how the field compares with scientific practice;
- The goals of applied problem solving;
- How GIS can be used to study and solve problems in transportation, the environment, local government, and business.

LEARNING OBJECTIVES

The chapter teaches students to:

- **Grasp the many ways in which we interact with GIS in everyday life;**
- **Appreciate the range and diversity of GIS applications in environmental and social science;**
- **Be able to identify many of the scientific assumptions that underpin real-world applications;**
- **Understand how GIS is applied in the representative application areas of transportation, the environment, local government, and business.**

KEYWORDS AND CONCEPTS

Problem solving with GIS; the five M's; government and public service; tax assessment; business and service planning; geodemographics; housing study; logistics and transportation; emergency evacuation; environment; deforestation

OUTLINE

2.1 Introduction

2.2 Science, geography, and applications

2.3 Representative application areas and their foundations

2.4 Concluding comments

CHAPTER SUMMARY

2.1 Introduction

2.1.1 One day of life with GIS

- A fictitious daily diary highlights how GIS:
  - affects each of us, every day;
  - can be used to foster effective short- and long-term decision making;
  - can be applied to many socio-economic and environmental problems;
  - encourages public participation in decision making
  - supports mapping, measurement, management, monitoring, and modeling operations;
  - generates measurable economic benefits;
  - requires key management skills for effective implementation;
  - provides a challenging and stimulating educational experience for students;
  - can be used as a source of direct income;
  - can be combined with other technologies;
  - is a dynamic and stimulating area in which to work.

2.1.2 Why GIS?

- GIS is being widely implemented because of

- Wider availability of GIS through the Internet, as well as through organization-wide local area networks.
- Increasingly wide availability of low-cost, locationally aware, hand-held devices.
- Reductions in the price of GIS hardware and software because economies of scale are realized by a fast-growing market.
- Greater awareness that decision making has a geographic dimension.
- Greater ease of user interaction, using standard windowing environments.
- Better technology to support applications, specifically in terms of visualization, data management and analysis, and linkage to other software.
- Proliferation of geographically referenced digital data, such as those generated using GPS technology or supplied by value-added resellers (VARs) of data.
- Availability of open-source, free to use software across the Web, in addition to sophisticated packaged GIS solutions that are ready to run out of the box.
- The accumulated experience of applications that *work*.

2.2 Science, geography, and applications

2.2.1 Scientific questions and GIS operations

- Within the spatial domain, the goals of applied problem solving include,
  - Managing spatial operations and inventories
  - Rational, effective, and efficient allocation of resources
  - Monitoring and understanding observed spatial distributions of attributes
  - Understanding the difference that place makes
  - Understanding of processes in the natural and human environments
  - Prescription of strategies for environmental maintenance and conservation

2.2.2 GIScience applications

- GIS applications need to be grounded in sound concepts and theory.

2.3 Representative application areas and their foundations

2.3.1 Introduction and overview

- Applications generally fulfill the five M's of GIS: mapping, measurement, monitoring, modeling, and management
- Applications can be traditional, developing, and new
- Figure 2.6 shows the classic Rogers model of innovation diffusion and the text applies this to GIS
- Four domains of GIS applications are: Government and public service; Business and service planning; Logistics and transportation; and Environment.

2.3.2 Government and public service

- As GIS has become cheaper, so it has come to be used in government decision making at all levels from the nation to the neighborhood.
- Figure 2.6 shows the hierarchy of GIS use in government decision-making
- Table 2.1 summarizes GIS applications in local government including inventory applications, policy analysis, and management/policy-making

2.3.2.2 Case study: GIS in tax assessment

- Scientific foundations (2.3.2.4)
    - is dependent on an unambiguous definition of parcels, and common standards about how different characteristics (such as size, age, and value of improvements) are represented.
    - although the application is driven by results rather than scientific curiosity, it follows scientific procedures of controlled comparison.
- Principles
    - Combines Tobler's First Law with local knowledge

- Techniques
    - Tax assessment requires a good database, a plan for system management and administration, and a workflow design.
- Analysis
    - Tax assessment uses standard GIS techniques such as proximity analysis, and geographic and attribute query, mapping, and reporting.
- Generic scientific questions (2.3.2.5)
    - Once a property database has been created, it becomes a very valuable local asset
    - Public works departments may use it to label access points for repairs and meter reading
    - Housing departments may use it to maintain data on property condition
    - Many other departments may like shared access to a common address list for record keeping and mailings.
- Management and Policy (2.3.2.6)
    - Easy to develop a cost-benefit case for this application
    - GIS is an important tool for efficiency and equitable local government.

2.3.3 Business and service planning

- Geodemographic analysis is an important operational tool in market area analysis, where it is used to plan marketing campaigns.
    - *Geodemographics* is a shorthand term for composite indicators of consumer behavior that are available at the small-area level (e.g., census output area, or postal zone).
    - Often combined with *lifestyles* data on the consumption choices and shopping habits of individuals
    - *Market area analysis* describes the activity of assessing the distribution of retail outlets relative to the greatest concentrations of potential customers.

- Is increasingly being adapted to improving public service planning, in areas such as health, education, and law enforcement.
- Tools are used to analyze and inform the range of *operational*, *tactical*, and *strategic* functions of an organization.
    - Operational functions concern the day-to-day processing of routine transactions and inventory analysis in an organization, such as stock management (see Logistics section following)
    - Tactical functions require the allocation of resources to address specific (usually short term) problems, such as store sales promotions.
    - Strategic functions contribute to the organization's longer-term goals and mission, and entail problems such as opening new stores or rationalizing existing store networks

2.3.3.2 Case study: Hierarchical diffusion and convenience shopping (Tesco)

- Objective is to promote a new 'Express' format Tesco store to encourage repeat patronage.
- Method
    - Identify postal addresses all of the households within a 1 km radius.
    - Overlay geodemographic profiles in order to tailor coupon offerings to the differing consumption patterns (from lifestyles data)
- Scientific foundations
    - Distance decay and Tobler's First Law
        - An assumption that the differences in the observed social and economic characteristics of residents between neighborhoods are greater than differences observed within them.
        - Has the potential to invoke ecological fallacy – individual resident in an area is assigned the characteristics of the area.
        - Text discusses ethical and scientific implications

- Principles
    - Linear distance versus other kinds of distance (network, psychological)
- Techniques
    - Assigning postcode coordinates to catchment area requires point in polygon analysis
- Analysis
    - Need to include analysis of spatial interaction between this and other stores
- Generic scientific questions (2.3.3.5)
    - While it is the mix of individuals with particular characteristics that largely determines the likely store turnover of a particular location, this example illustrates the kinds of simplifying assumptions that we may choose to make using the best available data in order to represent consumer characteristics and store attributes.
    - Even blunt-edged tools can increase the effectiveness of operational and strategic R&D activities many-fold.
- Management and policy (2.3.3.6)
    - Increasing role of SAPs as mainstream managers alongside accountants, lawyers, and general business managers.
    - Key roles in organizational activity such as marketing, store revenue predictions, new product launch, improving retail networks, and the assimilation of pre-existing components into combined store networks following mergers and acquisitions.

2.3.4 Logistics and transportation

- Deal with the movement of goods and people from one place to another, and the infrastructure (highways, railroads, canals) that moves them.
- Has two parts
    - the static part that deals with the fixed infrastructure, and

- the dynamic part that deals with the vehicles, goods, and people that move on the static part.

- GPS is an important technology in this area
- Many applications involve optimization, or the design of solutions to meet specified objectives

2.3.4.2 Case study: Planning for emergency evacuation

- Discusses a planning tool that allows neighborhoods to rate the potential for problems associated with evacuation, and to develop plans accordingly.
  - The tool uses a GIS database containing information on the distribution of population in the neighborhood and the street pattern.
  - The result is an evacuation vulnerability map and identification of worst-case scenarios for a given locations.
- Method (2.3.4.3)
  - Census data are used to determine population and household counts, and to estimate the number of vehicles involved in an evacuation.
  - The locations of streets are obtained from street centerline files, which give the geographic locations, names, and other details of individual streets
  - Every intersection in the network is tested to see if it presents a bottleneck, by dividing the total number of vehicles that would have to move out of the neighborhood by the number of exit lanes.
- Scientific foundations
  - Census data are aggregated to areas that, while small, nevertheless provide only aggregated counts of population.
  - The street layouts of TIGER and other sources can be out of date and inaccurate, particularly in new developments, although users willing to pay higher prices can often obtain current data from the private sector.
  - the essentially geometric approach cannot deal with many social issues: evacuation of the disabled and elderly, and issues of culture and language that may impede evacuation.

- Principles
    - Central to the analysis is connectivity, an instance of a *topological* property
- Techniques
    - Spatial interpolation performed across the network from the values calculated at intersections
    - Shortest path
- Analysis
    - an excellent example of the use of GIS analysis to *make visible what is otherwise invisible*.
- Generic scientific questions (2.3.4.5)
    - Logistic and transportation applications of GIS rely heavily on representations of networks, and often must ignore off-network movement.
- Management and policy (2.3.4.6)
    - GIS is applied to this area in all three modes - operational, tactical and strategic

2.3.5 Environment

- Monitoring land use change
- Assessing the impact of urban settlements
- Simulation of processes in the urban and natural environment

2.3.5.2 Case study: Deforestation in the Philippines

- Objective is to identify a range of different development scenarios that make it possible to anticipate future land use and habitat change, and hence also anticipate changes in biodiversity.
- Method (2.3.5.3)
    - used qualitative data collected through stakeholder interviews in a quantitative GIS-based analysis to calculate the probabilities of land use transition under three different scenarios of land use change

- The three different scenarios not only resulted in different forest *areas* by 2019 but also different *spatial patterning* of the remaining forest.

- Scientific foundations (2.3.5.4)
  - The theme of inferring *process* from *pattern*, or function from form, is a common characteristic of GIScience applications.
  - Contrasts nomothetic and idiographic approaches
- Principles
  - GIS makes it possible to incorporate diverse physical, biological, and human elements, and to forecast the size, shape, scale, and dimension of land use parcels.
  - It makes use of the core GIS idea that the world can be understood as a series of layers of different types of information, that can be added together meaningfully through overlay analysis to arrive at conclusions.
- Analysis
  - Process is inferred not just through size measures, but also through spatial measures of connectivity and fragmentation
- General scientific questions (2.3.5.5)
  - Irrespective of the quality of the measurement process, uncertainty will always creep into any prediction
  - Data are never perfect
  - Simulations are subject to exogenous forces not included
  - GIS users should not think of systems as black boxes,
  - Users of GIS should always know exactly what the system is doing to their data.
  - User awareness of these important issues can be improved through appropriate metadata and documentation of research procedures
  - The results of analysis should always be reported in sufficient detail to allow someone else to replicate them.

2.4 Concluding comments

- The principles of the scientific method have been stressed throughout
    - the need to maintain an enquiring mind, constantly asking questions about what is going on, and what it means;
    - the need to use terms that are well-defined and understood by others, so that knowledge can be communicated;
    - the need to describe procedures in sufficient detail so that they can be replicated by others; and
    - the need for accuracy, in observations, measurements, and predictions.

ESSAY TOPICS

1. Write an account of how you think that GIS impacts on your daily life. Now imagine the world in a decade's time and speculate how things might have changed. (Save your answer for future reference!)
2. Since the mid 1990s there has been an explosive growth in the range of applications of GIS technology. Explain why this has happened.
3. It is often suggested that GIS is an 'applications led' technology. What does it mean to be 'applications led' and what are the likely consequences for the design and development of GI software?
4. Write an account of the ways in which GIS can assist in business logistics.
5. One of the major ethical issues raised by critics of GIS is that of protecting personal privacy. List and review the privacy implications of each of the case study applications discussed in this chapter.
6. How has the emergence of the Global Positioning System (GPS) affected applications in GIS?
7. Geodemographics assumes that where you live is a good predictor of your social and economic status ('birds of a feather flock together'). To what extent is this assumption justified?

MULTIPLE CHOICE QUESTIONS (MCQ)

The material, and the intended learning objectives set for this chapter, do not readily lend themselves to the use of MCQs.

CLASS AND INDIVIDUAL ACTIVITIES

1. In Chapter 2 (2.3.1), the five M's of GIS are claimed to be mapping, measuring, management, monitoring and modeling. Examine each of the applications described in Sections 2.3.2, 2.3.3, 2.3.4 and 2.3.5, and in each case classify the application into its principal M. Is there anything to be learned from these differences?

2. Devise a diary for your own activity patterns for a typical (or a special) day, like that described in Section 2.1.1, and speculate how GIS might affect your own daily activities. What activities are not influenced by GIS, and how might its use in some of these contexts improve your daily quality of life?

3. Compare and contrast the operational, tactical, and strategic priorities of the GIS specialists responsible for the specific applications described in Sections 2.3.2, 2.3.3, 2.3.4 and 2.3.5.

4. The Chapter provides detail of four applications of GIS (2.3.2.3, 2.3.3.2, 2.3.4.2 and 2.3.5.2). In each case, identify the 'added value' in using a GIS in preference to a standard data base management system (DBMS).

5. Visit gbnames.publicprofiler.org and type in your own surname and/or those of several famous people in history. You will see that the information returned to you for each search includes an index of the geodemographic profile of people with the selected surname. Does this descriptive profiling tell you anything useful?

6. Assume that you are working in a brand new GIS facility located in a water supply/resources company. Your responsibility extends to the rivers and water distribution mechanisms over a county-sized area. Your GIS is needed to support operations such as monitoring rainfall, reservoir capacity, stream flow and abstraction for public use. Think about, write down, and justify how the GIS could be used. This outline project briefing can be modified according to taste to address almost any applications domain. The books listed under Resources can be used to assist!

7. A role-play simulation (see Gold et al., Section 5.6). In a GIS context a useful simulation to set up is a 'competitive' bid for a contract to create a specific GIS. Divide the class into teams for this, spreading the exercise over at least three formal sessions. Each team takes on the role of a GI consultancy bidding for a contract that addresses a deliberately, but realistically brief and poorly specified request for proposals (RFP) drafted by the instructor. Each bid must specify the number of person days that the work will take, and include costings for completing the work based on labour market rates, supplied by the

instructor. The final session should consist of timed presentations with voting to decide which bid wins. A variant of this is to invite groups to bid for one of a range of consultancy projects, spread across a range of applications domains. This exercise is based on a similar suggestion from Peter Keene: Keene, P. (1988) Teaching physical geographers to talk. Journal of Geography in Higher Education, 12 (1), 85-94. It also introduces students to terminology used in the AM/FM Project Life Cycle Model, an introduction to which can be found at the Geographer's Craft website: http://www.colorado.edu/geography/gcraft/notes/lifecycle/lifecycl.html

8. A similar role play, making use of the same sources of reference, is drafting a Request for Information (RFI) for some obvious GI systems. Use four groups of 14 or so, asking them to produce a formal RFI of, say, 1,500 words. Students are required to act as GIS-literate members of an IT section, requested by management to produce such a document. It is assumed that it is in their interests to procure such a system. Topics should be as specific as possible, even down to using agencies that actually exist and that have formal terms of reference or obvious objectives (eg. a supermarket planning system to vary their product mix geographically, a specified River Authority, a police authority). In seminar, each presents the RFI to their 'senior management' for approval (15 minutes/team).

9. Reading a paper. All students read the same paper and isolate what they think to be the two most important issues that arise from their reading. Students then discuss the paper in pairs, isolating the two most important of their four issues. Next, the exercise is repeated in groups of four and so on until a suitable stopping point arises. For obvious reasons, this device is called a pyramid exercise, and its value lies in the student discussion. For this chapter, and although the detail is dated, a suitable paper is that by Goddard and Openshaw: Openshaw, S. & J Goddard (1987) Some implications of the commodification of information and the emerging information economy for applied geographical analysis in the United Kingdom *Environment and Planning A* 19, 1423 - 1439

FURTHER READING

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Bonham-Carter G F 1994 *Geographic information systems for geoscientists: modeling with GIS*. New York, Pergamon (see the various applications developed throughout the book).

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Longley P A, Higgs G, Martin D J 1996 The rates revisited? A geographical reassignment of property valuations and local tax burdens under the council tax. *Environment and Planning C* 14: 101-20

Martin D J, Longley P A 1995 Data sources and their geographical integration. In P Longley, G Clarke (eds) *GIS for Business and Service Planning*. New York, John Wiley: 15-32

O'Looney J. 2000 *Beyond Maps: GIS and Decision Making in Local Government*. Redlands, CA: ESRI Press.

RELATED READING

Maguire D.J., Goodchild M.F. and Rhind D.W. (eds) 1991 *Geographical Information Systems: Principles and Applications*. Harlow, UK: Longman (text available online at www.wiley.co.uk/gis/volumes.html).

See all the chapters in Section III Applications

ONLINE RESOURCES

ESRI Virtual Campus, (training.esri.com) - see various courses on applications of GIS

There are numerous blogs detailing many new and innovative applications of GIS:

- http://www.spatiallyadjusted.com/

- http://www.esri.com/blogs
- http://blog.gisuser.com/
- http://mapperz.blogspot.com/