Unit 002 - What is Geographic Information Science?

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Advanced Organizer

Topics covered in this unit

- definitions of geographic information, GI technologies, GI systems and GI science

Learning Outcomes

- after learning the material covered in this unit, students should be able to:
  - define basic terms associated with geographic information including
    - technologies, systems, science, studies
  - explain why geographic information systems are important
  - explain why a science of geographic information is needed
  - know where to look for more information on these topics

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Metadata and Revision History

What is Geographic Information Science?

1. Opening definitions

1.1. Geographic information

- is information about places on the Earth's surface
- knowledge about *where* something is
- knowledge about *what* is at a given location

- can be very detailed, for example:
  - information about the locations of *all* buildings in a city
  - information about *individual* trees in a forest
- can be very coarse, for example:
  - climate of a large region
  - population density of an entire country
- in these examples it's the *geographic* resolution that varies

- other characteristics of geographic information are:
  - often relatively static
    - natural features and many features of human origin don't change rapidly
    - only static information can be portrayed on a static paper map
  - can be very voluminous
    - a terabyte (10^{12} bytes) of data is sent from a single satellite in one day
    - gigabytes (gigabyte = 10^{9} bytes) of data are needed to describe the US street network

1.2. Digital geographic information

- geographic information expressed in digital form
  - coded in an alphabet that uses only two characters (0 or 1), called ***bits***
  - data is represented as sequences of bits
  - GISCC section "Defining characteristics of computing technology" will explore this topic
- once a package of information is in digital form, it looks like any other package of information - a 'bag of bits'
  - many kinds of information can be handled by the same technology
    - a digital disk can store words, numbers, maps, sounds
    - the Internet can transmit any type of information

1.3. Geographic information technologies

- are technologies for collecting and dealing with geographic information
- there are three main types:

1.3.1. Global Positioning System (GPS)

- a system of Earth-orbiting satellites transmitting precisely timed signals
  - a similar system deployed by the Russian Federation is called GLONASS (global navigation satellite system)
- signals are received by a special electronic device
  - the smallest versions are hand-held and even smaller
- provides direct measurement of position on the Earth's surface
- location is expressed in latitude/longitude or other standard system
- see GISCC section Global Positioning Systems

1.3.2. Remote sensing

- use of Earth orbiting satellites to capture information about the surface and atmosphere below
- satellites vary depending on how much detail can be seen, what parts of the electromagnetic spectrum are sensed
- signals transmitted to Earth receiving stations where they are transformed for dissemination as digital images
- see the Remote Sensing Core Curriculum

1.3.3. Geographic information system (GIS)

- a system for input, storage, manipulation, and output of geographic information
- a class of software
- a practical instance of a GIS combines software with hardware, data, a user, etc., to solve a problem, support a decision, help to plan
- the next section is a basic introduction to GIS

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2. What is GIS?

- GIS stands for "*geographic information system"*
  - is a special kind of "information system"
    - information systems are used to manipulate, summarize, query, edit, visualize - generally, to work with information stored in computer databases
    - a commonly encountered application are the information systems used by airlines and travel agents to make reservations, check in passengers, etc.
  - uses special information about *what is where* on the Earth's surface
- there are many kinds of information used in computers
  - numbers:
    - computers are used to add, multiply, divide, ...
  - text:
    - computers are used as word processors
    - to create, edit, send, and receive text
  - pictures:

        - computers are used as image processors
    - lists, tables
        - in spreadsheets
    - sounds
        - in music synthesizers
    - maps and images of the Earth's surface
        - in GIS
- why use computers to handle information?
    - easy to store, retrieve, query, manipulate, send, receive, copy, display...
        - most of these things can be done by hand, but only slowly
        - paper maps are difficult to handle, store, send, receive, copy...
    - GIS makes all of these operations easier
- today, all kinds of information are being handled in computers
    - good to have one place to go for all kinds of information
    - one system (the Internet) used to send, receive all kinds

2.1. What does a GIS look like? How would I know one if I saw one?

- are two distinct meanings of the question "is this a GIS?"
    1. GIS is a real application, including the hardware, data, software and people needed to solve a problem (a GIS *application*)
    2. GIS is a type of software sold by a software developer (compare Microsoft Word)
        - will focus on #1 first

- GIS hardware is like any other computer (nothing special about the hardware)
    - keyboard, display monitor (screen), cables, Internet connection
- with some extra components perhaps
    - maps come on big bits of paper
        - need specially big printers and plotters to make map output from GIS
        - need specially big devices to scan and input data from maps to GIS
            - digitizers, scanners
    - but not all GISs will need these
- what is important is the kind of information that's stored
    - information about *what* is *where*
        - the contents of maps and images
    - you would know a computer was being used for GIS because the data stored in it would include maps and images
- but in addition, a GIS includes the tools to do things with this information
    - special functions that work on geographic information
    - functions to:
        - display on the screen
        - edit, change, transform
        - measure distances, areas
        - combine maps of the same area together
    - those were simple, but functions can be much more sophisticated
        - keep inventories of what is where
        - manage properties, facilities

judge the suitability of areas for different purposes
        - help users make decisions about places, to plan
        - make predictions about the future
    - these sophisticated functions require human expertise as well

- the functions that a GIS can perform are part of its software
    - now we are into the second meaning above - a GIS is a type of software
    - the user combines the software with his or her data and performs various functions
    - this software will probably have been supplied by a company that specializes in GIS
    - the price of the software may be anywhere from $50 to $50,000
    - there are many different GIS software vendors
        - some specialize in GIS
        - for others, GIS is one of many markets for their products
- there are several other versions of "What is GIS on the net"
    - see the Web References section below

2.2. What is GIS used for?

- why go to all this trouble and expense?
- who needs to know what is where?
- here are just a few of the most important uses:

2.2.1. Utility companies

- includes gas, phone, electric, water, cable TV companies
- a single company may have hundreds of thousands of customers
    - each with a connection to the network
    - plus thousands of miles of wires, underground pipes
    - with transformers, switches, poles...
    - representing billions of dollars of installed infrastructure
- a utility company receives thousands of maintenance calls per day
- they need to:
    - keep track of all this activity
    - maintain accurate information about what is where
    - keep records up to date
    - make daily work assignments to crews
    - provide information to others
        - e.g. another company wishes to dig up a street, what do they need to avoid?

2.2.2. Transportation

- a state department of transportation needs to
    - store information on the state of pavement everywhere on the state highway network
    - maintain an inventory of all highway signs

    - analyze data on accidents, look for 'black spots'
- a traveling salesperson needs
    - a system in the car for finding locations, routes
- a delivery company, e.g. Federal Express, UPS, needs to
    - keep track of shipments, know where they are
    - plan efficient delivery routes
- a school bus operator needs to
    - plan efficient collection routes
- a transit authority needs to
    - know where transit vehicles are at all times
- studies have shown substantial savings when routes and schedules are managed using GIS

2.2.3. Farmers

- increasingly use detailed maps and images to plan crops
    - analyze yields
    - plan efficient application of fertilizers, chemicals
- these techniques are known as ***precision agriculture***

2.2.4. Forestry

- need to keep track of what timber is growing where
- need to be able to plan timber harvest
    - how to provide for timber needs now, but maintain a healthy forest resource for the future
- need to plan locations of roads, methods of cutting and removing logs to comply with environmental regulations
- need to manage forests for many purposes, including recreation

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3. Systems, science and studies

- ***what does it mean to be "doing GIS"?***
    - for a lengthier discussion see Wright, Goodchild, and Proctor (1997)
- it might mean *using the tools* of **Geographic Information Systems** to solve a problem
    - such as those in the previous examples
    - a GIS project might have the following stages:
        1. define the problem
        2. acquire the software (and the hardware?)
        3. acquire the data
        4. clean the database
        5. perform the analysis
        6. interpret and present the results
- or it might mean *helping to build the tools*
    - adding to existing geographic information technologies

helping to invent or develop new ones
- or it might mean *studying the theory and concepts* that lie behind GIS and the other geographic information technologies
    - thus GIS = **Geographic Information Science**
        - a different way of decoding the acronym 'GIS'
    - more discussion follows
    - Goodchild (1992) discusses what a GIScience might be in detail
- Forer and Unwin (1997) add a fourth variant
    - is a third way of decoding 'GIS' = **Geographic Information Studies**
    - are *studies of the societal context* of geographic information
        - the legal context
        - issues of privacy, confidentiality
        - economics of geographic information

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4. Geographic information science (finally!)

- is the science behind the technology
    - considers fundamental questions raised by the use of systems and technologies
    - is the science needed to keep technology at the cutting edge
- is a multidisciplinary field
    - many disciplines contribute to these issues
        - e.g. cartography, geodesy, photogrammetry, ...
        - today we should extend the list to include areas like cognitive psychology, spatial statistics
    - the terms 'geomatics' and 'geoinformatics' have similar meaning
        - 'geomatics' is more popular in Europe and Canada
- is it 'spatial' or 'geographic'?
    - 'geographic' has to do with the Earth
        - its two-dimensional surface
        - its three-dimensional atmosphere, oceans, sub-surface
    - 'spatial' has to do with any multi-dimensional frame
        - medical images are referenced to the human body
        - engineering drawings are referenced to a mechanical object
        - architectural drawings are referenced to a building
    - 'geographic' is a subset of 'spatial'
        - often the terms are used interchangeably
    - 'geospatial' is sometimes used
        - does 'geographic' sound too 'soft'?

4.1. The big questions of GIScience

- what questions does GIS raise?
    - or geographic technologies in general
- questions of representation
    - the Earth's surface is infinitely complex
        - decisions must be made about how to capture it, represent it in a digital

system
        - about how and where to sample
        - about what data format options to use
    - what criteria can be used to select a representation?
        - accuracy of representation
        - accuracy of predictions, decisions based on representation
        - minimizing volume of data
        - maximizing speed of computation
        - compatibility with other projects, users, software
        - compatibility with how people actually think about the world
- how to assess a representation
    - how to measure its accuracy
    - how to measure what's missing, its uncertainty
    - how to express these in ways that are meaningful to the user
        - how to describe them in documentation
        - how to visualize them
        - how to simulate their impacts
- questions about the relationship between the representation and the user
    - how to people, rather than machines, think about the world?
    - how can computer representations be made more like the ways people think?
    - how do people reason with, learn about, communicate about the geographical world?
    - how can output from GIS be made more intelligible
        - to certain types of users, e.g. children
        - under certain constrained situations, e.g. in a fighter cockpit
- questions about data models and structures
    - how to store a given representation efficiently
    - how to retrieve information rapidly through appropriate indexing
    - how to achieve interoperability between systems
- questions about the display of geographic data
    - how do methods of display affect the interpretation of geographic data?
    - how can the science of cartography be extended to take advantage of the power of the digital environment?
    - what basic properties of display determine its success?
- questions about analytical tools
    - what is the nature of human spatial intuition, and how can it be enhanced by GIS tools?
    - what methods of analysis are needed to support specific types of decisions made using GIS?
    - how can methods of analysis be presented so that users can choose effectively between them?
- there are many other big questions
    - a quick look at recent books and papers in the GIS research literature will suggest many more
- the University Consortium for Geographic Information Science is a group of over 30 U.S. universities dedicated to promotion of GIScience
    - the UCGIS research agenda includes many important and current research areas in GIScience

- see http://www.ucgis.org

4.2. The disciplines of GIScience

- disciplines that have traditionally researched geographic information technologies
  - cartography, the science (and art) of map-making
  - remote sensing, the science of Earth observation from space
  - geodesy, the science of accurate measurement of the Earth
  - surveying, the science of accurate measurement of natural and human-made features on the Earth
  - photogrammetry, the science of measurement from photographs and images
  - image processing, the science of handling and analysis of image data
- disciplines that have traditionally researched digital technology and information in general
  - computer science, particularly:
    - databases
    - computational geometry
    - image processing, pattern recognition
  - information science
- disciplines that have traditionally studied the Earth, particularly its surface and near-surface, in either physical or human aspect
  - geology
  - geophysics
  - oceanography
  - agriculture
  - biology, particularly ecology, biogeography
  - environmental science
  - geography
  - sociology
  - political science
  - anthropology
  - and many more
  - these sciences are all potential *users* of GIS
- disciplines that have traditionally worked to integrate knowledge from different disciplines, within the context of the Earth's surface
  - geography
  - environmental science
  - newer fields like global change, integrated assessment
- disciplines that have traditionally studied the nature of human understanding, and its interactions with machines
  - psychology, particularly cognitive psychology, environmental psychology
  - cognitive science
  - artificial intelligence

4.3. How do I find out more about GIS and GIScience?

- besides studying further in this curriculum

- look up the references given below
- surf the Web
- settle down with a good book

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5. Summary

- geographic information is information about places on the earth's surface
- geographic information technologies include global positioning systems (GPS), remote sensing and geographic information systems.
- geographic information systems are both computer systems and software
- GIS can have many different manifestations
- GIS is used for a great variety of applications
- geographic information science is the science behind GIS technology

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6. Review and study questions

1. What do 'geographic' and 'spatial' mean, and why is the term 'geospatial' popular?

2. Identify any traditional disciplines missing from the lists given in the unit and explain their relationship to GIScience.

3. Explain why geographic information science should or should not be a distinct discipline:
   - with its own journals.
   - with its own departments.
   - with its own degrees.
4. Cartography was identified as both a science and an art; why is this, and why were other disciplines not similarly identified?

5. It is tempting to think of a GIS as a computer containing maps but is that not like talking about the automobile as a horseless carriage? Explain why this vision is limiting.

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7. References

7.1. Print references

7.1.1. Cited references

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Longley, M.F. Goodchild, D.J. Maguire, and D.W. Rhind (editors) *Geographical Information Systems: Principles, Techniques, Management and Applications*. Cambridge: GeoInformation International.

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7.1.2. Basic and practical introductions to GIS

John C. Antenucci and others (1991) *Geographic Information Systems: A Guide to the Technology*. New York : Van Nostrand Reinhold.

Tor Bernhardsen (1992) *Geographic Information Systems*. Arendal, Norway: Viak (but widely available in the US).

Keith C. Clarke (1997) *Getting Started with Geographic Information Systems*. Upper Saddle River, NJ: Prentice Hall.

Michael N. DeMers (1997) *Fundamentals of Geographic Information Systems*. New York: J. Wiley & Sons.

- references to more advanced books will be found elsewhere in this curriculum

- all of these and many others are obtainable through online GIS 'bookstores':
  - http://www.esri.com
  - http://www.geoplace.com

7.2. Web references

- some cool sites that do GIS over the Web
  - http://www.mapquest.com
  - http://www.esri.com and try the live demos
- sites of some major GIS software vendors
  - http://www.esri.com
  - http://www.intergraph.com
  - http://www.autodesk.com

What is Geographic Information Science?

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Unit 002 - What is GIS?

Metadata and Revision History

1. About the main contributors

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2. Details about the file

- unit title
  - What is Geographic Information Science
- unit key number
  - 002

3. Key words

- GISystems, GIScience,

4. Index words

- geographic information, geographic information technologies, what is gis, geographic information science, precision agriculture

5. Prerequisite units

- none

6. Subsequent units

- all

7. Other contributors to this unit

8. Revision history

- 23 July 1997 - original draft created
- 25 July 1997 - original draft posted to net
- 7 October 1997 - minor edits

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