28 INTRODUCTION TO GEOGRAPHIC INFORMATION SYSTEMS

Asterisks (*) indicate problems that have partial answers given in Appendix G.

28.1 Describe the concept of layers in a geographic information system.

From Section 28.1, Paragraph 4:
A generalized concept of how data of different types or "layers" are collected and overlaid in a GIS is illustrated in Figure 28.1. In that figure, maps A through G represent some of the different layers of spatially related information that can be digitally recorded and incorporated into a GIS database, and include parcels of different land ownership A, zoning B, floodplains C, wetlands D, land cover E, and soil types F. Map G is the geodetic reference framework, consisting of the network of survey control points in the area. Note that these control points are found in each of the other layers thereby providing the means for spatially locating all data in a common reference system. Thus composite maps that merge two or more different data sets can be accurately created. For example in Figure 28.1, bottom map H is the composite of all layers

28.2 Discuss the role of a geographic reference framework in a GIS.

From Section 28.1, Paragraph 4:
It allows the user to relate information on different layers of the GIS

28.3 List the fundamental components of a GIS.

From Section 28.1, Paragraph 2:
A more detailed definition (Hanigan, 1988) describes a GIS as "any information management system that can:

1. Collect, store, and retrieve information based on its spatial location;
2. Identify locations within a targeted environment that meet specific criteria;
3. Explore relationships among data sets within that environment;
4. Analyze the related data spatially as an aid to making decisions about that environment;
5. Facilitate selecting and passing data to application-specific analytical models capable of assessing the impact of alternatives on the chosen environment; and
6. Display the selected environment both graphically and numerically either before or after analysis."

28.4 List the fields within surveying and mapping that are fundamental to the development and implementation of GISs.

From Section 28.1, Paragraph 7:
Virtually every aspect of surveying, and thus all material presented in the preceding chapters of this book, bear upon GIS development, management, and use.

28.5 Discuss the importance of metadata to a GIS.

From Section 28.8, Paragraph 1:
Once created, data can travel almost instantaneously through a network and be transformed, modified, and used for many different kinds of spatial analyses. It can then be re-transmitted to another user, and then to another, etc.2 It is important that each change made to any data set be documented by updating its associated metadata.

28.6 Name and describe the different simple spatial objects used for representing graphic data in digital form. Which objects are used in raster format representations?

From Section 28.4.1:
The simple spatial objects most commonly used in spatially locating data are illustrated in Figure 28.2 and described as follows:

1. Points define single geometric locations. They are used to locate features such as houses, wells, mines, or bridges [see Figure 28.2(a)]. Their coordinates give the spatial locations of points, commonly in state plane or UTM systems (see Chapter 20).

2. Lines and strings are obtained by connecting points. A line connects two points, and a string is a sequence of two or more connected lines. Lines and strings are used to represent and locate roads, streams, fences, property lines, etc. [see Figure 28.2(b)].

3. Interior areas consist of the continuous space within three or more connected lines or strings that form a closed loop [see Figure 28.2(c)]. For example, interior areas are used to represent and locate the limits of governmental jurisdictions, parcels of land ownership, different types of land cover, or large buildings.

4. Pixels are usually tiny squares that represent the smallest elements into which a digital image is divided [see Figure 28.2(d)]. Continuous arrays of pixels, arranged in rows and columns, are used to enter data from aerial photos, orthophotos, satellite images, etc. Assigning a numerical value to each pixel specifies the distributions of colors or tones throughout the image. Pixel size can be varied, and is usually specified by the number of dots per inch (dpi). As an example, 100 dpi would correspond to squares having dimensions of 1/100 in. on each side. Thus 100 dpi yields 10,000 pixels per square inch.

5. Grid cells are single elements, usually square, within a continuous geographic variable. Similar to pixels, their sizes can be varied, with smaller cells yielding improved resolution. Grid cells may be used to represent slopes, soil types, land cover, water table depths, land values, population density, and so on. The distribution of a

given data type within an area is indicated by assigning a numerical value to each cell; for example, showing soil types in an area using the number 2 to represent sand, 5 for loam, and 9 for clay, as illustrated in Figure 28.2(e).

28.7 What are the primary differences between a GIS and LIS?

From Section 28.2, Paragraph 1:
The distinguishing characteristic between the two is that a LIS has its focus directed primarily toward land records data.

28.8 How many pixels are required to convert the following documents to raster form for the conditions given:

(a)* A 384-in. square map scanned at 200 dpi.
$384^2(200)^2 = 5{,}898{,}240{,}000$

(b) A 9-in. square aerial photo scanned at 1200 dpi.
$9^2(1200)^2 = 116{,}640{,}000$

(c) An orthophoto of 11 × 17 in. dimensions scanned at 300 dpi
$11(17)(300)^2 = 16{,}830{,}000$

28.9 Explain how data can be converted from:

(a) Vector to raster format
See Section 28.6.1

(b) Raster to vector format
See Section 28.6.2

28.10 For what types of data is the vector format best suited?

From Section 28.4.2, Paragraph 7:
Examples include aerial photos, orthophotos, and satellite images.

28.11 Discuss the compromising relationships between grid cell size and resolution in raster data representation.

From Section 28.4.2, Paragraph 6:
It is important to note, that as grid resolution increases, so does the volume of data (number of grid cells) required to enter the data.

28.12 Define the term topology and discuss its importance in a GIS.

From Section 28.4.3, Paragraph 1:
Topology is a branch of mathematics that describes how spatial objects are related to each other. The unique sizes, dimensions, and shapes of the individual objects are not addressed by topology. Rather, it is only their relative relationships that are specified
From Section 28.4.3, Last Paragraph:
The relationships expressed through the identifiers for points, lines, and areas of Table 28.1, and the topology in Table 28.2, conceptually yield a "map." With these types of information available to the computer, the analysis and query processes of a GIS are made possible.

28.13 Develop identifier and topology tables similar to those of Tables 28.1 and 28.2 in the text for the vector representation of (see the following figures):

(a) Problem 28.13(a)

Identifier	Coordinates	Line Identifier	Points	Area Identifier	Lines
1	x_1,y_1	a	1,2	I	a,g,f,e
2	x_2,y_2	b	2,3	II	b,h,g
3	x_3,y_3	c	3,4	III	c,d,f,h
4	x_4,y_4	d	4,5		
5	x_5,y_5	e	5,1		
		f	5,6		
		g	6,2		
		h	6,3		

Connectivity		Direction			Adjacency		
Nodes	Chains	Chain	From Node	To Node	Chain	Left Polygon	Right Polygon
1-2	a	a	1	2	a	0	I
2-3	b	b	2	3	b	0	II
3-4	c	c	3	4	c	0	III
4-5	d	d	4	5	d	0	III
5-1	e	e	5	1	e	0	I
5-6	f	f	5	6	f	I	III
6-2	g	g	6	2	g	I	II
6-3	h	h	6	3	h	II	III

(b) Problem 28.13(b)

Identifier	Coordinates	Line Identifier	Points	Area Identifier	Lines
1	x_1,y_1	a	1,2	I	b,c,q,l
2	x_2,y_2	b	3,4	II	d,r,m,q
3	x_3,y_3	c	4,5	III	e,f,n,r
4	x_4,y_4	d	5,6	IV	g,k,l,m,n,o,p
5	x_5,y_5	e	6,7	V	a,o,s,j
6	x_6,y_6	f	7,8	VI	h,i,s,p
7	x_7,y_7	g	8,9		
8	x_8,y_8	h	9,10		
9	x_9,y_9	i	10,11		
10	x_{10},y_{10}	j	11,1		
11	x_{11},y_{11}	k	2,3		
12	x_{12},y_{12}	l	3,13		
13	x_{13},y_{13}	m	13,14		
14	x_{14},y_{14}	n	14,8		
15	x_{15},y_{15}	o	2,12		
16	x_{16},y_{16}	p	12,9		
17	x_{17},y_{17}	q	5,13		
18	x_{19},y_{18}	r	6,14		
19	x_{19},y_{19}	s	11,12		

Connectivity		Direction			Adjacency			Nestedness	
Nodes	Chains	Chain	From Node	To Node	Chain	Left Polygon	Right Polygon	Polygon	Nested Node
1,2	a	a	1	2	A	0	V	III	d
3,4	b	b	3	4	B	0	I	IV	b,c
4,5	c	c	4	5	C	0	I	V	a
5,6	d	d	5	6	D	0	II		
6,7	e	e	6	7	E	0	II		
7,8	f	f	7	8	F	0	III		
8,9	g	g	8	9	G	0	IV		
9,10	h	h	9	10	H	0	VI		
10,11	i	i	10	11	I	0	VI		
1,11	j	j	1	11	J	0	V		
2,3	k	k	2	3	K	0	IV		
3,13	l	l	3	13	L	I	IV		
13,14	m	m	13	14	M	II	IV		
8,14	n	n	8	14	N	III	IV		
2,12	o	o	2	12	O	IV	V		
9,12	p	p	9	12	P	IV	VI		
5,13	q	q	5	13	Q	I	II		
6,14	r	r	6	14	R	II	II		
11,12	s	s	11	12	S	V	VI		

28.14 Compile a list of linear features for which the topological relationship of adjacency would be important.

Streets, railroads, rivers, streams, transmission lines, bus routes, mail routes, electric circuits, water mains, and so on

28.15 Prepare a raster (grid cell) representation of the sample map of:

(a) Problem 28.15(a), using a cell size of 0.10-in. square (see accompanying figure).

(b) Problem 28.15(b), using a cell size of 0.20-in. square (see accompanying figure).

28.16 Discuss the advantages and disadvantages of using the following equipment for converting maps and other graphic data to digital form:

(a) tablet digitizers

From Section 28.7.3, Last Paragraph:
Data files generated in this manner can be obtained quickly and relatively inexpensively. Of course the accuracy of the resultant data can be no better than the accuracy of the document being digitized, and its accuracy is further diminished by differential shrinkages or expansions of the paper or materials upon which the document is printed and by inaccuracies in the digitizer and the digitizing process.

(b) scanners.

From Section 28.7.6, Last Paragraph:
Accuracy of the raster file obtained from scanning depends somewhat on the instrument's precision, but pixel size or resolution is generally the major factor. A smaller pixel size will normally yield superior resolution. However there are certain tradeoffs that must be considered. Whereas a large pixel size will result in a coarse representation of the original, it will require less scanning time and computer storage. Conversely, a fine resolution, which generates a precise depiction of the original, requires more scanning time and computer storage. An additional problem is that at very fine resolution, the scanner will record too much "noise," that is, impurities such as specks of dirt. For these reasons and others, this is the least preferred method of capturing data in a GIS.

28.17 Explain the concepts of the following terms in GIS spatial analysis, and give an example illustrating the beneficial application of each: (a) adjacency; and (b) connectivity.

From Section 28.9.2:
Adjacency and connectivity are two important boundary operations that often assist significantly in management and decision-making. An example of adjacency is illustrated in Figure 28.10(d) and relates to a zoning change requested by the owner of parcel A. Before taking action on the request, the jurisdiction's zoning administrators are required to notify all owners of adjacent properties B through H. If the GIS database includes the parcel descriptions with topology and other appropriate attributes, an adjacency analysis will identify the abutting properties and provide the names and addresses of the owners.
Connectivity involves analyses of the intersections or connections of linear features. The need to repair a city water main serves as an example to illustrate its value. Suppose that the decision has been made that these repairs will take place between the hours of 1:00 and 4:00 P.M. on a certain date. If infrastructure data are stored within the city's GIS database, all customers connected to this line whose water service will be interrupted by the repairs can be identified and their names and addresses tabulated. The GIS can even print a letter and address labels to facilitate a mailing announcing details of the planned interruption to all affected customers.

28.18 If data were being represented in vector format, what simple spatial objects would be associated with each of the following topological properties?

(a) Connectivity	Points and Lines
(b) Direction	Points and Lines
(c) Adjacency	Interior Areas
(d) Nestedness	Interior Areas and Points

28.19 Prepare a transparency having a 0.10-in grid, overlay it onto Figure 28.4(a), and indicate the grid cells that define the stream. Now convert this raster representation to vector using the method described in Section 28.6.2. Repeat the process using a 0.20-in grid. Compare the two resulting vector representations of the stream and explain any differences.

Suggestion: If you have access to a scanner, scan Figure 28.4(a) and have the students import it into their CAD package. Then set both the grid and snap to 0.1 and 0.2. and have the student trace the image in raster format. They will quickly realize the number of problems that occur when scanning linear features such as streams and edges of features.

28.20 Discuss how spatial and non-spatial data are related in a GIS.

From Section 28.5, Paragraph 2:
In general, spatial data will have related nonspatial attributes and thus some form of linkage must be established between these two different types of information. Usually this is achieved with a common identifier that is stored with both the graphic and the nongraphic data. Identifiers such as a unique parcel identification number, a grid cell label, or the specific mile point along a particular highway may be used.

28.21 What are the actual ground dimensions of a pixel for the following conditions:

(a) A 1:10,000 scale, 9 in. square orthophoto scanned at 500 dpi?

$(9 \times 500) / 10{,}000 = 0.45$ in.

(b)* A 748 in. square, 1:24,000 map, scanned at 200 dpi?

$(748 \times 200) / 24{,}000 = 6.23$ in.

28.22 Describe the following GIS functions, and give two examples where each would be valuable in analysis:

(a) line buffering, and

From Section 28.9.1, Paragraph 2:
Line buffering, illustrated in Figure 28.10(b), creates new polygons along established lines such as streams and roads. To illustrate the use of line buffering, assume that to preserve the natural stream bank and prevent erosion, a zoning commission has set the construction setback distance from a certain stream at D. Line buffering can quickly identify the areas within this zone.

(b) spatial joins

From Section 28.9.3, Paragraph 2:
Having these various data sets available in spatially related layers makes the overlay function possible. Its employment in a GIS can be compared to using a collection of Mylar overlays in traditional mapping. However, much greater efficiency and flexibility are possible when operating in the computer environment of a GIS, and not only can graphic data be overlaid, but attribute information can be combined as well.

28.23 Go to the PASDA web site or a similar web site in your state and download an example of:

(a) An orthophoto
(b) Zoning
(c) Floodplains and wetlands
(d) Soil types

28.24 Compile a list of data layers and attributes that would likely be included in an LIS.

Control to establish a common basis of reference coordinates; political boundaries; U.S. Public Land System, legal descriptions in metes and bounds, block and lot deeds; easements; improvements; parcel ownership, parcel values, hydrography, and so on.

28.25 Compile a list of data layers and attributes that would likely be included in a GIS for:

(a) Selecting the optimum corridor for constructing a new rapid-transit system to connect two major cities

Control; state, county, and municipal boundaries; U.S. Public Land Survey System; legal descriptions and parcels; easements; parcel ownership; parcel values; existing transportation routes; topography; hydrography; existing land use; zoning; soil types; depth to bedrock or underground mines; depth of water table; utilities; and so on.

(b) Choosing the best location for a new airport in a large metropolitan area
All layers in (a) plus building locations with heights; tower locations and heights; and other vertical obstructions; quiet zones; and so on.

(c) Routing a fleet of school buses

Control; state, county, and municipal boundaries; existing transportation routes with data on widths, grades, pavement type/condition, and speed limits; load and height restrictions on highways and bridges; construction activity; detours; and so on.

(d) Selecting the fastest routes for reaching locations of fires from various fire stations in a large city

Control; municipal boundaries; ward boundaries; fire station locations; transportation routes with grades, lighting, and traffic signals; traffic counts; accident records; construction activity; detours; and so on.

28.26 In Section 28.9.3, a flood-warning example is given to illustrate the value of simultaneously applying more than one GIS analytical function. Describe another example.

Answers will vary

28.27 Consult the literature on GISs and, based on your research, describe an example that gives an application of a GIS in:

(a) Natural resource management
(b) Agriculture
(c) Engineering
(d) Forestry

Independent Project