UNIT 16 - OUTPUT

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Compiled with assistance from Jeffrey L. Star, University of California at Santa Barbara

This is another unit that could be placed in several different locations within an introductory course. We have chosen to place it here as it falls within the topic of Using the GIS. However, you may find several other places for it. This unit should be illustrated with several examples of hardcopy and possibly "soft" output. Maps plotted by different types of plotters and printers would be especially useful. The slide set contains some examples of the hardware items described here.

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A. INTRODUCTION

- output from GIS does not have to be a map
- in fact, many GIS are designed with poor map output capabilities

Types of output

- text - tables, lists, numbers or text in response to query
- graphic - maps, screen displays, graphs, perspective plots
- digital data - on disk, tape or transmitted across a network
- other, not yet common
    - computer-generated sound
    - 3D images

B. TEXT OUTPUT

- perhaps more important than maps for reporting results of analysis
- results might be a list or table of selected objects with attributes
- queries might result in numerical results, e.g. totals, distances, areas, counts
- text output might be delivered by voice generator, e.g. navigation instructions like "turn left at next traffic signal"

Tables

- e.g. list of all cuttable areas of timber, giving area, species, age, estimate of yield in board feet
- list is not of great value without an accompanying map to identify each object in the list
- examples of specialized lists:
    - personalized letter to be mailed to all households within 500 m of a planned expressway
    - list of all hazardous materials stored within 100 m of a fire, transmitted by FAX to firetruck
    - driving directions for a garbage collection route
    - workorder and accompanying map and marked travel route for each service vehicle operated by utility company, giving day's work locations, nature of work
    - list and accompanying map of all city voting precincts ranked by degree of support for party in last election

C. GRAPHIC OUTPUT

Graphics peripherals

- provide graphic input and output of maps, diagrams and charts
- interactive graphics devices allow users to point to objects and identify them in their correct spatial context

- an early interactive version of the Space War computer game, developed at MIT in the early 1960s, ran on a PDP-1 computer using video displays
- television-like terminals became common in the early 1960's, and are now the most common way users interact with computer systems
- in the next few sections we look at devices for graphic output and the ways their development has influenced GIS
- costs are approximate, correct to order of magnitude only

Raster and vector devices

- graphic output devices can be classified into raster and vector groups
- raster devices build a picture by filling it with uniform picture elements, usually in rows
  - e.g. line printers, dot matrix printers, scanners, most CRT terminals
  - the elements of the picture are called pixels or pels
  - resolution is sometimes expressed in megapels (approximately equal to 106 pixels) 640x480 pixel resolution is 0.3 megapels; 1280x1024 is 1.3 megapels
- vector devices build a picture by drawing lines, shading areas etc.
  - e.g. plotters, storage tube CRT technology
- a raster device may be driven by vector commands, which it then converts for display, and vice versa
- conversion between raster and vector may thus occur at several points in a GIS between input and output

D. HARDCOPY OUTPUT

Line printers

- the first common device for computer output, cost $30,000
- capable of printing 200-1,000 lines of text per minute
- each line composed of 132 characters in fixed positions
- entire line printed simultaneously by impact of hammers on ink ribbon
- limited set of printable characters
- image must be created row by row from the top
- drawbacks for graphical output because:
  - rectangular cells
  - resolution is fixed, e.g. 1/6 inch by 1/10 inch (4.2 mm by 2.5 mm)
  - fixed cell location
  - only limited set of characters can be printed
  - difficult to draw continuous lines
  - shades of grey must be generated by overprinting
    - e.g. black = A + O + B + V + X
  - results are best when viewed from a distance
- used as the output device for SYMAP, the earliest mapping package released in 1967
- most useful for repeated mapping of statistics on a constant base, e.g. census atlas, weekly reports of crime statistics

overhead - Line printer map

Dot matrix printers/plotters

- image composed of rows of dots - often printed in blocks, e.g. 9 or 25 rows at a time
- to create shades of grey, control the fraction of dots which are printed in any small area
    - the dots must be selected randomly, or &QUOTdithered", to avoid unwanted patterns
- early versions used hammers on ribbons for each dot - cost $500
- more recent versions use lasers and xerography technology, resolutions up to 300 dots per inch - cost $2,000
- color versions are available - squirt ink from jets of three or four primary colors - cost $2,000
- electrostatic plotters use rows of dots, create images of map size - cost $40,000

Pen plotters

- create images by moving a pen under computer control
- most are incremental - draw a line using large numbers of movements of fixed size in fixed directions
    - many have two motors, one for x and one for y
        - get diagonal movement in only eight directions by using combinations of one or both motors
        - however, step size is so small that lines appear to go equally easily in all directions

diagram

- from a GIS perspective, an important advantage is the ability to plot on top of pre-printed base maps
    - this avoids having to have all of the base map information in digital form

Types of plotters

- lowest cost - $2,000 - are desktop size, take standard A4 or similar paper
    - paper is flat
    - pens can be changed automatically to generate different colors
- mid-range - $25,000 - are map size
    - paper rolls over drum
    - movement of pen is parallel to axis of drum
    - second direction of movement is by rotating drum
    - problems keeping paper in registration since it may move and stretch during construction of the map/graphic
    - problems keeping pens moist during long plotting jobs
    - typical plot jobs can last 3 to 6 hours
- top range - $100,000 are high precision
    - used for drafting, map production
    - usually flat (&QUOTflatbed"), medium held on exactly flat surface
    - pen may be replaced by cutting tool on scribe coat

demo - display a map from a plotter

Optical scanners

- output on photographic paper

- paper mounted on inside of a rotating drum
- image created in helical fashion by rotating drum and moving light source along axis of drum
- common output devices for remote sensing, image processing
- other devices output directly to 35 mm slide film

E. CRTS (CATHODE RAY TUBES)

- earliest (ca. 1968) could display rows of characters in fixed positions, little use for showing maps or images

Storage tube technology

- Tektronix introduced terminals based on storage tube technology ca. 1970
  - major breakthrough in low-cost graphic display ($5,000)
  - images drawn by moving electron beam over screen under computer control
  - image is permanent, not refreshed, so must be erased completely - no selective deletion possible

Refresh image technology

- terminals with refreshed images began to replace storage tube technology ca. 1975
- significantly lower cost
- image redrawn from internal memory 25-50 times per second
- image created by lighting dots in fixed positions
- resolution determined by number of rows and columns of dots - some common screen resolutions: IBM PC Color Graphics Adapter (CGA) - 320x200 Enhanced Graphics Adapter (EGA) - 640x350 Video Graphics Array (VGA) - 640x480
- 1280x1024 is a common resolution for high quality graphics

Color

- color is created by using groups of 3 dots, glowing red, green and blue respectively when illuminated by different electron guns
  - different percentages of illumination create different colors

overhead - Colors for RGB

Bit planes and palettes

- recall from Unit 3:
  - a bit is a unit of computer storage - it can be on or off
  - a byte is a group of 8 bits
  - a K (kilo) is 1024 - 64K bytes equals 65,536 bytes
- to display a black and white image, the terminal or display adapter must have one bit of storage per pixel
  - 320x200 or 64,000 bits or 8,000 bytes for a CGA monochrome image
- to display color we use several bits per pixel
  - 2 bits can have 4 combinations of on and off, so can display any of 4 colors
  - to display any of 16 colors requires 4 bits per pixel

- if there are 4 bits per pixel, we say there are 4 bit planes
- a device with 20 bit planes (common for high resolution graphics) can display any of 220 colors in each pixel
    - hint: to convert powers of 2 to powers of 10 approximately, multiply the exponent by 0.3 - 220 is about 106 or 1,000,000 - in fact 1,048,576
- the number of bit planes determines how many colors can be displayed simultaneously
    - this may be different from the number of possible colors
    - e.g. the VGA has 4 bit planes, allows simultaneous display of 16 colors, but these can be defined using any combination of 64 levels of red, 64 of green and 64 of blue, for a total of 262,144 possible colors
- the limited set of colors chosen at any one time is called the palette
- the storage requirements of a VGA adapter (4 bit planes, 640x480 resolution) are 4x640x480 = 1,228,800 bits = 153,600 bytes = 150 Kbytes
- the requirements for a 20 bit plane, 1280x1024 device are 20x1280x1024 = 26,214,400 bits = 3,276,800 bytes = 3200 Kbytes

3-D display

- some vendors are now offering 3-D stereo display devices
- these create the illusion of depth by rapidly switching between two images, one for the left eye and one for the right
    - a filter in front of the screen polarizes the images differently
    - the user wears eyeglasses containing clear polarizing filters
- because each of the two images must be refreshed 25-50 times/second, the display must operate at 50-100 images/second

Memory and processing components

1. Object memory
    - some display devices have an optional local object memory to store the entire set of objects/vectors in the image to be displayed (often called &QUOTdisplay list")
    - allows rapid redisplay of objects without new input
    - most useful for pan or zoom, or rotation of 3-D objects
2. Vector-raster converter
    - since display is always by pixels it is necessary to compute raster images from vector input
        - e.g. which dots must be turned on to display this line?
3. Display memory
    - stores the color number to be displayed in each pixel
4. Color lookup table
    - identifies the combination of red, green and blue corresponding to each color in the current palette
    - by changing the color lookup table, can produce very rapid changes of color patterns on the screen without affecting display memory
5. Digital/analog (D/A) converter
    - converts the digital signal stored in display memory to a voltage applied to the CRT

F. GRAPHICS STANDARDS

- the large number of graphics input and output peripherals have a confusing array of data requirements
  - the instructions sent to a laser printer may have nothing in common with those sent to create the same picture on a desktop plotter
- there have been many attempts to create standards for communicating with devices
  - the format used by the early Tektronix storage tube terminals has been extended many times but is still widely used - known as Tektronix or 4010 format
  - many devices recognize the format established by Hewlett-Packard and known as HPGL
  - several companies have introduced common formats and provided &QUOTdrivers" to convert these for specific devices, e.g. DI-3000 and DISSPLA
  - the most successful recent format is PostScript, recognized by a large number of output devices

REFERENCES

Maguire, D.J., 1989. Computers in Geography, Wiley, New York. A good general introduction to computer use and spatial data: chapters 5 and 11 have excellent reviews of hardware.

DISCUSSION AND EXAM QUESTIONS

1. Low-quality dot matrix printers use 9 hammer pins in a vertical column to create each line of print at 6 lines per inch, and thus achieve a resolution of about 50 dots per inch or 2 dots per mm. Compare the output of this device to the contents of the standard topographic map.

2. Compare the desktop plotter and the color CRT screen as display devices. Which would you find more useful as a location analyst for a major retailer?

3. Cartography is constrained by the two-dimensional nature of its paper medium. What new ways of displaying spatial data can you devise to take advantage of 3-D display capabilities?

4. &QUOTRaster and vector are not only different approaches to constructing a picture, but fundamentally different ways of looking at the world". Discuss.

Last Updated: August 30, 1997.

UNIT 16 IMAGES

CLASS:	0	1	2	3	4	5	6	7	8
SYMBOL:		....	----	****	CCCC	0000	PPPP	WWWW	####
		....	----	****	CCCC	0000	PPPP	WWWW	####
		....	----	****	CCCC	0000	PPPP	WWWW	####
FREQUENCY:	73.	20.	15.	52.	64.	72.	70.	48.	60.

CLASS:	9	10	11	12	13	14	15
SYMBOL:	@@@@	MMMM	ZZZZ	RRRR	RRRR	WWW	TTTT
	@@@@	MMMM	ZZZZ	RRRR	RRRR	WWW	TTTT
	@@@@	MMMM	ZZZZ	RRRR	RRRR	WWW	TTTT
FREQUENCY:	23.	38.	18.	32.	120.	44.	51.