LEGIBILITY OF LETTERING ON REMOTELY SENSED IMAGE MAPS

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Abstract: The legibility of lettering on image maps is a continuing cartographic design problem. Many past lettering studies benefited from examining the practices devised for type legibility on line maps, while other studies focused on the use of lettering in high-contrast, text-reading situations. With increasing requirements for remotely sensed image maps, preserving imagery while maintaining lettering legibility is an area of important research.

The U.S. Geological Survey produced 24 experimental printings of a four-color Landsat Thematic Mapper image for a portion of the 1:250,000-scale Monterey, California, quadrangle. The visual variables of ink reflectance and hues, together with lettering display techniques, were altered for part of this printing. This paper describes the methodology and presents an evaluation of this research.

INTRODUCTION

To make a map, a two-dimensional graphic representation of a portion of a three-dimensional form is created. A map generalizes geographic phenomena by using a combination of symbols, colors, photographs, statistical data, and type. An effective map fully uses these elements to graphically communicate a theme to a reader. To achieve this goal the cartographer must thoroughly plan and design the map by visually balancing these elements.

Type is a graphic symbol used by cartographers to identify, locate, and show the linear or areal extent of geographic features. By using

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different aspects of type, including size, style, and color, a cartographer also classifies these features to aid the reader in their interpretation of the map. The effective use of these type variables will create a map with lettering that is easy to read and interpret. Altering lettering display techniques can affect type legibility. Achieving legibility requires a thorough knowledge of the proper use of many technical aspects of printing and graphics and an understanding of how type interacts with other map elements. Four common display techniques for type on a four-color image map are examined in this study: (1) overprinting of the imagery, (2) lettering in dropouts, (3) haloing of type, and (4) outlining of type.

CARTOGRAPHIC TYPE LEGIBILITY

The overall legibility of a map is determined in part by whether a map user can read and interpret the type. *Webster's Ninth New Collegiate Dictionary* (1986) defines legibility as anything "capable of being read or deciphered." Eduard Imhof, the noted Swiss cartographer, defined legible type on maps as being "easily read, easily discriminated, and easily and quickly located" (1975, p. 129). He also states that lettering legibility is dependent on the variables of "type form, type size, and type color" (1975, p. 129). Borden Dent refines this definition by saying type legibility is the "coordination of typographical factors inherent in letters and other symbols, words and converted textural material which affect ease and speed of reading" (1985, p. 284).

Achieving type legibility is a major cartographic concern and should be addressed during the early stages of map design. Careful type placement to avoid visual conflicts with base map features involves subjective choices in the context of generally accepted cartographic design principles. These principles and their subjective application are mastered by experience in producing traditional line maps; however, the increasing use of remotely sensed images for mapping introduces new challenges to achieving type legibility.

IMAGE MAPS AND LETTERING

Image maps are "snapshots" of geographic landscapes made from data captured by remotely located sensors. These data are captured and recorded either photographically on film, such as aerial photographs, or digitally on a magnetic medium, such as multispectral systems or radar. These data represent geographic areas as an array of variable image tones or numeric data representing these tones. This imagery is manipulated and transformed, by photomechanical or

electronic methods, into printable halftone images. The halftone image has the appearance of a photograph at normal viewing distance and displays variable tones, textures, and patterns that reveal the spatial distribution of geographic phenomena.

Image maps display vast amounts of geographic data with minimum manual cartographic intervention for data generalization or graphic symbology. Unlike line maps, however, they require that the reader perform the landscape interpretation. The demand for monochrome and multicolor image maps as line map substitutes or as end products in their own right has steadily increased as more sensing systems, data, and processing and display capabilities become available.

An image map's final appearance is difficult for the cartographer to envision until a prepress color proof is generated from lithographic halftone films. Producing legible type on a traditional line map is a painstaking task. Image maps present even greater challenges because the cartographer has limited control over how the base imagery appears. The selection of display technique can "make-or-break" lettering legibility and readability on an image map.

Several printing techniques are available to the cartographer that will enhance lettering in areas where background imagery is cluttered or noisy. The best technique is subjective; the lettering selection decision is dependent on the characteristics of the imagery and the intended use of the map. Type overprints and hides image data, therefore some people are critical of using any type on an image map. The validity of this criticism is not addressed in this paper; what is described is how best to achieve and maintain lettering legibility with a minimum loss of data.

TYPE VARIABLES

For mapping, type is a literal symbol designed to encode location and areal extent of cultural and geographic features (Robinson and others, 1984, p. 195). Guidelines for displaying type on image maps to ensure legibility are needed. With the effective use of the typeface, style, size, and color, the cartographer can relate to the reader a feature clarification and a visual hierarchy. An understanding of how visual variables affect type legibility is necessary prior to developing type guidelines.

Position and Spacing

The physical position of type on a map locates named features. General cartographic conventions have been developed to aid type placement on maps. For example, names are commonly placed to the right of point symbols. In some instances, type also can be used to show the linear orientation and areal extent of features.

Typeface

Several typefaces, Helvetica, Souvenir, Times, and Univers, are legible on maps. Variations in typeface permit the classing of features and give a visual cue to the map reader searching for specific feature types.

Type Style

Type style is a physical design characteristic, such as character curvature, line thickness, condensed or expanded, serif or sans serif, italic or upright, used to create a mood or feeling. Different styles of one typeface are commonly used to nominally classify features. For example, serif-italic is used for hydrologic features, nonserif expanded upright for topographic features, and nonserif light (thin line) italic for transportation features.

Type Size

By using variations in type size to classify feature names, a cartographer can express the relative size or importance of features.

Type Color

The variation of type color or hue is used to group features having similar qualitative attributes. For example, on traditional line maps cultural or manmade feature names usually are printed in black, and hydrologic names usually are printed in blue. Hue distinctions can assist in reducing the search time when looking for a category of features.

IMAGE MAP DESIGN

Designing the appropriate visual balance to facilitate lettering legibility on an image map is a difficult art. Unlike on line maps, the cartographer does not control image design variables of hue, texture, and pattern. The cartographer does control the selection and

texture, and pattern. The cartographer does control the selection and use of lettering variables dependent on the level of desired type visibility.

Visual Contrast

Proper visual contrast is a critical requirement to achieve a good map design. Visual contrast between type and the image base is a two-part problem requiring careful use of typeface, style, hue, gloss, and size. First, to be easily read, type must contrast in hue and brightness value with the underlying base map colors. Second, brightness intensity value must be sufficient for both map elements to be separated visually. Careful letter positioning to avoid as much background conflict as possible then becomes critical.

Figure/Ground

Achieving proper visual contrast between map type and the image base produces a visual impression of a figure over ground. Most typefaces are designed to create a visible contrast when printing over achromatic or monochrome backgrounds, as text in a book. Type is easily dominant in this figure/ground hierarchy. The visual complexity of image maps overprinted by text presents a greater reading difficulty. Lettering competes for figure dominance with other features or patterns on a map (Imhof, 1975, p. 129). If type loses visual contrast and blends with the background—a loss of figure/ground—letter recognition will be impeded (Shortridge, 1979, p. 18).

Visual separation of type when overprinting image maps requires that letters occupy a different level of the visual hierarchy from the image background. This distinction of elements, either visually or organizationally, creates a separation between figure and ground. The figure/ground phenomenon organizes two map elements, type and imagery, so the "eye and mind" recognize a contrast (Robinson, 1984, p. 148-149). The element that first separates and then is clearly envisioned is described as the figure. The less dominant or formless "amorphous" element is described as the ground (Robinson, 1984, p. 149). Separation of map content into these two elements is a subconscious mental process that can be affected by careful map design. Exploitation of this figure/ground phenomenon requires careful planning of all design variables and production processes to ensure the desired visual hierarchy.

Problems of Type on Image Maps

Image maps display geographic features by variations of textures, patterns, tones, and colors. When type is used to overprint these maps, costly image data can be masked and lost. The current U.S. Geological Survey solution is to print an image map and line map back-to-back on one sheet of paper. No image data are covered by type, and the line map can be used to locate features and place names. The primary disadvantage of this process is the additional cost of printing two maps and the difficulty of trying to correlate image features with their symbolized and lettered equivalents. Table 1 is a partial listing of Survey maps that were produced with this technique.

Table 1.—Partial Listing of Image Maps With Line Maps Printed on the Back by the U.S. Geological Survey

Title	Scale	Year
AZTEC, N.M. - COLO.	1:250,000	1980
DENALI NATIONAL PARK AND PRESERVE, ALASKA	1:250,000	1984
DENVER, COLO.	1:250,000	1983
DURANGO, COLO.	1:250,000	1980
HARRISBURG, PA	1:250,000	1982
LAS VEGAS, NEV.; ARIZ., CALIF.	1:250,000	1981
RICHMOND, VA.; MD.	1:250,000	1983
PAHUTE MESA, NEVADA	1:100,000	1984
OLATHE, KANSAS-MISSOURI	1:100,000	1984
POINT LOMA, CALIF.	1: 24,000	1987

Options to avoid visual conflicts are more limited when positioning type on image maps than when positioning type on line maps. Careful planning is needed to avoid this visual conflict on image maps. In addition, the figure/ground contrast must always be

considered when planning and designing an image map. Specific design problems include:

- The visual separation of type from background imagery.
- The proper use of color to contrast type and imagery.
- The degree of image detail underneath the type.

TEST MAP PREPARATIONS AND SPECIFICATIONS

A test was designed and implemented as a controlled printing study to explore methods to improve type legibility on image maps. A multicolor Landsat Thematic Mapper satellite scene of Monterey, California, at 1:250,000 scale was used as the base image for overprinting a variety of feature names. Twenty-four different type display techniques were evaluated. The critical element during test printing was to maintain visual control of the base map image by altering only ink hues and display techniques for the type.

The Imagery

A satellite image scene was selected having many geographic features that are encountered in the United States represented by different hues, tone patterns, and physical features. The Monterey, California, scene was chosen because of its diverse colors and varied geographic features. It has large bodies of water requiring type to overprint many shades of blue. The San Joaquin Valley features result in printing names over multiple shades of red that represent variations in vegetation type and density. The mountain ridges and ranges in areas like Ortigalita Ridge or Gabilan Ridge require that type be placed in conflict with a variety of shapes and patterns.

Type

All names used for this test were selected directly from type plates for the existing Geological Survey Monterey 1:250,000-scale topographic-bathymetric series quadrangle map. All names were printed in Univers typeface, with variations in style and sizes positioned for reproduction already determined for the quadrangle map. The criteria for name selection included feature location, areal extent, and the possible conflict of background noise created between the existing type and the color and texture of the surrounding image. Emphasis was placed on lettering over as many image variables as possible to evaluate the effect of figure-background conflicts on type legibility. The resulting density of names is less than normally

found on a 1:250,000-scale line map, but considerably more than on most Survey color image maps.

Name Classes

Four classes of features were named and subdivided by using typeface, lettering size, and type style variables, which permitted easy visual identification and association of names with features:

1. Open Water (OW) - large bodies of natural water.
2. Drainage (D) - interior networks, either natural or man-made.
3. Hypsographic (H) - topographic features that extend over a relatively large area.
4. Place Names (PN) - point locations of cultural features.

PRINTING PROCEDURES

To ensure control of all variables for the test printing, the base imagery needed to be exactly alike on each test. The same halftone films and inks were used and printed to the same ink densities. All test images and type plates were printed on a single-color Heidelberg model KORD 65 sheetfed offset press. The press image size is 17 by 22 inches, which necessitated cropping the Monterey scene to include only a portion of the normal Survey 1° x 2°, 1:250,000-scale quadrangle area. Four lettering overprint techniques were evaluated for this test.

Full Image

Printing lettering on an unaltered image map is a common technique. It requires the least amount of prepress preparation. The base image is first printed by using all four halftoned images in yellow, cyan, magenta, and black. The lettering plate then is over-printed. Special care in type placement is needed to avoid covering or hiding critical image data.

All critical registration between type and the base image is performed during film preparation or during the layout stage of production. This technique is both cartographically and lithographically preferred because of its ease in use. To create visual contrast with light or lightly textured portions of the base image, type is generally printed in a black ink. When classification of feature names is important, type style and size are varied to achieve a visual hierarchy.

Dropout Printing

Dropout printing is accomplished by placing a photographic positive of the lettering in direct contact and physically registered with each halftone image exposed during lithographic platemaking. This lettering film positive prevents light from exposing the plate emulsion. When the base image is printed, lettering appears as white type as a result of the unprinted paper showing through. The white type contrasts with the dark or heavily textured portions of the color imagery and is easy to read. A variation of this method is overprinting solid ink colors in the nonimage dropout area, which results in colored type without any interference from the halftone image.

Halo Printing

Halo printing is a variation of dropout printing. This procedure also uses a positive type image to block out the halftone imagery during platemaking. The type positive is photographically distorted, however, which makes the letters slightly larger than normal type. When printed, this distorted image blocks out more base imagery than does the dropout technique. The type image then is printed in black or colored ink inside the white area. The result is type surrounded by a thin outline or "halo" of white paper, which forms a visual separation between type and imagery.

Haloing is an effective visual tool for separating type from background imagery. As in the basic dropout method, this technique permits the use of different ink colors to classify feature names without interference from the base imagery.

Outline Technique

This process creates a new image of type by photographically combining a film negative and positive of the type plate. The resulting film positive contains an outline of each letter. This visual effect is unique but the photographic process is difficult to control with the use of standard photographic equipment. Special photographic exposure equipment is manufactured to ensure precision and consistent letter manipulation.

RESULTS

This study consisted of printing and evaluating 24 variations of printing type on an image map. Table 2 describes the lettering techniques and ink hue combinations that were used for this project.

Table 2.—Lettering Colors and Imagery Technique

Feature: OW, open water (large bodies of natural water); D, drainage (interior networks, either natural or manmade); H, hypsographic (topographic features that extend over a relatively large area); PN, place names (point locations of cultural features). Lettering code: 0, clear/white paper; 1, cyan; 2, metallic silver; 3, metallic gold; 4, metallic anthracite; 5, metallic brown; 6, magenta (warm); 7, contour brown; 8, black.

Image approach	Full image				Drop out				Halo				Outline			
Feature	OW	D	H	PN	OW	D	H	PN	OW	D	H	PN	OW	D	H	PN
					0	0	0	0					8	8	8	8
	2	2	2	2	2	2	2	2	2	2	2	2				
	3	3	3	3	3	3	3	3	3	3	3	3				
	4	4	4	4	4	4	4	4	4	4	4	4				
	5	5	5	5	5	5	5	5	5	5	5	5				
	8	1	8	8	0	1	6	0	1	1	8	8				
					0	1	7	0								
					0	0	7	6								
					0	0	6	8								
					0	0	2	2								
					0	0	3	3								
					0	1	8	8								
					1	1	6	8								

Selection of these combinations was subjective in an attempt to display as many combinations as possible.

Most Promising Techniques

Of the 24 tested methods only three techniques proved promising: full image, dropout, and halo. Each technique is useful in printing type over imagery of varying density or complexity to ensure necessary figure/ground distinction. The best method creates type that is easy to locate and read at the desired level of visual dominance. The dominance hierarchy is determined by the message or theme the type is intended to convey to the reader.

The following is a subjective synopsis of each method and how each can be used most appropriately.

1. The first choice is use of silver metallic ink to overprint a full image. A map reader can decide if the type should be visible or not simply by changing the light angle at which the map is viewed. This process requires a minimum amount of printing and cartographic manipulation to tie and fit lettering directly to the imagery.

2. The second choice is a variation of the dropout lettering method. Dropouts require that the shape of the type be blocked out from the printed imagery, and so the unprinted paper appears as white type. This technique is an alternative to using opaque white ink to obtain a high reflectance level. Dropouts overprinted with different ink hues permit a cartographer to group and classify names together by type color. This technique can give type a strong figure presence over the base image.

Dropout lettering needs further study to determine a selection of the ink hues that will best classify and discriminate feature names to facilitate easier interpretation.

From the printer's perspective, a change to improve printability for dropout is printing a slightly distorted and enlarged type image. The "bleed" letter, which is slightly wider than the dropout area, overprints into the image. Bleeding is a forgiving process in that it minimizes any misregistration or fit problems between the type and imagery when printed.

3. The use of outline type with the halo display technique is viable because the black ink outlines do an excellent job of

separating type from the image base. Type appears printed in a white ink, but with a definite outline. The resulting map has a strong "finished" appearance. Printing problems caused by images being misregistered and leaving a "rainbow" ink signature at the edge of the dropout area are eliminated using this method. The black ink masks or covers these edges.

A handicap of this method in photomechanical reproduction is that outlining requires a dedicated contact vacuum frame designed especially for making these film negatives, and thus adds a step and expense to the reproduction process. However, this is an excellent means to achieve a high type visibility.

Overview

Each method described can be used effectively and efficiently in the cartographic reproduction for printing type over image maps. The choice depends on the map's purpose, the role that type is to play in the map context, and the production resources that are available to the cartographer. As type and words become more important to a theme, lettering will need to be emphasized. If names of features require grouping or classification, the type variables, such as style and ink hues, become an important design consideration. Displaying type on remotely sensed image maps requires careful selection of imaging techniques to produce the desired visual hierarchy, feature classification, and level of importance.

FUTURE RESEARCH

Legibility of type on image maps is important for the map reader and cartographer. More studies are needed to help determine how readers react to different type variables overprinted on images of different colors and levels of complexity.

Studies using dropout and outline display methods need to focus on style and hue combinations to communicate desired feature groupings and levels of visual dominance. The overprint methods used in this study are effective, but need refinement and further evaluation, including studies of their impact on the user's ability to search and find names easily and reliably.

Further research is needed in the use of typefaces, styles, sizes, and color to determine which combinations display best on image maps. A related issue is to determine the density of names best displayed on an image map, and how that number relates to the

purpose of the map. These questions will have complex answers and will require research regarding the effects and interactions of map scale, theme, and image characteristics of specific image types.

Type legibility is obtainable today on image maps. The best method depends on the desired visual distinction between lettering and the image base. As experience is gained through map readers' responses and experimentation, guidelines that can be applied to the design of all image maps can be established.

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