CARTOGRAPHIC USE OF DITHERED PATTERNS ON 8-COLOR COMPUTER MONITORS

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ABSTRACT

As microcomputers are increasingly used in cartography, their limitations are becoming more apparent. The limited numbers of colors available on inexpensive computer monitors can be artificially increased through the use of dithered patterns, a computer graphics technique. This paper addresses which types of dithered patterns are suitable for cartographic purposes and investigates some simple aspects of the perception of these patterns.

INTRODUCTION

Recent decreases in microcomputer prices have brought these devices within the reach of most organizations; however, most inexpensive color monitors can display only 8 or 16 colors. This limited palette restricts the cartographer in making complex or aesthetically-pleasing maps on these monitors. Dithering, a common technique of computer graphics, can be used to increase the range of perceptibly different colors on common color raster displays.

Dithering, sometimes referred to as halftoning, has typically been used to display three-dimensional graphics on computer monitors (Ryan, 1983) and for solid modeling. By varying pixel color or intensity gradually across the image, the impression of depth and shadow is achieved. The individual pixels merge visually to create the illusion of a new color or change in value. The dithering technique is not limited to the display of three-dimensional objects, however.

Truckenbrod (1981) recognized the potential of incremental color mixing on color monitors. By varying the proportions of two colors across a display plane, she effectively varied the color elements of hue, value and chroma in both graded and discrete steps. Her examples are particularly illustrative of what can be achieved through the dithering technique, but the patterns are a bit too busy for effective use in mapping.

Cartographic convention and research limit which patterns are suitable for mapping purposes. Jenks and Knos (1961), for example, found that map users prefer dot patterns rather than line or irregular patterns in a graded series.

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In addition, users prefer uniform texture among patterns of a series and find finer textures most pleasing.

As little research had focused on dithered patterns, the preliminary investigation centered on creating patterns suitable for mapping. After appropriate patterns had been chosen, research questions then focused on the perception of dithered patterns. In particular, the ability of subjects to distinguish dithered patterns from one another was investigated. Later research will address the use of these patterns in a mapping context.

CHOICE OF DITHERED PATTERNS FOR MAPPING

On expensive color graphics monitors (i. e., those with 256 or more colors available), the possible combinations to create dithered patterns are almost infinite. On more inexpensive monitors, the number of possible patterns is still large, but is constrained by the number of available colors and limited ability to vary pixel intensity. By requiring the dithered patterns to be suitable for mapping, the number of possible patterns is limited even further.

The diterered patterns chosen for the cartographic application addressed in this paper were created by varying the proportions of two hues of pixels to fill polygons. Only patterns that resembled screened tones (as used in printing) were used. These patterns were created by turning on a regular lattice (usually a triangular grid) of pixels on a background of a contrasting color. Polygons were filled with the patterns using a program based on an algorithm by Pavlidis (1982).

In choosing the patterns, the intent was to create a value scale of patterns using blue and white pixels. For example, the patterns would range from 0% blue to 100% blue in discrete steps. The patterns were not difficult to create on the computer screen, but problems arose with the appearance of some patterns on the monitor.

While it was easy to create patterns at both ends of the value spectrum, the middle-range value patterns often had disturbing optical effects. For example, the 50% blue pattern, which consisted of a checkerboard of single blue and white pixels, appeared to have an "op-art" effect. The arrangement of pixels on some other middle-range value percentages created the appearance of either vertical or horizontal stripes. Apparently, when single pixels are rapidly varied in close proximity, disturbing optical effects are possible. As a result, the middle-range value percentage patterns were adapted to eliminate the unintended effects. Instead of varying single pixels of the foreground color, some patterns varied two adjacent foreground pixels to create the dithered patterns.

The dithered patterns chosen for the test represented a value range from 0% blue to 100% blue in discrete, but uneven steps. Twenty-three patterns were selected for testing. These patterns and their value percentages are shown in Figure 1.

METHODOLOGY

Each pattern was paired with itself and the five most adjacent value percentage patterns. The resulting 124 pairs of patterns were photographed as slides from the computer screen (a Texas Instruments Professional Computer with a color monitor). The slides were divided into two groups for ease of testing.

Subjects were undergraduate and graduate students and faculty of the Geography Department of Michigan State University. Subjects were tested in small groups (usually 3-4 subjects at a time) in a small room darkened for viewing the slides. Thirty-four subjects were tested on one group of slides; thirty-three were tested on the other group. Each slide was presented to the subjects for 10 seconds.

While viewing the slides, subjects were instructed to compare the two patterns to determine whether the patterns seemed to contain the same percentage of blue. If the patterns were judged to contain different percentages of blue, subjects were to indicate which pattern appeared bluer.

RESULTS

The results were tested using the normal approximation to the binomial distribution. Six of the original twenty-three patterns were excluded after the test as being too coarsely textured to be used on maps (Patterns 2, 3, 5, 19, 21, and 22). Of the remaining eighteen patterns, twelve were determined to be perceptibly different from one another ($p \leq .05$). These were patterns 1, 4, 7, 8, 9, 10, 11, 12, 13, 15, 20, and 23.

DISCUSSION AND SUMMARY

Dithered patterns suitable for mapping purposes can be created on inexpensive color monitors. The preliminary research on these patterns, however, shows that care must be taken in their selection for use in cartographic applications. Patterns to be viewed or photographed from a monitor should be free of disturbing optical effects, yet be as finely textured as possible. Cartographic conventions and the findings of psychophysical research such as that of Jenks and Knos (1961) and others should be followed when designing displays with the patterns.

In the present study, subjects were able to distinguish a surprising number of patterns. Although given only 10 seconds to view each slide, subjects seemed to have sufficient time to make very fine discriminations between the pattern pairs. The author does not believe the twelve

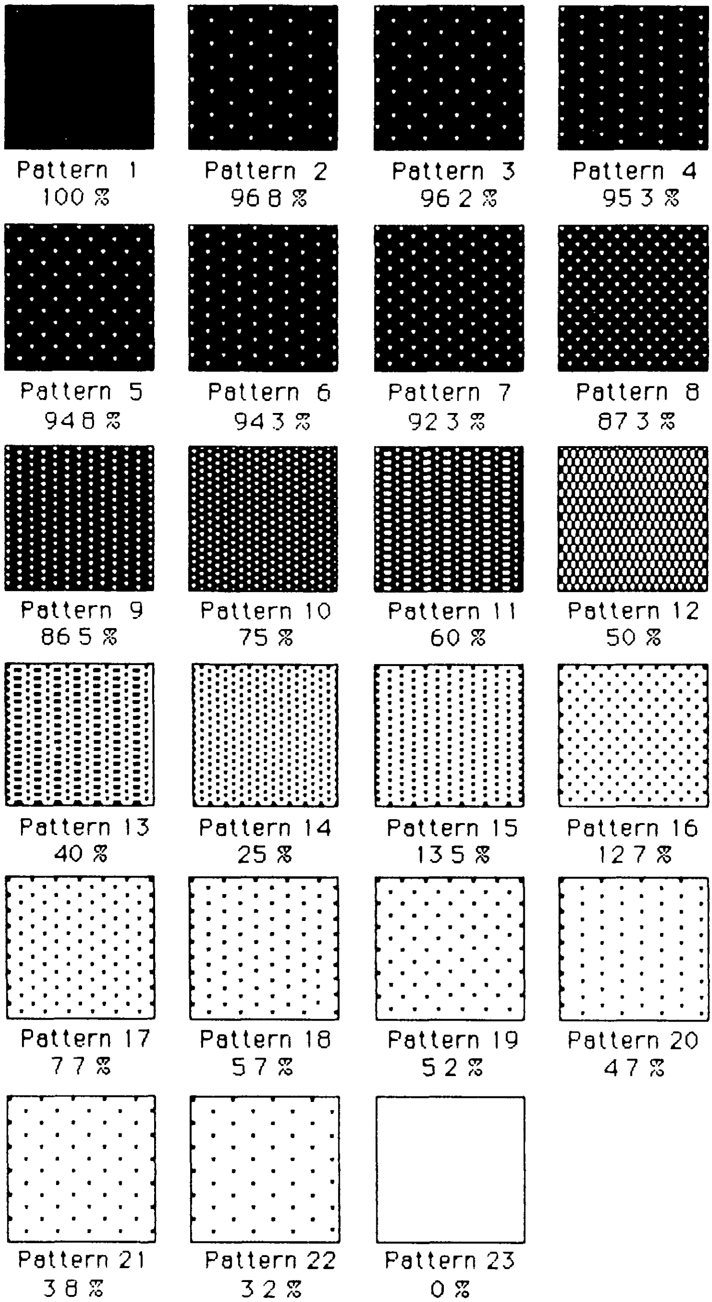

Figure 1. Arrangement of pixels and percentage of blue pixels in the 23 patterns chosen for study.

patterns found to be perceptually different in this study could be used simultaneously (as they would be in mapping) and still be easily distinguished.

Subjects were able to better differentiate patterns at the dark end of the value scale. White pixels appeared very bright on the computer screen and were easy to distinguish against the predominantly blue background. When the proportions of blue to white are reversed, however, the brighter white pixels may overwhelm the darker blue pixels.

Dithered patterns are potentially useful in many mapping applications. They readily lend themselves to situations where areal fill patterns of different colors or values are needed (e. g., choropleth or shaded isoline maps). In addition, they are potentially useful in continuous-tone applications. These patterns, however, remain to be investigated in a mapping context. The author will use the twelve perceptually different patterns found in this study to create choropleth maps as part of her future research.

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