J. of the Environmental Sciences
Vol. 11, No. 8, 765~771(2002. 8)

Relationship between Image-processed Color Content and Human Color Visibility Estimation of Natural Forest Scenes

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(Manuscript received 16 April, 2002 ; accepted 27 August, 2002)

The current study investigated the relationship between image processed data and human visibility data for natural forest scenes from the perspective of color. In particular, the results indicated relatively low Pearson product-moment correlations between the color ratings obtained from the two methods used in the study. The first method measured the color content of slides using a image processing program, while the second used a panel of human judges to rate the color content of each slide.

Key words : landscape assessment, visual quality, RGB, CYMK, image processing

1. Introduction

In recent decades, public policy-makers have demonstrated an increased interest in the impact of natural resource management practices on the "intangible" or "non-commodity" value of forest environments. For example, the effect of activities such as timber harvesting on the scenic beauty of forest environments seems to be particularly important to the enjoyment of outdoor recreation[1]. Market Opinion Research[2] has found that natural beauty is the single most important reason cited by people for choosing to visit a particular park, beach, or recreation area.

Due to the public concern for scenic beauty, a considerable body of research addressing the visual impact of forest management has developed[3]. Systematic approaches to natural landscape assessment have only been developed in the past 30 years. Many of these studies were initiated in an effort to identify predictors of public response to different forest landscapes[4]. Taken together, the findings highlight various physical features of a forest, such as tree size[3], understory screening[5], and ground condition[6].

However, no previous forest visual-quality research has explicitly examined the effect of color on scenic-beauty judgements. Palmer and Sena[7] point out that foresters are normally not interested in the pattern, color, density, or other features of foliage in forest scenes. For commercial purposes, wood fiber, such as that in tree stems, is more important. As such, predictor variables describing the volume of commercial timber and pulpwood in a scene have dominated forest scenic-beauty models. This approach de-emphasizes the use of color in scenic-beauty models, because, unlike foliage, color tends to be an unimportant correlate of wood fiber measures.

Nonetheless, from a non-commodity perspective, color is one of the most noticeable and pervasive features of a forest environment. Color is affected by both the temporal rhythm of the seasons and specific forest management practices that alter species types and change the forest structure. In addition, color has been shown to affect physiological arousal levels, moods, and ultimately, human preferences[8]. In fact, societal values revealed by the popularity of spring blossom tours and fall leaf-color excursions suggest that color is one of the most important physical determinants

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of human attraction to forest landscapes.

Yet little research has examined the effect of color on natural scenes. Accordingly, two different procedures were used in the current study to compare and analyze the color influences of forest landscape scenes; image processed color content and human color visibility estimation.

Image processing is largely concerned with the generation of new images from existing images. As such, the new image can be manipulated to suppress noise, remove blurring, or accentuate edges. Most of these techniques stem from linear system theory, which is well-known in applied mathematics9). However, it was not until the development of advanced computer technology that image processing became a popular tool with all kinds of applications10). One classic example is from the Jet Propulsion lab. at NASA, which used image processing to analyze the moon surface conditions before the final landing. Recent applications for image processing include the medical field, for ample, the examination of blood and cancer cells11,12).

Digital image processing involves the transformation and manipulation of an image of an object13). This technology helps people "to see more" in an image, and the end product is still an image, yet in a digital format. After transformation by image processing, the desired features in the image are easier to detect by human eyes. Image analysis is thus used to embody the idea of automatically extracting useful information from an image of an object.

However, there has been relatively little research about color in the context of analyzing landscape scenes in the field of park and tourism sciences. Therefore, the purpose of the current study was to investigate the difference between image-processed and human visibility-estimated data of the natural environment based on the effect of color. It is hoped that the results may help develop hybrid procedures for landscape assessment in which the scientific strength of computer technology is combined with the theoretical strength of psychological methods, thereby contributing to human perception research and the development of new visual quality assessment procedures based on scientific technology.

2. Method

2.1 Study Setting

The setting for the current study was the Ouachita National Forest in central Arkansas(1.6 million acres). The forest is a mixture of pine, oak, gum, maple, sycamore, dogwood, and other hardwoods, and provides a wide spectrum of recreational opportunities, ranging from wilderness and backpacking experiences to fishing, hunting, swimming, boating, river floating, picnicking, camping, and horseback riding14). The fall color change in the Ouachita Mountains is a major tourist attraction, with the peak season occurring between mid-October and the first of November.

The survey area was selected because the Ouachita National Forest, the largest continuous national forest in the eastern half of the United States, is a very popular tourist destination in the region and provides various kinds of recreational opportunities. Also, the seasonal dynamics of the forest scenes display different seasonal colors.

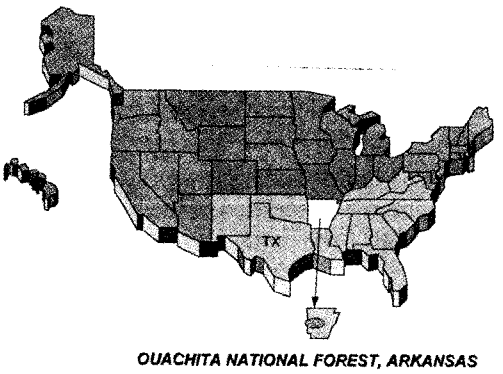

Fig. 1. Key map : Survey area.

The research was conducted at 20 experimental plots in the Winona Ranger District of the Ouachita National Forest. The plots primarily consisted of second-growth shortleaf pine(*Pinus echinata* Mill.) with a hardwood component dominated by white oak(*Quercus alba* L.) and lesser amounts of other oak species. Each plot consisted of a 0.2 ha division within a 0.65 ha treated area. The Winona area was established during the 1988-89 dormant season under the Ouachita/Ozark-St. Francis ecosystem management research program. The plots were oriented along an east-west ridge, with elevations ranging from 195 to 240m above sea level.

2.2 Photo Sampling

Photo-sampling was conducted in each season of the year. The summer sampling took place in September and October, when the green of the vegetation in the area was at a maximum. The autumn slides were taken in November after telephone calls to the Winona Ranger District indicated that the leaf-color change had begun. The winter photo-sampling occurred in January after most vegetation in the plots, with the exception of the pine needles, had turned brown. The spring photo-sampling took place after the hardwoods in the plots had begun to sprout new leaves. All the photo-samples were taken two growing seasons after the treatments were imposed. The weather conditions during the sampling periods were always clear. Four photos were taken per plot and 80 photos per 20 plots for each season. The total number of 320 slides was then analyzed. The photographs were taken with an f1/2.8 lens from four surveyed points on the perimeter of each plot. The direction of the four perimeter shots was toward the center of the plot. Ektachrome 35mm color slide film, speed ISO 400, was push-processed to ISO 800 to compensate for any dimly lit conditions that often characterized the within-stand views.

2.3 Color Rating Procedures

Two color rating procedures were used in the current study. The first procedure analyzed the color content of the slides using an image processing program. The color scanning was performed at the STARR Laboratory in the Department of Rangeland Ecology and Management at Texas A&M University. All 320 slides used in the analysis were scanned and digitized using a color scanner and image processing software. The scanning and data processing were performed on a personal computer equipped with a super VGA monitor. A Red-Green-Blue(RGB) color rating scale was employed, which defined specific colors as particular combinations of the three base colors. The definition of a color was constructed with the help of a "color look-up table"[15] that displayed the exact RGB combination for a particular shade. Using the color rules provided by this table, the 256 color values available in the color look-up table were amalgamated into eight color groupings: red, green, blue, cyan, yellow, magenta, black, and white. Each of the 320 slides was then assigned a percent value for all eight colors, so that the percentage for each slide totaled 100.

Fig. 2. Photo-scanned and digitized image.

The second procedure involved the use of a panel of human judges to rate the color content of each slide after a pretest of the rating procedure. Due to the time and effort involved in using humans to rate colors, the number of colors rated in each slide was limited to four. Three of these colors duplicated ones used in the image-processed procedure: blue, green, and yellow. A fourth color, brown, was also rated by the human judges because theory[1] suggests that the amount of brown in natural scenes may have a significant impact on scenic-beauty judgments. Each slide was shown on a screen for five seconds.

2.4 Data transformation

The human color visibility estimations were transformed using the RMRATE program[16], developed by scientists at the Rocky Mountain Forest and Range Experiment Station of the USDA Forest Service. RMRATE includes color visibility estimations(CVEs) among the scale values it estimates from the rating data, and computes median and mean ratings, standardized scores, and a new scale based on a least-square analysis of the ratings. The CVE scaling procedure of RMRATE is described below.

The ratings are computed based on the procedures developed by Daniel and Boster[17]. The raw color visibility ratings are converted to a set of standardized (Z) scores per slide, based on the frequency distribution of the ratings for all subjects in that slide(Equation 1).

$$mZi = \frac{1}{n-1} \sum_{k=2}^{n} \frac{1}{\Phi} (CPik) \quad \text{Equation} \quad 1)$$

where, mZ_i = mean Z for slide
$1/\Phi$ = inverse normal integral function
CP_{ik} = cumulative probability of observers giving view i a rating of k or more
n = number of rating categories

Next, the mean of the Z scores for the baseline slides, which are interspersed systematically with the remaining slides so that they make up every fifth slide shown and then used to create CVEs, is subtracted from the Z score for every other slide to yield a standardized difference for each view. Finally, the origin-adjusted Z scores are multiplied by 100 to remove any decimals and referred to as color visibility estimations(CVEs) (Equation 2).

$$CVE_i = (mZ_i - mZmB) * 100 \qquad \text{(Equation 2)}$$

where, CVE_i = CVE of slide i
mZ_i = mean Z of slide i
mZmB = mean of mean Zs of baseline slides

A slide with a positive CVE value means that it was rated with a higher color visibility than the average baseline slides, whereas a slide with a negative CVE value means that it was rated with a lower color visibility than the average baseline slides.

3. Results

3.1 Image processing of slide color content

The computer scanning process evaluated all 320 slides for their color content. The initial color characterization of the Ouachita National Forest slides was based on the RGB system, where the proportion of red, green, blue, black, and white was measured for each slide. Thereafter, the CYMK system was used to further divide the 256 color values available in the RGB system. In addition to the colors already described, the CYMK-based analysis measured the proportion of cyan, yellow, and magenta in each slide. As a result, the scanned images were finally analyzed for their color content based on the following categories: red, green, blue, cyan, yellow, magenta, black, and white. This analysis was performed at the pixel level, where one pixel was equal to an area of 0.00001114662 square inches. A summary of the statistics for each of the eight colors in the tested slides is presented in Table 1.

Table 1. Image-processed color content of the 320 tested slides(percent)

color	mean	std.dev.	minimum	maximum
red	2.07	2.32	0.00	16.87
green	34.31	12.39	7.96	67.05
blue	1.70	2.67	0.03	18.64
cyan	6.77	6.09	0.17	40.63
yellow	2.67	2.56	0.00	16.23
magenta	0.41	0.76	0.00	8.12
black	46.40	18.90	1.99	87.83
white	5.67	8.09	0.01	48.85

According to previous studies[5,17~18] and on-site observation, each color was represented by physical features in the forest scenes. The visual inspection of each slide suggested that red in the forest scenes was associated with fall foliage, whereas yellow represented sun-splashed grass and a fall leaf-color. Blue seemed to be primarily associated with a deep blue sky, while cyan(light blue) seemed to represent wood, debris, vegetation, light shadow, and some sky. Green appeared to represent foliage and grass in the summer and spring, while black seemed to include dark green and dark shadows. Magenta was a rare color in the images. The amount of green and black together made up 80 percent of the color in the forest scenes, with black predominating. The reason that black took up such a large percentage of the total color content in the slides(46.40 % on average) appeared to be because the scanner's reading of black included the darkest shades of other colors, such as green and blue. For this reason it was decided to compare the results obtained from scanning with those obtained from human judgements of color visibility in each forest scene.

3.2 Human judgement of slide color visibility

The color-visibility ratings of all the slides were obtained from graduate students enrolled in the Department of Recreation, Park, & Tourism Sciences. The ratings by these judges were transformed using the same RMRATE program used to compute the scenic-beauty estimations. The resulting color ratings were also referred to as color visibility estimations(CVEs). The CVE value for each slide represented the average of the transformed ratings for that slide obtained from each of the judges.

A summary of the statistics for the blue, green, yellow, and brown color visibility for all the slides is presented in Table 2. The green and yellow CVEs were rated with a lower color visibility than the average baseline slides, whereas the blue and brown CVEs were higher than the average baseline slides. A correlation matrix for the CVEs is shown in Table 3, where the Pearson product-moment correlations ranged from 0.24 to -0.82. The strongest correlation was between brown and green(r=-0.82). This negative correlation was probably the effect of the season, with green being highly visible in summer foliage, and brown being more visible in winter foliage. The weakest correlation(r=0.00) was between brown and yellow. The reason for this lack of association was unclear.

Table 2. Human CVE's

color	mean	std.dev.	minimum	maximum
green	-0.37	45.08	-74.27	83.18
blue	4.95	21.65	-31.09	68.26
yellow	-3.66	23.12	-40.27	70.52
brown	1.79	31.88	-81.19	68.94

Table 3. Correlation matrix of CVE's

color	green	blue	yellow	brown
green	1.00			
blue	-0.17^a	1.00		
yellow	-0.15^a	-0.20^b	1.00	
brown	-0.82^b	0.24^b	-0.00	1.00

$^a p < 0.01$, $^b p < 0.001$

To examine the consistency between the computer-based color content ratings and the CVEs provided by the human judges, Pearson's product-moment correlations were computed between the two measurements. Individual correlations were calculated for the amount of blue, green, and yellow in each slide. The correlations of the green, blue, and yellow CVEs with the corresponding color contents(CCs) (percentages) obtained from the image processing are shown in Table 4. The Pearson product-moment correlations between the color ratings obtained from the two methods were relatively small and ranged from 0.33 to -0.29. The strongest correlation was between the blue CVEs and green CCs(r=0.33), while the weakest correlation(r=0.01) was between the yellows of the two procedures.

Table 4. Correlations between Image data and human CVE's

color	green	blue	yellow	(human CVE's)
green	0.25^b	0.33^b	0.15^a	
blue	-0.29^b	0.07	0.01	
yellow	-0.21^b	-0.02	0.22^b	
(image CC's)				

$^a p < 0.01$, $^b p < 0.001$

4. Conclusion

The key measurement issue raised by the current study pertains to the assessment of color in forest environments. The problems encountered when using the two color-measurement processes employed in this study are discussed below.

Initially, color was measured using a computer-based scanning technique in which each slide was scanned at the pixel level and one of eight color values was assigned to each pixel. The main problem noted with this procedure was that on average almost one-half of each slide was recorded as black in color. This outcome did not conform to the investigator's own evaluation of the slide color contents when the images were projected on a white surface. Although it is conceivable that black is present in greater quantities in forest scenes than discerned by the human eye, the fact that the dependent variable in this study was itself a human perception raised fears that a measure of color content that conflicts with human judgment could cause problems in later analyses.

Visual inspection suggested that darker shades of other colors also were more common in the summer months, again because of the leaf canopy. Unfortunately, many of these darker hues were apparently recorded by the scanner as black. One explanation for this is that a pixel was assigned a single color value corresponding to the hue that comprised the majority of that pixel's area. Pixels containing mostly black would thus be recorded by the scanner as pure black, even though humans may perceive these points as a darker shade of another color. However, the upshot was to tilt the color-scanning data in favor of black, especially during the summer season, at the expense of other dark colors within the visible spectrum.

Once the decision was made to use human judges to gauge the color visibility in comparison with the scanned data, a method for measuring these judgments had to be developed. It was clear that the task of obtaining color data from human judges would require much effort. Therefore, due to the time involved in evaluating the slides visually, it was decide to limit the number of colors rated to a total of four. Thus, one shortcoming of using human judges is that, when compared to computer scanning, the amount of color data that can be collected is relatively restricted.

Furthermore, the physical properties of the colors observed also seemed to play a role in the color perception in the present study. As such, the experience with the color-judgment procedures used in this study suggested that greater attention should be paid to training judges in similar future studies. In conclusion, it is hoped that the current results may help advance a hybrid approach to visual quality assessment in which the empirical strength of computer-based technology is combined with the theoretical strength of psychological methods.

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