SCENIC BEAUTY ESTIMATION OF FORESTRY IMAGES

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Abstract - **The aesthetic quality of forests in the U.S. is actively managed by the United States Department of Agriculture (USDA) Forest Service. To support this mission, several forest lands in the southern U.S. have been carefully photographed and analyzed for factors contributing to scenic content. In this paper we describe algorithms that we developed to automatically assess the scenic quality of images. The goal of the project was to develop objective techniques to determine the scenic beauty rating of the image and correlate the rating to the subjective ratings available from human experimentation. The evaluation database that was developed for this task is also described.**

INTRODUCTION

An increase in the awareness of protecting our environment and conserving our forest resources has led the United States Department of Agriculture (USDA) to conduct extensive research in the areas of forest management and forest cultivation [1]. One particular interest in this effort is to preserve the aesthetic values of forest land. Determining the scenic beauty of forest lands helps identify the means to cultivate and manage the forest. The challenge is to develop algorithms to obtain an objective scenic beauty rating which correlates well with subjective ratings.

There are various factors affecting the scenic beauty of an image such as the color, size of the trees, and ground pattern. Visual preferences may vary from viewer to viewer though the physical properties of the image are the same. Statistical models suggest that a low density of trees and high visual penetration are associated with high scenic beauty, while high density of foliage, twigs, small stems, and thin trees are associated with low scenic beauty [2]. The goal is to use these invariant characteristics to develop an objective method to quantify the subjective judgement.

In this paper we present a system that determines the scenic beauty estimate (SBE) of an image. We report results on a database of images that were collected under controlled conditions by the USDA Southern Forest Experiment Station (see DATABASE). We have emphasized the need to make the system comprehensive and systematic and the code extensible to additional algorithms in the development of the relevant software. We discuss several techniques used to extract features from the images and their implementation. A comparison of the subjective and objective scores is also presented.

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ALGORITHMS

Some important features to be considered for scenic beauty estimation are color, size and shape of trees, and ground patterns of vegetation. In our initial experiments, we have investigated the use of color and line segment distributions.

Histogram

Color is one of the most noticeable features of a forest environment. It is affected by a number of factors including the temporal rhythm of seasons and the time of day. Winter views are typically judged less scenic than the other seasons. Human preference is correlated with seasonal color patterns. A histogram is a simple tool that can be used to estimate the frequency distribution of each color in an image represented in an RGB format. These histograms can then be compared using the root-mean-square (RMS) error. Reference templates can be built from images judged by humans to be scenic, and images judged not to be scenic. The distributions for a given image can then be compared to these reference distributions, and a distortion measure can be used to determine the degree to which an image is scenic.

Edge Detection

The size of the vegetation (i.e., bushes, trees) in an image is an important feature in scenic estimation. Based on subjective ratings, it has been established that visually penetrative images (images in which objects interior to the plot can be easily seen) are more scenic. This led to the conclusion that tall trees aid scenic beauty whereas short bushes and foliage have a negative impact [3].

We used the Canny edge detection algorithm [4] that uses standard horizontal and vertical masks to compute the gradient of the image to obtain the edges of objects. The masks for calculating the x and y gradients, G_x and G_y respectively, are given in (1):

$$G_x = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix} \qquad G_y = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} \tag{1}$$

This algorithm operates on a grayscale version of an image. Our data consisted of the 24-bit color images, which were converted to an 8-bit luminance value. The conversion from color to grayscale, or luminance, is described in (2):

$$Y = 0.299R + 0.587G + 0.114B \tag{2}$$

where R, G, and B are the red, green, and blue values respectively, and Y is the output grayscale value. As tall trees have longer vertical lines and short bushes have shorter vertical lines, the edge detected image is then used to compute the number and length of each of the vertical lines. The percentages of the long and short lines give an estimate of the density and size of the trees and bushes in the image.

DATABASE

We have prepared a database of 680 images with the help of the Southern Forest Experiment Station (SFES). The images included in the database were drawn from a study spanning four years dealing with the Ouachita Forest in Arkansas, USA. Photographs taken under controlled conditions have been digitized using an extremely high quality scanning process and converted into computer readable data. The areas studied were partitioned into four blocks. The database we have developed is based on two sets of images taken approximately four years apart during 1990-91 and 1994-95. Each of the 20 plots selected in the forest were photographed from at least four different angles.

The original images were delivered in a proprietary format known as the photoCD (PCD) format [5] created by Kodak specifically for archiving high-quality photographs. Since the photoCD format is not publicly accessible, we selected the PPM format as the format to be used for the archival of the data. Further, we decided to use the 4x photoCD resolution, which generates images in a 1536 pixel wide x 1024 pixel high format.

In addition to the raw data, there are a number of measures computed by having viewers manually assess the images. For example, the subjective scenic beauty ratings on all images are available as part of the database. There are also 20 baseline slides available which are used as reference to scale the ratings of different groups of viewers. The baseline images can be identified from the comment fields. A typical image is shown in Fig. 1. A histogram of the SBE values for all images in the database is shown in Fig. 2.

RESULTS

The algorithms were evaluated on 50 images, 40 from plot 3 and 10 from plot 1. We have taken all the images from a single plot to cover images photographed from different angles, and during different seasons and different sessions of time. The values of features computed in three of these images are given in Table 1. The correlations of these features with the subjective rating is shown in Table 2. The results show a correlation of 0.58 between the subjective rating and the objective rating when all 50 images are considered. There is a slight variation in the correlations from 90-91 to 94-95 due to the change in the pattern of the vegetation in the images for these two periods.

Figure 1. Two typical images from the evaluation database.

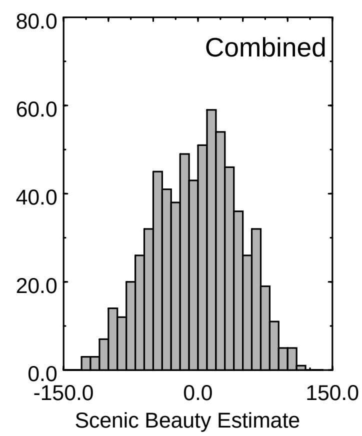

Figure 2. A zero-mean histogram of the SBE values for the image database. Images with less than zero SBE are considered to be less scenic than average; an SBE above zero indicates an image is more scenic than average.

Image File	mean(red)	man(green)	man(blue)	% long lines	%short lines	Derived SBE	Ref. SBE
b01_t02_p003_a045_091590.ppm	37	52	24	3.24	73.89	0.51	7.58
b01_t02_p003_a225_102294.ppm	59	69	30	2.51	71.13	0.44	5.49
b01_t02_p003_a180_013191.ppm	55	61	59	0.84	81.12	0.33	2.63

Table 1. Typical feature measurements for a range of images (most scenic, average, and least scenic). The last column contains the reference SBE derived from human evaluations.

year	man(red)	man(green)	man(blue)	% long lines	% short lines	Derived SBE
90 - 91	-0.59	-0.49	-0.68	0.36	-0.45	0.68
94 - 95	-0.33	-0.15	-0.32	-0.59	0.65	0.49
combined	-0.50	-0.38	-0.52	-0.10	0.16	0.58

Table 2. Correlations of features with the reference SBE scores are presented. The first row corresponds to features computed only on ‘90-’91 data, the second row corresponds to the ‘94-’95 data, and the last row combines all images into a single group.

When the ‘90-91 baseline stimuli were used with ‘94-95 images, baseline means were significantly different by 1 point when used with ‘90-91 images. Such results suggests caution in assuming SBE values from the two survey periods are comparable [3]. We anticipate that SBE value differences by survey period are minor or can be accounted for when developing algorithms from digitized images.

SOFTWARE

We have implemented this system in an object-oriented paradigm using C++ in order to combine several algorithms into a single computational framework. The software assumes that the input image format is a portable pixel map (PPM), a popular public domain standard [5]. The analysis program is driven from a parameter file, in which the user can specify the processing mode (training, testing, and updating), the choice of algorithm (currently histograms and edge detection are supported) and all secondary parameters related to these choices. The software is available at the URL: *http://isip.msstate.edu/software*.

CONCLUSIONS

This paper introduces an implementation of an algorithm to determine the scenic beauty of an image and to compare it with the actual SBE. Significant correlation has been observed between the derived SBE and the reference SBE. Several tools have been developed to support research on this database, including an objective evaluation paradigm that can be used to benchmark algorithm performance.

Our efforts in the future will be directed towards developing algorithms to determine the relation of the scenic beauty on the other factors such as the texture of image and ground pattern. Image analysis techniques such as frequency response and fractal dimension will be used to extract more composite features about the images. Morphological approaches in which we model the images as a hierarchy of objects will also be introduced. A factor analysis approach to feature combination will be replaced with a neural network. Finally, these same techniques will be extended to the prediction of vegetation growth, and to provide an ability to simulate growth and ageing of a forest. Our goal is to develop a completely automated image analysis tool for forestry images.

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