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SEGMENTATION OF COLOR AERIAL PHOTOGRAPHS USING HSV COLOR MODELS

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Abstract

Color aerial photographs have been widely used for grasping most updated land uses. As the first step towards the automatic extraction of such features as roads, houses, etc. from color aerial photographs, we report on the evaluation of several color models used for region segmentation. We first transformed the RGB color images into an HSV space by using one of several HSV color models, including the ones proposed by the authors, and then applied a segmentation process based on the Euclidean distance in the HSV space. The results show that our newly proposed models yield better segmentations, which can compete with the results obtained by CIE L*a*b* color system.

1 INTRODUCTION

Aerial photographs have become to be used instead of maps more often for development of urban areas or building geographic information systems. This is because most updated usage of land can be captured by them.

We are now working on color aerial photographs, aiming eventually at building a system for matching the photographs and maps, and supporting detection of changes between them. In this paper we report an investigation on region segmentation of color aerial photographs.

The images used are taken from a photograph of scale 1/15,000 for aerial survey, input with an RGB color dram scanner. Region segmentation is done mostly in HSV color space, where H stand for Hue, S for Saturation, and V for Value or Intensity. There have been proposed several HSV color space models, or conversion formulas from RGB to HSV, we compare and evaluate those models, including two new models proposed here, in a limited goal of region segmentation of color aerial photographs.

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2 HSV COLOR MODELS

(a) Smith's Model [1]
Use the main diagonal of RGB color cube as the V axis and, by projecting the RGB cube to a plane perpendicular to the V axis, let the angle from the R axis be H and the distance from the V axis be S. The conversion formula is:

$$H = \begin{cases} 60(b-g), & \text{if } R = \max\{R,G,B\} \\ 60(2+r-b), & \text{if } G = \max\{R,G,B\} \\ 60(4+g-r), & \text{if } B = \max\{R,G,B\} \end{cases}$$

$$S = \frac{\max\{R,G,B\} - \min\{R,G,B\}}{\max\{R,G,B\}}$$

$$V = \max\{R,G,B\}$$

where, $r = \frac{\max\{R,G,B\}-R}{\max\{R,G,B\}-\min\{R,G,B\}}$, $g = \frac{\max\{R,G,B\}-G}{\max\{R,G,B\}-\min\{R,G,B\}}$, $b = \frac{\max\{R,G,B\}-B}{\max\{R,G,B\}-\min\{R,G,B\}}$

(b) Joblove's Model [2]
Let the main diagonal of RGB color cube be the V axis and define as $V = (\max\{R,G,B\} + \min\{R,G,B\})/2$. H and S are defined as follows:

H : the same as in Smith's model

$$S = \begin{cases} \dfrac{\max\{R,G,B\} - \min\{R,G,B\}}{\max\{R,G,B\} + \min\{R,G,B\}}, & \text{if } V \le 0.5 \\ \dfrac{\max\{R,G,B\} - \min\{R,G,B\}}{2 - \max\{R,G,B\} - \min\{R,G,B\}}, & \text{otherwise} \end{cases}$$

(c) Tenenbaum's Model [3]
In this model H, S and V are calculated by the following nonlinear transformation:

$$H = \arctan \frac{\sqrt{3}(G-B)}{(2R-G-B)}$$

$$S = 1 - 3\min\{\frac{R}{R+G+B}, \frac{G}{R+G+B}, \frac{B}{R+G+B}\}$$

$$V = \frac{R+G+B}{3}$$

(d) New HSV Model No.1

In Joblove's model S can take any value in [0,1] even if V is near 0 (black) or near 1 (white). Thus its HSV space has a shape of cylinder as shown in Fig.1(a). Since at $V = 0$ or $V = 1$ S is defined to be 0, there are discontinuities at those points. We defined a new model by modifying Joblove's model so that the range of S decreases linearly as V gets far from 0.5 and approaches 0 or 1. Thus S in our model is defined by S in Joblove's model as $S(1 - |1 - 2V|)$. This new S can be calculated more simply as shown in the following conversion formula. The shape of the color space of this new model is composed of two cones whose bottoms meet together(Fig.1(b)).

H : the same as in Smith's model

$$S = \max\{R,G,B\} - \min\{R,G,B\}$$
$$V = \frac{\max\{R,G,B\} + \min\{R,G,B\}}{2}$$

(e) New HSV Model No.2

As in the new HSV model No.1, S is converted from that of Joblove's model in order to transform its color space nearly to double cones. The difference of this model from the previous one is the definition of V. In new HSV model No.1 only the maximum and the minimum among R, G, B are taking account of in calculating V; the median of them does not influence V. In the second model V is defined as the mean of R, G and B. The point where S takes its maximum (i.e., 1) is lowered at red, green and blue, and lifted at cyan, magenta and yellow, compared to the first model. The conversion formula is as follows.

H : the same as in Smith's model

$$S = \max\{R,G,B\} - \min\{R,G,B\}$$
$$V = \frac{R+G+B}{3}$$

3 PROCEDURE FOR REGION SEGMENTATION

In this study we segment first preprocessed color aerial photographs by applying a modified version of Ohlander's recursive thresholding[4], then merge oversegmented regions (see Fig.2).

3.1 Preprocessing

In order to reduce noise as well as enhance blurred edges, we apply first pixelwise region enlargement. After converting RGB values of a pixel into HSV values, choose a neighboring pixel or region whose color is the closest to the color of the pixel in question, and if the color difference is less than a predetermined threshold d_{TH}, then merge the pixel to the chosen pixel or region. Here the color of a pixel or a region is specified by a point in HSV space and a color difference is calculated by the Euclidean distance between two points. The merged region is given their average color, that is, average of R, G, B, respectively. This process is performed by scanning the picture only once from its top-left to bottom-right.

3.2 Region Splitting

We used Ohlander's recursive thresholding method with a modification described below.

In Ohlander's method the histograms constructed for nine color features R, G, B, H, S, V, Y, I, and Q. Then choose the histogram which has the sharpest peak and set a threshold between the peak and other peak(s) of the histogram. Classify the pixels in the image into two: those belonging to that peak and the others. For each connected component in the image of thus dichotomized pixels, calculate again histograms of nine features, find another threshold, and dichotomize the pixels; repeat this process recursively until no good separation of any histogram can be found.

As stated above, in the original Ohlander's method the histograms of features are calculated for each connected component in the image produced by the previous histogram thresholdings. However, if we adopt this method as it is, the number of the pixels in a connected component decreases very rapidly and meaningful histograms can not be constructed. For this reason we modified his approach so that the histograms are calculated for each subspace of the color space produced by the thresholdings, instead of for each connected component.

3.3 Region Merging

Both the original and modified versions of recursive thresholding explained in 3.2 produce generally good region segmentations, but tend to yield many small regions in noisy part of the image or along the boundaries between two significant regions. So we add a region merging stage as a postprocessing of region splitting.

Small regions are merged into one of the adjacent regions, if the Euclidean distance between them in the HSV space is smaller than the threshold defined as follows. Let d_{ij} be the distance in HSV space between the average colors of region R_i in question and the adjacent region R_j which gives the minimum d_{ij} and define the threshold for d_{ij} by

$$d_{TH} = a/S_i + b$$

where S_i is the area of region R_i and a, b are constants. If $d_{ij} \leq d_{TH}$, then merge R_i and R_j. Repeat this procedure in the increasing order of the area of region R_i until no more merging of regions occurs.

4 COMPARISON OF HSV COLOR MODELS

Since in all the three stages for region segmentation HSV features and color differences in HSV space are used, the result of segmentation varies from model to model. In our experiment we compare the results obtained by using each of five HSV color models introduced in Section 2, both subjectively and quantitatively, in the following three cases:

- the case that all the parameters d_{TH}, a, and b are fixed at the same values for all five models.
- the case that the parameters are chosen to the empirically optimal values for each model.
- the case that the parameters are set so that the number of the resulting regions is the same.

We will report here only the third case, because of the limited space and generally similar tendency in three cases. In the experiment we set the ratio between the length of V axis and the (maximal) radius in S direction to 1:1, which seemed to give a best result in preliminary experiments. We used four different parts of a color aerial photograph, 256 x 240 pixels each, with various objects and with different extent of blurring.

4.1 Subjective evaluation

To summarize, the new HSV model No.1 and No.2 produced better segmentations than the other models, with slight superiority of No.2 new model. Fig.3 shows an input image and Fig.4 the result using the new HSV model No.2.

4.2 Quantitative evaluation

The resulting segmentation is considered better if the colors of pixels are similar within regions. However, since the volume of color space in each model differs, the similarity should be normalized by color similarity between regions. Thus we evaluated the result by the ratio of within-region standard deviation of colors σ_W to between-region standard deviation σ_B. For the five color models σ_W/σ_B is shown in Fig.5. Since the number of segmented regions are the same, this comparison is fair.

We also compared each result with the result of human segmentation. The procedure is as follows. First a human subject input interactively the boundaries of specified various objects in an aerial picture shown on a graphic terminal. Given the following points,

- the pixel on a human-input boundary : 4 points
- the pixel adjacent to a human-input boundary : 2 points
- the pixel two-pixel apart from a human-input boundary : 1 point
- others : 0 point

sum up the points for all the pixels on the boundaries between the regions produced by a segmentation. However, if a result yields a fine segmentation, it would be likely to have a high score. In order to compensate that effect we used the ratio of total points to the total length of boundaries in a segmentation result.

Roads, grounds, houses and buildings, grass and tree areas, and rivers are chosen for the objects for evaluating the segmentation. The ratios are shown in Fig.6, in relative scores to that of (a) Smith's model.

4.3 Summary of comparison

As seen from the results in the previous two subsections, our newly proposed HSV model No.1 and No.2 generally yield better segmentations than the other models do. They are appropriate for segmenting the color space uniformly, regardless whether in the near part of white or black, or in a bright color. We suppose that it is due to the double-cone shape of the color space as in shown in Fig.1. New HSV color model No.2 is better at a variation of intensity than new model No.1. In a subjective evaluation the new model No.2 produced as good or slightly better segmentations than the CIE L*a*b* color model did.

5 CONCLUSION

We compared several HSV color models, including two models we proposed here, for segmentation of color aerial photographs. The comparison shows our proposed models yield better results than other models.

References

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[3] J. M. Tenenbaum et al.: *An interactive facility for scene analysis research*, Technical Note 87, Artificial Intelligence Center, Stanford Research Institute (1974)

[4] R. Ohlander, K. Price and D.R. Reddy: *Picture segmentation using a recursive region splitting method*, Computer Graphics and Image Processing, vol.8, pp.313-333 (1978).

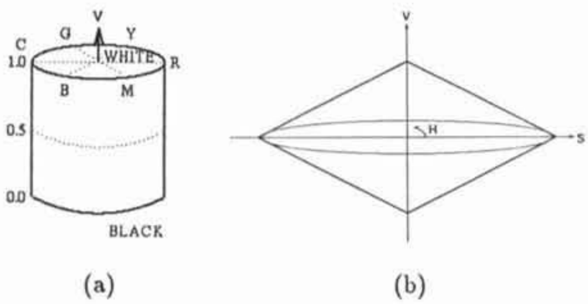

Fig.1 Color spaces of Joblove's model (a) and the new model No.1 (b).

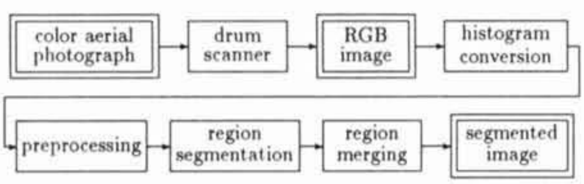

Fig.2 Process for region segmentation.

Fig.3 A color aerial photograph (256 x 240 pixels, dither output of Value component).

Fig.4 Result of segmentation using the new model No.2.

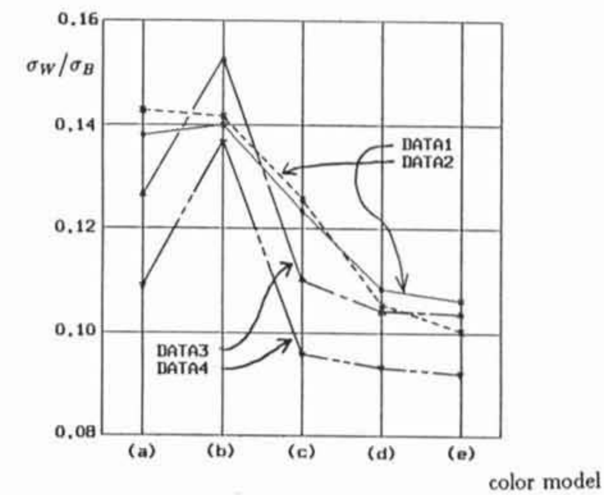

Fig.5 Normalized color deviations within segmented regions.

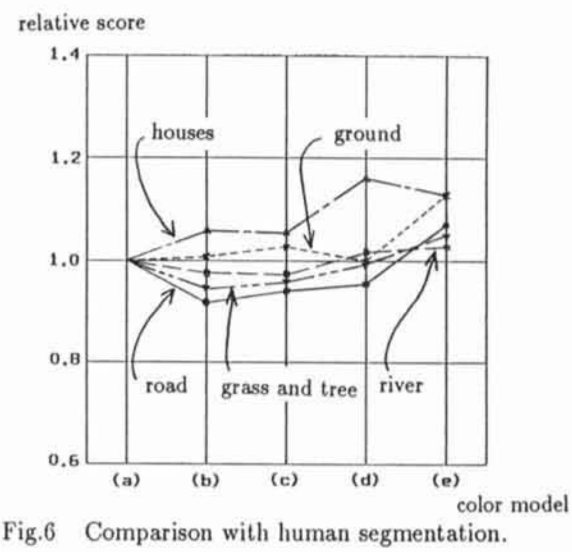

Fig.6 Comparison with human segmentation.