Improvement of Method to Estimate Colors of Amber

Hina Ishikawa^{a,*}, Yoichi Kageyama^{a,*}, Chikako Ishizawa^a, Tsuyoshi Takahashi^a, Makoto Nishida^b, Hisao Shinden^c,
Toshio Takizawa^c, Taro Koyama^c, Makoto Kobushi^c

^aAkita University, 1-1 Tegata Gakuen-machi, Akita-shi, Akita 010-8502, Japan

^bThe Open University of Japan, 1-1 Tegata Gakuen-machi, Akita-shi, Akita 010-8502, Japan

^cKuji Kohaku Co., Ltd., 19-156-133 Kokuji-cho, Kuji-shi, Iwate 028-0071, Japan

*Corresponding Author: kageyama@ie.akita-u.ac.jp

Abstract

In a previous study, we demonstrated the color features of ambers and a method to estimate amber colors. We specifically focused on the red, green, blue (RGB) color space and the hue, saturation, value (HSV) color space. We proposed a method to estimate amber in four colors (yellow, brown, black, and ambers with an outer cover (AOCs) created with solid resin or amber dirt). However, due to the presence of ambers with partially exposed outer covers (APEOCs), the estimation accuracy of AOCs was 57.1%. In this paper, we therefore demonstrate the color features of ambers and a method aimed at improving the estimation accuracy of AOCs. Specifically, we focus on five kinds of ambers: three colors (yellow, brown, and black), AOCs and APEOCs are examined. The proposed method consists of masking, detection of AOC, estimation of amber color, and detection of APEOC. Experimental results for 185 ambers show that the proposed method can estimate amber color with an accuracy of 96.7%. It is also shown that an estimation accuracy of 91.4% for AOC color estimations is achieved.

Keywords: amber, color, RGB, HSV

1. Introduction

Amber is derived from resin, the composition of which can vary vastly; insects, leaves, flowers, and bark can be embedded in the amber for up to hundreds of millions of years, creating a very rare appearance that is also of academic and scientific importance [1]. The city of Kuji in Japan is one of the world's great producers of amber, and raw amber is processed into its finished form here. It is important to determine the color and quality of amber depending on its application; however, this discrimination is currently done with human eyes. A new compound,

named kujigamberol, has been isolated from amber [2]. Further, regenerated amber, with 100% purity, has been made from pieces of amber [1]. Therefore, it is necessary to develop a method for estimating the type of color in amber debris, which in turn will contribute to cost reduction and high-speed processing. In a previous study, we demonstrated the color features of ambers and a method to estimate amber in four colors (yellow, brown, black, and ambers with an outer cover (AOCs) created with solid resin or amber dirt) [3]. However, due to the presence of ambers with partially exposed outer covers (APEOCs), the estimation accuracy of AOCs was 57.1%. In this paper, we therefore demonstrate the color features of ambers and a method aimed at improving the estimation accuracy of AOCs.

2. Data Acquisition Environment and Color Features

The data was acquired in a dark room with two LED lights. It includes photographs taken with light falling from above (top-light images) and photographs taken with light coming from the bottom (bottom-light images). The top-light images have been taken with five different illumination levels (luminance levels 500–2500 lx, in stages of 500 lx). The bottom-light images have been taken with nine different illumination levels (luminance levels 500–2500 lx, in stages of 250 lx). Fig. 1 shows the environment where the photographs were taken. The study focuses on five kinds of amber: three colors (yellow, brown, and black), ambers with an outer cover (AOCs) created with solid resin or amber dirt, and ambers with partially exposed outer covers (APEOCs). Fig. 2 shows the training data used in this study.

For the experiment, 185 ambers (yellow amber: 70, brown amber: 40, black amber: 40, and AOC: 35) were used. In addition, we use 260 images (RGB color images;

Fig. 1 Photography setup

Fig. 2 Five kinds of amber sets used in the training data

5184 × 3456 pixels) of amber (185 top-light images and 75 bottom-light images). The top-light images consisted of 70 images of yellow amber, 40 images of brown amber, 40 images of black amber, and 35 images of AOCs. The bottom-light images consisted of 40 images of brown amber and 35 images of AOCs.

In a previous study, we focused on the hue (H) component of the hue, saturation, and value (HSV) color space and the red (R) component of the red, green, blue (RGB) color space as features useful for estimating the colors of amber [3].

In previous experiments, the mode value of the H component has shown there was little overlap between the three colors of ambers except AOCs. The findings indicated that the average value of the R component can be used to distinguish between yellow amber and the other ambers. The average value of the S component of AOCs was lower than that of the other ambers. It was also found that the average value of the V component was quite similar to the average value of the R component. The findings indicate that the value of the R component in the amber area was the largest because the V component was defined as the largest component of the RGB color space.

In the conventional method, color estimation was done using the above results.

Furthermore, in this study, we focused the variance value of the H component as a feature function for estimating APEOCs. Fig. 3 shows that the variance value of the H component of APEOCs and brown amber is lower than the variance value of the other ambers. This finding suggests that the variance value of the H component can be used to distinguish APEOCs and brown amber from other ambers.

3. Proposed Method

In our previous study, we proposed a method (the conventional method) for estimating amber to classify them into four kinds (yellow, brown, black, and AOC) [3]. The conventional method consists of masking, detection of AOC, and estimation of the amber color. Fig. 4 shows a flowchart of the conventional method. In the proposed method, APEOC detection has been added to the conventional method to improve the estimation accuracy of AOCs. This process uses top-light and bottom-light images. Fig. 5 shows a flowchart of the proposed method.

3.1 Masking

For top-light images, masking is done and the amber area is extracted. The masking comprises gray-scaling, binarization, expansion, and contraction processing with 10 operations, followed by color inversion [4].

3.2 Detecting AOCs

To detect AOCs, RGB values and HSV values are obtained from the amber area. The proportion of pixels with $R = V$ is calculated in the amber area. When the resulting value is 0.75, with good results obtained between 0.70 and 0.90 for every step of 0.05 or more, it is judged as an amber.

Fig. 3 Relation between hue and illuminance

Fig. 4 Flowchart of the conventional method

Fig. 5 Flowchart of the proposed method

Furthermore, the average value of the S component in the amber area of the target image is also calculated. When the calculated average value is above the threshold value, it is added to the list of ambers. Here, the threshold of the S component was set to 32.9 because good results were obtained for 73% of the average value of black ambers. The rest were classified as AOCs.

3.3 Estimating Amber Colors

In order to estimate the colors of the ambers, two degrees of attribution (α and β) are calculated to estimate colors.

(a) Degree of Attribution α

The degree of attribution α is calculated using equation (1). The average of the R component in the reference data is A, and the average of the R component in the amber area is B. The tolerance is C. Table 1 lists the preset values for calculating the degree of attribution α .

$$\alpha = 1.0 \quad \text{if } |A - B| \leq C$$

$$\alpha = 1.0 - \frac{|A - B| - C}{255 - 2C} \quad \text{else} \quad (1)$$

(b) Degree of Attribution β

The degree of attribution β is calculated using equation (2). The mode value of the H component in the reference data is A, and the mode value of the H component in the amber area is B. The tolerance is C. Table 2 lists the preset values for calculating the degree of attribution β .

$$\beta = 1.0 \quad \text{if } |A - B| \leq C$$

$$\beta = 1.0 - \frac{|A - B| - C}{(360 - 2C) \div 2} \quad \text{else} \quad (2)$$

(c) Membership of Each Amber Category

The degree of membership γ for each amber category (yellow, brown, and black) is determined from the above two degrees and equation (3). The target image is also estimated as the amber color having the highest value.

$$\gamma = 0.5\alpha + 0.5\beta \quad (3)$$

3.4 Detecting APEOCs

(a) Detecting APEOCs from Yellow Amber and Black Amber

When the target image is estimated to be yellow amber or black amber, the variance value of the H component in the amber area is calculated. If the calculated variance value is above the threshold, it is added to the APEOC set. In this study, since good results have been obtained, the yellow amber threshold value was set to

Table 1 The preset values for calculating the degree of attribution α

	Yellow	Brown	Black
A	237	148	114
C	15		

Table 2 The preset values for calculating the degree of attribution β

	Yellow	Brown	Black
A	43	358	249
C	30		

15000 and the black amber threshold value was set to 9000 in advance. The rest were classified as yellow amber and black amber.

(b) Detecting APEOCs from Brown Amber

For target images estimated to be brown amber, masking is done in the conventional method for bottom-light images of the same amber, and the amber area is extracted. Furthermore, masking with mean shift [5] is done for the amber area, and the AOC area is extracted. A target image having many AOC regions is added to the APEOC set. In this study, the threshold of the area was set to 60%.

4. Experimental Results of Amber Estimation

In order to verify the usefulness of the proposed method, we conducted an experiment to estimate 185 ambers. A parallel experiment was also conducted to estimate 185 ambers using the conventional method.

When carrying out these experiments, we first selected the optimum illuminance of the data set. As a result, the proposed method describes the results using top-light images at about 1500 lx and bottom-light images at about 750 lx. Table 3 shows the results of the amber estimation using the proposed method, and Table 4 shows the results of the amber estimation using the conventional method. Fig. 6 shows the results of the estimation. The proposed method successfully distinguishes 179 out of 185 ambers (96.7%). This result shows an improvement of accuracy of 6.4% over the conventional method. Furthermore, by applying the APEOC detection technique of the proposed method, an APEOC estimated to be amber by the conventional method is estimated to be an AOC (Fig. 7 and Fig. 8). As a result, the estimation accuracy of AOCs has been improved by 31.4% compared with the conventional method.

The average processing time per image was calculated. The experimental environment consisted of a PC with Windows 7, Intel (R) Core (TM) i7-6700K @ 3.40 GHz CPU, and 8 GB of RAM. The processing time was about 0.173 s.

Table 3 Estimation results of the proposed method

Amber	Number of pieces	Success	Accuracy(%)
Yellow	70	70	100.0%
Brown	40	39	97.5%
Black	40	38	95.0%
AOC	35	32	91.4%
Total	185	179	96.7%

Table 4 Estimation results of the conventional method

Amber	Number of pieces	Success	Accuracy(%)
Yellow	70	70	100.0%
Brown	40	39	97.5%
Black	40	38	95.0%
AOC	35	20	57.1%
Total	185	167	90.3%

(a) Yellow amber

(b) Brown amber

(c) Black amber

(d) AOC

Fig. 6 Estimation results of amber using the proposed method

Fig. 7 Estimation results of APEOCs using the conventional method

Fig. 8 Estimation results of APEOCs using the proposed method

5. Conclusions

In this study, we proposed a method to estimate amber for the purpose of improving the estimation accuracy of AOCs. In order to verify the usefulness of the proposed method, we conducted an experiment to estimate 185 ambers using the proposed method and the conventional method. Experimental results showed that the proposed method is useful for estimating amber. In particular, it was shown that the estimation accuracy of AOCs using the proposed method has improved with the help of APEOC detection compared with the conventional method.

The above conclusions suggest that the proposed method is useful as a method to estimate the colors of amber.

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