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Supplemental Material: Aesthetic Rating and Color Suggestion for Color Palettes

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Appendix A: Proposed Algorithm

The algorithms proposed in Section 4 of the main paper are given below.

Algorithm 1 Suggesting Compatible Colors

procedure COMPATIBLECOLORS(palette t, index k, #cands N_{cand}, #samples N_{sample}, threshold (τ, κ))
 $\triangleright$ *Sampling candidate's HSVs*
 $f \leftarrow$ COMPUTEHUEPROBABILITY(t, k) $\triangleright$ *Eq. 3 or Eq. 4*
 $h_i \leftarrow$ SAMPLINGFROMHUEPROB(f, N_{sample})
 $s_i \sim \mathcal{N}(\mu_s, \sigma_s)$ $\triangleright$ §4.2
 $v_i \sim \mathcal{N}(\mu_v, \sigma_v)$ $\triangleright$ §4.2
 $\triangleright$ *Compute rating*
 for $i = 1 \rightarrow m$ **do**
  $c_i \leftarrow (h_i, s_i, v_i)$
  $C_i^{\text{cand}} \leftarrow$ COMPATIBLECANDIDATES(t, c_i, τ) $\triangleright$ *Eq. 2*
 end for
 $C \leftarrow$ PERCEPTUALTHRESHOLDING$(C^{\text{cand}}, N_{\text{cand}}, \kappa)$ $\triangleright$ *Eq. 5*
 return C
end procedure

Algorithm 2 Sampling from the Hue Probability Distribution Function

procedure SAMPLINGFROMHUEPROB(function f, #samples n)
 $H \leftarrow \emptyset$ $\triangleright$ initialize a set that holds accepted hue samples
 for $i = 1 \rightarrow n$ **do**
  $\triangleright$ *Rejection sampling from f*
  $h_i \leftarrow$ RANDOMINTEGER$[0,360]$ $\triangleright$ Select a hue value
  $u_i \sim \mathcal{U}_{[0, \max f]}$
  if $u_i \leq f(h_i)$ **then**
   $H \leftarrow H \cup \{h_i\}$
  end if
 end for
 return H $\triangleright$ Out of n samples, m accepted hue samples are returned
end procedure

Appendix B: Feature Extraction

We extract the following features from a given palette. The basic, plane, and HSV features are derived from those used in [OAH11].

Color space. We extract the features of a given palette from RGB, CIELAB, HSV, and CHSV color spaces.

Basic feature (BF). Basic statistics, i.e., `Mean`, `StdDev`, `Median`, `Max`, `Min`, and `MaxMinDiff`, for each of the three dimensions of a color space are extracted. For the BF vector, 72 features are extracted.

Plane feature (PF). A 2D plane is fitted to 3D color coordinates using PCA in RGB, CIELAB, and CHSV color spaces, and `Normal`, `Variance`, and `SSE` are computed as the plane features. Twenty-one features are extracted for the PF vector.

HSV feature (HsvF). In HSV color space, we extract the `Mean`, `StdDev`, `Min`, `Max`, `LogMean`, `LogStdDev`, `LogMin`, and `LogMax` features from the hue probability of color c; p_c. We also extract these features from the hue adjacent probability of colors b and c; p_{bc}^{adj} and the hue joint probability of b and c; p_{bc}^{joint}. Here p_c is the percentage of colors in training palettes with hue c, p_{bc}^{adj} is the percentage of adjacent colors b and c, and p_{bc}^{joint} is the percentage of colors b and c in the same palette. Twenty-five features are extracted for HsvF.

In addition, we extract the hue entropy, which is defined as a probability distribution $p(\theta)$ computed using the hues of a given palette comprising n colors as a mixture of von Mises distribution, i.e., $p(\theta) \propto \sum_{i=1}^{n} \exp(2\pi \cos(\theta - \theta_i))$.

Additional feature (CH and Grads). In addition to the above 118 features, we also extract three additional features. The first feature is Color Harmony (*CH*) [OL06]. The process to calculate *CH* is given in Appendix D. The other features are lightness and hue gradation (Grads), according to the analysis described in Appendix E. We compute linear regressions in ascending/descending order of colors in a palette, and the resulting R^2 values are used as the gradation features. In total, we extract 121 features from a given palette.

Appendix C: Model Analysis

A detailed analysis of the contributions of each feature extracted from a given palette is shown in Table 1. The results show that BF has the largest contribution. According to the results, we include all these features for feature extraction (row 13).

Table 1: *Contributions of each feature (BF, Basic Feature; PF, Plane Feature; HsvF, HSV Feature; CH, Color Harmony; Grads, Gradation).*

	BF	PF	HsvF	CH	Grads	R value
1	✓					0.70
2		✓				0.38
3			✓			0.27
4				✓		0.33
5					✓	0.14
6		✓	✓			0.42
7				✓	✓	0.37
8	✓			✓	✓	0.71
9		✓	✓	✓	✓	0.51
10	✓	✓	✓			0.71
11	✓	✓	✓	✓		0.71
12	✓	✓	✓		✓	0.72
13	✓	✓	✓	✓	✓	**0.72**

Appendix D: Two-color Harmony Model

Ou et al. proposed the following two-color harmony model based on the results of a user study [OL06]:

$$CH = H_C + H_L + H_H, \tag{1}$$

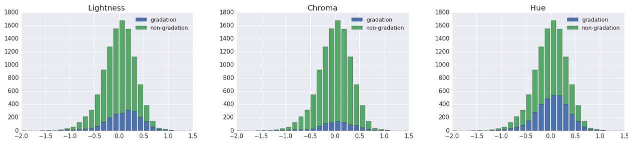
where H_C, H_L, and H_H are the terms related to chroma, lightness, and hue, respectively, calculated by the following equations.

$$\begin{aligned}
H_C &= 0.04 + 0.53\tanh(0.8 - 0.045\Delta C) \\
\Delta C &= [(\Delta H^*_{ab})^2 + (\Delta C^*_{ab}/1.46)^2]^{\frac{1}{2}} \\
H_L &= H_{L_{\text{sum}}} + H_{\Delta L} \\
H_{L_{\text{sum}}} &= 0.28 + 0.54\tanh(-3.88 + 0.029 L_{\text{sum}}) \\
&\quad \text{in which } \ L_{\text{sum}} = L^*_1 + L^*_2 \\
H_{\Delta L} &= 0.14 + 0.15\tanh(-2 + 0.2\Delta L) \\
&\quad \text{in which } \ \Delta L = |L^*_1 - L^*_2| \\
H_H &= H_{\text{SY1}} + H_{\text{SY2}} \\
H_{\text{SY}} &= E_C(H_S + E_Y) \\
E_C &= 0.5 + 0.5\tanh(-2 + 0.5 C^*_{ab}) \\
H_S &= -0.08 - 0.14\sin(h_{ab} + 50^\circ) - 0.07\sin(2h_{ab} + 90^\circ)
\end{aligned}$$

Here L^*, C^*_{ab}, and h_{ab} are the lightness, chroma, and hue values in the CIELAB color space, respectively. We calculated CH as a feature for all combinations of colors in a given palette.

Appendix E: Gradation Analysis

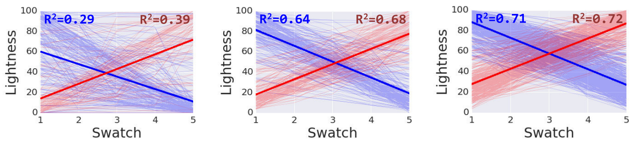
We analyzed whether a color palette in the [OAH11] dataset displays linearity in the order of colors. We counted the lightness/chroma/hue gradation of a palette for all palettes in the dataset to determine if the order of colors decreases (increases) monotonically in the palette's line plot (Fig. 1). A palette with lightness gradation tends to obtain a higher rate than those without lightness gradation (Fig. 1a). As can be seen, hue gradation has the same tendency as lightness gradation (Fig. 1c); however, no significant differences were observed for chroma (Fig. 1b).



(a) Lightness (b) Chroma (c) Hue

Figure 1: *Histogram of #palette of (non-)gradations in the dataset*

We also analyzed the quality of linearity of the lightness gradation. We split the dataset to lower-/middle-/higher-rated groups. Each group had 1,000 palettes. Then, all the palettes in the group were plotted and linear regression was computed (Fig. 2). The bold blue and red lines are the fitting results. From the R^2 value, it can be observed that linearity tends to increase as the ratings increase. Therefore, we include the gradation term in the feature extraction method.



(a) Low-rated (b) Mid-rated (c) High-rated

Figure 2: *Linearity of lightness gradation.*

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