A Unified Color and Contrast Age-Dependent Visual Content Adaptation

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Introduction

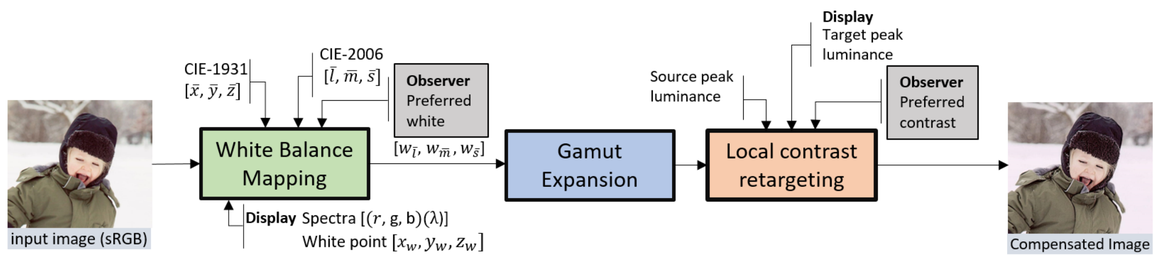
Human color and contrast perception differ from person to person even among color-normal observers. This variability is not taken into account in current display technologies, and it is assumed that a single average standard observer can represent the entire population.

Objectives

1. To develop a unified visual method to correct the effect of age on color perception and contrast sensitivity.
2. To personalize the viewing experience of the observer.
3. To introduce a method that determines the "effective age" of a specific observer.

Age-Based Content Adaptation Method

Two parts of our age-based visual content adaptation method consist of a color modification based on the observer white preference and a contrast enhancement based on the observer's preferred level of detail.



The diagram of the proposed age-dependent content adaptation algorithm

1. White Balance Mapping

- CIE-2006 model of age-based observer color-matching functions (CMF), which establishes a method for computing LMS cone-responses to spectral stimuli [1].
- Determine the normalized spectra $(r, g, b)_n(\lambda) = (r, g, b)(\lambda)J_{r,g,b}$.

$$\left[(\bar{x}, \bar{y}, \bar{z})^T(\lambda)(r, g, b)(\lambda)\right] J_{r,g,b} = y_w^{-1}(x_w, y_w, z_w) \quad (1)$$

- Determine the RGB factors $\mathbf{x} = (x_r, x_g, x_b)$ that achieve the desired black body color match $\mathbf{w} = (w_{\bar{l}}, w_{\bar{m}}, w_{\bar{s}})$.

$$\left[(\bar{l}, \bar{m}, \bar{s})^T(\lambda)(r, g, b)_n(\lambda)\right] \mathbf{x} = \mathbf{w} \quad (2)$$

- With $m = max(x_r, x_g, x_b)$, determine the linear factors: $(r, g, b) = m^{-1}\mathbf{x}$ to apply to each RGB pixel to map an image to the desired white point.
- Perform the gamut expansion part using a hybrid color mapping (HCM) [2].

2. Local Contrast Retargeting

- New model of the contrast sensitivity function (CSF) [3], an extension of the one proposed by Barten [4] with age dependency a.

$$CSF(\rho, L_a, a) = \frac{1}{m_t(\rho, a)} = \frac{M_{opt}(\rho, a)}{2k(a)}\sqrt{\frac{(XYT)(\rho)}{\Phi_{ph}(a) + \Phi_0(a)/M_{lat}^2(\rho, a)}} \quad (3)$$

- The contrast enhancement is performed locally and will follow the methodology developed by Wanat et al. [5]. The detection threshold M_t is estimated by the CSF function

$$M_t = \frac{\Delta L}{L} = \frac{1}{CSF(\rho, L_a, a)} \quad (4)$$

- The localized broadband contrast is defined by [5]:

$$c(x, y) = \sqrt{(g_\sigma * [l(x, y) - (g_\sigma * l)(x, y)]^2)(x, y)} \quad (5)$$

- Contrast retargeting is performed as a local enhancement of the Laplacian pyramid [5]:

$$\tilde{P}_k(x, y) = P_k(x, y).\frac{c_k(x, y) - G(M_t) + G(\tilde{M}_t)}{c_k(x, y)} \quad (6)$$

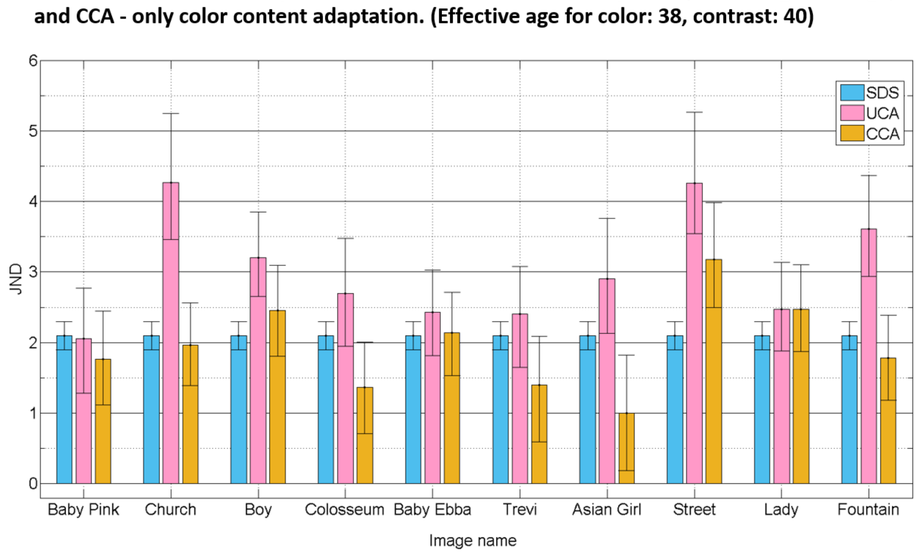
where P_k refers to the source image pyramid level, and G is the logarithmic contrast.

- The reconstruction of the enhanced image in terms of the contrast is done by summing all processed levels of the pyramids $\tilde{P}_k(x, y)$ with the addition of the base band (which was not modified by the local contrast step).

Experimental Validation

- Subjective evaluation using the pairwise comparison approach.
- To determine the observer's effective age, the observer was presented with two videos showing the change of an image's color and level of details separately.
- 30 observers (7 females and 23 males from the age of 23 to 60) participated in the study.
- On average, the whole experiment took about 10 minutes to complete.

Content adaptation examples. UCA - our unified content adaptation, SDS - original image, and CCA - only color content adaptation. (Effective age for color: 38, contrast: 40)



Subjective evaluation results of pairwise comparison representing as JND values. UCA: our unified content adaptation, SDS: original image, and CCA: only color content adaptation.

Conclusion

- A method that adapts both color and contrast to the observer's effective age.
- Preferred over adapting the color only (CCA) and same drive signal (SDS) methods on a variety of images.
- The key is to merge a white balance age-based adjustment procedure with a local contrast enhancement based on a CSF age-based model.
- In the future, we hope to refine our procedure to determine the observer's effective age and extend our approach for all ranges of luminance (mesopic and scotopic vision).

References

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