A New Model for Adaptive Displays Based on von Kries Hypothesis

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1. Introduction
Color appearance of images on self-luminous displays, such as LCD monitors, depends on two sources of illumination: scene illumination within the image itself and ambient illumination in the viewing environment. Color appearance models (CAMs) attempt to predict how perception changes as ambient illumination changes. At their best they provide viewers with an illumination-independent viewing experience. However, existing CAMs are complex and application-specific. Thus they are poorly suited to adaptive displays. For example, existing adaptive displays provide only achromatic adaptation, limiting the complexity of CAMs and minimizing tuning. We propose a new model based on von Kries adaptation, the theory on which most CAMs are based upon. It takes into account the mixed adaptation state produced by self-luminous displays. Compared to existing CAMs, our model is simpler and more efficient, yet shares the generic features of more complex CAMs.

2. Related Work
The new model draws on three important research areas of computer graphics: chromatic adaptation, color appearance models (CAMs) and adaptive display technology. Chromatic adaptation is an internal mechanism that helps to discount varying illumination so as to preserve color appearance: adaptive displays must take it into account. CAMs are mathematical models that predict color appearance: a fortiori, they take into account chromatic adaptation [1]. Such CAMs have been utilized in displays that automatically adjust their luminance output based on viewing conditions.

3. Our Approach
When ambient illumination equals scene illumination, the viewer’s adaptation is correct for the scene (Figure 1). The perceived color (Z) equals the displayed color (Y). Z, in terms of color appearance, equals the true color (X) on the image. When ambient illumination differs from scene illumination (Figure 2), because of chromatic adaptation the perceived color (Z) differs from the displayed color (Y) and the true color (X). To compensate, we adjust the displayed color (to Y’) to make the perceived color (Z) match the true color (X) (Figure 3). Photoreceptors convert displayed color (Y) into three cone signals. With von Kries adaptation, each signal is scaled independently by an illumination-dependent factor [2]. Our model is based on the demonstration that any color to be displayed on the screen (Y’) can be computed by an appropriate scaling of each color channel, so that the change in perceived color (Z) caused by chromatic adaptation is undone.

4. Results
A simulation was written to compare the new model with existing CAMs (Figure 4): CIECAM02, Fairchild, CIELAB [3], for illumination changes from white light of color temperature 6500K to incandescent light of color temperature 2700K. Figure 5 shows the original image (middle) and the images computed by each model, adjusted for display with incandescent ambient light.

5. Conclusions and Future Work
We propose a simple and practical model for building adaptive displays that automatically adjust color based on viewing conditions. Research so far shows that the new model to produces results comparable to existing models. Our work bridges color science and display technology, both of which are of great importance to computer graphics. In the future, we plan to build an adaptive display based on the model and do user studies.

References