Color transform to optimize fruit ripeness discrimination in dichromats

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Aim: To develop and test a color transform for red-green color defectives to enhance tomatoipeness judgements.

Experimental Method: Congenital protan and deutan color defectives suffer sensitivity losses in the red-green mechanism [1] compromising performance in color-discrimination-based everyday tasks [2], which may be compensated by procedures designed to optimize image color gamuts to minimize color confusion [3]. Given that red-green defectives retain normal discrimination along the blue-yellow axis in color space [1], we propose a simple procedure to recode red-green color differences in CIELAB color space as blue-yellow color differences, to allow red-green defectives to correctly judge the ripeness of tomatoes.

An agricultural cooperative of Perelló supplied and classified by color the tomato samples in a controlled manner in four standard ripeness stages. Sample color was measured with a portable Minolta CR-300 colorimeter (Minolta Co. Ltd, Osaka, Japan). Tomatoes were photographed with a Smartphone (Samsung Galaxy S7 edge model SM-G935F with a 12.2 MP camera). RGB values of the image were transformed to XYZ values using Matlab's sRGB transform, and then to CIEL*a*b*, using as reference white a white sample illuminated as the samples. Dichromatic perception of the images was simulated by the corresponding pair algorithm [4]. The modified palette was obtained by exchanging the values of the red-green (a*) and blue-yellow (b*) descriptors (Fig. 1).

Results: The CIE2000 color difference (ΔE) [5] between the tomato ripeness stages was computed for normal and dichromats, both for the original and the transformed images. The efficiency of the transform was defined as the average of the color differences between stages, normalized to the color difference for normals in the original images. The results show that tritanopes can perfectly distinguish different ripeness stages without any color transform, although not to the same degree as normals. Protanopes can distinguish the color of tomatoes with 55% efficiency and deuteranopes with 30% efficiency. After applying the chromatic transform, efficiency for normals is reduced to 87%, while protanopes rise to 88% and deuteranopes to 85%.

Discussion: The application of a color transform that swaps the a* and b* parameters of CIEL*a*b* color space considerably increases the chromatic difference between the different ripeness stages of tomato, losing only 15% of efficiency for normals compared to the 45% and 70% loss for protanopes and deuteranopes in the original image, respectively. Although this transform is colormap specific, and would not necessarily work equally well in scenes that are not defined mainly in the red-green axis (with small b* values), the underlying principle (to translate colors in the red-green axis, where the subject discrimination is poor, to the blue-yellow axis, where discrimination is normal) would still hold in general.

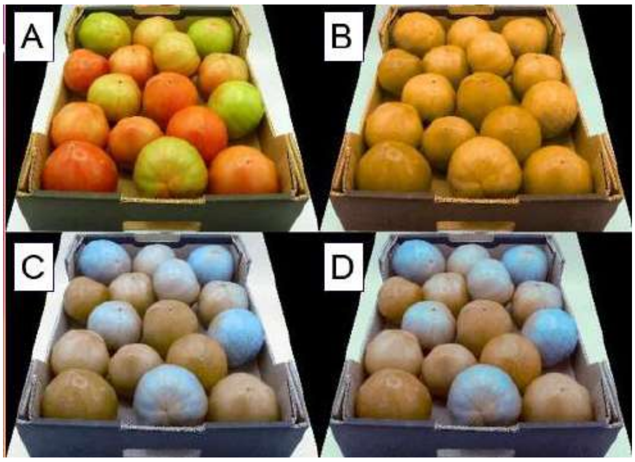

Figure 1.- Original(A) and transformed (C) image. Protanopic perception of the original (B) and transformed (D) image.

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