# Enhancing the chromatic diversity of natural scenes with optimized coloured filters

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**ABSTRACT**

The goal of this work was to determine the transmittance spectra of coloured lenses for optimizing the number of colours visible in natural scenes. This number in each scene was estimated by computing the scene representation in CIELAB space and by counting the number of non-empty unit cubes. Transmittance spectra were computed to maximize the number of discernible colours in a set of such scenes whose spectral properties were obtained by hyperspectral imaging. The number of discernible colours viewed with optimum filters increased by up 30% when compared with natural viewing.

## 1. INTRODUCTION

The number of different colours visible in natural scenes can be estimated from hyperspectral data. The technique consists of computing the representation of the scenes in CIELAB space and counting the number of corresponding non-empty unit cubes[1]. This method was applied to a collection of hyperspectral images of natural scenes with and without[2] viewing through coloured lenses[3]. It was found that with some coloured lenses the number of colours estimated was significantly larger than without the lenses, up to 15% of the total number of colours. The purpose of the present work was to find computationally the spectral transmittance profile of an ideal coloured filter that maximizes the number of discernable colours in natural scenes.

## 2. METHOD

Hyperspectral images of natural scenes were acquired over 400-720 nm at 10-nm intervals and calibrated to obtain the spectral radiance at each pixel of the scene. The imaging system was developed from an earlier device[4] and comprised a low-noise Peltier-cooled digital camera providing a spatial resolution of 1344 × 1024 pixels (Hamamatsu, C4742-95-12ER) with a fast-tuneable liquid-crystal filter (VariSpec, model VS-VIS2-10HC-35-SQ, Cambridge Research & Instrumentation, Inc., MA, USA) mounted in front of the lens, together with an infrared blocking filter[5]. Images of scenes were obtained during the summer of 2002 and of 2003, almost all under a clear sky. Particular care was taken to avoid scenes containing movement.

The transmittance spectra of several coloured lenses of commercial sunglasses were measured with a spectrophotometer (Shimadzu, UV-3101PC, UV-VIS-NIR) and their effect on the spectra of light reaching the eye from the natural scenes computed. The coloured lenses were of acrylic type tinted blue, rose, grey, green and brown, and of glass type tinted green and brown. Figure 1 shows the transmittance of an example of a brown coloured glass lens (Filter 10).

The number of discernible colours in each scene viewed with and without the coloured lenses was estimated by computing for each image the CIELAB representation of all pixels and counting the number of non-empty unit cubes in the three-dimensional volume defined by the scene in that space, as illustrated in Figure 2.

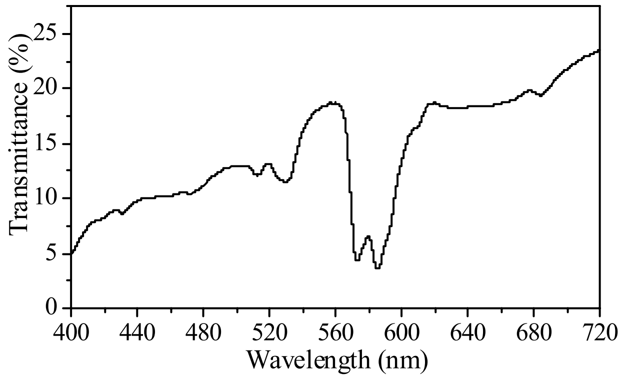


**Figure 1:** Transmittance spectrum of a brown sunglasses lens (Filter 10), measured with a spectrophotometer (Shimadzu, UV-3101PC, UV-VIS-NIR).

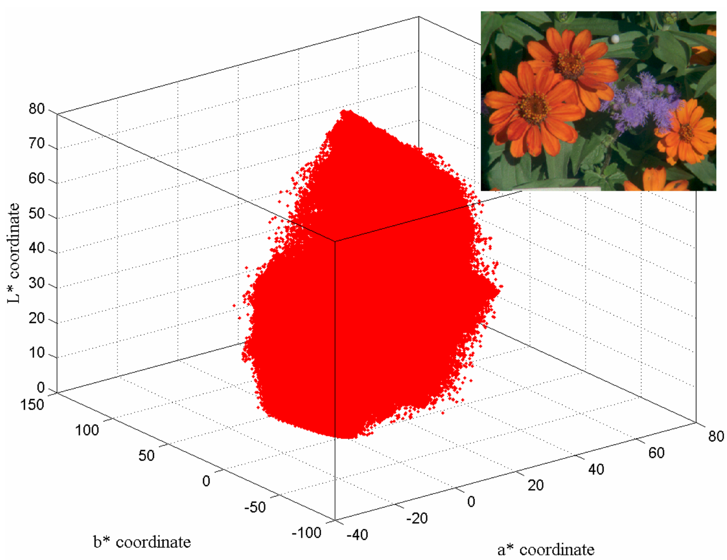


**Figure 2:** Computed CIELAB colour volume of a natural image. The number of discernible colour was estimated by counting the number of non-empty unit cubes in the volume defined by the scene in that space.

The ideal filter for each scene was computed with a maximization routine that used as starting spectrum one of the real filters. The transmittance at each wavelength was adjusted independently to maximize the number of discernible colours viewed through the theoretical filter lens.

## 3. RESULTS

It was found that, in general, the effect of coloured filters was to increase the estimated number of discernible colours. Table 1 shows the data obtained for several scenes with the coloured filter of Figure 1 (Filter 10) and with the corresponding optimized filter. The application of the maximization routine allowed the computation of spectral transmittances that improved even further the chromatic diversity of scenes by increasing the number of discernible colours by up to 23% of those obtained with the corresponding real coloured filters.

Figure 3 shows the transmittance spectrum of Filter 10 and the transmittance spectrum of the corresponding optimized filter. Also shown is the corresponding natural scene.

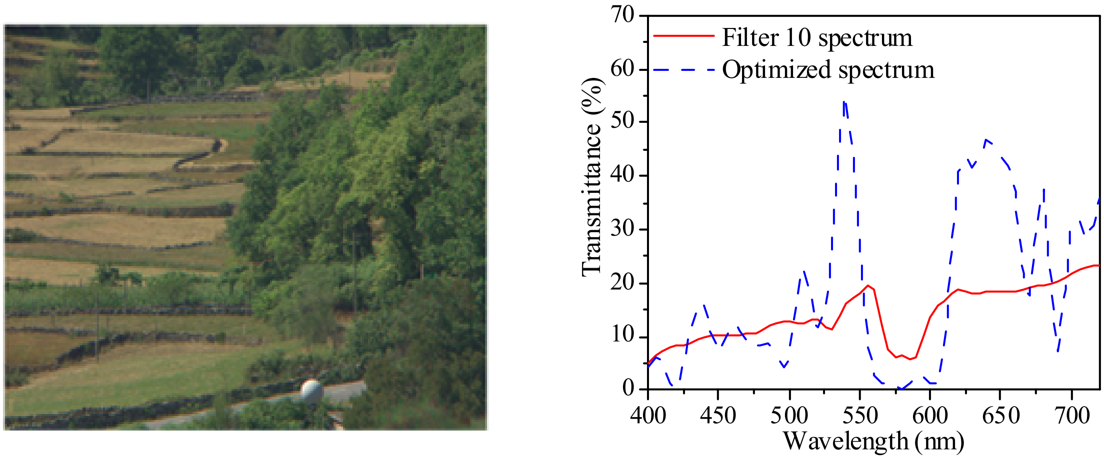


**Figure 3:** Rural scene (left) and the spectral transmittance of filter 10 (continuous line) and the corresponding optimized filter (dashed line) obtained for rural scene shown.

**Table 1:** Number of discernible colours in natural scenes in natural viewing and when viewed through real and optimized theoretical filters.

| Number of discernible colours<br>Natural viewing | Number of discernible colours<br>Filter 10 | Number of discernible colours<br>Optimized lenses |
|---|---|---|
| Scene 2 [33139] | 36982 [+10%] | 44134 [+16%] |
| Scene 5 [100775] | 114641 [+12%] | 130747 [+12%] |
| Scene 9 [124252] | 143018 [+13%] | 184892 [+22%] |
| Scene 15 [70799] | 81089 [+12%] | 100093 [+19%] |
| Scene 18 [136381] | 149937 [+9%] | 195897 [+23%] |

## 3. CONCLUSIONS

Coloured lenses can enrich the chromatic content of natural scenes, a result that can be achieved both with real filters and with idealized coloured filters. The main implication of these results is that it may be possible to design coloured lenses with specific spectral transmittance profiles to enhance significantly the chromatic diversity of natural scenes.

## References

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