Failure of surface color cues under natural changes in lighting

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Color allows us to effortlessly discriminate and identify surfaces and objects by their reflected light. Although the reflected spectrum changes with the illumination spectrum, cone photoreceptor signals can be transformed to give useful cues for surface color [1]. But what happens when both the spectrum and the geometry of the illumination change, as with lighting from the sun and sky? Is it possible, as a matter of principle, to obtain reliable cues by processing cone signals alone? This question was addressed here by estimating the information provided by cone signals from time-lapse hyperspectral radiance images of five outdoor scenes under natural lighting. The scenes contained mixtures of herbaceous vegetation, woodland, barren land, rock, and rural and urban buildings [2]. A time-lapse sequence from one scene is shown in Figure 1. For each scene, mutual information between cone signals was estimated at increasing time intervals. These estimates have an operational interpretation given by Shannon's channel-coding theorem. It sets a theoretical upper limit on the number of points that can be reliably identified across time by transforming cone signals alone [3]. For all five scenes, the number of identifiable points declined markedly with increasing interval, although not always monotonically. This decline represents an irretrievable loss in information. The implication is that processing cone signals alone cannot give reliable cues for surface color under natural changes in lighting. More complicated spatial interactions between cone signals must also be involved.

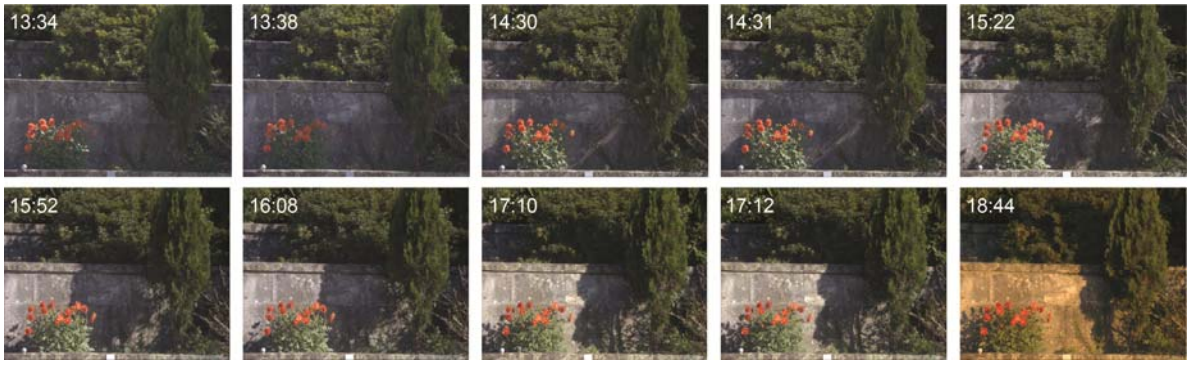

Figure 1. Color renditions from a sequence of time-lapse hyperspectral radiance images of an outdoor scene. Acquisition times are indicated. Data from [2].

References

[1] A. Gijsenij, T. Gevers, and J. van de Weijer, "Computational Color Constancy: Survey and Experiments," *IEEE Trans. Image Process.*, vol. 20, pp. 2475-2489, 2011.

[2] D. H. Foster, K. Amano, and S. M. C. Nascimento, "Time-lapse ratios of cone excitations in natural scenes," *Vision Res.*, vol. 120, pp. 45-60, 2016.

[3] I. Marín-Franch and D. H. Foster, "Estimating Information from Image Colors: An Application to Digital Cameras and Natural Scenes," *IEEE Trans. Pattern Anal. Mach. Intell.*, vol. 35, pp. 78-91, 2013.