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Invited Papers

Visual appearance and total appearance – from petits pois to the Eiffel Tower

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Fifty years ago the food industry discovered that the CIE system of colour specification was just the start of something promising. Lack of understanding led to a belief that a change in *appearance* could be measured as a change in *colour*.

Appearance, as colour, is derived from two elements – the physical properties of what is in front of our eyes (including characteristics of the illumination), and our personal perceptual, physiological and psychological characteristics. The scene under consideration may be a single material or complex consisting of many materials.

Standard procedures can be used to ‘measure’ the visual appearance of industrial materials, such as paints and plastics. Such materials are ‘simple’, that is, flat, uniform, homogeneous and opaque. However, many other materials are more complex. Not only do the linear dimension and the effect of time need to be considered, but also these materials are usually not opaque and are non-uniform in colour, translucency and gloss. Moreover, nowhere does the total appearance perception of a single material achieve the complexity that it does with food.

Visual appearance comprises those properties we perceive as ‘visual structure’, ‘visual texture’, and variation in ‘colour’, ‘translucency’, ‘gloss’, as well as changes of these properties with time. These attributes, derived under standard conditions, combine and interact with other sensory perceptions and our personal psychology to form a total appearance perception. These we can hope to scale, ‘measure’ and understand.

When we think of objects as having derived attributes, such as *acceptability* of appearance of petits pois, the *ripeness* of tomatoes, appearance *warmth* of a room, *elegance* of the Eiffel Tower, then we are thinking in terms of *total appearance*. Such attributes are related specifically to our psychological estimates of quality. As such they are scalable and understandable in terms of visual appearance attributes and their interactions.

The colour appearance of chromatically textured natural surfaces

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Natural surfaces possess intrinsic chromatic texture. A banana is neither uniformly coloured nor uniformly bright, whether ripe yellow or unripe green. This feature of natural surfaces is not captured by traditional studies of colour perception, which typically employ stimuli of uniform colour and luminance. We consider the effect of surface ‘polychromaticity’ (Beeckmans, Philosophical Psychology, 2004) on colour appearance under changing illumination.

Computational models of colour constancy demonstrate (implicitly or explicitly) that the estimation of the illuminant spectral power distribution improves as the number of distinct surface reflectance samples increases. The underlying assumption of such models is that each distinct surface is uniform in reflectance. Yet, a single polychromatic surface may provide a large number of reflectance samples on its own, and thereby undergo improved colour constancy. On the other hand, chromatic texture within a surface also blocks simultaneous chromatic contrast between the surface and its background, most powerfully when the background is uniform (Hurlbert & Wolf, Prog. Brain Res., 2003). Therefore, local between-surface contrast – a strong contributor to colour constancy for artificial, homogeneous surfaces (e.g. Kraft & Brainard, Proc. Nat. Sci. Acad., 1999) – is likely to be weak for chromatically textured surfaces.

To quantify and characterise surface chromatic texture, we analysed the surface colour distributions of natural and man-made objects, imaged under artificial daylight illumination using a tristimulus-calibrated camera system (the DigiEye, courtesy of Leeds University Color Science). Transforming surface colour coordinates into physiological cone-contrast values reveals that the magnitude of within-surface chromatic texture for most objects is greater than the threshold to block spatial chromatic contrast induction. Thus, the potential stabilising factor of local between-surface contrast is not sufficient to achieve constancy for natural surfaces.

On the other hand, the distribution of within-surface cone contrasts for a given object forms a distinct signature in three-dimensional cone-contrast space. For many natural surfaces, the distribution is an elongated cluster, which, in the RG-BY chromatic plane, appears as a ‘thick’ vector, whose length gives the magnitude of the chromatic-only component of cone contrast, and direction the hue. For many surfaces, the direction of the cone contrast ‘vector’ remains constant under changes in illumination, if the cone contrasts are calculated with respect to the illumination whitepoint. Thus, object colour constancy may be achieved via adaptation to the illumination whitepoint.

Yet if the cone contrasts are calculated with respect to the mean cone excitation levels from the object alone (adaptation to the ‘object’), the cone-contrast distribution acquires a different shape, which shifts characteristically under changes in illumination. For identifiable objects, these gamut shifts may aid in estimating the spectral properties of the illuminant.

We therefore predict that surface colour constancy may be better for objects with natural chromatic texture than for the homogeneous surfaces typically used in laboratory measurements of constancy, for two reasons: (1) polychromatic colours may be encoded as directions of vectors which remain stable under adaptation to the illumination; and (2) illuminant estimation may be enhanced by adaptation to the mean colour of individual identifiable polychromatic objects.

Physical phenomena involved in the color and visual effects of natural and synthetic materials

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Visual effects like gloss, matte, iridescence, opal, nacre are new fundamental subjects of research under the point of view of vision and perception. This fundamental interest is related with the development of the use of these effects in materials and applications devoted to color: cosmetics, paints, prints, glass, ceramics… Most of these effects are inspired by Nature (mineral, vegetal or animal worlds), leading to the denomination of bio-inspired materials (even if this term sounds restrictive) when they are transposed in the domain of artificial materials produced by the industry.

The analysis of these effects is conducted at two levels: (i) the level of the elaboration of the light stimulus reaching the eye, (ii) the level of the perception itself, involving the psycho-physical treatment of the stimulus by the eye and the brain. It is the first level which is addressed in this communication. Under this point of view, all these visual effects are structural effects which can be described by purely physical concepts. The color itself supporting these effects has two possible origins: either pigments or again structural-physical phenomena.

Our aim in this communication will be to make a survey of the physical analysis of both color and visual effects in relation with the morphology of structured materials and to show how the physico-mathematical modeling has progressed in predicting their optical properties and simulating these colors and effects.

Basic physical phenomena will be first recalled: refraction, diffraction, interferences, light scattering, photonic crystal. They will be illustrated by examples mainly taken in Nature, due to more or less complex structures implicating these phenomena: insects shells or eyes, butterfly wings, oyster shells, natural opals, sky, clouds. We will then envisage different human realizations, already using these effects and others like surface plasmons, since the antique age: ruby glass, luster in ceramics, glacis in paintings. We will finally show recent developments in the use of these concepts and effects in the domains of paints, cosmetics and prints and also in the domain of new light sources.