# A New Approach to Appearance Characterization


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Received 20 May 2005; revised 25 July 2005; accepted 17 October 2005



*Abstract: A proposal to characterize appearance in three different categories—color, cesia, and spatial properties or spatiality—is made. Color will include whiteness and yellowing and is related to optical power spectral properties of the stimulus detected by observers. Cesia will include transparency, translucence, gloss, luster, haze, lightness, opacity, matt, etc., and is related to the properties of reflecting, transmitting, or diffusing light by objects or materials evaluated by human observation. Spatial properties are divided in two main groups: (1) modes of appearance in which color is modified depending on the angle of observation related to the light incidence angle, such as metallic, pearlescent, or iridescent materials, and (2) modes of appearance related to optical properties of surfaces or objects in which effects of ordered patterns (textures) or finishing characteristics can be described by spatial filtering (roughness, polish, distinctness of image, orange peel, etc.).* © 2006 Wiley Periodicals, Inc. Col Res Appl, 31, 164–167, 2006; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/col.20205



*Key words: appearance; color; cesia; spatial properties; definitions*


### INTRODUCTION

Since 1930 when Pfund[1] described the first instrument to measure gloss on which ASTM specified the method and instrument to evaluate the appearance attribute of materials called gloss,[2] more than 70 years have passed. Since then electronics and optical research and development have modified almost everything in the technological world. Today a new branch of technology exists called electro-optics, and new developments have created a great number of new lamps, including the most recent light-emitting diodes, which consequently have completely modified the old instruments used to measure appearance.

At the same time, research on the different forms of appearance of objects has been performed, first trying to understand how the human mind processes the information in such a way that is able to distinguish between the different forms of appearance and second, with the advent of the science of information process in robotics and the techniques of color management in graphic arts, trying to put it all together in a common approach: appearance.

Appearance is a variable of the perceptual world detected by the visual system. To investigate the perceptual world of human beings, psychophysicists have developed methods to evaluate physical stimulus in terms of psychological responses. The exponential or Stevens[3] law is widely used to describe the relationship between both stimulus and sensation.

More recently, the term cesia has been proposed for modes of appearance other than color (Caivano[4]). Also Caivano[5] has proposed a semiotic approach to describe the relationship between appearance of objects and the evaluation of signals by the human mind, considering the different modes of appearance to act as signals and be considered part of the human interpretation of the significance of those signals.

Also in the past 20 years, the term color appearance was introduced by Hunt,[6] Pointer *et al*.,[7] and Pointer[8] to describe color under different types of light, which gave place to different proposals, most of them listed in Fairchild's *Color Appearance Models*.[9]

### A NEW APPROACH TO APPEARANCE DEFINITION

Appearance can be divided into three components: color, cesia, and spatial variations or spatiality. Color is also divided in three variables: red, green, and blue stimulus, which are transformed into the three variables $X$, $Y$, $Z$, as defined by the CIE,[10] or converted with another mathematical transformation in the CIELAB ($L^*,a^*,b^*$ or $L^*,C^*,h$)


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for solid colors or CIELUV ($L^*,u^*,v^*$) for color lights. These later models provide a better uniform chromatic space; that is, differences between adjacent colors in different parts of the chromatic space are represented by more similar lengths than in the CIE *XYZ* system.

Cesia, as defined by Caivano,[11] is also divided into three components. Absorption, or absorptivity, is associated with the ability of surfaces or objects to absorb or re-emit light, producing sensations of darkness, or its contrary, luminosity, in an individual. Diffusion, or diffusivity, is related to the property of surfaces or objects to deviate light from the path of its regular reflectance or transmittance, therefore defining its contrary: regularity. Finally, permeability is defined as the proportion between subjective quantities of light seen by transmission or reflection or both, thus defining its contrary: opacity.

In these terms Caivano proposed eight scales grouped into three sets: the first one deals with the antagonism between absorptivity and luminosity for the different kinds of cesia and they are:

(1) matte white versus black,
(2) specular versus black,
(3) translucent versus black,
(4) transparent versus black.

The second group deals with the variation in diffusivity versus regularity (meaning that light follows the optical laws of regular reflectance or transmittance), going from highly glossy samples to matte ones, and the other from totally transparent to totally translucent:

(5) specular versus matte,
(6) transparent versus translucent.

In the third group the variation is between permeability and opacity, while diffusion is kept constant:

(7) specular versus transparent,
(8) matte versus translucent.

It is important to remember that the property of absorption gives place not only to luminosity, but also to luminous transmittance or reflectance, which, psychophysically, is the radiant flux transmitted or reflected in terms of the CIE standard observer known as $V(\lambda)$.[12]

## THE THIRD DIMENSION OF APPEARANCE: SPATIALITY

As mentioned above, the spatial variations of surfaces and objects give place to a group of perceptions that are clearly differentiated from those described previously. When a human being looks at a glass filled with pure wine or milk, he recognizes it in pure terms of a two-dimensional evaluation, because at sight there are no spatial differences in the samples that can recall his attention. The same happens when he is looking at two samples painted with ordinary paint, which can differ in color, and he must evaluate that difference.

Normally observers try to limit the range of perceptual appearance to the minimum quantity of variables, as does an inspector of textiles, trying to define whether a sample passes or does not pass the color quality control. He usually disregards the texture in the sample, because he just tries to evaluate color. Often he is able to do it.

Texture in textiles, carpets, metal finishes, plastic accessories for the automobile, some paints, bricks, leather, and wood, among a long list, give appearance modes to them, not described by the previous definitions of cesia. Even when cesia is present the phenomena involved are more complex and sometimes involve new aspects.

Let us see, for example, variations in color due to different angularity (of incidence or observation or both). This phenomenon is present when interference colors appear due to the optical effect of a very thin layer of a transparent material over a substrate with a different refraction index. This is the case of pearlescent and iridescent appearance. Another case is that of metals, showing a "metallic" appearance. Paints with metal or mica flakes also evidence this mode of appearance, in which color changes with the spatial variation of illumination and/or observation.

The second variable of spatiality is what is known as "spatial frequency." Related to roughness of a surface along a direction, described by a "surface profile" and mathematically treated through Fourier analysis, it is described by spatial frequency components, with wavelengths from 0.1 to about 30 mm, being the frequencies with wavelength under about 0.5 mm, treated and observed as polished or tarnished appearance. Beyond that wavelength, linear texture appears, defined in the object by repeated linear structures, such as those present in some marine shells, with lines or curves defined separately. This analysis depends on the observation angle and the distance to the object under analysis. One of these phenomena is the so-called "orange peel" defect in automobile paints.

The third variable of spatiality is texture in three dimensions, mainly applicable to textiles, carpets, hairs, furs, and some ceramics, where patterns of two or three dimensions give an indication, conscious or not, to the observer who tries to evaluate the scene. Different techniques have been developed to deal with these patterns, mainly because of modern digital imaging techniques used in the recognition of objects by means of video cameras and image processing, which are described at length in a recent report of the NPL.[13]

This article does not propose new techniques to measure or identify appearance but tries to classify them in a different order than is usual, hoping that this approach could clarify the complex phenomena involved and help to establish more adequate methods to qualify and quantify appearance.

## A NEW APPROACH TO THE DEFINITION OF APPEARANCE

ASTM International[14] defines appearance in two ways: (1) "the aspect of visual experience by which things are recog-

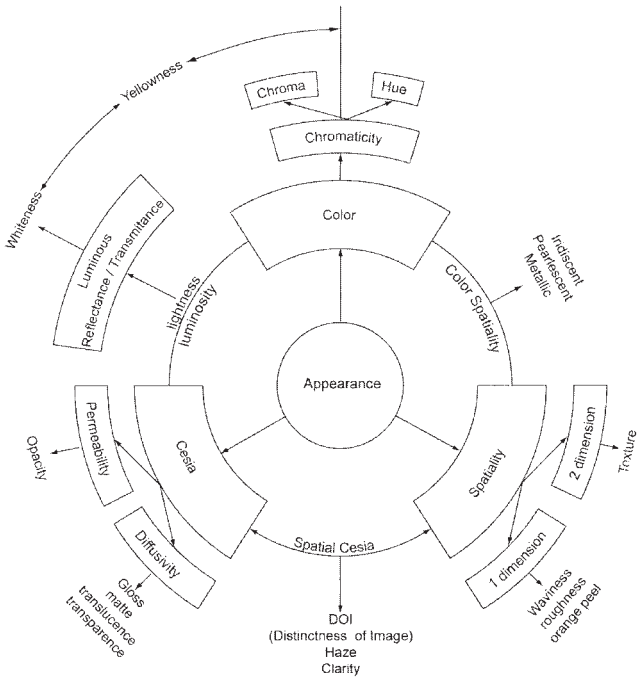


FIG. 1. Schematic drawing showing the relations among different characteristics of visual appearance, color, cesia, and spatiality, and derived appearance modes.

nized" and (2) "*in psychological studies*, perception in which the spectral and geometric aspects of a visual stimulus are integrated with its illuminating and viewing environment." The first definition is ambiguous. It does not define what "aspect" is or what "things" mean. It can be applied almost to anything, even dreams. With this definition anything that a person can see could be described as appearance, including ghosts.

The second definition is better, but the limitation to "psychological studies" indicates that it cannot be applied to materials or objects not related to these studies.

Next is a proposal of a new definition:

*For classifying and measuring purposes, appearance is a psychophysical property of materials and objects interacting with light, provided by a specific light source in a defined mode (spatial and spectral composition) and being detected, observed and perceived by human beings at a defined spatial position with respect to them. It is composed of color, cesia and spatiality.*

The proposed definition is probably too long and too complicated, but it can be said in its defense that, in this respect, it is similar to the phenomena defined.

Figure 1 shows the relation among the three components. Perhaps this scheme makes it easier to understand the relationship between the different modes of appearance and the underlying idea.

In the center is the appearance of an object, under the circumstances in which it is seen, defined by a human observer. These circumstances are defined by the (spectral and spatial) quality of the illumination and the surround (color, contrast, light level). It must be understood that if any part of this environment changes, it is possible, and even likely, that the appearance also changes.

The appearance, then, can be divided into three parts: color, cesia, and spatiality. Color is also divided into three parts: lightness, chroma, and hue. The last two variables form what we call chromaticity. Lightness is related to cesia when it is converted to luminosity, also giving place to luminous transmittance or reflectance.

Cesia is also divided into three parts: luminosity (already mentioned above, related to lightness), diffusivity, and permeability.

Diffusivity is related to the property of materials or objects to deviate the light from the regular directions defined by the optics laws due to the interaction of light with particles of different refractive index than the media, in the surface or in the interior of the material. Cesia properties associated with diffusivity are gloss and matte, translucence and transparency, or clarity.

Permeability is related to the property of an object or material to allow the light flux to penetrate its interior. Metals, unlike most plastics, do not allow light to go further than their surface. The contrary of permeability is opacity.

Cesia is also related to spatiality, in what is being named spatial cesia, when spatial characteristics of cesia like diffusivity give place to appearance modes such as haze and distinctness of image (DOI).

Spatiality too is divided into three components. One is related to color, in what is called color spatiality. It comprises appearance phenomena in which color changes with different observation or incident angles such as in metallic, pearlescent, and iridescent materials.

Another component of spatiality is developed in one dimension, in which different modes are identified, such as waviness, roughness, polishness, and orange peel, and they are perceived as variables along a line, such as horizontal or curved parallels. This component is also directly related to spatial cesia. The other one is developed in two dimensions and is recognized as texture or textured surface, which applies when the observer is not able to simplify the perception of the scene in just one dimension and needs more dimensions to describe the scene.

## DISCUSSION

Several authors (Hunter,[15] Pointer,[16] Hutchings[17]) considered and studied appearance in different ways. Hutchings introduced the concept of total appearance, but mainly applied the concept to foods and related it with other human senses, such as smell, taste, and mouth consistency. He also uses the term "Gestalt," described as "the view of the whole," or the "gestalt appearance," which means more or less the same but includes in the evaluation much more than physical characteristics of the stimulus that produces the appearance sensation and perception. He tries to establish that appearance is produced by "product attributes" and in his schema the product, the ambient or situation, and the "perceiver," which is our observer, can vary. Then, the mind status of the perceiver affects the perception; thus, in his

proposal, there are anticipatory and participatory attributes of the scene and object that are based on the experience of the subject. Hutchings indicates that the total appearance of a scene consists of the visual images within us.

That is not what this article intends to deal with; it is beyond its purpose, which is to define the physical variables related to visual appearance. This article does not intrude with psychology, semiotics, or total appearance as defined by Hutchings.

Also, it does not consider color appearance models mentioned above, because adaptation is a psychological effect that does not interfere with the measurement of physical variables. We only need to know the different spectral composition of the lights under consideration to calculate the color shifts in a color appearance model.

What is necessary to consider are the different gloss categories defined by Hunter.[15] Specular gloss and sheen are of the same type, and the fact that sheen is specular gloss evaluated at grazing angle does not change its nature. Contrast gloss is a relation between specular gloss and diffuse reflectance, which, in fact, indicates what the observer sees when the diffusion component is important, such as in woods, some plastics, non-glossy textile fibers, yarn, cloth, bond papers, ceramics, or some metals. It applies when the relation between the specular and the diffuse component of reflection is of near the same order of magnitude. Therefore, it consists of two measurements: one for specular gloss and the other for diffuse reflectance.

The other two categories of gloss defined by Hunter such as absence of bloom and DOI, are part of what is being classified as spatiality in this article, because they are truly dependent on the spatial distribution of the reflected light. In the case of absence of bloom or absence of haze, also defined by Hunter, the measurement of the light reflected is done within an angle of about 2.5° of a cone around the specular angle. If the reflected light is within a solid cone, smaller or larger than that dimension, it is of no importance from the point of view of phenomena classification. The effect depends on the spatial distribution of the light flux and can be classified among what is defined as one-dimension spatiality. This approach is also applicable to transparency phenomena where diffusion gives place to haze (also called wide-angle scattering) or clarity (also called narrow-angle scattering or see-through quality). In both cases, reflectance or transparency can be classified as spatial cesia or one-dimension spatiality.

The last type of gloss classified by Hunter, called surface uniformity gloss, is not really gloss. In our above definition, this is texture and can be classified among those cases grouped in one- or two-dimension spatiality, depending on the structure of the texture considered.

There are cases that need further research, such as velvets and corduroy. Color measurement of velvet requires pressure to keep the diffuse (light) component constant, but these measurement results do not agree with what people see. The diffuse component due to the reflections of hairs (or short threads or yarns), which is easily seen on curved pieces, produces dramatic changes in the luminous reflectance depending on the incident light and observation angles. To visually recognize velvets, subjects must see a cloth piece bent or folded under a directed light; then the soft changes in reflection tell people that they are dealing with velvet. This is a spatial property of one dimension.

The same criteria can be applied to corduroy, but in this case there are defined lines and spatial filtering that can be used to define the components of the reflected light. With a basic component of a wavelength of a couple of millimeters, the spectrum between 1 and 0.1 mm will give a reasonable relation with its softness, as for velvets.

It is very important to establish that spatiality is a property of appearance that highly depends on the distance between the observer and the object under consideration; therefore, methods of measurement should be established that are related to such ability of a human being to see, detect, identify, or classify spatial structures and textures.


## ACKNOWLEDGMENTS

I thank José Luis Caivano for his comments and help in preparing this work.



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