Gloss Characterization: a Cyclic Approach

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ABSTRACT

In this paper, an approach to gloss characterization is described. We examine how information is transferred from the physical domain to the visual domain and how material properties are inferred from a cognitive interpretation, completing the characterization cycle.

Keywords

Gloss, BRDF, cognitive metrology

1. INTRODUCTION

Gloss is an appearance attribute related to surfaces. Its characterization is connected to several scientific domains: material science, optics, vision and cognition. Here, we investigate how information transfers from one domain to the next, in a cyclic approach (Engeldrum, 2000; Pointer, 2005). The mechanical, electrical and chemical properties of a material control the light-reflecting characteristics of a surface. The directional distribution of the light reflected at the surface transfers as a spatio-temporal distribution of luminance in the retinal image which constitutes the stimulus for vision. Contrasts within the stimulus are encoded by the visual system and processed so as to extract visual features. Ultimately, the brain organizes information related to the surface and the context so as to obtain a perceptive representation of the visual environment and to infer operational properties about the surface and the material the object is made of.

2. FROM MATERIAL PROPERTIES TO THE BRDF

Physically, gloss originates from the directional distribution of light reflected by a surface. The optical information relevant to gloss is provided by the bidirectional reflectance distribution function (BRDF) that measures the luminance exiting the surface at various angles depending upon the direction of the incident illumination. The BRDF is strongly dependent on the roughness of the surface and on the structure and the electrical properties of the subsurface components (McCamy, 1998; Comar et al., 2012).

3. THE RETINAL IMAGE

The retinal image interfaces the physical world with the human visual system.

3.1 The complexity of the BRDF

Measurements such as those provided by glossmeters are much too simplistic to control the final appearance of a surface (ASTM, 1999).

The BRDF is a complex distribution which has often been reduced to simple and realistic 3D models such as the Phong (1975) or the Ward (1994) model. Physically-based BRDFs can be approximated with diffuse, directional-diffuse and specular components (Lafortune et al., 1997). Microfacet models tend to capture the reflection effects dominated by surface scattering (Torrance, Sparrow, 1967). Additional terms are needed to account for subsurface scattering (Ashikhmin et al., 2000).

Material or surface-dependent models bring some complexity to the BRDF description. The profile of the specular peak in BRDFs of real coated samples has been related to Gaussian microfacet normals distribution for mat samples and to a Lorentzian distribution for glossy samples. (Obein et al., 2003). Matusik (Matusik et al., 2003) presented a generative model for isotropic BRDFs based on over 100 acquired reflectance data. Then, each acquired BRDF was treated as a single high-dimensional vector taken from a 14D space of possible BRDFs.

At this point, we don't know which parameters should be extracted from the BRDF to be perceptually meaningful with respect to real materials.

3.2 From the BRDF to the visual stimulus

Whereas gloss originates from a directional distribution of light impinging the eye, the actual stimulus for gloss is the retinal image that shows spatial and temporal variations of illuminance.

Image-based methods can be used to speed gloss measurements by gathering light reflected at many aspecular angles at once (Marschner et al., 1999). An optical transfer function transforms the specimen-centered scan produced by a goniophotometer to an eye-centered scan produced by a camera that measures the light reflected at various aspecular angles. The technique covers a whole class of surfaces.

Thus the distribution of light in the image comprises all the information that induces gloss perception.

4. VISUAL PROCESSING

Through the visual pathways, the incoming information from the retinal stimulation is mapped into abstract feature maps (Kohonen, Hari, 1999).

4.1 A second-order attribute

Gloss can be considered as a second-order visual attribute, i.e. it results from an interpretation by the brain of first-order signals such as simple luminance variations. Indeed, when an observer inspects a glossy surface, he spontaneously collects in sequence or in parallel the light in the vicinity of the specular direction. Thus, he scrutinizes the surface in a way very similar to what a gonioreflectometer would do to record the BRDF.

4.2 Dimensionality of gloss stimulus

4.2.1 Gloss scales

Whereas much is known about the local processing of contrasts and borders in the retinal image, the extraction of information

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about gloss is not well understood. Nevertheless, rating gloss seems to be reliable and reproducible. Obein (Obein et al., 2004), using a series of black samples, and Ji (Ji et al., 2006), using painted grey and color samples, derived similar unidimensional gloss scales. Ng and colleagues (Ng et al., 2004), rating print samples with moderate gloss index, Ferwerda (Ferwerda et al., 2001), rating virtual objects, and Leloup (Leloup et al., 2010), enriching the illumination geometry above real samples, have proposed 2-D scales.

4.2.2 Gradients and statistics

Visual sensitivity studies related to statistics, to the relative position of highlights, to gradient discrimination, or to eye movement patterns have been conducted.

Shading and highlights produce gradients with different profiles. Experiments with real surfaces have shown that the visual system can use the information within the gradient for detecting or discriminating it (Garcia-Suarez et al., 2008). Experiments with photographic images of textured stucco surfaces have revealed that the skew in the luminance histogram is positively correlated with judgments of greater glossiness and lower lightness (Motoyoshi et al., 2007).

These relationships suggest that the activity of separate visual channels in processing darkness and brightness information might play a role in recovering histogram statistics, and skew in particular (Kingdom, 2008).

4.3 Any role for binocularity or eye movements?

Indeed, eye vergence might help to evaluate the distinctness-of-image, or parallax might help to extract highlights.

As the intensity of the light reflected from glossy surfaces is different for different viewpoints, the disparities of the retinal images of flat surfaces produce the effect of lustre (Helmholtz, 1856; Sakano, Ando, 2010). However disparities also provide visual cues for depth perception. Ho et al. (Ho et al., 2009) showed an interaction between the perception of bumpiness and the perception of glossiness.

5. COGNITIVE METROLOGY

Perception is a construction. The features incoming from the peripheral visual system have to be integrated and interpreted (Treisman, Gelade, 1980).

5.1 Multiple interactions

Neural networking takes place in the brain in order to sort out and eventually extract pertinent aspects of the scene (Leonards, et al., 2005). Much of the computation is performed in parallel, in space and in time (Broackes, 2010). A multisensory approach, especially tactile approach, is also useful to confirm the judgment about gloss.

One task for the neural computation is to disambiguate gloss from other attributes such as colour, shading, translucency, or depth (Simonot, Elias, 2003).

Another task is to distinguish between light and material information, in order to achieve material constancy. Whereas environmental conditions may substantially modify the absolute value of a stimulus, our perceptual system is able to identify the properties of objects such as size and shape, as well as the properties of materials such as graininess, colour or gloss (Obein et al., 2004; Vangorp et al., 2007).

Alike other appearance attributes, gloss is regulated by adaptation. Adaptation to patterns with skewed statistics can alter the apparent lightness and glossiness of surfaces that are subsequently viewed (Motoyoshiet al., 2007).

5.2 Previously acquired knowledge

Gloss cannot be appraised independently of the surface or of the object to which it is attached. The human brain has to call up stored knowledge about objects and materials properties.

Moreover, the incoming information from the image and the previously acquired knowledge would not be useful without applying a number of learned rules, such as statistics, light propagation or 3D geometry. Humans are sensitive to image statistics for a variety of judgments. In addition to gloss, perceived surface roughness and translucency also depend on image statistics (Landy, 2007; Motoyoshi, 2010). Only computation allows for checking gloss consistency against the illumination context.

In return, an active strategy is adopted, allowing for iterations until the decision is made to characterize gloss (Leek et al., 2012).

5.3 Categorization

All senses produce percepts adequately represented in memory into categories (Dubois, 2007). The principles of categorization rely on similarities, but also on personal experience. We suggest that observers spontaneously infer the identity of a material from the gloss appearance. Indeed, they are able to intuitively classify materials along perceptive “traits” that can be correlated with acquired BRDF within a multidimensional model (Matusik et al., 2003, Ged et al., 2010).

Thus, gloss perception serves material characterization.

6. CONCLUSION

Gloss is connected to the physical world on the one hand and to human vision on the other hand. With respect to its connection to materials and optics, gloss is characterized by complex distributions of physical quantities however universally describable through instrumentation and uniquely transferable from one domain to the other. On the other hand, gloss is an appearance attribute appraised by human vision privately. Whereas low-level visual mechanisms operate almost automatically, gloss perception is highly linked to other appearance attributes and dependent upon the interaction of cognitive cues.