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Analysis of Material Appearance using Real-World Objects and Rendered Images
実物体と画像を用いた質感解析に関する研究

Analysis of Material Appearance using Real-World Objects and Rendered Images

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Abstract

In this dissertation, the author analyzed shitsukan using real-world objects and rendered images. After the fundamental investigation of shitsukan perception under different viewing conditions based on color naming experiments, the author conducted two different experiments to investigate the perceptual qualities, and appearance harmony using real materials and rendered images. In the first experiment for investigating the perceptual qualities of material appearance using real materials and rendered images, the author found that the representation method of some materials affected their perceptual qualities. By using methods such as PCA and k-means clustering, the author determined that material categories were more likely to be confused when materials were represented as images, especially gray images. In the second experiment for investigating the harmony of the material appearance, the author indicated that the appearance harmony of some materials was significantly affected by the reactions of subjects to the visual information about samples that are (are not) displayed on the monitor, rather than tilting a sample.

In Chapter 1, the author presented an overview of the motivations and purposes of the psychophysical experiments in this dissertation. Then he contents and the structure of the dissertation are introduced.

In Chapter 2, the author presented the fundamental experiment of shitsukan perception under different viewing conditions that investigates color naming for 2D and 3D rendered samples. Conventional color naming experiments using a priori clues generally involve 2D clues such as color patches. However, in real-world scenes, most objects have 3D shapes, and their colors are affected

by illumination effects such as shadow and gloss. The author used 2D and 3D rendered samples as clues in the experiments, and analyzed the relationship between color terms and object surfaces. First, the author developed a color term collection system that can produce 218 test colors. The author rendered the color images of a flat disk as a 2D sample and a sphere as a 3D sample on a calibrated display device. It is assumed that the 2D and 3D surfaces with the same object color are obtained under the same viewing and illumination conditions. The results of the color naming experiments show that for 2D and 3D samples, there are differences in the color terms. Important findings are as follows: (1) when observing achromatic colors, brighter color terms tend to be chosen as the 3D samples compared to the 2D samples, (2) achromatic color terms are chosen as 3D samples having low saturation, and (3) for chromatic colors, a darker color term is generally chosen relative to the corresponding 2D samples having the same color. By changing the illumination angle rom 0° to 45° to the surface normal, these properties become more prominent.

In Chapter 3, the author presented the first main topic to investigate the perceptual qualities of material appearance using real materials and rendered images. Recent experimental evidence supported the idea that human observers are good at recognizing and categorizing materials. Using projected images, Fleming et al. reported that perceptual qualities and material classes are closely related. In this experiment, the author further investigated these findings using real materials and degraded versions of images of the same materials. The author developed a real material dataset, as well as four image datasets by varying chromaticity (color vs. gray) and resolution (high vs. low) of the material images. To investigate the fundamental properties of the materials' static surface appearance, the author used stimuli that lacked shape and saturated color information. The author then investigated the relationship between these perceptual qualities and the various types of image representation by performing psychophysical experiments. The results showed that the representation method of some materials affected their perceptual qualities. These

cases could be classified into the following three types: (1) perceptual qualities decreased by reproducing the materials as images, (2) perceptual qualities decreased by creating gray images, and (3) perceptual qualities such as “Hardness” and “Coldness” tended to increase when the materials were reproduced as low-quality images. Using methods such as PCA and k-means clustering, the author found that material categories are more likely to be confused when materials are represented as images, especially gray images. Furthermore, the additional analysis showed the possibility of explaining the relationship between the physical properties and psychophysical assessments.

In Chapter 4, the second main topic was introduced. In this experiment, which was aimed at investigating the harmony of a material appearance, the author investigated the appearance harmony of various materials by conducting psychophysical experiments to collect quantitative data. The author conducted three experiments using 435 round-robin pairs of 30 samples made from 10 actual materials. In the first experiment, subjects were allowed to tilt the pair of samples to obtain a comprehensive assessment of the harmony, based on the reflectance properties of the actual surface and the surface appearance. In the second experiment, the samples were placed such that their surfaces and viewing directions were perpendicular to the subject. In the third experiment, static sample images were displayed on a monitor. The results indicated that the sample pairs with similar surface properties were viewed as harmonious, although their materials were different. Indeed, the appearance harmony of the materials differed among static real samples, tilted samples, and the displayed static images. In particular, the appearance harmony of some materials was significantly affected by the reactions of subjects to visual information about the samples with/without observation of the monitor, rather than by tilting a sample. The PCA results indicated that the harmony between categories of glossy materials was more likely to change, when the materials were displayed as images. Further consideration for analyzing the relationship between physical properties and psychophysical assessments were conducted. The findings indicated that human evaluates the

appearance harmony of materials using psychological properties obtained from physical information such as the texture and reflectance characteristics of a material surface.

Contributions

Journal Papers

1. M. Tanaka, T. Horiuchi and S. Tominaga, Color Naming Experiments using 2D and 3D Rendered Sample, Color Research and Application, Vol.40, Issue 3, pp.270-280, Jun., 2015 (DOI: 10.1002/col.21886, Article first published online: Apr., 2014).

2. M. Tanaka and T. Horiuchi, Investigating Perceptual Qualities of Static Surface Appearance using Real Materials and Displayed Image, Vision Research, Vol.115, Part B, pp.246-258, Oct., 2015 (DOI: 10.1016/j.visres.2014.11.016, Article first published online: Dec., 2014)

3. M. Tanaka and T. Horiuchi, Appearance Harmony of Materials using Real Objects and Displayed Images, Journal of the International Colour Association, (Accepted for publication).

International Conferences

1. M. Tanaka, T. Horiuchi and S. Tominaga, Color Control of a Lighting System using RGBW LEDs, Proc. 23rd IS&T/SPIE Symposium on Electronic Imaging, 78660W (Jan., 2011)

2. M. Tanaka, S. Tominaga and T. Horiuchi, Color Naming Experiment using 2D and 3D Rendered Samples, Proc. Midterm Meeting of the International Colour Association, pp.90-93 (June, 2011)

3. M. Tanaka, T. Horiuchi and S. Tominaga, Color Naming Experiment using Plural Stimuli under Different Viewing Environments, Proc. Interim Meeting of the International Colour Association, pp.72-75 (Sep., 2012)

4. M. Tanaka, T. Horiuchi and S. Tominaga, Visual Perception of Fluorescent and Neon Colors on an LCD Monitor, Proc. Congress of the International Colour Association, pp.1053-1056 (July, 2013)

5. M. Tanaka and T. Horiuchi, An Investigation of the Appearance Harmony of Material, Proc. Interim Meeting of the International Colour Association, pp.449-457 (Oct., 2014)

6. M. Tanaka and T. Horiuchi, An Investigation of the Appearance Harmony using Real Materials and Displayed Image, Proc. Midterm Meeting of the International Colour Association, pp.314-319 (May, 2015)

Invited Talk

1. M. Tanaka, Perceptual Qualities and Harmony of Material Appearance, International Symposium on Foundations of Visual Information, pp.31-36 (Sep., 2015)