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Perception of car shape orientation and anisotropy alignment

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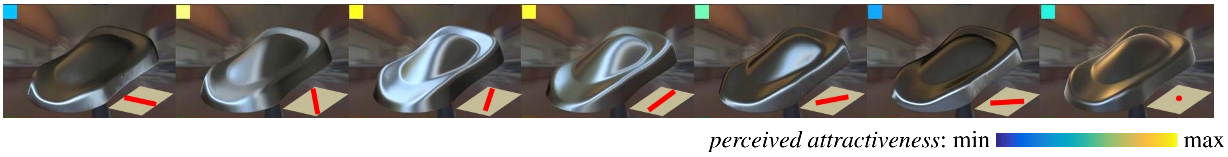

Figure 1: *Material appearance as a function of anisotropy axis alignment compared to a baseline isotropic appearance (right).*

Abstract

The color designers are used to introduce customized product design, visually communicating the unique impression of a car. They always carefully observe harmony of color and body shape to obtain desired visual impression. This paper studies to what extent anisotropic appearance improves a visual impression of a car body beyond a standard isotropic one. To address this challenge, we ran several psychophysical studies identifying the proper alignment of an anisotropic axis over a car body. We have shown that subjects preferred an anisotropy axis orthogonal to car body orientation and that the majority of subjects found the anisotropic appearance more visually appealing than the isotropic one.

1. Introduction

Various industries are continue to strive to create cutting edge, unique visual properties so as to achieve a value-added and customized product design. This allows for the creation of visual and functional properties of a product, thus positioned so that it stands out from the masses and leaves a unique perceptual impression. In automotive design color selection is a crucial factor defining the future success of a particular model. Apart from the rest of production process running from engineered blue-prints, the body shape and color design are main stages involving demanding and costly iterative design cycles of an experienced designer. The goal of this process is to achieve visual harmony between the body shape and its color. While current industrial coating application procedures can relatively well control and predict the inclination of flakes within the coating layer, they cannot orient them in a particular azimuthal direction. Due to this random azimuthal distribution of flakes designers can achieve, at a macroscopic level the same appearance regardless of the rotation of the material (or simultaneous rotation of light and camera over the material). We call this constant azimuthal behavior isotropic.

In contrast, a majority of real world materials; including individual coating flakes, have variable appearance when rotated along their normal. For instance fabric materials contain threads of fibers in combination with weaving patterns, wood or hair contain fibers, polished metals have unidirectional scratches. All these microscopic structural elements interact with incoming light depending on its direction. We call such behavior anisotropic. Fig. 2 compares an isotropic appearance (left) to the anisotropic one for variable orientation of structure elements.

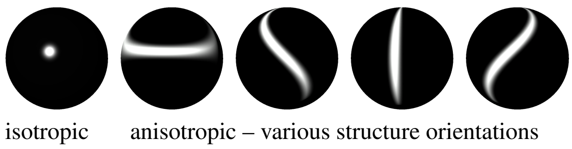

Figure 2: *A comparison of isotropic (left) and anisotropic appearance.*

We observe that while for isotropic appearance, a main visual feature is specular highlight whose location depends purely on the mutual position of light and camera, for anisotropic appearance, the shape and location of highlight is dependent on the azimuthal orientation of structural elements over the material's structure. We call the orientation orthogonal to anisotropic highlight peak as an *anisotropic axis alignment*. This parameter has a significant impact in material appearance and thus on product design, as appropriate alignment of anisotropic highlights over a product's surface can accent its visual appearance. Anisotropic materials vastly expand visual variability of isotropic appearance, due to the variable location of an anisotropic highlight. Although anisotropic behavior is present to some extent in a majority of natural materials, its application to man-made ones is limited by material type and its production process. A downside of anisotropic appearance manufacturing is its restriction to only limited materials like plastic, metal, where micro-structure can be easily introduced by surface finishing.

In this paper we analyze the human perception of a car body visual attractiveness as a function of car body orientation and anisotropic axis alignment (see Fig. 1). To address this task we ran several psychophysical experiments obtaining human judgments of the visual attractiveness.

2. Related Work

Several overview papers exist summarizing the understanding of human visual perception of materials [Fle14] and 3D shapes [Tod04] The extent of a highlight in any given direction is negatively related to the magnitude of curvature in that direction [NTO04]. The orientation structure of specular reflections appears to be a powerful source of information in visual perception [FTA04]. These studies have shown that people are good at recovering the 3D shape of perfectly mirrored objects. Distorted reflections across a specular surface provide a stable, powerful source of information about 3D shape. The prediction of anisotropic highlights locations has already been studied [LKK00] and recently further extended to arbitrary geometry with interactive tangents editing [RGB*14]. A simplified method of anisotropic highlight detection for the purpose of anisotropic materials adaptive measurement was shown in [FV15]. Filip [Fil15] used a database of anisotropic BRDFs to analyze as to what extent people can detect anisotropy in rendered images and proposed an intuitive approach for detecting the anisotropic behavior in captured materials. Ferwerda et al. [FWSP04] analyzed to what extent virtual reality rendering methods can be used for discriminating differences in car body shapes under different viewpoints. They conclude that the view point has an effect on the ability to discriminate shape, where surface reflections are an important source of information. Rendering method has effect on ability to discriminate shape changes (global illumination method doubled the sensitivity). Shimizu et al. [SM10] proposed an intuitive tool for the fast design of automotive colors by picking face and flop colors from so called virtual mood boards. In this paper we are analyzing the impact of anisotropy axis alignment over the object surface on visual perception of its attractiveness.

3. Material appearance and illumination models

Textureless materials are commonly represented using a Bidirectional Reflectance Distribution Function (BRDF) introduced by Nicodemus et al. [NRH*77]. It describes the ratio of energy reflected by material for a certain combination of incoming and outgoing directions (specified by θ polar and φ azimuthal angles). When we assume the separate processing of color channels, the anisotropic BRDF is a four-dimensional function $B(\theta_i, \varphi_i, \theta_v, \varphi_v)$, whereas the isotropic BRDF is merely three-dimensional, i.e., $B(\theta_i, \theta_v, |\varphi_i - \varphi_v|)$. Isotropic and anisotropic material appearance Fig. 2 within this paper was represented by an BRDF model [FHV15] allowing an intuitive control of main features of anisotropic highlights. To reflect natural color of environment, we set the model parameters to produce achromatic high contrast between highlights and other regions. For object illumination, we used *uffizi* and *kitchen* illumination environments from as shown in Fig 3. Each environment map is represented by 128 directional lights. In representing a car body, we used a plastic car-like shape common in the coating industry for assessing effect coatings. The shape 3D geometry was acquired by a laser scanner.

Figure 3: *Environment illuminations used in our experiments.*

4. Car body and anisotropy orientations analysis

We ran a psychophysical study to identify the most visually attractive orientation of a car body owing to the viewer. To make the study tractable, we preselected five different orientations of our 3D model between frontal and lateral as shown in rows of Fig. 4. We ran two experiments: in a controlled environment (**C**) and uncontrolled web-based study (**U**). To adjust visual scales in both experiments, subjects were first shown an image containing all variants of car shape rendered for different orientation and anisotropy axis alignments (see Fig. 4). Then individual images were shown to them one by one and their task was to rank their visual attractiveness on a scale 1-5, where 1 was the best and 5, the worst. In total 21 subjects participated in the controlled experiment. There was consistent office lighting and stimuli were shown on a calibrated 24" screen. Subjects observed a screen from the distance of 0.6m and stimuli subtended visual angle 25°. In the uncontrolled web-based experiment 85 subjects participated. They were advised to run the experiment with dim office illumination and stimuli shown in full screen mode. One session in both experiments took approximately 2.5 minutes. The controlled experiment was performed in *kitchen* illumination environment (red outlines),

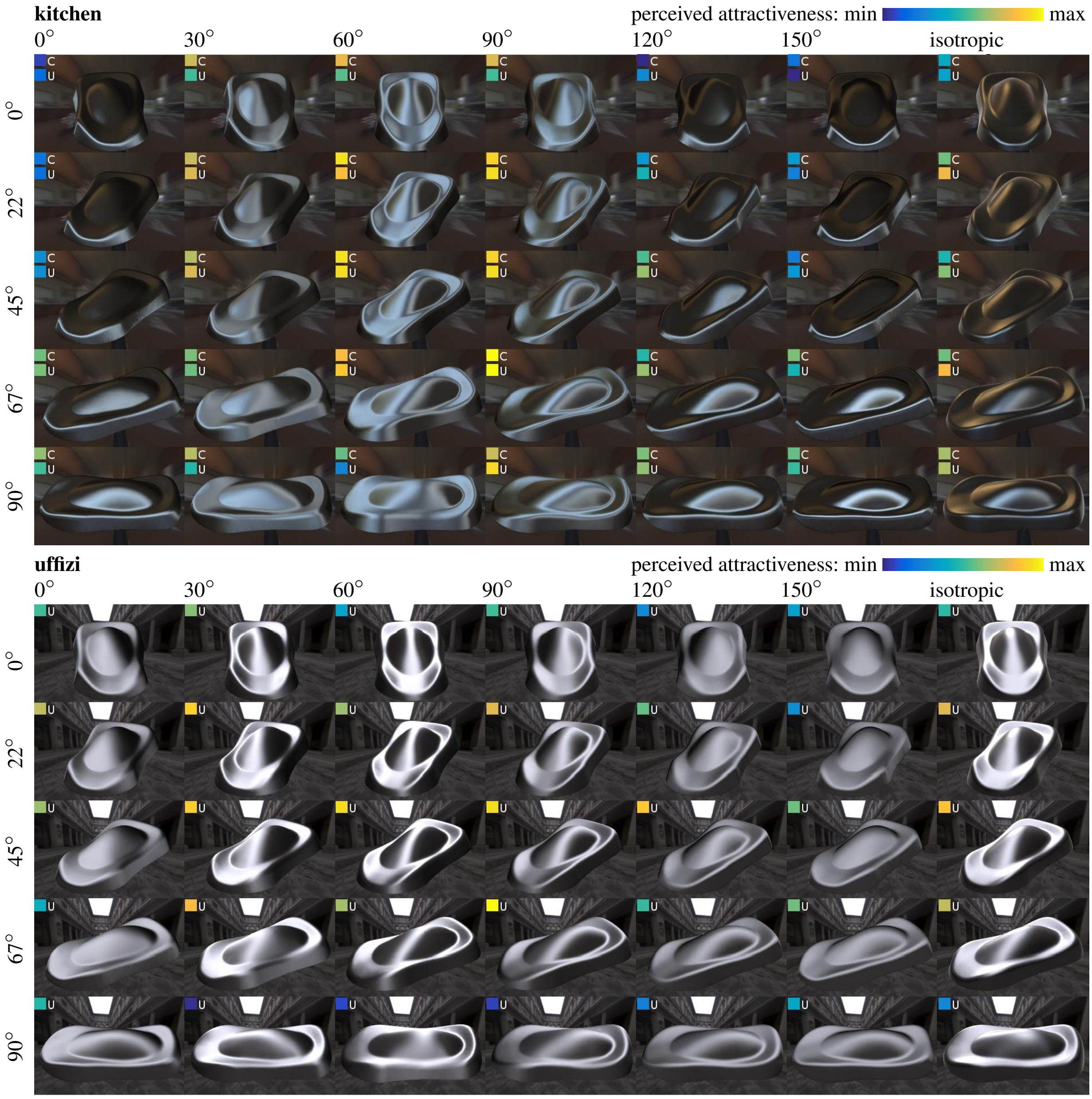

Figure 4: *Material appearance as a function of object orientation (rows) and anisotropy axis alignment (columns). The last column shows isotropic appearance. Inset squares depict color-coded perceived attractiveness for controlled (**C**) and uncontrolled (**U**) experiments.*

while a web-based one was performed in *kitchen* and *uffizi* environments (blue and green outlines). From the subjects responses, we obtained mean opinion scores and standard errors of perceived attractiveness as a function of object orientation are shown in Fig. 5-a, and as a function of anisotropic axis alignment in Fig. 5-b. Fig. 4 show all stimuli images with color-coded mean opinion scores of visual attractiveness. We can observe a good consistency between the data from controlled (**C**, blue outline) and uncontrolled (**U**, red outline) experiments for the same *kitchen environment*. Results of uncontrolled study in *uffizi* environment are shown in green outline. There were two types of data for each test – the full outline represents an average across anisotropic appearance for a different orientation of main axis of anisotropy, while the dashed outline is for isotropic appearance. In general, in Fig. 5-a we observe a decrease in

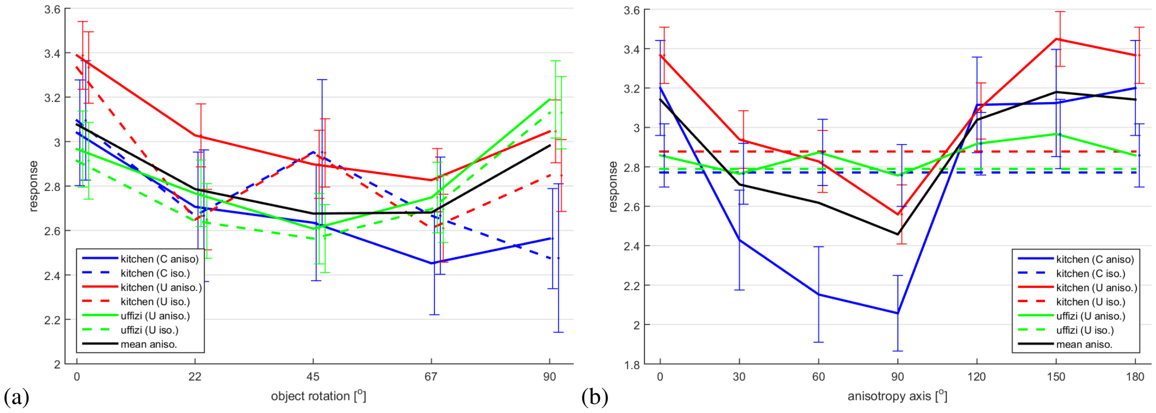

Figure 5: *A comparison of perceived attractiveness as a function of (a) object orientation – from frontal to lateral, (b) anisotropic axis alignment compared to a constant representing an isotropic appearance.*

value between the frontal and lateral object orientation. Interestingly, there are two minima for isotropic appearance in the *kitchen* environment (recorded for both controlled and uncontrolled experiments). As for anisotropy axis orientation, in Fig. 5-b one can observe higher attractiveness (i.e., lower values) for anisotropy alignments between 60 –90°. For these alignment the anisotropic appearance (full outlines) was considered as much more visually appealing that the baseline isotropic (dashed outlines). From these results we assume that the appearance of a car body was visually more attractive for anisotropy axis orientation (i.e., directional structure elements) aligned with its lateral axis, regardless of the tested illumination environments.

5. Conclusions

We studied visual attractiveness of anisotropic appearance as a function of anisotropic elements orientation over the material surface. We represented appearance using a BRDF model and focused our analysis on car body shape. We performed controlled and uncontrolled psychophysical studies with static stimuli and two illumination scenarios. We conclude that subjects preferred anisotropy orientation aligned with lateral axis of the car body. This is presumably due to enhanced visibility of lengthwise shape contours. As for a car body orientation, subjects preferred orientations between frontal and lateral. These results demonstrate that anisotropic materials represent an abundant source of attractive appearance variations to be explored and applied in product design.

In a future work we plan to use dynamic stimuli to analyze impact of different illumination environments and investigate the visual cues determining subjects' preference.

Acknowledgements

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