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User Study of Viewing and Illumination Dependent Material Appearance

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ABSTRACT

Our research focuses on a way how people view real materials with respect to their orientation as well as illumination direction. We performed user study with fifteen naive subjects using novel interactive stimuli where subjects could arbitrarily change orientations of planar surface and directional illumination. Seven real materials were represented by means of illumination and view dependent textures. The study comprised two experiments, free-view and task-oriented, and user behavior across different samples together with their answers to questionnaire were recorded and analysed.

Categories and Subject Descriptors

I.3.7 [Three-Dimensional Graphics and Realism]: Color, shading, shadowing, and texture; Social and Behavioral Sci- ences [Psychology]

Keywords

texture, material, appearance, orientation, visual perception, phychophysical experiment, user study

1. INTRODUCTION

Appearance of all real world objects is significantly influenced by materials covering them or materials from which they are made of. Therefore, to provide realistic digital simulation of real world appearance we have to solve tasks such as its effective measurement, analysis, and visualization. Different representations can be used dependently on a type of material, ranging from spatially smooth reflectance to high-dimensional bidirectional scattering functions. Many of these representations allow feasible and accurate appearance measurements, however, the size of these measurements is often a bottleneck in measurement-processing- visualization pipeline. Additionally, when these massive data are used for image processing algorithms such as content- based-retrieval the computational demands become unacceptable. Therefore, filtering of these enormous data already at the measurement stage would help considerably. However, decision which data are important and which not is extremely difficult and is heavily dependent on the intended application. Main goal of these applications is to conform with expected visual perception of human observers. Hence, we believe that study of a way human subject view material appearance will help us to understand a way people process material-dependent visual information and thus may provide us with data filtering rules applicable for general measurement and processing of any material appearance data.

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2. USER STUDY

To pursue this research goal we designed user study exploiting strictly controlled interactive stimuli. Fifteen naive subjects participated in the study. Material appearance is captured by means of bidirectional texture functions, i.e. illumination and view dependent texture images [1]. In our experiment we used data containing 81×81 illumination and view directions, i.e., containing 6561 texture images of material appearance. These data were compressed and visualized on graphics hardware in a way to allow subjects arbitrarily control orientation of a flat material sample owing to their view direction, as well as a position of a single directional light (Fig. 1).

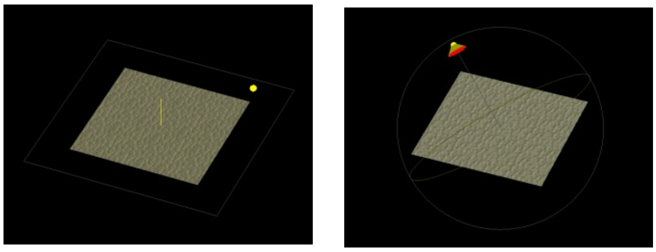

Figure 1: Example of interactive stimuli in sam- ple move mode (left), and illumination move mode (right). Material: leather light.

Using a flat sample was crucial in our study as it allowed us to record illumination/viewing directions of the sample and their durations as the subjects moved with the sample and light. Whenever subject moved, either with the sample or light, corresponding angles were recorded together with a time-stamp. Vertical/horizontal move of the mouse with left button pressed were translated into tilt/rotation of the sample, while moves of mouse with right button pressed intuitively controlled light direction. Seven material samples of different visual properties, ranging from specular to diffuse, were used in our study. Their examples on sphere are shown in Fig. 2. Second row of the figure shows materials directional properties (illumination directions rows, viewing directions columns). We split the study into two experiments, that were performed in a dark-room and materials were showed to them in the same order as presented in Fig. 2.

Experiment 1

The first experiment consisted of consecutive free viewing of the samples for non-restricted time. After each material viewing subjects were asked to assess: its identifiability, roughness, specularity, and anisotropy on a scale from 1 to 9. All subjects were trained to use the system on a sample excluded from the study before the experiment, and all questions were explained them in to detail including extreme cases of the queried properties.

Experiment 2

In the second experiment subject viewed the same set of samples in the same way, however, with a defined task: to find orientations of sample and light source that produce interesting/attractive appearance of the material. In such a case they were asked to press a defined key and they could do this several times. They were free to move to a next sample whenever they wanted.

3. RESULTS

First we analyzed statistics of user viewing behavior. Median duration between moves, duration of single material viewing, and total number of moves are compared for individual materials in Fig. 3. First/second row represents data from the first/second experiment. Results of both experiments are very similar and suggest that materials having smoother, non-regular spatial structure (lacquered wood, dark and light leather) are observed more intensively (high number of moves), but the moves were performed more quickly (median duration), while a total time spent on a sample was similar across materials (material duration). We observed the same behavior with the same samples during eye-tracking visual search [2], where such materials received more fixations, that were shorter than for remaining materials. We believe that in the case subjects detect regularity of patterns in the sample they automatically assume that spatial behavior of the material is similar and further focus only on directional properties of the materials. While for non-regular materials they take material's spatial structure as additional source of information.

Averaged answers to questionnaires recorded in the first experiment are shown in Fig. 4. Generally, subjects were not very successful in identifying the materials with exceptions of dark leather and knitted wool. This may be caused by controlled but unreal single light directional illumination. On the other hand, subject were relatively good in identification of roughness and specularity, while quite insensitive to anisotropy. Their results were compared with relative ref- erence measures shown as green outlines (representing: 1) mean variance, 2) contrast specular vs. off-specular high-light, 3) span of azimuthally dependent luminance for mutually fixed positions of light and camera).

Interesting results, were obtained also by angular analysis of subjects' viewing behavior. Viewing directions (i.e., sample orientations) were concentrated quite near perpendicular view and the remaining directions were distributed uniformly across hemisphere of possible viewing angles. In contrast, distributions of illumination directions varied more significantly between the two experiments as well as across tested materials as it is shown in Fig. 5. In the first experiment subjects sampled illumination directions almost uniformly, while in the second experiment their behavior was more material dependent. Reason for this difference may be that in the second experiment they were already accustomed to stimuli control and additionally motivated by the given task. When these results are compared to two reference measures computed from the input texture datasets: mean luminance and variance over all view and illumination dependent images, we can see that subjects attention was not driven by stimuli luminance, otherwise they would sample more frequently reflections near specular highlights (light opposite to the camera). Instead of this, they followed light orientations providing higher contrast simulated by the variance feature in the last column. While the leathers were mostly illuminated from oblique angles, lacquered wood received uniform distribution of illumination directions, and fabrics and wool received close to sample's normal illumination.

Finally, we also analyzed the subjects responses collected from the second experiment, i.e., directions giving visually interesting material appearance. However, due to relatively low number of subjects and given massive state space of possible answers, it was difficult to draw reliable conclusions.

4. CONCLUSIONS

Our research on human viewing strategies of material appearance has shown close relation to our recent human gaze data analysis of the same material samples. Subjects viewing strategy was different for regular/high-contrast vs. non-regular/low-contrast materials, where for the latter they performed in general more sample/illumination moves which were shorter. Subjects' ability to recognize the material and its degree of anisotropy was low, but they were relatively accurate in estimate of material's roughness and specularity. Directional analysis of the data revealed that subjects preferred orthogonal orientations of the sample to their view to obtain enough information, while they positioned illumination source to directions giving higher texture contrast. Given these encouraging pilot results, we believe that this research may provide us with even more specific and applicable results, in the case more subjects would participate in the study.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[1] K. Dana, B. van Ginneken, S. Nayar, and J. Koenderink. Reflectance and texture of real-world surfaces. ACM TOG, 18(1):1–34, 1999.

[2] J. Filip, P. Vácha, and M. Haindl. Analysis of human gaze interactions with texture and shape. In Springer LNCS 7252, April 2012.

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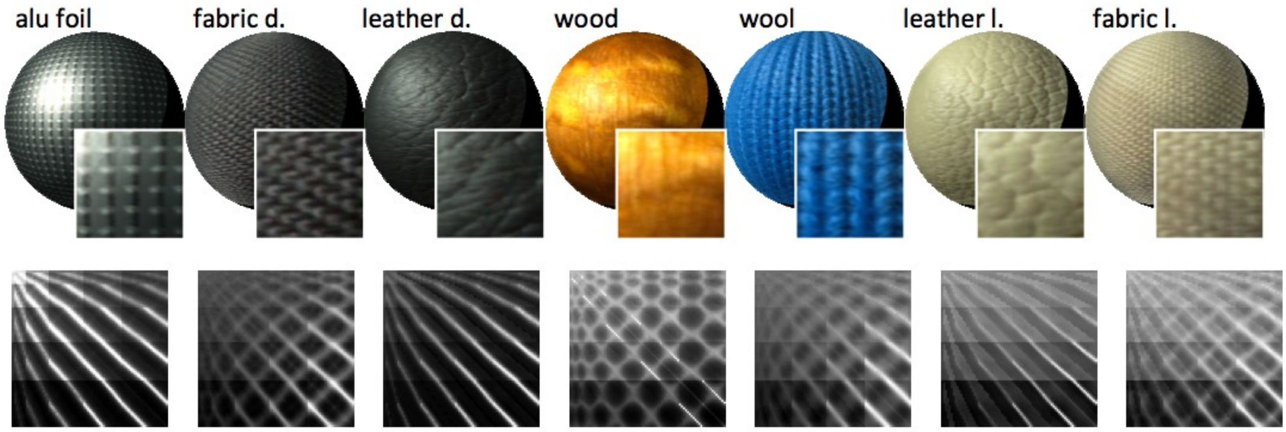

Figure 2: Material samples used in the study, represented as BTF data. Second row shows materials' average reflectance directional properties in a form of luminance BRDFs (illumination directions as rows, viewing directions as columns). Note that mapping on sphere is used for illustration purposes only.

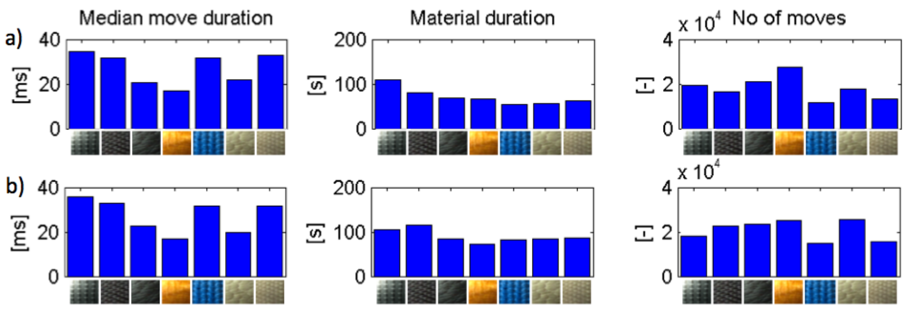

Figure 3: Statistics of average subjects behavior during the experiment: median durations of light/sample move, material viewing time, number of moves. (a) experiment 1: free-viewing, (b) experiment 2: search task.

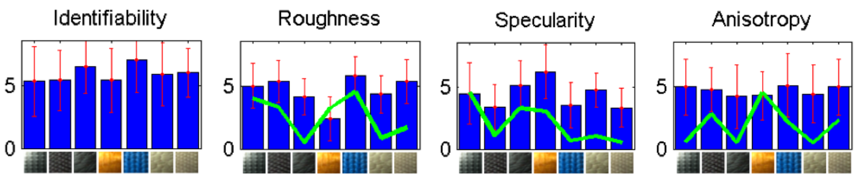

Figure 4: Average subject evaluation of material properties in the first experiment: material identifiability, roughness, specularity, and anisotropy.

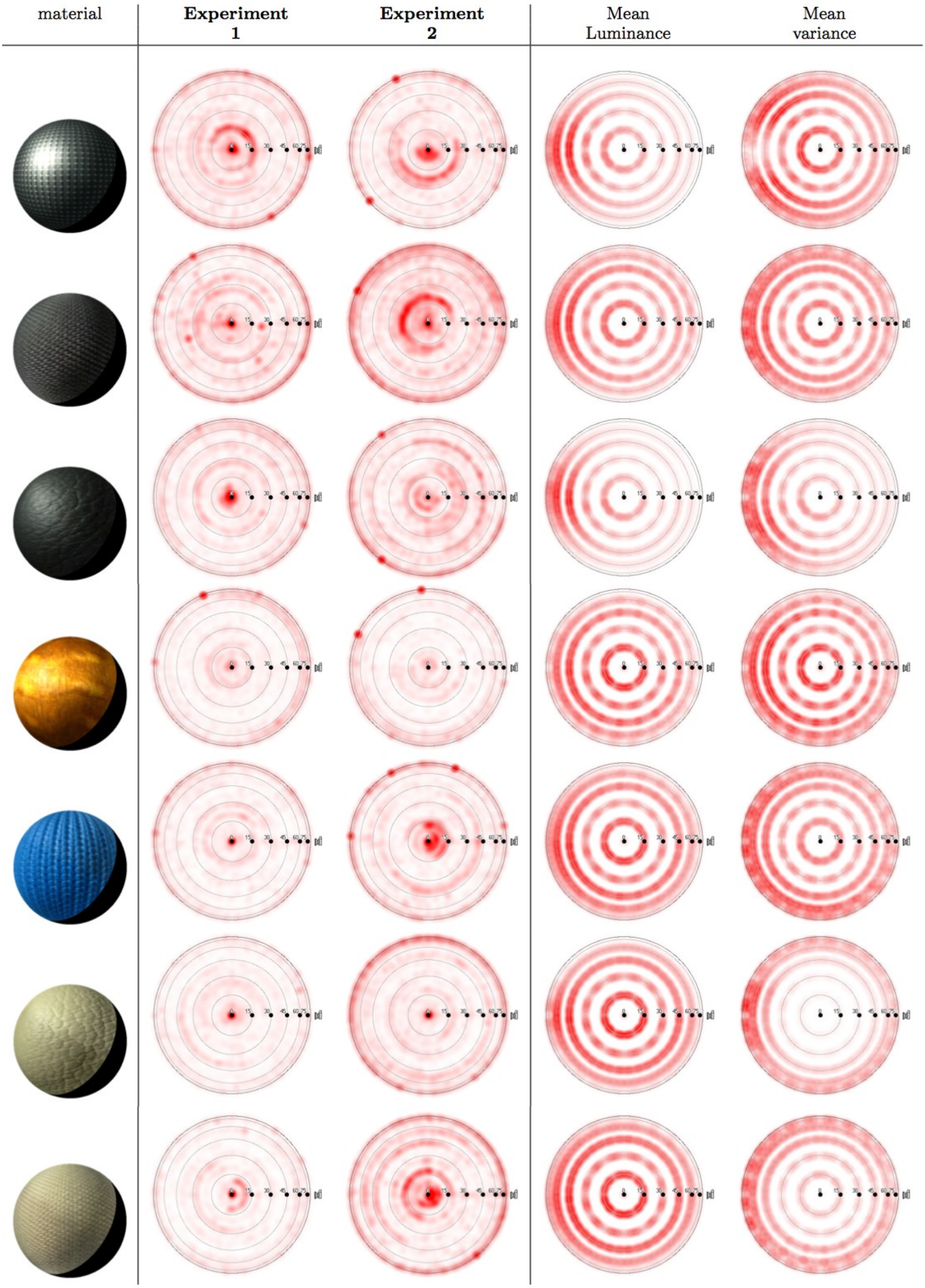

Figure 5: Distributions of illumination directions used by subjects in the experiments. Directions are shown across hemisphere over the sample surface for viewing direction from the right-side of the hemisphere. Results of the experiments (first two columns) are compared with two selected computational reference measures (mean luminance and variance across individual texture images).