Problems of Perceiving Gloss on Complex Surfaces

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Problems of Perceiving Gloss on Complex Surfaces

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ABSTRACT
Over the past 20 years, there have been many studies looking at how highlight disparity affects an observer's perception of glossiness. Most of these studies have used relatively smooth surfaces, and simple lighting models.

We are using surfaces which are rougher and more naturalistic than those used before, using a rendering method which takes into account physically accurate properties of light to create stimuli which are as close to 'real' samples as we can currently generate.

To this end, we present the results of a pilot experiment designed to look into this problem. These results seem to imply that the relationship between gloss perception, highlight disparity and roughness is more complex than previously reported.

Categories and Subject Descriptors
Vision and Scene Understanding – *3D/stereo scene analysis, Intensity, colour, photometry, and thresholding, Shape.*

General Terms
Measurement, Performance, Human Factors, Experimentation

Keywords
Appearance, Stereoscopy, Gloss, Fractals, Roughness, Surfaces

1. INTRODUCTION
From early studies into the effect of stereopsis on gloss [1], to more recent studies expanding that original work [2,3], most state that the presence of accurate highlight disparity improves the perceived realism and increases the perceived strength of a surface's glossiness.

Our current work uses surfaces which have been shown to appear in nature ($1/f^\beta$ fractal surfaces) and have been used successfully in previous roughness experiments [4]. These surfaces are rendered as static images (using a renderer with physically accurate lighting - www.luxrender.net) and are much more complex and rough than surfaces used in earlier studies. As a result of this, our stimuli have much higher detail and take into account the effects of interreflections. We aim to discover if the results found with smoother surfaces hold true for these more complex surfaces. Does highlight disparity reliably alter an observer's perception of either the realism or intensity of a surface's glossiness when considering rough surfaces?

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2. APPARATUS
The pilot experiment was conducted in a darkened room, with the half-images required for stereoscopic fusion presented side-by-side on a single 24 inch NEC PA241W monitor. This monitor was selected for its impressive colour correctness (provided by a 14-bit per colour 3D LUT), wide viewing angles with minimal colour deviation and luminance uniformity (< 5%) across the panel [5].

Participants viewing these stimuli did so through a custom made mirror stereoscope which consisted of four front surface aluminium mirrors mounted on an optical rail which allowed for calibration to different interoccular distances as required. This stereoscope is shown in Figure 1.

The monitor was positioned 80cm away from the viewer, with the viewing distance for each eye being approximately 85cm with the mirrors taken into account.

3. STIMULI
We used a densely sampled two-dimensional $1/f^\beta$ noise process [6,7] to create naturalistic surface relief, before rendering it with a physically accurate renderer. $1/f^\beta$ noise images were used due to their success in previous papers [4,8] and the evidence that fractal surfaces and structures appear in nature [9].

Every surface used had the same reflectance qualities and was lit by exactly the same light source, in the same relative position to make sure there was no perceived difference in roughness which occurs from differing illuminant angles or viewing angles [10,11].

The finished stimuli had a maximum possible resolution of 568 x 568 pixels, and therefore a maximum possible size on the monitors used of 15.2cm square. The maximum difference in depth was 2.53 cm in real terms. These monocular half-images were then presented side-by-side on a black background with a minimum separation of 10cm to make sure that there was no cross-talk between an observer's eyes. Examples of the stimuli used are available in Figure 2.

4. EXPERIMENTAL DESIGN
We used a two-alternative forced choice (2AFC) experimental design. Due to the nature of the stereoscope being used, it wasn't practical to present the participants with both choices at the same time. Therefore, the stimuli were displayed consecutively, with a masking image in between. Once both stimuli in a pair were shown, the user was asked to indicate their answer on a keyboard, as seen in Figure 3.

Four participants was presented multiple pairs of different surfaces with the same roughness, and asked to indicate which was 'most glossy'. In the experiment, there were six different levels of roughness, with the β-values used to generate the surfaces at intervals of 0.1 from $1/f^{1.5}$ to $1/f^{2}$. At each roughness, two different surfaces were generated which were statistically identical, but visually distinct. This was to stop possible per-pixel comparisons between the stimuli. The only difference between the two surfaces was how they were presented. Each stimuli could be presented in one of three ways:

'Monocular' surface - Where the image in both eyes is identical

'Half Stereo' surface - Where the surface and lambertian shading is identical in both eyes but the specular highlights have disparity

'Full Stereo' surface - Where both eyes see images rendered from the correct, differing viewpoints to give a image with correct depth and lighting.

5. HYPOTHESIS

Although previous experiments have shown how important highlight disparity is to accurate gloss perception, we believe the nature of rough surface reflections, where you have fewer and smaller highlight patches [12], might make it much harder for participants to notice any specular disparity. In addition, the possibility of highlights only being present in one eye, or multiple points on the surface reflecting the same point of the scene might make stereo matching impossible or inaccurate [13].

Therefore, we expect that 'Full Stereo' surfaces will be consistently perceived as glossier for smoother surfaces, but for it to make no difference for the rougher surfaces. We also expect that participants will find surfaces with specular disparity glossier than those with no disparity ('Half Stereo' vs 'Monocular'). This would also imply that 'Half Stereo' and 'Full Stereo' surfaces of the same roughness should appear to have the same glossiness, as both of these conditions contain specular disparity.

6. RESULTS

To simplify the discussion of the results, they have been split into three different graphs, one for each possible condition (Figure 4 - Figure 6). These will be discussed in turn.

For three participants (FRB, MK, SM), it appears that the results found in previous experiments hold true across all roughnesses, as they consistently picked the stereoscopically presented stimuli as glossier (Figure 4). EF, however, gave results which were more similar to the hypothesis. For the roughest surfaces, ($\beta = 1.5 - \beta = 1.7$) EF often selected the monocular stimuli as being glossier, or seemed unable to notice a difference. As the surfaces became smoother, however, they switched to seeing the 'Full Stereo' stimuli as being glossier. With only 4 participants, it is difficult to tell which of these two response patterns accurately reflects the common perception of gloss on this type of surface.

As stated in the Hypothesis section, we believed that if the participants were able to successfully see the disparity in the specular highlights, then the 'Half Stereo' surfaces should appear glossier than the Monocular ones. This is clearly not the case, however, as shown in Figure 5. Instead we saw almost perfect equivalence between 'Half Stereo' and Monocular surfaces. This seems to imply that participants were not using specular disparity to determine glossiness.

The final comparison shown in Figure 6 seems to disagree slightly with the previous results. It is clear that the results from this part of the experiment are subject to much more noise than the comparison between 'Full Stereo' and Monocular stimuli. Most tellingly, perhaps, participant EF's results no longer show the same pattern as before, instead showing a much more linear pattern which is likely to be noise. It is apparent at this stage that these results are not clear enough to confirm that highlight disparity is sufficient to improve gloss strength.

7. DISCUSSION

While our experiment appears to confirm that stereo disparity increases perceived glossiness on rough surfaces, it didn't hold true for all participants. In addition, specular highlight disparity alone wasn't enough to ensure increased perceived glossiness.
We believe that these results show the problem is more complex with rougher surfaces than previously thought due to the increasing difficulty of stereo correspondence and the decreasing amount of gloss information a rougher surface provides.
We think therefore, that this topic merits further study with more participants and roughness levels. We hope that we will be able to determine if there is an obvious threshold where surfaces become too rough to accurately detect specular disparity and therefore have a perceivable effect on how glossy a surface is.

8. ACKNOWLEDGMENTS

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9. REFERENCES

[1] Blake, A. and Bulthoff, H. Does the brain know the physics of specular reflection? *Nature*, 343, 6254 1990), 165-168.
[2] Wendt, G., Faul, F. and Mausfeld, R. Highlight disparity contributes to the authenticity and strength of perceived glossiness. *Journal of Vision*, 8, 1 (January 22, 2008 2008).
[3] Sakano, Y. and Ando, H. Effects of head motion and stereo viewing on perceived glossiness. *Journal of Vision*, 10, 9 (November 23, 2010 2010).
[4] Padilla, S., Drbohlav, O., Green, P. R., Spence, A. and Chantler, M. J. Perceived roughness of 1/f[beta] noise surfaces. *Vision Research*, 48, 17 2008), 1791-1797.
[5] Baker, S. *NEC PA241W Review*. TFT Central, City, 2010. [6] Mandelbrot, B. B. The fractal geometry of nature/Revised and enlarged edition. *New York, WH Freeman and Co., 1983, 495 p.*, 11983).
[7] Saupe, D. Algorithms for random fractals. *The science of fractal images*1988), 71-136.
[8] Qi, L., Chantler, M. J., Siebert, J. P. and Dong, J. *How Mesoscale and Microscale Roughness Affect Perceived Gloss*, 2011.
[9] van der Schaaf, A. and van Hateren, J. H. Modelling the power spectra of natural images: statistics and information. *Vision Research*, 36, 17 1996), 2759-2770.
[10] Ho, Y. X., Landy, M. S. and Maloney, L. T. How direction of illumination affects visually perceived surface roughness. *Journal of Vision*, 6, 5 2006), 634-648.
[11] Ho, Y. X., Maloney, L. T. and Landy, M. S. The effect of viewpoint on perceived visual roughness. *Journal of Vision*, 7, 1 2007).
[12] Nayar, S. K., Ikeuchi, K. and Kanade, T. Surface Reflection - Physical and Geometrical Perspectives. *Ieee T Pattern Anal*, 13, 7 (Jul 1991), 611-634.
[13] Welchman, A., Muryy, A., Ban, H. and Fleming, R. *Seeing in 3D – human psychophysics, modelling and brain imaging*, 2011.

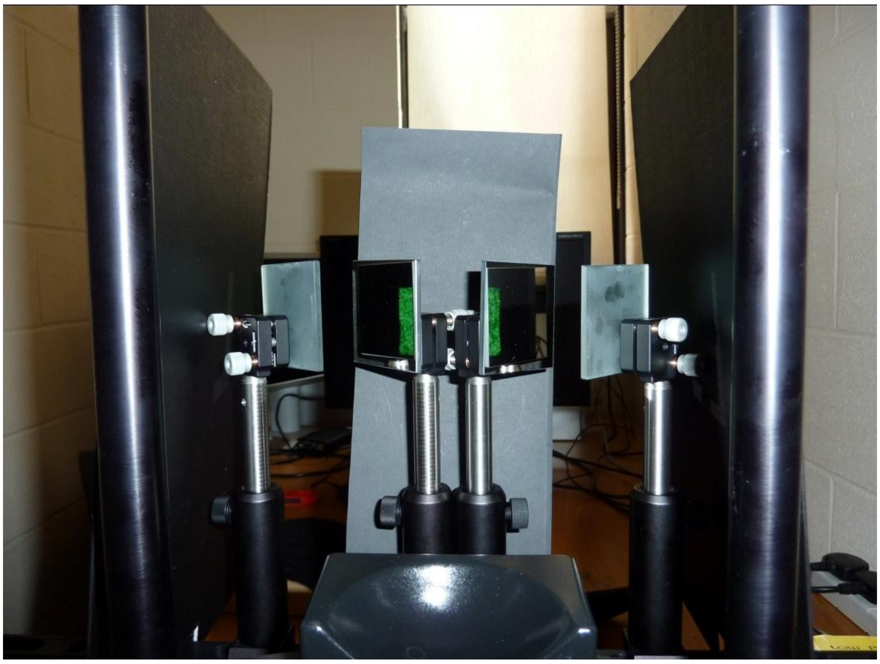

Figure 1 - Apparatus Setup

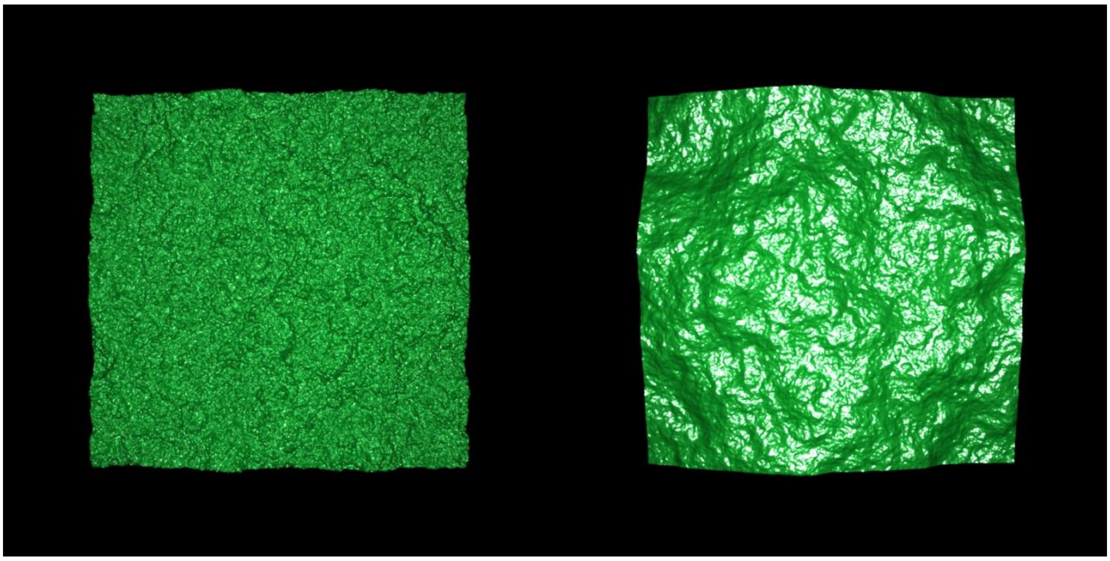

Figure 2 - Example Surfaces with the same surface properties but different roughnesses. β = 1.5 (left) and β = 2 (right)

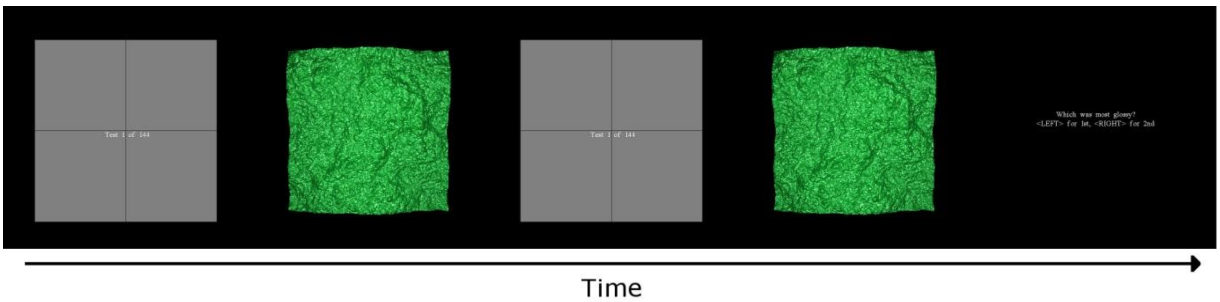

Figure 3 - 2AFC Experiment Design (Text in last frame: 'Which was most glossy? <LEFT> for 1st, <RIGHT> for 2nd')

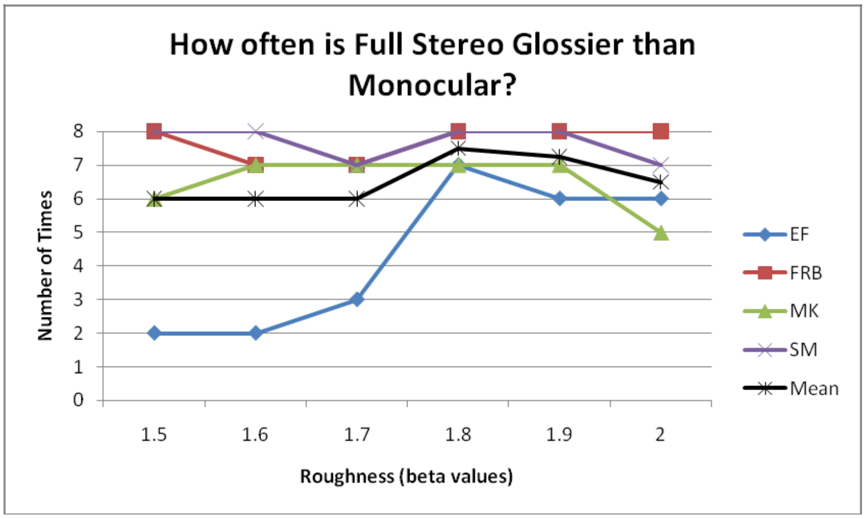

Figure 4 - How often is Full Stereo Glossier than Monocular?

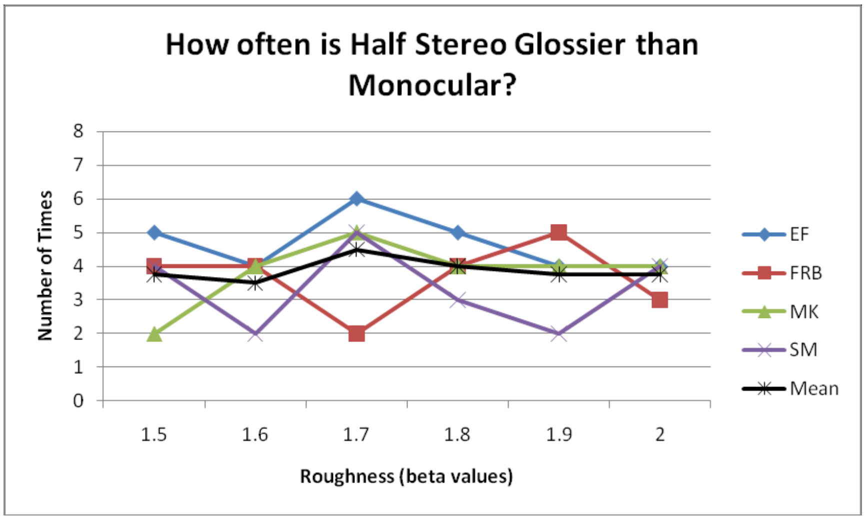

Figure 5 - How often is Half Stereo Glossier than Monocular?

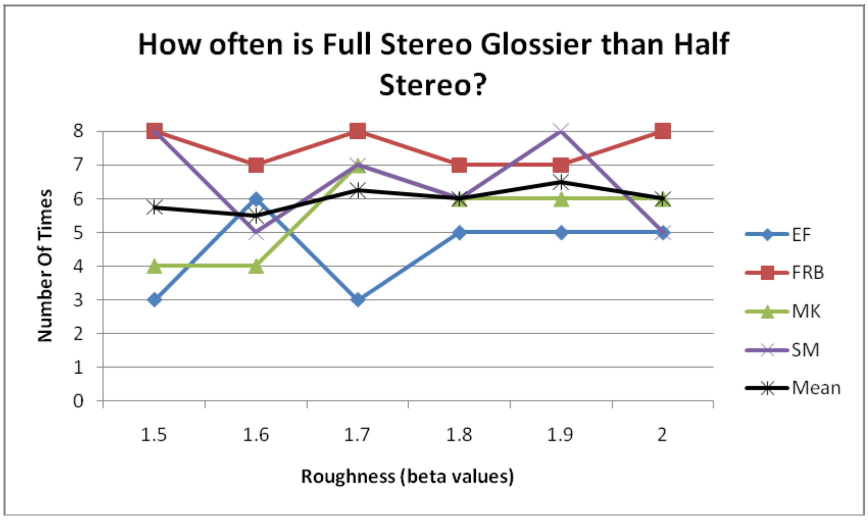

Figure 6 - How often is Full Stereo Glossier than Half Stereo?