

Showing Shape with Texture: experimental findings on the effects of various texture characteristics

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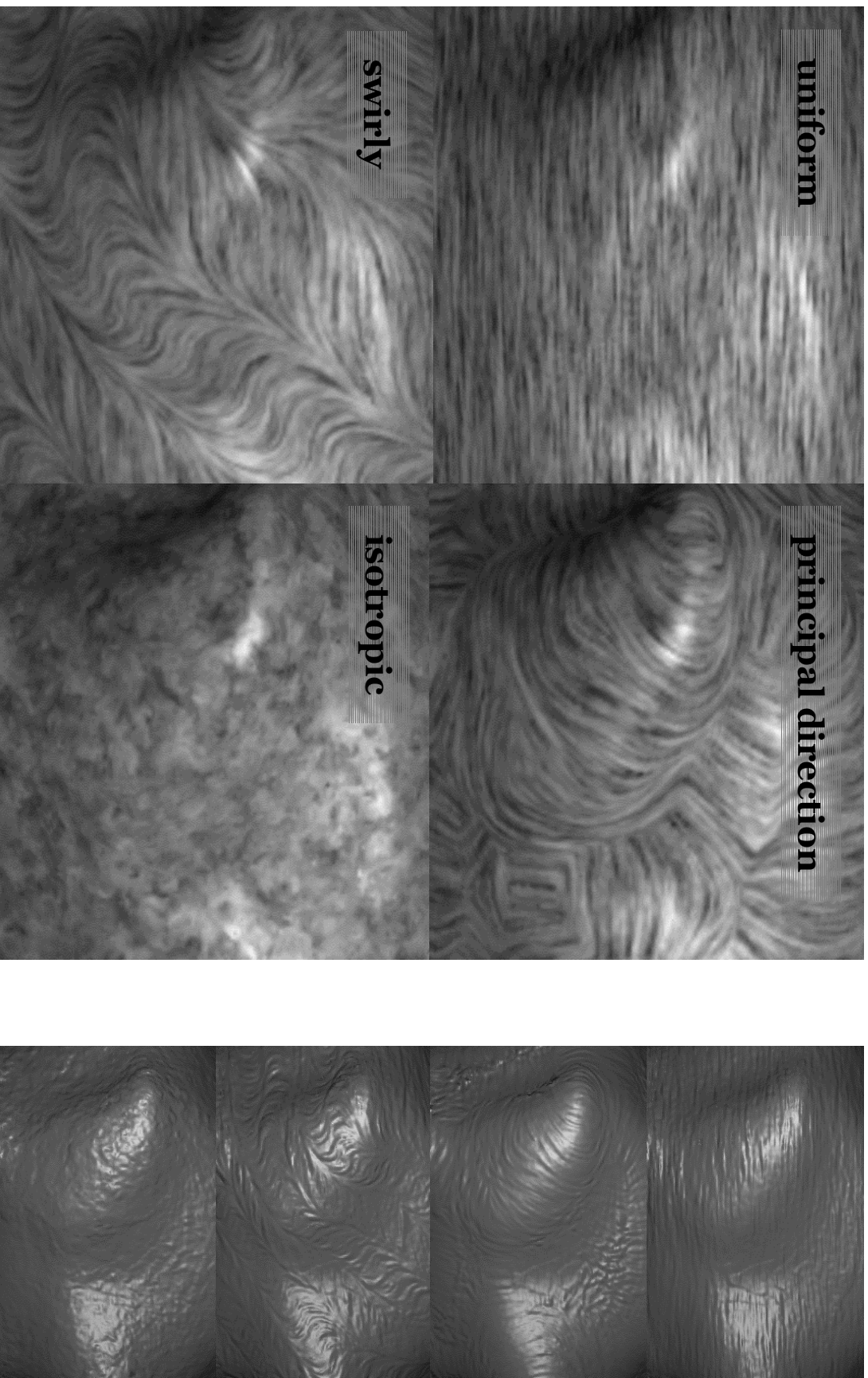
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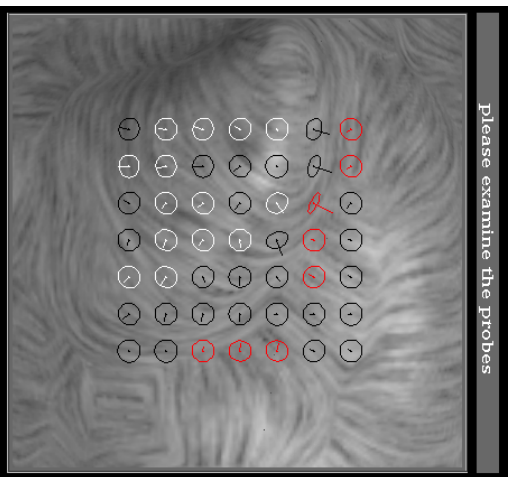
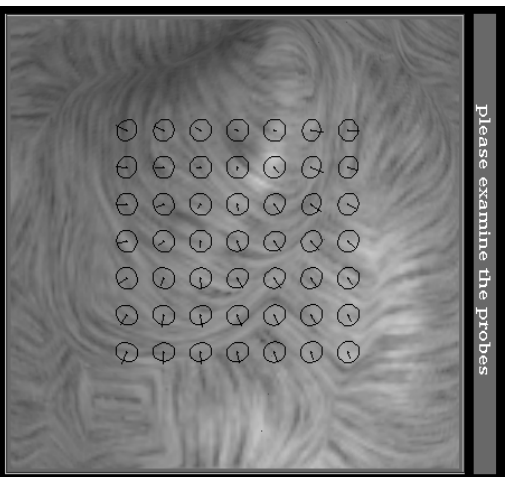
Motivation

If we could design the perfect texture pattern to apply to any smooth surface in order to enable observers to more accurately perceive the surface's shape, what would the characteristics of that texture pattern be? How much better can we do, using a well-designed texture pattern, than simply smooth shading (the most popular default option)? The answers to this question have important potential impact in a wide variety of visualization applications, from molecular modeling to medical imaging, in which scientists need to efficiently attain an accurate, intuitive understanding of the shapes of complicated, smoothly curving surfaces in their data.

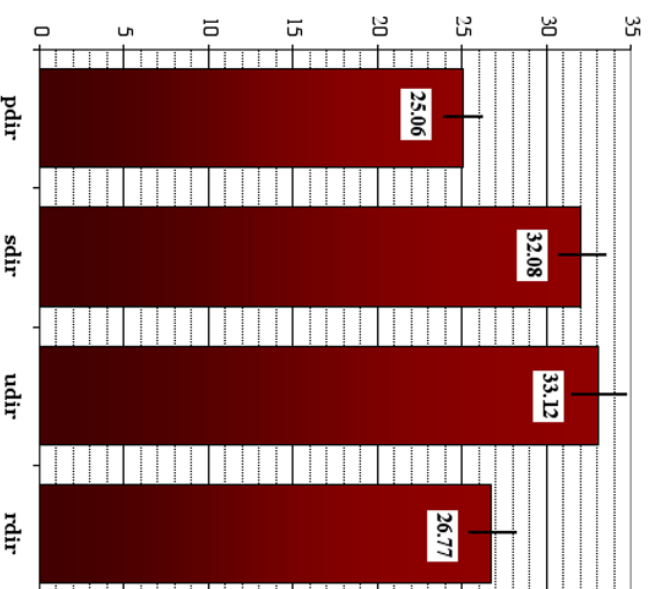
Over the past several years, we have carried out a series of experiments intended to investigate the impact on shape perception of various characteristics of surface texture patterns. In this poster, we summarize the cumulative results of these studies.

Experiment 1: How does texture orientation affect shape perception?

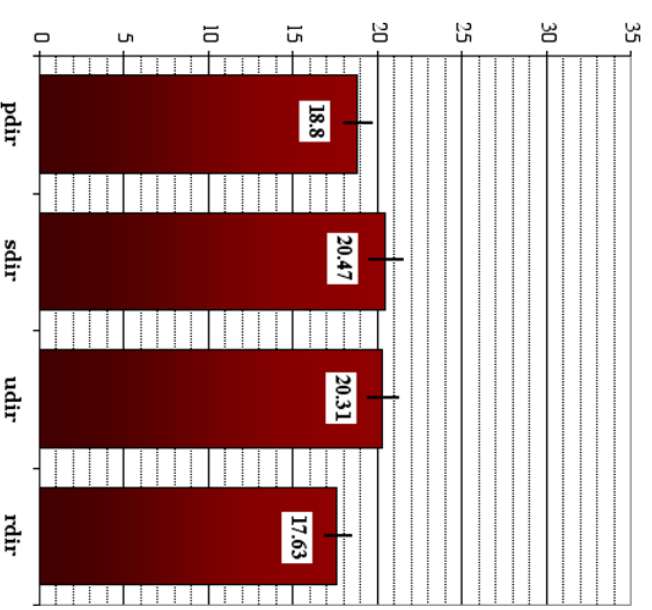




- Shape perception accuracy varies significantly with texture type
- Accuracy is poorer in the cases of anisotropic textures that are out of alignment with the principal directions
- Accuracy is equivalent with an isotropic texture and with an anisotropic texture that follows the first principal direction
- Results are similar for displacement and luminance textures



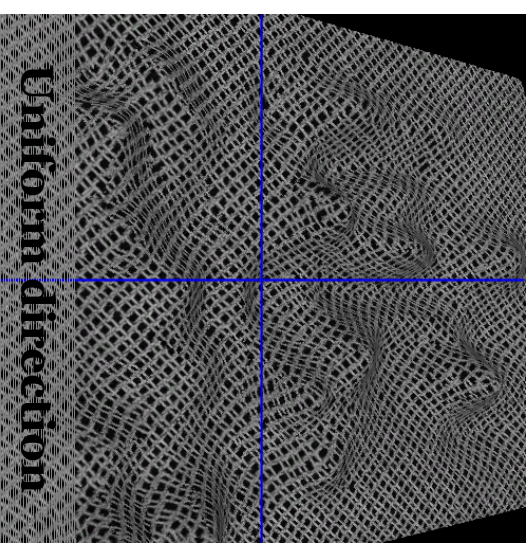
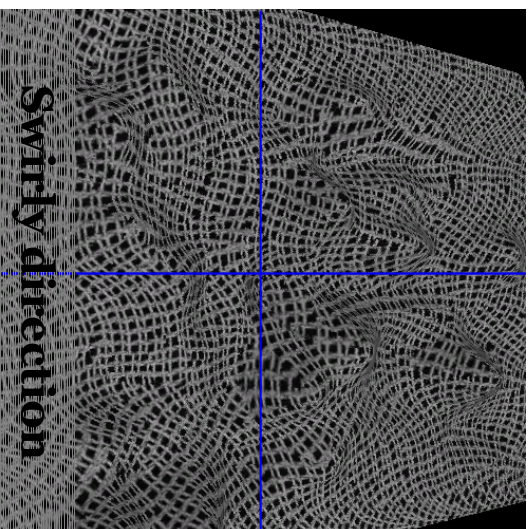
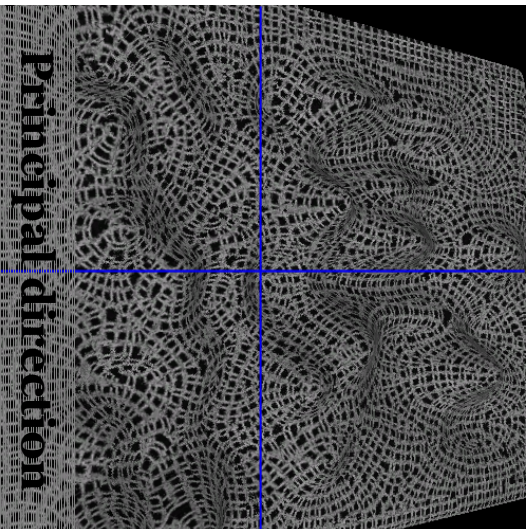
Top: true probe orientations
Bottom: results from a typical trial



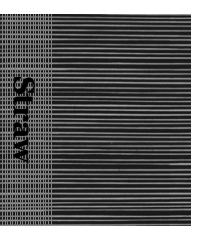
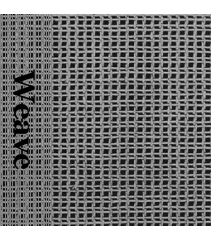
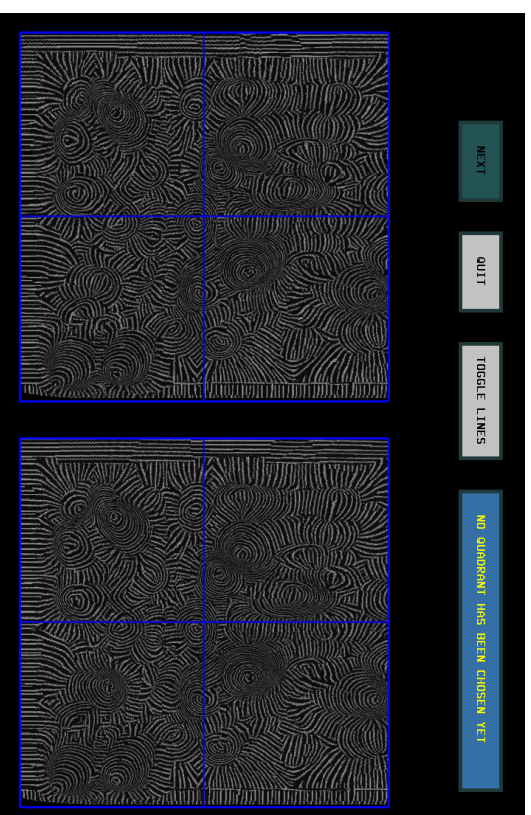
Mean 3D Angle Error, Flat

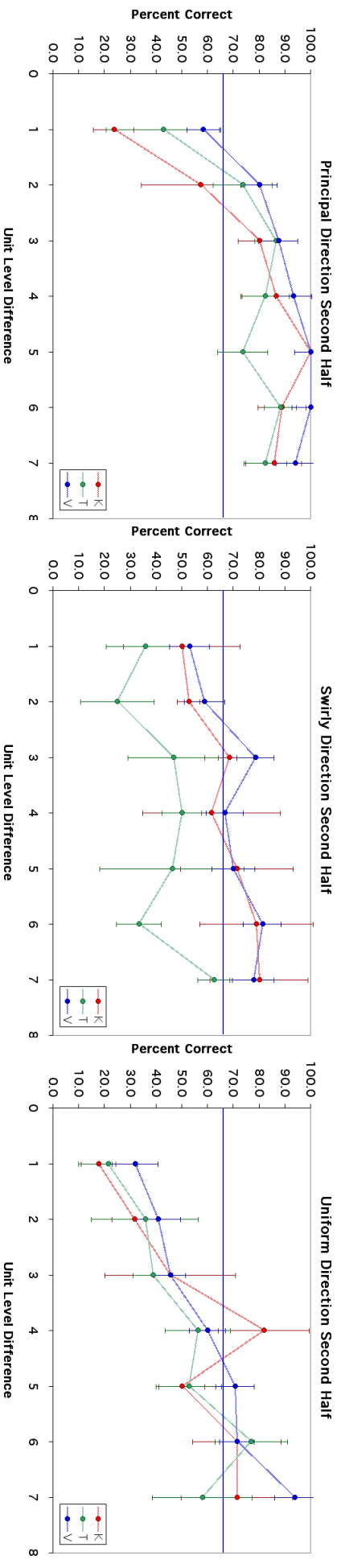
Mean 3D Angle Error, Stereo

Experiment 2: Do non-principal direction textures mask surface shape?



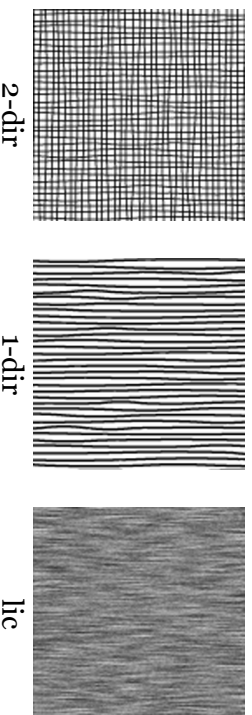
- 4 alternative forced choice task:
 - in which quadrant are the surface shapes different?
- **672** trials per subject:
 - 3 orientations: pdir, sdir, udir
 - 2 patterns: weave, straw
 - 4 types of shape changes
 - 7 levels of change / quadrant
 - 2 viewing conditions: flat, tilted
- 2 repeated measures





- Accuracy increases with shape difference, under all orientation conditions
- The rate of accuracy increase differs between orientation conditions
- Accuracy is best in the principal direction condition
- The results appear to support the hypothesis that the principal direction pattern carries more information about shape, or, that the non-principal direction oriented patterns tend to mask surface shape
- We did not see significant differences for the weave vs. straw patterns

Experiment 3: What other texture characteristics affect shape perception?



- Surface probe manipulation task:

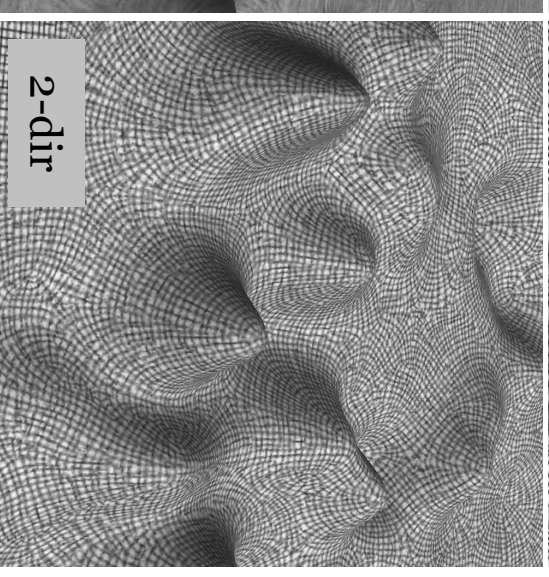
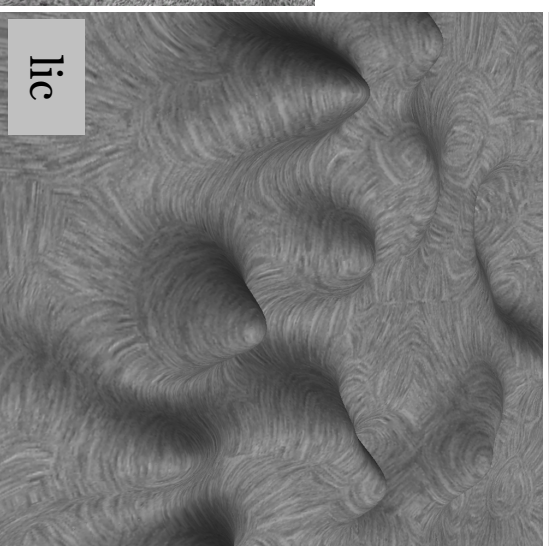
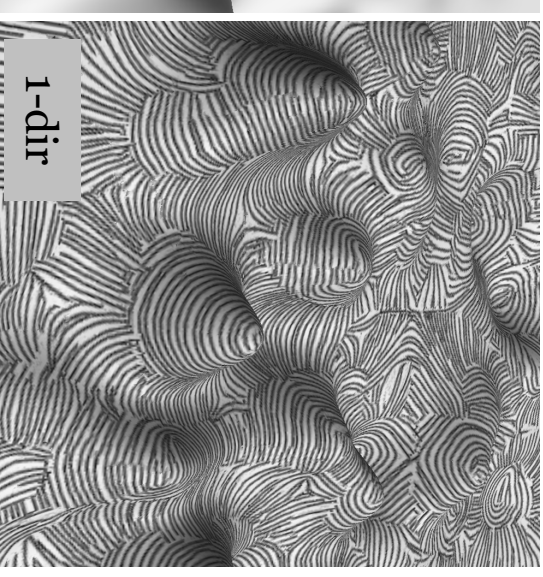
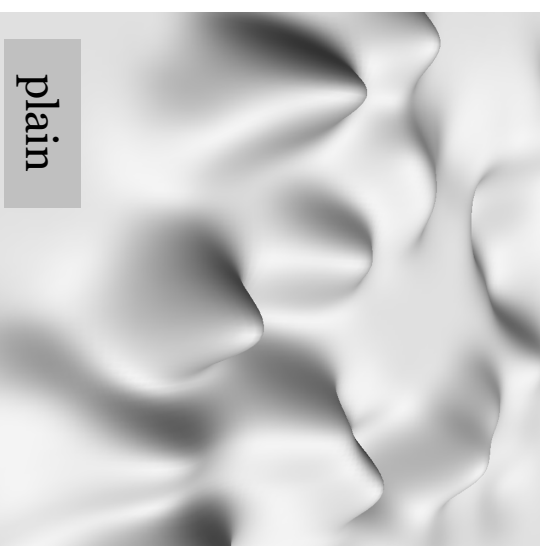
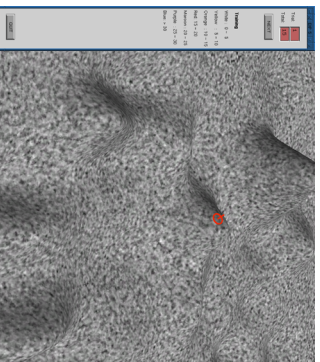
- subjects orient a probe so that it appears to lie in the surface, with its perpendicular extension pointing in the surface normal direction

- **200** trials per subject:

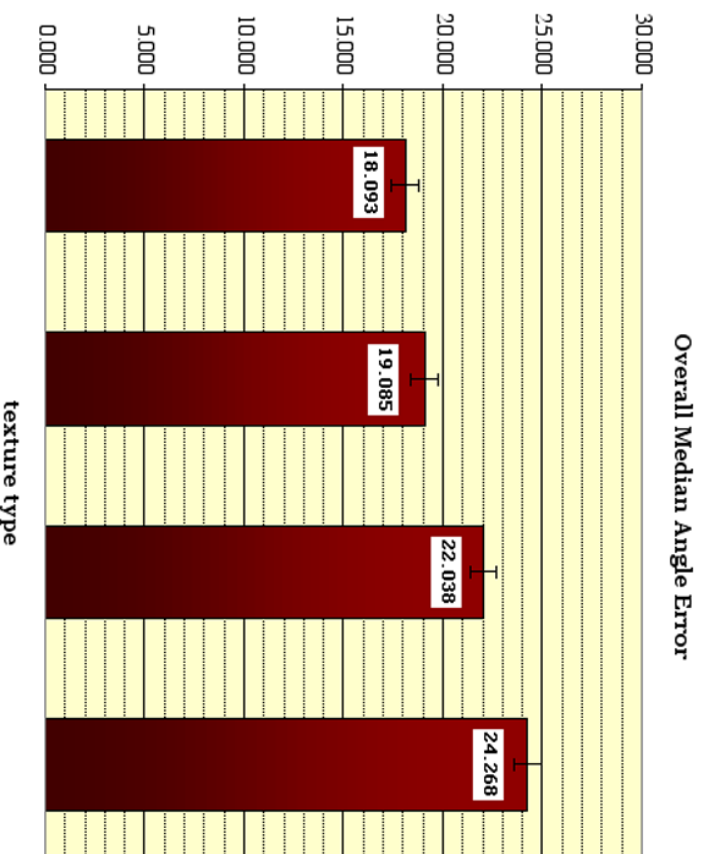
- 4 texture types: 2-dir, 1-dir, lic, plain
- 5 unique surfaces
- 10 probe locations (2 per surface)
- 5 repeated measures

- Training:

- ensures that all subjects can perform at or above an equivalent, minimum level of competence



- Overall performance:
2-dir < lic < 1-dir < plain



- Anova analysis:
 - We found significant main effects of:
 - texture type ($p = 0.0002843$), and
 - probe location ($p = 0.0000264$),
 - We also found a significant two-way interaction between texture type and probe location ($p = 0.00000001$)

- Tukey's HSD analysis:
 - We found the following differences statistically significant (at $p < 0.01$):
 - 2-dir < 1-dir, - lic < 1-dir
 - 2-dir < plain, - lic < plain
 - 1-dir < plain

All of the tested principal direction oriented textures show shape better than when no texture is present. Shape perception is facilitated, in the case of a principal direction oriented texture, when the pattern contains internal variations along the first principal direction. Shape perception is particularly good with the orthogonal grid pattern.

References and Acknowledgments

1. Sunghee Kim, Haleh Hagh-Shenas and Victoria Interrante (2002) "Showing Shape with Texture: Two Directions are Better than One", *Vision Sciences Society, poster presentation*, May 2002.
 2. Victoria Interrante, Sunghee Kim and Haleh Hagh-Shenas (2002) "Conveying 3D Shape with Texture: recent advances and experimental findings", *Human Vision and Electronic Imaging VII*, January 2002.
 3. Victoria Interrante and Sunghee Kim (2001) "Investigating the Effect of Texture Orientation on the Perception of 3D Shape", *Human Vision and Electronic Imaging VI*, January 2001.
 4. Gabriele Gorla, Victoria Interrante and Guillermo Sapiro (2001) "Texture Synthesis for 3D Shape Representation", *IEEE Transactions on Visualization and Computer Graphics*, to appear.
- *This work was supported by a National Science Foundation Presidential Early Career Award for Scientists and Engineers (ACI-9875368) and by a McKnight Land-Grant Professorship. Brenda DeBlois and Kathy Barnes provided us with assistance in the experimental analysis through the Statistical Consulting Clinic, which is supported by funding from the Minnesota Agricultural Experiment Station. The texture synthesis and image rendering for experiments 2 and 3 was done using software written by Gabriele Gorla, with support from a University of Minnesota Grant-in-Aid of Research, Scholarship and Artistry, and with co-advice from Guillermo Sapiro. Thanks go to David Banks for suggesting early on that we look into using surface markings that follow both of the principal directions. We are grateful to Jeremy Leboy for implementing an early version of the surface attitude probe, and to Krista Janssen for developing prototype surface modeling code, with support from the CRA-W Distributed Mentor Project.*