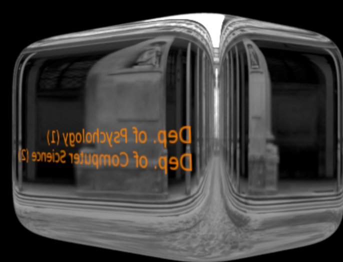
Perceived shininess and rigidity - Measurements of shape-dependent specular flow of rotating objects

Katja Doerschner[(1)], Paul Schrater[(1,,2)], Dan Kersten[(1)]

University of Minnesota



Radiance Workshop, October 1-2, 2007

Overview

1. Introduction & Motivation
2. Experiment: Shininess-Rigidity
3. Velocity Measurements of Specular Flow *(work in progress)*

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Specular Reflection:

• Reflection of a scene point by a mirror-like surface (not just highlights)

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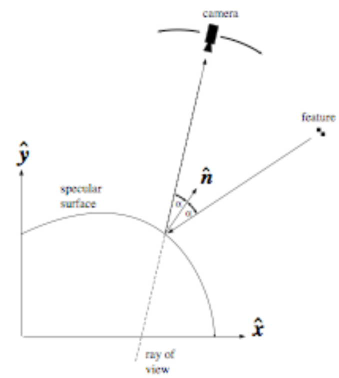
• Reflection of a scene point by a mirror-like surface (not just highlights)
• is visible only where the surface normal is oriented halfway between the direction of incoming light and the direction of the viewer



Oren,Nayar, IJCV, 1996

Introduction

Specular Flow:

• Flow of virtual features on the specular surface due to:

• Camera Motion
• Observer Motion
• Object Motion

Introduction

Specular flow contains information:

• The shape of an object

 • *A theory of specular surface geometry. Michael Oren, Shree K. Nayar, IJCV,24(2):105-124, 1996*
 • *Specular Flow and the Recovery of Surface Structure. Stefan Roth, Michael Black, CVPR, vol.2,pp.1869-1876*
 • *Specular reflections and the perception of shape. Roland W. Fleming, Antonio Torralba, Edward Adelson, JOV, 2004, (9) 798-820.*
 •*…*

Introduction

Specular flow contains information:

• The shape of an object

• The material

 • ***Distinguishing shiny from matte.*** *Bruce Hartung, and Dan Kersten (2002). [Abstract]. Journal of Vision, 2(7), 551a, http://journalofvision.org/2/7/551*

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• ***Specular Flow and the perception of surface reflectance****. Stefan Roth, Fulvio Domini, Michael J. Black. (2003). [Abstract]. Journal of Vision, 3(9), 413a, http://journalofvision.org/3/9/413/*

Introduction

Discrimination between concave and convex

Roth et. al, 2003.
- No spatial information
- Flow across a sphere

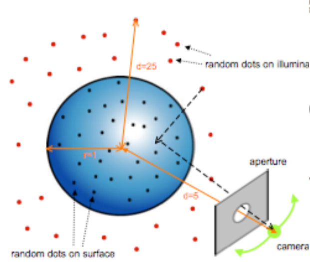
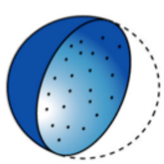


Figure 3: Scene setup (left – convex shape,



– concave shape).

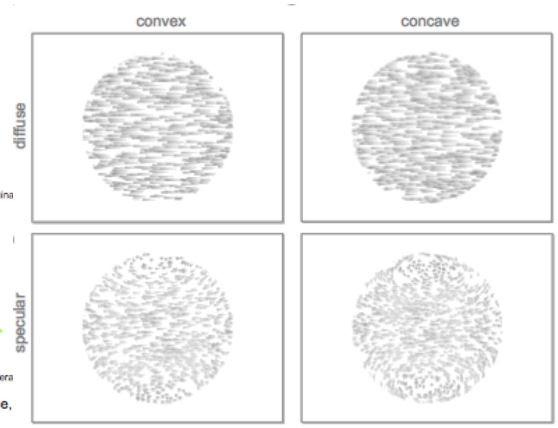


Figure 2: Motion traces showing the flow of random dots corresponding to diffuse and specular motion.

Introduction

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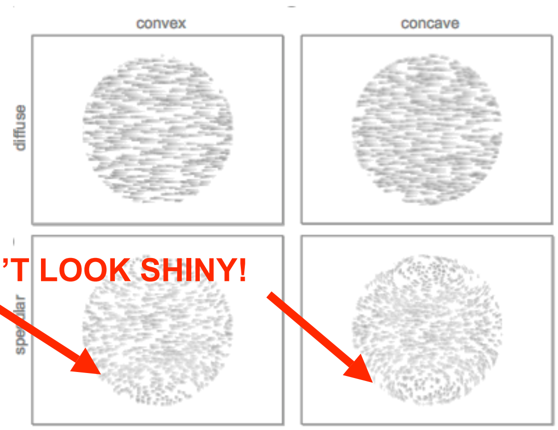

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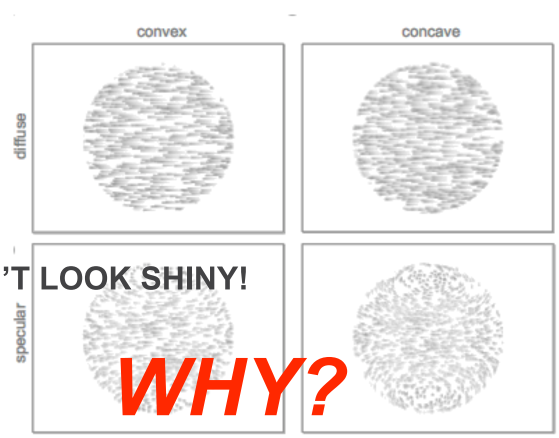

Figure 2: Motion traces showing the flow of random dots corresponding to diffuse and specular motion.

Introduction

Some important information must be missing in the Roth et al. displays.

We want to find out what properties drive the percept of shininess when looking at specular flow patterns.

Introduction

Possibility 1:

- Properties of the reflected environment important?

  (e.g. Fleming et. al, Real World Illuminations and the perception of surface gloss, 2003)

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Specular highlight motion:
Relative displacement is negatively related to the magnitude of surface curvature (Highlights cling to regions of high curvature)
Photometric Invariants related to solid shapes. Jan J. Koenderink and Andrea J. van Doorn, Optica Acta, 27(7), pp.981-996 (1980).

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Highlight velocity affects perceived surface curvature. More curved at lower velocities, less curved at high velocities.

Recognition and Perceptual use of Specular Reflections. Anya C. Hurlbert, B. G. Cumming, A. J. Parker. Inv. Ophth. Vis. Sci. Suppl. Vol 32, No 4 (1991).

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Experiment Which properties drive the percept of shininess when observing specular flow patterns?

http://gl.ict.usc.edu/Data/HighResProbes/

Stimuli:

- Environment maps [Possibility 1]

Original BW | Inverted IN | Partial scramble SC | Full scramble FU

GRACE

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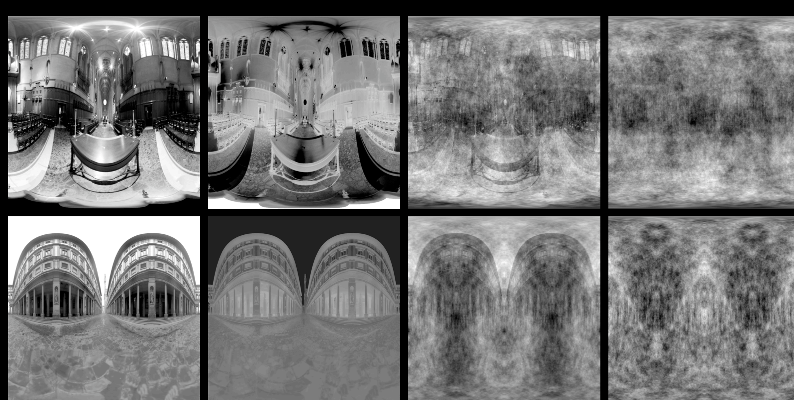
GRACE

UFFIZI



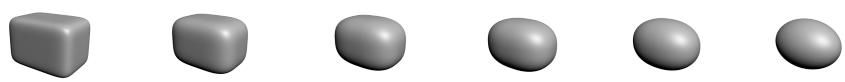
Experiment Which properties drive the percept of shininess when observing specular flow patterns?

Stimuli:

- Shapes [Possibility 2]

$$f(x,y,z) = \left[\left| \frac{x}{r_x} \right|^{2/n_2} + \left| \frac{y}{r_y} \right|^{2/n_2} \right]^{n_2/n_1} + \left| \frac{z}{r_z} \right|^{2/n_1}$$

Superellipsoids



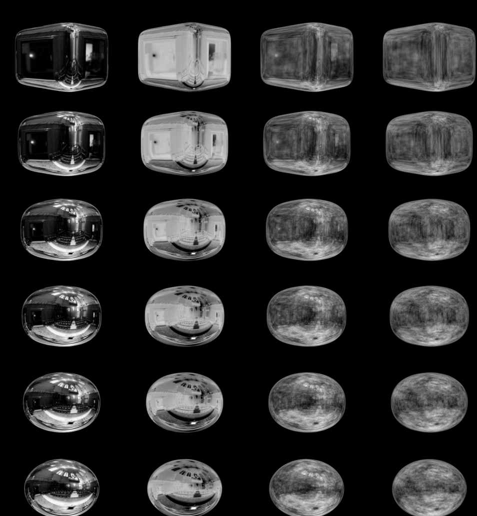
$n_1 = n_2 = 0.3$ $n_1 = n_2 = 0.5$ $n_1 = n_2 = 0.7$ $n_1 = n_2 = 0.8$ $n_1 = n_2 = 0.9$ $n_1 = n_2 = 1.0$

Experiment Which properties drive the percept of shininess when observing specular flow patterns?

Stimuli:

Naturalness of reflected environment

Corner –roundedness of shape



Rendering: Radiance

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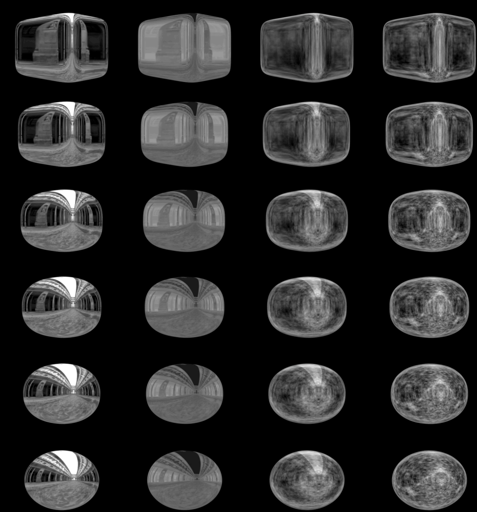
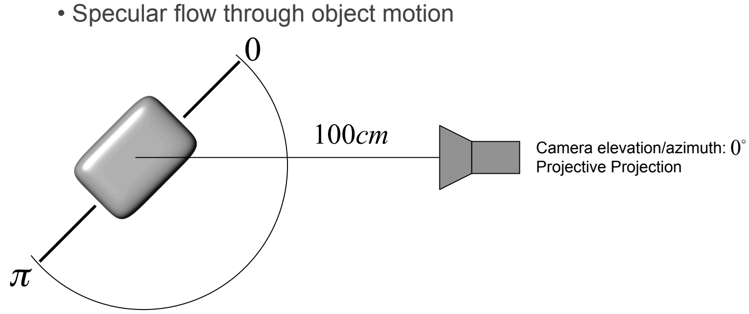


Rendering: Radiance

Experiment Which properties drive the percept of shininess when observing specular flow patterns?

Stimuli:

- Specular flow through object motion

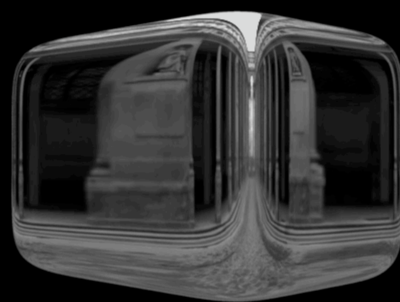


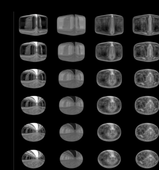
- Quicktime movies

Experiment Which properties drive the percept of shininess when observing specular flow patterns?

Stimuli: Set UFFIZI

61 frames @ 50 frames/second, G5 workstation Sony GDMC520 (1024x1280) Refresh rate 75 Hz, NVIDIA GeForce 6800 UltraDLL





Experiment Which properties drive the percept of shininess when observing specular flow patterns?

Task & Procedure:

- Experiment I – Rating apparent shininess of the object on a scale from 1 (matte) to 7 (most shiny)

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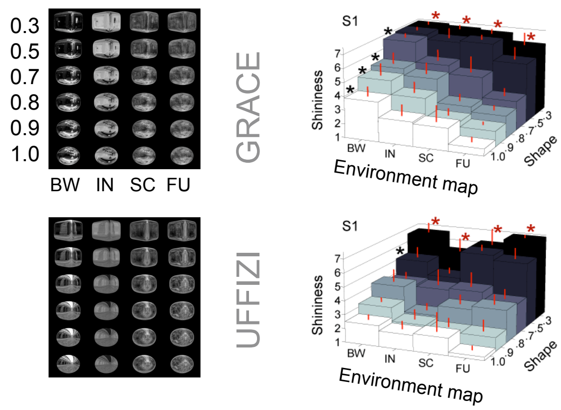
- Experiment II – Rating apparent rigidity on a similar scale

- Prior to experiments observers were familiarized with the concepts of shininess and rigidity
- Clips could be re-viewed if desired
- Order of experiments counterbalanced across observers
- Each condition (60) repeated 8 times, randomized order of presentation.
- Experimental software written in Matlab using Psychtoolbox (Brainard,1997)

Experiment Which properties drive the percept of shininess when observing specular flow patterns?

Results: *Shininess*

* $F(3,28), p<0.01$ *(illumination)*
* $F(5,42), p<0.01$ *(shape)*



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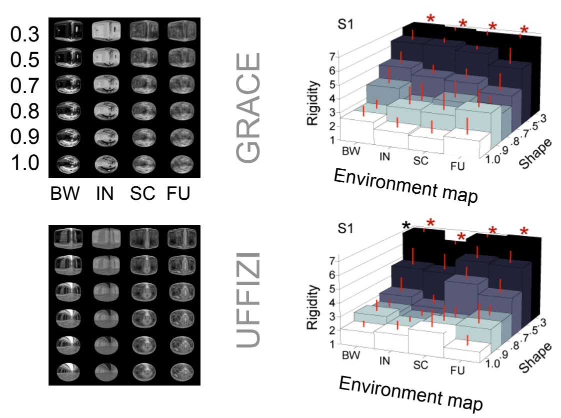

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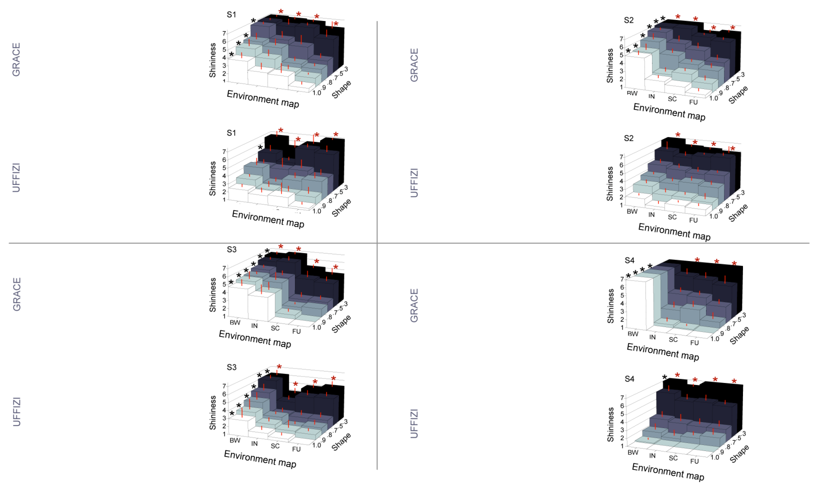

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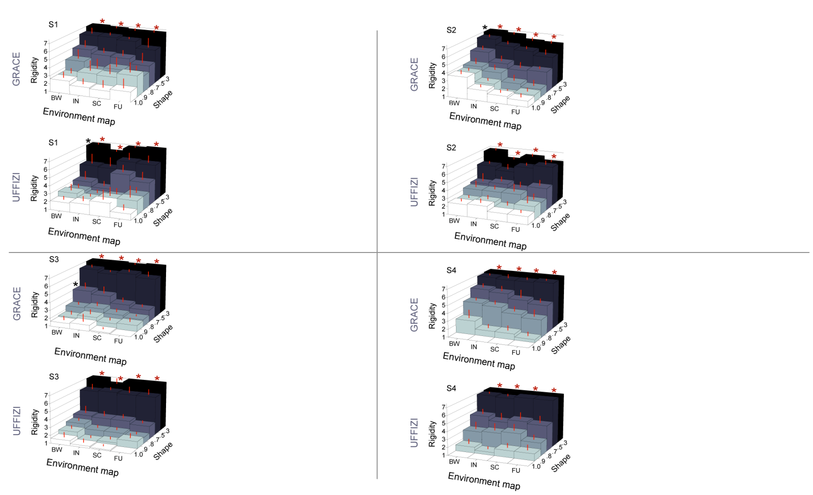

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Summary:

1. Perceived shininess of objects depends on the “naturalness” environment map (but not always).

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Experiment Which properties drive the percept of shininess when observing specular flow patterns?

Summary:

1. Perceived shininess of objects depends on the “naturalness” environment map (but not always).
2. Perceived shininess depends on shape – cuboidal objects appear more shiny than ellipsoidal ones
3. Objects that look rigid also tend to look shiny (in our set).

Experiment Which properties drive the percept of shininess when observing specular flow patterns?

Intermediate Conclusions:

Possibility 1:

- Are properties of the reflected environment important?

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- Not-so-natural maps: the most cuboidal shapes still look very shiny

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- Not-so-natural maps: the most cuboidal shapes still look very shiny

Possibility 2:

- Shape?

Experiment Which properties drive the percept of shininess when observing specular flow patterns?

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Observation:

- Shape (corner-curvedness) appears to give rise to different image velocity patterns for shiny (rigid) and matte (non-rigid) objects!

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Proposal:

1. These distinct image velocity patterns for rotating shiny and non-shiny objects may be used by human observers as a cue to shininess.

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Proposal:
1. These distinct image velocity patterns may be used by human observers as a cue to shininess.
2. Image velocities of the matte teapot and the ellipsoidal specular shapes have something in common – which give rise to these objects' matte appearance.

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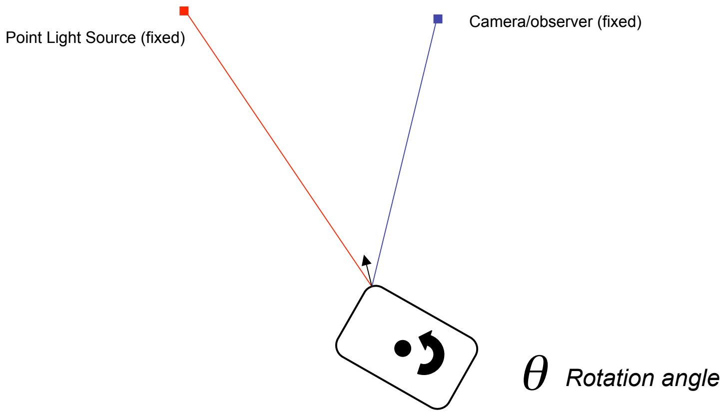
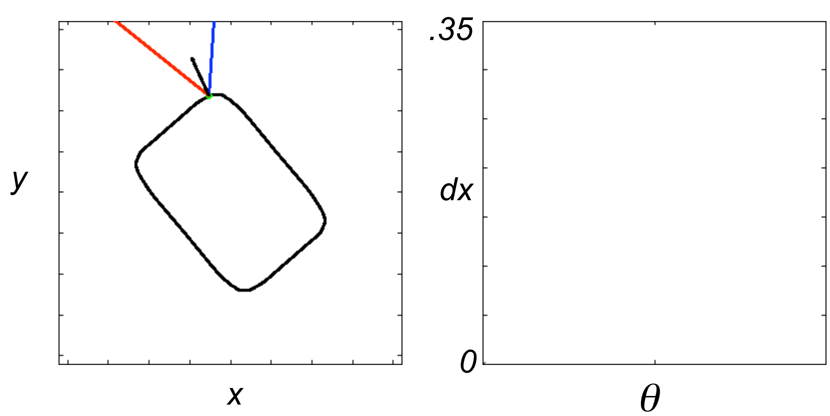
Velocity Measurements of Specular Flow

Specular flow: Setup



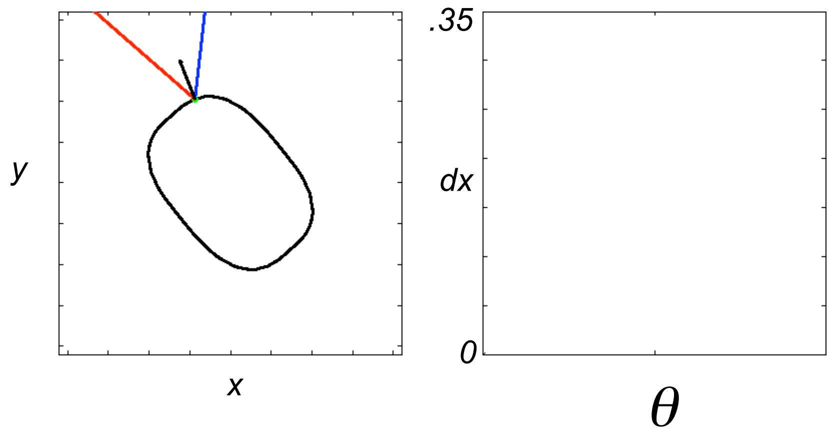
Velocity Measurements of Specular Flow

Specular flow: Superellipsoid n1=0.3



Velocity Measurements of Specular Flow

Specular flow: Superellipsoid n1=.07



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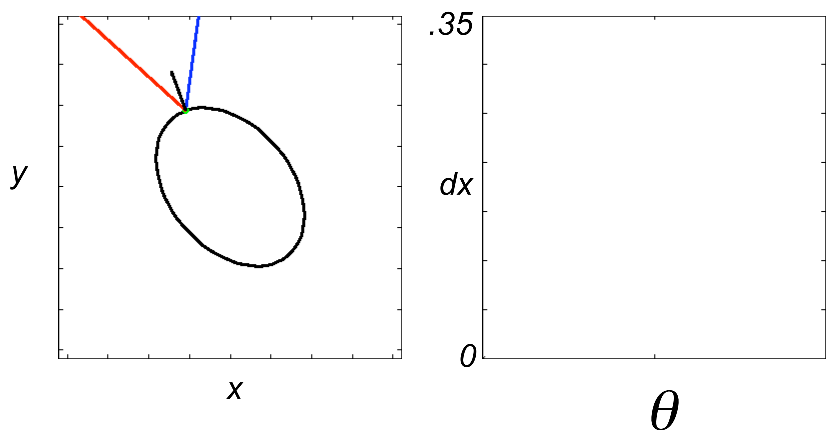
Velocity Measurements of Specular Flow

Specular flow: Superellipsoid n1=1.0



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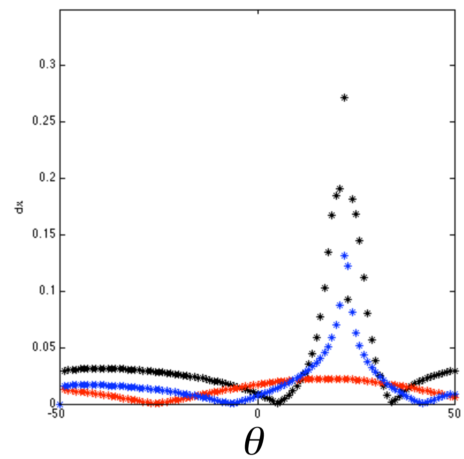
Velocity Measurements of Specular Flow

Shape-dependent differences in specular velocities for perceived shiny and non-shiny specular objects.



"Velocity contrast"

Velocity Measurements of Specular Flow

Shape-dependent differences in specular velocities for perceived shiny and non-shiny specular objects.

- Let's verify this with actual measurements on our experimental stimuli.

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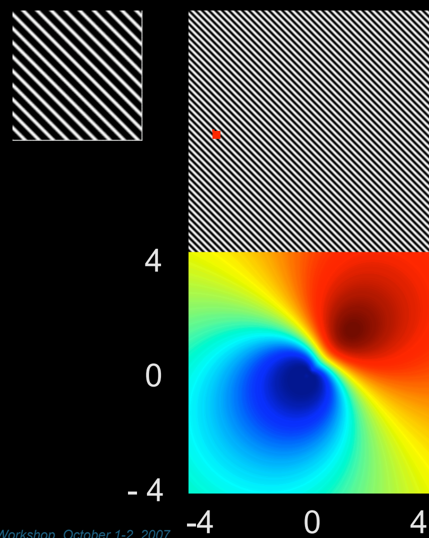
Velocity Measurements of Specular Flow

Spatiotemporal filtering

Derpanis & Gryn 2004. "Three-dimensional nth derivative of Gaussian Separable Steerable Filters"



Velocity Measurements of Specular Flow

Spatiotemporal filtering

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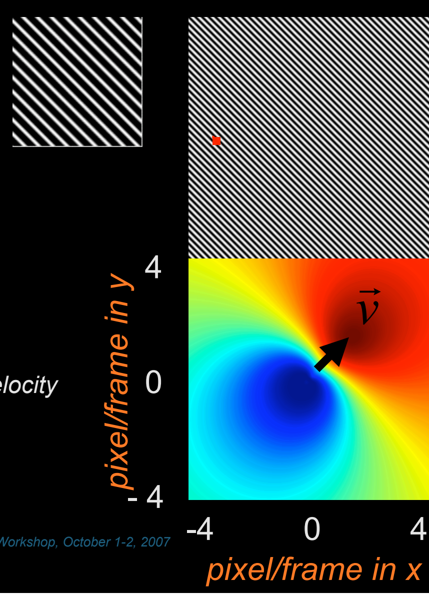
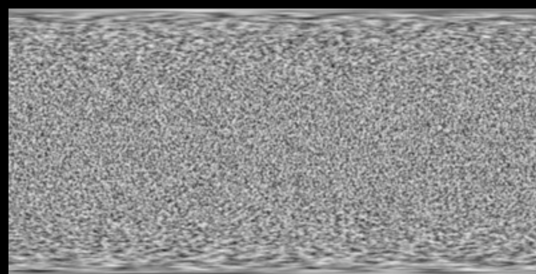
Good estimate for this pixel's velocity (magnitude and direction)



Velocity Measurements of Specular Flow

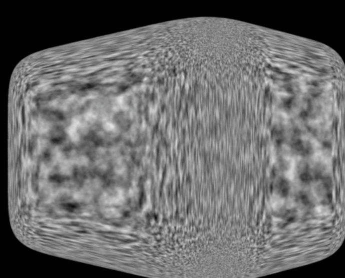
Environment map: 3D Perlin noise



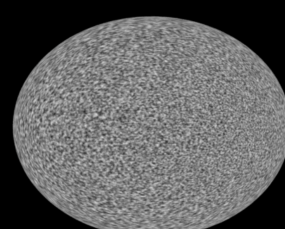
http://mrl.nyu.edu/~perlin/noise/INoise.java

Velocity Measurements of Specular Flow

Stimuli



n1=0.3
Angular velocity: 0.1 deg per frame
9 frames



n1=1.0
Angular velocity: 1.0 deg per frame
9 frames

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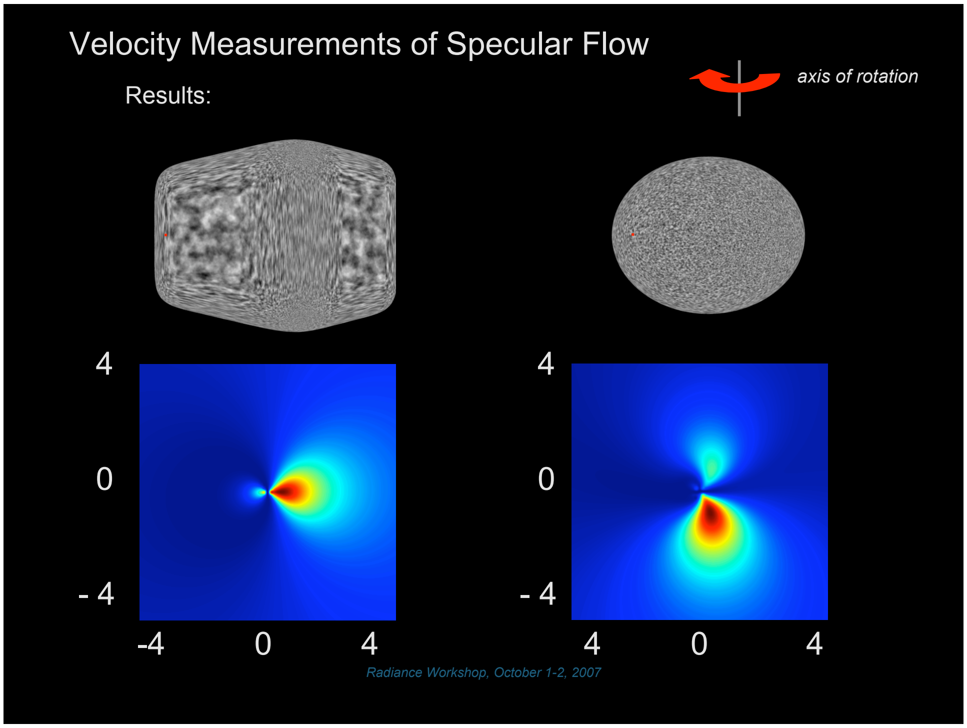

Velocity Measurements of Specular Flow
Results:
axis of rotation
4
0
- 4
-4
0
4
4
0
- 4
4
0
4
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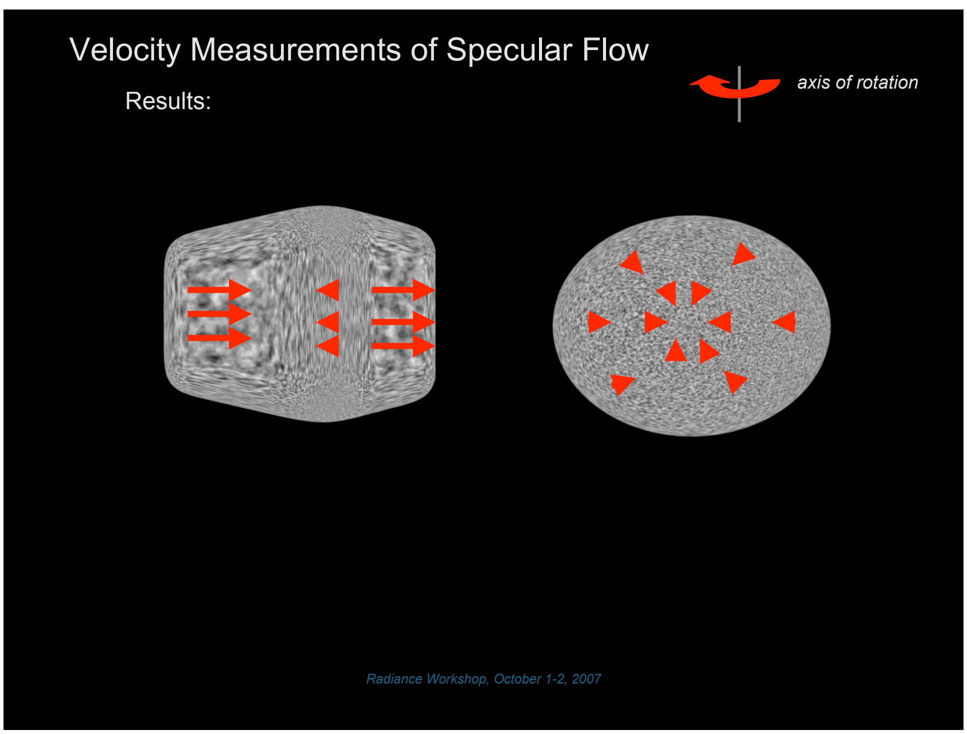

Velocity Measurements of Specular Flow
Results:
axis of rotation
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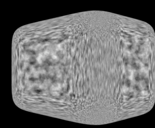
Velocity Measurements of Specular Flow

Next steps: Analyzing velocity maps for all pixels



Shiny:
2 cluster – (relative) slow & fast
- opposing in direction

Velocity Measurements of Specular Flow

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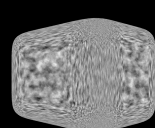

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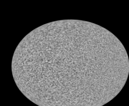

Matte:
1 cluster: slow – multiple directions

Velocity Measurements of Specular Flow

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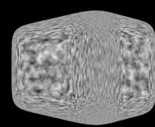

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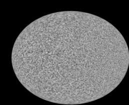
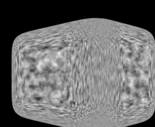


Matte:
1 cluster: slow – multiple directions

Wait! one more

Velocity Measurements of Specular Flow

Next steps: Analyzing velocity maps



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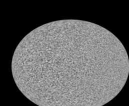

Matte & nonrigid:
1 cluster: slow – multiple directions

Matte & rigid:
1 cluster: slow – one direction

Velocity Measurements of Specular Flow

Summary

- Since Roth et. al simulated specular flow on a sphere, the resulting flow pattern lacked the velocity contrast necessary for the percept of shininess

Velocity Measurements of Specular Flow

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- Since Roth et. al simulated specular flow on a sphere, the resulting flow pattern lacked the velocity contrast necessary for the percept of shininess
- In our experiment, the more ellipsoidal an object, the lower the velocity contrast – the less shiny the object appears to the observer

Velocity Measurements of Specular Flow

Summary

- Since Roth et. al simulated specular flow on a sphere, the resulting flow pattern lacked the velocity contrast necessary for the percept of shininess
- In our experiment, the more ellipsoidal an object, the lower the velocity contrast – the less shiny the object appears to the observer
- Objects appear nonrigid (and matte) when velocity contrast is low and velocity directions across the object vary

Velocity Measurements of Specular Flow

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- Objects appear rigid when velocity contrast is low and motion directions are uniform across the object

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Velocity Measurements of Specular Flow

What we may need to incorporate into our analysis:

- Spatial frequency: reflections are compressed across high curvature points -> high SF components in the image & possible correlation between (relative) high SF and (relative) low velocities and low SF and high velocities

Velocity Measurements of Specular Flow

To do list:

- Systematically vary surface curvature (single bump) and measure perceived shininess and corresponding velocity maps
- How many sticky and fast areas are enough for a percept of shininess (1 each ?)
- Role of the object boundary
- Shiny moving texture synthesis

Thank you.