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

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Overview

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

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Introduction

Specular Reflection:

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

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
  • Specular Flow and the Recovery of Surface Structure. Stefan Roth, Michael Black, CVPR, vol.2, pp.1869-1876
  • …

• The material
Introduction

Specular flow contains information:

* The shape of an object

* The material


Discrimination between concave and convex

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

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

BUT THIS DIDN'T LOOK SHINY!

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

WHY?
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.

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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Possibility 2:
- Shape (surface curvature)?

Specular highlight motion:
\textit{Relative displacement is negatively related to the magnitude of surface curvature (Highlights cling to regions of high curvature)}

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

Possibility 2:
• Shape (surface curvature)?

  Specular highlight motion:
  Relative displacement is negatively related to the magnitude of surface curvature (Highlights cling to regions of high curvature)

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

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

Stimuli:
- Environment maps [Possibility 1]

http://gl.ict.usc.edu/Data/HighResProbes/
Experiment: Which properties drive the percept of shininess when observing specular flow patterns?

Stimuli:
- Shapes [Possibility 2]

\[ f(x, y, z) = \left( \frac{x}{r_x} \right)^{\frac{2}{n_x}} + \left( \frac{y}{r_y} \right)^{\frac{2}{n_y}} + \left( \frac{z}{r_z} \right)^{\frac{2}{n_z}} \]

Superellipsoids

- \( n_x = n_z = 0.3 \)
- \( n_x = n_z = 0.5 \)
- \( n_x = n_z = 0.7 \)
- \( n_x = n_z = 0.8 \)
- \( n_x = n_z = 0.9 \)
- \( n_x = n_z = 1.0 \)

Naturalness of reflected environment

Corner-roundedness of shape

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

Stimuli:

- Specular flow through object motion

Camera elevation/azimuth: 0°
Projective Projection

- Quicktime movies

Naturalness of reflected environment

Rendering: Radiance
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

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

• 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)

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

**Results:** *Rigidity*

* $F(3, 28), p < 0.01$ (illumination)
* $F(5, 42), p < 0.01$ (shape)
Experiment Which properties drive the percept of shininess when observing specular flow patterns?

Results: **Shininess**

![Graphs showing shininess results](image)

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

Results: **Rigidity**

![Graphs showing rigidity results](image)
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.
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).

Intermediate Conclusions:

Possibility 1:

• Are properties of the reflected environment important?
Experiment Which properties drive the percept of shininess when observing specular flow patterns?

Intermediate Conclusions:
Possibility 1:
• Are properties of the reflected environment important?

Doesn’t seem to be the whole story

• Natural environment maps: ellipsoidal objects look significantly less shiny than cuboidal ones
Experiment: Which properties drive the percept of shininess when observing specular flow patterns?

Intermediate Conclusions:

Possibility 1:
- Are properties of the reflected environment important?
  
  *Doesn’t seem to be the whole story*
  
  - Natural environment maps: ellipsoidal objects look significantly less shiny than cuboidal ones
  - Not-so-natural maps: the most cuboidal shapes still look very shiny

Possibility 2:
- Shape?
Intermediate Conclusions:
Possibility 2:
  • Shape.

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

**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.
Experiment

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

Intermediate Conclusions:
Possibility 2:
• Shape.

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

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

Point Light Source (fixed) — Camera/observer (fixed)

θ Rotation angle

Velocity Measurements of Specular Flow

Specular flow: Superellipsoid n1=0.3

x y

dx

0 0.35

θ

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Velocity Measurements of Specular Flow

Specular flow: Superellipsoid $n_1 = 0.07$

Specular flow: Superellipsoid $n_1 = 1.0$
Shape-dependent differences in specular velocities for perceived shiny and non-shiny specular objects.

"Velocity contrast"

- Let’s verify this with actual measurements on our experimental stimuli.
Velocity Measurements of Specular Flow

Spatiotemporal filtering

Derpanis & Gryn 2004, “Three-dimensional nth derivative of Gaussian Separable Steerable Filters”

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
Velocity Measurements of Specular Flow

Results:

axis of rotation
Velocity Measurements of Specular Flow

Next steps: Analyzing velocity maps for all pixels

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

**Matte:**
1 cluster: slow – multiple directions
Velocity Measurements of Specular Flow

Next steps: Analyzing velocity maps for all pixels

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

**Matte:**
1 cluster: slow – multiple directions

*Wait! one more*

---

Velocity Measurements of Specular Flow

Next steps: Analyzing velocity maps

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

**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

• 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.

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

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.