Image-Based Modeling of Complex Surfaces

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Modeling Appearance: Face Recognition

Modeling Appearance: Tracking

Modeling Appearance: Applications
♦ Object recognition
♦ Face recognition
♦ Visual tracking
♦ Human-computer interfaces
♦ Compression
♦ Navigation
♦ Surveillance
♦ Metrology
♦ Inspection
♦ Vision for Graphics

Appearance

Detection/tracking of facial features
[Colmenarez et al., 1999]

Spatial-Time Faces
[Shan et al., 2004]
Non-parametric Appearance: Uniform Sampling?

Appearance = Shape + Reflectance

Outline

1. SHAPE

Outline

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Outline

2. REFLECTANCE
Shape: Restrictive Reflectance Assumptions

- Shape from shading (Tsai and Shen, 1984)
- Variational Stereo (Heeger and Kovesi, 1988)
- Multiple-vision stereo (Pavlović et al., 1997)
- Space Carving (Kutulakos and Seitz, 1998)

Simple (and Common!) Reflectance Model

LAMBERTIAN: IDEALLY DIFFUSE

Example: Conventional Stereo

Reflectance: BRDF

$f_i(\hat{n}, \hat{e})$

$f_i(\hat{n}, \hat{e}_1) \neq f_i(\hat{n}, \hat{e}_2)$
**Helmholtz Reciprocity**

\[ f_i(\hat{i}, \hat{c}) = f_i(\hat{c}, \hat{i}) \]

[Helmholtz 1925; Minnaert 1941; Nicodemus et al. 1977]

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**Stereo vs. Helmholtz Stereo**

**STEREO**

**HELMHOLTZ STEREO**

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**Stereo vs. Helmholtz Stereo**

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**Reciprocal Images**

- Specularities "fixed" to surface
- Relation between \( l \) and \( l' \) independent of BRDF

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**Reciprocity Constraint**

\[ \begin{align*}
  l = f_i(\vec{v_i}, \vec{v}) \cdot \hat{n} \\
  l' = f_i(\vec{v_i}, \vec{v}) \cdot \hat{n} \\
  l = f_i(\vec{v_i}, \vec{v}) \cdot \hat{n} \\
  l' = f_i(\vec{v_i}, \vec{v}) \cdot \hat{n}
\end{align*} \]

Arbitrary reflectance
Surface normal
Image-Based Modeling of Complex Surfaces

Reciprocal Acquisition

Recovered Normals

Recovered Surface

Helmholtz Stereopsis: Recent Work

Outline

Spatially-varying Reflectance

1. SHAPE

2. REFLECTANCE

5º sampling: 1,000,000 images; >1x10⁶ Mb
1º sampling: 625,000,000 images; >1x10⁹ Mb
Point-wise Reflectance Measurement (& Light Fields)

Reflectance Sharing = Scattered Data Interpolation

Application: Human Face

Predicting Appearance in Real Time

Diffuse Specular

\[
\begin{align*}
\mathbf{I}_f(q) &= \mathbf{a}_f(x) + \mathbf{I}_d(p(q) + \sum \lambda_i q^i - \hat{q}) \\
&= R, G, B
\end{align*}
\]
Conclusion

Future Work

1. Face/object recognition
2. Surface structure at shape/reflectance interface, transparency
3. Appearance over time
   ♦ weathering, aging
4. Dynamic appearance
   ♦ Reflectance under deformation