
Models and Measurements of 3D Textures

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Talk Overview

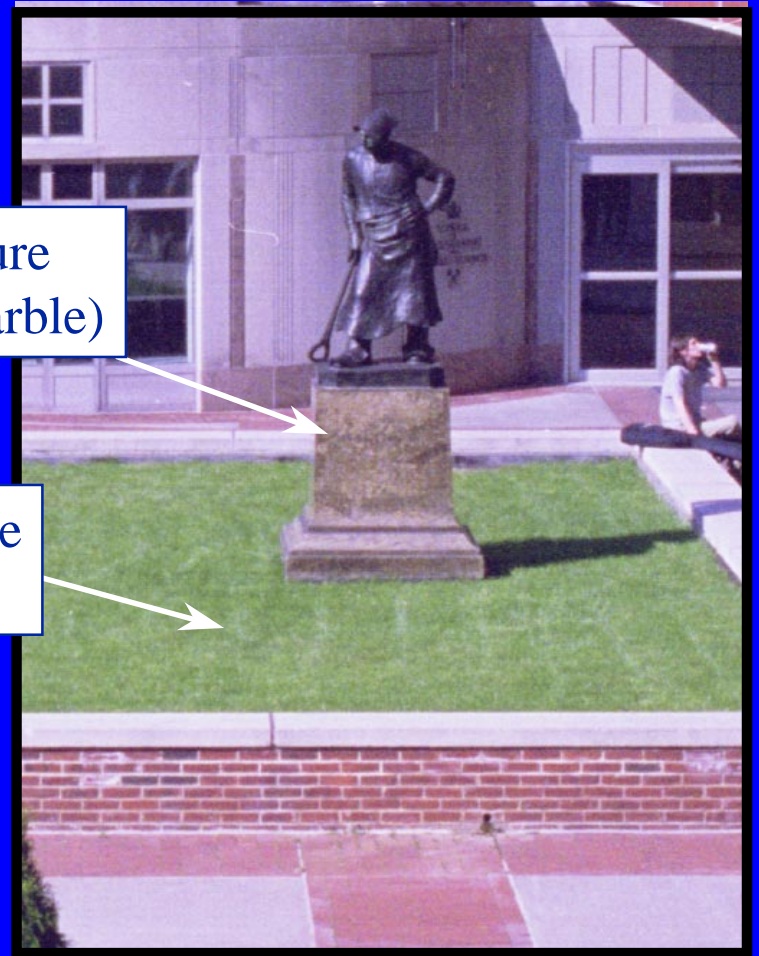
- ➔ ♦ What is 3D Texture ?
 - ♦ Measurements
 - ♦ Model

3D Texture vs. 2D Texture

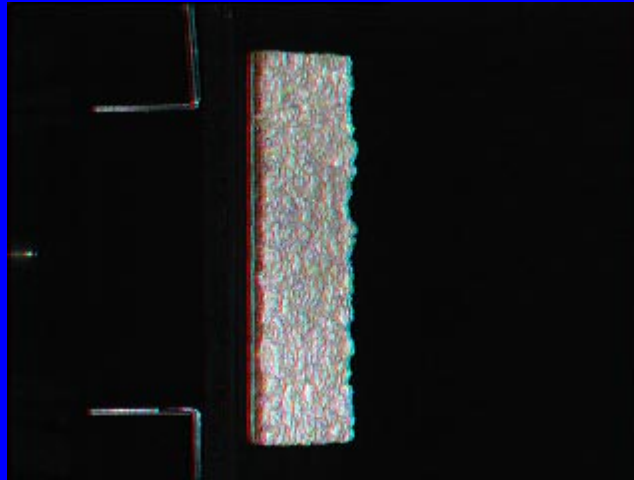
- ◆ 2D Texture:
 - albedo or color variation
- ◆ 3D Texture:
 - surface height variation

2D Texture
(smooth marble)

3D Texture
(grass)

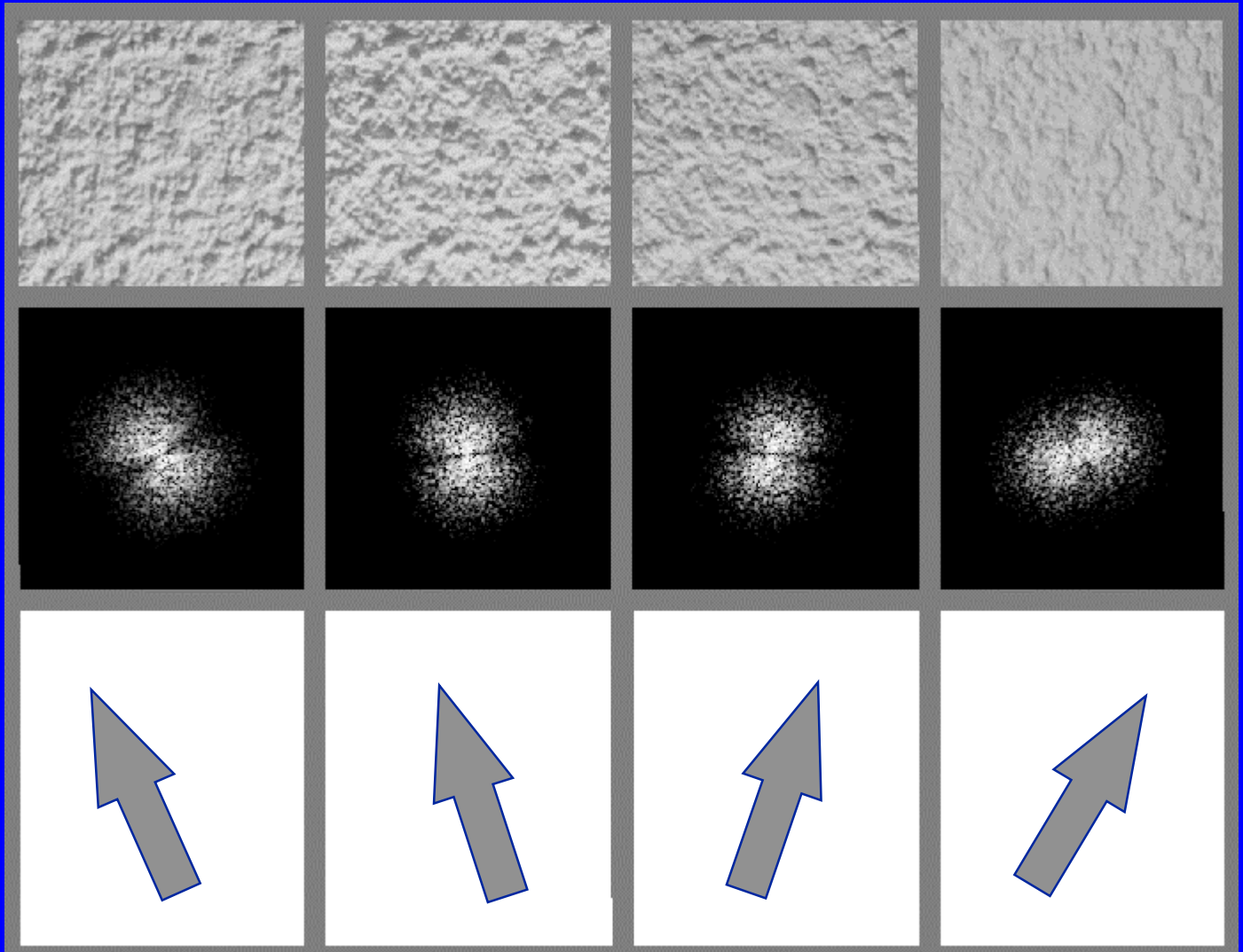


Texture Appearance



Photometry of 3D Textures

Texture Images

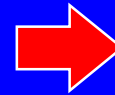
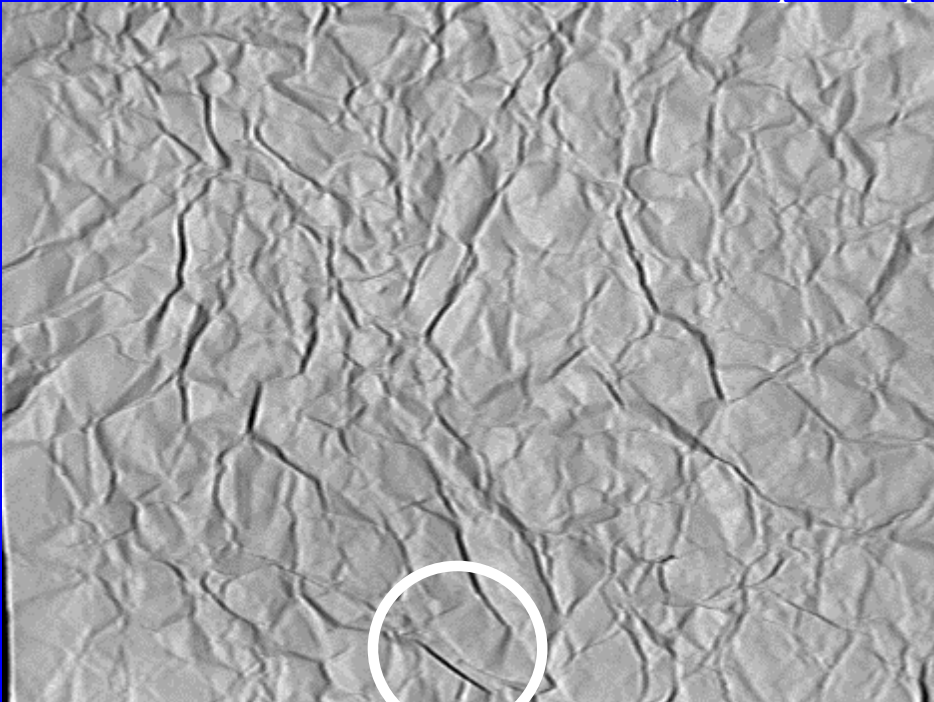


Fourier
Transform
Magnitude

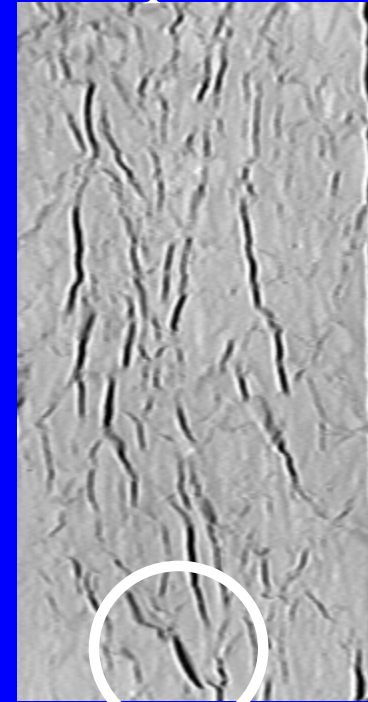
Illumination
Direction

Geometry of 3D Textures

Frontal View (Crumpled Paper)



Oblique View



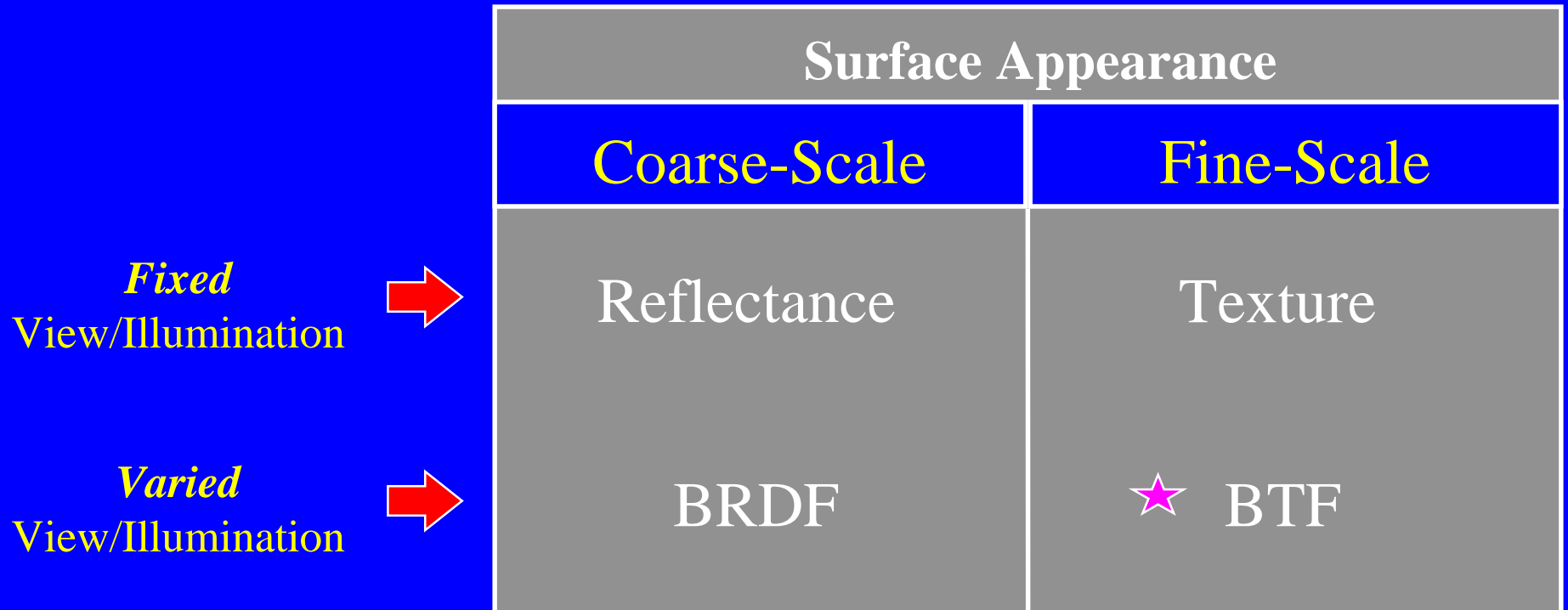
notice extension of shadowed region

Columbia-Utrecht Reflectance and Texture Database

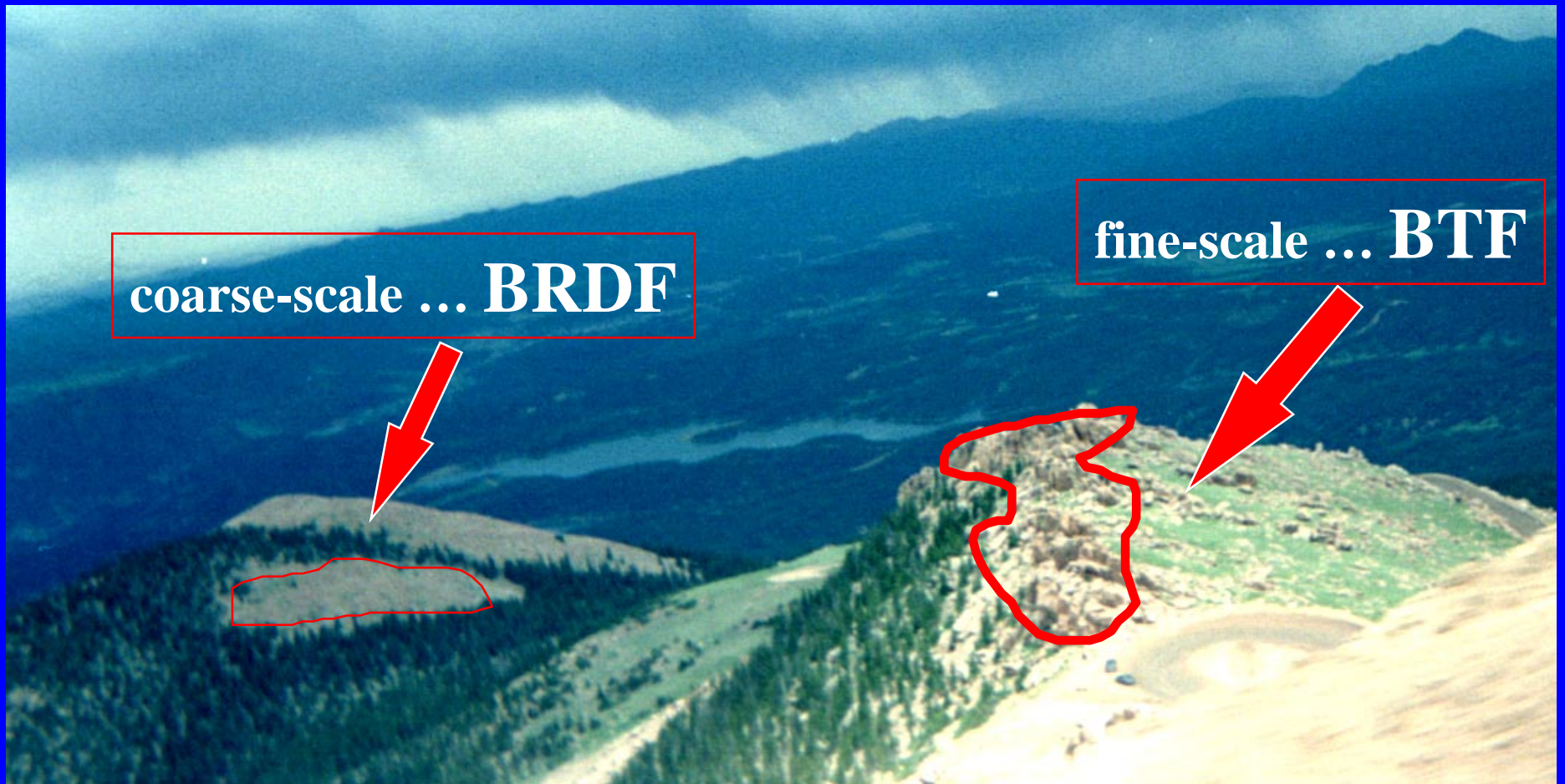
Kristin J. Dana
Shree K. Nayar
Columbia University

Bram van Ginneken
Jan J. Koenderink
Utrecht University

Taxonomy



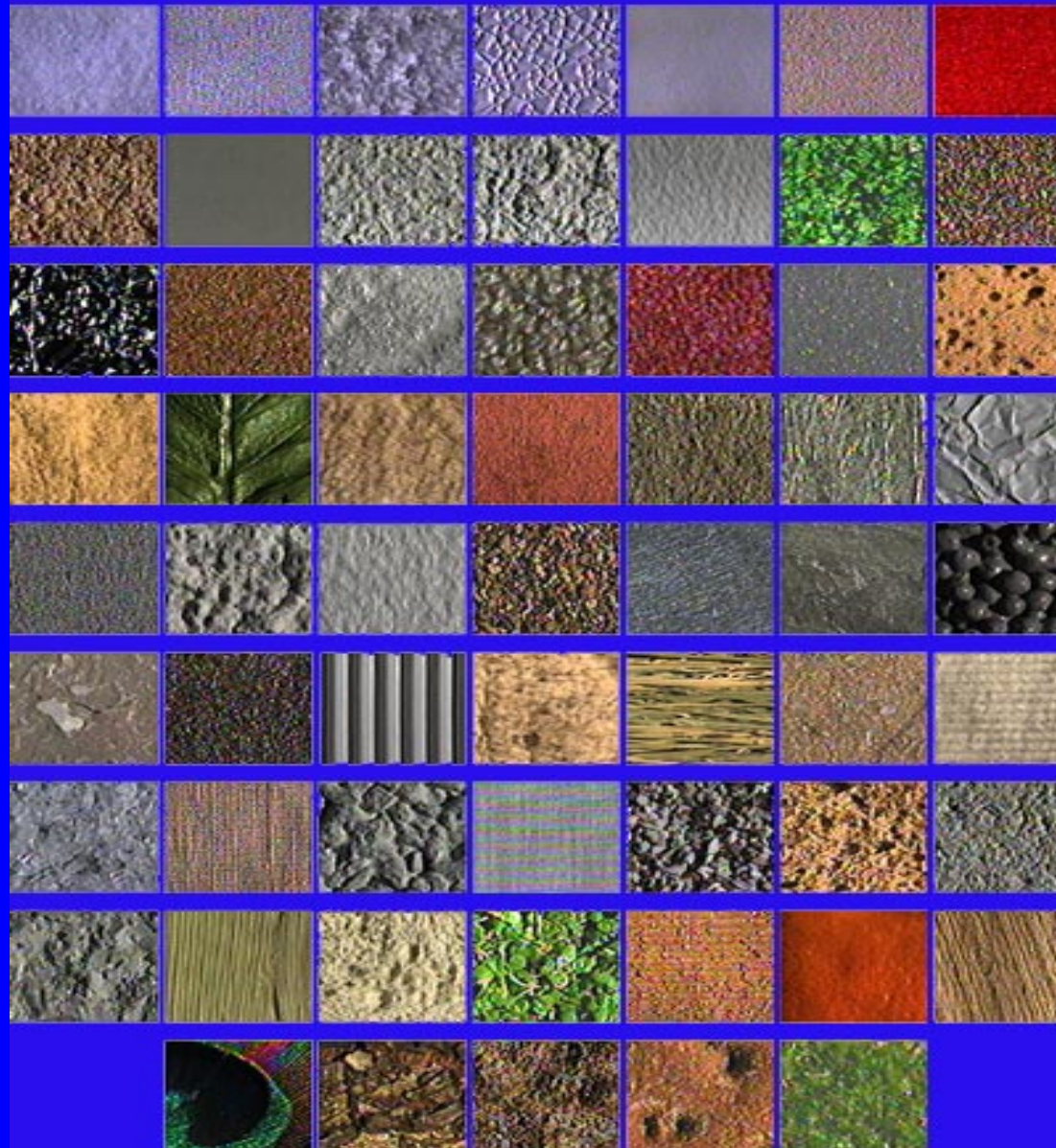
BRDF vs. BTF



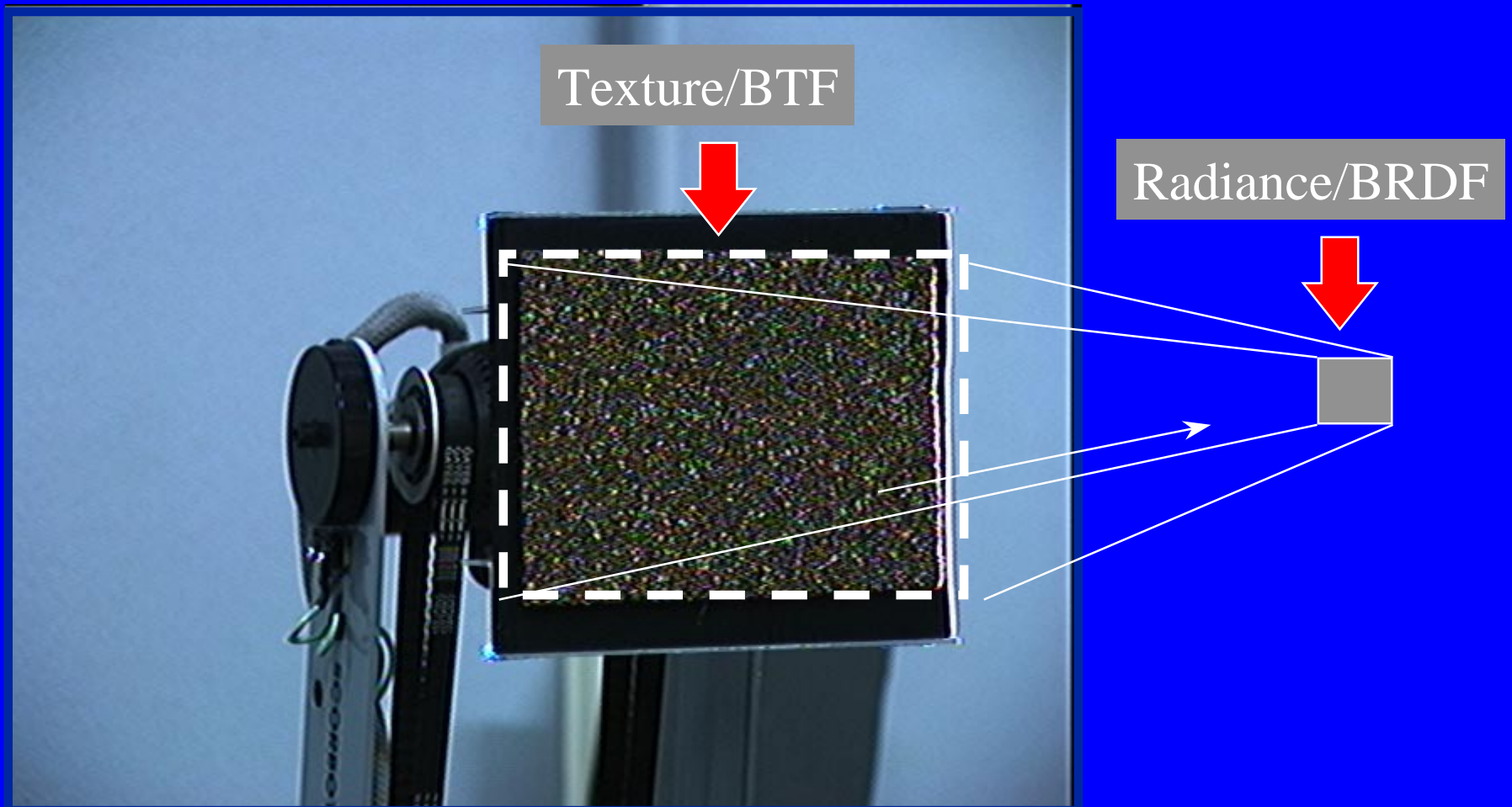
Samples for Measurements

61 samples:

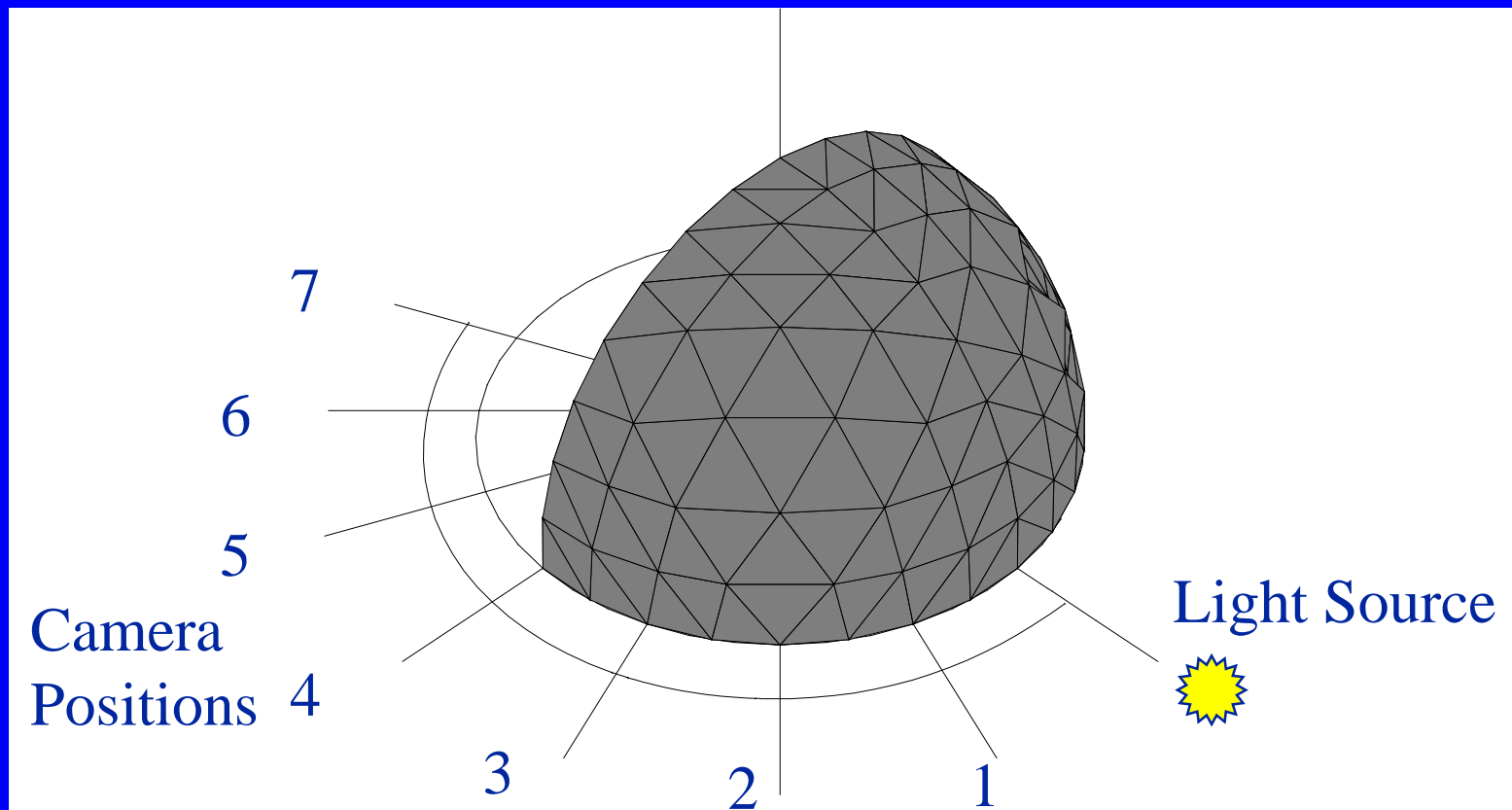
- ◆ *specular* (foil, artificial grass)
- ◆ *diffuse* (brick, plaster)
- ◆ *natural* (fur, moss)
- ◆ *man-made* (velvet, leather)
- ◆ *isotropic* (bread, concrete)
- ◆ *anisotropic* (corn husk, wood)



Measurement Methods

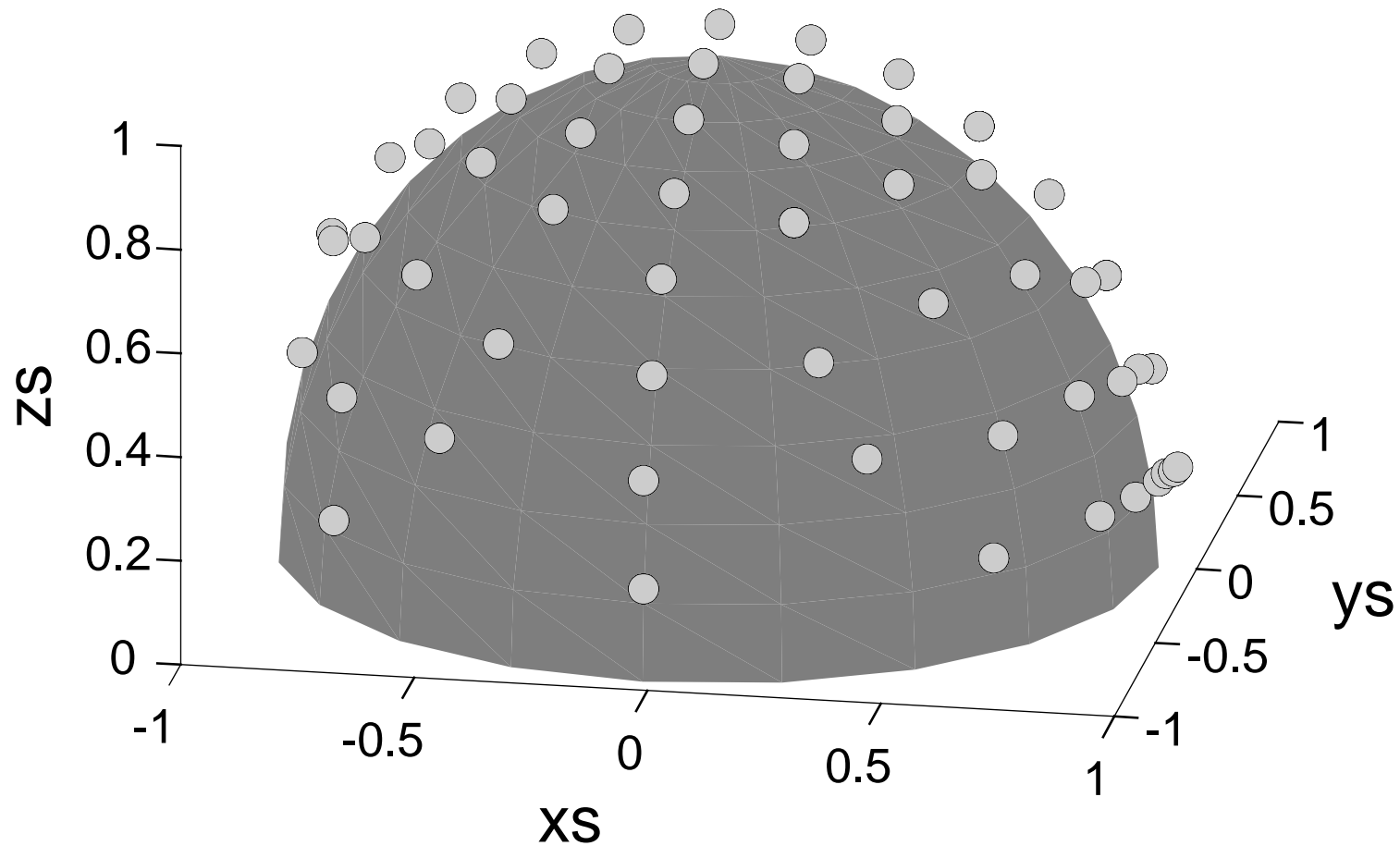


Measurement Methods

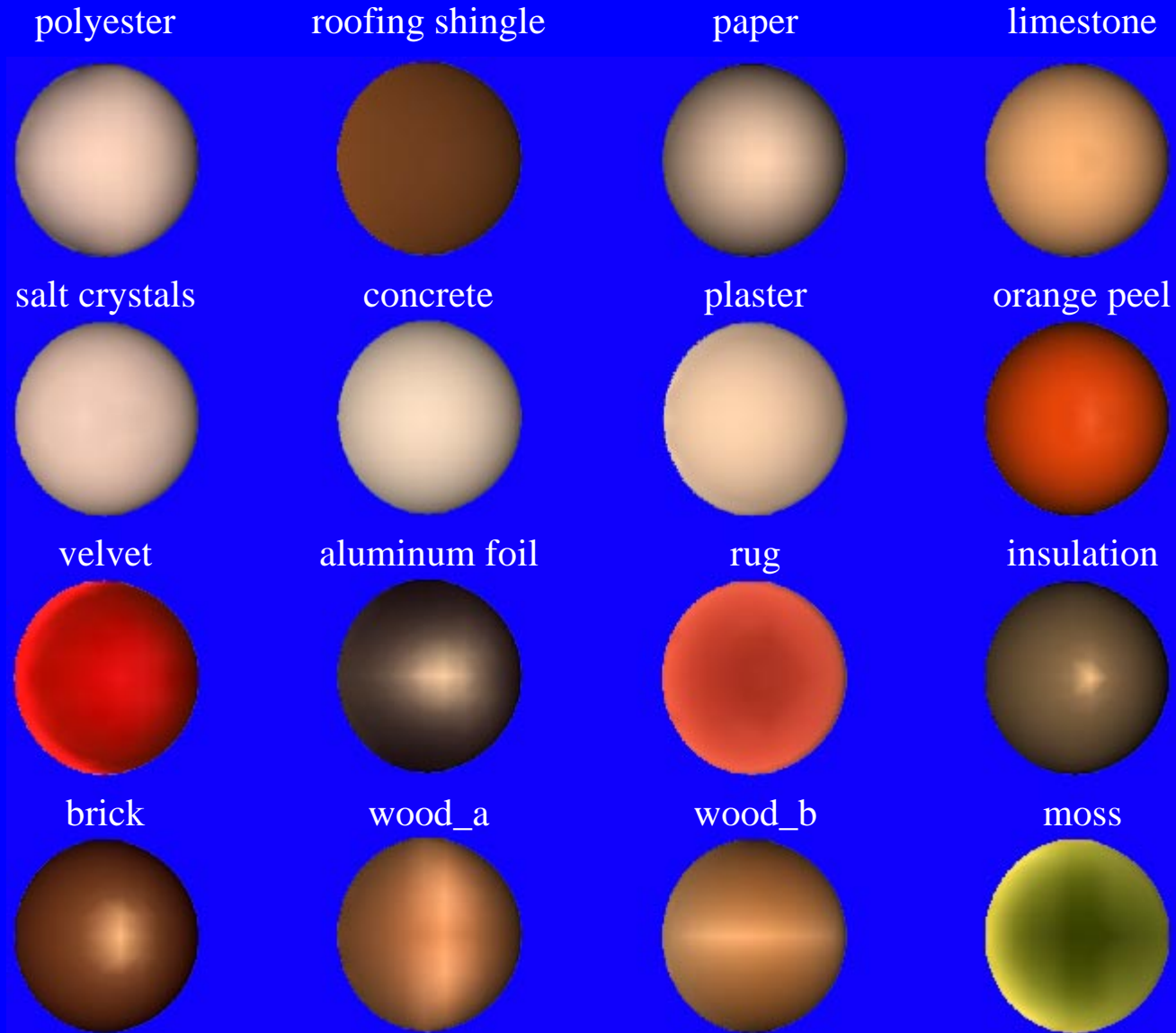


Measurement Methods

Illumination Directions



Rendered Spheres using BRDF Measurements



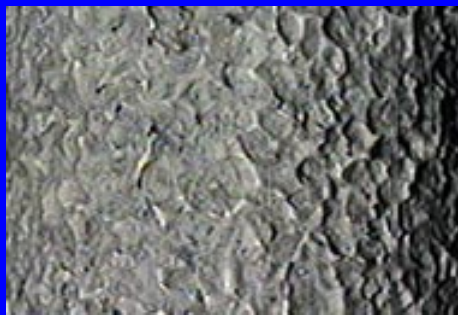
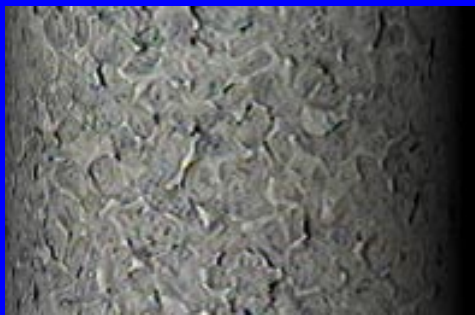
Texture-mapping using BTF



standard
texture-mapping

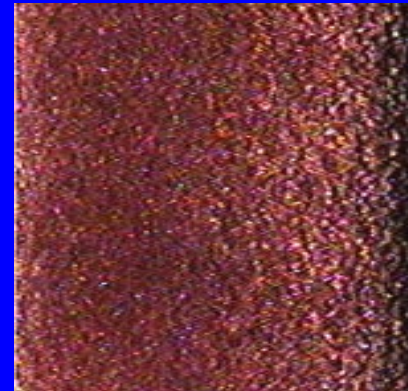


texture-mapping
with the BTF



Texture-mapping using BTF

standard
texture-mapping



texture-mapping
with the BTF

Summary of Contributions

- ◆ BRDF Measurement Database
- ◆ BTf Measurement Database
- ◆ BRDF Model Parameter Database

Histogram Model for 3D Textures

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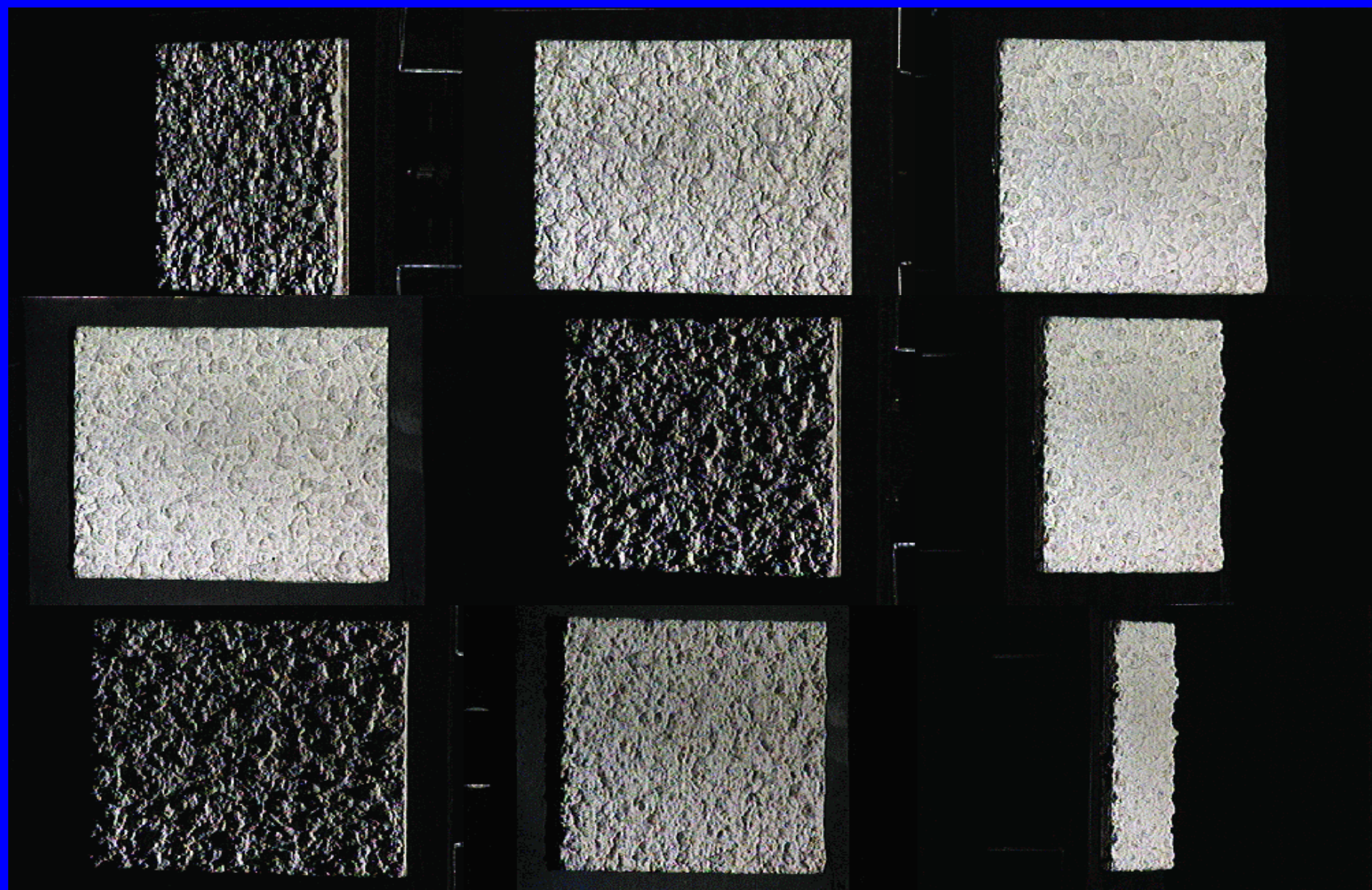
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CVPR 98

Texture Representations (2D)

- ◆ **intensity histogram**
Lowitz 1983 , Mailloux et al., 1985
- ◆ **multidimensional histograms (co-occurrence matrices)**
Haralick et al. 1973, Chien and Fu 1974, Davis et al. 1979, Valkealahti and Oja 1999
- ◆ **feature histograms (e.g. gradient)**
Vilnrotter et al. 1986, Bajla et al. 1993, Lam 1996, Horng et al, 1996
- ◆ **correlation function/power spectrum**
Chen 1982, Kashyap 1984, Kondepudy and Healey 1993
- ◆ **space/frequency decompositions (wavelet, Gabor)**
Bastiaans 1980, Fogel and Sagi 1989, Bovick et al. 1990
Mallat 1989, Chang and Juo 1993, Livens et al. 1997
- ◆ **multiscale histograms**
Heeger and Bergen 1995, Debonet 1997

Example images



Class of 3D texture for model

- ◆ Lambertian
- ◆ Isotropic
- ◆ Monochrome
- ◆ Randomly Rough (with gaussian surface statistics)
- ◆ Examples:



Sample 8-Pebbles



Sample 11-Plaster



Sample 50-Concrete

Development of Histogram Model

- ◆ Two Main Tasks:

1. PDF conversion

Surface Normal PDF

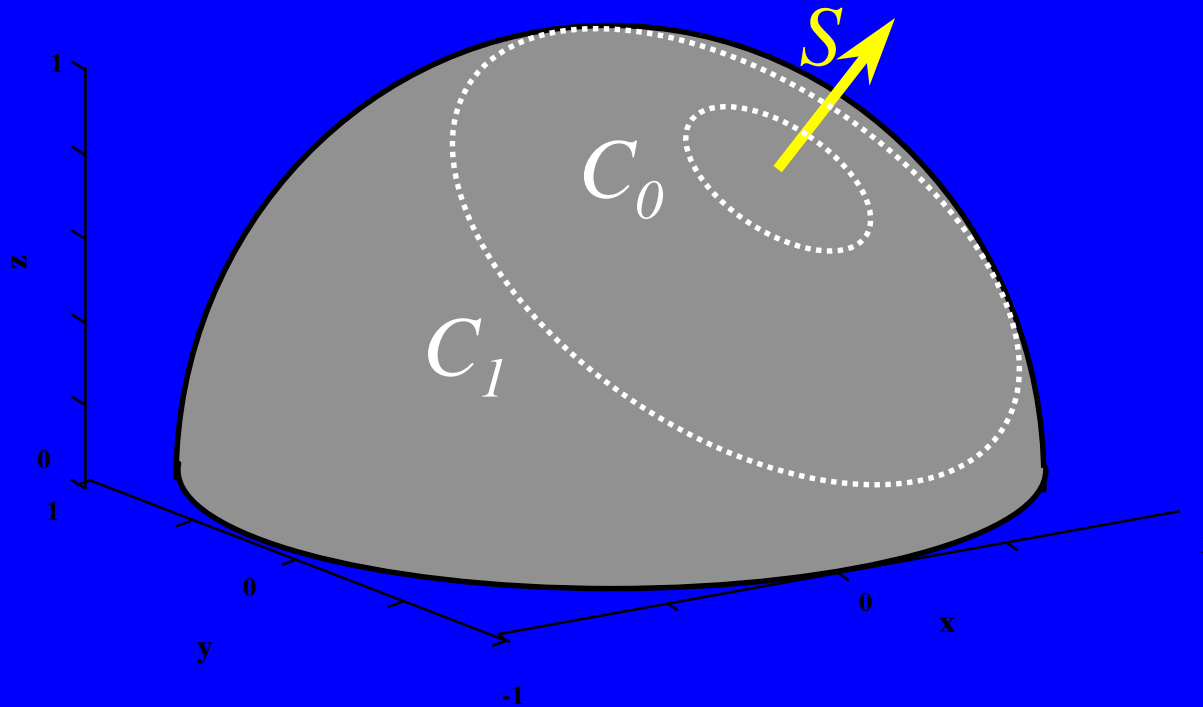


Image Intensity PDF

2. Approximation of Resulting Integral

Iso-Brightness Cone

- ◆ Let C_0 be the set of surface normals for intensity I_0
- ◆ Lambertian implies C_0 is $\{n: n \cdot S = I_0\}$



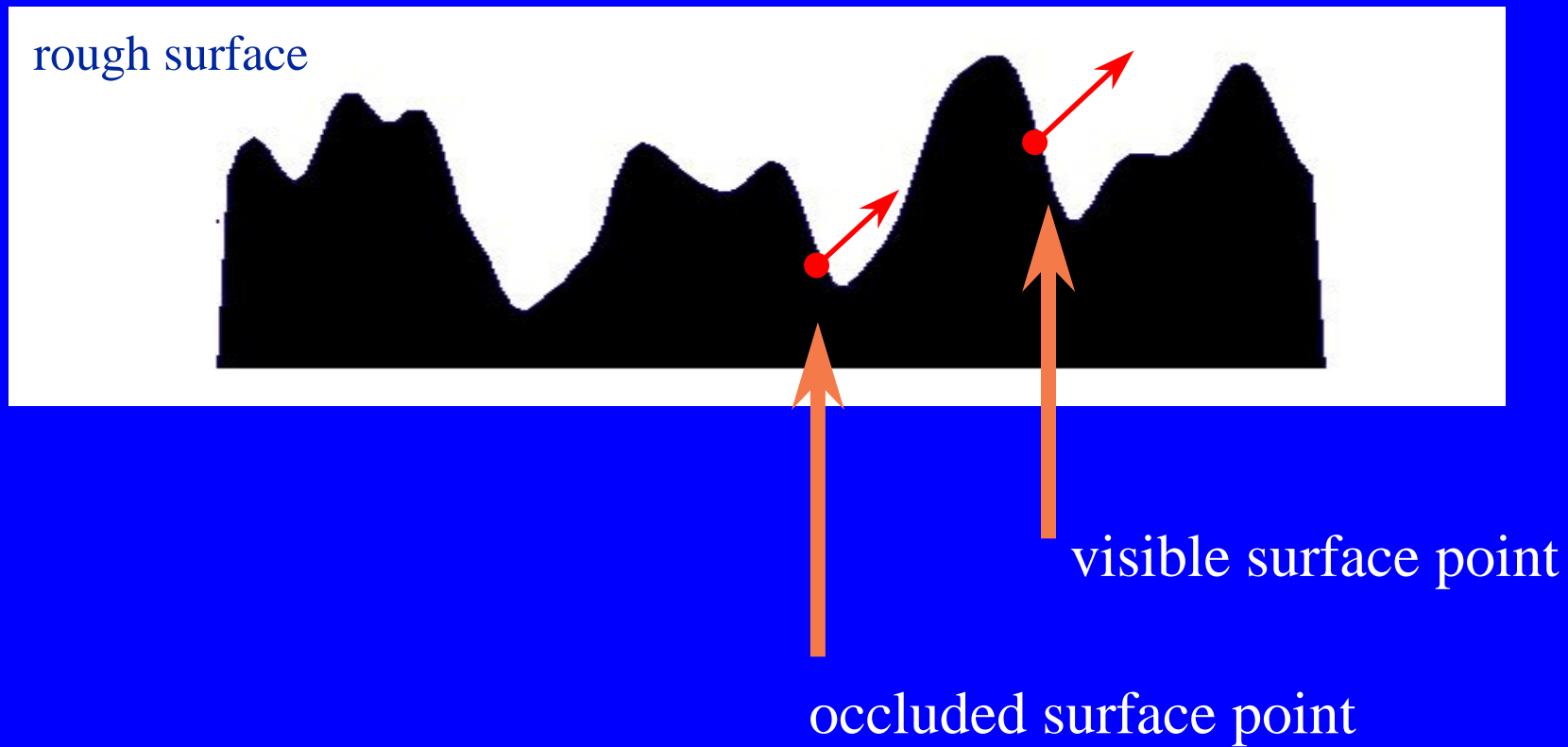
Limits of Iso-brightness Cone

$$\Pr(I_0) \neq \Pr(N \in C_0)$$

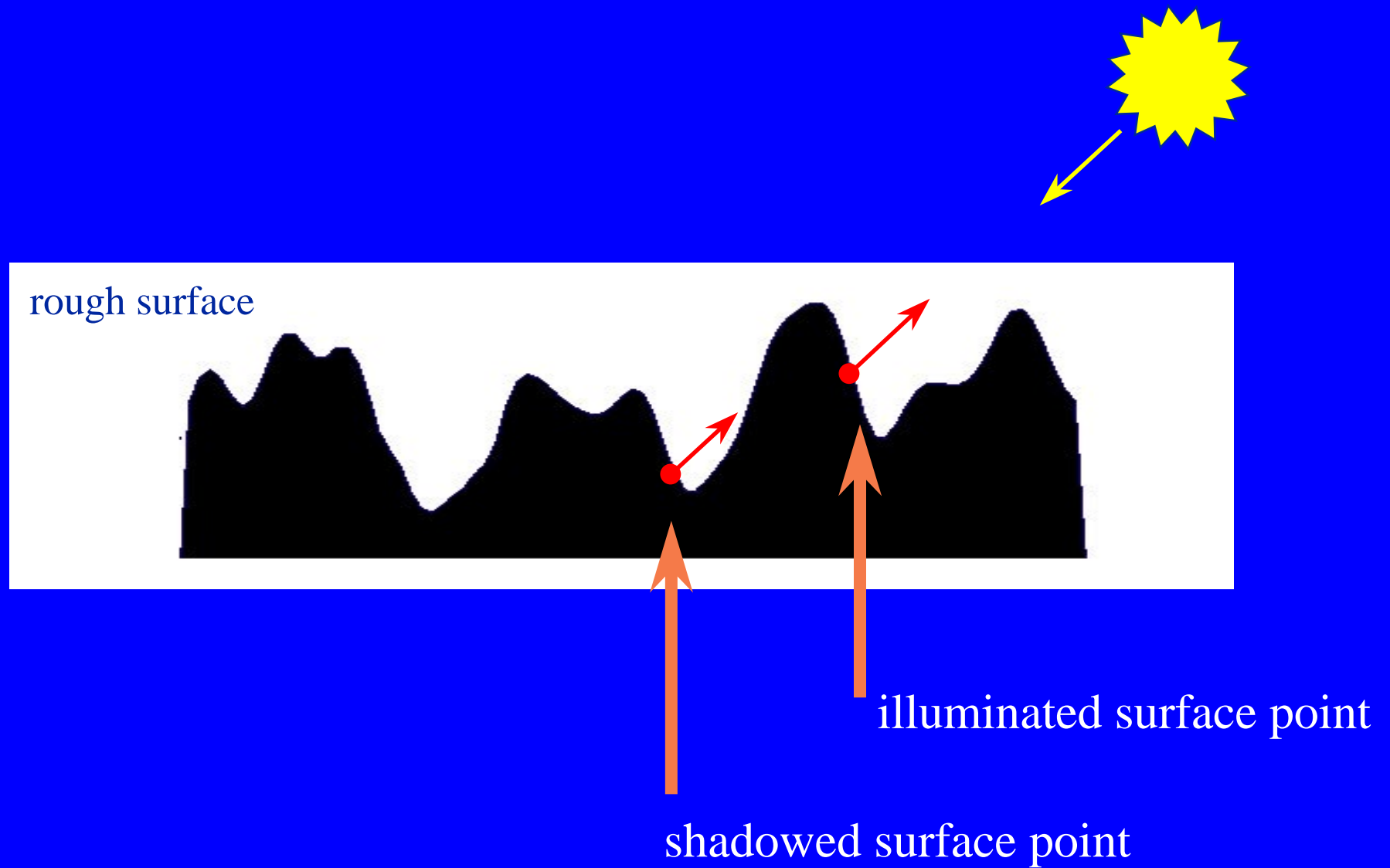
These probabilities are not equal because of:

- Visibility
- Shadowing
- Foreshortening

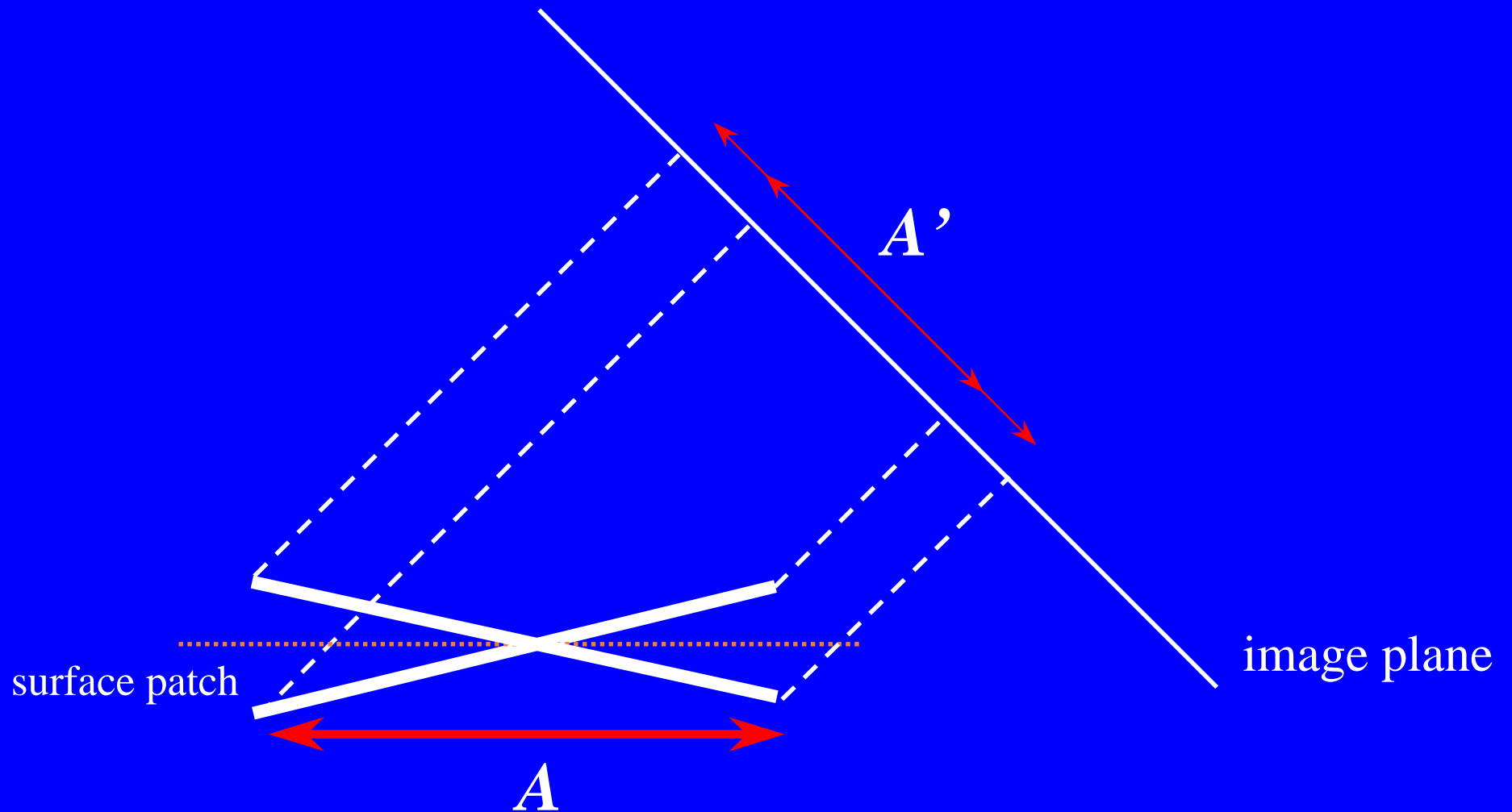
Visible vs. Occluded Surface Points



Illuminated vs. Shadowed Surface Points

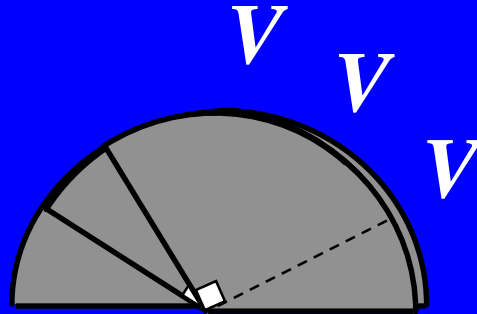


Foreshortening Effects



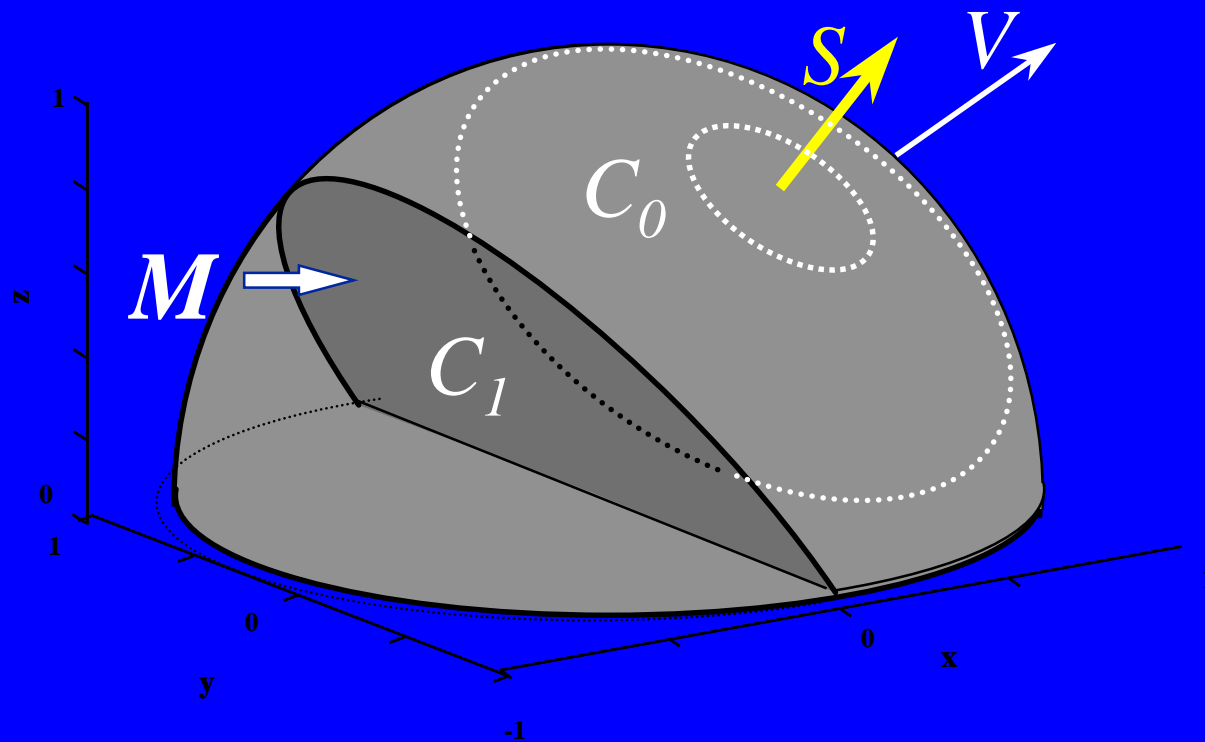
Visibility Effects

Visible points have surface normals where $n \cdot V > 0$



M = set of imaged surface normals

Visibility Effects

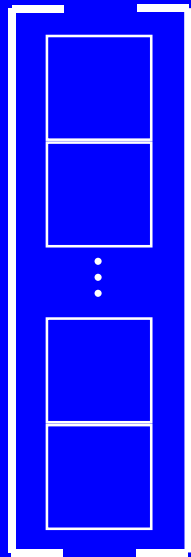


\mathcal{M} = set of imaged surface normals

Histogram Model

modeled histogram

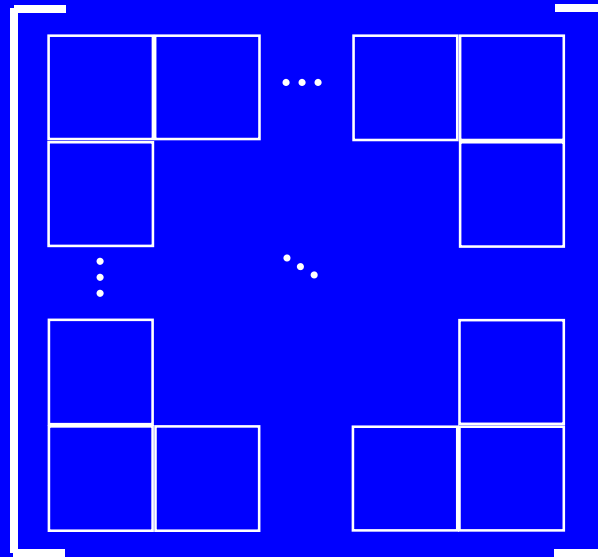
h



256 x 1

imaging matrix

Ω



256 x L

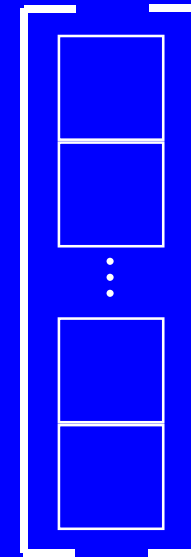
(V, S)

viewing
direction

source
direction

coefficient vector

α



L x 1

(σ)

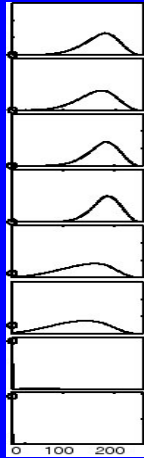
roughness

=

$$\frac{q}{q_v F}$$

Histogram Analysis and Synthesis

Analysis



histograms

Estimation

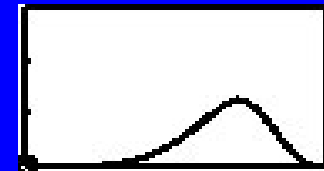
σ - roughness parameter

Synthesis

V, S

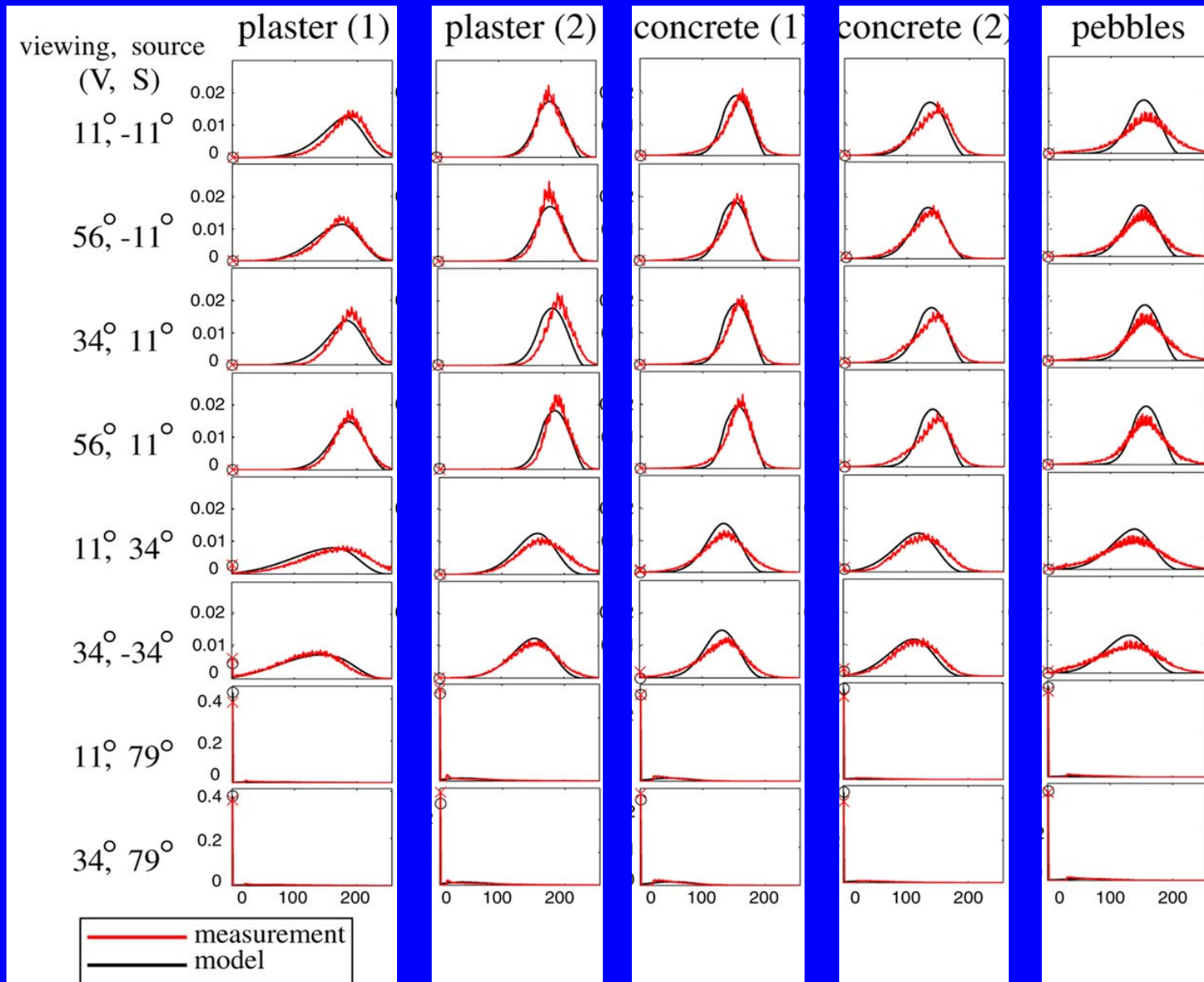
σ

Histogram Generation



simulated histograms

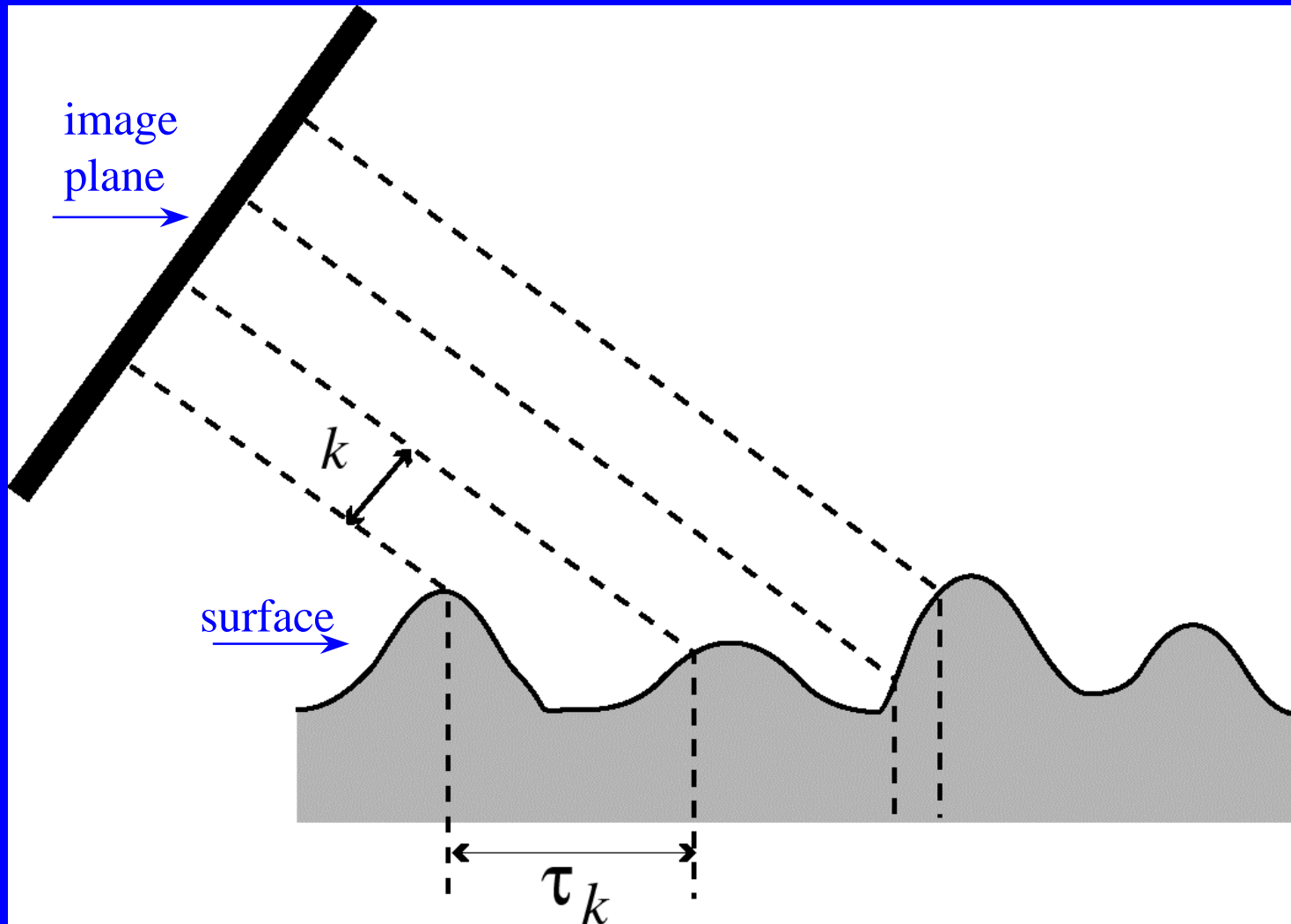
Histogram Model Fits



Modeling the Correlation Function

- ◆ Histogram model does not capture spatial correlation
- ◆ Correlation function of 3D texture depends on illumination and viewing direction
- ◆ Correlation model and histogram model of 3D texture serve as a more complete texture model

Sampling Distance as a Random Variable



Modeling the Correlation Function

$$\mathbb{E}(I[j]I[j - k])$$

intensity at pixel
in image



$$I[j]$$

$$I(t)$$



intensity at point
on surface

$$I[j - k]$$

$$I(t - \tau_k)$$

τ_k is a random variable

$$\mathbb{E}(I(t)I(t - \tau_k))$$

Modeling the Correlation Function

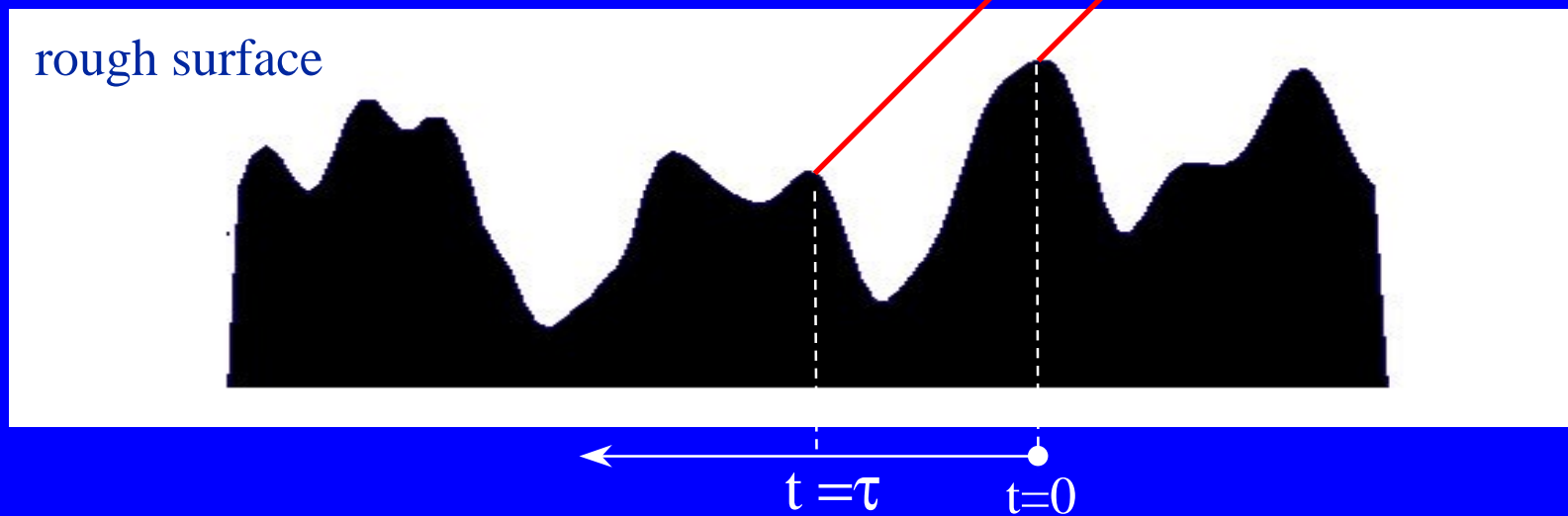
$$\mathbf{E}(I[j]I[j-k]) = \mathbf{E}\left\{\mathbf{E}\left(I(t)I(t-\tau_k) \mid \tau_k\right)\right\}$$

Need to derive:

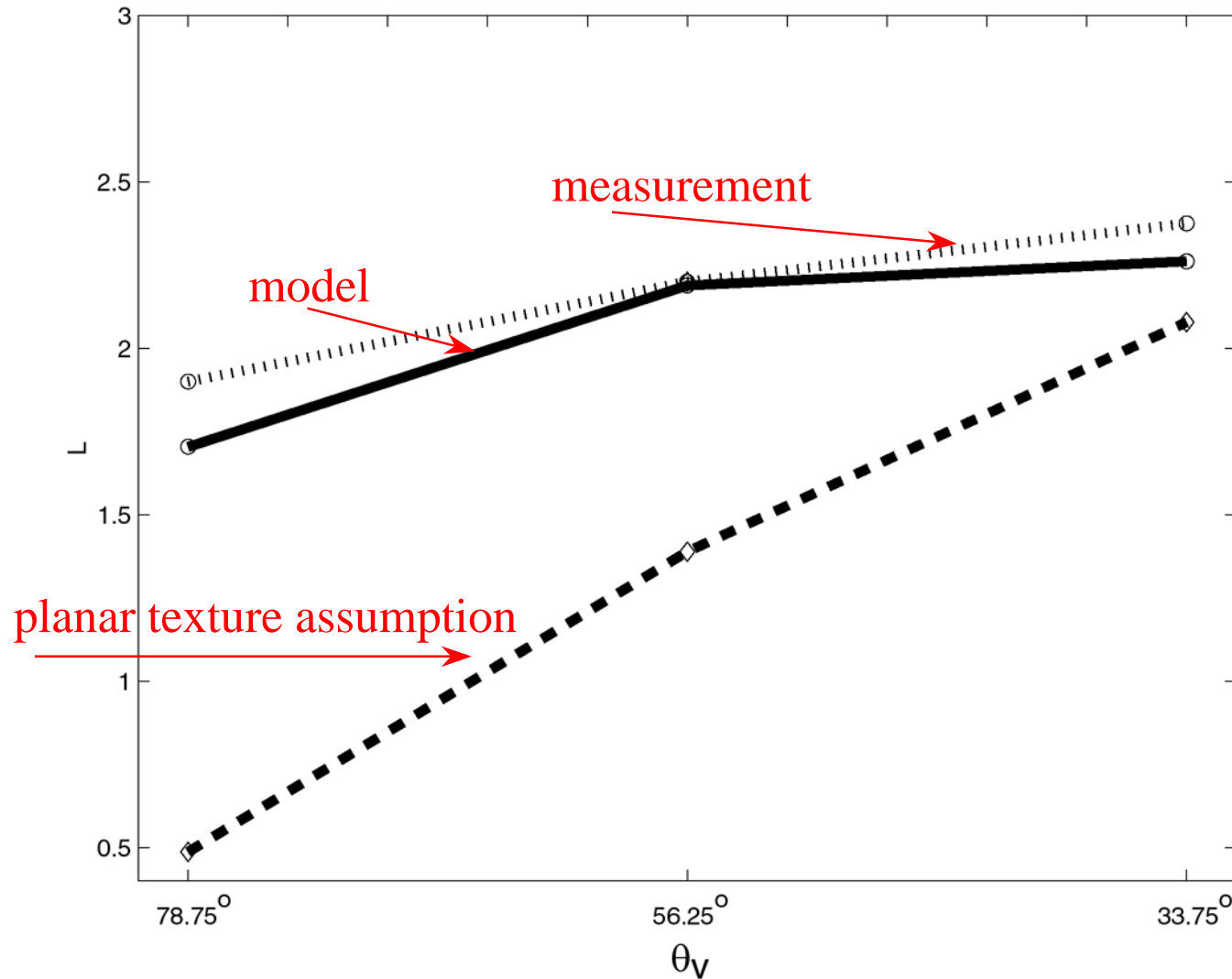
$$p(\tau_k)$$

Modeling the Correlation Function

$$p(\tau_k) = \text{Prob} \left[\begin{array}{l} \text{surface point at } (t = \tau) \text{ is visible} \\ \text{AND} \\ h(\tau) = a\tau + b \end{array} \right]$$



Correlation Length



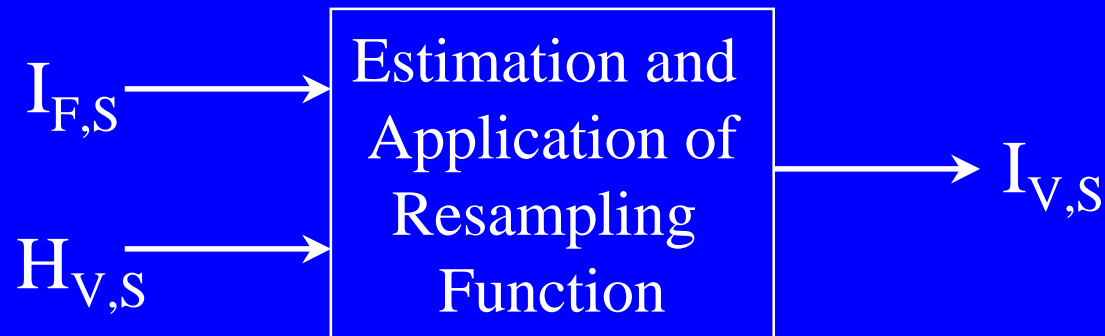
Texture Synthesis Algorithm

- ◆ Goal:

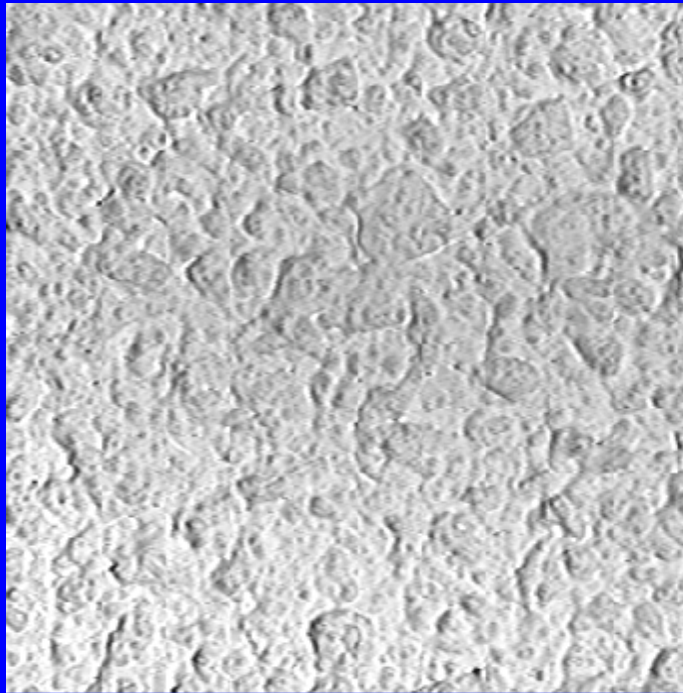
frontal view texture \longrightarrow oblique view texture

- ◆ Method: estimate resampling function

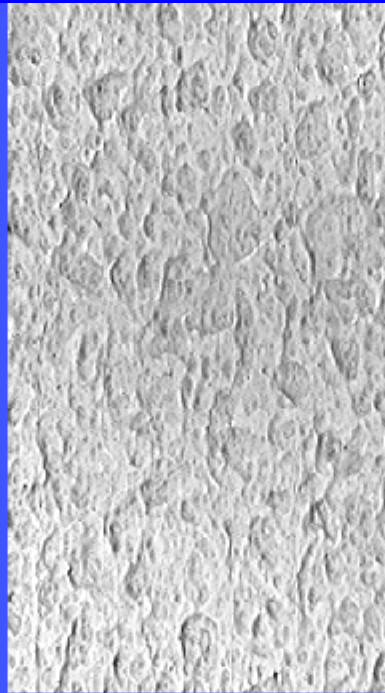
- ◆ Estimation driven by histogram matching



3D Texture Synthesis

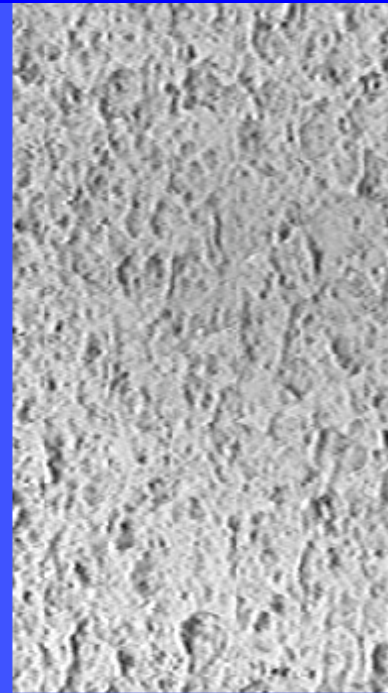


Near Frontal View

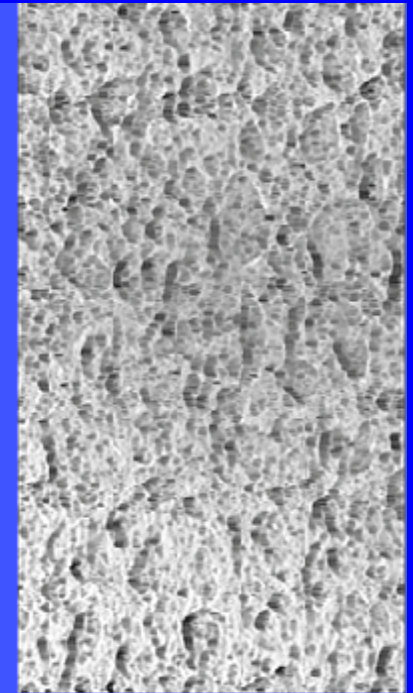


Simulated
Oblique View

Texture-Mapping



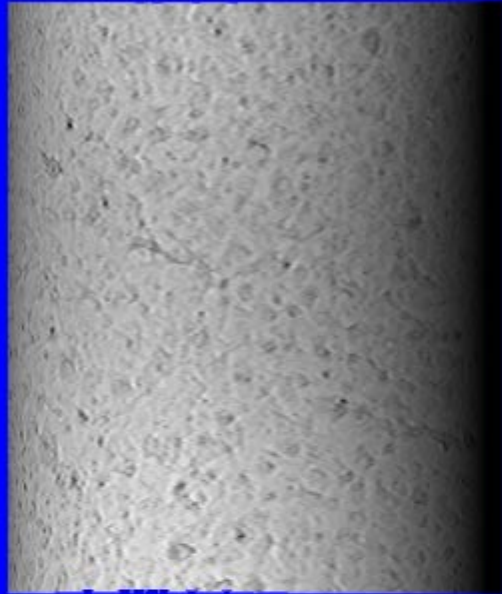
Actual
Oblique View



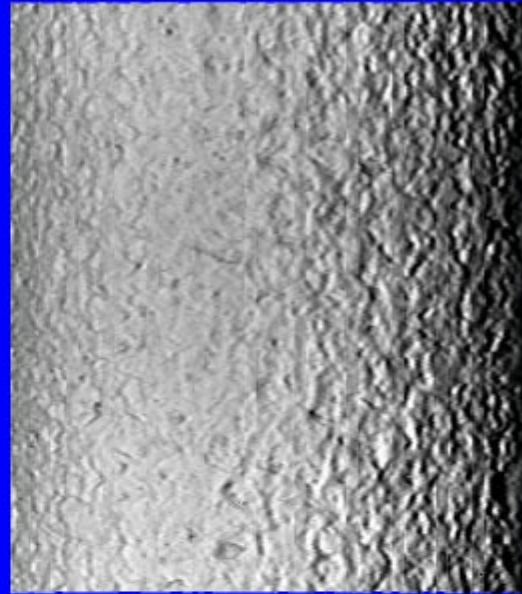
Simulated
Oblique View

Texture-Morphing

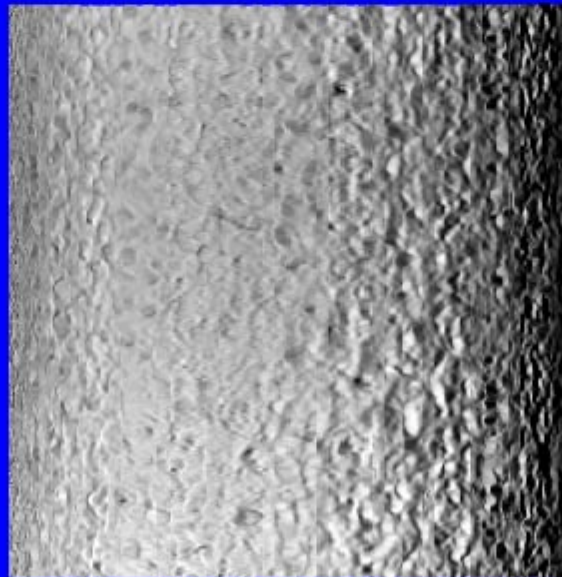
standard
texture-mapping



texture-mapping
with the BTF



texture-MORPHING



Web Page: www.cs.columbia.edu/CAVE/curet

CUReT

Columbia-Utrecht Reflectance and Texture Database

