3D Textured Surface Modeling

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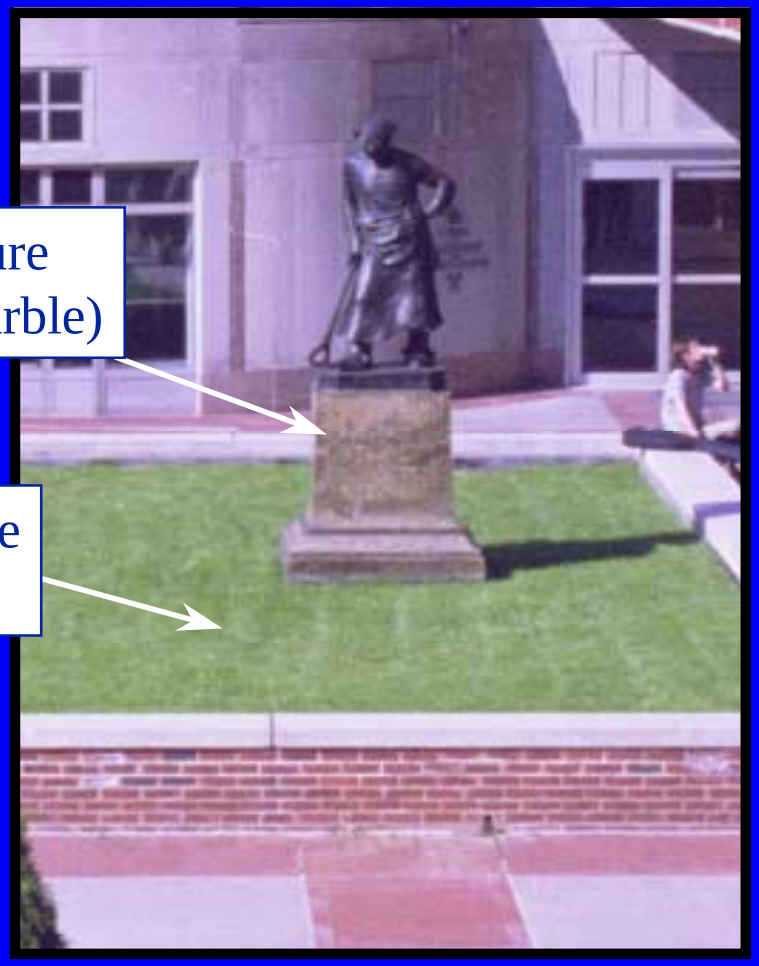
3D Texture vs. 2D Texture

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



Motivation

Object

Surfaces

3D Texture

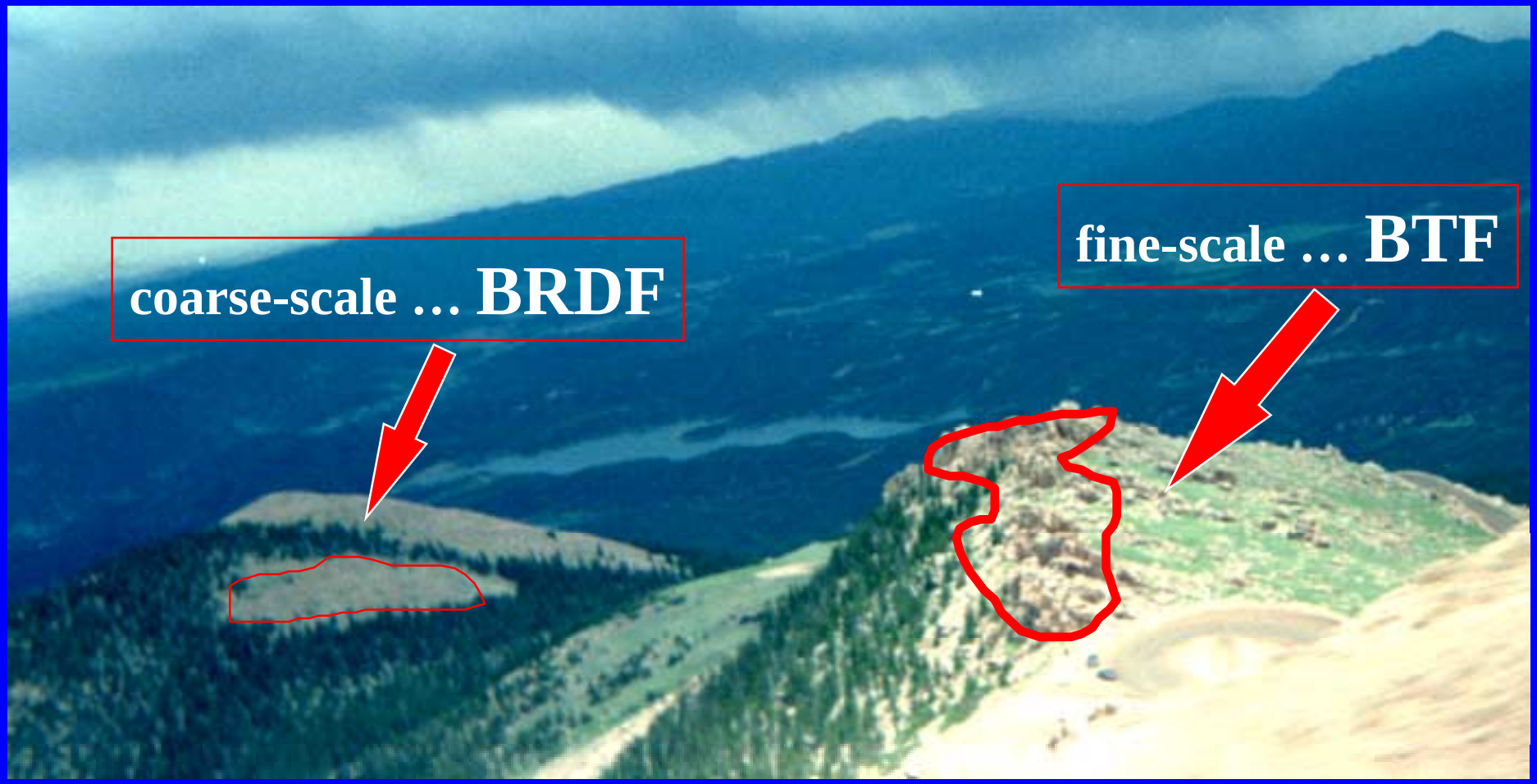
2D Texture

appearance-based

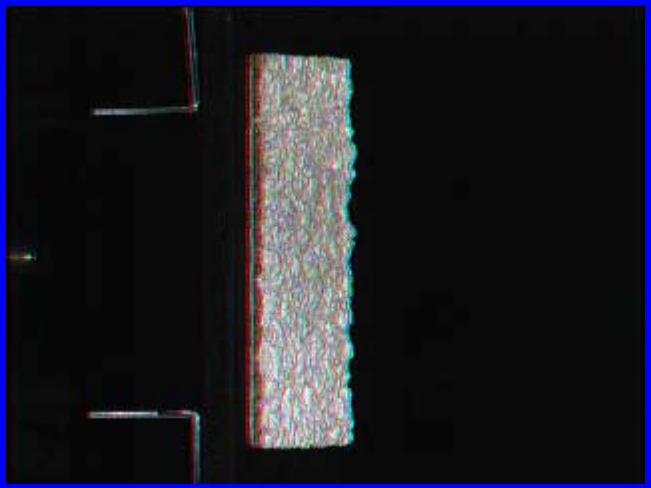
BRDF/BTF Taxonomy

	Surface Appearance	
	Coarse-Scale	Fine-Scale
Fixed View/Illumination	Reflectance	Texture
Varied View/Illumination	BRDF	☆ BTF

BRDF vs. BTF



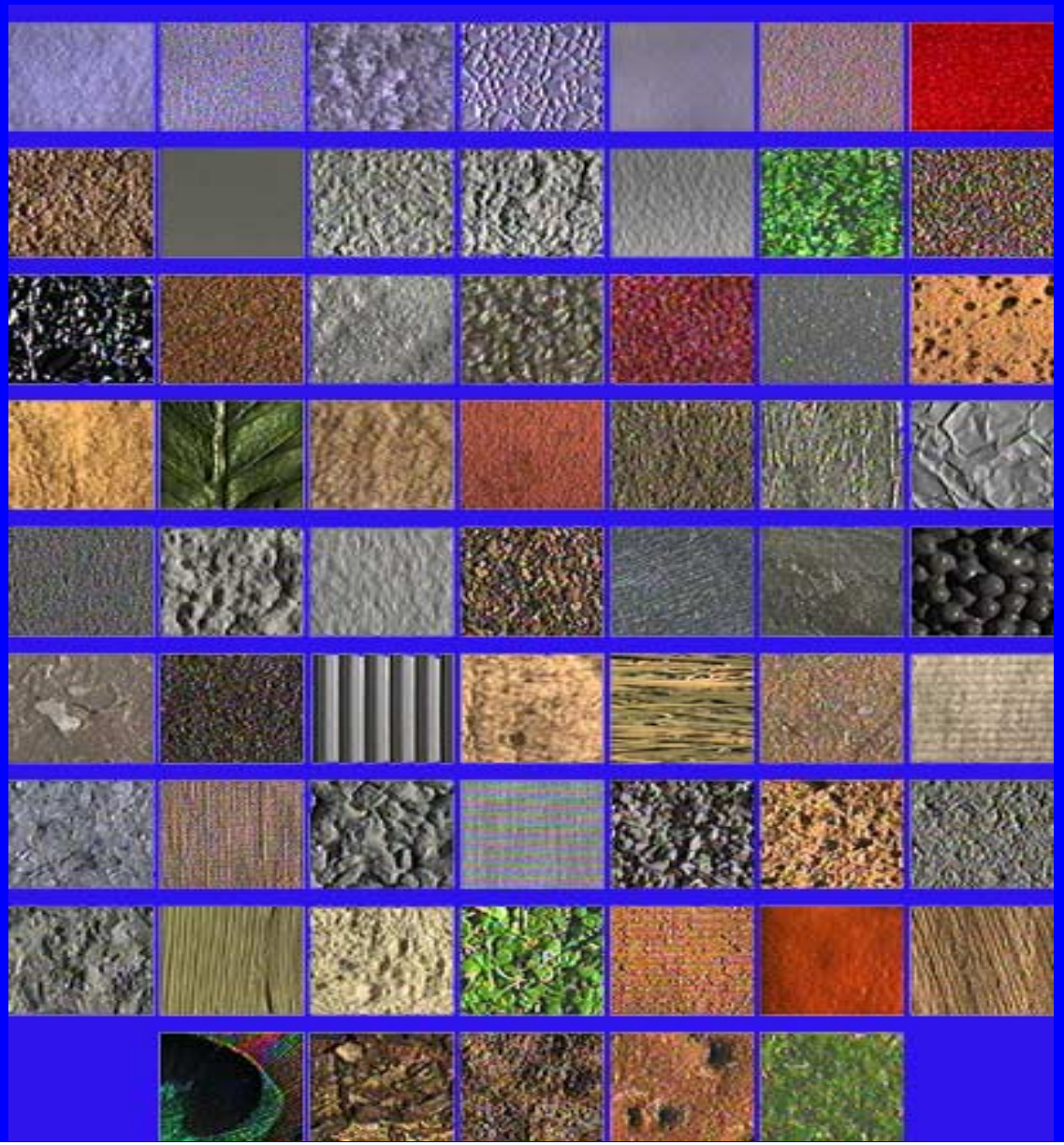
Texture Appearance



CUReT (Columbia-Utrecht Reflectance and Texture Database)

61 samples:

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



BRDF Model-Fitting:

- Koenderink et al. ECCV 1996
- Oren, Nayar IJCV 1995

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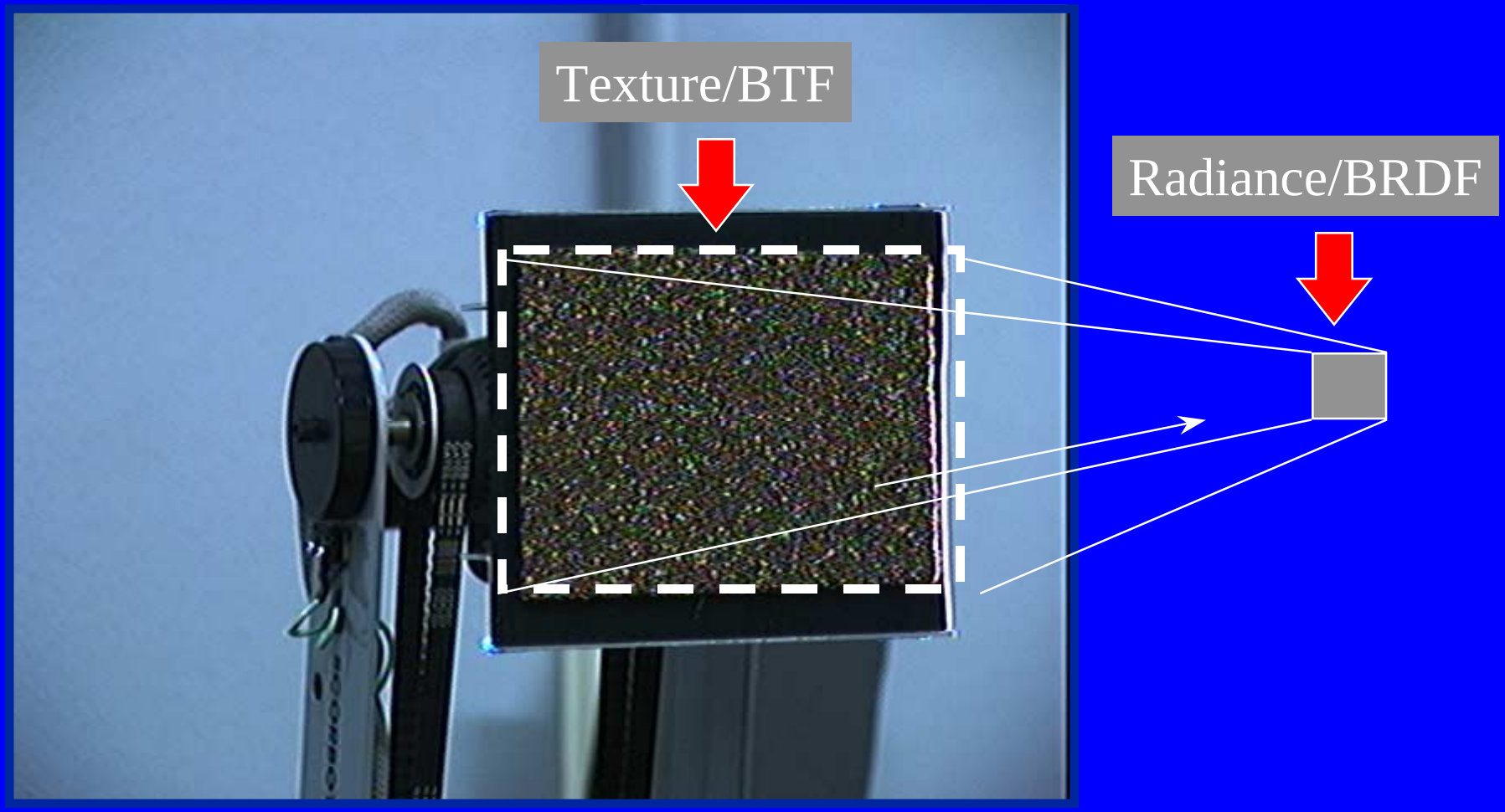
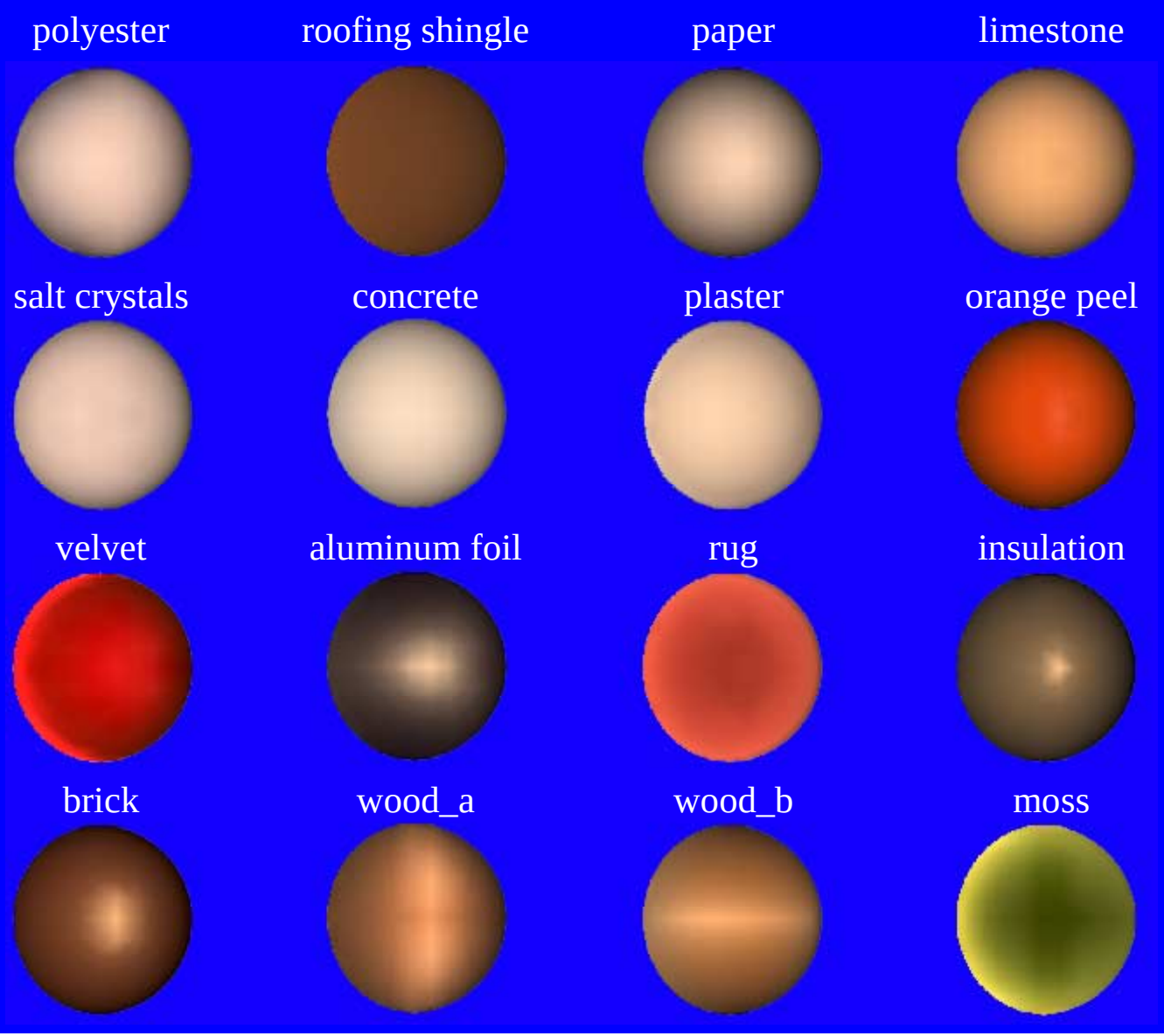
CVPR 97, TOG 99

Shree K. Nayar

Measurement Methods



Rendered Spheres using BRDF *Measurements*



Texture-mapping using BTF

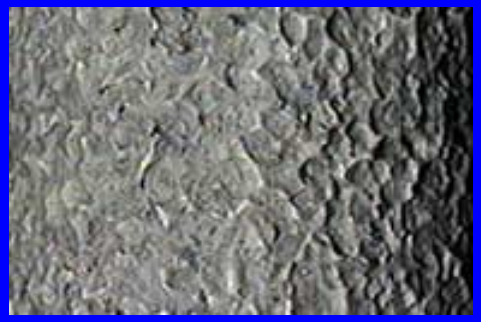
standard texture-mapping

texture-mapping with the BTF

plaster

pebbles

concrete

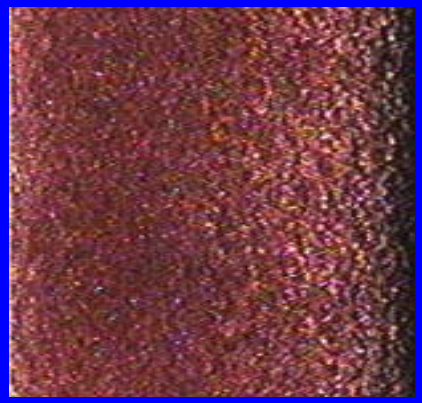


Texture-mapping using BTF

crumpled paper

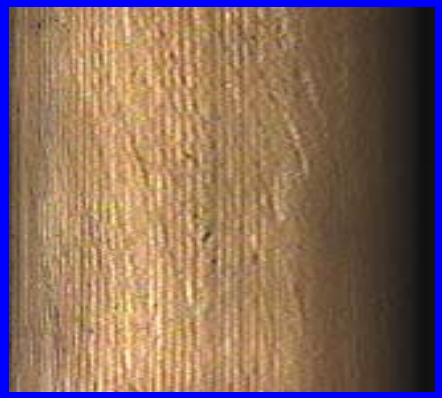
standard texture-mapping

carpet



texture-mapping with the BTF

wood

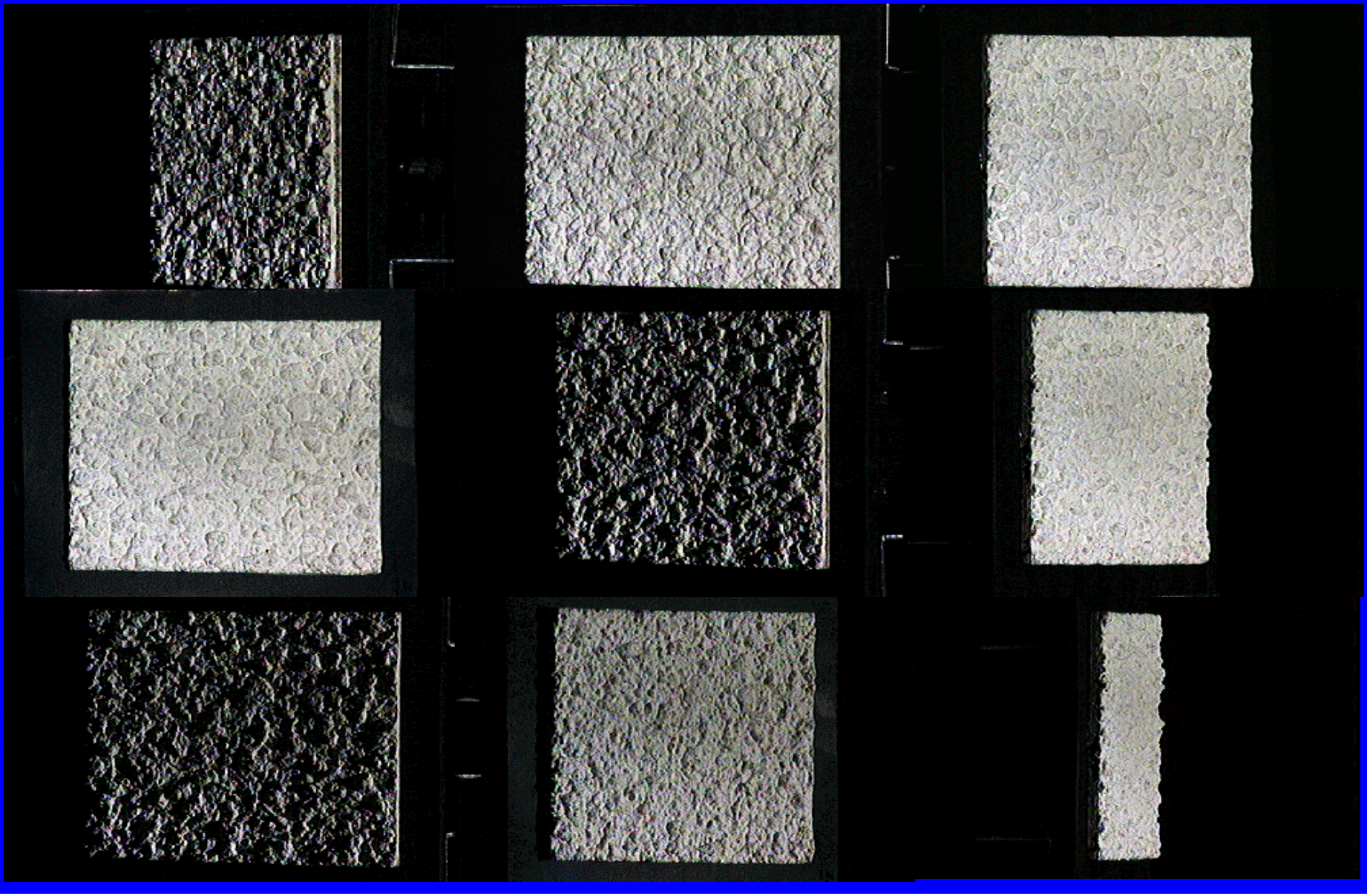


BTF Models

- Histogram Model (CVPR 98 Dana and Nayar)
- Correlation Model (ICCV 99 Dana and Nayar)
- PCA on Multiscale Conditional Histograms

- Histogram simulations (IJCV 99 van Ginneken et al.)
- PCA on Color Correlation (CVPR 98 Suen and Healey)

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:

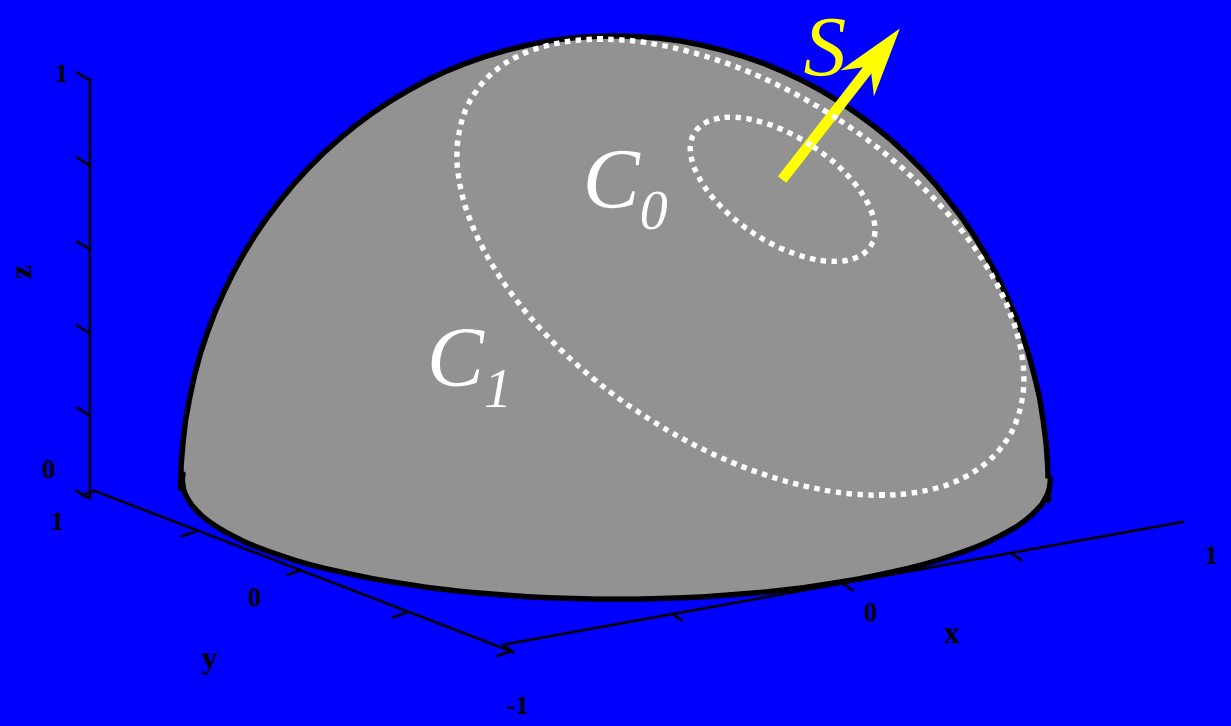
1. PDF conversion

Surface Normal PDF → **Image Intensity PDF**

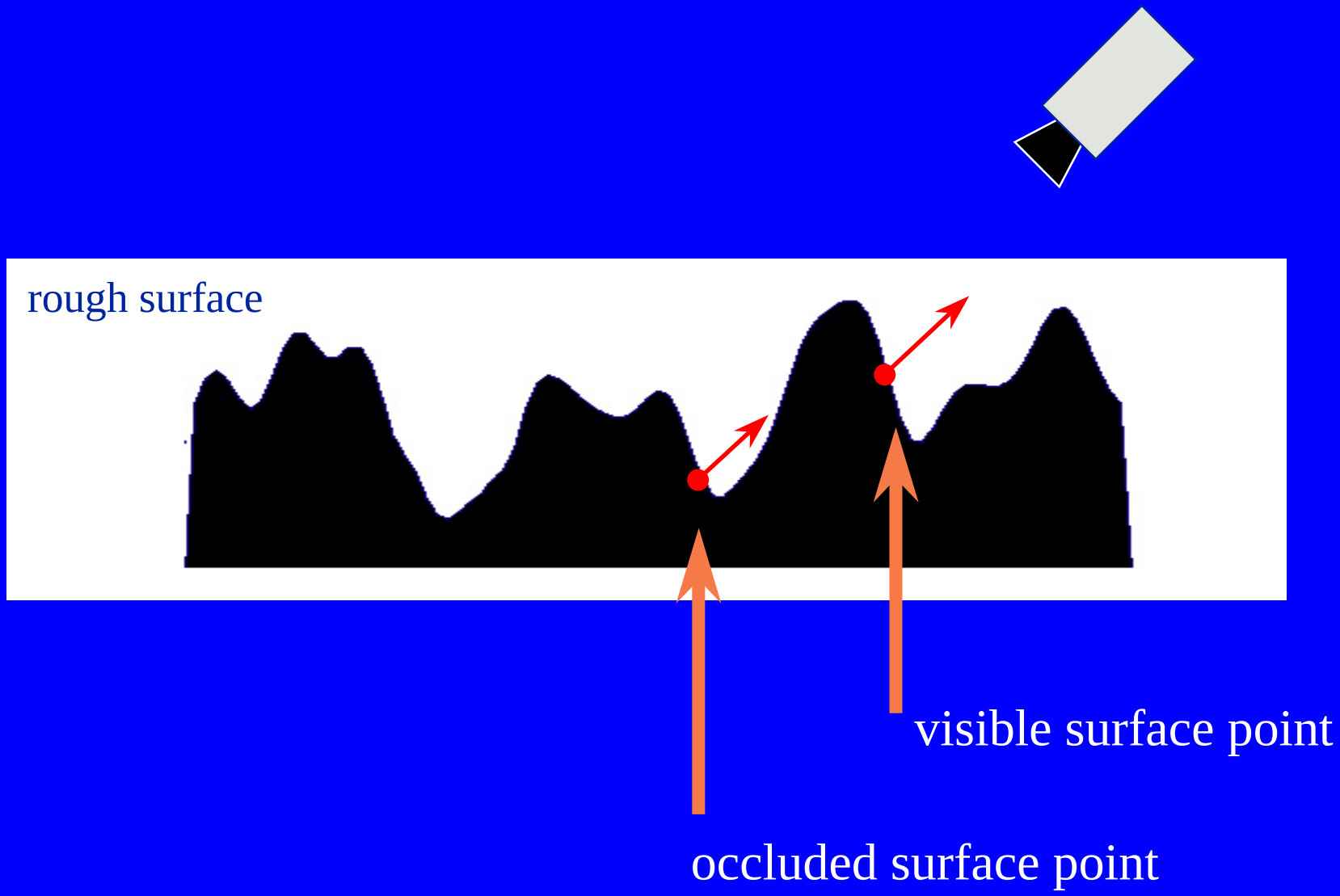
2. Approximation of Resulting Integral

Iso-Brightness Cone

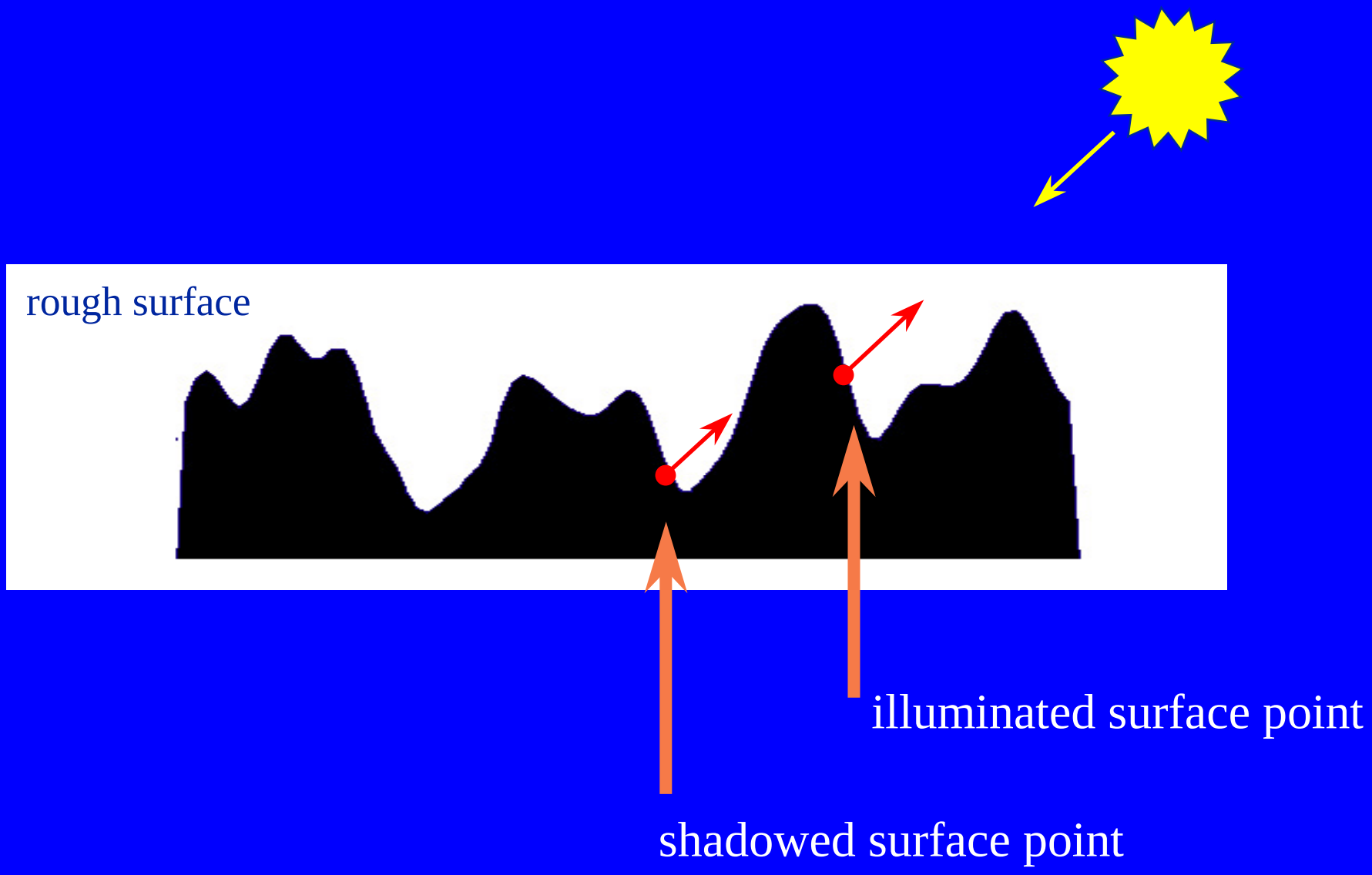
- Let C_0 be the set of surface normals for intensity I_0
- Lambertian implies C_0 is $\{n\colon\ n \cdot S = I_0\}$



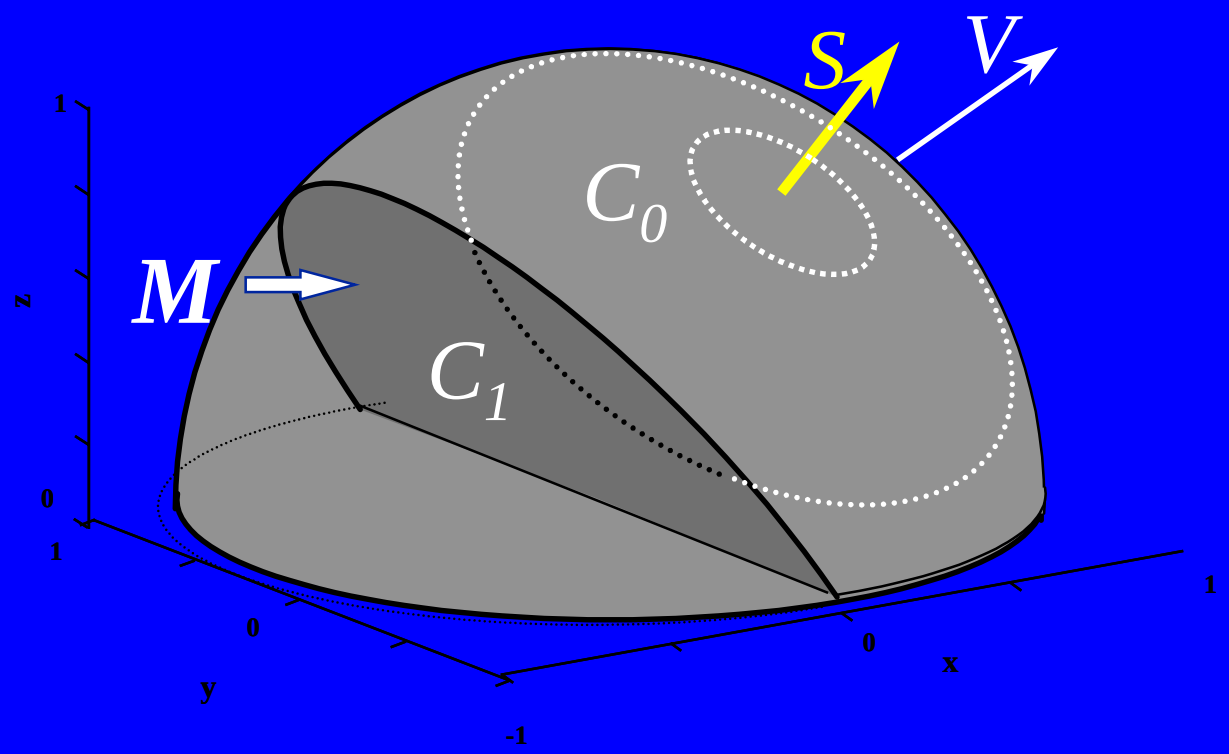
Visible vs. Occluded Surface Points



Illuminated vs. Shadowed Surface Points



Effect of Local Occlusion



M = set of imaged surface normals

Histogram Model

modeled histogram → η

imaging matrix → Ω

coefficent vector → α

$$\begin{bmatrix} \\ \\ \vdots \\ \\ \\ \end{bmatrix} = \frac{q}{q_v F} \begin{bmatrix} \cdots & \\ \vdots & \ddots \\ & \end{bmatrix} \begin{bmatrix} \\ \\ \vdots \\ \\ \\ \end{bmatrix}$$

256 x 1 | 256 x L | L x 1

(*V*,*S*)

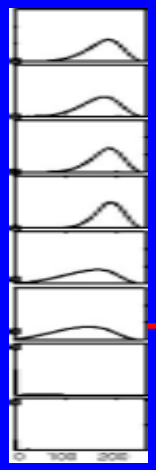
viewing direction | source direction

(σ)

roughness

Histogram Analysis and Synthesis

Analysis



histograms

Estimation

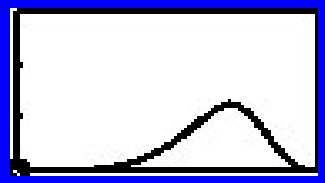
σ - roughness parameter

Synthesis

V,S

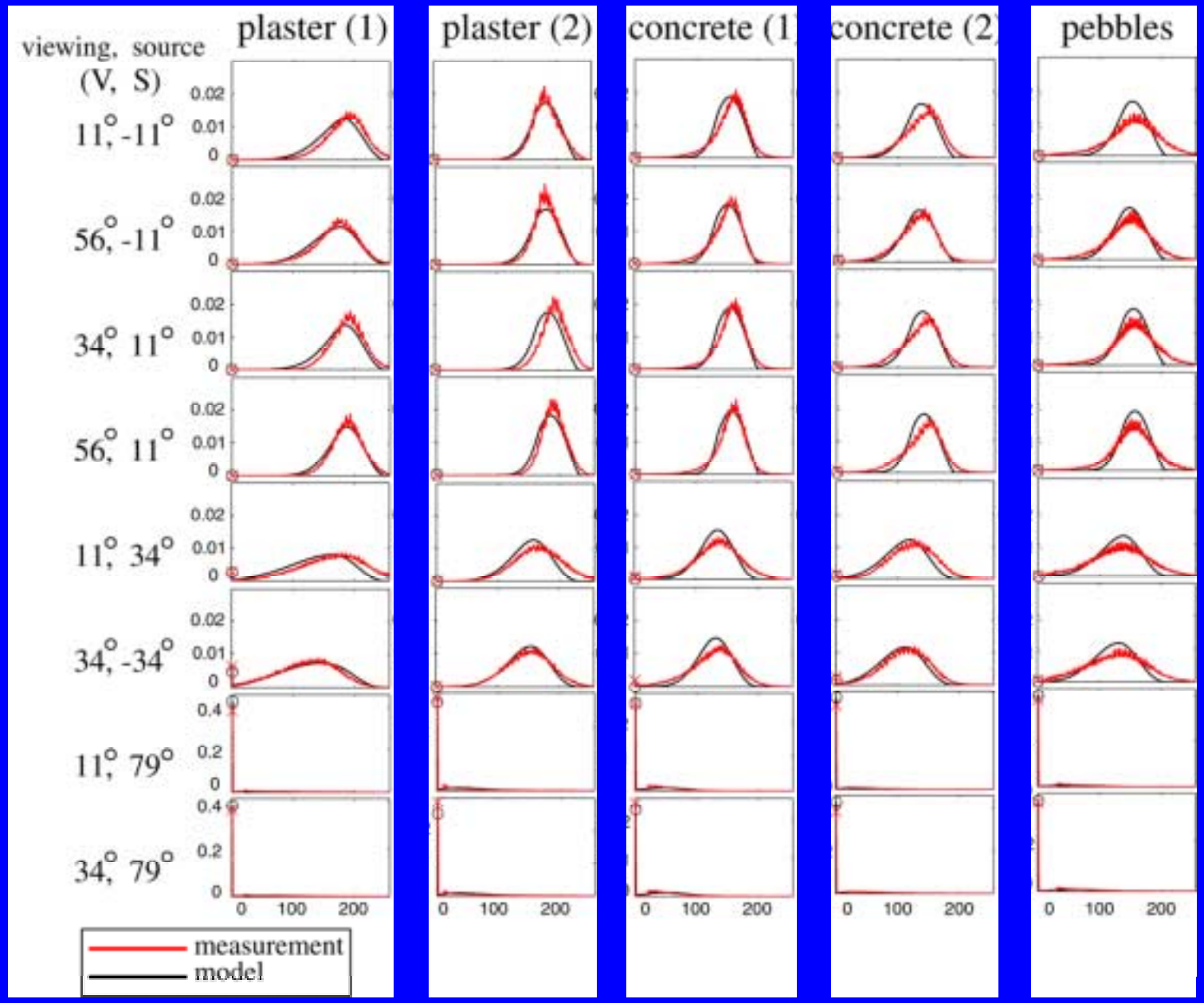
σ

Histogram Generation



simulated histograms

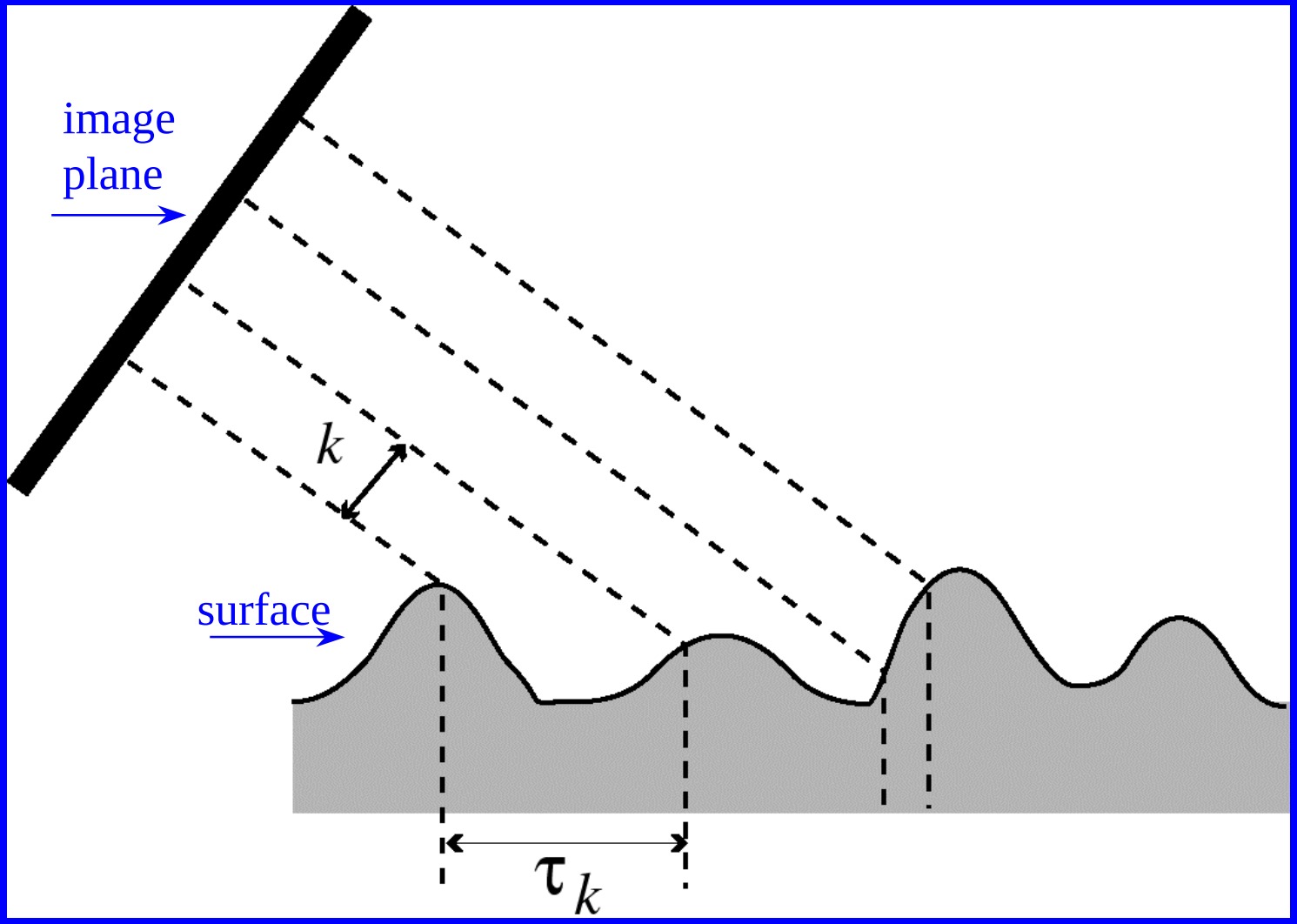
Histogram Model Fits



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

$$\mathrm{E}\left(I[j]I[j-k]\right)$$

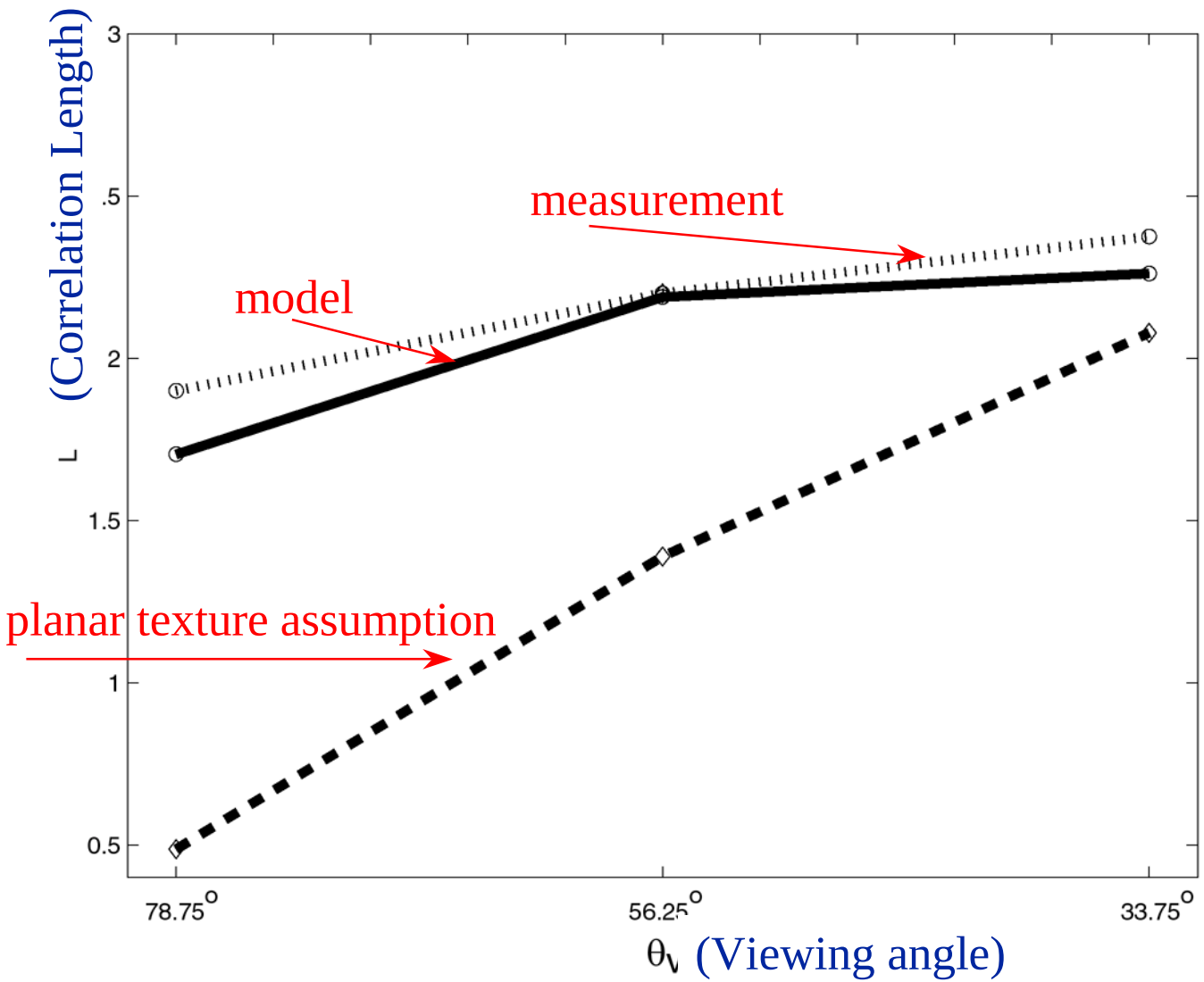
intensity at pixel in image → $I[j]$

$\mathrm{I}(t)$ ← intensity at point on surface

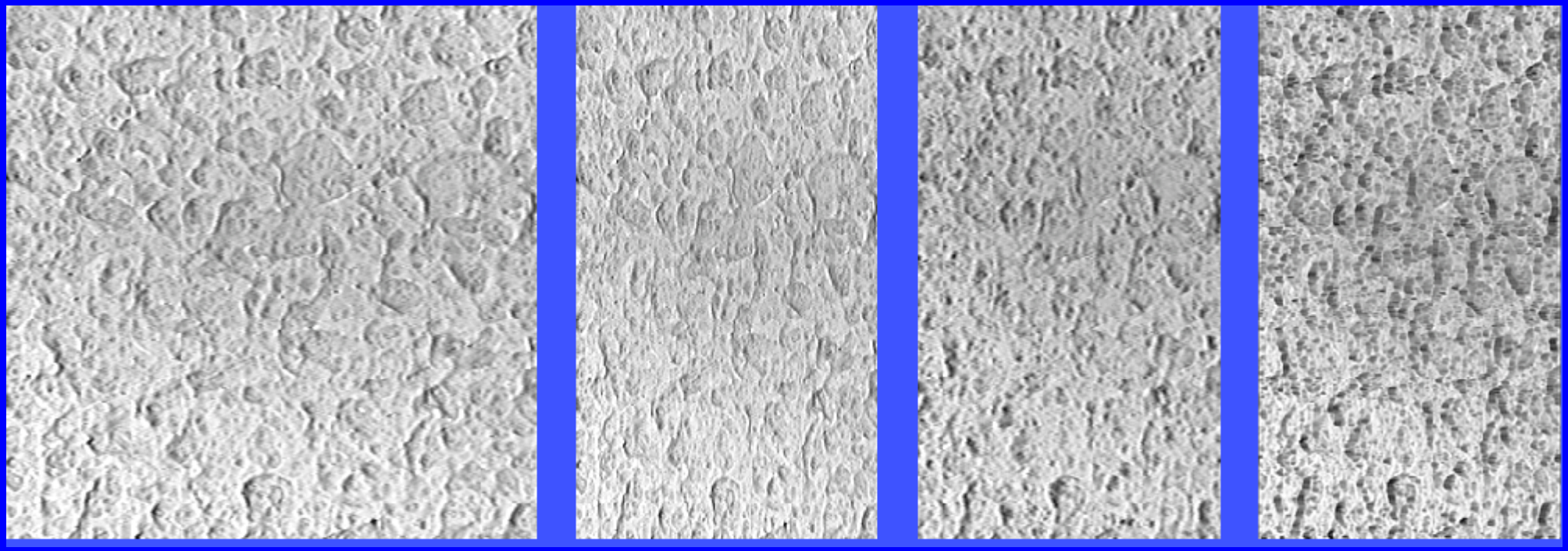
$$\mathrm{E}\left(I(t)I\left(t-\tau_{\kappa}\right)\right)$$

- (ICCV 99 Dana and Nayar)

Correlation Length



3D Texture Synthesis



Near Frontal View

Simulated **Oblique View**

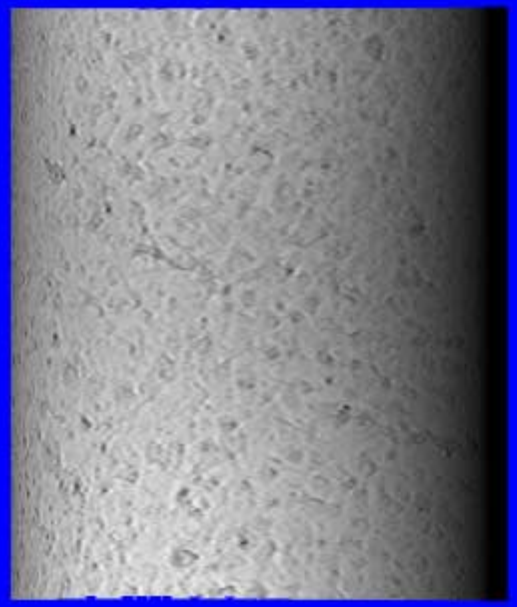
Texture-Mapping

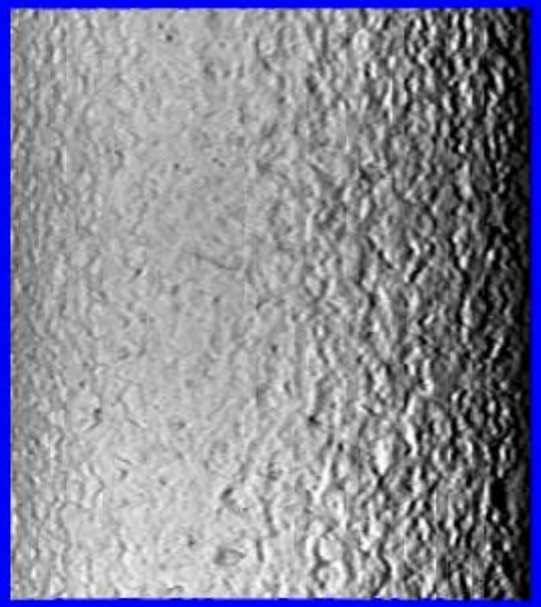
Actual **Oblique View**

Simulated **Oblique View**

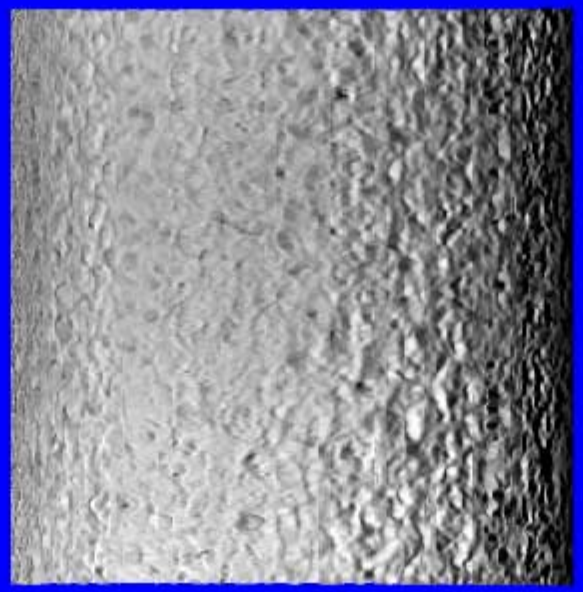
Texture-Morphing

standard
texture-mapping





texture-mapping
with the BTF

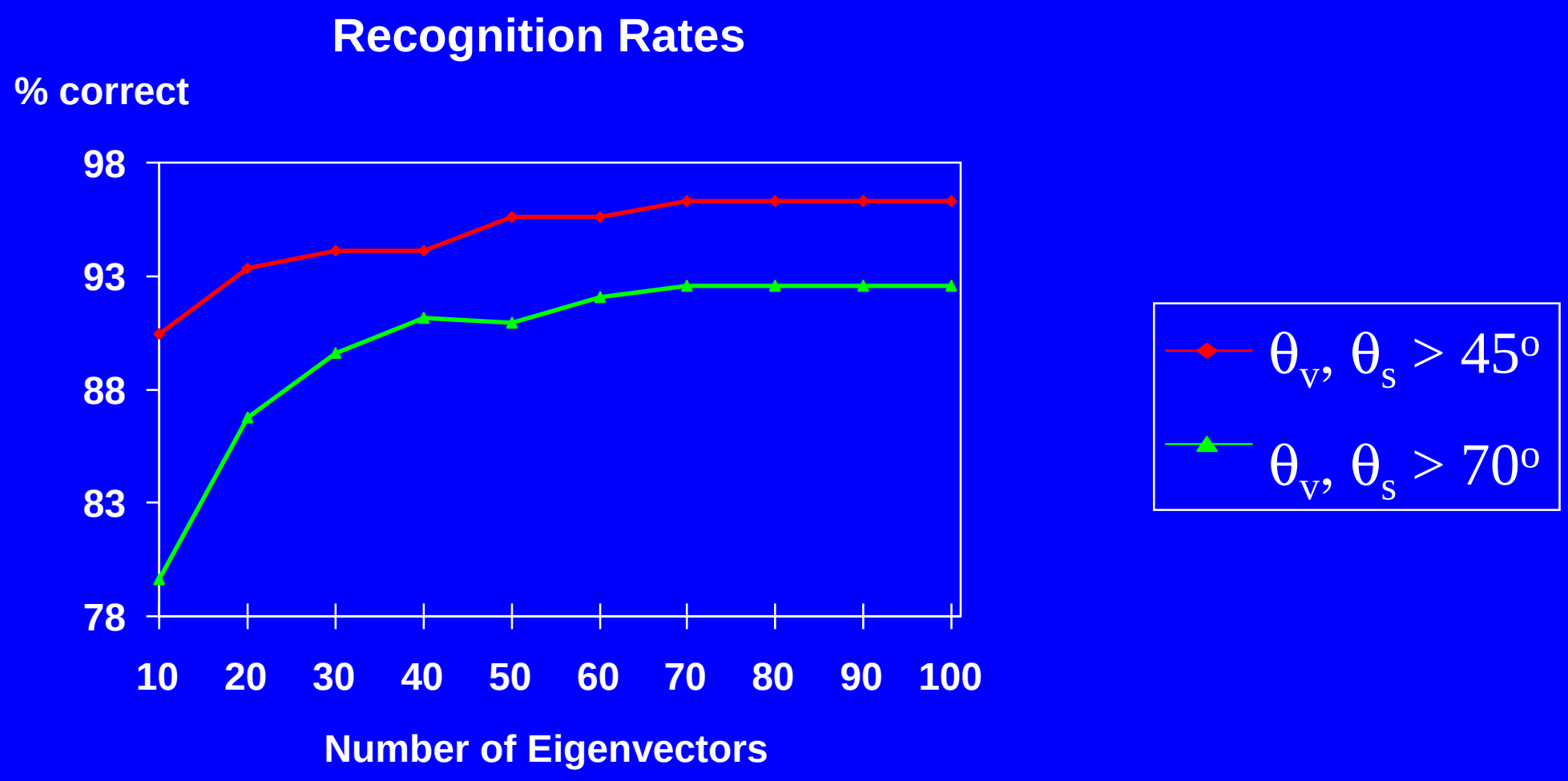


texture-MORPHING

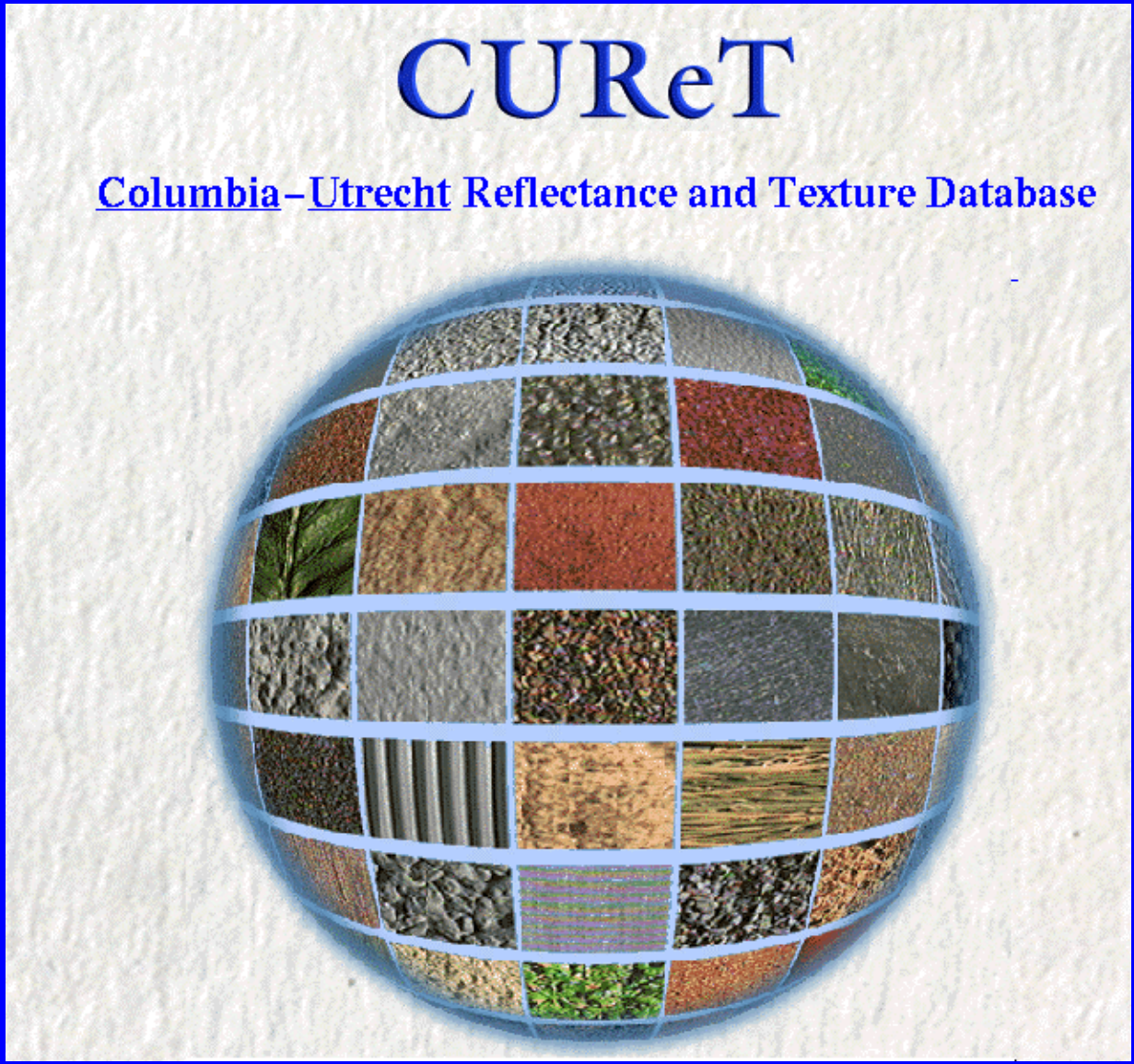
Texture Recognition

- Multiscale Conditional Histograms for 2D Texture (Heeger and Bergen 95, Debonet 98)
- PCA extension to 3D Texture:
  - no physical model
  - fewer assumptions
  - more parameters required
- SLAM software (Nene, Nayar and Murase 1994)

Recognition Experiments



Summary

- BRDF/BTF Measurements:
  - CUReT Database
- BTF Models:
  - Histogram
  - Correlation
  - PCA
- Applications:
  - Texture Synthesis
  - Texture Recognition

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