Visualisation, Rendering and Animation

2 VO / 1 KU

Heinz Mayer, Franz Leberl & Andrej Ferko

ferko@icg.tu-graz.ac.at

Local Illumination Video 2020

5.
Light-Material Interaction

Illumination models

„Computer Graphics…

- *… can be formulated as a radiometrically „weighted“ counterpart of computational geometry…*
- *… rendering is done through the application of a simulation process to quantitative models of light and materials to predict/synthesize appearance“*

D. Dobkin & S. Teller, 1999

Computer Graphics...

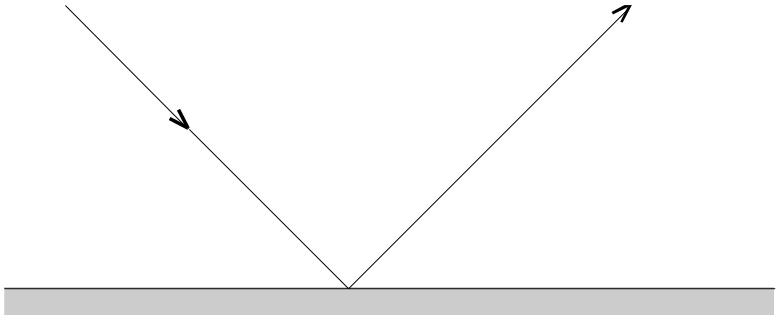
- *… must account geometry*
- *material properties: reflectance/color, refractive index, opacity, and (for light sources) emmisivity*
- *radiometry*
- *output for viewing: explicitly or implicitly psychophysics*

by D. Dobkin & S. Teller

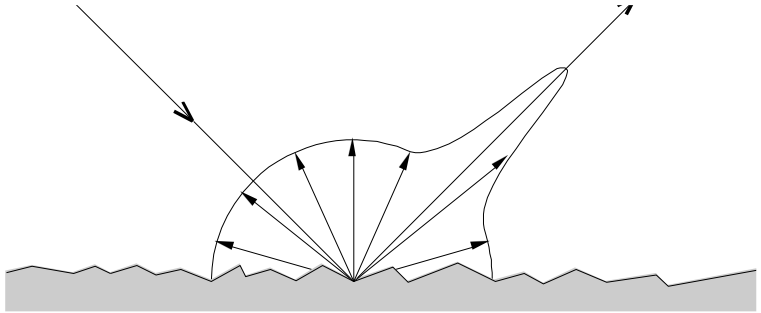
Illumination Models

- **Local Illumination Models (first order)**
  - Empiric Models (feasible)
  - Physical Models (possible, but expensive)
- **Globale Illumination Models (second order)**
  - Ray-Tracing (photons)
  - Radiosity (waves, „key is the light“)

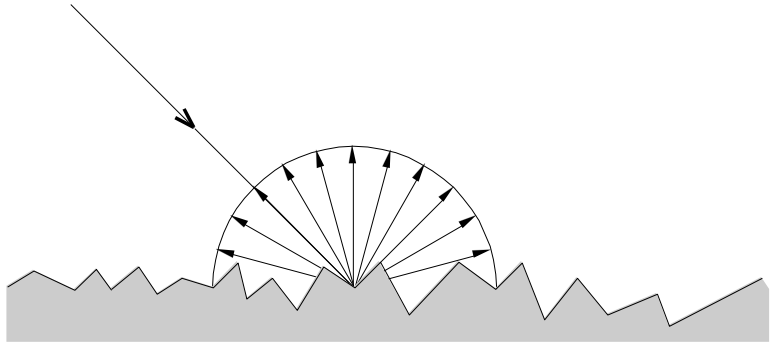
Reflexion Properties



Perfect Specular

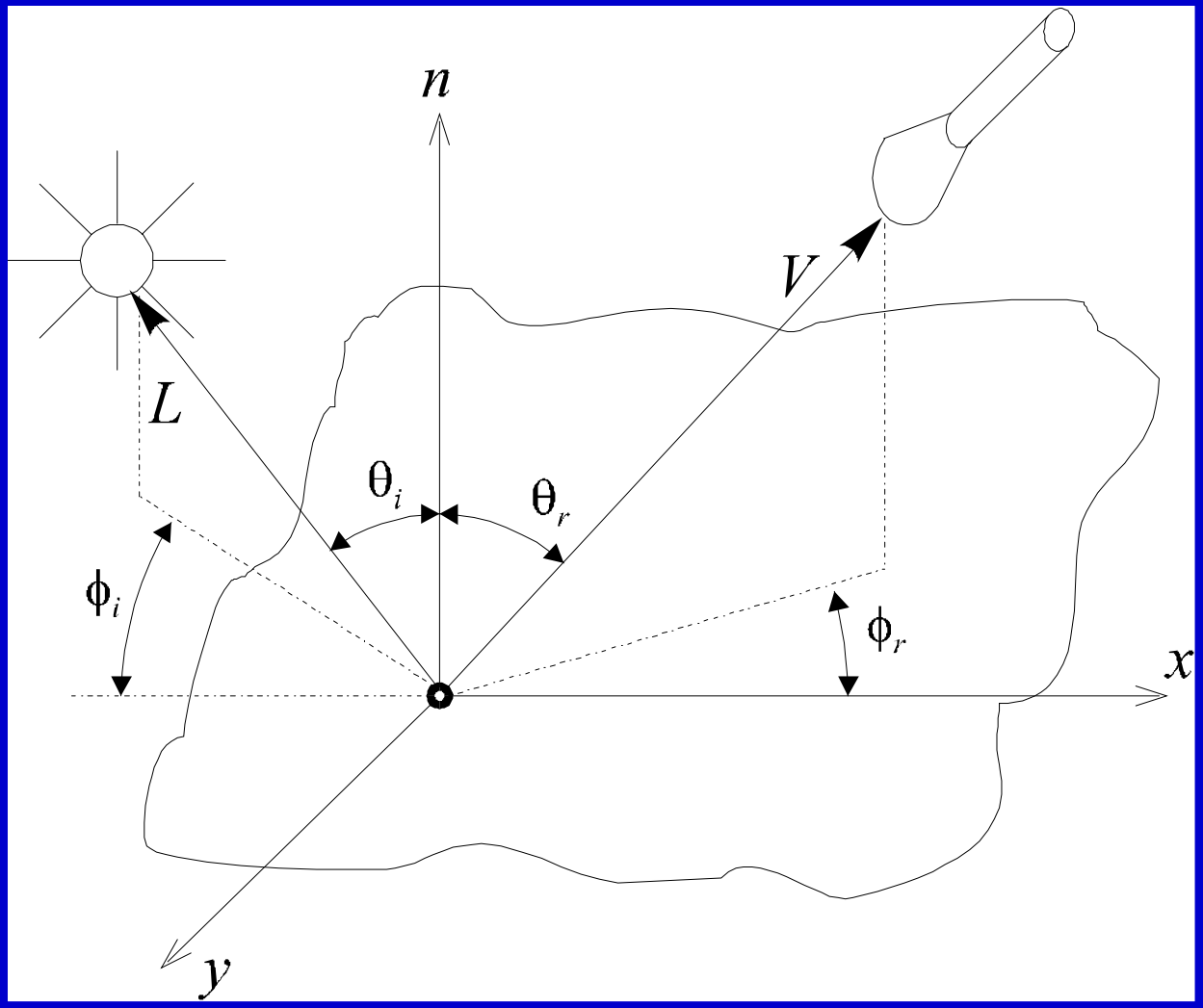


Imperfect Specular



Diffuse

BRDF



Ambient Light

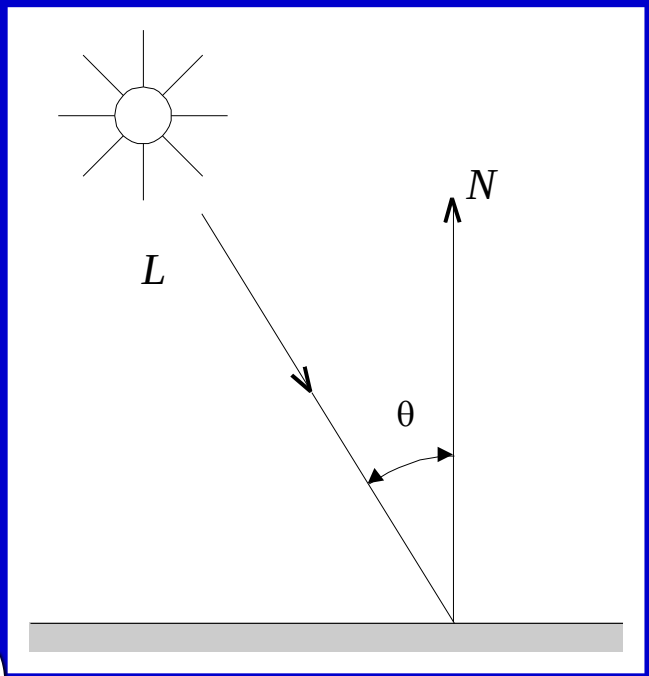
- Daylight (diffuse, undirected) lightsource
- Intensity in the given scene constant
- Multiple reflections on surfaces in the scene
- Trivial Illumination Model: $I = I_a k_a$

I_a intensity of ambient light
k_a ambient reflection coeficient

Lambertian Illumination Model

- Directional lightsource(s) added
- Diffuse reflection: independent from the camera position
- Illumination Model:

$$I = I_p\, k_d \cos\theta = I_p\, k_d\, (N \bullet L)$$



I_p Intensity of directional lightsource, point

k_d diffuse reflection coeficient

Intensity attenuation

- **Intensity contribution:**
  d_L *lightsource distance*

$$f_{att} = \frac{1}{d_L^2}$$

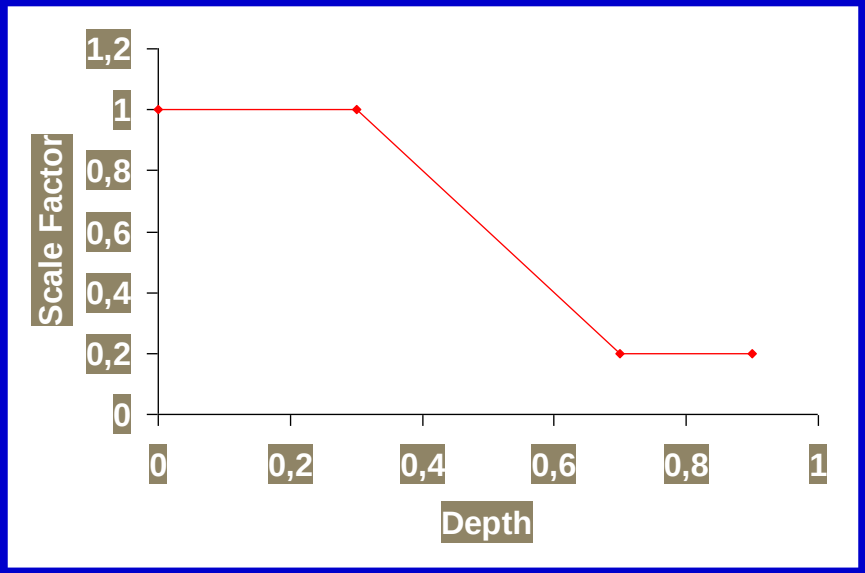
- **Alternative representation:**

$$f_{att} = \min\left(\frac{1}{c_1 + c_2 d_L + c_3 d_L^2}, 1\right)$$

- **Lighting model:** $I = I_a k_a + f_{att} I_p k_d (N \bullet L)$

Depth-cueing

- Distant objects appear darker (optionally „color-shift“, too)
- „Athmospheric perspective“



- Linear interpolation: $I' = s_0 I_f + (1 - s_0) I_b$
- Scaling between „front/backplane“

Shaders, shading models

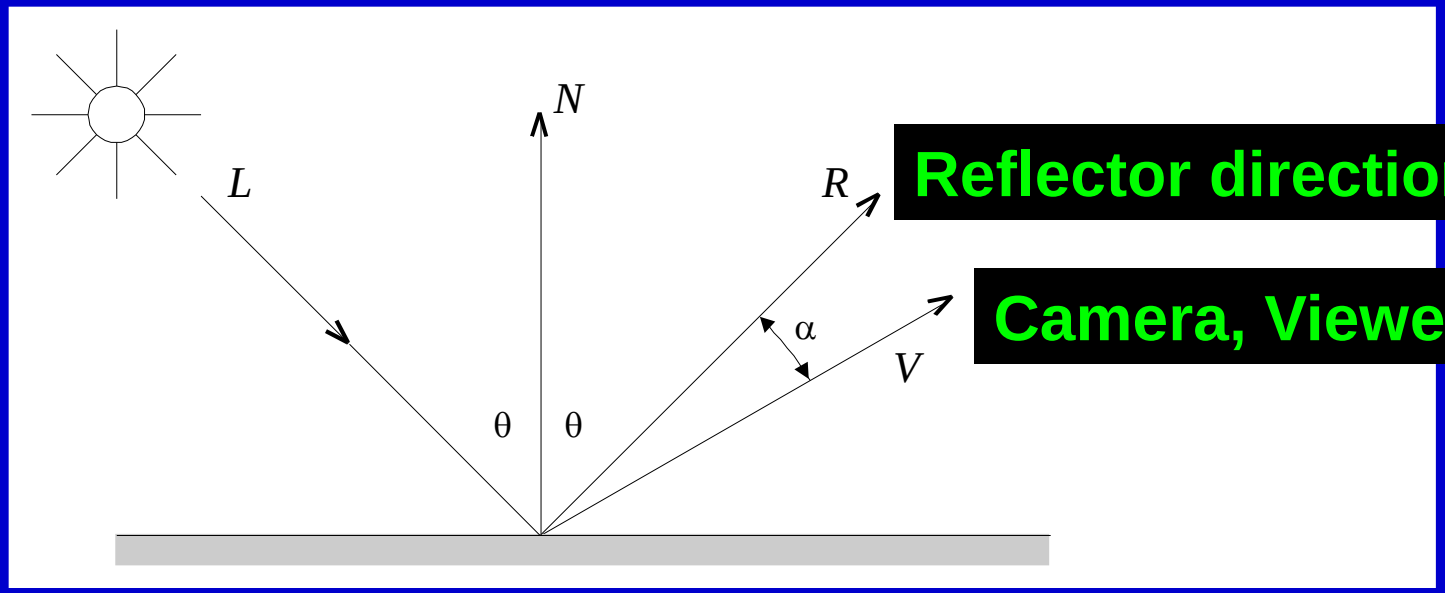
- Fill polygons after transformations and rasterization by color values
- Flat-Shading:
  - Lamberts illumination model
  - single color value for each polygon/triangle
  - advantage: very fast
  - drawbacks: Mach-bands, causing nonrealistic appearance
- Better ones: Gouraud-, Phong-Shading

Phong Illumination Model

- **Adding specular reflection (depends on camera position)**
- **New Illumination Model:**

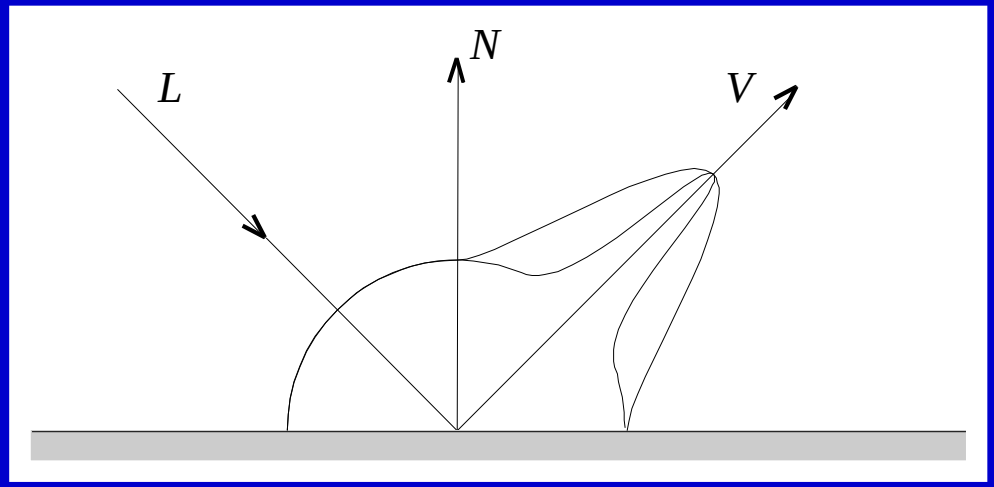
$$I = I_a k_a + f_{att} I_p (k_d \cos \theta + k_s \cos^n \alpha) =$$
$$I_a k_a + f_{att} I_p [k_d (N \bullet L) + k_s (R \bullet V)^n]$$

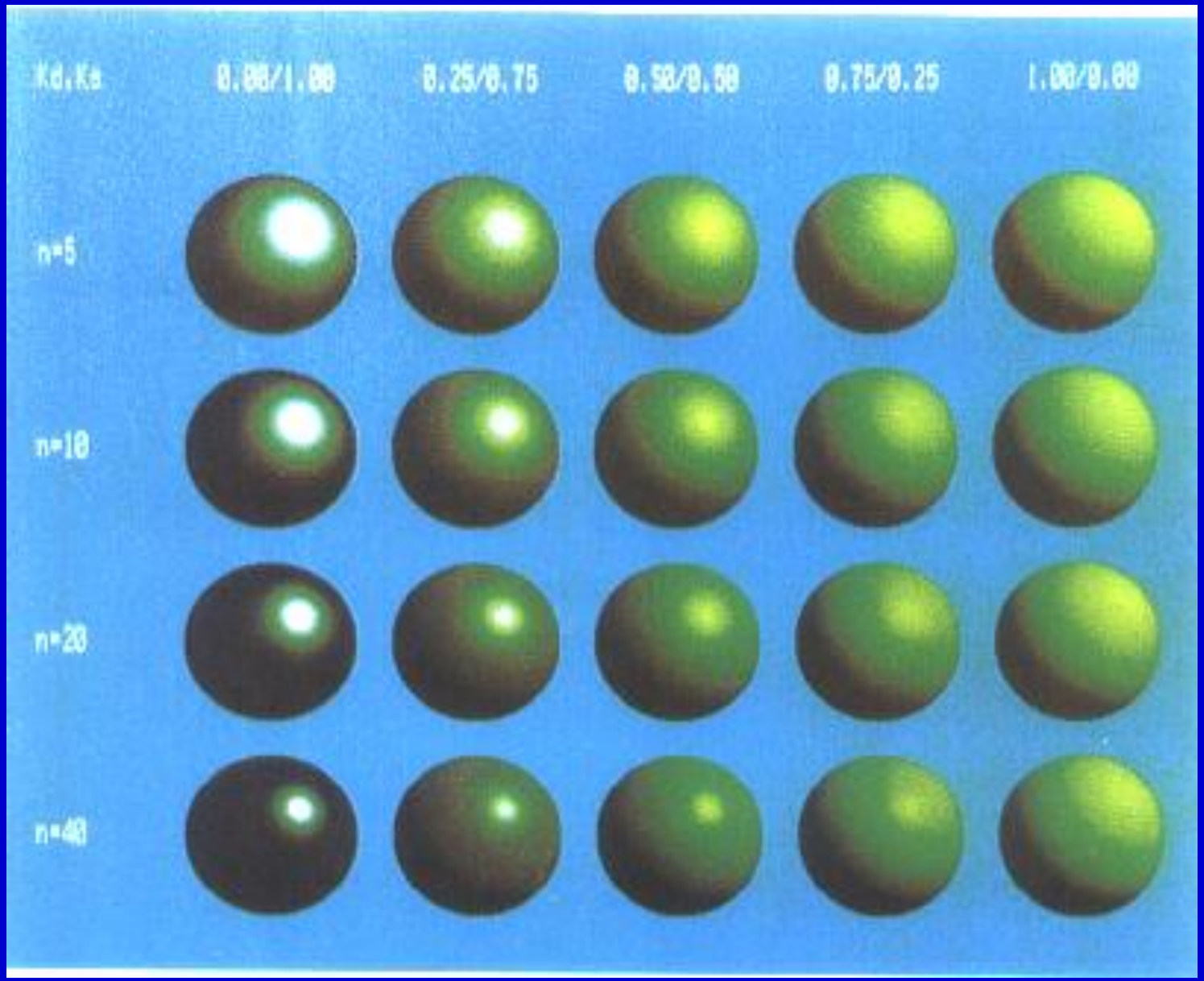
k_d **diffuse reflection coeficient**
n **(*Spiegelneigung*), „shininess“ parameter**
R **Reflected photon direction vector**
V **Viewer/Camera direction vector**



Reflector direction

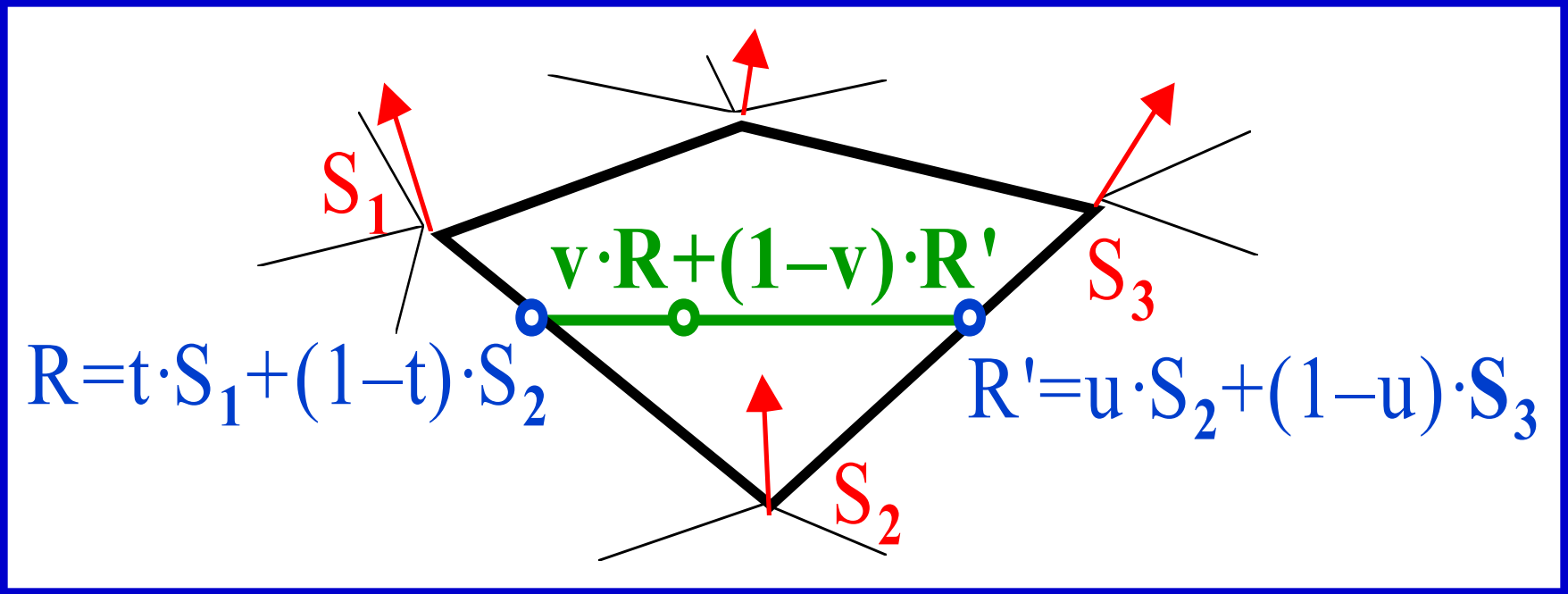
Camera, Viewer




Kd,Ks
0.00/1.00
0.25/0.75
0.50/0.50
0.75/0.25
1.00/0.00
n=5
n=10
n=20
n=40

Gouraud Shader

- Lambert / Phong Illumination Model
- Color values in the vertices
- Normal vectors given by:
  - Face normals
  - Face normals averaging
- Linear Interpolation of Color:
  - Along the edges
  - Along the „scan-lines“
- Drawback: quality
- Advantage: speed

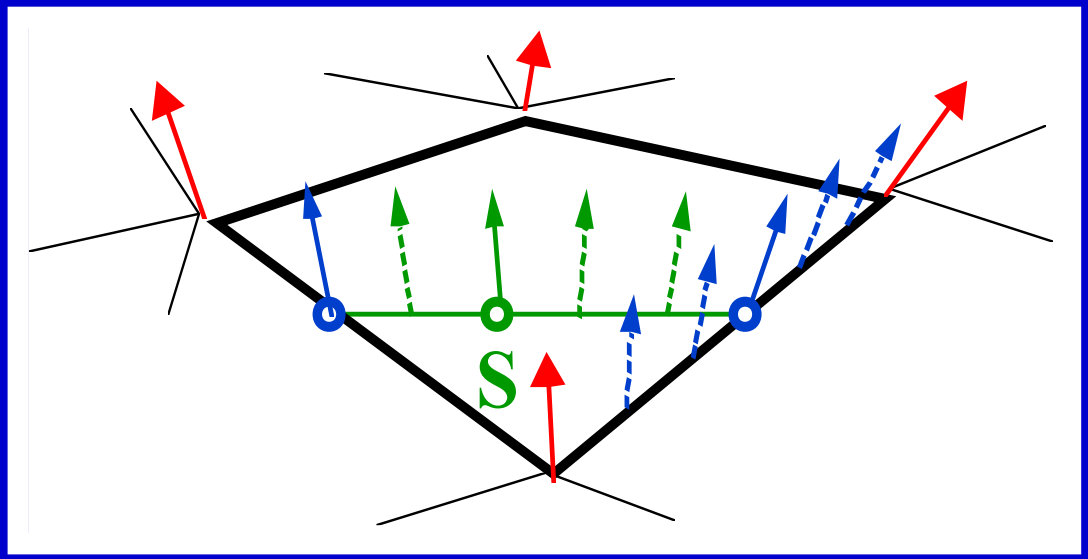


1. *find normal vectors at corners and calculate shading (intensities) there*
2. *interpolate intensities along the edges linearly*
3. *interpolate intensities along scanlines linearly*

Phong Shader, phong

- Normal vectors like Gouraud
- Linear interpolation of normal vectors instead of color value
- Color computation per pixel
- Pro: specular highlights in the given polygon rendered correctly
- Con: computationally expensive

phong



1. normal vectors at vertices
2. interpolate normal vectors along the edges
3. interpolate normal vectors along scanlines and calculate shading (intensities) for every pixel

Interpolation Problems

- Polygon-Silhouette
- Interpolations artefacts from the given „scanline“ - direction
  - Orientation dependent
  - Perspective dependent
- Not representative vertex no
- Hint: refine the triangulation (more complex model)

Rendering Polygonal Scene

- 1. Extract polygons from the database
- 2. Transform to WC and VRC
- 3. Backface culling and visibility
- 4. Clip against the visible volume
- 5. Projection of clipped polygons
- 6. Shading by incremental shader:
  - 1. Rasterize,
  - 2. Depth and visibility, (z-buffer)
  - 3. Shading (constant, Gouraud, Phong…)

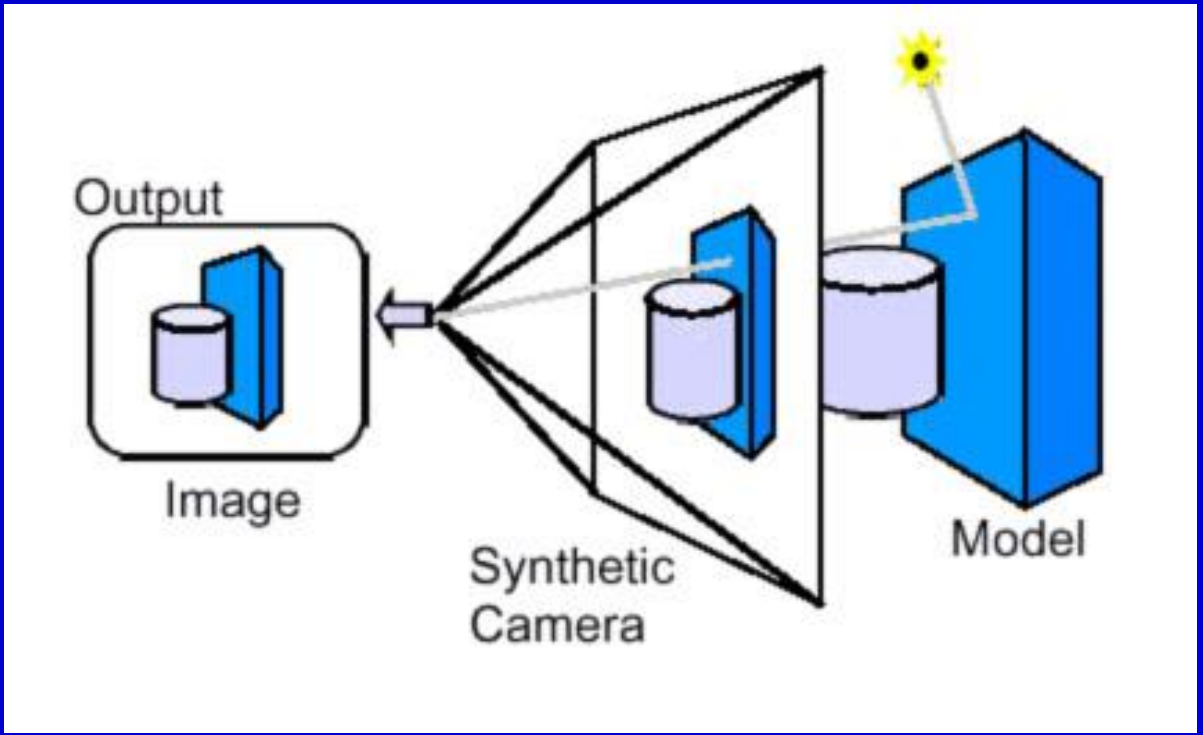
Local Illumination Summary

- Empirical shading models
  - constant, Gouraud, Phong...
- Ambient, diffuse and specular reflection
- Light rays only
- Polygonal scenes
- Rendering summary (polygonal case)
- More: transparency, bumpy surfaces, textures, global illumination, animation...

Definition of Light Sources

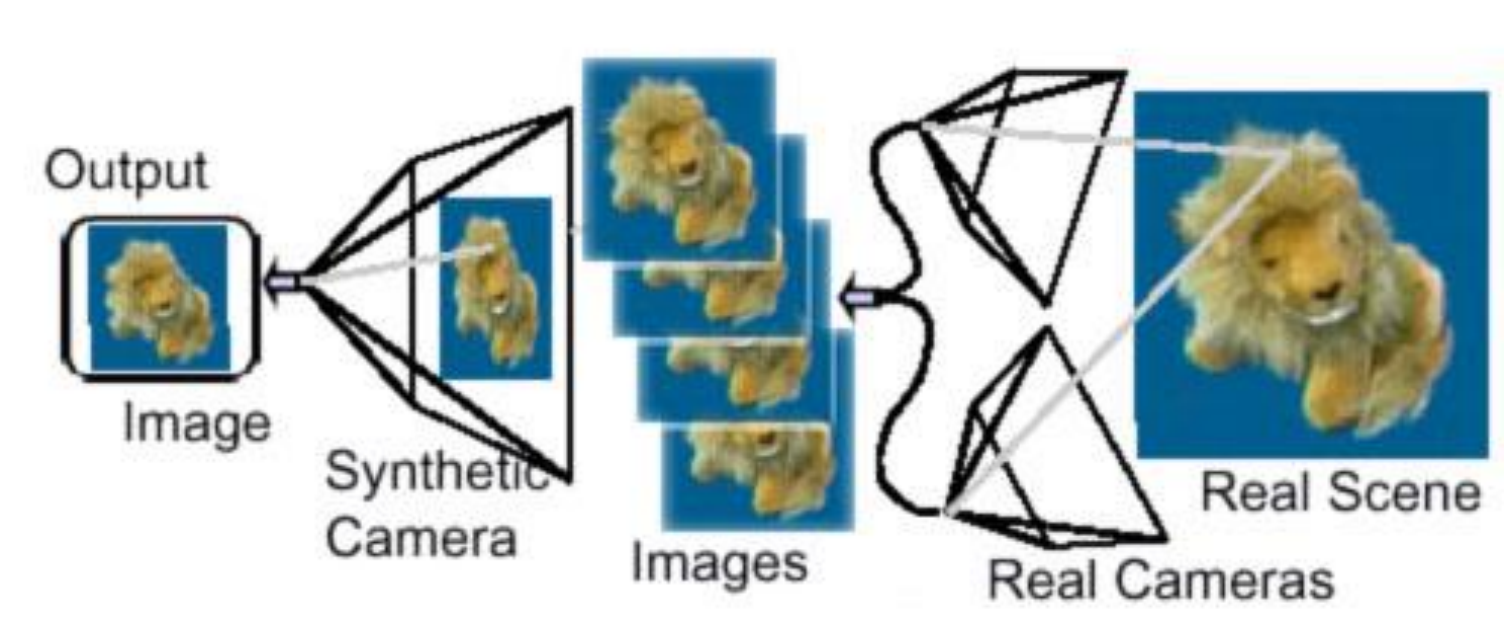
- Point light source
- Multiple point sources… area
- 4 abstract lightsources - ambient, directional, point, flood
- intensity/fog = I/(a*d*d…*d + b)
- flood: powers of cosine (Phong)

Model-Based-Rendering



The real scene built with geometric objects

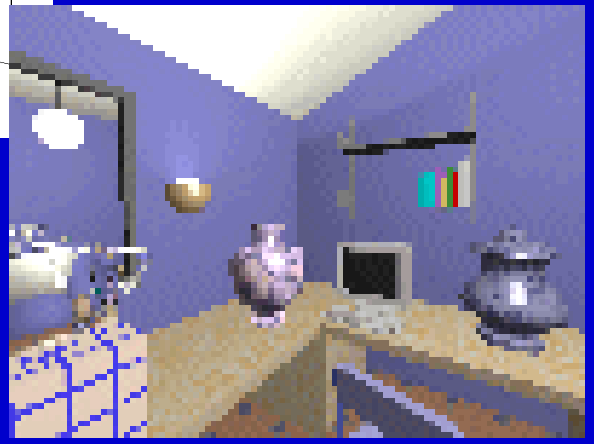
Image-Based-Rendering



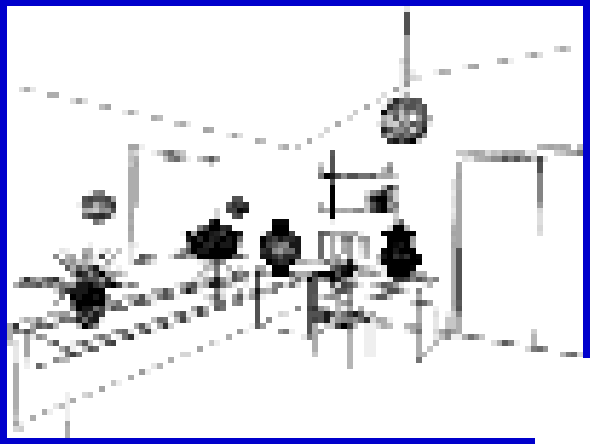
Varied views on real scene combined to the new one

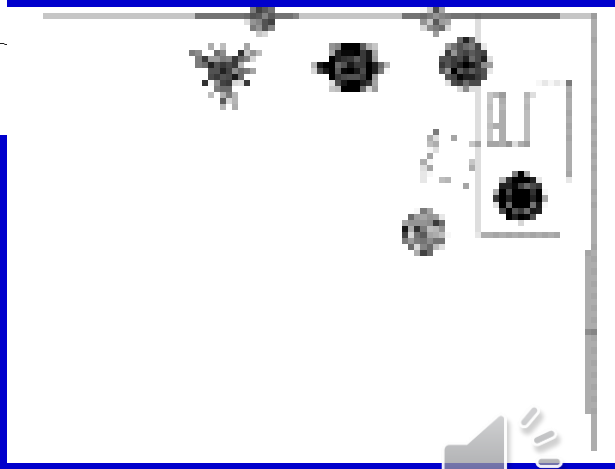
Main Scene

- ***Orthographic projection and the nearest perspective view***



- ***Wireframe, hidden line removal, and hidden line from above***





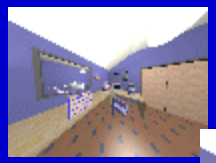
- ***Front and back clip planes, using front clip to see inside geometry***

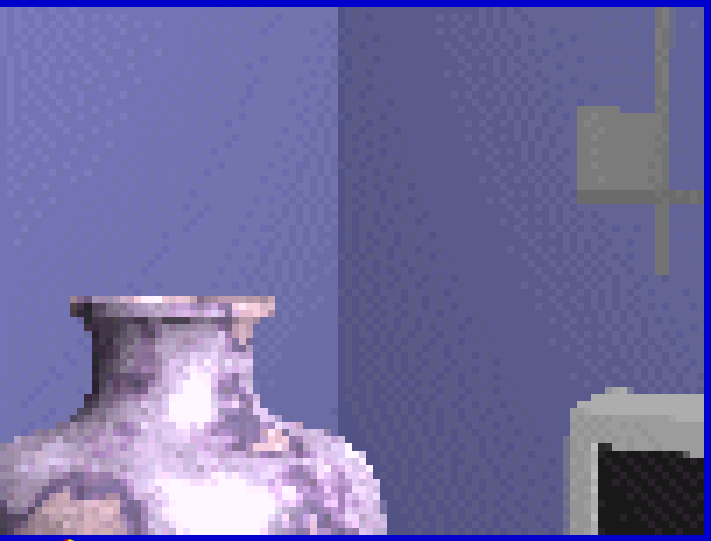
- ***FOV varying from 20 to 160 degrees (8 images)***



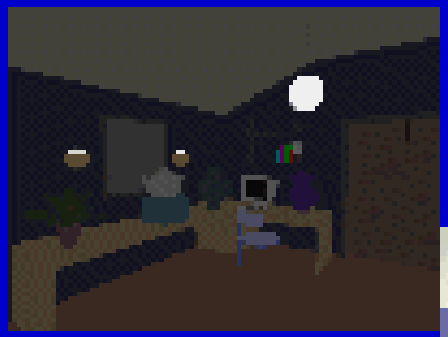






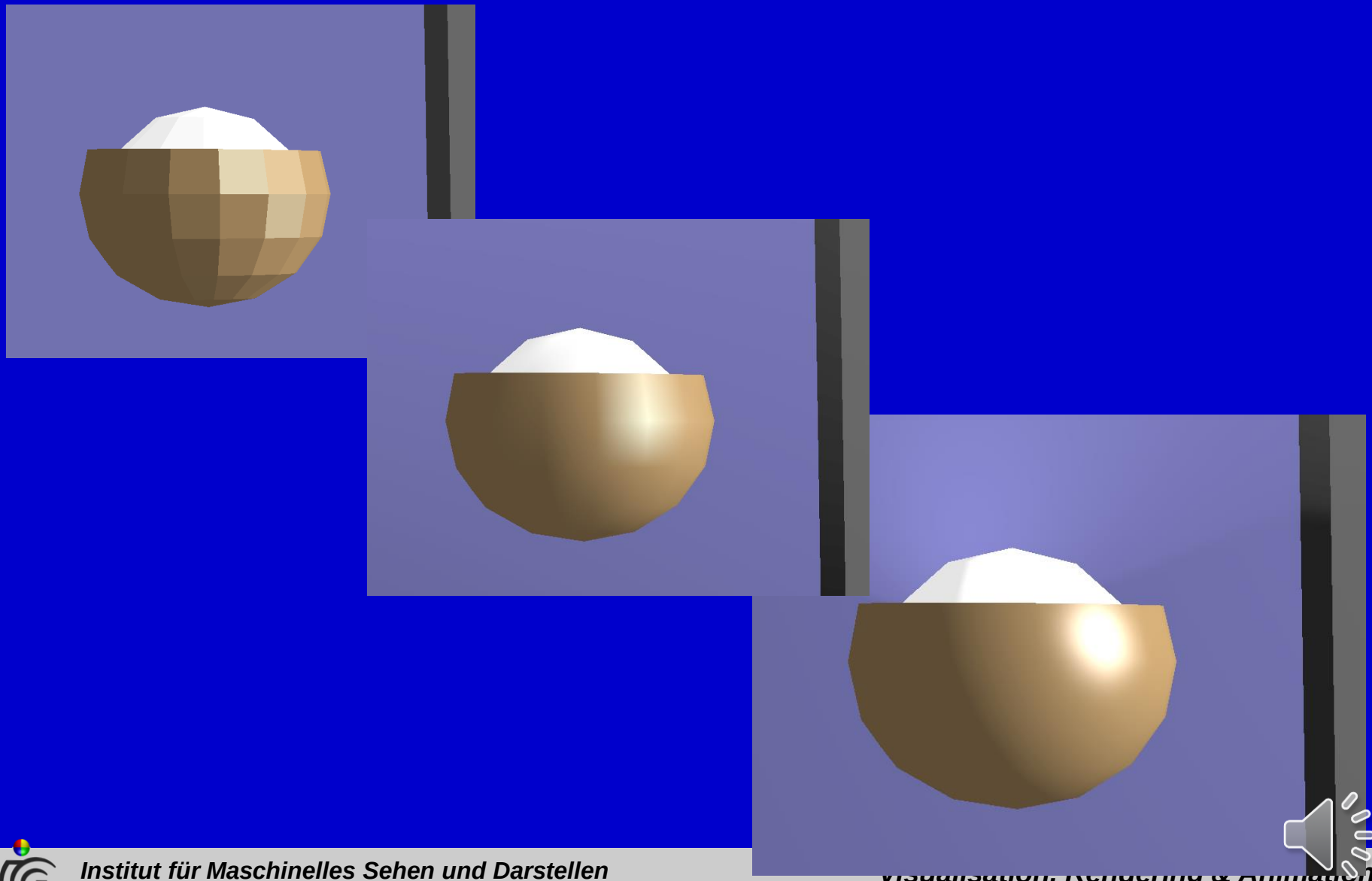



- ***Phong shaded scene: ambient, amb.+diffuse, amb.+diff.+specular***



- ***Flat, Gouraud, and Phong shaded scene***

- ***Flat, Gouraud, and Phong shaded scene - zoom in***



Material Realism

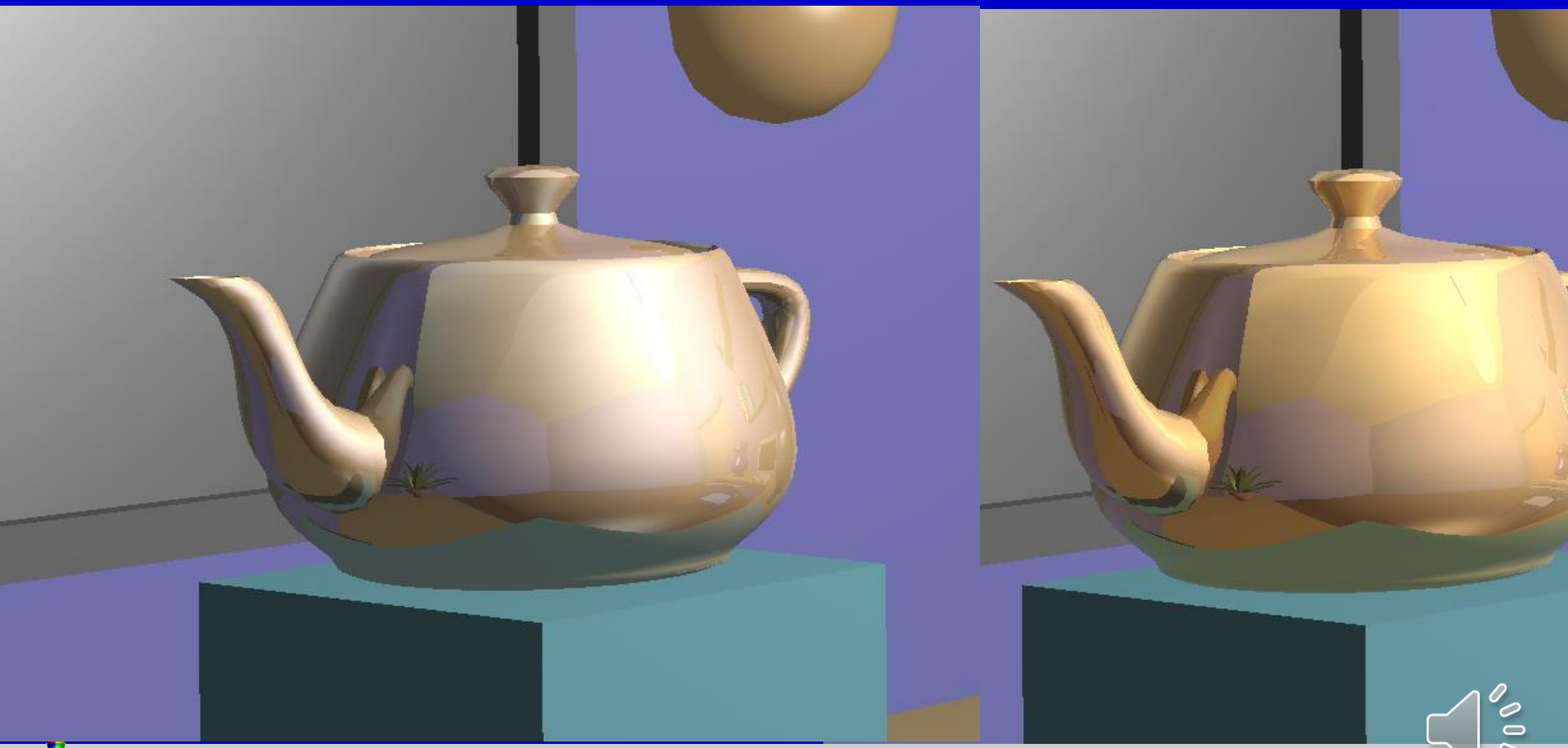
by A. Watt (2000)

selection and layout A. F. (2002)

Materials used (5*5 array)

- iron steel stainless steel machine steel antique brass
- polished brass copper bronze nickel zinc
- lead cast aluminiummachined aluminium magnesium gold
- burnished gold polished gold silver silver plate tungsten
- platinum chromium chromium plate graphite mercury

- *Difference of polished brass & gold ...*
  - *… hard to achieve by Phong shading*



5.
Light-Material Interaction

Shadow generation

Visualisation, Rendering and Animation

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