Illumination, Phong, Gouraud

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Illumination and Shading

- Shading: model the apparence of the object under the influence of light
  - reflection
  - refraction
  - transparency
- Object material model
  - heuristic models (=hacks): Phong
  - physically based: Torrance-Sparrow

Map of the lecture

- Material models:
  - ambient light
  - diffuse light
  - specular light
  - Phong model
- Interpolation:
  - Gouraud shading, Phong shading
  - Problems with interpolation

Shading

- Objects under the influence of light
- Assume point light source
- Excludes any interaction between objects:
  - shadows, reflections, color-bleeding
- Compute color at every point

Ambient Light

- Color does not depend on the position, only on the object:

  $$I = Ia\ ka$$

- Ia : ambient light
- ka: ambient reflection coefficient
- Very crude model
  - object shape is invisible
  - but used nevertheless to hide other models artefacts

Ambient Light

Increasing ka

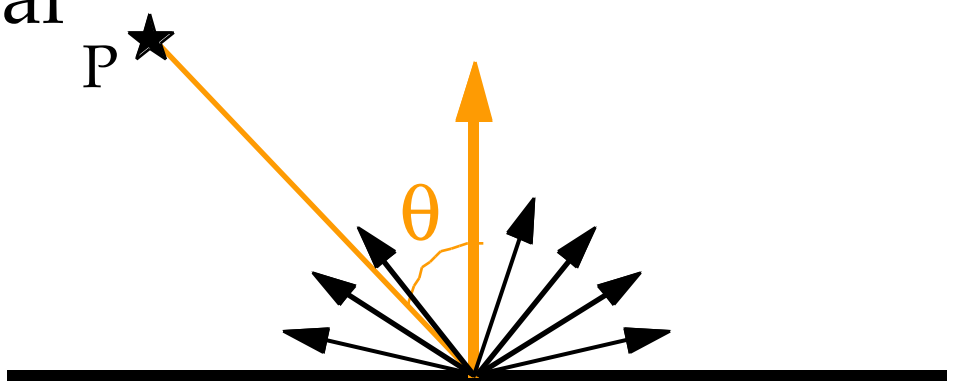
Diffuse Reflection

- aka mate reflection
- Light from the light source is sent in every direction
- Object aspect independant from viewer position
- Only depends on relative position of light source:

$$I = I_p k_d \cos\theta$$

Diffuse Reflection

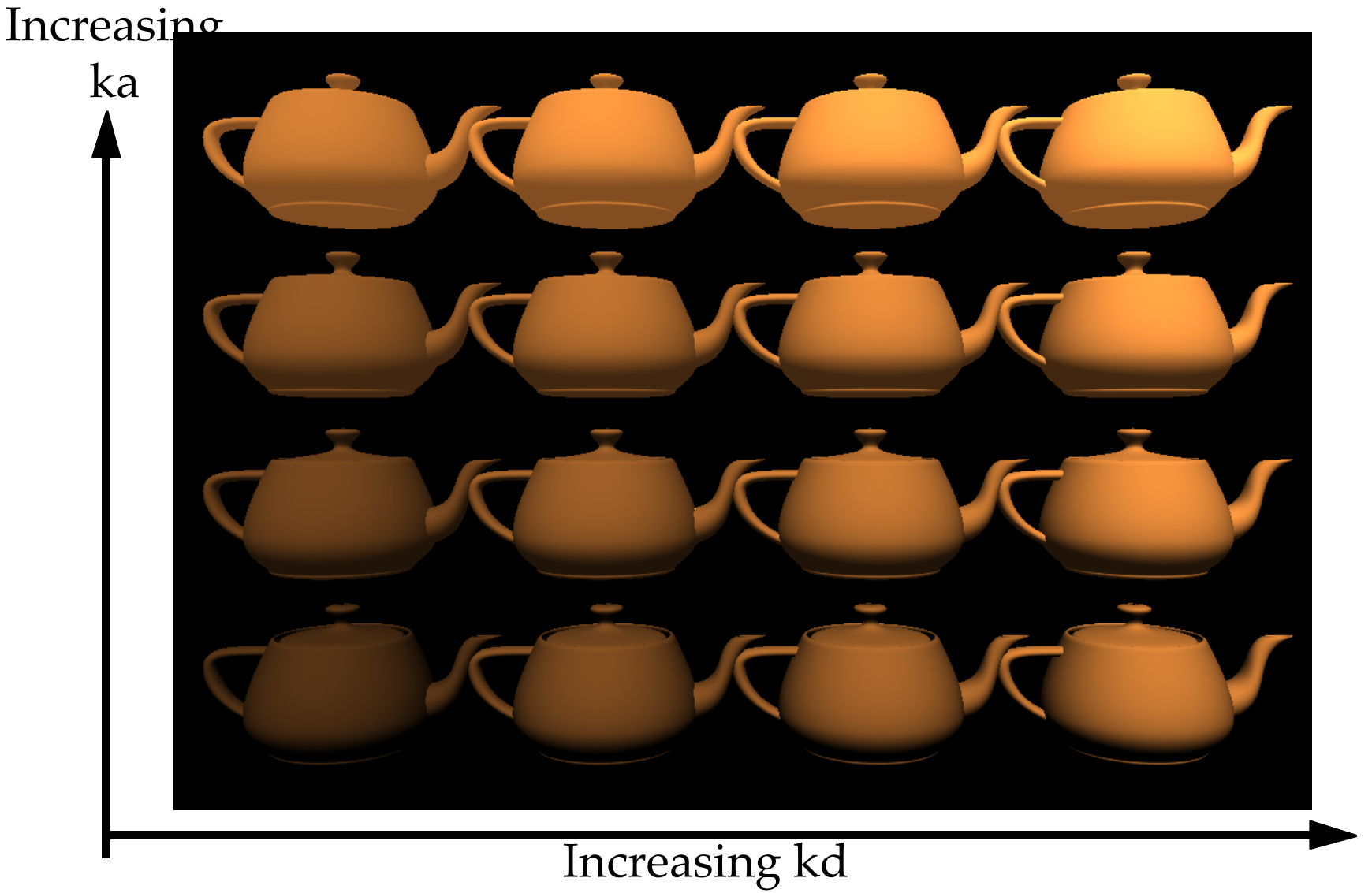
- $I = I_p k_d \cos\theta$
- I_p : point light source
- k_d: diffuse reflection coefficient
- θ : angle between light source and normal



Diffuse reflection alone

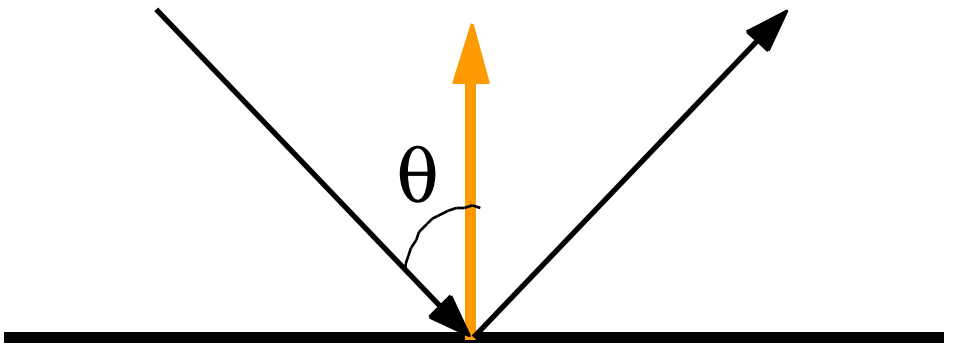
Increasing kd (ka=0)

Diffuse + ambient



Specular reflection

- Snell's law:
  - light reaching the object is reflected in the direction having the same angle:

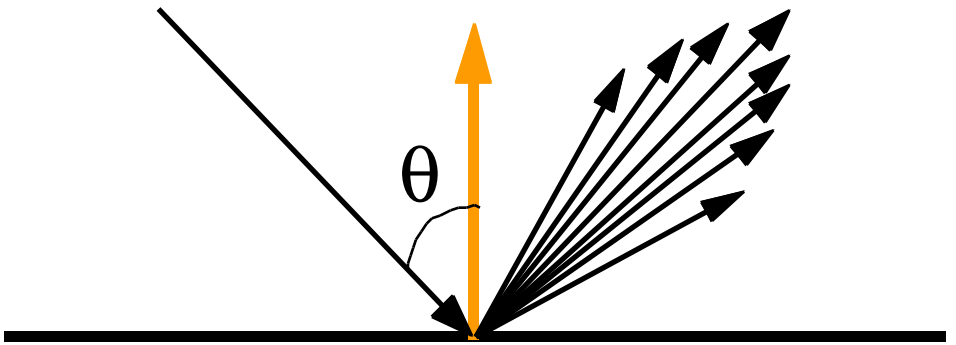


Specular Reflection problem

- With point light source, effect is visible only at one point on the surface
- Useful for indirect illumination (reflection and shadows)

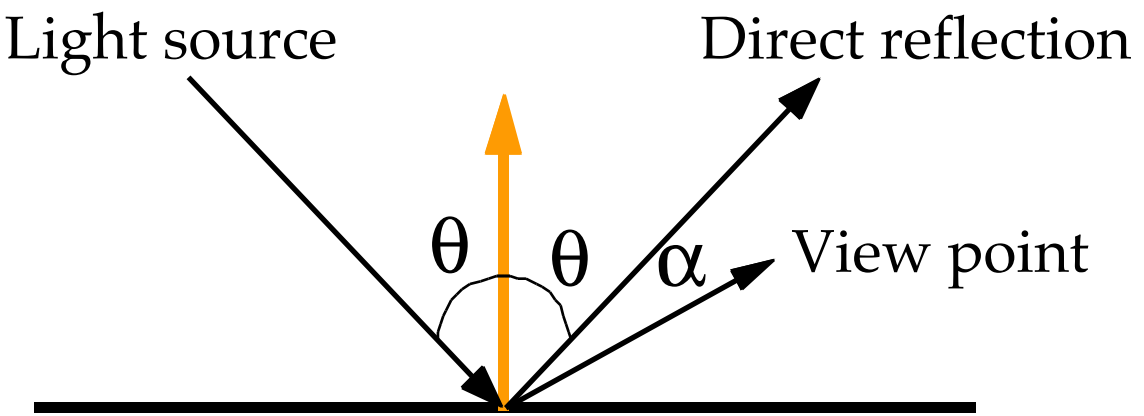
Phong Model

- Imperfect specular reflector:

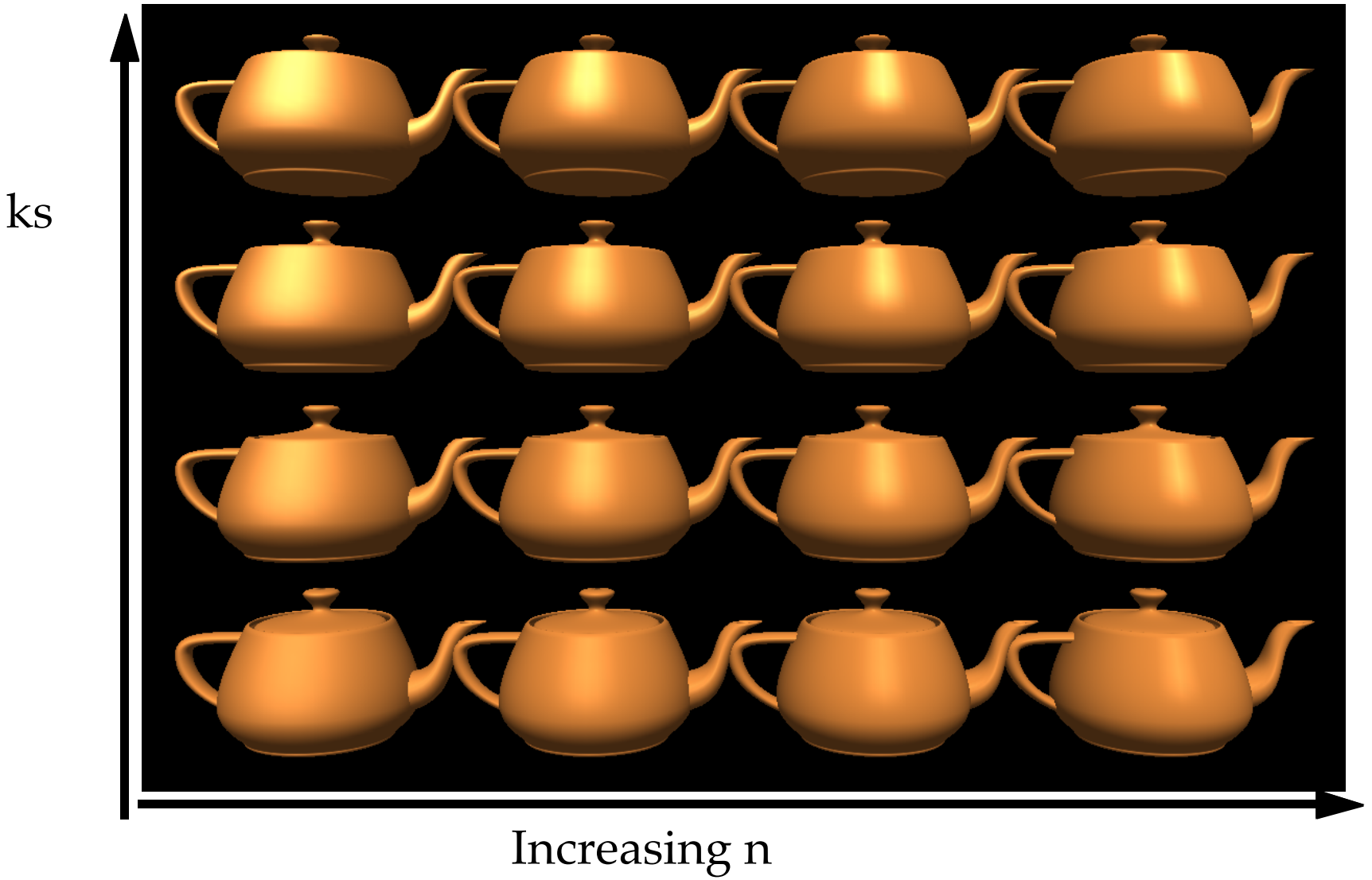


Phong Model

- $I = Ip\ k_s\ (\cos \alpha)^n$



Phong Model

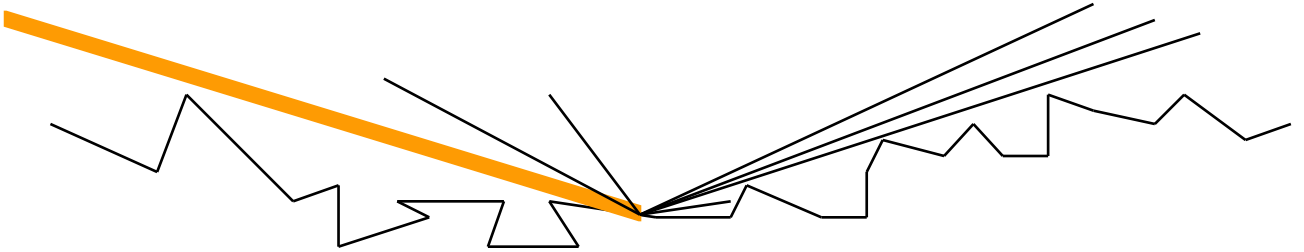


Torrance-Sparrow Model

- Phong model has no physical meaning
- Happens to look good, but we don't know why
- How to relate it to physical properties (roughness)?
- Cook-Torrance-Sparrow Model
  - related to physical properties
  - but complex

Torrance-Sparrow Model (2)

- The surface is modelled as micro-facets:



- Light incoming on the facets is scattered, reflected, obscured…
- Depends on the geometrical distribution of the facets

Torrance-Sparrow

- Geometrical factor expressing the facets effects
- Depends on light and viewpoint direction: $\rho(\theta,\phi,\theta',\phi')$
- No simple function like $(\cos\theta)^n$
- Approximates very well physical effects (shininess, roughness…)

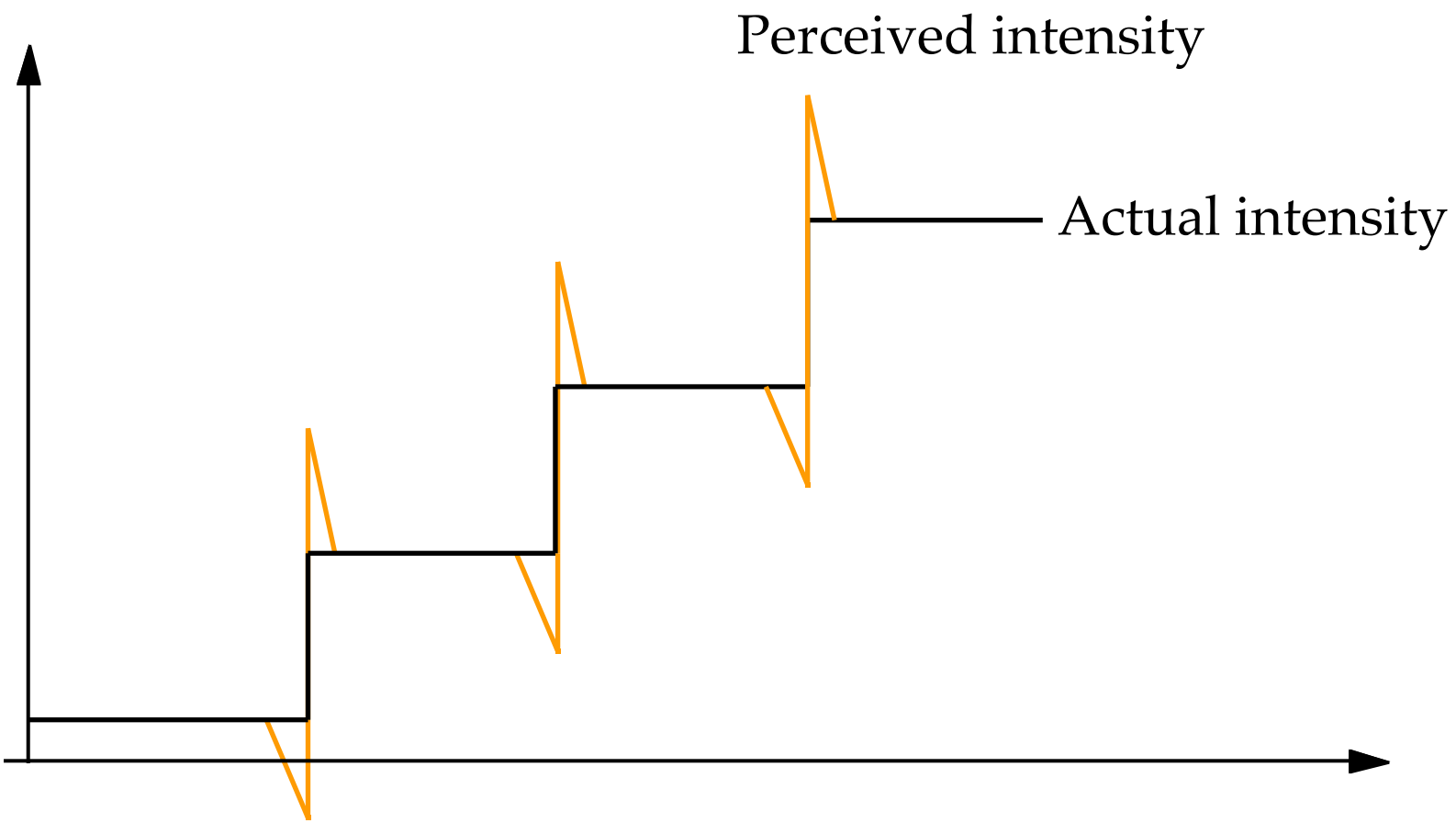
Shading a whole object

- We have seen only shading computations for a single point
- We could compute shading information for all visible points in the scene
  - What??
- Constant shading for each patch
- Interpolated shading across the patch
- Mach banding effect

Mach Banding

- The eye is a complex receptor
  - can adapt from a starry night to a bright halogen lamp
- The eye exagerates changes in intensity and changes in slope of intensity
  - called Mach banding effect
- Problem if we compute a constant value for each polygon

Mach banding

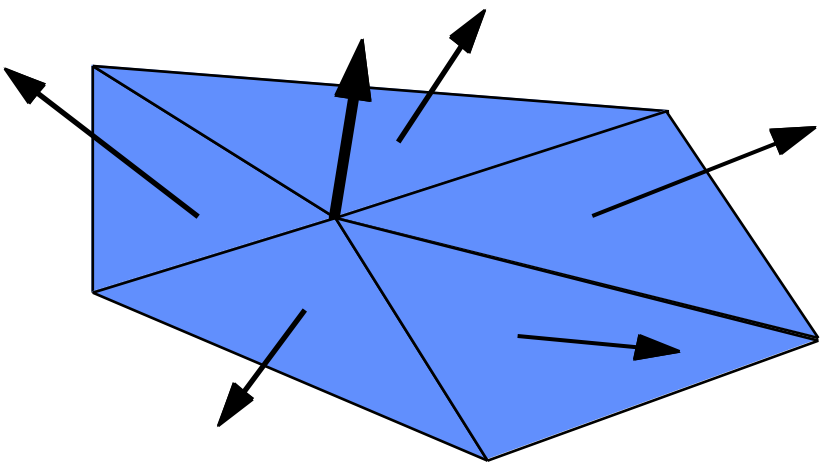


Interpolated Shading

- Gouraud: compute color value for each vertex, then interpolate
- Start with a polygonal mesh
- What is the normal at a vertex?

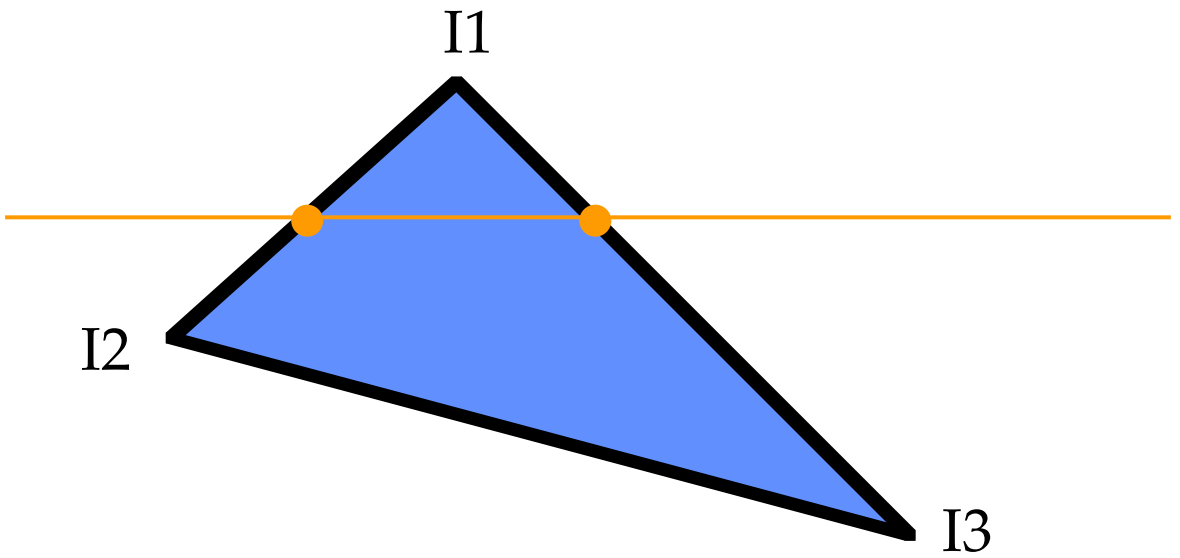
Gouraud shading

- Normal at one vertex:
  - interpolate normals at neighbouring patches



Gouraud Shading

- Having the normal at one vertex:
  - compute color value at this vertex
- Then, interpolate on each scan line:

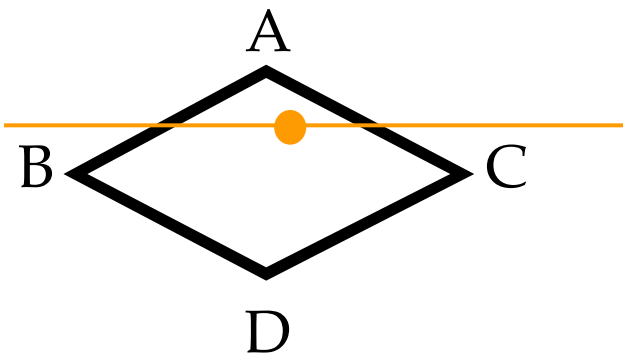


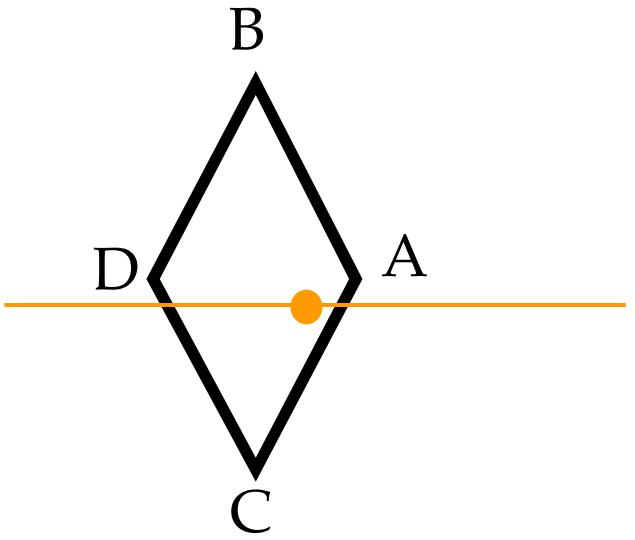
Phong Shading

- Instead of interpolating the colors, interpolate the normals
- Interpolation of the normals on each scan line too
- Much slower than Gouraud, but looks better

Problems with interpolation

- Polygonal silhouette
  - add more patches
- Orientation dependant:





Shadows and transparency

- So far, only one object
- Objects may interact with each other
- Local *vs.* global approach:
  - local: simpler, faster. Mostly tricks.
  - global: models everything. More sophisticated.
    - ray-tracing
    - radiosity

Local computation of shadows

- Visible surface determination from the light source
- Surfaces invisible from the light source are in the shadow
  - but still lit by ambient term, in order to appear on the picture.

Local transparency

- Each polygon is colored using not only its color, but that of the polygon immediately behind
  - implies knowledge of relative order
    - depth-sort algorithm
    - scan-line algorithm
    - specifically excludes Z-buffer

Texture mapping

- Change the surface local behaviour to model complex objects
- Map an image onto the surface of the object
- Correspondance between (u,v) space of the image and (s,t) space of the object

Shading: conclusion

- Realism has its price
- Trading between quality and time
- Most of the time, hacks that happen to look good
- Algorithm simplicity is crucial:
  - Gouraud shading and texture mapping can be done in hardware, or optimized in assembly language