Computer Graphics (CS 543)
Lecture 9c: Soft Shadows & Fog

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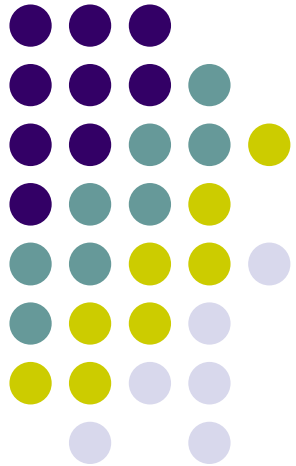
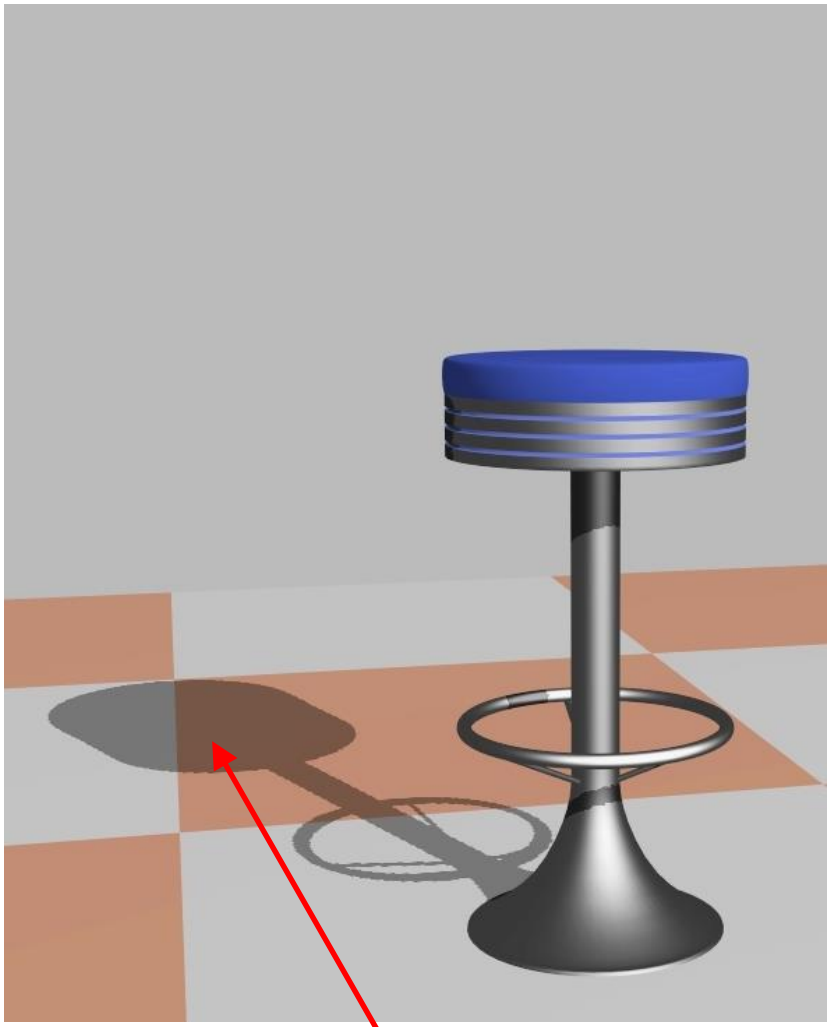
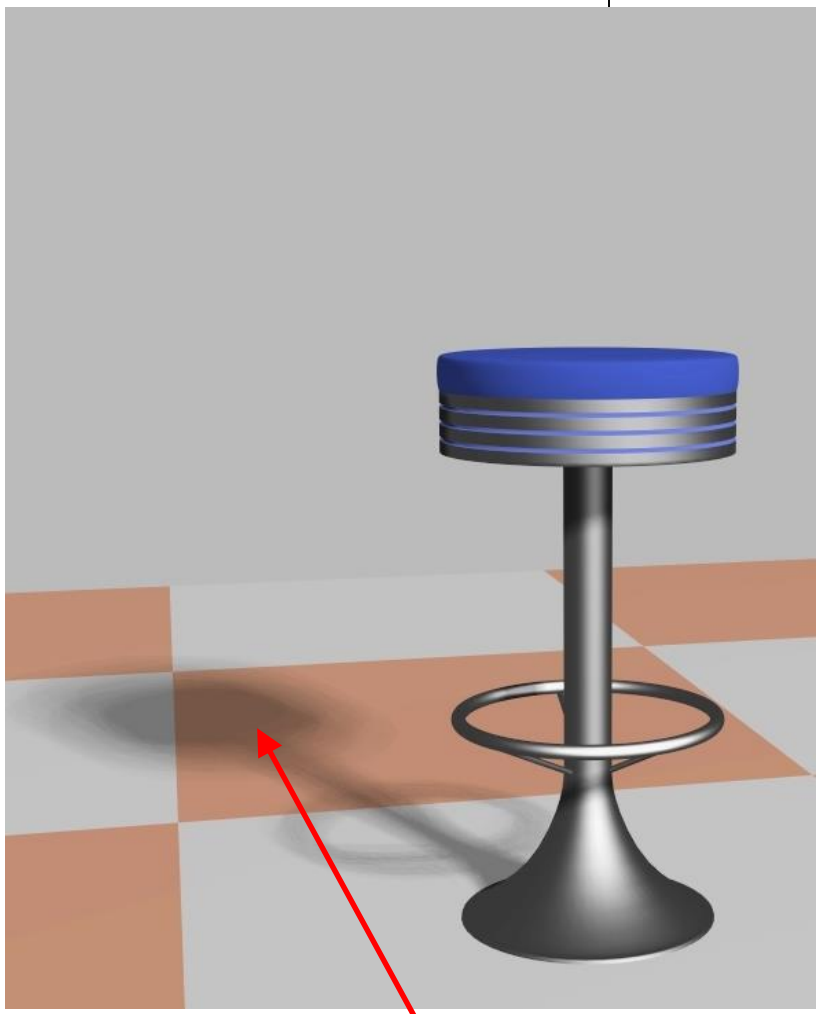


Example: Hard vs Soft Shadows



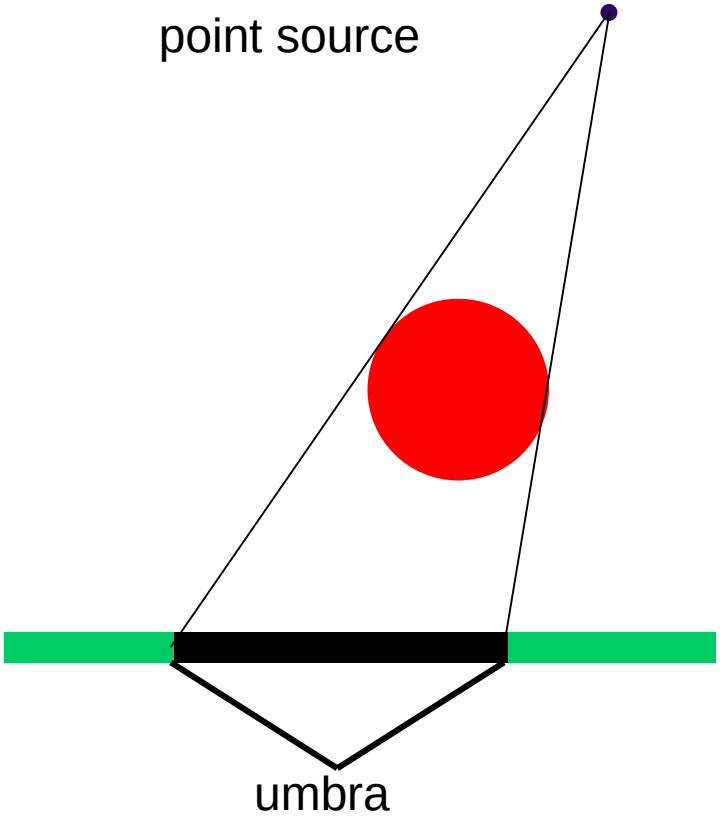
Hard Shadow

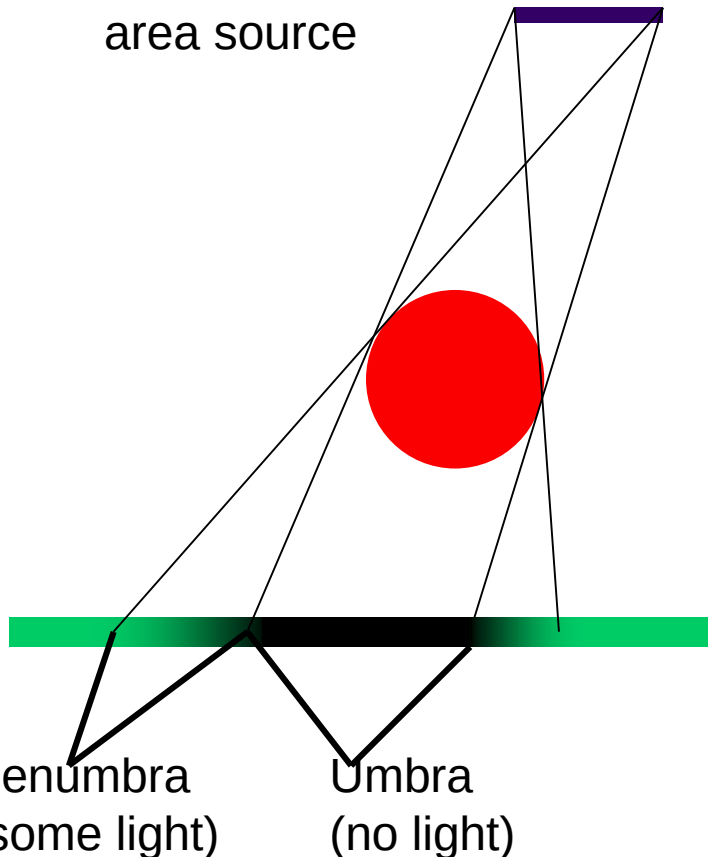


Soft Shadow

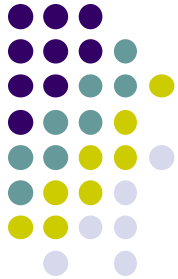
Definitions

- Point light: create hard shadows (unrealistic)
- Area light: create soft shadows (more realistic)

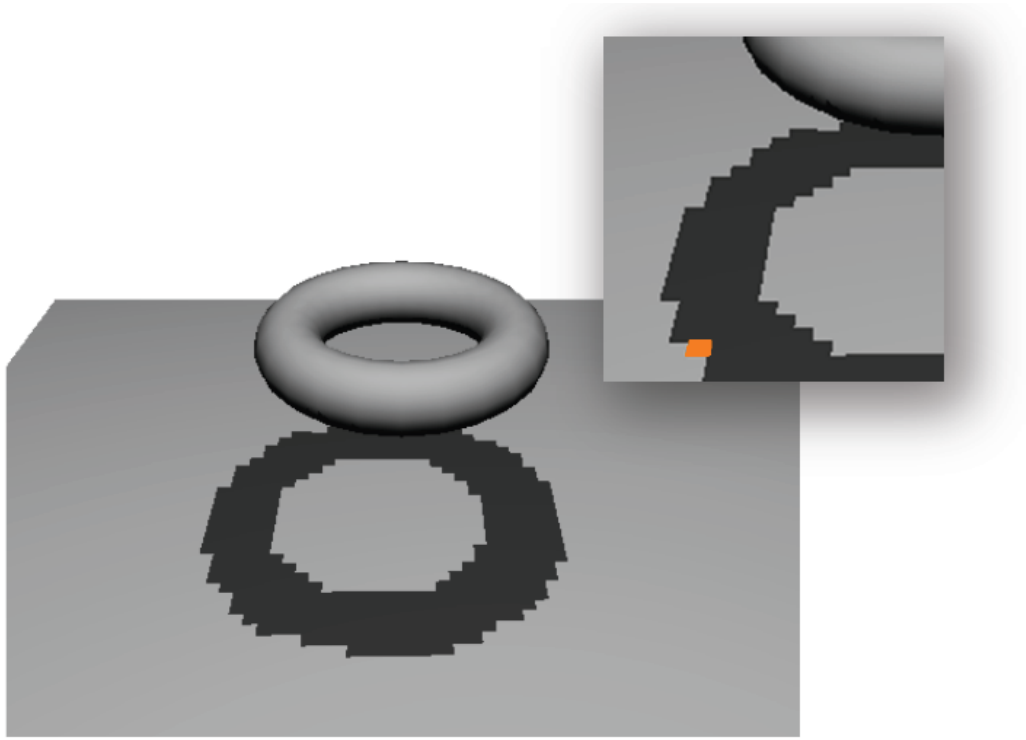




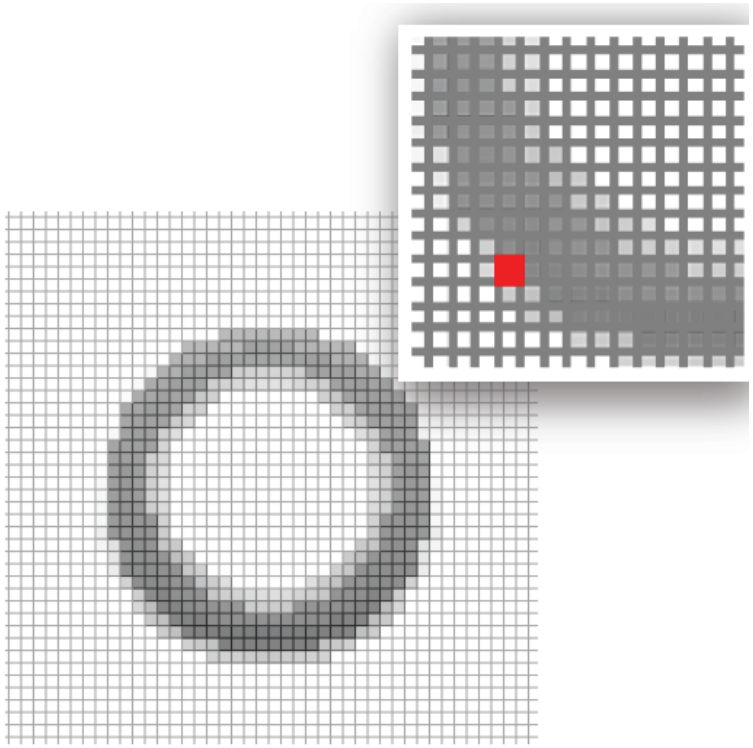
Shadow Map Problems



- Low shadow map resolution results in jagged shadows



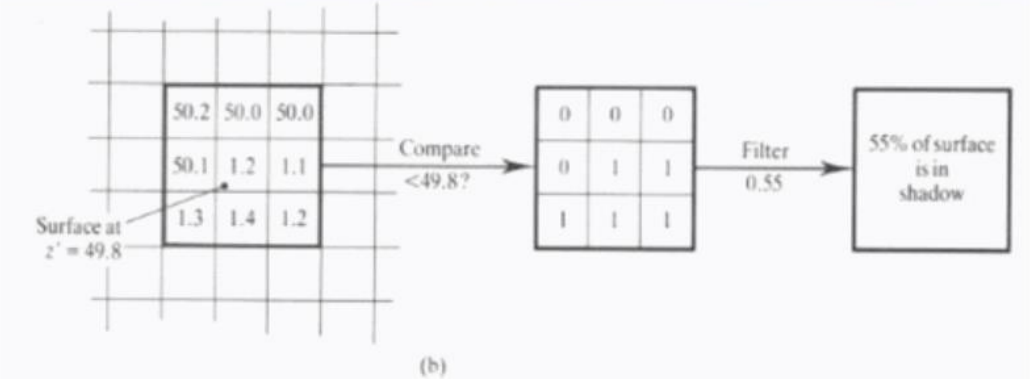
from viewpoint



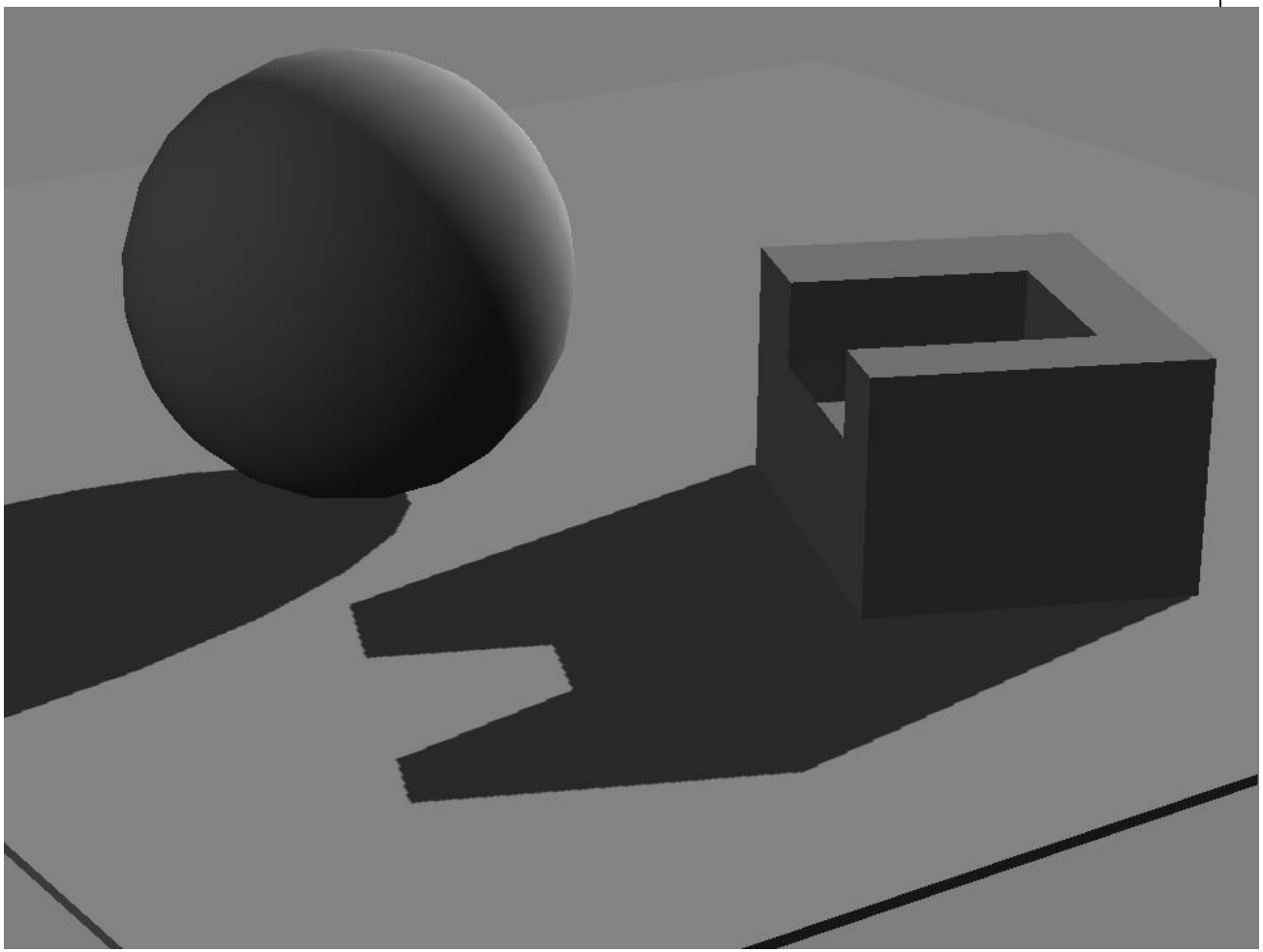
from light

Percentage Closer Filtering

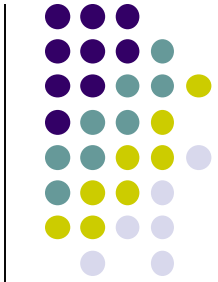
- Blend multiple shadow map samples to reduce jaggies



Shadow Map Result

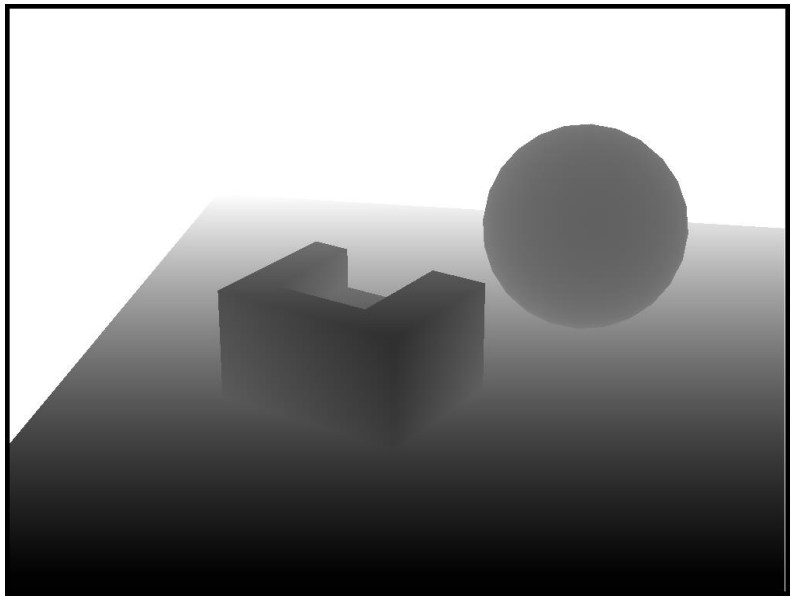


Arbitrary geometry



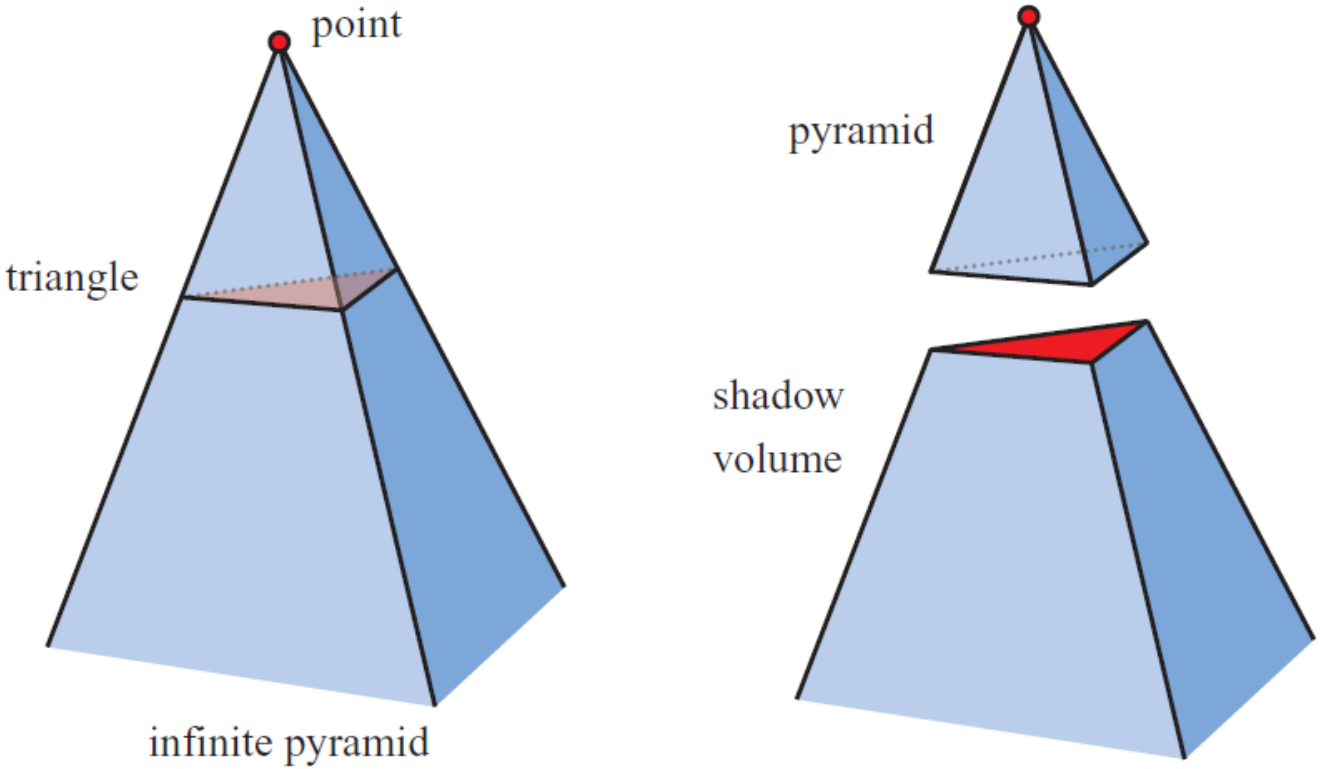
- Shadow mapping and shadow volumes can render shadows onto arbitrary geometry
  - Recent focus on shadow volumes, because currently most popular, and works on most hardware
- Works in real time…
- Shadow mapping is used

  in Pixar's rendering software



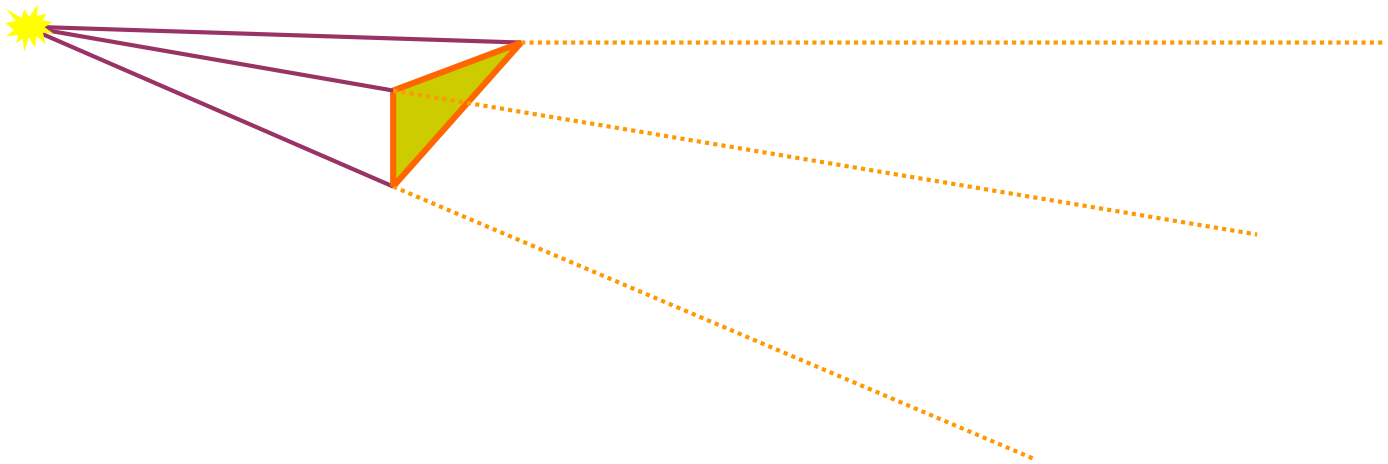
Shadow volumes

- Most popular method for real time
- Shadow volume concept



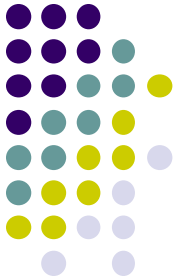
Shadow volumes

- Create volumes of space in shadow from each polygon in light
- Each triangle creates 3 projecting quads



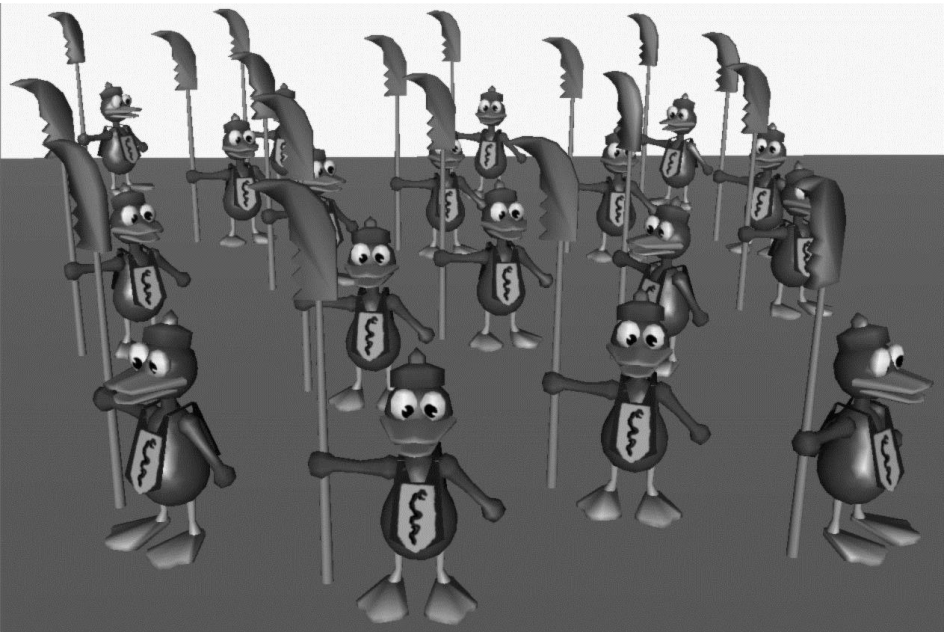
Shadow Volume Example

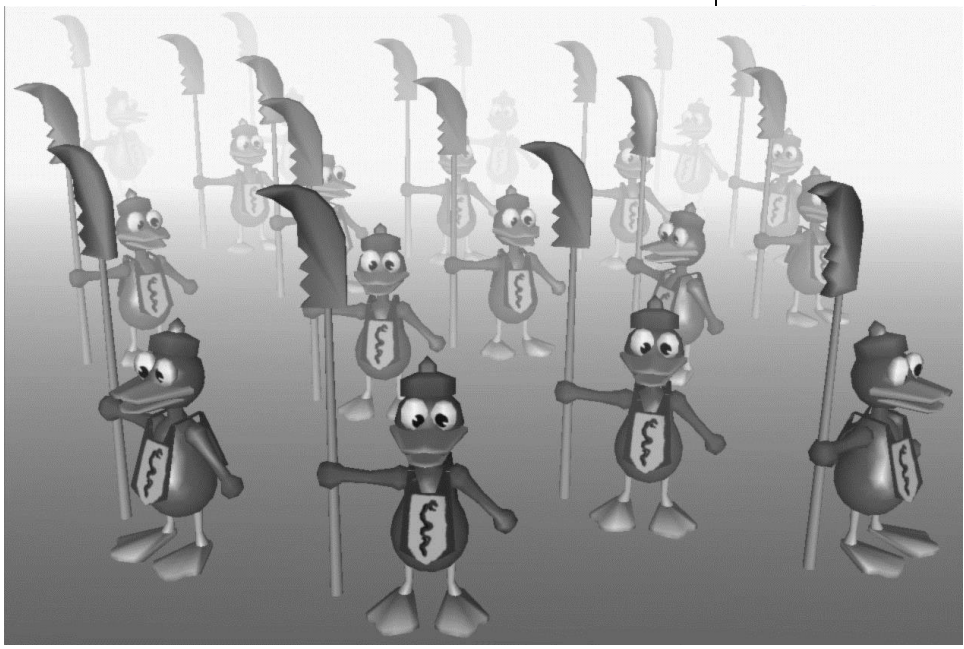
Image courtesy of NVIDIA Inc.



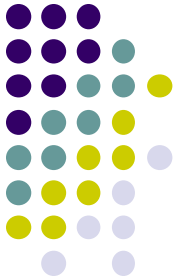
Fog

Fog example





- Fog is atmospheric effect
  - Better realism, helps determine distances



Fog

- Fog was part of OpenGL fixed function pipeline
- Programming fixed function fog
  - **Parameters:** Choose fog color, fog model
  - **Enable:** Turn it on
- Fixed function fog **deprecated!!**
- Shaders can implement even better fog
- **Shaders implementation:** fog applied in fragment shader just before display

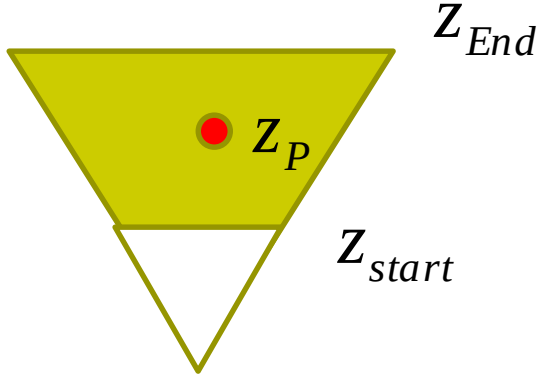
Rendering Fog

- Mix some color of fog: $\mathbf{c}_f$ + color of surface: $\mathbf{c}_s$

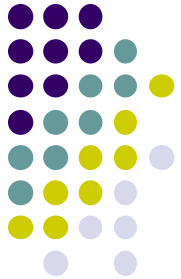
$$\mathbf{c}_p = f\mathbf{c}_f + (1-f)\mathbf{c}_s \qquad f \in [0,1]$$

- If *f = 0.25*, output color = 25% fog + 75% surface color
  - *f* computed as function of distance *z*
  - 3 ways: linear, exponential, exponential-squared
  - Linear:

$$f = \frac{z_{end} - z_p}{z_{end} - z_{start}}$$



Fog Shader Fragment Shader Example



$$f = \frac{z_{end} - z_p}{z_{end} - z_{start}}$$

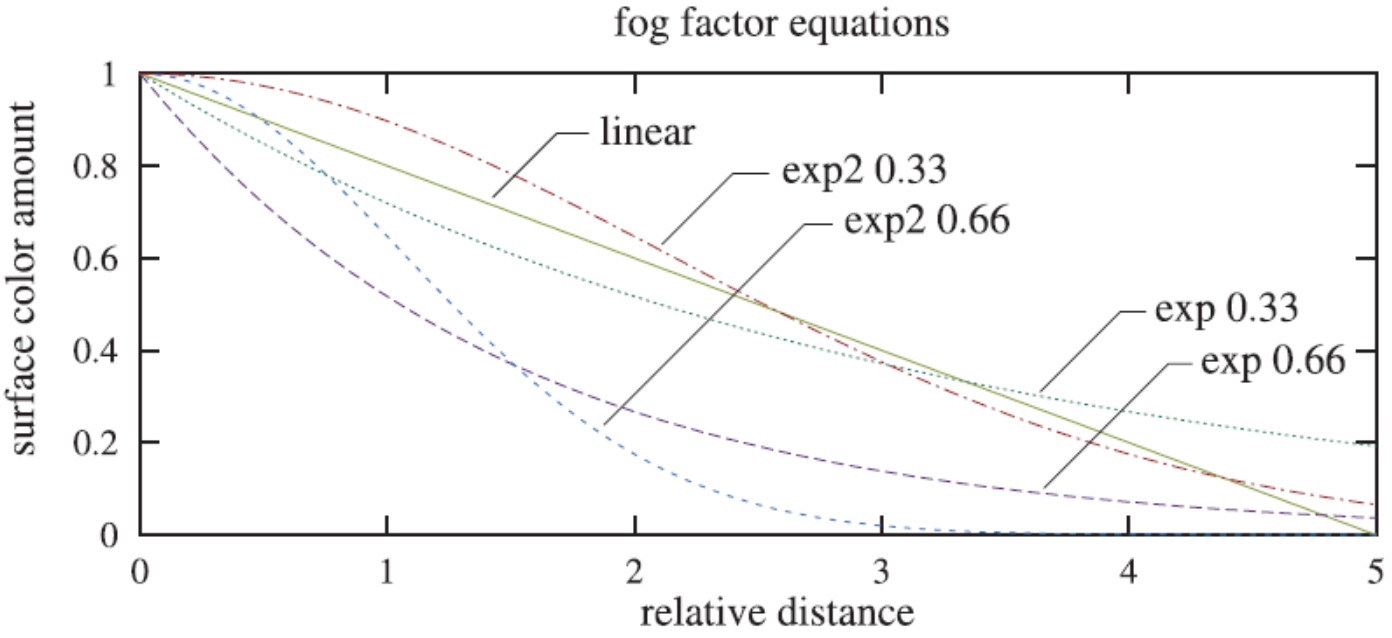
```
float dist = abs(Position.z);
Float fogFactor = (Fog.maxDist - dist)/
                                Fog.maxDist - Fog.minDist);
fogFactor = clamp(fogFactor, 0.0, 1.0);

vec3 shadeColor = ambient + diffuse + specular
vec3 color = mix(Fog.color, shadeColor,fogFactor);
FragColor = vec4(color, 1.0);
```

$$\mathbf{c}_p = f\mathbf{c}_f + (1-f)\mathbf{c}_s$$

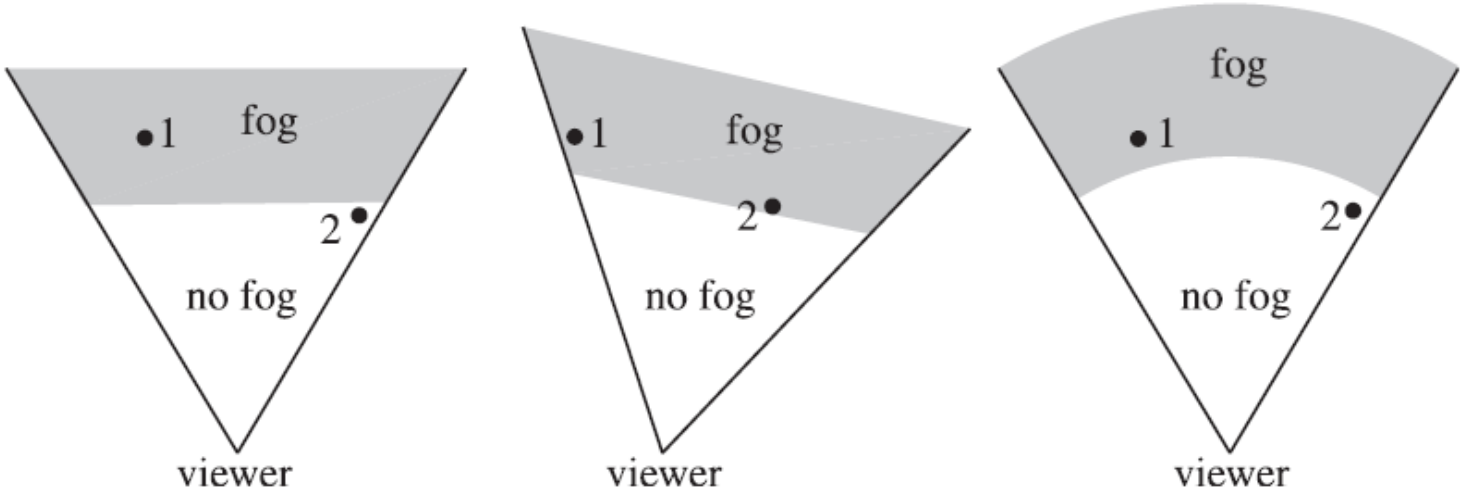
Fog

- Exponential $f = e^{-d_f z_p}$
- Squared exponential $f = e^{-(d_f z_p)^2}$
- Exponential derived from Beer's law
  - **Beer's law:** intensity of outgoing light diminishes exponentially with distance

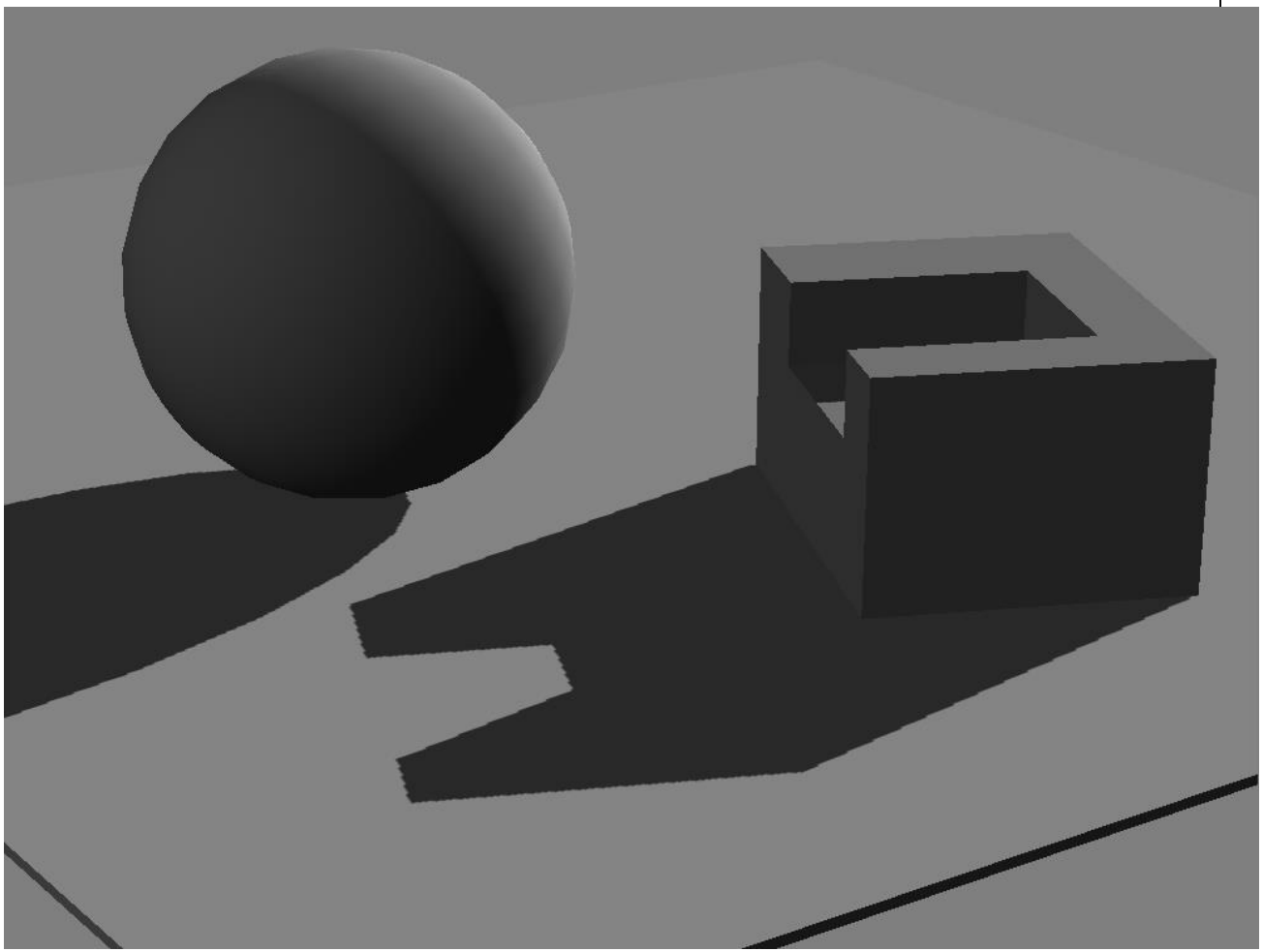


Fog Optimizations

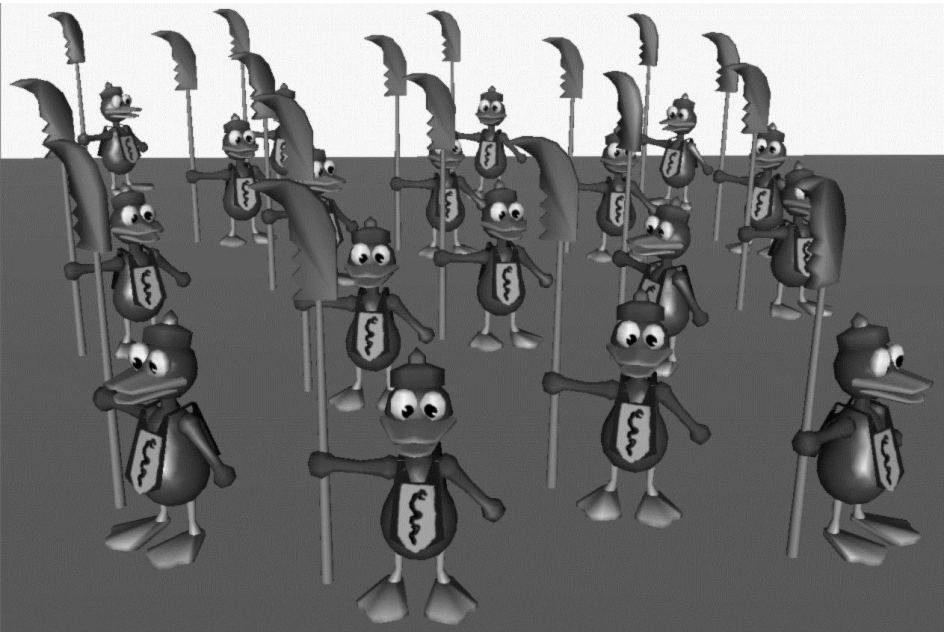
- *f* values for different depths (z_p)can be pre-computed and stored in a table on GPU
- Distances used in *f* calculations are planar
- Can also use Euclidean distance from viewer or radial distance to create ***radial fog***

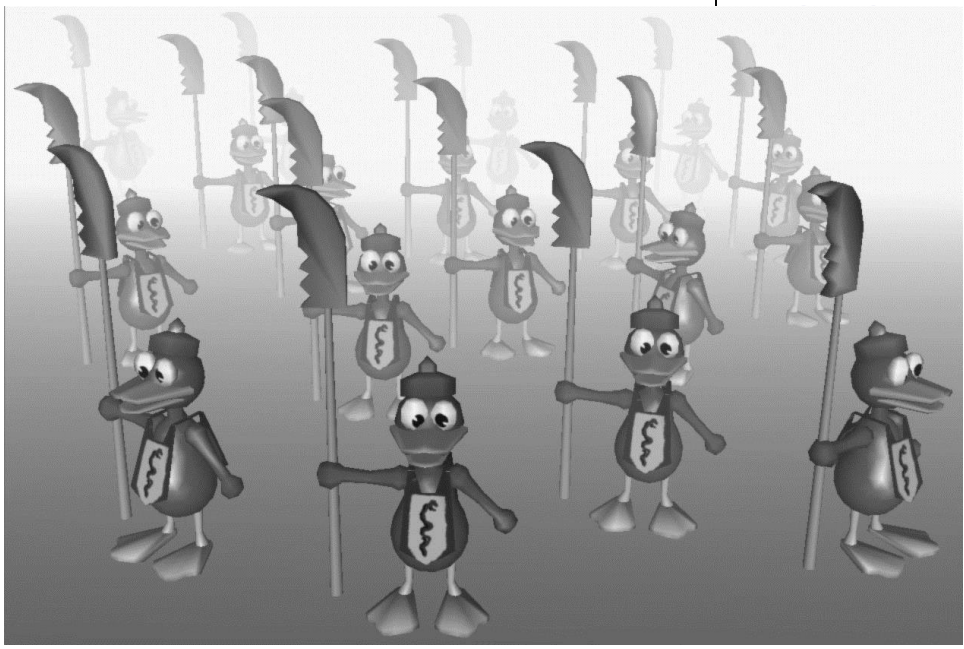


Shadow Map Result



Fog example





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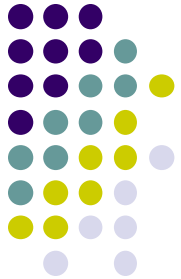

References

- Interactive Computer Graphics (6th edition), Angel and Shreiner
- Computer Graphics using OpenGL (3rd edition), Hill and Kelley
- Real Time Rendering by Akenine-Moller, Haines and Hoffman