A Light Hierarchy for Fast Rendering of Scenes with Many Lights

E. Paquette, P. Poulin, and G. Drettakis

EUROGRAPHICS '98
Lisbon, Portugal

University of Montreal & iMAGIS

Motivation

- Scenes with many light sources are expensive to render
  - Shading and shadowing cost dominates
- Typical scenes: city lights, chandelier, Christmas tree ornaments, flame simulation

Introduction

- Goal: Accelerate the shading calculation for scenes with many light sources
- Our solution: Hierarchical multi-resolution representation of the light sources
- Context: Ray-tracing, point light sources
- Currently restricted to unoccluded light sources (no shadows)

Outline

➔ Previous work
- Hierarchical representation of light sources
- Diffuse and specular shading
- Treating visibility
- Conclusion & future work

Previous Work

- Adaptive shadow testing [Ward91]
  - Problem with many similar contributions
- Monte Carlo [Shirley et al. 96]
  - Noise component can be very high
- Hierarchical radiosity with clustering [Smits et al. 94] [Sillion95]
  - Problems with clusters containing light sources

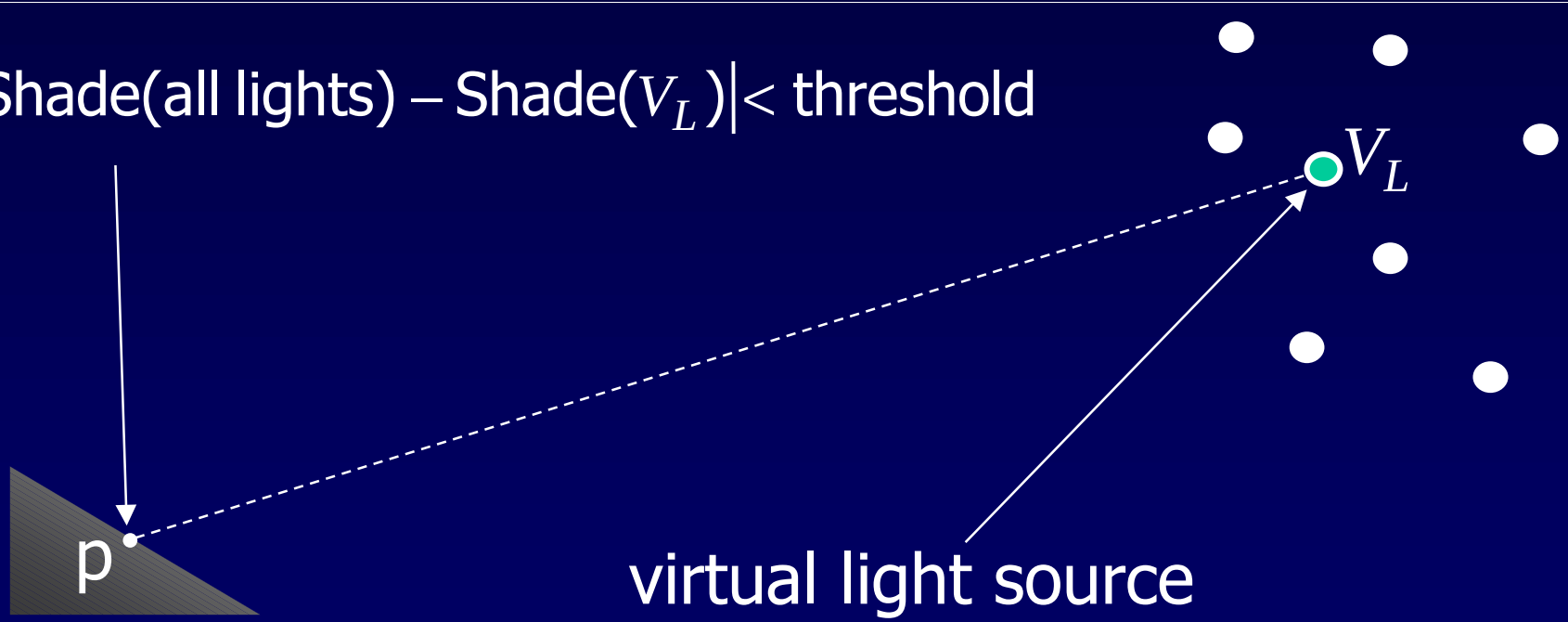
Outline

- Previous work
- → Hierarchical representation of light sources
- Diffuse and specular shading
- Treating visibility
- Conclusion & future work

Hierarchical Representation

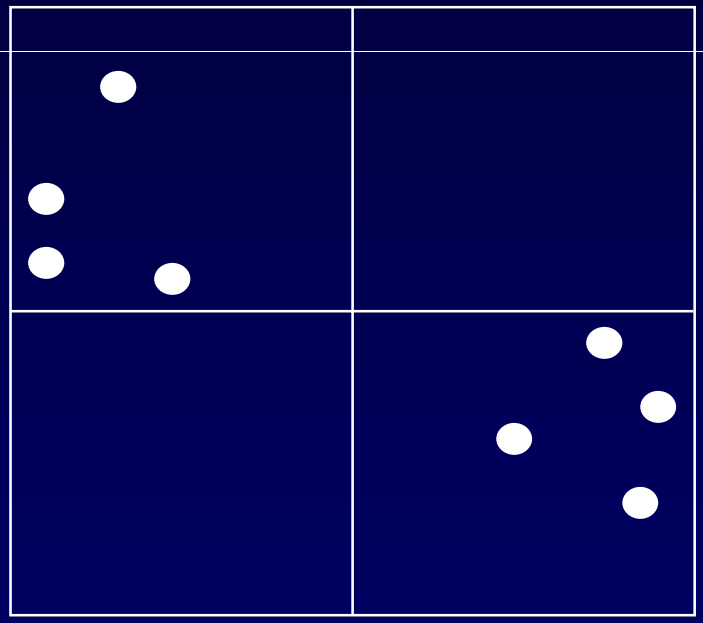
- Distant lights need less accurate treatment

$$|\text{Shade(all lights)} - \text{Shade}(V_L)| < \text{threshold}$$



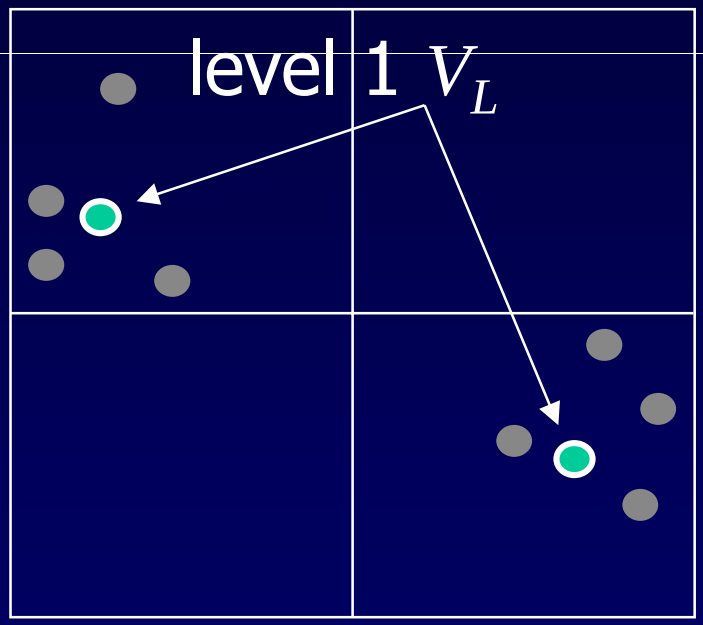
Construction

- Light hierarchy (octree)



Construction

- Light hierarchy (octree)

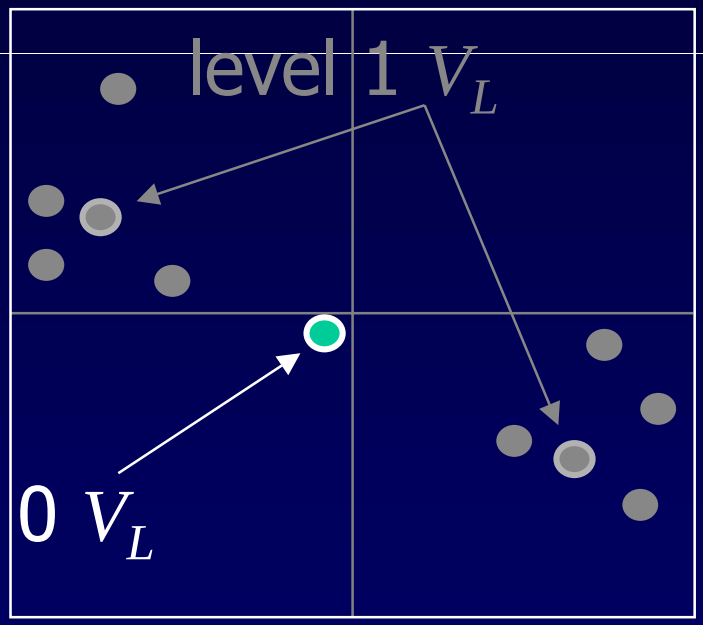


intensity of V_L
= Σ intensities

position of V_L
= weighted
average of positions

Construction

- Light hierarchy (octree)



intensity of V_L
= Σ intensities

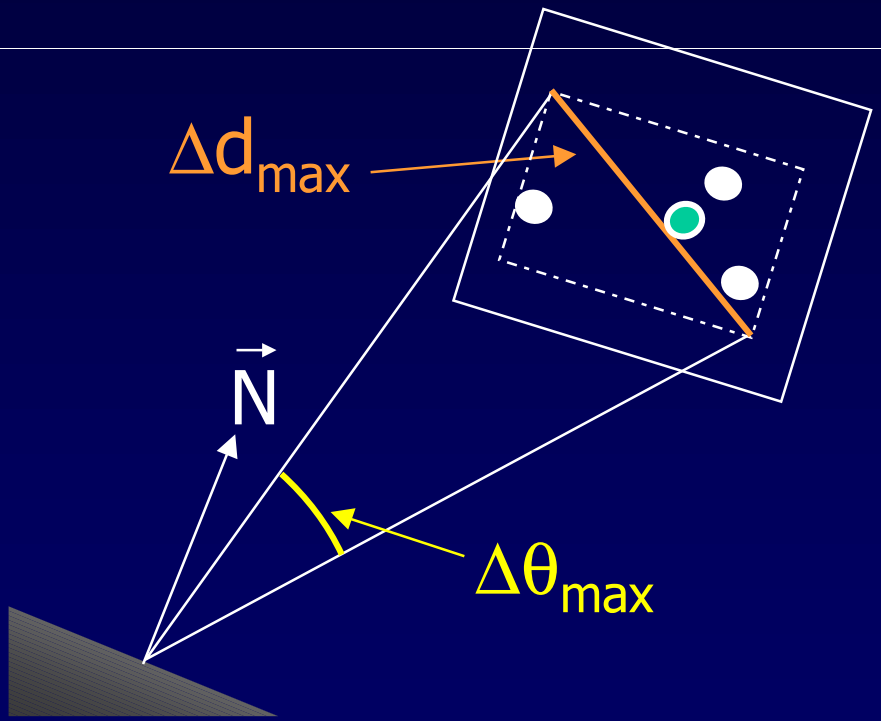
position of V_L
= weighted
average of positions

- Separate object hierarchy for ray-tracing acceleration

Outline

- Previous work
- Hierarchical representation of light sources
- ➔ Diffuse and specular shading
- Treating visibility
- Conclusion & future work

Diffuse Reflection Approximation

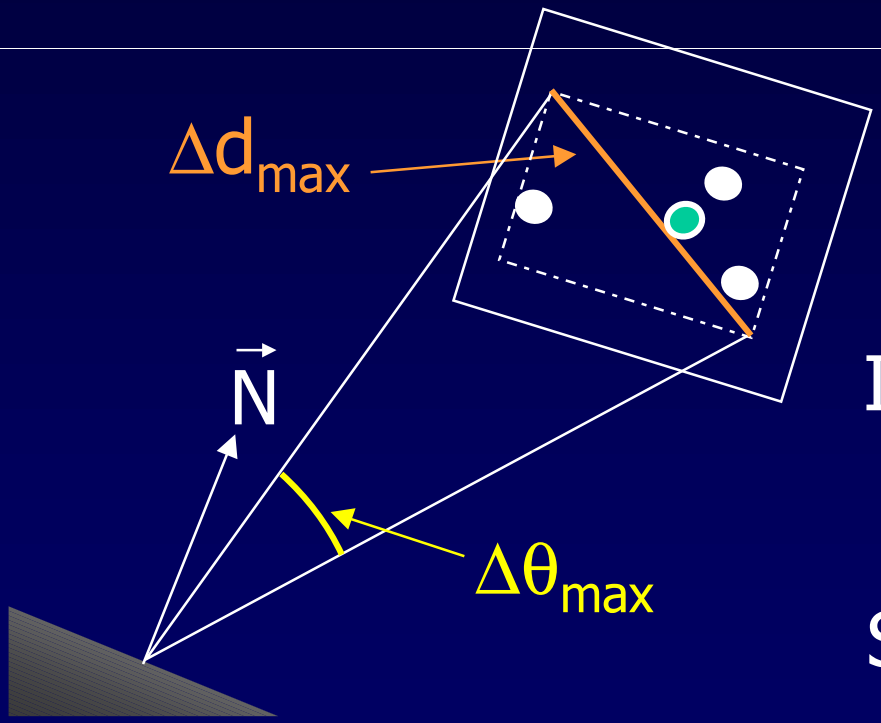


$$I = \sum I_i \, k_d \, \frac{\cos\theta_i}{d_i^2}$$

$$I_{approx} = I_v \, k_d \, \frac{\cos\theta_v}{d_v^2}$$

Diffuse Reflection Error Bound

- Derive an error bound on the virtual light usage



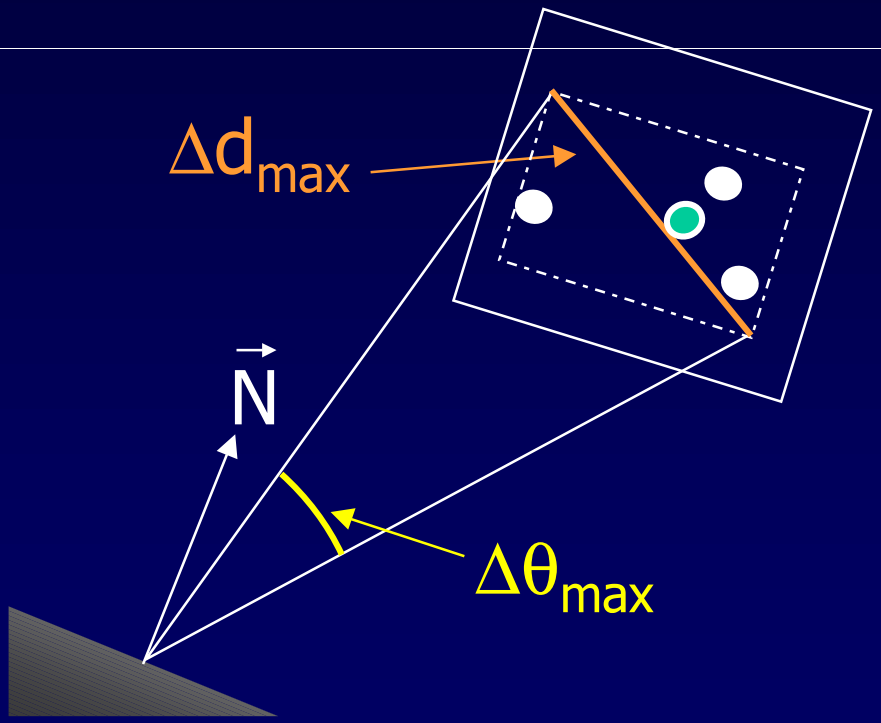
$$I = \sum I_i \, k_d \, \frac{\cos\theta_i}{d_i^2}$$

$$I_{min} = I_v \, k_d \, \frac{\cos(\theta_v) - \Delta\theta_{max}}{(d_v + \Delta d_{max})^2}$$

Similarly for I_{max}

Diffuse Reflection Error Bound

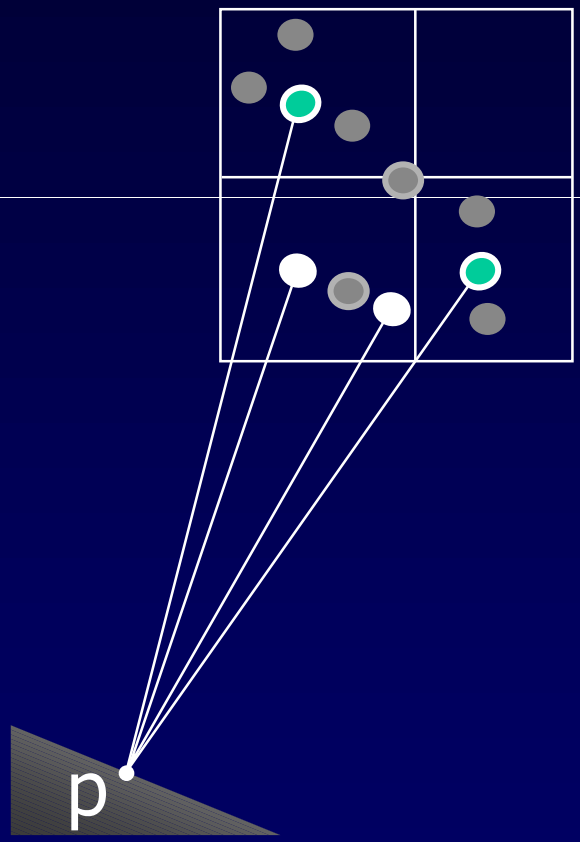
- Derive an error bound on the virtual light usage



$$\text{Error} = \max\begin{pmatrix} I_{approx} - I_{min}, \\ I_{max} - I_{approx} \end{pmatrix}$$

Diffuse Reflection Shading

```
HierShading(Point p, Voxel v)
   if Error(p, v) > T_diffuse then
      ShadeAtLowerLevel(p,v)
   else
      AddErrorList(v, Error(p, v))
```

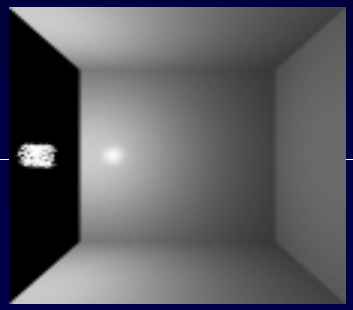


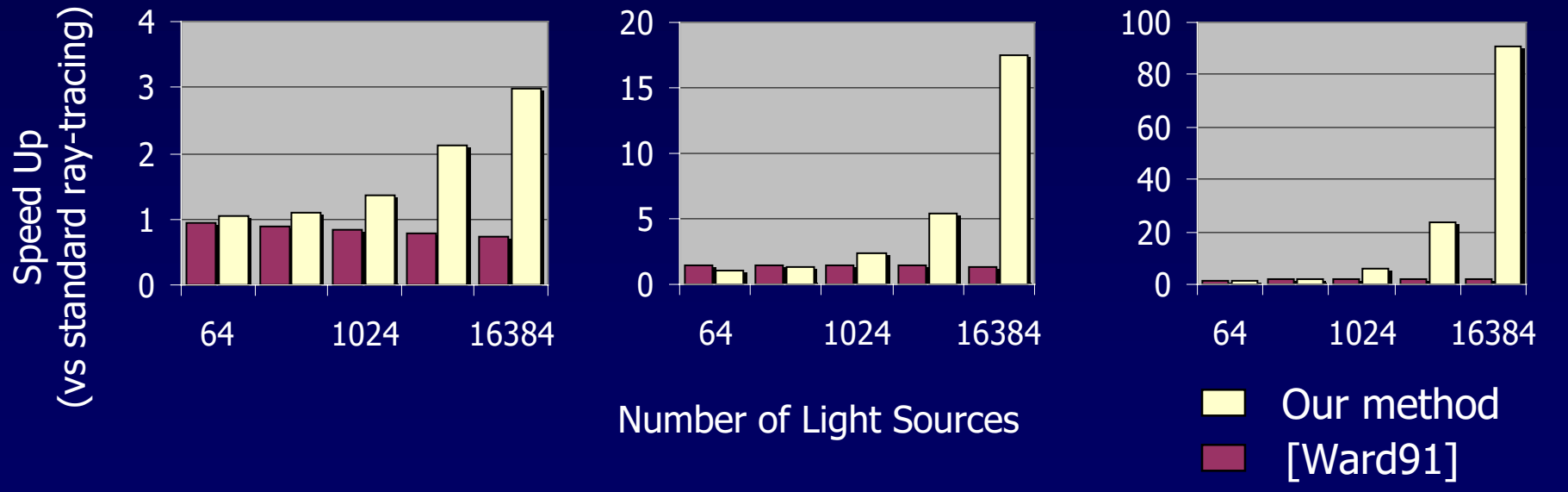
Error List

- Error bound for replacing **one** cluster by V_L
- Using lower levels replaces **many** clusters with corresponding $V_L s$

```
while Sum(errorList) > T_diffuse
        v = VoxelWithGreatestError( errorList )
        ShadeAtLowerLevel(p,v)
```

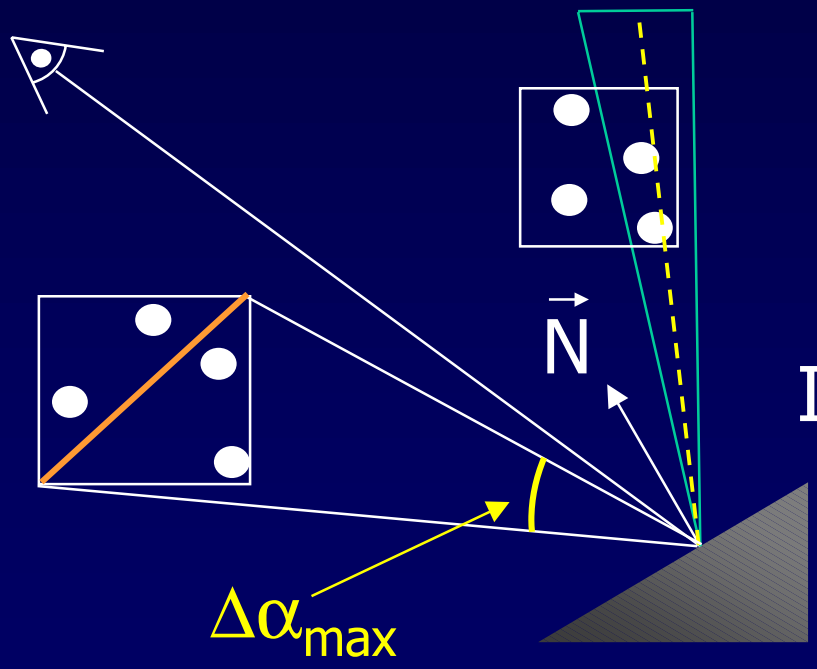
Diffuse Reflection Results





Specular Reflection

- Select important voxels and light sources in the hierarchy based on maximal potential contribution

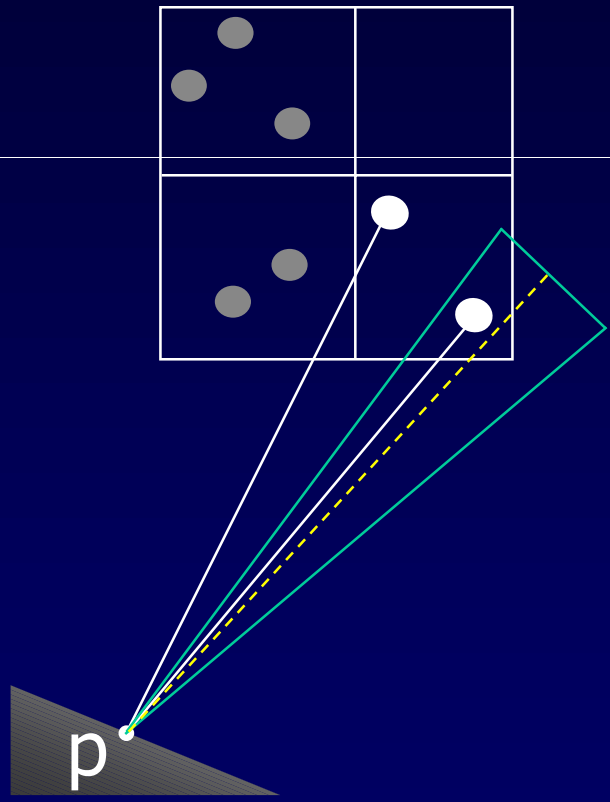


$$I = \sum I_i \, k_s \, \frac{\cos^n \alpha_i}{d_i^2}$$

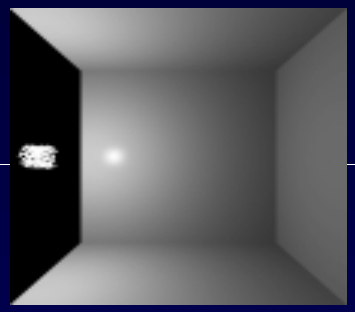
$$I_{max} = I_v \, k_s \, \frac{(\cos(\alpha_v) + \Delta\alpha_{max})^n}{(d_v - \Delta d_{max})^2}$$

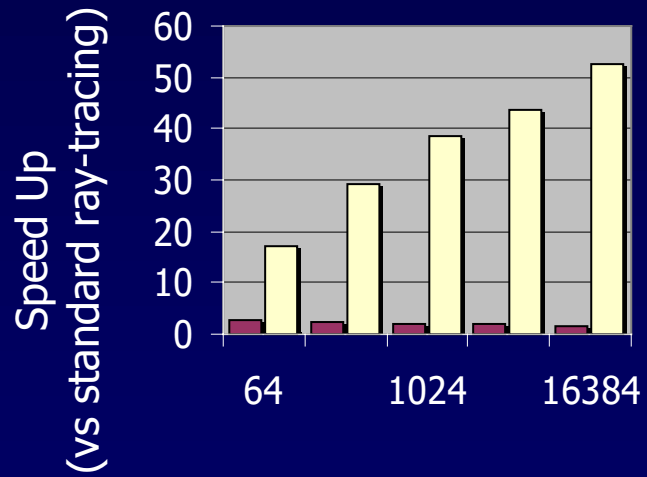
Specular Reflection Shading

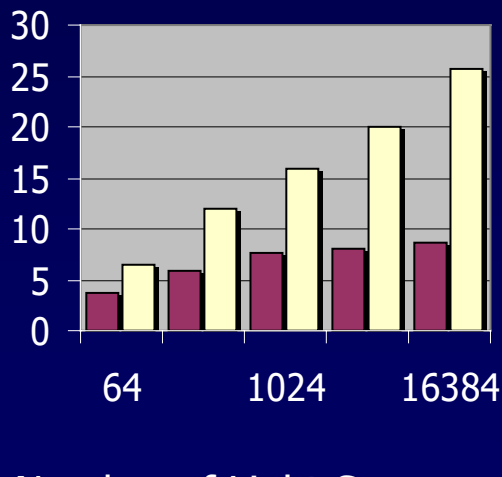
```
HierShading(Point p, Voxel v)
    if I_max(v) > T_specular then
        ShadeAtLowerLevel(p,v)
    else
        AddErrorList(v, I_max)
```

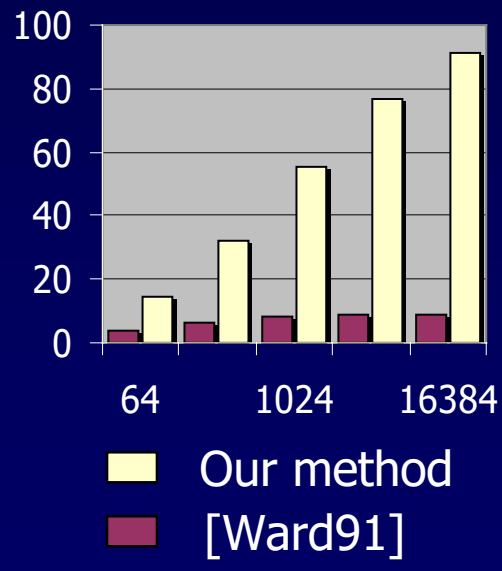


Specular Reflection Results



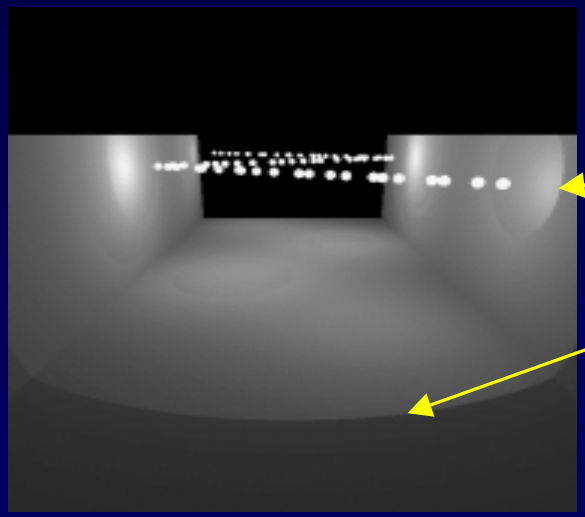




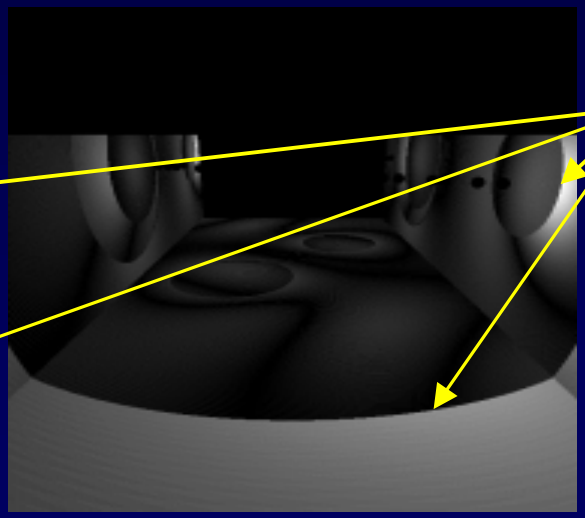


Artifacts

- Artifacts that result from increasing the threshold



Rendered image



Difference image
(enhanced contrast)

Discontinuities from discrete choice of hierarchy level

Solution:

Interpolation

Outline

- Previous work
- Hierarchical representation of light sources
- Diffuse and specular shading
- ➔ Treating visibility
- Conclusion & future work

Treating Visibility

- Hierarchical algorithm gives appropriate nodes of the light sources hierarchy
- Warnock style decision
  - Full occlusion, full visibility, partial occlusion
- Use lower level nodes when partial visibility
- Approximate volumetric visibility method similar to [Sillion95]
- Need error bounds or estimates

Outline

- Previous work
- Hierarchical representation of light sources
- Diffuse and specular shading
- Treating visibility
- ➔ Conclusion & future work

Conclusion

- Hierarchical multi-resolution representation of the light sources
- Logarithmic rendering time in the number of light sources (diffuse algorithm)
- Accelerates rendering in the presence of many light sources (up to 90 times faster than standard ray-tracing)

Future Work

- Shadows
  - Visibility classification (full, partial or no occlusion)
  - Approximate visibility
- Non point light sources
  - Area, canned light sources, etc.
- General BRDF
  - Bounds on BRDF value